



# National Solar Radiation Database 1991–2010 Update: User's Manual

Stephen Wilcox

**NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.**

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## Preface

The 1991–2010 National Solar Radiation Database was produced by the National Renewable Energy Laboratory under the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy in collaboration with these partners:

- Atmospheric Sciences Research Center, State University of New York at Albany
- Climate Systems Branch, National Aeronautics and Space Administration
- Clean Power Research
- National Climatic Data Center, U.S. Department of Commerce
- Northeast Regional Climate Center, Cornell University
- Solar Consulting Services, Colebrook, New Hampshire
- Solar Radiation Monitoring Laboratory, University of Oregon.

Most of the modeled solar radiation data were generously provided by Clean Power Research under special arrangement with the National Renewable Energy Laboratory. This arrangement allows release of their satellite-modeled SolarAnywhere<sup>®</sup> data product (version 2.2) for public use as part of the National Solar Radiation Database. The SolarAnywhere<sup>®</sup> data set is produced using an updated model from the State University of New York at Albany.

All meteorological data were provided by the National Climatic Data Center from its Integrated Surface Database. This work would not have been possible without this extraordinary data set and frequent assistance from experts at the National Climatic Data Center.

The measured solar radiation data came from:

- Atmospheric Radiation Measurement Program, Department of Energy
- Florida Solar Energy Center, State of Florida
- Integrated Surface Irradiance Study and Surface Radiation Budget Measurement Networks, National Oceanic and Atmospheric Administration Air Resources Laboratory and Earth System Research Laboratory Global Monitoring Division
- Measurement and Instrumentation Data Center, National Renewable Energy Laboratory
- University of Oregon Solar Radiation Monitoring Laboratory Network
- University of Texas Solar Energy Laboratory.

We gratefully acknowledge these organizations and the many individuals involved in the collection and maintenance of these valuable solar data sets. Their dedication and efforts go far beyond description in the short space available here.

We also acknowledge the extensive work and vision of Gene Maxwell, who headed the National Renewable Energy Laboratory project to create the original 1961–1990 National Solar Radiation Database.

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## Acronyms

AOD	aerosol optical depth
ARM	Atmospheric Radiation Measurement
ASCII	American Standard Code for Information Interchange
ASOS	Automated Surface Observing System
BAOD	broadband aerosol optical depthDNI direct normal irradiance
DQMS	Data Quality Management System
FSEC	Florida Solar Energy Center
GHI	global horizontal irradiance
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
ISD	Integrated Surface Database (formerly ISH, Integrated Surface Hourly)
ISIS	Integrated Surface Irradiance Study
MBE	mean bias error
METSTAT	Meteorological-Statistical (solar model)
MISR	Multi-Angle Imaging Spectroradiometer
MMDT	monthly mean daily total
MODIS	Moderate Resolution Imaging Spectroradiometer
NARR	North American Regional Reanalysis
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NSRDB	National Solar Radiation Database
NVAP	NASA Water Vapor Project
NWS	National Weather Service
RMS	root mean square
RMSE	root mean square error
SAMSON	Solar and Meteorological Observation Network
SI	International System (of Units)
SOLRAD	Solar Radiation (network)
SUNY	State University of New York at Albany
SURFRAD	Surface Radiation Budget Measurement
TOMS	Total Ozone Mapping Scanner
TZ	time zone
UO	University of Oregon Solar Radiation Monitoring Laboratory
USAF	United States Air Force
UT	University of Texas Solar Energy Laboratory
WBAN	Weather Bureau Army Navy

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# 1 How To Use This Manual

This manual describes how to obtain and interpret the data products from the updated 1991–2010 National Solar Radiation Database (NSRDB). This is an update of the original 1961–1990 NSRDB released in 1992 (NREL 1995) and the 1991–2005 NSRDB released in 2007.

## Important

Nearly all of the solar data in the original and updated versions of the NSRDB are modeled. The intent of the modeled data is to present hourly solar radiation values that, in the aggregate, possess statistical properties (e.g., means, standard deviations, and cumulative frequency distributions) that are as close as possible to the statistical properties of measured solar data over the period of a month or year. *These data do not represent each specific hourly value of solar radiation to the same or equivalent accuracy as the long-term statistics.* One must read sections 2.1.5, 2.2, and 2.3 to understand the content of the database and its applicability.

*Users are also encouraged to fully understand the uncertainty of the data in order to gauge the impact on subsequent analyses. See Section 1.4.5.1*

## 1.1 Introduction

In 2003, the National Renewable Energy Laboratory (NREL) investigated the feasibility of updating the NSRDB and began collaborative work with several agencies, including the National Aeronautics and Space Administration (NASA), the National Climatic Data Center (NCDC), the Northeast Regional Climate Center, the State University of New York at Albany (SUNY), the University of Oregon, the University of Wisconsin, and the private firm Solar Consulting Services (Wilcox 2004).

The original NSRDB held a serially complete data set for all sun-up hours for 239 stations. Because of expected changes in the roster of National Weather Service (NWS) sites, as well as the potential for adding NSRDB sites, the updated list of stations was not restricted to those same 239. Instead, it included as many stations and as much data as possible to increase the usefulness of the data set. This update therefore provides data for 1,454 stations.

In addition to the expanded station list, this update differs from the original NSRDB in several ways. It contains:

- New or modified solar models
- New gridded data product
- New station identification numbers
- New station classification scheme
- New data formats
- Different meteorological fields
- Revised uncertainty estimates.

Each of these topics is discussed later. *Users are encouraged to carefully consider the sections on modeled data and data uncertainty to better understand the applicability of the NSRDB for specific work.*

### **1.1.1 New Models**

Nearly all of the solar data in the original NSRDB and this update were produced using solar radiation models. *Less than 1% of the records in this update contain measured data.* See the important note at the top of Page 1.

The original NSRDB (NREL 1995) was produced using the Meteorological-Statistical (METSTAT) model (Maxwell 1998), which, in turn, was developed using NWS observations of total and opaque cloud cover and measured solar data from the SOLRAD (Solar Radiation) network. In the early 1990s, the NWS began supplementing or replacing its conventional manual weather observations with the Automated Surface Observing System (ASOS). For many aviation applications, the ASOS data are comparable with the manual observations. However, for some climatological applications, including solar radiation modeling, the manual and automatic cloud observations are not comparable, as discussed in this manual. Full sky total and opaque cloud cover observations from trained personnel were replaced with cloud estimates from ceilometers, which rely on a temporal evaluation of clouds passing directly above the instrument. The ceilometer has a 12,000-ft reach in altitude and can neither detect high clouds nor distinguish between total and opaque clouds. In addition, the resolution of the reported sky cover went from tenths or oktas to a coded scheme that at times yields only four values of sky cover (i.e., clear, scattered, broken, and overcast). This compares with eleven values for units of tenths (0–10 tenths) or nine for units of oktas (0–8 oktas).

To compensate for this change, NCDC’s ASOS Cloud Data Set (Graumann 2003), also called the ASOS Supplemental Cloud Product, was used to derive cloud cover values compatible with the METSTAT model. The Supplemental Cloud Product uses satellite imagery for total cloud cover estimates that include cloud height information. From this, total and opaque cloud estimates were developed in tenths, with cloud height distinguishing between them (Wilcox 2005). (Opaque clouds predominantly occur at lower heights.) See Section 2.1.2.

In addition to the NREL METSTAT model, SUNY developed a model that uses Geostationary Operational Environmental Satellite (GOES) imagery to estimate solar radiation. This model has been regularly updated and produces data for the SolarAnywhere<sup>®</sup> data set used for much of the NSRDB. In simple terms, this satellite model uses the inverse relationship between reflected irradiance (that reflected by clouds and atmosphere back to space and the satellite sensor) and ground irradiance (that transmitted through the atmosphere to the Earth’s surface). In model-evaluation work conducted as part of the NSRDB project, this satellite model proved comparable with meteorological-based models. (The project also evaluated a model from the Northeast Regional Climate Center that uses ASOS data. It was also found comparable with other models; however, the METSTAT meteorological-based model was chosen because of its NSRDB legacy.)

Based on simplicity and consistency, the SUNY model would have replaced the METSTAT model but for its limited period of record. GOES imagery for the project was archived starting in 1998, leaving the period of 1991–1997 without coverage. Hence, a hybrid production effort that uses both models was designed. (The distribution of model data is explained in Section 1.1.5.)

### **1.1.2 Gridded Data Product**

The 2005 and 2010 updates not only contain far more stations than the original NSRDB but also include a 10-km gridded database taken from the SolarAnywhere<sup>®</sup> version 2.2 data set produced by the SUNY model. One very attractive feature of that model is its ability to create a high-resolution gridded data set (Perez 2002). Whereas the METSTAT model relies on scattered and sometimes sparse point-source ground meteorological observations, the SUNY model runs on the virtually seamless GOES satellite images. Although GOES images provide up to 1-km resolution, in the SUNY model these data are down-sampled to 10-km resolution (0.1° x 0.1°). This resolution is adequate for most solar radiation resource applications and represents a practical trade-off between resolution and processing and data storage considerations. An enhanced SolarAnywhere<sup>®</sup> product provides some solar data at 1 km resolution, but those data are not used in the NSRDB. The model uses both GOES-East and GOES-West satellites for the best coverage of the United States.

The SUNY model produces estimates of global and direct irradiance at hourly intervals on the 10-km grid for all states, excluding Alaska, where the geostationary satellites cannot resolve cloud cover with necessary detail.

The hourly NSRDB records hold hour-ending irradiance values that represent an integration of the previous hour's irradiance. GOES satellite imagery is a snapshot of the earth disk, and, hence, the irradiance values in the SolarAnywhere<sup>®</sup> grid represent an instant in time rather than an integrated value. Further, the GOES-West satellite images are produced on the hour, and the GOES-East images are produced at 15 minutes past the hour. To make the satellite model data conform to the top-of-hour time convention, the SolarAnywhere<sup>®</sup> data set includes irradiance values shifted in time to better represent the characteristics of hourly integrated values. This approach also allows the gridded data to be used for existing applications that expect a top-of-hour timestamp.

Note: Because the SUNY model derives solar radiation measurements from image brightness data and (averaged) ancillary data, it represents a “snapshot” solar radiation value for a particular hour that may be significantly different from METSTAT data, which is based on estimates from meteorological data and the attendant statistical modifications included in the METSTAT model, particularly under variable atmospheric conditions. Source flags for the solar radiation modeled data indicate the source of the estimated solar radiation data. See sections 2.1.6 and 2.3.5.

### **1.1.3 Station Identification Numbers**

Station identification numbers in the 1961–1990 NSRDB were based on the five-digit Weather Bureau Army Navy (WBAN) numbering scheme, which was used by NCDC at the

time for its station list. Since then, NCDC began using the six-digit United States Air Force (USAF) numbering system in addition to the WBAN system, and to conform, the NSRDB also uses the USAF scheme. Appendix A lists all stations and identifiers ordered alphabetically by state and site name, along with site location information. Table A-1 lists all sites ordered by USAF identifier. Appendix B provides a translation from the WBAN numbers of the 239 stations in the 1961–1990 NSRDB to their equivalent USAF identifiers in this 1991–2010 update.

#### **1.1.4 New Station Classification Scheme**

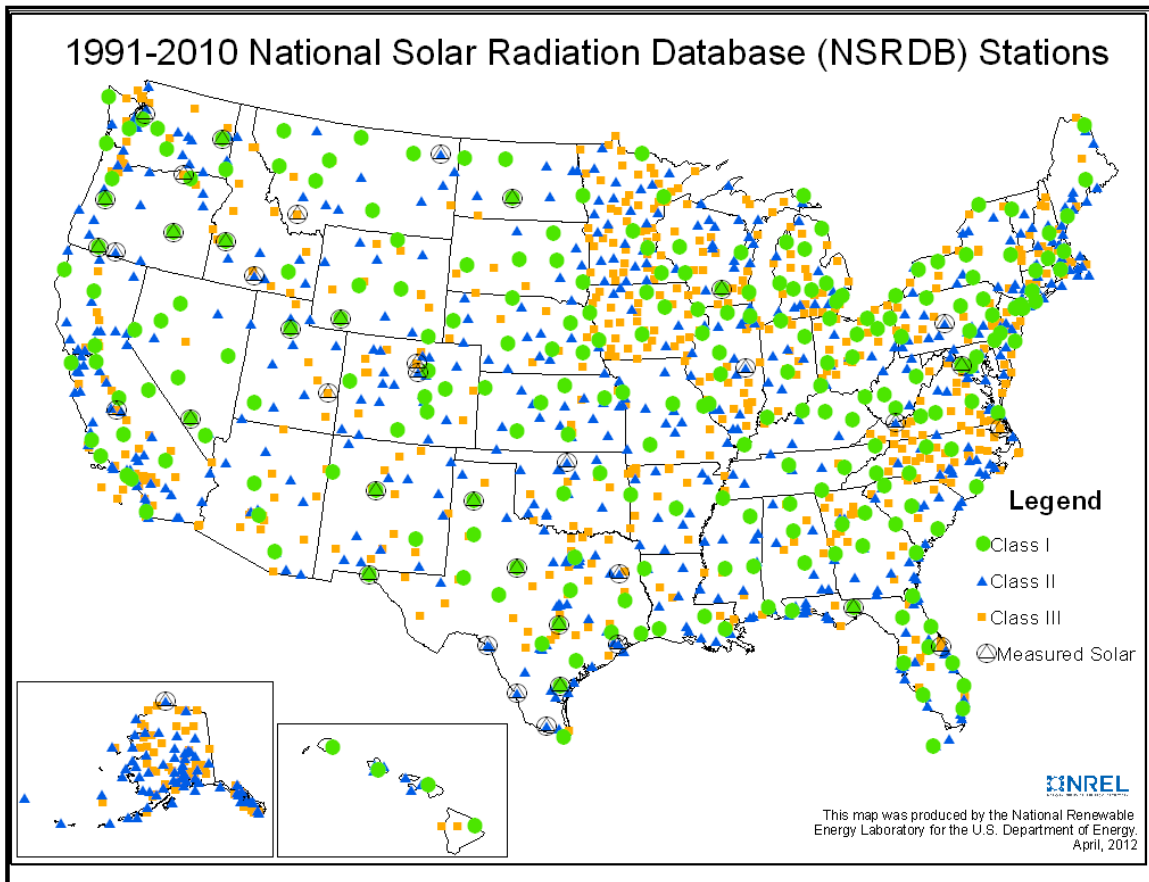
The 1961–1990 NSRDB had two station classifications: primary and secondary, so designated by whether the station's data included measured (versus modeled) solar radiation values. Fifty-six sites were designated as primary; the rest (183) were secondary.

For the 1991–2005 and 1991–2010 NSRDB updates, that classification method was dropped and replaced with a classification based on data quality and completeness (see Section 2.3.7). Further, the original NSRDB convention of merging measured data with modeled data when it was available was dropped in favor of separate fields for measured and modeled data. This decision hinged on differences between measured and modeled data. The nature of solar energy measurements often results in values slightly or even grossly inconsistent among coupled parameters, and measured data sets are rarely serially complete. This fact results in an impossibly complex circumstance of sorting out which parameters are correct and which are in error and how to bring parameters into compliance. Modeled data, on the other hand, cannot accurately reproduce a variable solar time series required by some system performance applications. (This is because of a lack of definitive information about the spatial relationship among the sun, clouds, and a ground observer—in other words, whether any clouds in a one-dimensional sky cover observation are occluding the sun.) Thus, the two sets of output fields afford users the consistency of modeled data while accommodating applications that demand measured data.

The Supplemental Cloud Product used for more accurate cloud estimates as described above is complete neither in time nor space for the update period. That and other variations in cloud observations, and the use of the SUNY satellite model output where and when it was available, led to different levels of uncertainty in the modeled data. From this, the three-class scheme for categorizing sites was developed to best convey to users variations in the quality of data. This scheme is detailed in Section 2.3.7.

Although 40 stations include some measured solar data (though none with a complete period of record), the inclusion of measured data is not a factor in the new station classification. Stations in all three classifications may include measured data. See Appendix C for a list of stations with measured solar data and the instrumentation used for measurements.

Figure 1 shows the distribution of the NSRDB update sites by class and includes the locations of the 1961–1990 NSRDB sites.



**Figure 1. Distribution of NSRDB sites by class and measured solar data**

### **1.1.5 Data Formats**

The 1961–1990 NSRDB was distributed in two formats: the NSRDB Synoptic format (used in the NCDC Solar and Meteorological Observation Network, or SAMSON, disks) and the NCDC TD3282 format. Because of immense changes in data distribution methods and efficiencies since the first release in 1992, NCDC distributes the NSRDB via the Internet.

The NSRDB is also distributed by NREL without the meteorological fields. Although it doesn't have meteorological fields, it has many other solar-related fields that are of interest to researchers, such as separate fields for METSTAT and SolarAnywhere<sup>®</sup> modeled data, clear sky modeled values, and the measured data. The NREL data set also includes some ancillary data fields, such as aerosols, water vapor, and ground albedo. The 10-km gridded product is distributed by NCDC at no cost. (This product does not contain any meteorological data.)

See Section 1.3.3 for a summary of the data availability options.

### **1.1.6 Meteorological Fields**

Relative to the 1961–1990 NSRDB, one measurement pair was added to NSRDB update records starting with the 1991-2005 update, and three were removed.



- A pair of fields for liquid precipitation was added. This measurement was not in the original NSRDB but was subsequently added to the NCDC SAMSON data set as hourly values. This measurement is included in the updated NSRDB as two fields of magnitude and time, according to the Integrated Surface Database (ISD) convention.
- Snow cover and days since last snowfall were removed from the update because of a lack of consistent snow cover data in the ISD data set. These parameters were used to modify the albedo input to the METSTAT model during periods of snow cover. However, the new ground albedo data sets used for the update include the effects of snow (although based on climatological monthly averages rather than daily resolution).
- The present weather field was removed. This field was originally used by the METSTAT model to modify the multiple-reflectance algorithm. The model has subsequently been modified to use ceiling height for this purpose.

### **1.1.7 Uncertainty Estimates**

The uncertainty estimates in the 1961–1990 NSRDB were based on the uncertainties of the input data sets. Starting with the updated 1991–2005 NSRDB, base uncertainty estimates are founded in model evaluation results that use high-quality model input data and compare the model output with measured data. This base uncertainty was then modified for the increased uncertainty of filled or the ASOS data when such input data were used. With the SUNY model, a base uncertainty was similarly determined in the model evaluation and then increased for periods of snow cover or high latitude—circumstances known to degrade model performance.

From even the early stages of planning, the uncertainty of the 1991–2005 NSRDB was expected to be greater than that of the 1961–1990 NSRDB because of changes in cloud observations that reduced the accuracy of the cloud estimates. A critical part of the production plan was to conspicuously include realistic estimates of data uncertainty in the data to afford users the opportunity to evaluate the applicability of the database to any application or pass through uncertainties to derivative data sets. Hourly uncertainties for modeled data range from 8% under optimal conditions to more than 25% for less-than-optimal input data.

The METSTAT model, and to a lesser extent the SUNY model, can have hourly uncertainties that far exceed even the extreme uncertainties quoted above. This follows from a lack of information about the spatial relation among the sun, clouds, and a target measurement on the ground. For example, a cloud amount of 50% does not convey whether the sun is fully visible between scattered clouds or is entirely blocked by a cloud. Further, the METSTAT model (not the SUNY model) deliberately randomizes cloud cover to better produce long-term statistics. Hence, the uncertainty should be in the context of the model’s design objective of reproducing the statistical characteristics of a solar data set rather than any specific hourly value. As stated in the 1961–1990 NSRDB user’s manual:

Given this objective, the assignment of uncertainties with reference to the true solar radiation for specific hours would not provide the user with useful

information. It was decided, therefore, that the uncertainty of individual hourly values estimated by METSTAT should be interpreted to mean that the *true* mean of measured hourly values under *fixed atmospheric conditions* lies within the range established by the estimated mean plus or minus the uncertainty, 95% of the time. (NREL 1993)

This observation underscores model evaluation findings that the modeled data may have large root mean square (RMS) errors relative to measured data but much smaller bias errors. *This also indicates that NSRDB-modeled data may introduce unexpected errors if used for applications that require accurate hourly tracking of true solar irradiance, such as photovoltaic system performance analyses.* This caveat is less critical under cloudless (0% cloud cover) or completely overcast (100% cloud cover) conditions, in which a cloud observation leaves no ambiguity. However, even under these conditions, other atmospheric constituents (particularly aerosols, see Section 2.2.1.2) or varying cloud opacity can have significant effects on the measured irradiance values.

### **1.1.8 Changes from the 1991-2005 NSRDB Update**

- Updated Satellite data—Clean Power Research has implemented several model refinements in SolarAnywhere<sup>®</sup> since the SUNY data set used in the 1991-2005 update.
- Changed cloud cover input to the METSTAT model—The ASOS cloud algorithm for the METSTAT model was changed after research showed that ASOS tends to overestimate cloud cover at cloudy sites. See Section 2.1.2.

Note that no new measured solar radiation data were added to the database. Future updates are expected to have additional measured data available after 2005.

## **1.2 How To Use and Interpret Database Products**

The NSRDB 1991–2010 update is a serially complete collection of hourly values of the three most common measurements of solar radiation (i.e., global horizontal, direct normal, and diffuse horizontal) over a period of time adequate to establish means and extremes and at a sufficient number or locations to represent regional solar radiation climates. *Nearly all of the solar data in the NSRDB are modeled, and only 40 sites have measured solar data—none of them with a complete period of record (see Appendix C).*

The updated NSRDB is distributed in two formats; one format is distributed by NCDC and the other by NREL. (See the discussion under Section 1.1.5). The solar radiation and meteorological elements in the NCDC data sets are listed in Table 2. The data elements distributed in the NREL data set are listed in Table 3.

The 1991–2010 NSRDB contains data for 1,454 sites, which are subdivided into three classes of stations.

- **Class I Stations** have a complete period of record (all hours 1991–2010) for solar and key meteorological fields and have the highest-quality solar modeled data (242 sites).

- **Class II Stations** have a complete period of record but significant periods of interpolated, filled, or otherwise lower-quality input data for the solar models (618 sites).
- **Class III Stations** have some gaps in the period of record but have at least 3 years of data that might be useful for some applications (594 sites).

Note: Completeness in period of record for station classification is based on solar, dry-bulb, and dew-point temperatures; humidity; wind and wind direction; aerosol optical depth (AOD); precipitable water; and station pressure. Other fields in Class I and II stations may not be serially complete.

*Because of the data-filling methods used to accomplish the goal of serial completeness for the solar data, NSRDB meteorological data may not be suitable for climatological work. The meteorological fields in the NSRDB should be used only as ancillary data for solar deployment and sizing applications. Filled/interpolated meteorological data should not be used for climatic applications. (All such data are flagged.) ISD data are better for such applications and are available at <http://cdo.ncdc.noaa.gov>.*

See Section 2.3.7 for the method used to assign station classifications. The stations and their classifications are listed in Appendix A, along with plots that show the proportion of modeled solar data by year and the amount of measured solar data included in a station's data set. Appendix C lists sites that include measured solar radiation data.

International system (SI) units are used for all elements in the database except for atmospheric pressure. Atmospheric pressure is reported in millibars because these units are commonly used in computer models to estimate solar radiation and are consistent with standard NWS reporting practices. However, one millibar is equivalent to one hecto pascal, which is an SI unit.

All data are referenced to local standard time according to the United States official time zone descriptions (Shanks 1996). The solar radiation elements represent radiant energy integrated over the hour preceding the designated time. Meteorological elements are values observed at or near the designated time according to meteorological measurement practices.

The goal of the updated NSRDB is to provide users with accurate, reliable, and up-to-date solar resource information to support the objective of national energy independence. The need for an update arose from several considerations:

- Most recent resource data may best represent future conditions.
- Interannual and interdecadal variability and trends are of increasing importance to industry, which requires continuous updating of records.
- There were numerous requests for an update.
- Quality and completeness of information needs to grow along with a growing industry.

*Although growing interest in climate trends also provided impetus for an update, the uncertainties in the modeled solar data likely make the data inadequate to discern the small annual or even decadal changes caused by climate change. The measured solar data, if at sites with sufficient quantity and quality, may offer value for climate change research. (See Appendix C for station instrumentation and period-of-record information.)*

### **1.3 Database Product Options**

Current products available for the NSRDB 1991–2010 update are described here. These products are intended to meet the needs of most solar resource assessment applications.

Product options include:

- Serial hourly data in three formats (one of which is an hourly gridded product)
- Hourly, daily, and persistence summary products for solar radiation and several meteorological elements (Class I and II stations only).

#### **1.3.1 Hourly Data**

The serially complete hourly data provided in the NSRDB update are distributed in three formats available from two sources:

- **NCDC data sets**  
NCDC distributes a ground-based solar and meteorological data set with fields most useful for general solar resource assessment. The 10-km SolarAnywhere<sup>®</sup> gridded data set produced by the SUNY model for years 1998–2009 is also distributed by NCDC. The solar fields are also included in the NCDC Climate Data Online service, merged with existing meteorological data in the ISD product (but without the data filling).
- **NREL data set**  
NREL distributes a research solar radiation data set that includes a superset of fields related to solar radiation (i.e., both ground-based and satellite-based solar radiation estimates) but no meteorological data. (See the discussion under Section 1.1.5.)

Format descriptions are located in sections 1.4.1 to 1.4.3.

#### **1.3.2 Statistical Summaries**

The NSRDB update contains statistical summaries computed from the hourly data for the entire period of record for Class I and II stations. Gaps in the record for Class III stations make a statistical comparison of those stations inconsistent with the other two classes of stations and prevent the provision of statistical summaries for Class III sites. For the solar radiation data, these statistics include the average and standard deviation of the daily total solar energy (direct normal, diffuse horizontal, and global horizontal) for each station-year-month and each station-year. The 20-year averages and the standard deviations of monthly and annual means from 1991–2010 are also provided. For the meteorological elements, only monthly, annual, and 20-year averages were computed. Future work includes a merging of the old and updated NSRDBs for 30-year statistical summaries (for those sites with an appropriate period of record).

The hourly statistical product provides yearly files that include monthly and annual averages and standard deviations for each hour of the day for global horizontal, direct normal, and diffuse horizontal solar radiation. The averages can be used to prepare average diurnal profiles of hourly solar energy. The hourly values have also been binned in 24 50-Wh/m<sup>2</sup> bins from 0 to 1,200 Wh/m<sup>2</sup>. The mean number of hourly values falling into each bin has been determined for each station-month for the period of record from 1991–2010. These statistics can be used to plot histograms and determine cumulative frequency distributions.

A solar radiation persistence product exists for each station-month by calculating the number of times the daily total solar radiation energy persisted above or below set thresholds for periods from 1 to 15 days. These calculations were performed for the entire period 1991–2010.

The 1961–1990 NSRDB also included quality summary files, which are not reproduced for the 1991–2010 NSRDB update. Instead, a quality summary with additional information for each site in the NSRDB update is included in Appendix A, where plots indicate the relative quality of a site’s data for each year.

### 1.3.3 Data Availability

Data described in sections 1.3.1 and 1.3.2 are accessible from the sources listed in Table 1.

**Table 1. NSRDB Data Access Options**

<b>Data Set</b>	<b>Distributor</b>	<b>URL</b>
NSRDB solar and filled meteorological fields	NCDC	<a href="ftp://ftp.ncdc.noaa.gov/pub/data/nsrdb-solar/">ftp://ftp.ncdc.noaa.gov/pub/data/nsrdb-solar/</a> <a href="http://www1.ncdc.noaa.gov/pub/data/nsrdb-solar/">http://www1.ncdc.noaa.gov/pub/data/nsrdb-solar/</a>
NSRDB solar and ISD meteorological fields (no data filling)	NCDC	<a href="http://cdo.ncdc.noaa.gov">http://cdo.ncdc.noaa.gov</a> <a href="http://gis.ncdc.noaa.gov/map/cdo/?thm=themeHourly&amp;select=true">http://gis.ncdc.noaa.gov/map/cdo/?thm=themeHourly&amp;select=true</a>
SUNY 10-km gridded data	NCDC	<a href="ftp://ftp.ncdc.noaa.gov/pub/data/nsrdb-solar/">ftp://ftp.ncdc.noaa.gov/pub/data/nsrdb-solar/</a> <a href="http://www1.ncdc.noaa.gov/pub/data/nsrdb-solar/">http://www1.ncdc.noaa.gov/pub/data/nsrdb-solar/</a>
NSRDB statistical summaries	NCDC	<a href="ftp://ftp.ncdc.noaa.gov/pub/data/nsrdb-solar/">ftp://ftp.ncdc.noaa.gov/pub/data/nsrdb-solar/</a> <a href="http://www1.ncdc.noaa.gov/pub/data/nsrdb-solar/">http://www1.ncdc.noaa.gov/pub/data/nsrdb-solar/</a>
NSRDB research solar fields; no meteorological	NREL	<a href="http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2010">http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2010</a>

## 1.4 Reading and Understanding Database Products

This section provides the information necessary to use the products developed for the NSRDB 1991–2010 update. This includes an explanation of the flags and uncertainty fields.

### 1.4.1 NCDC Format

The primary provider for ground-based NSRDB data is NCDC, and data appear in site-year files in comma-separated value American Standard Code for Information Interchange (ASCII) format.

Table 2 describes the fields in the NCDC data set. See Section 1.4.3 for the 10-km gridded data sets also distributed by NCDC.

**Table 2. NSRDB Data Fields Distributed by NCDC**

Field	Element	Unit	Resolution	Description
1	Date	YYYY-MM-DD	--	Date of data record
2	Time	HH:MM	--	Time of data record (local standard time)
3	Hourly mean zenith angle (for sunup periods)	Decimal degree	0.1°	Solar zenith angle (angle between sun and the zenith) as the mean of all 1-minute sunup zenith angle values for the 60-minute period ending at the timestamp
4	Hourly mean azimuth angle (for sunup periods)	Decimal degree	0.1°	Solar azimuth angle (angle between sun and north) as the mean of all 1-minute sunup azimuth angle values for the 60-minute period ending at the timestamp
5	Hourly extraterrestrial radiation on a horizontal surface	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation received on a horizontal surface at the top of the atmosphere during the 60-minute period ending at the timestamp
6	Hourly extraterrestrial radiation normal to the sun	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation received on a surface normal to the sun at the top of the atmosphere during the 60-minute period ending at the timestamp
7	Modeled global horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Total amount of direct and diffuse solar radiation (modeled) received on a horizontal surface during the 60-minute period ending at the timestamp
8	Modeled global horizontal uncertainty	±%	1%	See Section 1.4.5.1

Field	Element	Unit	Resolution	Description
9	Modeled global horizontal source flag		--	See Table 7
10	Modeled direct normal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (modeled) received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp
11	Modeled direct normal uncertainty	±%	1%	See Section 1.4.5.1
12	Modeled direct normal source flag		--	See Table 8
13	Modeled diffuse horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (modeled) received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
14	Modeled diffuse horizontal uncertainty	±%	1%	See Section 1.4.5.1
15	Modeled diffuse horizontal source flag		--	See Table 8
16	Measured global horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Total amount of direct and diffuse solar radiation received on a horizontal surface during the 60-minute period ending at the timestamp
17	Measured global horizontal quality flag	SERI-QC	--	See Table 11
18	Measured direct normal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp
19	Measured direct normal quality flag	SERI-QC	--	See Table 11
20	Measured diffuse horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp

Field	Element	Unit	Resolution	Description
21	Measured diffuse horizontal quality flag	SERI-QC	--	See Table 11
22	*Total sky cover	Tenth of sky	1 tenth	Amount of sky dome covered by clouds or obscuring phenomena at the time indicated
23	*Total sky cover flag		--	See Section 1.4.5.2
24	*Opaque sky cover	Tenth of sky	1 tenth	Amount of sky dome covered by clouds or obscuring phenomena that prevent observing the sky or higher cloud layers at the time indicated
25	*Opaque sky cover flag		--	See Section 1.4.5.2
26	*Dry-bulb temperature	Degree C	0.1°	Dry-bulb temperature at the time indicated
27	*Dry-bulb temperature flag		--	See Section 1.4.5.2
28	*Dew-point temperature	Degree C	0.1°	Dew-point temperature at the time indicated
29	*Dew-point temperature flag		--	See Section 1.4.5.2
30	*Relative humidity	Percent	1%	Relative humidity at the time indicated
31	*Relative humidity flag		--	See Section 1.4.5.2
32	*Station pressure	Millibar	1 mbar	Station pressure at the time indicated
33	*Station pressure flag		--	See Section 1.4.5.2
34	*Wind speed	Meter/second	0.1 m/s	Wind speed at the time indicated
35	*Wind speed flag		--	See Section 1.4.5.2
36	*Wind direction	Degrees from north (360° = north; 0° = undefined)	10°	Wind direction at the time indicated
37	*Wind direction flag		--	See S Section 1.4.5.2
38	Horizontal visibility	Meter	1 m	Distance to discernible remote objects at the time indicated
39	Horizontal visibility flag		--	See Section 1.4.5.2
40	*Ceiling height	Meter	1 m	Height of the cloud base above local terrain



Field	Element	Unit	Resolution	Description
41	*Ceiling height flag		--	See Section 1.4.5.2
42	Liquid precipitation depth	Millimeter	1 mm	The amount of liquid precipitation observed at the indicated time for the period indicated in the liquid precipitation quantity field
43	Liquid precipitation depth flag		--	See Section 1.4.5.2
44	Liquid precipitation quantity	Hour	1 hr	The period of accumulation for the liquid precipitation depth field
45	Liquid precipitation quantity flag		--	See Section 1.4.5.2
46	*Precipitable water	Centimeter	0.1 cm	The total precipitable water contained in a column of unit cross section extending all of the way from the earth's surface to the "top" of the atmosphere. See Section 2.2.1.4
47	*Precipitable water flag		--	See Section 1.4.5.2 and Table 13
48	*Aerosol optical depth, broadband	[Unitless]	0.001	The broadband optical depth per unit of airmass due to extinction by the aerosol component of the atmosphere (randomly perturbed). See Section 2.2.1.2
49	*Aerosol optical depth flag		--	See Section 1.4.5.2 and Table 13

\*Asterisks indicate a field is subject to data filling and is used for station classification (see Section 2.3.7). Completeness of these fields is used to determine if a site has a "complete period of record." Other fields may have gaps even if these fields are complete.

Data are stored on the NCDC server (see Table 1) in .tar files that hold yearly files in a compressed gzip (.gz) format. Files are named according to the station identifier. Several utilities exist to uncompress .tar and .gz files. Among them (with no implied endorsement) are tar and gzip on unix and linux computers, WinZip and 7-Zip on Windows, and WinZip and Stuffit on the Macintosh. *Files must be transferred from the server using a binary protocol (not ASCII), or the uncompression step will fail.*

### 1.4.2 NREL Format

A secondary source of NSRDB data is NREL, which distributes a full set of solar radiation fields but no meteorological fields (see discussion under Section 1.1.5). Data sets are distributed in comma-separated value ASCII format in site-year files. Table 3 describes the NREL data set.

**Table 3. NSRDB Data Fields Distributed by NREL**

Field	Element	Unit	Resolution	Description
1	Date	YYYY-MM-DD	--	Date of data record
2	Time	HH:MM	--	Time of data record (local standard time)
3	Hourly mean zenith angle (for sunup periods)	Decimal degree	0.1°	Solar zenith angle (angle between sun and the zenith) as the mean of all 1-minute sunup zenith angle values for the 60-minute period ending at the timestamp
4	Hourly mean azimuth angle (for sunup periods)	Decimal degree	0.1°	Solar azimuth angle (angle between sun and north) as the mean of all 1-minute sunup azimuth angle values for the 60-minute period ending at the timestamp
5	Hourly extraterrestrial radiation on a horizontal surface	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation received on a horizontal surface at the top of the atmosphere during the 60-minute period ending at the timestamp
6	Hourly extraterrestrial radiation normal to the sun	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation received on a surface normal to the sun at the top of the atmosphere during the 60-minute period ending at the timestamp
7	SUNY-modeled global horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Total amount of direct and diffuse solar radiation (SUNY-modeled) received on a horizontal surface during the 60-minute period ending at the timestamp
8	SUNY-modeled global horizontal flag	--	--	See Table 5
9	SUNY-modeled global horizontal uncertainty	±%	1%	See Section 1.4.5.1
10	SUNY-modeled direct normal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (SUNY-modeled) received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp
11	SUNY -modeled direct horizontal flag	--	--	See Table 5
12	SUNY-modeled direct normal uncertainty	±%	1%	See Section 1.4.5.1

Field	Element	Unit	Resolution	Description
13	SUNY-modeled diffuse horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (SUNY-modeled) received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
14	SUNY -modeled diffuse horizontal flag	--	--	See Table 5
15	SUNY-modeled diffuse horizontal uncertainty	±%	1%	See Section 1.4.5.1
16	METSTAT-modeled global horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Total amount of direct and diffuse solar radiation (METSTAT-modeled) received on a horizontal surface during the 60-minute period ending at the timestamp
17	METSTAT-modeled global horizontal uncertainty	±%	1%	See Section 1.4.5.1
18	METSTAT-modeled direct normal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (METSTAT-modeled) received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp
19	METSTAT-modeled direct normal uncertainty	±%	1%	See Section 1.4.5.1
20	METSTAT-modeled diffuse horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (METSTAT-modeled) received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
21	METSTAT-modeled diffuse horizontal uncertainty	±%	1%	See Section 1.4.5.1
22	METSTAT-modeled clear sky global horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Total amount of direct and diffuse solar radiation (METSTAT-modeled with cloud cover set to zero) received on a horizontal surface during the 60-minute period ending at the timestamp
23	METSTAT-modeled clear sky global horizontal uncertainty	±%	1%	See Section 1.4.5.1
24	METSTAT-modeled clear sky direct normal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (METSTAT-modeled with cloud cover set to zero) received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp

Field	Element	Unit	Resolution	Description
25	METSTAT-modeled clear sky direct normal uncertainty	±%	1%	See Section 1.4.5.1
26	METSTAT-modeled clear sky diffuse horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (METSTAT-modeled with cloud cover set to zero) received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
27	METSTAT-modeled clear sky diffuse horizontal uncertainty	±%	1%	See Section 1.4.5.1
28	Measured global horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Total amount of measured direct and diffuse solar radiation received on a horizontal surface during the 60-minute period ending at the timestamp
29	Measured global horizontal quality flag	SERI-QC	--	See Table 11
30	Measured direct normal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of measured solar radiation received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp
31	Measured direct normal quality flag	SERI-QC	--	See Table 11
32	Measured diffuse horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of measured solar radiation received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
33	Measured diffuse horizontal quality flag	SERI-QC	--	See Table 11
34	Precipitable water	Centimeter	0.1 cm	The total precipitable water contained in a column of unit cross section extending from the earth's surface to the top of the atmosphere. See Section 2.2.1.4.
35	Precipitable water flag		--	See Section 1.4.5.2 and Table 13
36	Aerosol optical depth, broadband	[Unitless]	0.001	The broadband aerosol optical depth per unit of air mass due to extinction by the aerosol component of the atmosphere. See Section 2.2.1.4.
37	Aerosol optical depth flag		--	See Section 1.4.5.2 and Table 13
38	Aerosol optical depth broadband randomized (see Section 2.3.5)	[Unitless]	0.001	Broadband aerosol optical depth value randomized by the METSTAT model (see Section 2.3.3)

Field	Element	Unit	Resolution	Description
39	Aerosol optical depth broadband randomized flag		--	See Section 1.4.5.2 and Table 13
40	Ozone	Centimeter	0.001 cm	The total amount of ozone present in a column of unit cross section extending from the earth's surface to the top of the atmosphere. See Section 2.2.1.3.
41	Ozone flag		--	See Section 1.4.5.2 and Table 15
42	Albedo	[Unitless]	0.01	The ratio of reflected solar irradiance to global horizontal irradiance (GHI). See Section 2.2.1.5.
43	Albedo flag		--	--

The first line of each file contains a comma-separated value header that documents the field names.

### **1.4.3 SolarAnywhere<sup>®</sup> Format**

The gridded data set produced by the SUNY model is also available from NCDC.

#### **1.4.3.1 Data Format**

Table 4 describes the SolarAnywhere<sup>®</sup> format. Note that the format has changed since the 2005 update and no longer contains the unshifted data fields.

**Table 4. SolarAnywhere® Gridded Data Elements**

Field	Element	Unit	Resolution	Description
1	Date	YYYY-MM-DD	--	Date of data record
2	Time	HH:MM	--	Time of the data record
3	Hourly mean zenith angle (for sunup periods)	Decimal degree	0.1°	Solar zenith angle (angle between sun and the zenith) as the mean of all 1-minute sunup zenith angle values for the 60-minute period ending at the timestamp
4	SUNY-modeled global horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Total amount of direct and diffuse solar radiation (modeled) received on a horizontal surface during the 60-minute period ending at the timestamp
5	SUNY-modeled direct normal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (modeled) received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp
6	SUNY-modeled diffuse horizontal	Watt-hour per square meter	1 Wh/m <sup>2</sup>	Amount of solar radiation (modeled) received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
7	Data flag	--	--	See Table 5.

Data flags have been added to the SolarAnywhere® data by NREL. These flags are documented in Table 5.

**Table 5. SolarAnywhere® Data Flags Added by NREL**

Flag	Description
0	Global and direct unmodified; diffuse calculated by NREL (see Section 2.1.6)
1	Data have been added at high zenith angles by NREL (see Section 2.1.6)
2	Diffuse has been set to clear sky minimum and direct recalculated (see Section 2.1.6)
3	Data have been filled (see Section 2.1.6)

### 1.4.3.2 Finding Data for a Specific Location

Data files are accessed from the links in Table 1. To find data for a specific location:

1. Determine the name of the file that holds the desired data.
2. Find the file in the directory structure.

#### 1.4.3.2.1 Determining the File Name

Each file is explicitly named with latitude and longitude coordinates. For example:

NSRDB\_SolarAnywhere10km\_19910101\_20091231\_lat34.05lon-109.75.csv.gz

These coordinates represent the center of a pixel that is one-tenth of a degree on each side. In the example above, the data therein represent geographical coordinates from latitude 34.00 to 34.10 and longitude -109.70 to -109.80.

The proper file name is constructed by truncating (not rounding) the latitude and longitude values to tenth-of-a-degree resolution and adding 0.05. For example, to find data for Lat=34.01 and Lon=-109.79:

1. Truncate 34.01 to 34.00 and add 0.05 degrees for 34.05.
2. Truncate -109.79 to -109.7 and add 0.05 degrees for -109.75.

Look for the file with these coordinates in the name.

#### **1.4.3.2.2 Finding Specific Files in the Directory Structure**

Files are organized in directories with names that are coded and labeled by latitude and longitude in the following five-digit format:

TTNNN

(where TT is a two-digit integer latitude and NNN is a three-digit integer longitude).

These latitude and longitude coordinates represent the southwest corner of a 2-by-2 degree box, and all files in that directory fall within the geographical box. The longitude is actually negative, but the negative sign is not used in the directory coding; however, *it is used to determine the southwest corner*. Another way of stating this is that the directory latitude and longitude numbers are the lowest coordinate values of the 2-by-2 box. The coded directory coordinates are always even numbers.

For example, to find the directory holding the file named with latitude 34.05 and longitude -109.75:

1. Take the integer portion of both the latitude (34) and longitude (-109). Determine the next even number less than or equal to the integers, which in this example would be:

34 and -110 (remember that -110 is arithmetically less than -109)

2. Drop the negative sign, and put them together in latitude-longitude order to form the directory:

34110

3. Open that directory, and you will find the correct file:

NSRDB\_SolarAnywhere10km\_19910101\_20091231\_lat34.05lon-109.75.csv.gz

### 1.4.3.2.3 Extracting the Data

Data are in a comma-separated value format and have been compressed using the gzip utility, thus giving them a .gz file extension. Several utilities exist to uncompress a .gz file. Among them (no implied endorsement) are gzip on unix and linux computers, WinZip and 7-Zip on Windows, and WinZip and Stuffit on the Macintosh. *Files must be transferred from the server using a binary protocol (not ASCII), or the uncompression step will fail.*

## 1.4.4 Statistical Summaries

This section details the information required to view and use the statistical products from the NSRDB.

### 1.4.4.1 Daily Statistics

Figure 2 is an example of a daily statistics file. The header identifies the station using the six-digit USAF identifier, station name (the first 22 characters), and state code. The header identifies the time zone (TZ) for the station as the number of hours by which the local standard time lags (minus) or leads (plus) Universal Time (e.g., Eastern Standard Time is designated as -5). Latitude and longitude for the station are given in degrees and minutes, station elevation is in meters, and the mean atmospheric pressure is given in millibars.

The next line in each file identifies the year(s) for which the next section of data applies. In each file, the first group of data provides daily statistics for the 20 years 1991–2010. Statistics for each year for the entire period of record follow. As an example, Figure 2 gives 20-year statistics for Albuquerque, New Mexico. Monthly and annual statistics are given for 1991 to 2010, followed by similar monthly statistics for each year. The Fortran formats for reading the header, year(s), and data records are given at the bottom of Figure 2.

*The standard deviations of solar radiation elements (e.g., SDGLO) for individual years and for the period of record (1991–2010) are not the same. For individual years, the standard deviations provide a measure of daily variability. For the period of record, the standard deviations provide a measure of the interannual variability of monthly and annual averages.*

*The NSRDB mean values for meteorological elements may not be identical to the means published by NCDC. Small differences are expected as the result of different computational methods and differences in methods to replace missing data, but these differences have not been quantified.*

Two flags define the quality of each solar radiation element in the daily statistics files. The first flag gives the user information about the source of each hourly value for each solar radiation element, including the methods and input data used to derive model estimates. The flags are based on the hourly data and, in this context, represent the dominant category of source data for the period. Solar radiation source flags are defined in Table 6. The flags are ranked roughly from the highest- to the lowest-quality data. The first eight table entries (flags A–H) pertain to the 1961–1990 NSRDB and do not occur in the 1991–2010 update but are included here for historical completeness. Entries I–K (in bold) were added to denote the improved aerosol estimates used for the NSRDB updates.



**Table 6. Source Codes Solar Radiation Elements**

<b>Flag</b>	<b>Definition</b>
A	Post-1976 measured solar radiation data as received from NCDC or other sources
B	Same as "A" except the global horizontal data underwent a calibration correction
C	Pre-1976 measured global horizontal data (direct and diffuse were not measured before 1976) adjusted from solar to local time, usually with a calibration correction
D	Data derived from the other two elements of solar radiation using the relation $K_t = K_n + K_d$
E	Modeled solar radiation data using inputs of <i>observed</i> sky cover (cloud amount) and aerosol optical depths derived from direct normal data collected at the same location
F	Modeled solar radiation using <i>interpolated</i> sky cover and aerosol optical depths derived from direct normal data collected at the same location
G	Modeled solar radiation data using <i>observed</i> sky cover and aerosol optical depths <i>estimated</i> from geographical relationships
H	Modeled solar radiation data using <i>interpolated</i> sky cover and <i>estimated</i> aerosol optical depths
<b>I</b>	<b>Modeled solar radiation data using ground <i>observed</i> sky cover and revised aerosols</b>
<b>J</b>	<b>Modeled solar radiation data using <i>filled</i> sky cover and revised aerosols</b>
<b>K</b>	<b>Modeled solar radiation data using satellite imagery and revised aerosols</b>
?	Source does not fit any of the above categories.

The second flag designates the uncertainty attached to the value. Uncertainty, as used here, provides an estimate of the interval around a measured or modeled value within which the true value will fall 95% of the time. The flags are based on the individual hourly data and, in this context, represent the average uncertainty for the period. The uncertainty flags are defined in Table 7.

**Table 7. Uncertainty Ranges for Daily Statistics Files**

<b>Flag</b>	<b>Uncertainty (<math>\pm\%</math>)</b>
1	0–2
2	2–4
3	4–6
4	6–9
5	9–13
6	13–18
7	18–25
8	25–35
9	35–50
0	Not Applicable

#### 1.4.4.2 Hourly Means, Standard Deviations, and Distributions

The hourly statistics are presented in the form of means and standard deviations of the hourly values for each hour (from which diurnal profiles can be formed) and distributions generated by binning hourly values to determine the number of hours for which the radiation fell within 24 50-Wh/m<sup>2</sup> ranges (e.g., 0–50, 50–100, 100–150, ... 1100–1150, 1150–1200). The bin data have been normalized to indicate the percentage (in tenths) of all daytime hours for which the radiation fell within each bin. Figure 3 provides an example of these hourly statistics. The header information is the same as that used for the daily statistics, except that the year(s) represented by each file has been added as the last field of the header.

Following the header, the next record identifies the solar radiation element (e.g., global horizontal radiation in Wh/m<sup>2</sup>) and the statistics (e.g., arithmetic means) for which the following data records apply. Each file contains data for all three solar radiation elements and each of the three statistics, as indicated in Figure 3.

The first two fields in each data record designate the month (13 indicates *annual* statistics) and the source and uncertainty flags that apply to each monthly profile and distribution.

The data fields for means and standard deviations contain these hourly statistics in Wh/m<sup>2</sup> for each of the 24 hours of the day. For example, values for hour 01 represent the mean or standard deviation of the total radiant energy measured from midnight (2400) to 1 a.m. (0100). The data fields for the distributions designate the percentage of hours, in tenths of one percent, for which the average radiation fell within the 50-Wh/m<sup>2</sup> bins described above.

The Fortran formats for reading the header, statistic identification, and data records are given at the bottom of Figure 3.

#### 1.4.4.3 Daily Persistence Data

The persistence of weather events and the effect this has on the availability of solar radiation energy can affect many solar energy applications. In particular, the persistence of solar energy can affect energy storage requirements and the need for backup energy sources.

The persistence statistic calculated for the NSRDB is the number of sequential days (runs) in a month during which the daily total energy exceeded or fell below 12 energy thresholds (see Figure 4). The run lengths vary from 1 to 15 or more days. The total number of runs over the entire 20-year period of 1991–2010 was determined for each month. The decision to compute persistence on a monthly (rather than perpetual) basis resulted in the truncation of runs at the end of each month and, possibly, in an underestimation of longer runs. Although this procedure caused some distortion of the statistics, it provided important information about seasonal changes in persistence.

An example of the persistence statistic is shown in Figure 4. The thresholds for diffuse horizontal radiation (0–5,000 Wh/m<sup>2</sup> in 11 steps) are one-half those used for global horizontal and direct normal radiation (0–10,000 Wh/m<sup>2</sup> in 11 steps). The header information gives the USAF number, station name, state code, month, and solar radiation element.

Each number in the matrices on the left of Figure 4 is the number of times the daily total solar energy exceeded the threshold indicated for that row for no more or no less than the number of days indicated for that column. Each number in the matrices on the right is the number of times the daily total solar energy was less than the threshold indicated for that row for no more or no less than the number of days indicated for that column.

The numbers in these matrices can be used various ways. For example, the sum of all the numbers in the sector enclosed by the dotted line indicates that the daily total global horizontal energy fell below 6,000 Wh/m<sup>2</sup> for 4 or more days 27 times (the sum of all numbers in the sector) during 1991–2010. These matrices can be sectored in any manner that produces information useful to specific applications.

The Fortran formats for reading the headers, number of days, thresholds, and number of events are given at the bottom of Figure 4.

### 1.4.5 Hourly Quality Flags

Quality flags are attached to each hourly solar radiation and meteorological element. Each solar radiation element has a source flag and an uncertainty value, and each meteorological element has a source flag. These flags provide information about the source and uncertainty of a data element to allow users to evaluate its usefulness. The flags are further described in the following sections.

#### 1.4.5.1 Source Flags, Quality Flags, and Estimated Uncertainty for Solar Radiation Elements

For the modeled solar elements, the source flags are described in Table 8.

**Table 8. Modeled Solar Radiation Source Flags**

Flag	Description
1	Value modeled from the METSTAT model
2	Value from time-shifted SolarAnywhere <sup>®</sup> ; diffuse calculated by NREL (see Section 2.1.6)
3	Value from SolarAnywhere <sup>®</sup> , adjusted to a minimum low-diffuse envelope (see Section 2.1.6)
4	Value from SolarAnywhere <sup>®</sup> , filled by NREL (see Section 2.1.6)
99	Missing data (associated data field is filled with -9900)

The uncertainty flags ( $\pm\%$ ) are based on model type and quality of input data. The uncertainty is calculated based on model evaluation (Myers 2005) that compared predictions with measured ground data that have been averaged to monthly mean daily totals (MMDT). Since the release of the 1991–2005 NSRDB update, Clean Power Research, in partnership with SUNY, updated the SUNY model and released updated data sets, of which Version 2.2 is incorporated in the NSRDB. No independent analysis has been published to quantify the changes and presumed improvements. Until such time, the NSRDB will continue to use the results of Myers 2005 for the uncertainty analysis.

The approach is based on the International Bureau of Weights and Measures and ISO GUM (International Bureau of Weights and Measures 1993). From this evaluation, an optimal uncertainty,  $U_{opt}$ , for each parameter was calculated using the best available sky cover or satellite image input data.

$$U_{opt} = (U_{meas}^2 + U_{mod}^2 + U_{bias}^2)^{1/2} (\pm\%)$$

where

- $U_{meas}$  is the uncertainty of the measured data ( $\pm\%$ )
- $U_{mod}$  is the RMSE of the model ( $\pm\%$ )
- $U_{bias}$  is the mean bias error of the model ( $\pm\%$ ).

$U_{meas}$  ( $\pm\%$ ) is set as follows:

<b>Global</b>	<b>Direct</b>	<b>Diffuse</b>
6	5	6

These values are approximately double the ideal measurement uncertainty for the instrumentation and include additional uncertainties attributable to common operational problems at even well-maintained sites.

$U_{mod}$  and  $U_{bias}$  ( $\pm\%$ ) for each model and parameter are listed below.

<b>Model</b>	<b>Glo/Dif RMS (<math>U_{mod}</math>)</b>	<b>Glo/Dif MBE (<math>U_{bias}</math>)</b>	<b>Dir RMS (<math>U_{mod}</math>)</b>	<b>Dir MBE (<math>U_{bias}</math>)</b>
METSTAT	8	2	15	4
SUNY	5	0	14	1

Notes:

MBE – mean bias error

RMS – root mean square error

Finally, the calculated  $U_{opt}$  ( $\pm\%$ ) for each model is listed below.

<b>Model</b>	<b>Glo/Dif</b>	<b>Dir</b>
METSTAT	10	16
SUNY	8	15

These optimal uncertainties reflect model performance using the highest quality input cloud data and include the uncertainty of the ground measurements used for validation. For the METSTAT model, optimal cloud cover consists of a set of total and opaque cloud values derived using the NCDC Supplemental Cloud Product. Manual cloud observations, when available, are presumed to be as good or better than those derived from the Supplemental

Cloud Product but were not used in the model evaluation. For the SUNY model, optimal inputs are GOES pixels without snow cover and below 50° latitude.

To these optimal uncertainties, more uncertainty is added for an uncertainty, U, under non-optimal conditions.

$$U = (U_{\text{opt}}^2 + U_{\text{add1}}^2 + U_{\text{add2}}^2 \dots)^{1/2} (\pm\%)$$

where

–  $U_{\text{add}i}$  are additional sources of uncertainty.

Additional uncertainties for each model are shown in the tables below.

**Table 9. METSTAT Additional Uncertainties (±%)**

Condition	Additional Uncertainty	Comments
Short- and medium-term data filling	4	Data derived from close time proximity
Long-term filling	14	Based on interannual variability—data come from like dates in other years
Cloud probability derivation	4	Differences in total and opaque average less than 1 okta
Cloud probability from nearby site	4	Differences in total and opaque average less than 1 okta
ASOS-only	22	Limited okta resolution afforded by the coded ASOS-only data—a cloud measurement value could be in error by two oktas

Data filling is explained in Section 2.2.2.

**Table 10. SUNY Additional Uncertainties (±%)**

Condition	Additional Uncertainty	Comments
Time shifting	2	Shifting from satellite time to hourly local time causes some error in the hourly values or daily totals.
Ground snow cover	5	High ground albedo compresses the dynamic range of the model. Periods of snow cover were estimated for 5° latitude and longitude cells on a monthly basis using snow cover probability contours for the United States (Dickerson 1967). If the probability of snow for a given location was greater than 25%, the additional uncertainty was added to the data.

The source flag for the SolarAnywhere® data are described in Table 5. (See section 2.1.6) For the measured solar radiation fields, the flag fields hold SERI-QC flags (NREL 1993). A brief summary of the SERI-QC flags appears in Table 11.

**Table 11. SERI-QC Flag Descriptions**

Flag	Description
00	Untested (raw data)
01	Passed one-component test; data fall within min-max limits of $K_t$ , $K_n$ , or $K_d$
02	Passed two-component test; data fall within 0.03 of the Gompertz boundaries
03	Passed three-component test; data come within 0.03 of satisfying $K_t = K_n + K_d$
04	Passed visual inspection; <i>not used</i> by SERI-QC
05	Failed visual inspection; <i>not used</i> by SERI-QC
06	Value estimated; passes all pertinent SERI-QC test
07	Failed one-component test; lower than allowed minimum
08	Failed one-component test; higher than allowed maximum
09	Passed three-component test but failed two-component test by $>0.05$
10-93	Failed two- or three-component tests in one of four ways.
	To determine the test failed and the manner of failure (high or low), examine the remainder of the calculation $(\text{flag} + 2)/4$ .
<b>REM</b>	<b>Failure</b>
0	Parameter too low by three-component test ( $K_t = K_n + K_d$ )
1	Parameter too high by three-component test ( $K_t = K_n + K_d$ )
2	Parameter too low by two-component test (Gompertz boundaries)
3	Parameter too high by two-component test (Gompertz boundaries)
	The magnitude of the test failure (distance in K-units) is determined from: $d = (\text{INT}(\text{flag} + 2)/4)/100$ .
94-97	Data fall into a physically impossible region where $K_n > K_t$ by K-space distances of 0.05–0.10 (94), 0.10–0.15 (95), 0.15–0.20 (96), or $\pm 0.20$ (97).
98	Not used
99	Missing data (associated data field is filled with -9900)

SERI-QC flags of 6 were used when filling a missing solar value using two other solar components. The quality of these data can be estimated from the SERI-QC flag of either of the other two components.

*Note: No effort was made to filter the measured data based on quality to allow the user the opportunity to optimize the data set according to quality specifications demanded by a particular application.*

#### 1.4.5.2 Quality Flags for Meteorological and Other Elements

Meteorological data came from NCDC's ISD data (Lott 2001). The flags that accompanied the ISD data were carried through to the NSRDB data fields (NCDC 2004). If a value was modified or filled, additional flags specific to the NSRDB data set were added. ISD data with flags indicating questionable data were excluded from the NSRDB. An extensive hand inspection of anomalous data in the 2005 update found that many such data points were flagged as questionable. Thus the decision was made to exclude all such data and allow the subsequent data filling routines to populate those fields. Table 12 describes flags on the meteorological data.

**Table 12. Meteorological Data Flags**

Flag	Description
0-9	ISD data flags (unmodified data)
51	Value from short-term data filling or interpolation
52	Value from medium-term data filling
53	Value from long-term data filling
54	Value is calculated: <ul style="list-style-type: none"><li>• Relative humidity calculated from dry-bulb and dew-point temperatures</li><li>• Station pressure calculated from sea-level pressure, altimeter, and dry-bulb</li><li>• Data point undefined by convention (e.g., wind direction at zero speed)</li></ul>
55	Value from last-ditch data filling
56	Value statistically derived (cloud amounts based on probability tables)
61	Value modeled (total and opaque cloud derived from Supplemental Cloud Product; ceiling height as linear function of opaque cloud amount); pressure modeled from elevation
99	Value missing (associated data field is filled with -9900)

The flags attached to the aerosol optical depth data are described in Table 13. See Section 2.2.1.2.

**Table 13. Aerosol Optical Depth Flags**

<b>Flag</b>	<b>Description</b>
1	Direct normal irradiance (DNI) measurements used with inverted Climatological Solar Radiation model (1995)
2	From Southwest United States study by George and Gueymard (2001) using spectral data from ground-based sun photometers
3	Gridded data from Multi-Angle Imaging SpectroRadiometer spaceborne instrument and altitude corrections (Gueymard and George 2005)
51	Value from short-term data filling or interpolation
52	Value from medium-term data filling
53	Value from long-term data filling
55	Value from last-ditch data filling

The precipitable water data flags are described in Table 14. See Section 2.2.1.4.

**Table 14. Precipitable Water Flags**

<b>Flag</b>	<b>Description</b>
1	From National Aeronautics and Space Administration Water Vapor Project (NVAP) once daily from 1° x 1° grid
2	NVAP twice daily from 0.5° x 0.5° grid
3	From North American Regional Reanalysis (NARR) eight times daily from 32-km grid
4	From twice daily radiosonde
51	Value from short-term data filling or interpolation
52	Value from medium-term data filling
53	Value from long-term data filling
55	Value from last-ditch data filling

The ozone data flags are described in Table 15. See Section 2.2.1.3.

**Table 15. Ozone Flags**

<b>Flag</b>	<b>Description</b>
1	Total Ozone Mapping Scanner (TOMS) on a grid 1° in latitude and 1.25° in longitude
2	Ozone Monitoring Instrument (OMI) on a 1° x 1° grid
51	Value from short-term data filling or interpolation
52	Value from medium-term data filling
53	Value from long-term data filling
55	Value from last-ditch data filling



USAF	CITY	STATE	TZ	LAT	LONG	ELEV	PRES																		
723650	ALBUQUERQUE	INTL	ARPT	NM	-7	N35	2	W106	37	1619	836														
1991-2005																									
MO	AVGLO	FL	SDGLO	AVDIR	FL	SDDIR	AVDIF	FL	SDDIF	AVETR	AETRN	TOT	OPQ	H2O	TAU	MAX_T	MIN_T	AVG_T	AVGDT	RH	HTDD	CLDD	AVWS		
1	3001	K5	305	5119	K7	1123	891	K5	156	5150	14218	4.1	3.4	0.64	0.06	9.20	-2.21	3.21	5.49	51	460	0	3.1		
2	3869	K5	385	5482	K7	1304	1199	K5	234	6566	15262	4.8	4.0	0.64	0.08	12.07	-0.22	5.78	7.87	45	351	0	3.6		
3	5178	K5	455	6266	K7	1307	1515	K5	282	8386	16499	4.2	3.6	0.65	0.11	16.21	2.40	9.25	11.50	38	280	0	3.9		
4	6538	K5	394	7134	K6	1018	1862	K5	264	10053	17704	3.9	3.2	0.73	0.13	20.72	6.48	13.76	15.74	31	147	5	4.4		
5	7304	K5	627	7433	K6	1522	2059	K5	399	11142	18664	3.8	3.1	1.03	0.14	26.71	12.09	19.62	21.65	29	30	63	4.2		
6	7829	K5	375	8255	K6	920	1962	K5	267	11554	19101	3.3	2.8	1.35	0.13	31.48	16.63	24.23	25.90	29	2	174	4.0		
7	7258	K5	400	7210	K6	991	2038	K5	321	11288	18770	4.7	4.1	2.03	0.14	32.71	19.35	25.70	27.63	40	0	239	3.6		
8	6453	K5	301	6450	K6	714	2005	K5	181	10359	17837	5.1	4.5	2.18	0.11	31.04	18.48	24.30	26.19	46	0	199	3.3		
9	5694	K5	341	6788	K6	823	1529	K5	182	8878	16675	3.8	3.4	1.60	0.09	27.59	14.73	20.98	22.94	43	11	96	3.3		
10	4487	K5	283	6300	K7	758	1167	K5	139	7080	15465	3.5	3.0	0.99	0.08	21.08	8.04	14.37	16.72	44	124	7	3.4		
11	3337	K5	255	5706	K7	910	894	K5	136	5476	14378	3.5	3.0	0.73	0.05	13.32	1.48	7.12	9.02	46	328	0	3.3		
12	2794	K5	321	5269	K7	1220	751	K5	148	4705	13832	3.8	3.3	0.61	0.05	8.51	-2.59	2.67	4.83	50	476	0	3.0		
13	5312	K5	225	6451	K7	723	1489	K5	169	8386	16534	4.0	3.4	1.10	0.10	20.89	7.89	14.25	16.29	41	2207	782	3.6		
1991																									
1	2958	I5	958	5063	I6	3018	841	I5	354	5144	14214	4.2	3.3	0.62	0.04	7.41	-3.36	1.39	3.73	54	505	0	3.9		
2	4013	I5	832	5720	I6	2451	1207	I5	468	6548	15247	4.6	2.9	0.60	0.06	14.38	-0.40	6.84	9.63	39	317	0	4.1		
3	4863	I5	1354	5457	I6	3065	1643	I5	581	8359	16481	5.1	4.0	0.64	0.09	15.10	0.78	7.74	10.29	35	322	0	5.0		
4	6935	I5	911	8298	I6	2145	1536	I5	562	10032	17685	2.7	1.7	0.60	0.11	21.56	5.00	13.78	16.24	20	152	0	5.0		
5	7370	I5	1492	7914	I6	3027	1874	I5	696	11130	18650	2.7	1.9	0.91	0.12	27.15	10.35	19.24	21.86	22	34	47	5.4		
6	7194	I5	1256	6935	I6	2896	2189	I5	732	11553	19099	4.3	3.5	1.56	0.12	30.65	15.04	22.97	24.83	36	7	143	4.3		
7	7005	I5	826	6310	I6	2220	2389	I5	677	11297	18781	5.2	4.4	2.36	0.14	31.65	18.06	24.25	26.38	46	0	202	3.7		
8	6294	I5	673	5735	I6	1644	2258	I5	549	10378	17856	5.2	4.0	2.53	0.14	30.58	17.50	23.50	25.83	52	0	177	2.8		
9	5303	I5	992	5529	I6	2325	1816	I5	509	8903	16694	4.7	3.7	1.82	0.15	26.29	13.48	19.37	21.62	51	13	60	3.3		
10	4472	I5	1090	5747	I6	2287	1335	I5	324	7106	15484	2.8	1.9	0.96	0.17	23.21	7.49	14.99	18.26	36	105	13	3.8		
11	3002	I5	805	3833	I6	2116	1229	I5	300	5494	14390	4.2	3.3	0.88	0.17	12.25	0.20	5.95	8.14	53	363	0	4.2		
12	2216	I5	789	2779	I6	2180	1073	I5	286	4707	13834	5.3	4.2	0.81	0.19	7.97	-2.02	2.40	4.70	63	476	0	3.1		
13	5135	I5	1832	5777	I6	1537	1616	I5	499	8388	16535	4.2	3.2	1.19	0.13	20.68	6.84	13.53	15.96	42	2295	642	4.1		
1992																									
1	2648	I5	876	3205	I6	2102	1211	I5	288	5136	14212	3.8	3.0	0.60	0.22	5.74	-4.87	0.09	2.35	62	555	0	2.3		
2	3282	I5	1097	2948	I6	2049	1706	I5	381	6563	15259	5.6	4.6	0.76	0.26	11.94	-0.28	5.67	8.03	51	362	0	2.3		
3	4407	I5	1212	3567	I6	2529	2218	I5	613	8404	16509	5.0	3.9	0.79	0.28	16.27	2.32	9.19	11.79	44	280	0	2.3		

Notes:

- BOLD TEXT** is not part of the daily statistics file but is included to identify header elements. The third record (line) in the file identifies the Month, quality FLag, and data elements (see definitions below).
  - AVGLO/DIR/DIF – Average daily total solar radiation for the GLObal horizontal, DIRect normal, and DIFfuse horizontal elements (Wh/m<sup>2</sup>)
  - SDGLO/DIR/DIF – Standard deviation of daily total global, direct, and diffuse solar radiation (see Note 2) (Wh/m<sup>2</sup>)
  - AVETR & AETRN – Average daily total global horizontal (AVETR) and direct normal (AETRN) extraterrestrial solar radiation (Wh/m<sup>2</sup>)
  - TOT, OPQ, H2O, TAU – Average TOTal and OPaQue sky cover (tenths), precipitable water (cm), and broadband aerosol optical depth (unitless)
  - MAX\_T, MIN\_T, AVG\_T, AVGDT – Average maximum, minimum, 24-hour, and daylight temperatures (°C)
  - RH, HTDD, CLDD, AVWS – Average relative humidity (%), heating (HTDD) and cooling (CLDD) degree (°C) days (base 18.3°C), and wind speed (m/s).
- The standard deviations of solar radiation elements (e.g., SDGLO) for individual years and for the period of record (1991–2009) *are not the same*. For individual years, the standard deviation provides a measure of daily variability. For the period of record, the standard deviations provide a measure of the interannual variability of monthly and annual averages.

HEADER FORMAT ( I6, 1X, A22, 1X, A2, I4, 2X, A1, I2, I3, 2X, A1, 2I3, 2I6 )  
YEAR(S) FORMAT ( 1X, A11 )  
DATA FORMAT ( 1X, I2, 3( I6, 1X, A1, I1, I6 ), 2I6, 2F5.1, 2F6.2, 4F7.2, I4, 2I6, F5.1 )

Figure 2. Part of the daily statistics file for Albuquerque, New Mexico

USAF	CITY	STATE	TZ	LAT	LONG	ELEV	PRES	YEAR(S)																				
723650	ALBUQUERQUE	INTL	ARPT	NM	-7	N35	2	W106	37	1619	836	1998																
<b>STATISTIC I.D.</b>																												
GLOBAL MEANS																												
MO	FL	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
1	K5	0	0	0	0	0	0	0	7	203	356	466	544	559	513	398	270	105	0	0	0	0	0	0	0			
2	K5	0	0	0	0	0	0	0	71	275	417	540	579	584	557	467	320	162	24	0	0	0	0	0	0			
3	K4	0	0	0	0	0	0	0	5	196	370	525	645	691	731	666	571	434	253	84	0	0	0	0	0			
4	K4	0	0	0	0	0	2	156	359	535	688	782	860	869	826	723	558	362	169	9	0	0	0	0	0			
5	K4	0	0	0	0	0	9	242	444	640	812	933	994	936	844	734	582	394	213	51	0	0	0	0	0			
6	K4	0	0	0	0	0	73	277	475	661	826	942	992	995	911	787	640	459	261	88	0	0	0	0	0			
7	K4	0	0	0	0	0	1	204	359	529	686	819	876	894	825	639	497	316	157	84	0	0	0	0	0			
8	K4	0	0	0	0	0	2	160	332	515	708	825	890	907	845	708	516	334	150	32	0	0	0	0	0			
9	K4	0	0	0	0	0	0	90	300	500	657	783	821	830	773	622	454	253	78	0	0	0	0	0	0			
10	K5	0	0	0	0	0	0	2	187	345	502	554	661	631	564	481	314	134	6	0	0	0	0	0	0			
11	K5	0	0	0	0	0	0	0	103	265	406	490	532	515	460	357	219	51	0	0	0	0	0	0	0			
12	K5	0	0	0	0	0	0	0	2	204	348	463	512	541	471	353	197	42	0	0	0	0	0	0	0			
13	K4	0	0	0	0	0	7	95	236	420	578	687	746	749	688	570	417	239	95	22	0	0	0	0	0			
GLOBAL STANDARD DEVIATIONS																												
1	K5	0	0	0	0	0	0	0	7	52	86	124	119	112	102	93	71	33	0	0	0	0	0	0	0			
2	K5	0	0	0	0	0	0	0	65	82	126	142	187	185	169	137	111	75	18	0	0	0	0	0	0			
3	K4	0	0	0	0	0	0	11	77	132	178	211	274	251	230	214	162	102	40	0	0	0	0	0	0			
4	K4	0	0	0	0	0	3	46	80	130	170	235	229	233	187	142	112	72	38	9	0	0	0	0	0			
5	K4	0	0	0	0	0	22	41	50	79	78	99	113	226	232	191	154	133	68	16	0	0	0	0	0			
6	K4	0	0	0	0	0	21	15	25	52	48	91	136	128	184	183	132	97	68	14	0	0	0	0	0			
7	K4	0	0	0	0	0	2	53	100	164	172	189	227	217	230	264	231	169	97	27	0	0	0	0	0			
8	K4	0	0	0	0	0	3	34	68	95	58	105	131	115	98	132	154	124	71	21	0	0	0	0	0			
9	K4	0	0	0	0	0	0	47	33	37	52	63	151	108	112	133	117	88	39	0	0	0	0	0	0			
10	K5	0	0	0	0	0	0	3	86	144	174	249	202	233	199	148	119	69	9	0	0	0	0	0	0			
11	K5	0	0	0	0	0	0	0	46	92	130	150	171	165	154	107	66	20	0	0	0	0	0	0	0			
12	K5	0	0	0	0	0	0	0	4	50	98	109	122	75	75	71	54	8	0	0	0	0	0	0	0			
13	K4	0	0	0	0	0	21	108	165	163	173	181	181	175	167	155	149	139	93	34	0	0	0	0	0			
GLOBAL DISTRIBUTIONS																												
1	K5	188	53	50	38	103	59	32	85	67	44	94	103	62	23	0	0	0	0	0	0	0	0	0	0			
2	K5	172	43	71	58	55	52	58	77	43	58	74	58	40	28	6	0	0	0	0	0	0	0	0	0			
3	K4	178	64	67	57	27	57	42	32	37	37	42	37	44	57	27	74	47	32	0	0	0	0	0	0			
4	K4	148	7	43	69	50	31	29	45	74	7	29	45	60	31	31	48	57	33	55	57	52	0	0	0			
5	K4	153	48	15	13	65	65	9	11	41	87	4	9	35	78	20	11	65	46	35	94	68	28	0	0			
6	K4	129	108	19	8	12	92	33	6	10	69	46	4	6	83	29	8	60	50	19	94	92	21	0	0			
7	K4	156	60	83	21	77	34	36	23	51	23	21	19	53	30	19	47	32	26	85	45	58	0	0	0			
8	K4	152	36	32	84	27	18	32	61	25	25	23	68	27	32	57	57	41	70	84	52	0	0	0	0			
9	K4	154	51	78	2	17	59	54	15	20	64	64	22	32	69	54	61	81	69	34	0	0	0	0	0			
10	K5	188	40	67	62	59	70	19	46	54	35	27	48	67	51	73	54	32	8	0	0	0	0	0	0			
11	K5	190	91	61	47	70	67	47	64	47	53	73	88	58	41	3	0	0	0	0	0	0	0	0	0			
12	K5	196	47	19	41	149	9	25	146	32	63	133	139	0	0	0	0	0	0	0	0	0	0	0	0			
13	K4	167	54	50	42	59	51	35	50	42	49	49	54	43	45	32	28	37	29	29	28	22	4	0	0			

Notes:

1. **BOLD TEXT** is not part of the hourly statistic file but is included to identify header and data information.
2. For the means and standard deviations blocks, the bold column numbers 1 to 24 represent the hours of the day. For the distributions, these numbers times 50 give the upper value of the bin range in watt-hour per square meter. The lower value of the range for each bin is 50 Wh/m<sup>2</sup> less.
3. Each hourly statistic file contains similar statistics for the direct normal and diffuse horizontal elements.

HEADER FORMAT ( I6, 1X, A22, 1X, A2, I4, 2X, A1, I2, I3, 2X, A1, 2I3, 2I6, I7 )  
 STATISTIC I.D. FORMAT ( A30 )  
 DATA FORMAT ( X, I2, 1X, A1, I1, 24I5 )

Figure 3. Part of the hourly statistics file for Albuquerque, New Mexico

MONTHLY PERSISTENCE REPORT, SITE #723650, ALBUQUERQUE INTL ARPT (NM), MONTH 9, GLOBAL  
Number of runs of days solar energy EXCEEDED threshold      Number of runs of days solar energy LESS THAN threshold

(Run length in DAYS)																Wh/m2	(Run length in DAYS)															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	1		2	3	4	5	6	7	8	9	10	11	12	13	14	15+		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15		
13	1	1	1	0	0	0	0	0	0	0	0	0	0	0	7000	3	5	3	2	1	0	0	0	0	0	0	0	0	0	15		
22	24	10	6	3	4	1	1	1	0	1	0	1	0	0	6000	31	15	8	6	6	3	3	1	2	0	1	0	0	0	1		
13	13	9	6	4	4	6	1	2	2	1	2	2	1	3	5000	39	11	3	3	0	1	0	0	0	0	0	0	0	0	0		
4	6	2	1	5	7	4	2	1	4	2	3	1	2	6	4000	28	6	1	0	0	0	0	0	0	0	0	0	0	0	0		
2	1	2	1	0	2	1	0	2	0	2	3	1	2	11	3000	13	2	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2000	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

MONTHLY PERSISTENCE REPORT, SITE #723650, ALBUQUERQUE INTL ARPT (NM), MONTH 9, DIRECT  
Number of runs of days solar energy EXCEEDED threshold      Number of runs of days solar energy LESS THAN threshold

(Run length in DAYS)																Wh/m2	(Run length in DAYS)															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	1		2	3	4	5	6	7	8	9	10	11	12	13	14	15+		
6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	10000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15		
32	9	5	4	0	0	0	0	0	0	0	0	0	0	0	9000	12	9	8	3	6	2	2	2	2	5	2	1	2	2	4		
41	18	7	9	0	3	1	1	1	0	0	0	0	0	0	8000	27	18	7	8	7	8	4	1	0	0	1	0	0	0	1		
27	17	9	9	6	4	4	1	2	0	1	0	1	0	0	7000	38	12	10	5	7	1	2	1	0	0	0	0	0	0	1		
22	16	9	7	4	3	4	2	2	2	1	1	2	1	1	6000	41	15	5	4	3	2	2	0	0	0	0	0	0	0	0		
17	12	11	7	3	5	5	3	1	1	2	2	2	1	2	5000	37	17	5	3	1	0	0	0	0	0	0	0	0	0	0		
10	9	7	5	6	5	4	3	0	5	3	2	0	2	3	4000	36	9	5	0	0	0	0	0	0	0	0	0	0	0	0		
3	6	2	2	6	8	4	3	1	2	2	4	1	2	5	3000	29	7	0	0	0	0	0	0	0	0	0	0	0	0	0		
2	3	2	0	0	3	1	2	2	1	3	5	1	2	9	2000	19	2	0	0	0	0	0	0	0	0	0	0	0	0	0		
1	0	2	0	0	0	0	1	0	2	2	2	1	2	13	1000	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
1	0	1	0	0	0	0	0	0	1	2	1	0	1	14	500	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

MONTHLY PERSISTENCE REPORT, SITE #723650, ALBUQUERQUE INTL ARPT (NM), MONTH 9, DIFFUSE  
Number of runs of days solar energy EXCEEDED threshold      Number of runs of days solar energy LESS THAN threshold

(Run length in DAYS)																Wh/m2	(Run length in DAYS)															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	1		2	3	4	5	6	7	8	9	10	11	12	13	14	15+		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15		
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3000	0	0	1	0	0	0	0	0	0	0	1	0	0	0	15		
16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2500	1	1	1	1	1	2	2	3	0	2	1	2	0	2	12		
28	12	6	2	1	0	1	0	0	0	0	0	0	0	0	2000	11	8	8	6	2	7	4	2	0	5	1	0	1	2	5		
44	13	10	9	4	2	3	0	0	0	0	0	0	0	1	1500	32	21	10	6	7	4	4	2	0	0	1	0	0	0	0		
11	10	4	3	2	4	3	1	1	4	3	1	1	1	8	1000	38	4	2	3	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

The boxed data are discussed in Section 1.4.4.3.

HEADER FORMAT ( A132 ) Note: For eight lines before the data, including three blank lines.  
DATA FORMAT ( 1X, 15I4, I7, 2X, 15I4 )

Figure 4. The persistence statistics file for Albuquerque, New Mexico, for September

## **2 How the 1991–2010 NSRDB Update Was Produced**

### **2.1 Update History**

In 1992, NREL released the 1961–1990 NSRDB, a 30-year data set of measured and modeled solar radiation and accompanying meteorological data with solar estimates based on the METSTAT solar radiation model, also developed at NREL. In recent years, interest has grown in a NSRDB update that includes the decades beyond 1990.

In April 2003, NREL convened a meeting of experts to investigate the feasibility and desirability of an NSRDB update. Meeting participants concluded that the greatest challenge was a change in the measurements of cloud cover by the NWS. During the 1990s, the NWS migrated from a manual (human) system of full-sky cloud observations to the ASOS, which derives cloud cover from laser ceilometer observations at the zenith. The ASOS cloud observations are not compatible with the necessary inputs for the METSTAT model, which makes it impossible to create an updated NSRDB by simple METSTAT model runs using currently available meteorological data.

Meeting participants agreed that an update was desirable to provide constituents with the most recent climatology and, possibly, a data set with enhanced spatial resolution. Recent advances in satellite-based techniques for modeling solar irradiance and cloud algorithms provided further incentive.

A 1991–2005 NSRDB update was released by NREL in 2007, according to the methods listed below. Except as noted, these methods were also used for the 1991–2010 update.

#### **2.1.1 Update Planning**

From the 2003 meeting of experts came a multi-stage plan, and collaborative work began with several agencies, including the National Aeronautics and Space Administration, the NCDC, the Northeast Regional Climate Center, SUNY, the University of Oregon, the University of Wisconsin, and the private firm Solar Consulting Services. The first stage produced a small-scale evaluation database that enabled the investigation of database production issues, the assessment of input data availability and quality, and the development modeling alternatives. From this evaluation came a full-scale plan for a multi-year update.

Among the issues that needed to be resolved were:

- Cloud cover observations
- Aerosols, water vapor, and ozone
- A ground-measured evaluation data set
- Solar model selection
- Satellite-based modeled irradiance data.

#### **2.1.2 Cloud Cover Observations**

The difficulty of changing from manual to automated cloud observations in the 1990s was exacerbated by significant changes in the operation of several solar radiation networks during the same period. This removed a consistent reference for studying the effects of changing

inputs to solar models. Although the changes from manual to automated cloud observations were well supported by cost savings and exploitation of new technology, the effect on solar modelers—particularly in this project—has been a large discontinuity in the cloud observation data record and consistency. (In addition, cloud reporting since the ASOS deployment has been found to be inconsistent from station to station because of the use of augmented human-based observation at several sites.)

As previously discussed, the recent switch to automatic weather stations eliminated the human-observed total and opaque sky cover amounts used for inputs to the METSTAT model. The approach devised for the NSRDB update derived equivalent sky cover inputs (total and opaque cloud cover) for use with the METSTAT model from a combination of ASOS data and the NCDC ASOS Supplemental Cloud Product. ASOS detects clouds to 12,000 ft, and the ASOS supplemental cloud measurements provide cloud information, including heights more than 12,000 ft, for an area that is 50 km x 50 km centered on the ASOS station.

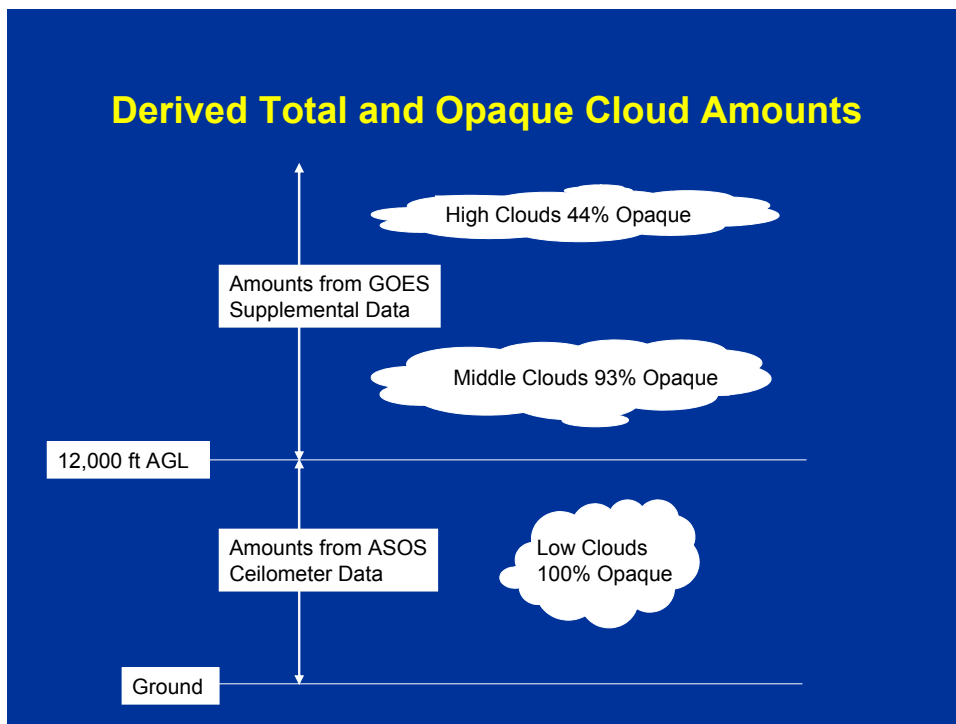
To minimize inconsistencies from station to station because of augmented human-based observations (Perez 2001), the ISD ASOS GD fields were used instead of the GF1 total sky cover field (NCDC 2004) to assign sky cover amounts below 12,000 ft for low clouds. The GD fields are sky cover summation fields that denote the portion of the celestial dome covered by all layers of clouds below a given height. Typically, as many as three GD fields might be present. For this work, the GD field with the greatest cloud-based height not exceeding 12,000 ft (3,657 m) was used for the total sky cover below 12,000 ft. GD fields with cloud base heights that exceeded 12,000 ft were ignored because they were assumed to be from human-based observations. GD sky cover amounts are integer values from 0 to 4 based on the few-scattered-broken reporting methodology. The representation in oktas, and the conversion to hundredths that was used to be consistent with sky cover amounts for heights above 12,000 ft, is shown in Table 16.

**Table 16. GD Field Sky Cover Amounts and Their Representation in Oktas and Hundredths**

GD Field Value	Reported	Oktas	Hundredths
0	Clear	0	0
1	Few	2 or less	25
2	Scattered	3–4	44
3	Broken	5–7	75
4	Overcast	8	100

For heights above 12,000 ft, the ASOS supplemental cloud data were used to determine sky cover amounts representing middle and high clouds. These data include three five-by-five matrices that provide cloud type (high, middle, or low), cloud top pressure, and effective cloud amount (percent or hundredths). If the cloud top pressure indicated that the cloud top was below 12,000 ft, the sky cover for the matrix element was assumed zero, and the ground measurement was used. Otherwise, cloud amounts were summed and then divided by 25 to give an average total sky cover amount. Opaque sky cover amounts were determined in a similar fashion after applying opacity factors to the individual cloud amounts based on cloud

type (low clouds opacity factor = 1.00; middle clouds opacity factor = 0.93; and high clouds opacity factor = 0.44). See Figure 5.



**Figure 5. Pictorial description of the cloud derivation method**

The low cloud amounts determined from the ASOS data and the middle and high cloud amounts determined from the ASOS supplemental data are combined using a random overlap equation to account for the low clouds overlapping the high and middle clouds.

$$\text{Sky Cover (hundredths)} = 100 - [(100 - \text{low amount}) \times (100 - \text{high and middle amount})] / 100$$

This procedure appears to work reasonably well to minimize inconsistencies from station to station because of augmented human-based observations.

In subsequent NSRDB tasks, we discovered the ASOS Supplemental Cloud Product was not available for several hundred of the candidate NSRDB sites, including all sites in Alaska and most in Hawaii. This placed significant restrictions on the geographical coverage and number of sites in the new NSRDB. To address this situation, a statistical method of estimating cloud cover was developed by computing probability distributions of total cloud cover (oktas) relative to opaque cloud cover amounts for every site where both total and opaque measurements were available from either human observations or the supplemental cloud method. These site-specific monthly distributions derive from the relative number of occurrences of each of the nine total cloud amounts for each of the nine opaque cloud amounts (in oktas as an integer range from 0 to 8). An example of the resulting distributions for the first 2 months of the year is shown in Table 17. For a given value of opaque for each

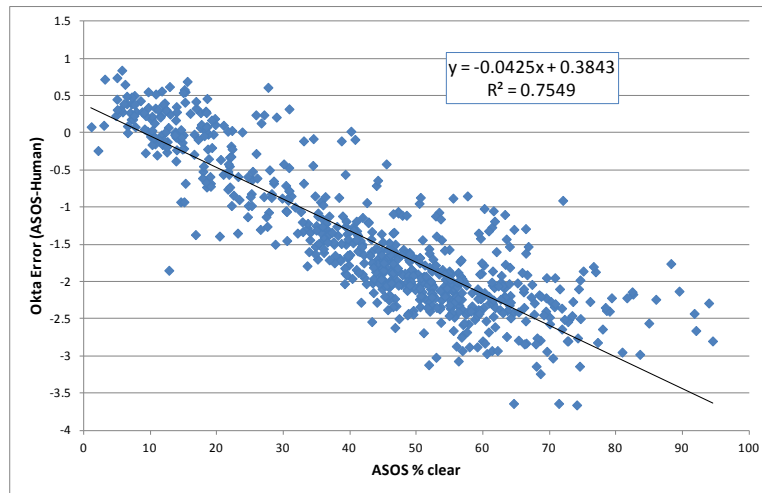
month, the resulting probabilities of each okta of total cloud cover are shown in the columns across the table. The total count of samples used to create the table is in the Count column.

**Table 17. Sample Total to Opaque Probability Table for January and February**

Month	Opaque	p-tot0	p-tot1	p-tot2	p-tot3	p-tot4	p-tot5	p-tot6	p-tot7	p-tot8	Count
1	0	0.90	0.03	0.06	0.01	0.00	0.00	0.00	0.00	0.00	1005
1	1	0.00	0.36	0.40	0.12	0.04	0.02	0.05	0.00	0.01	282
1	2	0.00	0.00	0.41	0.19	0.06	0.13	0.15	0.01	0.05	767
1	3	0.00	0.00	0.00	0.14	0.15	0.11	0.30	0.15	0.15	313
1	4	0.00	0.00	0.00	0.00	0.18	0.15	0.41	0.08	0.18	158
1	5	0.00	0.00	0.00	0.00	0.00	0.08	0.61	0.12	0.19	252
1	6	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.27	0.53	603
1	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.86	288
1	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	819
2	0	0.85	0.05	0.08	0.01	0.00	0.01	0.00	0.00	0.00	1011
2	1	0.00	0.30	0.54	0.08	0.03	0.03	0.02	0.00	0.00	225
2	2	0.00	0.00	0.31	0.19	0.08	0.14	0.18	0.05	0.05	486
2	3	0.00	0.00	0.00	0.09	0.14	0.11	0.28	0.19	0.19	180
2	4	0.00	0.00	0.00	0.00	0.06	0.21	0.41	0.08	0.24	107
2	5	0.00	0.00	0.00	0.00	0.00	0.04	0.52	0.15	0.29	226
2	6	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.34	0.45	545
2	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.88	243
2	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	728
...	...	...	...	...	...	...	...	...	...	...	...

For this method, the ASOS total cloud report was considered primarily as a measurement of opaque clouds for certain sites (see paragraph below) because the ASOS cloud measurement is limited to 12,000 ft and most translucent clouds occur above that altitude. At those times when only ASOS data are available, a total cloud amount for a particular hour is derived by randomly selecting a total cloud cover value based on the probability distribution derived from the ensemble of reported ASOS values. For sites that have neither the ASOS Supplemental Cloud Product nor the manual cloud observations necessary to create the probability distributions, the process uses the distribution table from the geographically nearest site. Better pairings of sites for this purpose could be possible if based on climatology, but project resource restrictions prevented the evaluation of each site based on climate.

Further research for the 1991–2010 update revealed that ASOS tends to *overestimate* clouds at relatively cloudy locations and *underestimate* clouds at relatively clear locations. This is shown in Figure 6, where ASOS error is plotted against ASOS percent clear sky. The error as ASOS minus the human observation was derived not from concurrent human and ASOS data, but from multi-year averages from each observation type for each station that had significant periods of record for both human and ASOS observations. The physics of these observations was not thoroughly probed but could be related to a possible preponderance of low clouds at sites with abundant clouds and a significant percentage of high cirrus clouds that occur beyond the range of the ASOS ceilometers at clearer locations.



**Figure 6. ASOS Error vs. ASOS clear sky. Error as ASOS minus Human, multi-year averages. Each point represents average data for one NSRDB station.**

Based on the apparent errors in ASOS data, the method of inserting the total cloud amount into the opaque field was modified for this most recent update to minimize over-correction. The percentage of ASOS clear sky records (zero cloud cover) was determined for each site, and sites with less than 30% clear sky observations were excluded from the method of inserting the total cloud measurement in the opaque field, as described above. For these cloudier sites, an opaque cloud cover was statistically derived from the total measurement, as described for human observations later in this section. Other methods were attempted to correct hourly ASOS cloud cover based on a regression such as that apparent in Figure 6, but were unsuccessful because they imposed unnatural characteristics in the data.

For Caribbean sites, no nearby sites with cloud tables exist. Sites in Florida were chosen for the pairings according to Table 18 based on an examination of the geography surrounding the sites using aerial photography.

**Table 18. Special Site Cloud Pairings for Caribbean Sites**

Caribbean Site ID	Site Name	Paired Site ID	Site Name
785145	Eugenio, PR	722110	Tampa, FL
785260	San Juan, PR	722020	Miami, FL
785263	San Juan, PR	722020	Miami, FL
785350	Roosevelt, PR	722020	Miami, FL
785430	Charlotte Amalie, VI	722010	Key West, FL

A similar process was developed to derive opaque clouds from total cloud data for sites where human cloud observations included total but not opaque cloud observations (a common situation at military sites). This method was also used for ASOS sites with less than 30% clear sky observations, as described above in this section.

Although the effectiveness of this technique may be diminished by interannual variability of distributions, the difference between total and opaque clouds is typically less than one okta.



Thus, the derivation of total cloud values and possible errors are secondary to the dominant ASOS measurement.

### **2.1.3 Aerosol, Water Vapor, and Ozone Estimates**

Both the METSTAT and SUNY models require input aerosols, water vapor, and ozone. The 1961–1990 NSRDB used only DNI measurements to estimate broadband aerosol optical depth (BAOD). Today, much less measured DNI data are available, but much more aerosol data are available from other sources, including sun photometers and satellite-based estimates. The compilation of these data sets is described in sections 2.2.1.2, 2.2.1.3, and 2.2.1.4.

### **2.1.4 Solar Measurements and the Evaluation Data Set**

Solar model validation relies on high-quality solar radiation measurements to evaluate model performance. A significant part of the update effort was to find, acquire, and quality-assess surface solar measurements to form an evaluation data set. These data sets would also be used in the measured solar data fields of the completed NSRDB. Thirty-three measurement sites were considered for the evaluation project based on their instrumentation, period of record, and proximity to NWS sites (see Table 19). Most data were available from data distribution websites maintained by network operators. Data were downloaded to NREL computers, imported to a database, and then evaluated with several quality-assessment tools, including SERI-QC (NREL 1993). Because of processing limitations, no additional measured solar radiation was added to the 1991–2010 NSRDB update. NREL expects to include additional available measured solar data in future updates.

**Table 19. Measurement Sites Used for NSRDB Model Evaluation (by State)**

<b>Site</b>	<b>Network</b>	<b>Site</b>	<b>Network</b>	<b>Site</b>	<b>Network</b>
Barrow, AK	ARM	Albany, NY	SUNY	Corpus Christi, TX	UT
Hanford, CA	ISIS	ARM-SGP, OK	ARM	Del Rio, TX	UT
Golden, CO	NREL	Burns, OR	UO	Edinburg, TX	UT
FSEC, FL	FSEC	Eugene, OR	UO	El Paso, TX	UT
Tallahassee, FL	ISIS	Hermiston, OR	UO	Laredo, TX	UT
Bondville, IL	SURFRAD	Klamath Falls, OR	UO	Overton, TX	UT
Ft. Peck, MT	SURFRAD	Pennsylvania State College, PA	SURFRAD	Salt Lake City, UT	ISIS
Elizabeth City, NC	NREL	Abilene, TX	UT	Sterling, VA	ISIS
Bismarck, ND	ISIS	Austin, TX	UT	Seattle, WA	ISIS
Albuquerque, NM	ISIS	Canyon, TX	UT	Madison, WI	ISIS
Desert Rock, NV	SURFRAD	Clear Lake, TX	UT	Bluefield State College, WV	NREL

Notes:

ARM – Atmospheric Radiation Measurement

FSEC – Florida Solar Energy Center

ISIS – Integrated Surface Irradiance Study

NREL – National Renewable Energy Laboratory Measurement and Instrumentation Data Center

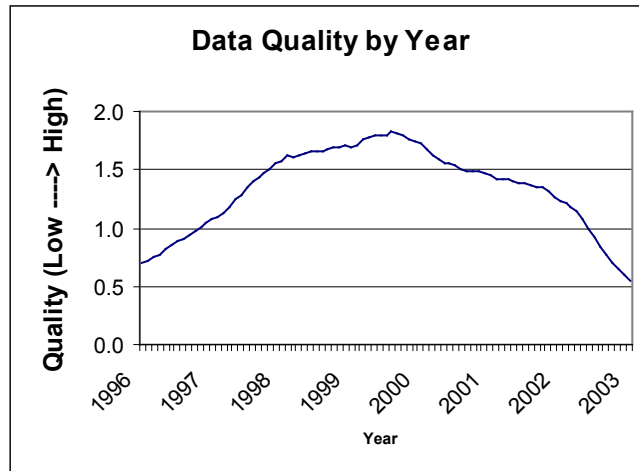
SUNY – State University of New York at Albany

SURFRAD – Surface Radiation Budget Measurement

UT – University of Texas Solar Energy Laboratory

UO – University of Oregon Solar Radiation Monitoring Laboratory

A data analyst used a rough scoring technique to evaluate data quality for each station-month, where 0 = missing or unacceptable, 1 = conditionally acceptable, and 2 = acceptable. A monthly mean score across all stations was calculated, and Figure 7 shows the moving 12-month average of these monthly means for the period of available data (1996–2003). A peak in data quality/availability is evident between 1999 and 2000—the 2 years ultimately chosen for the test-case evaluation data set.



**Figure 7. Solar radiation data quality/availability by year (12-month moving average)**

Note: The plot in Figure 7 should not be misinterpreted as indicating the absolute quality of solar measurements in the United States. The scale is arbitrary and mixes missing data with data quality—two distinct and not comparably scaled characteristics of data. Further, not all data from all stations were available at the time of the evaluation. The plot is presented only as an indicator of the best years to consider for the NSRDB model evaluation.

### **2.1.5 Selection of the NSRDB Model**

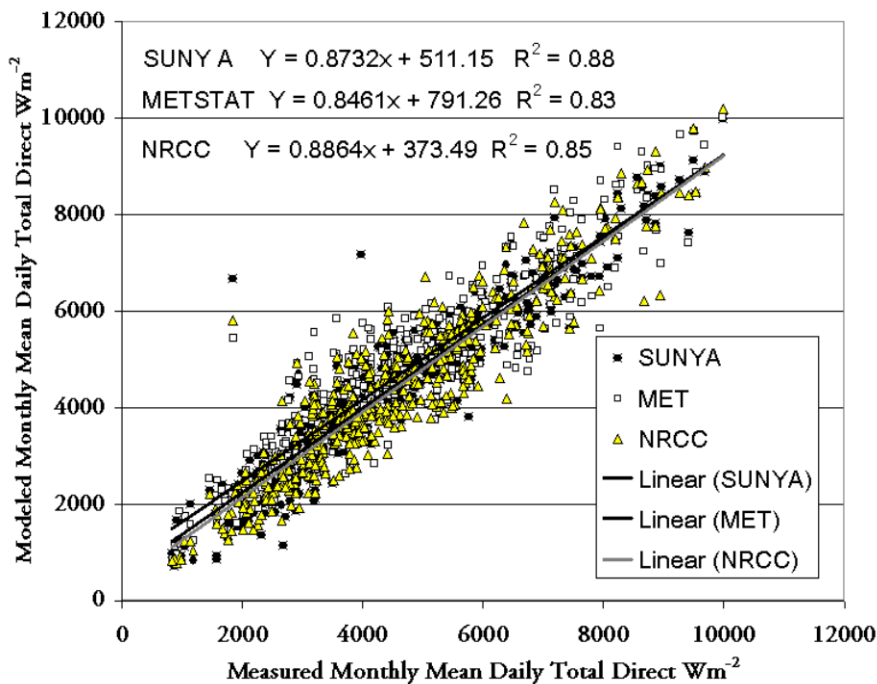
Three models were evaluated for modeling NSRDB data: the NREL METSTAT model; a model developed by the Northeast Regional Climate Center for the American Society of Heating, Refrigerating and Air-Conditioning Engineers (Belcher 2004); and the SUNY-developed satellite model (Perez 2002).

Several modifications have been made to the METSTAT model since its use for the original NSRDB.

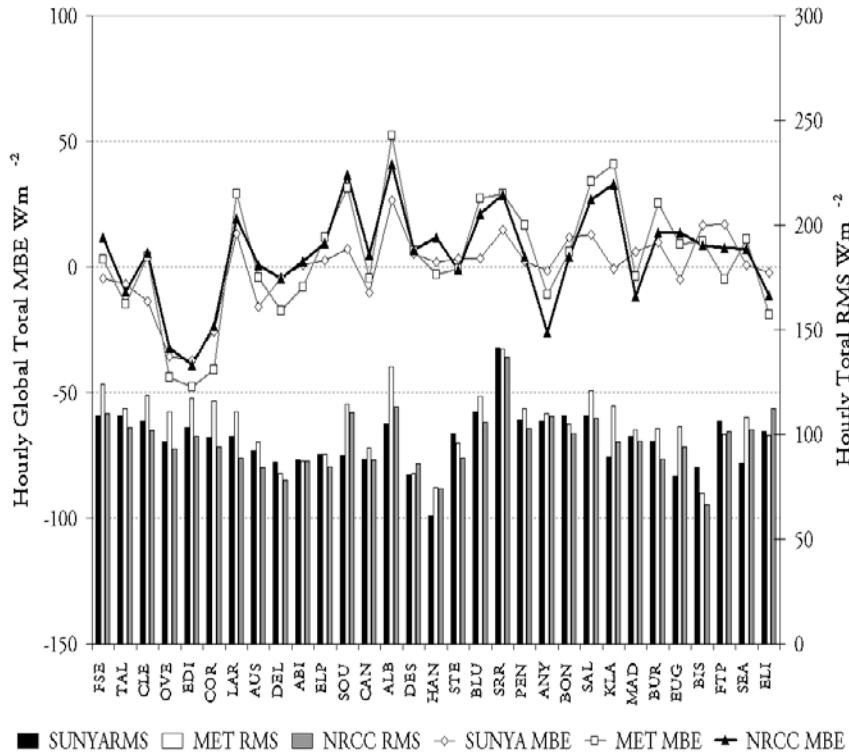
- The multiple-reflectance algorithm was modified for better performance under overcast skies by using ceiling height as an input rather than present weather (Vignola 1997, Myers 2002).
- A software switch that adjusts for the human perception of cloud amounts nearer the horizon being greater than actual was added for the perspective function. This function was turned off when the model was running on ASOS-based data, which is determined by examining only clouds directly overhead.
- When running the model with the statistics “on,” cloud cover amounts were not randomized if the total sky cover was 0 or opaque sky cover was ten-tenths. (If opaque sky cover is ten-tenths, the opaque sky cover should not be randomized to a value less than 10, which results in direct normal values greater than zero for overcast skies. Similarly, if the total sky cover is zero-tenths, it should not be randomized to a greater value). Also eliminated was the procedure that modifies the random number for consecutive clear or cloudy hours.
- Cloud indexing was changed to allow for fractional cloud amounts.

The analysis of the MMDT test data sets and the evaluation of the results are treated more thoroughly elsewhere (Myers 2005). The analysis data set included those hours from all sites for which measured and modeled output data for all models were concurrent. This process eliminated two sites from the analysis because there were no overlapping data (Barrow, Alaska, and Hermiston, Oregon). The analysis compares the measured data to the output for each model using the statistical measures of root mean square error (RMSE), MBE, frequency distributions, probability distributions, correlation, and autocorrelation.

The analysis reveals few significant differences among the three candidate models (i.e., Northeast Regional Climate Center, SUNYA, and METSTAT). The GHI monthly mean daily total MBE for all models ranged from -0.06% to 1.73%, and the RMSE ranged from 5% to 8%. The uncertainty of the validation data is estimated to be about 5%–10%, which easily encompasses these errors. The DNI MMDT RMSE was somewhat larger, but all models were very close and ranged from 13.7% to 15%. Figure 8, which shows errors for hourly global irradiance, illustrates not only the closeness of the model performance but also the similarity of excursions for all models in site-to-site variability. These excursions may indicate a common bias in the models or input data or an error in the ground validation data. Whatever the cause, it is important in this context to note that all models perform similarly. Figure 9 shows measured versus modeled DNI MMDT.



**Figure 8. MBE (lines, left scale) and RMSE (bars, right scale) for modeled hourly total GHI by site and model (Myers 2005)**



**Figure 9. Modeled versus measured DNI MMDTs, regression fit, and correlation coefficients by model**

The study concluded that each model performed comparably in comparisons with measured ground data, and the decision for which model to use rested less with technical considerations and more with those of convenience. In that context, the METSTAT model, which is already deployed at NREL and with which NREL has considerable experience, was chosen. Also, because of its use with the original NSRDB, METSTAT may provide greater consistency with the older data set.

### **2.1.6 Satellite Data Set**

The high-resolution SolarAnywhere<sup>®</sup> gridded data set derived from the SUNY model provides a consistency in modeled output data for its period of record that is not available from the METSTAT model during the same period because of the cloud observation issues discussed in Section 2.1.2 and elsewhere. The SUNY model covers only the years from 1998 to the present, the period for which necessary GOES imagery was archived by the project. Acquiring older imagery is beyond the financial resources of the project, and other input data sets (such as snow cover) required by the SUNY model do not exist prior to 1998.

The output from the SUNY model is not suited for direct inclusion in the conventional NSRDB ground-based data scheme, yet it is desirable that it be included at those times when METSTAT model input data are not available or are of lesser quality. The satellite data are pixel-oriented and based in a different hourly time realm. The pixels in the gridded data carry latitude-longitude location information, so it is a simple matter of selecting a corresponding pixel using the coordinates of a ground station. (Although more sophisticated methods of selecting pixel values, such as pixel interpolation, could have been used, it was believed that

the 10-km resolution of the pixels was high enough that uncertainty in the final product could not be significantly improved for most locations.)

The issue of converting the gridded data to the NSRDB time realm was more difficult, but the SolarAnywhere<sup>®</sup> data set provides as an option a time-shifted product that simulates hour-ending solar data. These time-shifted data are used in the NSRDB.

Time shifting can introduce errors primarily because of diurnal cloud patterns, day length, and the temporal magnitude of the shift.

- Day length affects the error because of shifting partial sunrise or sunset hours for which data may be either discarded or fabricated.
- Cloud patterns affect error because they can cause asymmetric profiles. Errors in the morning will be opposite those in the afternoon, and these errors cancel nicely in a symmetrical day. However, if the morning and afternoon profiles are not balanced, an error in the daily total occurs. (These errors are also presumed present in the unshifted satellite data because instantaneously sampling at different times can result in different daily totals, whereas changing the time slices of integrated data will not alter the daily totals.)
- The error because of the magnitude of the shift occurs as an imperfect model increases the distance from its anchor with the measured data point.

Although the errors in hourly values, and even daily totals, can be significant (ranging to more than 600 Wh/m<sup>2</sup>), they tend to cancel throughout the year leaving small residual bias errors. These residual errors are accounted for in the data uncertainty (see Section 1.4.5.1).

The SUNY model produces only values for global and direct solar radiation, and the diffuse radiation is calculated in the SolarAnywhere<sup>®</sup> data set. NREL added solar zenith angle calculations to the SolarAnywhere<sup>®</sup> data set for the convenience of NSRDB users, and because of apparent small differences between the NREL and SUNY solar geometry, NREL recalculated diffuse irradiance to maintain consistency with the solar geometry. As with the 2005 update of the NSRDB, NREL checked the diffuse values for reasonable physical limits and occasionally altered some values that fell below minimum values. These data records with identified low diffuse were adjusted to conform to a minimum clear-sky diffuse envelope,  $DIF_{min}$ , based on aerosols and water vapor according to this formula (Ineichen 2004):

$$DIF_{min} = GHI \cdot (0.1 \cdot (1 - 2 \cdot \exp(-(11.2 \cdot AOD + 0.333 \cdot \ln(W) + 2.106)))) \cdot (1 / (0.1 + 0.9 \cdot 0.98 / (\exp(-ALT/8000))))$$

where

- GHI is the modeled global horizontal irradiance (Wh/m<sup>2</sup>)
- AOD is the BAOD
- W is the precipitable water vapor (cm)
- ALT is the station altitude (m).

In cases in which the calculated diffuse irradiance is less than 85% of  $DIF_{min}$ , the calculated diffuse value is set to  $DIF_{min}$ , and the direct beam value, DNI, is replaced with:

$$DNI = (GHI - DIF_{min}) / \cos(ZEN)$$

where ZEN is the solar zenith angle.

The SUNY model often produces irradiance values of zero within a few minutes after sunrise or a few minutes before sunset. For the NSRDB distributions, NREL added extrapolated data for these records to make them consistent with the solar geometry.

Unlike the SUNY data set used for the 2005 NSRDB update, the SolarAnywhere<sup>®</sup> data set has data gaps when satellite imagery is not available for modeling. To ensure a serially complete data set conforming to NSRDB specifications, NREL filled missing data in a manner similar to the *Long Fill* method for meteorological data as described in Section 2.2.2. In essence, data were pulled from other years for the same date and time and used to fill the gap. The endpoints of the filled data were adjusted for smooth connection to the existing data on either side of the gap. In all cases, gaps due to missing satellite imagery affected all pixels in either the GOES East or GOES West regions. However, pixels were processed independently rather than as a linked group, and no effort was made to enforce homogeneity in fill data among adjacent pixels. As a result, data filled in this manner may exhibit unusual spatial characteristics (e.g., large irradiance gradients from one pixel to another for the same point in time) because data in the affected cells may have come from different years and likely different sky conditions.

These modified model data are flagged in the station-based NSRDB according to Table 8 and in the gridded data set according to Table 5.

## **2.2 Sources of Solar Radiation and Meteorological Data**

This section describes the sources of solar radiation and meteorological data that were used to produce the updated NSRDB. No additional measured solar data beyond 2005 were included in the 1991–2010 update.

### **2.2.1 Data Acquisition**

NCDC provided all of the surface meteorological data for the entire period of record.

Measured solar radiation data were collected from several sources:

- ARM Program Network, run by the Department of Energy
- FSEC, run by the State of Florida
- Historically Black Colleges and Universities Network, run by NREL
- Integrated Surface Irradiance Study (ISIS) Network, run by the National Oceanic and Atmospheric Administration
- SURFRAD Network, run by the National Oceanic and Atmospheric Administration
- University of Oregon Solar Radiation Monitoring Laboratory network
- University of Texas Solar Energy Laboratory.

See Section 2.3.6 for details of how measured solar radiation data were processed for the NSRDB update.

### 2.2.1.1 Meteorological Data

The meteorological data were available from the NCDC ISD data set (Lott 2001), which provided all model input data except for precipitable water, aerosols, ground albedo, and ozone. The sources used for these special inputs are detailed below.

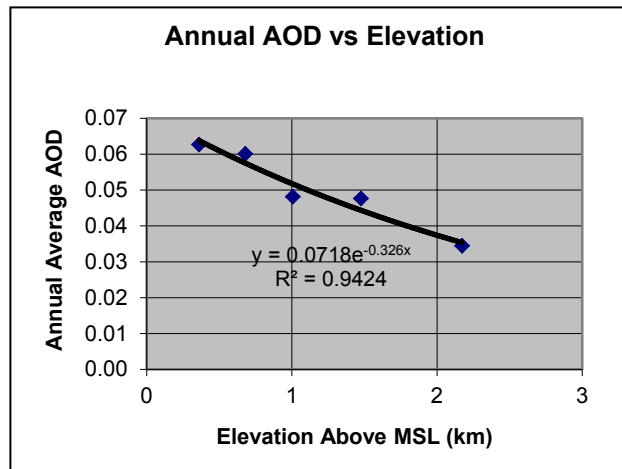
### 2.2.1.2 Aerosols

Cloud cover is the dominant input for solar models (excluding solar geometry). Next are aerosols, which under clear skies are *the* dominant meteorological input, which makes them a critical factor for estimating the resource for solar power applications. The 1961–1990 NSRDB used only DNI measurements to estimate BAOD, values that were subsequently hand-contoured for the United States and fitted to a seasonal cosine function. Today, much less measured DNI data are available, but aerosol data from other sources, including sun photometers and satellite-based estimates, are more abundant. These sources produce spectral rather than broadband data, so massaging of the data became necessary to make them usable by the METSTAT and SUNY models, both of which use BAOD as inputs.

A combination of surface sun photometry, satellite data from the NASA Multi-Angle Imaging SpectroRadiometer (MISR) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite-based instruments, and legacy DNI estimates of BAOD allowed creation of monthly mean estimates of BAOD for all locations in the United States. Spectral AOD data were converted into BAOD using estimated Ångström Alpha parameters from sun photometry (Gueymard and George 2005). Using monthly mean BAOD values rather than specific daily or hourly values is likely to introduce significant errors in direct and diffuse hourly irradiance predictions under clear skies. Limitations in existing data and budget constraints prevented the derivation of more detailed datasets. Still, it is emphasized that the approach used here is conducive to overall better accuracy than what was done for the 1961–1990 NSRDB.

All BAOD data were merged, interpolated, and adjusted to local elevation through use of an exponential function (Figure 10) and regrided if necessary. These monthly values were finally smoothly fit to daily values using a mean-preserving interpolation method (Rymes 2001). Values in the period of July 11, 1991, through Dec. 31, 1994, were adjusted with an additive factor,  $AOD_{\text{strat}}$ , to represent the effect of additional stratospheric aerosols from the Mount Pinatubo eruption using a double function of date with site-specific latitude parameters. The first is a ramp-up function, starting with July 11, 1991.





**Figure 10. Measured BAOD plotted against elevation for five stations: Maricopa, Rogers Lake, Desert Rock, Sevilleta, and Flagstaff**

$$AOD_{\text{strat}} = (AOD_{\text{max}} / \text{Norm}) \cdot (1.0 - \exp(-T/T1))$$

where

- $AOD_{\text{max}}$  is the function limit (set to 0.2 for all sites)
- Norm is a normalizing parameter
- T is the number of days since Jan. 1, 1991
- T1 is the last day of the ramp function (days since Jan 1, 1991).

The second is a decay function that starts at the end of the ramp-up function (T1), a site-specific parameter:

$$AOD_{\text{strat}} = AOD_{\text{max}} \cdot \exp(- (T-T1) / T2)$$

where

- T2 is a daily decay constant (250 for all sites).

A sample plot of the AOD additive functions appears in Figure 11.

### 911650 Pinatubo AOD

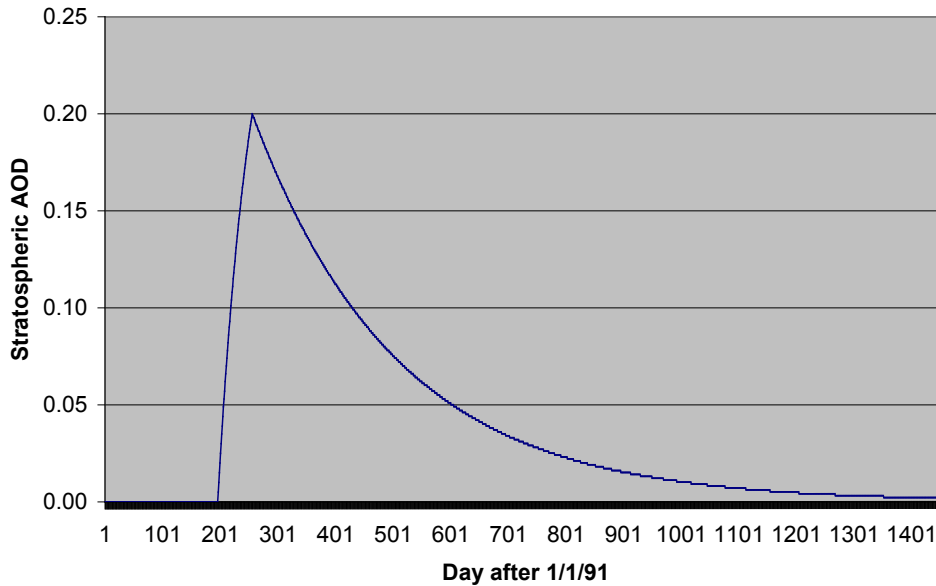


Figure 11. Pinatubo AOD function for Lihue, Hawaii

#### 2.2.1.3 Ozone

Total column ozone is derived from daily satellite observations from the Total Ozone Mapping Scanner (TOMS). Scans occur once per day on a grid with spatial resolution of  $1^\circ$  in latitude and  $1.25^\circ$  in longitude. The missing data are replaced with long-term mean values for that location. Ozone has only a second-order effect on broadband irradiance; hence, the uncertainty in the TOMS measurements or their replacement is not of concern. These data were used through 2004 in the 1991–2010 NSRDB update. For years 2005–2010, the newer Ozone Monitoring Instrument (OMI) data set was used. This data set also provided once-per-day input on a  $1^\circ \times 1^\circ$  grid.

#### 2.2.1.4 Precipitable Water

NREL used the NASA Water Vapor Project (NVAP) data set for daily estimates of water vapor on a  $1^\circ \times 1^\circ$  grid. NVAP integrates sounding data with satellite measurements of atmospheric water vapor. For the years 1988–1999, NVAP provides once-daily estimates of water vapor on a  $1^\circ \times 1^\circ$  worldwide grid. For years 2000 and 2001, NVAP provides the data on a  $0.5^\circ \times 0.5^\circ$  grid twice daily. These data were interpolated in space to the location of each of the NSRDB stations and interpolated in time to provide hourly data for all stations for the years 1991–2001.

Because of the limited period of record for the NVAP data set, the years 2002–2010 required a new source of data. For this, the recently released North American Regional Reanalysis (NARR) was chosen. This data source provides column water vapor every 3 hours on a nominal 32-km grid. This data product uses a data assimilation model derived from National Center for Environmental Prediction weather prediction models to interpolate weather observations onto a numerical grid. The data observations for precipitable water include

radiosondes, dropsondes from airplanes, and the infrared radiance data from the Television Infrared Observation Satellite Operational Vertical Sounder-1B satellite (over water).

Geographic information system analysis techniques were used to match each of the NSRDB stations with its nearest NARR grid point. Then, data from the NARR grids for each 3-hour period were downloaded and interpolated to hourly data files for each station.

#### **2.2.1.5 Albedo**

Albedo data are from the Earth Radiation Budget Experiment (ERBE) Monthly Albedo data set, a satellite product delivered on a  $1^\circ \times 1^\circ$  grid. Each station was assigned albedo values based on the  $1^\circ \times 1^\circ$  pixel that includes the station. Monthly mean albedo values were assembled based on multiple years of data. Those monthly mean values were assigned for each hour of the month. The albedo values include the enhanced effects of snow cover on a monthly interval. Unlike the 1961–1990 NSRDB, snow cover data were not used to estimate a daily enhanced albedo.

#### **2.2.2 Derived Input Meteorological Data (Data Filling)**

When the 1961–1990 NSRDB was designed, serially complete solar data was a primary goal of the project. Rather than attempting to fill gaps in the measured or modeled solar radiation data, the solar model input parameters were filled and the solar irradiance was modeled based on the filled input parameters. Filling input meteorological data for the model is preferred over filling output solar data because of the statistical nature of METSTAT, which imposes pseudo-natural variability on the output data (while still conforming to long-term means). Other meteorological parameters were also filled at the same time in an effort to produce a more complete output data set that is suitable for other applications.

*Important note: The data-filling methods described here were not designed to maintain climatological characteristics but rather to accomplish the goal of serial completeness with representative and realistic solar data. Thus, NSRDB filled meteorological data are not suitable for climatological work and should be used only as support data for solar technology applications.*

A criticism of the 1961–1990 NSRDB was that missing nighttime data were not filled (nighttime input data were not necessary for solar model operation). This approach had the benefit of increasing the population of sites in the NSRDB because many NWS sites routinely closed down at night—an operational constraint that would have eliminated them from a serially complete database. However, applications that required serially complete meteorological data were hampered by this approach.

In the context of the above discussion, significant value would be derived from an updated NSRDB with both serially complete solar and meteorological data. However, stricter requirements for serially complete data will increase the probability of a site's exclusion from the data set. (Even at full-time sites, there can be gaps of days, weeks, or months.) To determine if the design goal of serial completeness was reasonable, other data-filling methods were investigated.

The following methods were used in the 1961–1990 NSRDB:

- Short-term filling – For gaps of 5 hours or less, linear interpolation
- Medium-term filling – For gaps of 6–23 hours, substitution of data from the same hours of adjacent days
- Long-term filling – For gaps of 1 day to 1 year, substitution of data from the same calendar days from another similar year.

Additional techniques were employed to fill missing data when NREL developed the Typical Meteorological Year 2 data sets (for those data gaps that still existed after NSRDB methods were applied).

- Cloud cover was linearly interpolated over a nighttime-only gap.
- Dry-bulb temperature was linearly interpolated over a nighttime-only gap and modified for expected non-linearities, such as more rapid changes near sunrise or sunset.
- Dew-point temperature (which was not filled by NSRDB methods) was filled using psychrometric relationships with dry-bulb and relative humidity values (which were filled).
- Missing nighttime relative humidity was filled using psychrometric relationships with dry-bulb and dew-point temperatures.
- Wind speed and direction (up to 47 hours) were filled with linear interpolation and (wind speed) adjusted for expected diurnal non-linearities.
- Precipitable water (up to 47 hours) was filled with linear interpolation.

Another technique used for other projects is the Linacre method, which characterizes measurements from a nearby station to form a constant relationship with like measurements from the target site (Linacre 1992). Data at the target site are then filled with data from the nearby station and adjusted according to the relationship. This method was investigated but not used for the updated NSRDB because of various constraints. Rather, the method described below was used.

Most meteorological data were extracted from the ISD data set. The following parameters were filled in the NSRDB production database:

- Total and opaque cloud cover
- Dry-bulb and dew-point temperatures
- Relative humidity
- Ceiling height
- Barometric pressure
- Wind speed and direction
- Aerosol optical depth

- Precipitable water
- Ozone.

Relative humidity was not present in the ISD data set and was calculated using psychrometric relations of dry-bulb and dew-point temperatures after the completion of all data filling.

A primary goal of the complete hourly data for the period of record is to form the basis for climatological normals and means. Although short gaps of 4 or 5 hours can easily be filled with interpolation, over a multi-year period there may be operational circumstances that create larger gaps, sometimes of several months. Even one gap violates the goal of serial completeness; therefore, by developing methods to fill both large and small gaps, the number of sites included in the updated NSRDB (balanced against the downside of increased uncertainty attributable to the filling processes) was greatly increased.

Data-filling methods were categorized in four levels:

1. **Short-term interpolation**

Data gaps of up to 5 hours were filled with linear interpolation or, in the case of temperatures, a site- and month-specific diurnal profile imposed on a linear interpolation. Gaps that extended through the night were also filled with this method.

2. **Medium-term filling**

Gaps of up to 24 hours were filled by building an average profile from the same hours of previous and subsequent days and attaching that profile to the end points of the gap.

3. **Long-term filling**

Gaps of up to 1 year were filled by characterizing the data before and after the gap and then seeking the most similar data from other years to fill the gap. The first and last 12 hours of the fill data were scaled to fit the end points of the gap, and the rest of the fill data were used without modification. When filling dependent parameters (e.g., dry-bulb and dew-point temperature and total and opaque cloud and ceiling height), fill data were pulled from the same source dates when possible. If this could not be accomplished, coupling limits were enforced between the parameters.

4. **Last-ditch filling**

In a few cases, the above methods left gaps because of insufficient data before and after the gap for developing a diurnal profile or characterization. In these cases, data from the same days were examined from other years in random order to find an uninterrupted run of source data to fill the gap. In addition, if barometric pressure could not otherwise be filled, it was modeled from site elevation (resulting in a static value). If ceiling height could not be filled, it was modeled from a simple regression with opaque cloud cover.

The data-filling process creates log files for methods 3 and 4 to document the source year of the fill data. The type and density of data filling are used to determine the uncertainty of the modeled data.

These methods created serially complete model input data for more than half of the NSRDB sites. The sites for which the process was not successful typically had several years of missing data. Many were new sites that began operations only in the latter years of the NSRDB update period of record. These sites, in particular, have the potential for an expanded and more significant period of record in the future as data collection continues.

Because of the potential use of even incomplete data sets for some applications, the station classification system described in Section 2.3.7 was developed.

## **2.3 The Production Process**

In the development of the software for the NSRDB update, most resources were dedicated to data preparation—collecting, organizing, filling, and storing data such that the solar modeling could be completed in a simple input-process-output production run. After completion of the production database, additional work was required to produce summary statistics products, format the data for distribution, and create NSRDB documentation.

Data (both measured and modeled) were stored in a flat-file production database that holds one station-year per file and 106 fields, including measurement values and associated flags, per record. For speed of processing, the fixed-length data records were stored in the file as a binary image of the program's data structure, and all production software included a library of database access routines for reading and writing the production files. An NSRDB extractor tool was developed to convert the binary data to ASCII comma-separated value format to facilitate viewing or ancillary processing of the data by the production and reviewing teams.

During processes, backup copies of the database files were kept at each stage to guard against data loss or corruption and support easy modifications to processes. As software was developed, tested, and modified, this scheme allowed the production team to easily revert to a previous step and commence processing with modified software without having to reconstruct the entire database from the first step.

The production database was initially created by filling only fields for the date and time, the calculated extraterrestrial solar radiation, and the solar geometry (solar zenith and azimuth angles). The remaining data fields were flagged as missing. Each significant step in the process to complete the database is detailed below.

### **2.3.1 Meteorological Data Ingest**

For the 1961–1990 NSRDB, all hourly meteorological data were supplied to the project in the NCDC TD-3280 format (NCDC 1991), which consisted of simple hourly records with a top-of-hour timestamp. This was imminently compatible with the hourly records of the NSRDB.

The newer NCDC ISD format (NCDC 2004) has the ability to hold data with minute-resolution timestamps. Many observations with an on-the-hour timestamp in TD-3280 are actually taken at other times of the hour, and these data are represented in ISD at the actual time of observation. Further, some observations are recorded multiple times during an hour in the ISD data set. This required sorting and time-shifting of the meteorological data to conform to the NSRDB top-of-hour realm.

During reading of records from the ISD data file, each field of interest was identified, its timestamp recorded, and a validity score assigned based on its proximity to the top of the hour. Values with a timestamp more than 15 minutes before or after the top of the hour were discarded as non-representative of the NSRDB timestamp. From these candidate values for each parameter, the one closest to the top of the hour was chosen to be included in the NSRDB as that hour's value. Fields for which no value was found were marked as missing. All ISD flags were transferred to the NSRDB flag fields. (When fields were missing and subsequently filled, the ISD flag for missing data was replaced with an NSRDB filled-data flag.)

Special consideration was given to these fields:

- **Station pressure**  
If station barometric pressure was missing, the field was calculated from sea level pressure, dry-bulb temperature, and ISD altimeter setting if those fields were present.
- **Wind direction**  
With a wind speed of 0, ISD uses a missing value flag for the wind direction field (as the vector value is undefined at magnitude 0). To avoid the appearance of missing data in the NSRDB, a convention was adopted that placed 0 in the NSRDB field when wind speed is 0. To avoid ambiguity with measured vector values, winds from the north are given a direction value of 360° in the NSRDB.

### **2.3.2 Cloud Derivations**

The supplemental cloud data from NCDC was processed with the ISD data and converted to values of percent cloud cover for total and opaque cloud cover (see Section 2.1.2). These results were placed in the NSRDB production database. These percent values were converted to the nearest tenths for running the METSTAT model and inclusion in the NSRDB distribution files.

A process was run to create the cloud distribution probability tables, which were kept in files external to the NSRDB database for use in the subsequent process to fill total or opaque cloud fields when one of the two observations was missing (see Section 2.1.2).

### **2.3.3 Aerosols, Albedo, Water Vapor, and Ozone**

- **Aerosols**  
Using the methods described in Section 2.2.1.2, monthly mean aerosol values for each pixel in the SUNY grid were produced. For each ground station in the NSRDB, the 12 monthly mean values were extracted from the corresponding cell and then duplicated for each of the 20 years in the 1991–2010 NSRDB update period of record. The 20-year time series of monthly mean values were then interpolated using a mean-preserving smoothing algorithm (Rymes 2001) that produced daily values. These values were then adjusted for the effects of the Mount Pinatubo eruption for years 1991–1994. The final daily values were then duplicated for the 24 hours in each day. The smoothed daily values were subsequently randomly perturbed by the METSTAT model.
- **Albedo**  
A climatological monthly mean albedo value for each station in the NSRDB was

calculated according to the procedure in Section 2.2.1.5. These monthly mean values were then duplicated for each hour in the month to create a complete time series. No daily interpolation was performed.

- **Water vapor**  
A time series of hourly water vapor values was produced for the period of record according to the methods described in Section 2.2.1.4 and then added to the production database.
- **Ozone**  
A time series of daily ozone values was produced using the methods described in Section 2.2.1.3 and then added to the production database.

### 2.3.4 Data Filling

A single program performed the data-filling methods described in Section 2.2.2. The fields filled are listed in Table 20. For Method 1 (short-term interpolation), the table lists the maximum number of hours for interpolated data.

**Table 20. Filled Parameters and Short-Term Filling Limits**

<u>Parameter</u>	<u>Maximum Interpolation (Hours)</u>
Total and opaque cloud cover	5
Dry-bulb and dew-point temperatures, daytime	5
Dry-bulb and dew-point temperatures, nighttime	One night
Relative humidity	5
Ceiling height	5
Barometric pressure	47
Wind speed and direction	5
Aerosol optical depth	5
Precipitable water	5
Ozone	23

For the long-term filling process, which filled gaps using a continuous data series from the same dates in other years, a dividing line was determined between automated and manual cloud observations at each site. Mixing of these types of cloud data was prevented during filling. Further, when dependent parameters were subjected to long-term filling, the selection algorithm attempted to pull fill data for the related fields from the same records.

Dependent parameters are those for which a change in one can cause a direct change in another. These are:

- Total and opaque clouds and ceiling height
- Dry-bulb and dew-point temperatures
- Wind speed and wind direction.

In all filling methods for clouds, ceiling height, and temperatures, physical relationships were artificially enforced such that values for opaque cloud cover remain less than or equal to total



cloud cover, ceiling height is unlimited with 0 cloud cover, and dew-point temperature remains less than or equal to dry-bulb temperature.

### **2.3.5 Solar Modeling**

The SolarAnywhere<sup>®</sup> data set was transferred to NREL, where data gaps were filled based on methods outlined in Section 2.2.2. When performing short-term data filling, solar data were interpolated along a cosine-zenith angle curve taking into account airmass. Global and DNI were interpolated thusly, and diffuse was then calculated. Additionally, the diffuse was adjusted and flagged in this process according to the diffuse Rayleigh limit described in Section 2.1.6.

NREL ran the METSTAT model for each site using model input data drawn from each record in the production database and wrote the resulting solar values back to the database. The process also saved to the database the aerosol values randomized by the model. When the process encountered missing input parameters, the METSTAT solar fields were not filled. The model also was run with cloud cover set unconditionally to zero to produce solar data for the clear sky fields (NREL distribution described in Section 1.4.2).

### **2.3.6 Adding Measured Solar Data**

Few solar measurement sites are co-located with meteorological sites. Because of the need for meteorological data to model a complete period of record and the sensitivity of solar geometry to geographic location, *all NSRDB sites with measured solar radiation take on the coordinates of the measurement site rather than the meteorological site*. However, the site name and identifier remain that of the meteorological site (with a bracketed annotation in the name that refers to the measurement site and network). This is necessary to accommodate accurate solar geometry and existing identifiers for cataloging.

All such pairings were within 45 km of each other, and most were much closer. This may lead to some confusion among users who map site coordinates and find a named major international airport located, for example, at a nearby university campus or farm. To mitigate this confusion, NSRDB station metadata list both the meteorological and solar coordinates (see Appendix A), but all solar data are based on the solar site coordinates.

The measured solar data were obtained from the sources shown in Section 2.2.1. A variety of formats included measurements with time resolutions of 1, 3, 5, 15, and 60 minutes. Instrumentation included various makes and models of thermopile instruments, silicon-sensor instruments, and rotating shadowband instruments (also silicon-based).

Several processes were necessary prior to including the solar data in the NSRDB production database:

- The rotating shadowband radiometer data were corrected for spectral biases.
- The data were imported into the Data Quality Management System (DQMS) (Augustyn + Company 2004) for analysis.
- The data were quality-assessed using SERI-QC software (NREL 1993).

- The data were integrated to hourly values (for sub-hourly sampled data sets).
- The hourly data were quality-assessed using SERI-QC.
- The data were exported from DQMS to the NSRDB database.

Each step is described below.

#### ***2.3.6.1 Correcting the Rotating Shadowband Radiometer Data***

Several sites employ rotating shadowband radiometers as a low-cost method of collecting data. These instruments have known deficiencies related to a nonlinear spectral sensitivity of the sensor, a silicon-based device with a spectral response significantly different from the absorption characteristics of thermal-based solar technologies (Augustyn 2002). This is more apparent for clear-sky conditions and particularly for the diffuse measurement, under which the sensor sees a deep blue sky, a portion of the spectrum for which the device is less sensitive.

Some newer models of the instrument have compensation built in to the data acquisition system, but no data used for the NSRDB had this feature. Using a correction method refined by the University of Oregon (Vignola 2006), all rotating shadowband data were processed and the files created with corrected data to minimize the spectral bias. The original uncorrected data were not used for the NSRDB.

#### ***2.3.6.2 Importing to DQMS***

Each data set was imported to the DQMS software in its native time resolution to provide a common format-independent platform for all solar measurements. This required special reformatting software for each data source to put the data in a form easily ingested by DQMS.

#### ***2.3.6.3 Quality-Assessing the Data***

DQMS includes the SERI-QC quality assessment program, and SERI-QC boundaries of expected values were determined for each site-month of data using the QC-FIT program (a SERI-QC utility). Each data set was then subjected to SERI-QC to determine its overall quality and filter data with egregious errors from the subsequent process to integrate the hourly values. Only measured fields were imported, as some data sets include calculated parameters based on two other components. This excluded all of the rotating shadowband DNI data, as it is a calculated field. The SERI-QC software produces a better analysis of data quality without the use of calculated fields. (The direct component was later calculated for the hourly NSRDB values.)

#### ***2.3.6.4 Integrating and Quality-Assessing the Hourly Data Values***

The sub-hourly resolution data were exported from DQMS, integrated in a separate process, and then re-imported to DQMS as new hourly data sets. New SERI-QC boundaries were determined for each site-month of the hourly data and all data flagged in DQMS.

#### ***2.3.6.5 Exporting Hourly Data for the NSRDB***

Hourly data files with SERI-QC flags were exported from DQMS and prepared for importing to the NSRDB. The process to add the data and flags to the NSRDB included functions to fill missing solar values of global, direct, or diffuse if the other two components were present.

This included all of the rotating shadowband radiometer data, other sites that routinely recorded only two components, and occasional fields missing in three-component sites because of operational or data quality problems. All calculated data were specifically flagged in the NSRDB (see Section 1.4.5.1).

### **2.3.7 Statistical Summaries and Site Classification**

Software was created to produce the statistics and threshold files (see Section 1.4.4) according to specifications for the 1961–1990 NSRDB, with minor format changes to accommodate different years and a longer station identifier. This process also created tables of percent missing and data quality for each site. These were used for the plots in Appendix A. Based on an analysis of these data, the software also assigned site classifications. A Visual Basic program developed for Microsoft Excel and Word automated the creation of Appendix A.

The site classification assignments are an important conformance to specifications that data quality be communicated to users. Classifications were based on the uncertainty of the data and its completeness. Because of plans to create value-added data sets, such as Typical Meteorological Year, Class I and II stations were required to have no missing data in the following fields:

- Solar (global, direct, diffuse)
- Temperature (dry-bulb, dew-point)
- Humidity
- Wind speed
- Aerosol optical depth
- Precipitable water
- Station pressure.

If any data were missing in these fields, the station was designated Class III. If a station had less than 3 years of significant data density, it was not included in the NSRDB. (About half of the approximately 3,000 ISD stations in the United States were excluded for this reason.)

The algorithm distinguishes between Class I and II stations by examining the uncertainty for each hourly modeled value in the global field. If less than 25% of the data for the period of record exceeds an uncertainty of 11%, the station receives a Class I designation. Otherwise, it receives a Class II designation. Although the 11% threshold between high and low uncertainty may seem arbitrary, based on the uncertainty calculations in Section 1.4.5.1, this value easily discriminates between the data modeled with good human-observed or satellite-derived cloud cover and the filled or statistically derived cloud cover. It is important to note that because of the changes in NWS cloud observations, *all* sites had significant periods of high uncertainty data in the middle 1990s. But, in this sense, the user can more easily identify the best available data (not to imply or be confused with perfect data) and be alerted to data with higher uncertainty. The plots of high and low uncertainties in Appendix A allow users to further refine thresholds for station quality based on the requirements of specific applications.

### 2.3.8 Distribution Data Extraction

Extraction software was written to create the files to transfer the distribution fields to NCDC. The NCDC data set is a subset of the production database and contains those fields deemed most valuable to a broad range of users.

A different version of the production database was created for distribution at NREL. This data set contains all fields except for the meteorological fields, but it adds more solar fields.

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Wilcox, S.; Anderberg, M.; Beckman, W.; DeGaetano, A.; George, R.; Gueymard, C.; Marion, W.; Myers, D.; Perez, R.; Plantico, M.; Renne, D.; Stackhouse, P.; Vignola, F. (2005). "Progress on an Updated National Solar Radiation Database for the United States." *Proc. 2005 Solar World Congress*, Orlando, FL, International Solar Energy Society, 2005.

# Appendix A – Station Quality

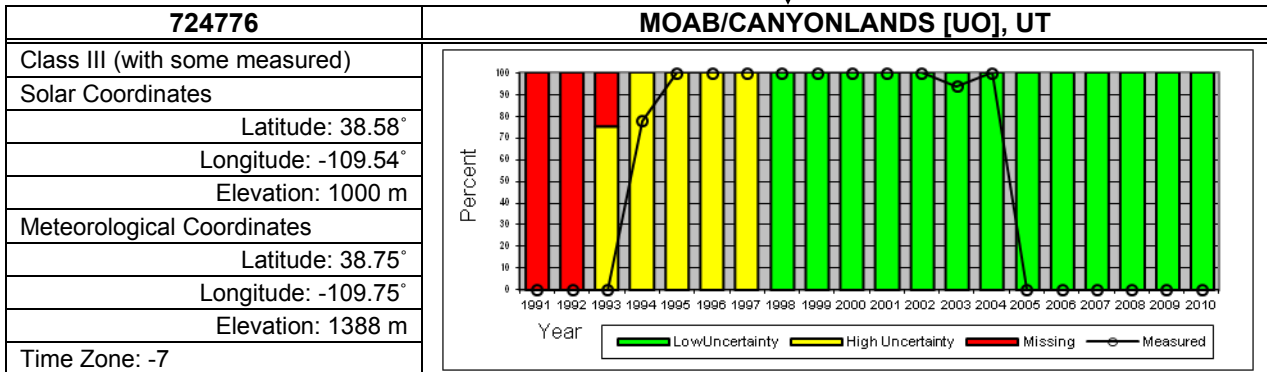
This section contains location and data quality information for all sites in the NSRDB listed in order by state and station name. At the end of the appendix, Table A-1 lists all sites ordered by site ID and includes the class designation, whether the site holds measured data, and the page number for the quality plots in this appendix. The annotated figure below describes the format for station information.

**Station ID**  
The six-digit USAF site code

**Station Name/State** If a site contains measured data, the name of the affiliated network appears in square brackets as part of the station name. Abbreviations for the networks are:

- ARM – Atmospheric Radiation Measurement, DOE
- FSEC – Florida Solar Energy Center, State of Florida
- ISIS – Integrated Surface Irradiance Study (NOAA)
- NREL – Measurement and Instrumentation Data Center, NREL
- SURFRAD – Surface Radiation Budget Network (NOAA)
- UO – University of Oregon Solar Radiation Monitoring Laboratory
- UT – University of Texas Solar Energy Laboratory

If the name of the measurement site is dissimilar from the meteorological site, that name appears in the brackets also. In this example, the solar site is similar to the measurement site name (Moab, UT), and only the network affiliation abbreviation appears in brackets (University of Oregon Solar Radiation Monitoring Laboratory).



**Station Information**

**Class Designation** – If the site holds measured data (as this one does), the class designation is followed by a notation that measured data are included.

**Solar Coordinates** – These coordinates correspond to those used for the modeled or measured *solar radiation* data.

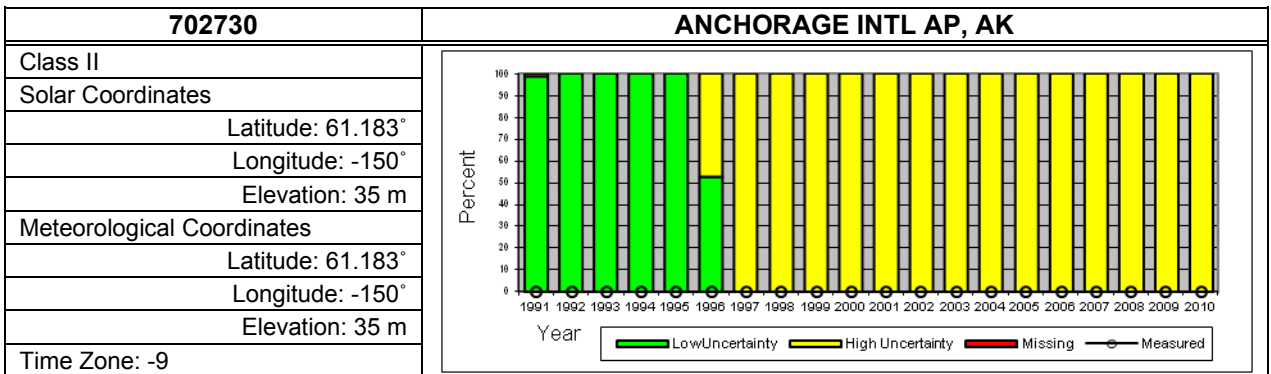
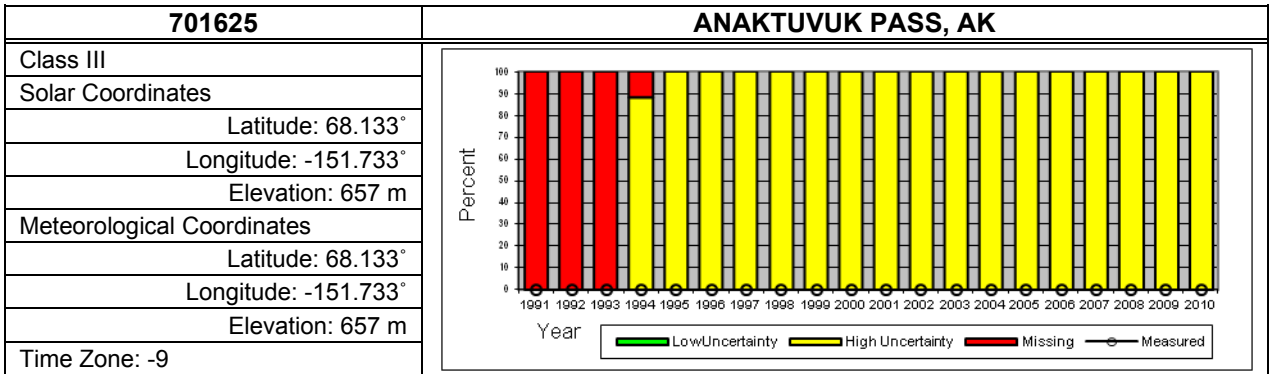
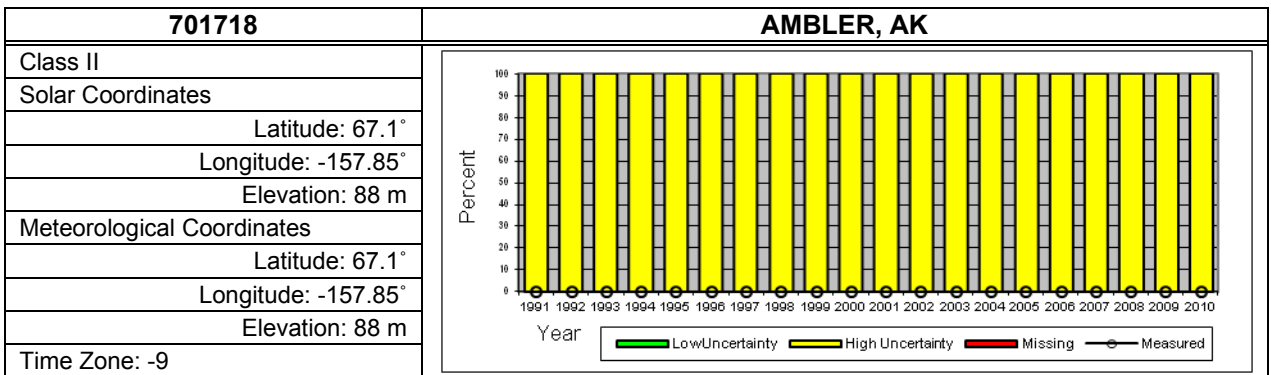
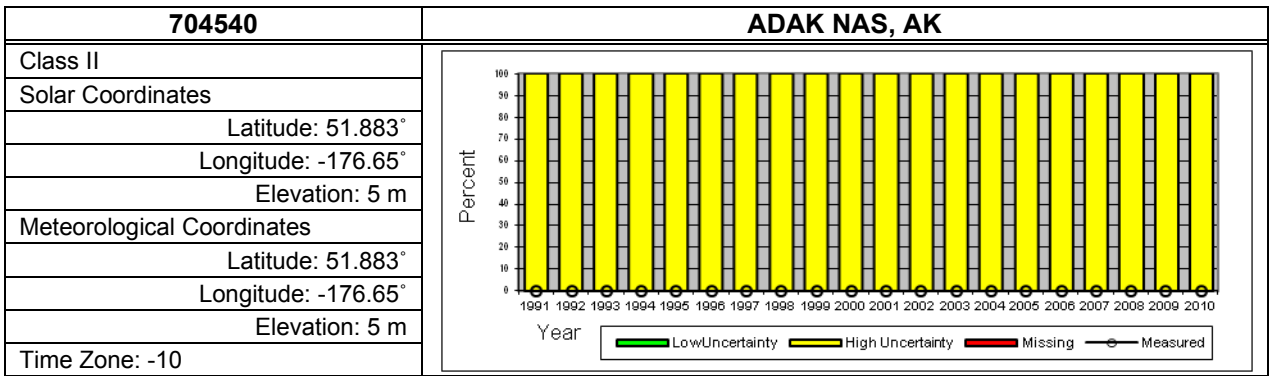
**Meteorological Coordinates** – These are the coordinates of the station collecting the *meteorological* data. If the station holds no measured solar data, these will match the solar coordinates. Because of the sensitivity of solar measurements to geographic location, coordinates for sites with measured solar data default to those of the solar measurement site. In such cases, the meteorological coordinates are included for purposes of documentation.

**Latitude and Longitude** – These are in decimal degrees—negative indicates west of the prime meridian. Elevation is the site altitude above mean sea level (meters). Time zone is the hourly offset from GMT (negative is west of GMT).

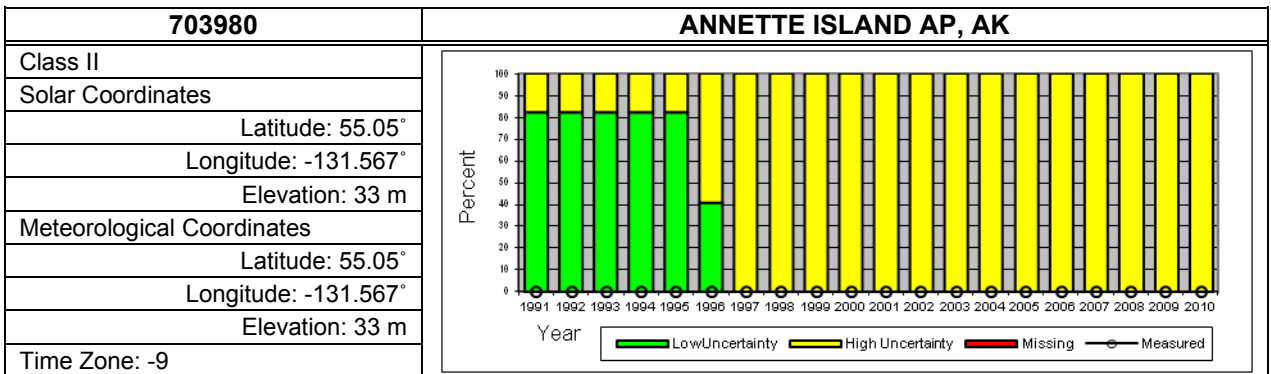
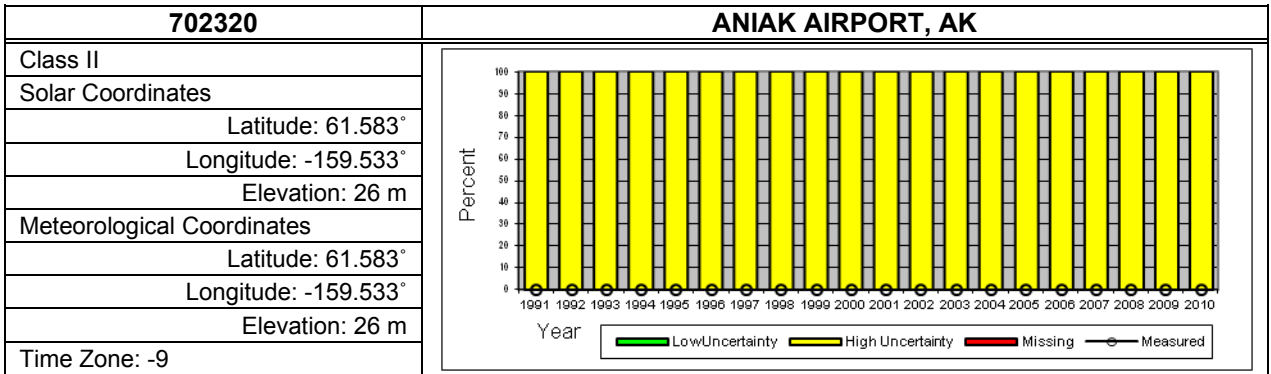
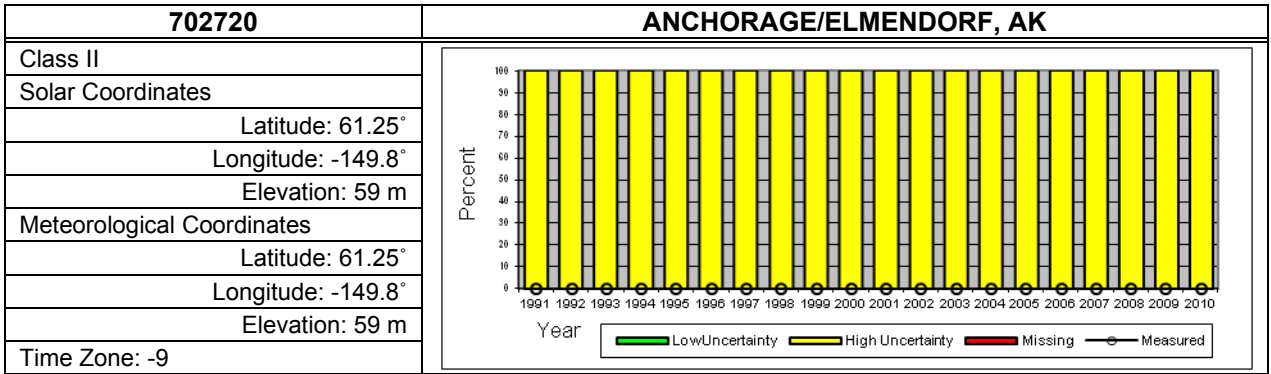
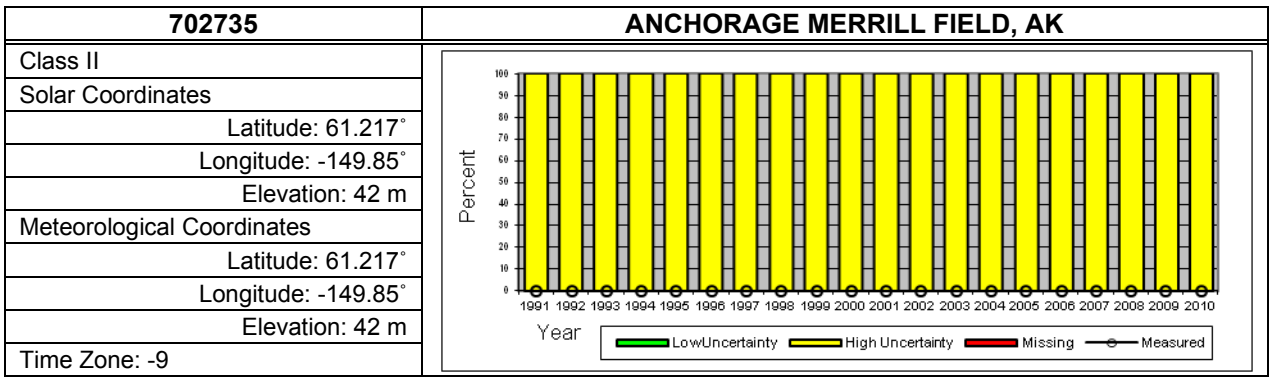
**Data Quality Plot**

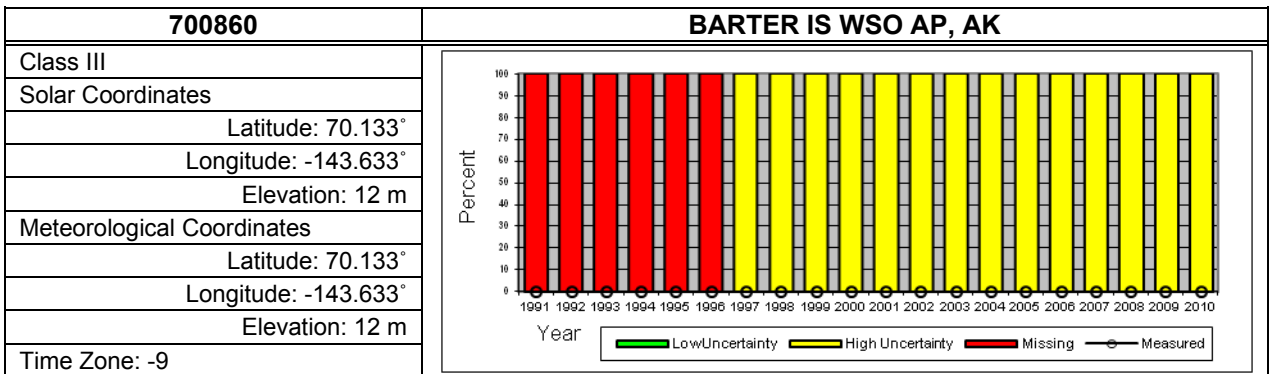
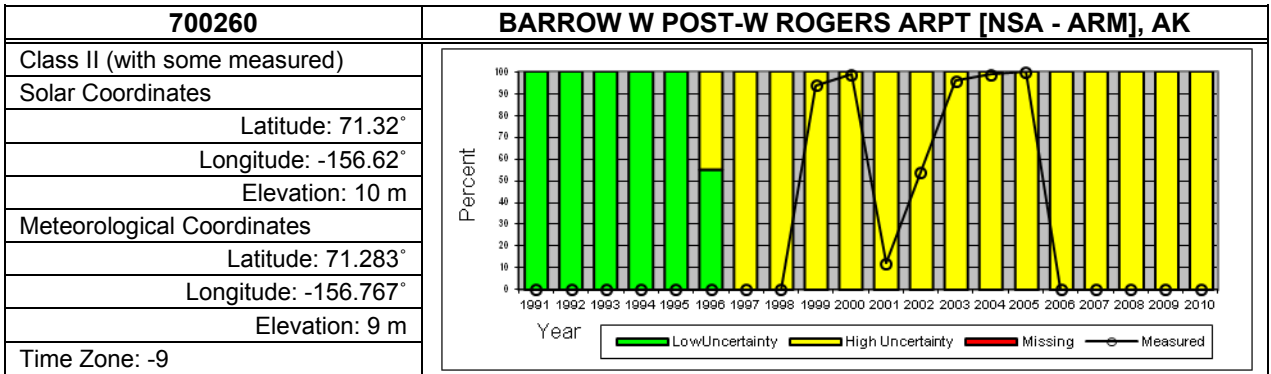
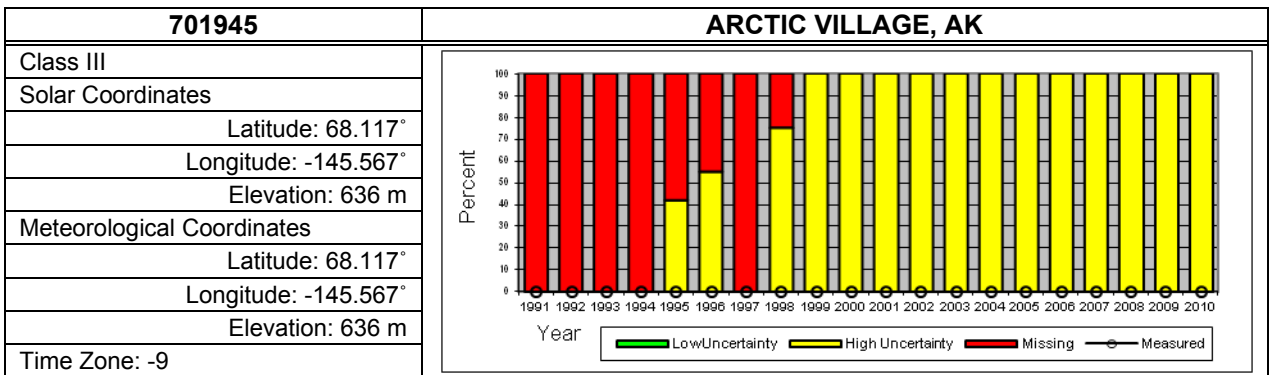
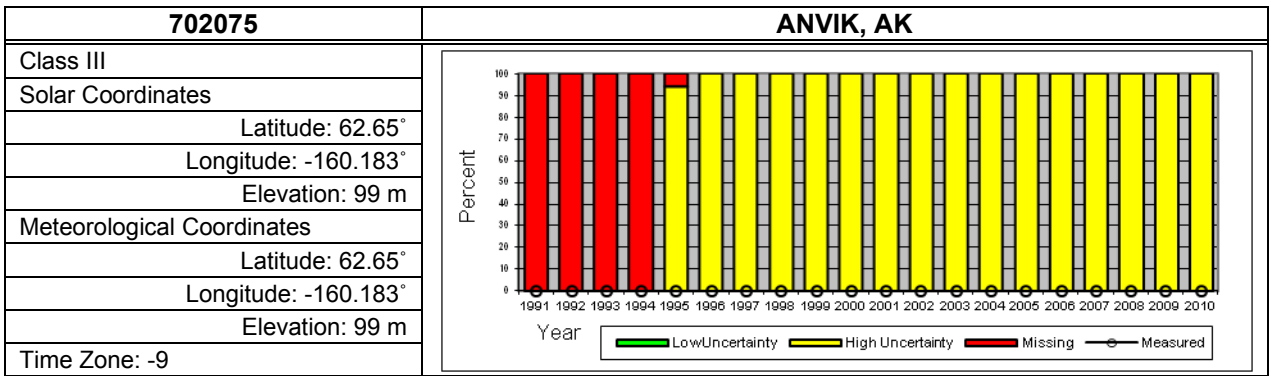
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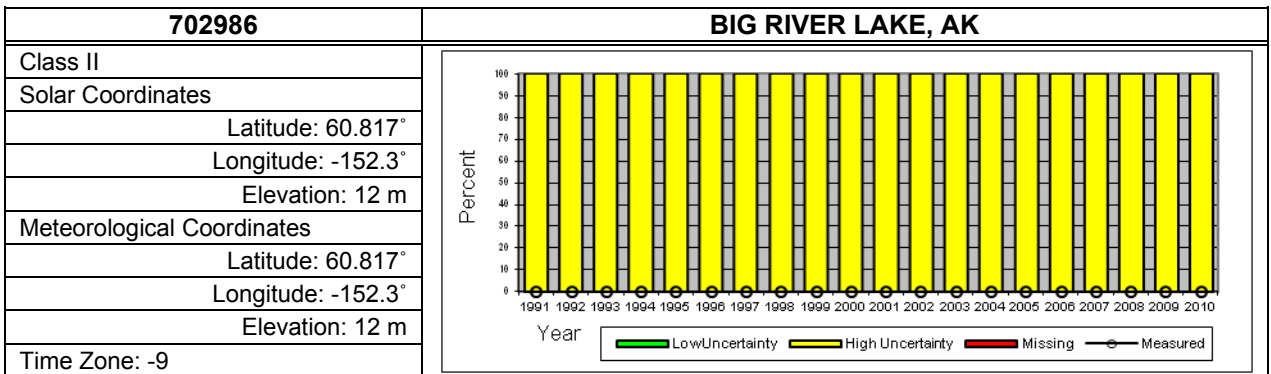
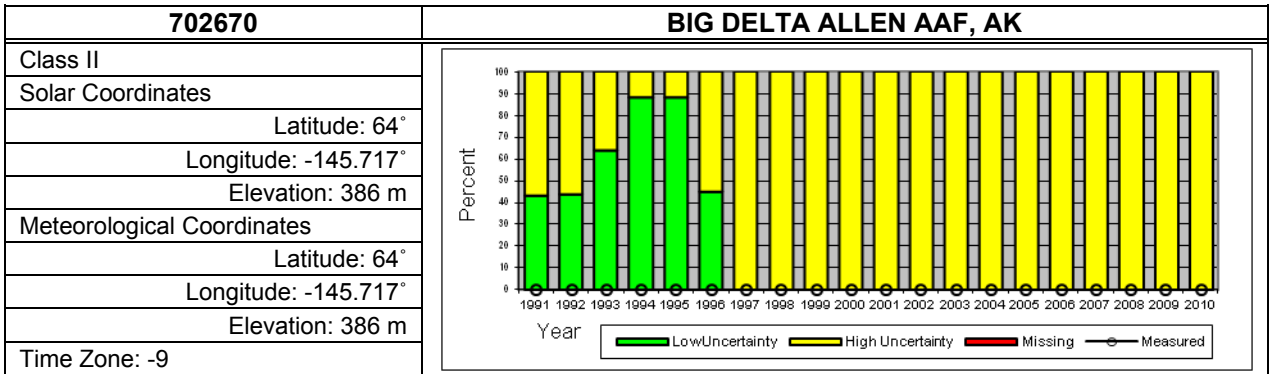
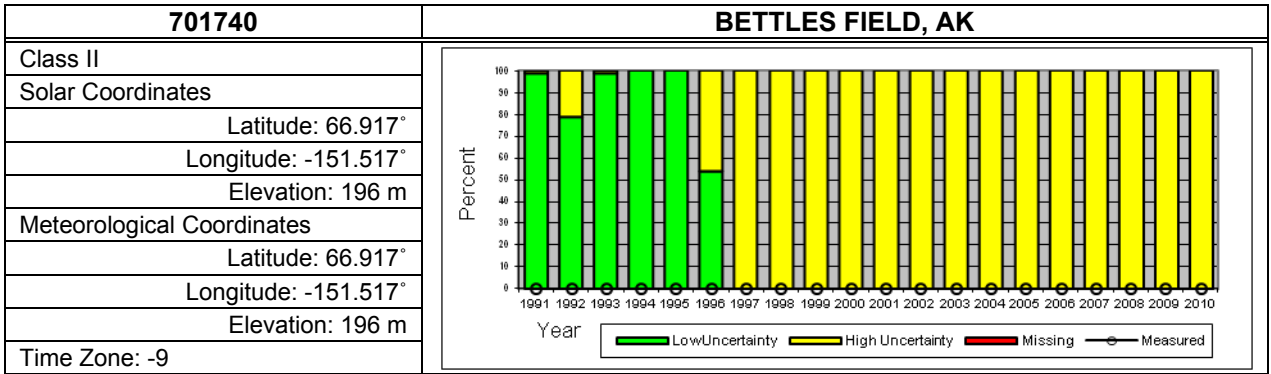
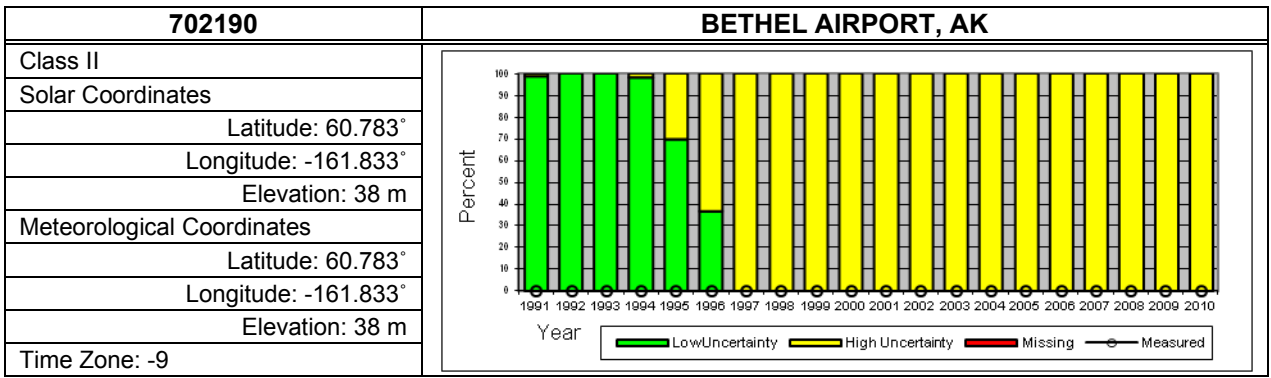
- Proportion of low and high uncertainty data as green and yellow stacked bars respectively
- Proportion of missing data as red bars
- Percent of measured data present in the data set as the black line graph with circle markers.

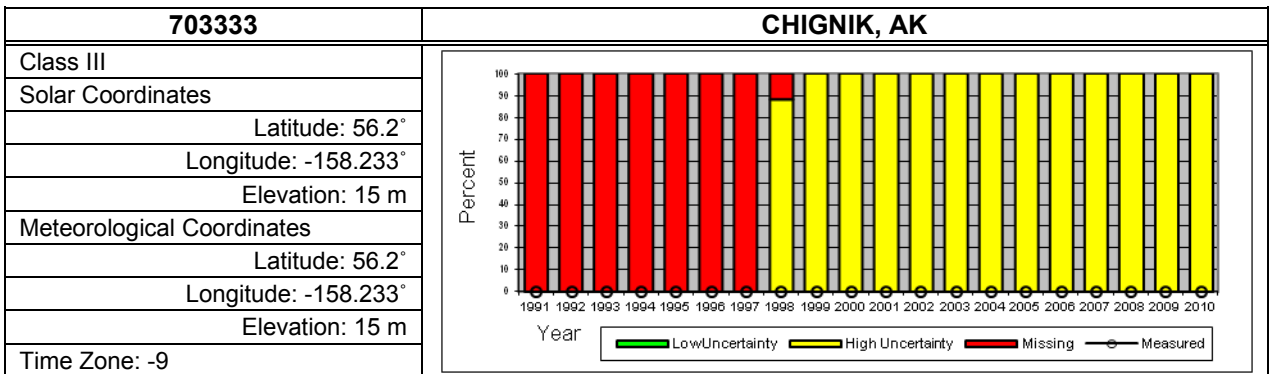
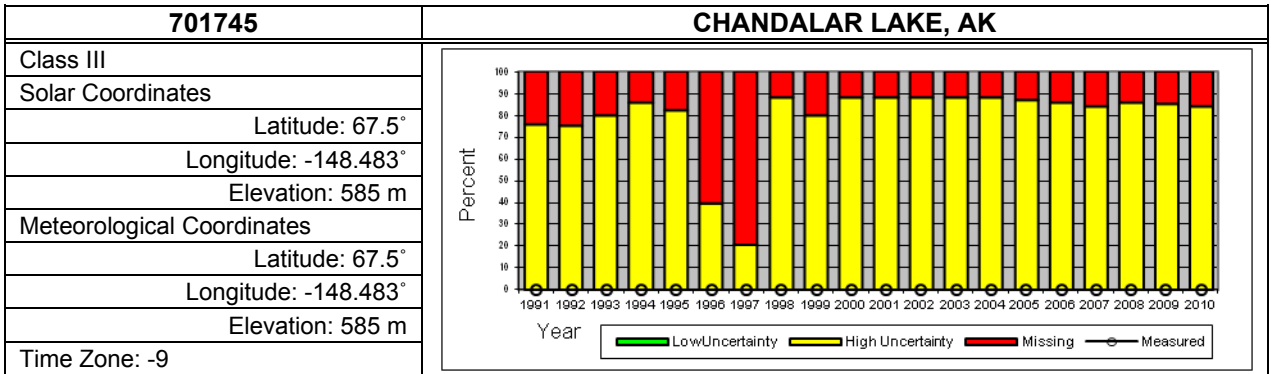
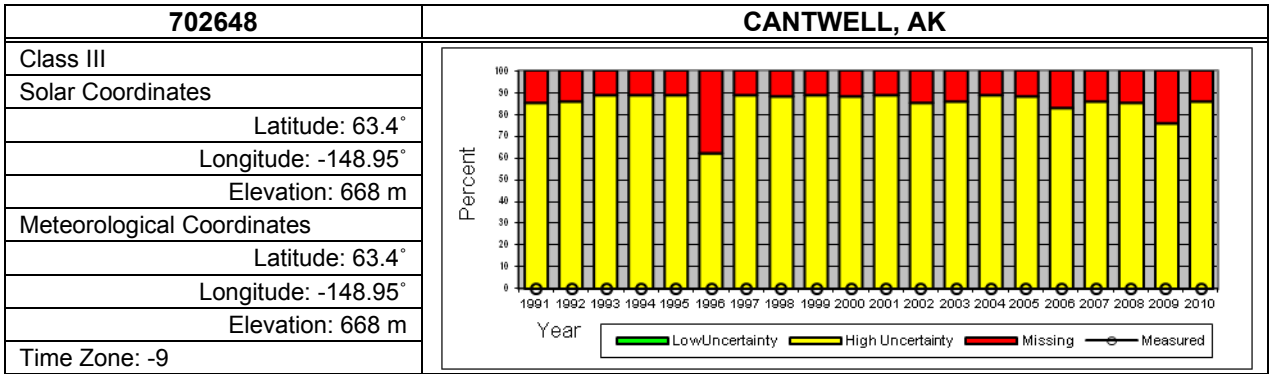
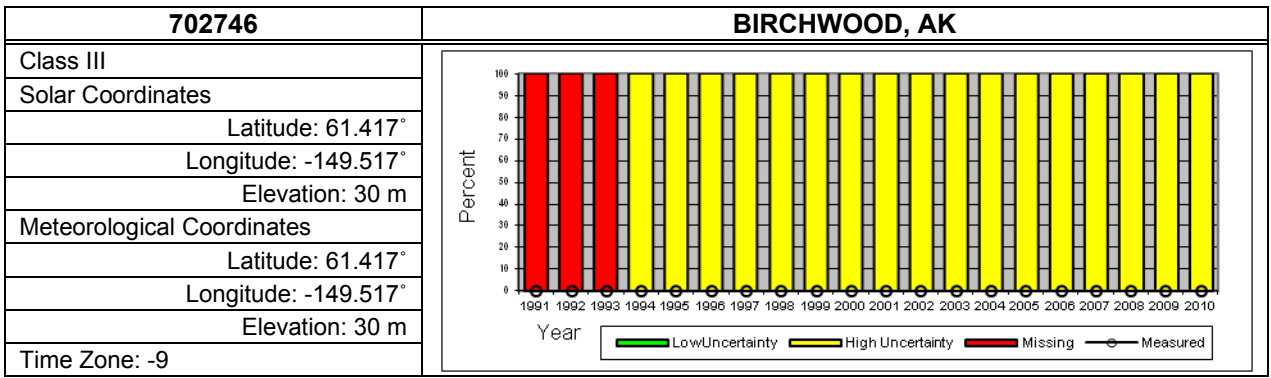


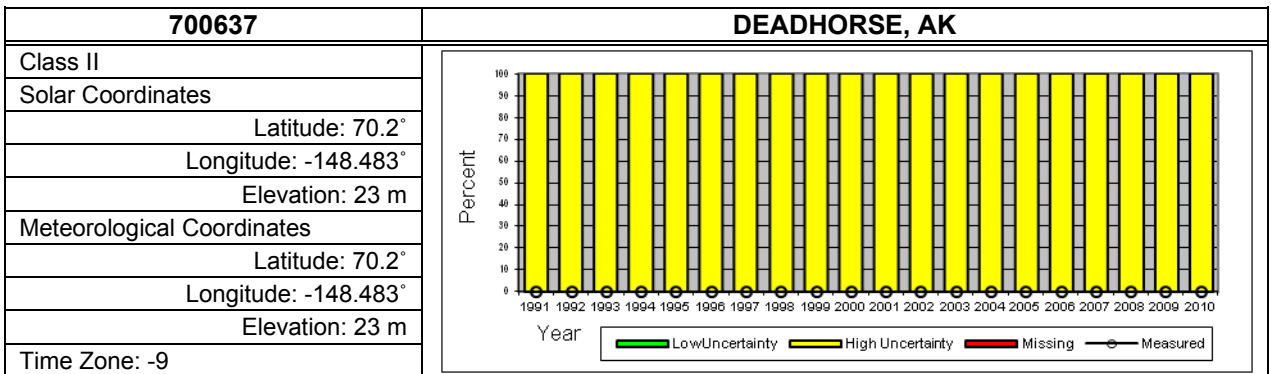
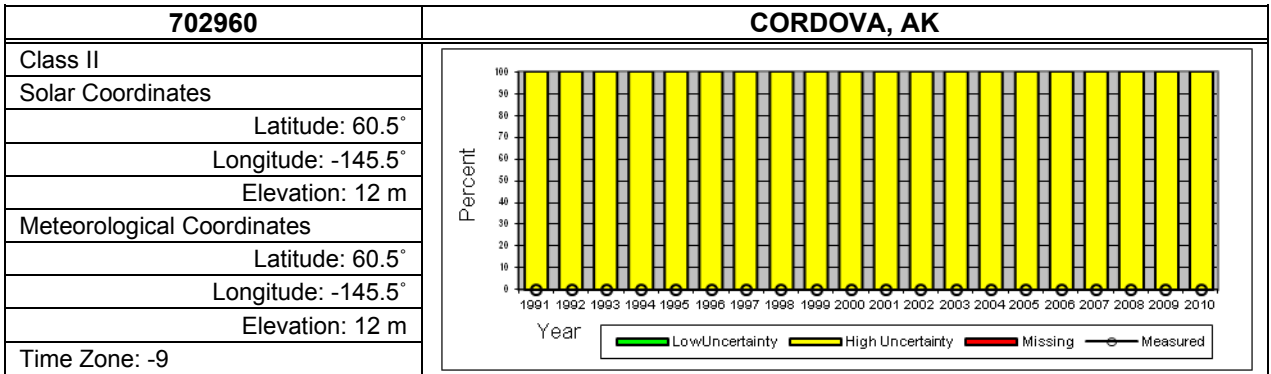
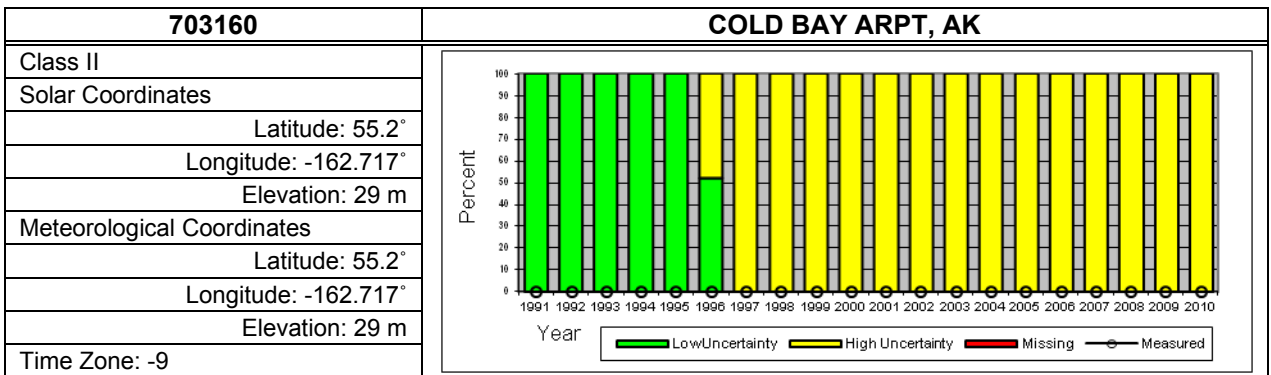
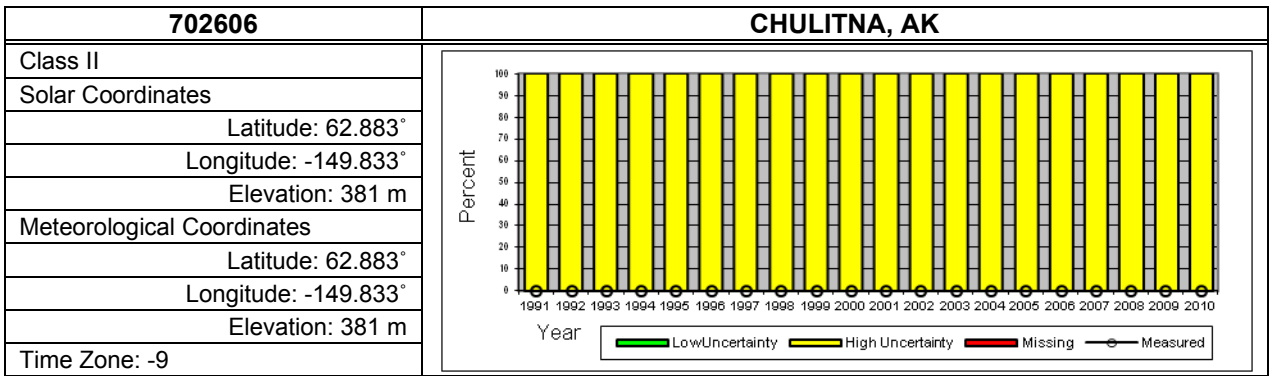


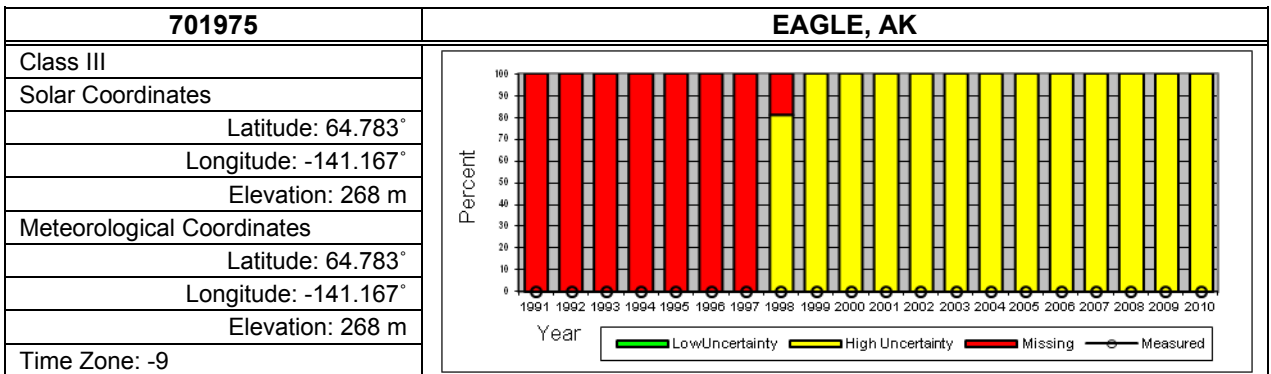
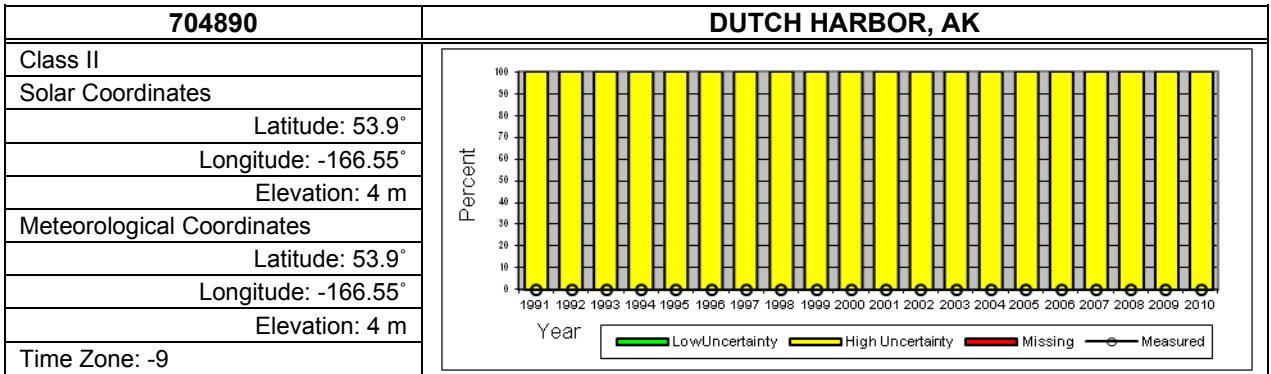
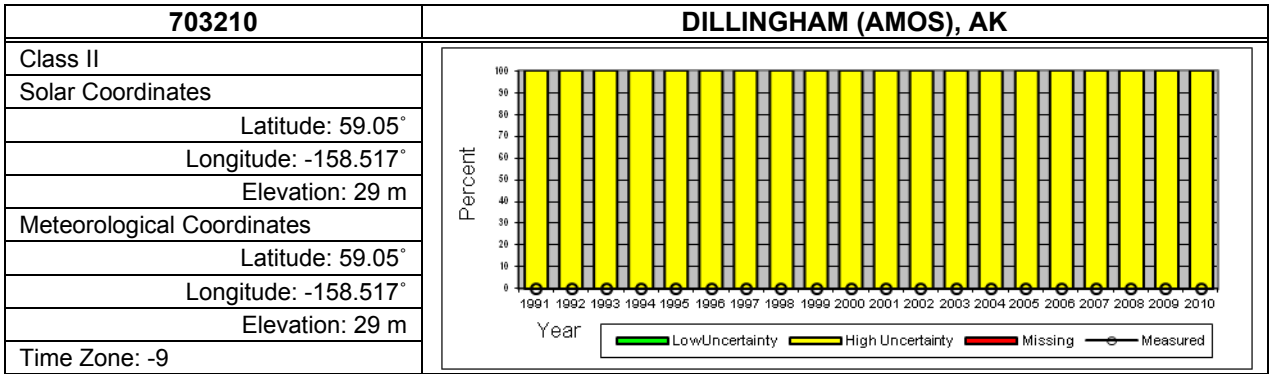
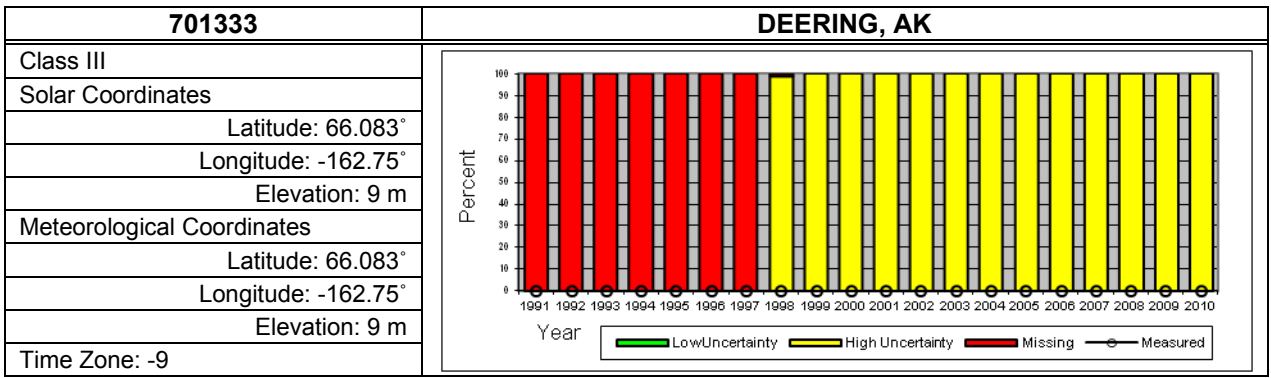


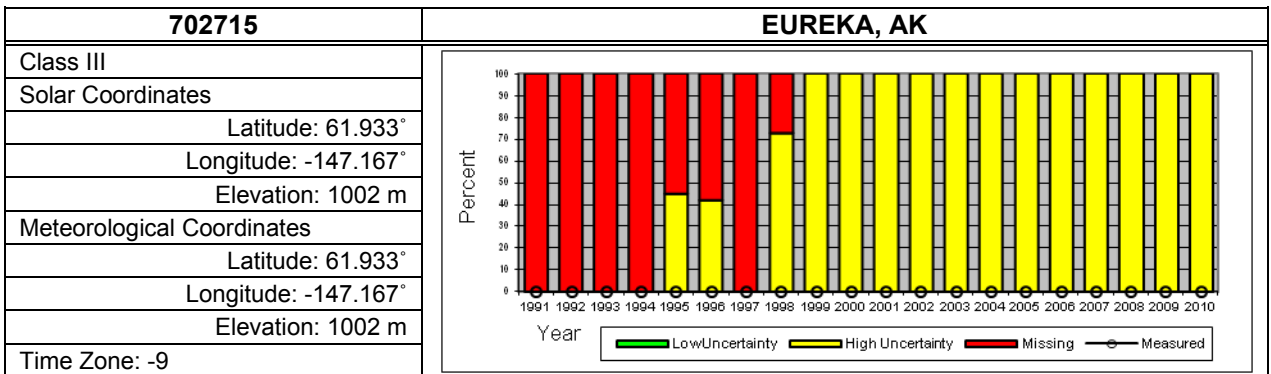
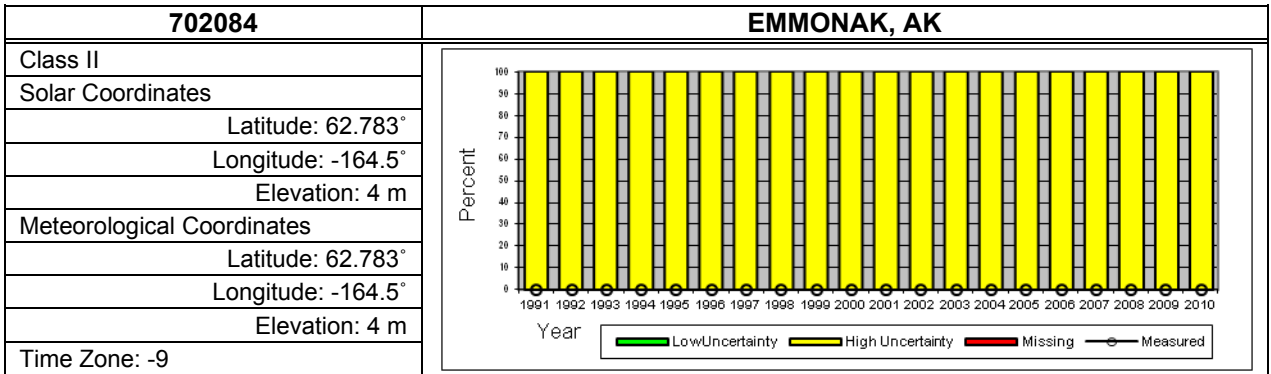
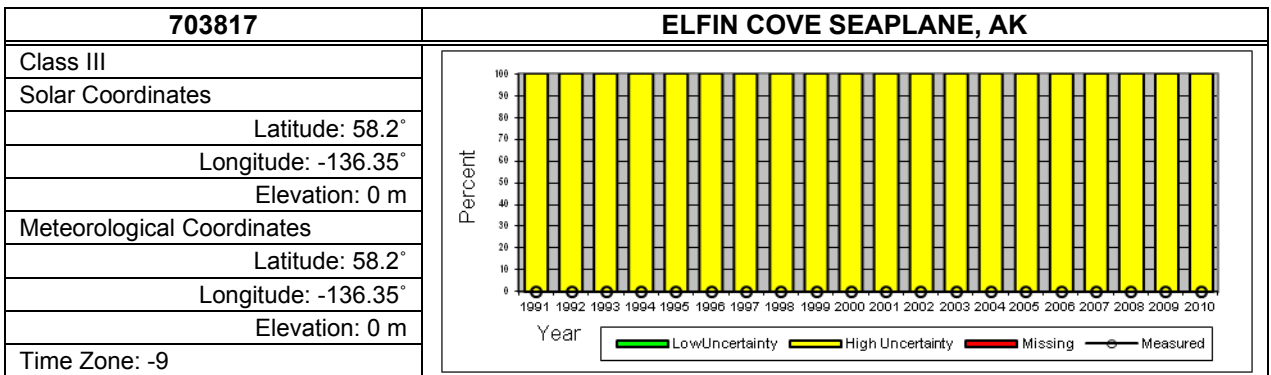
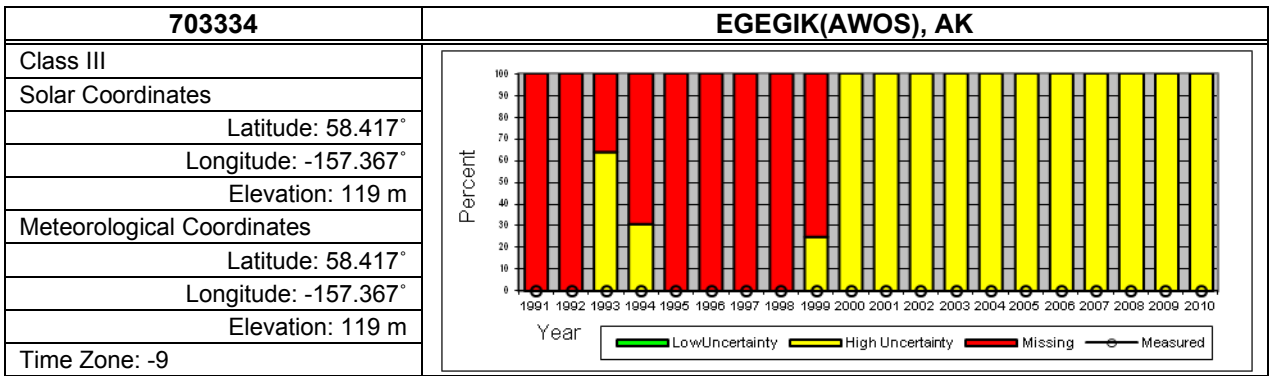


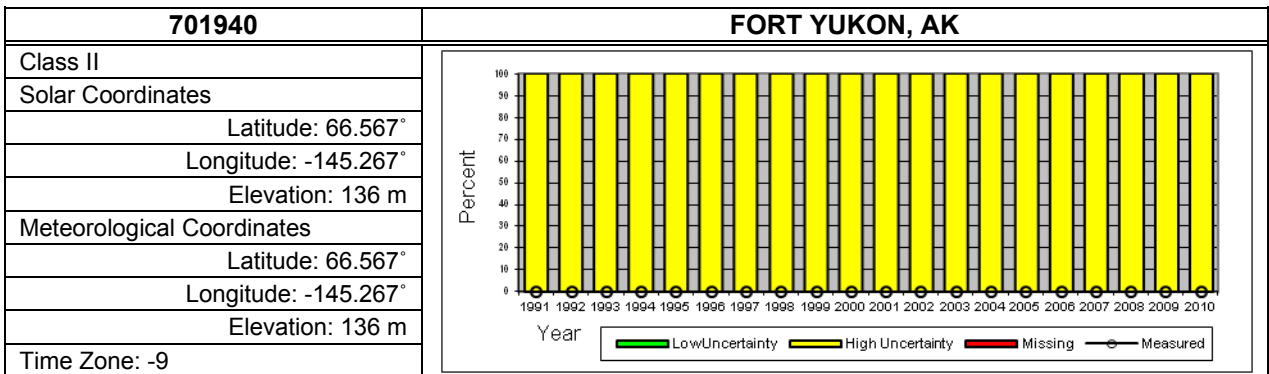
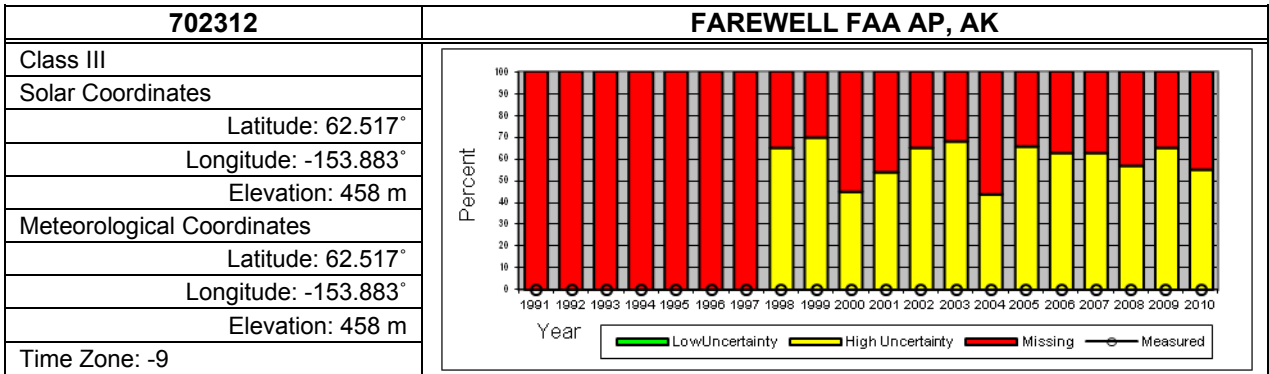
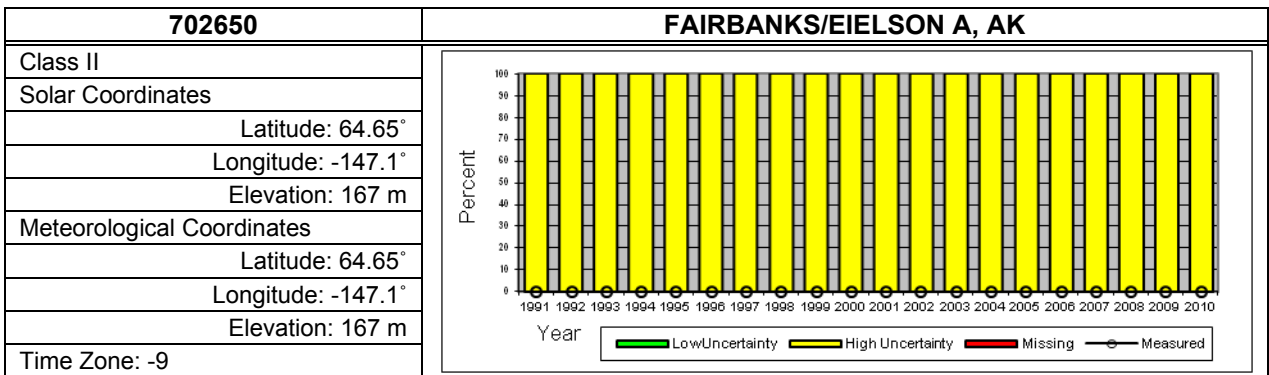
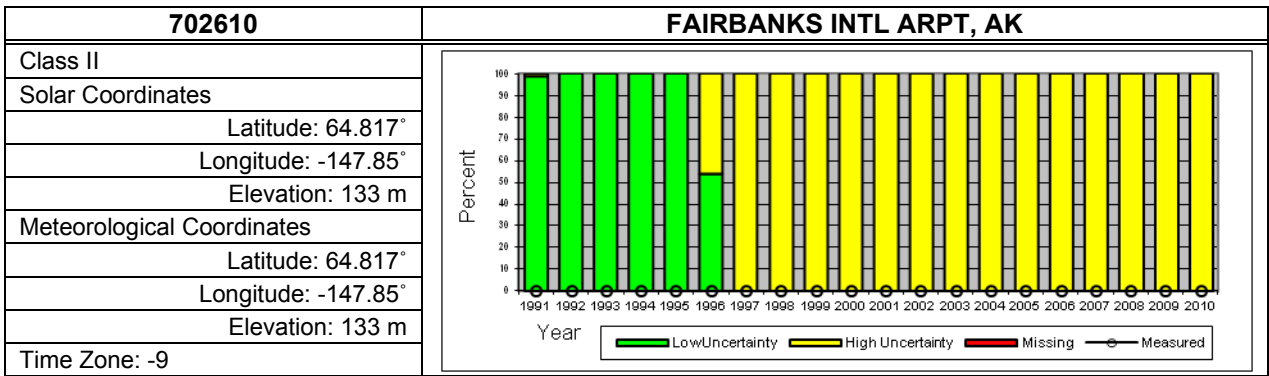




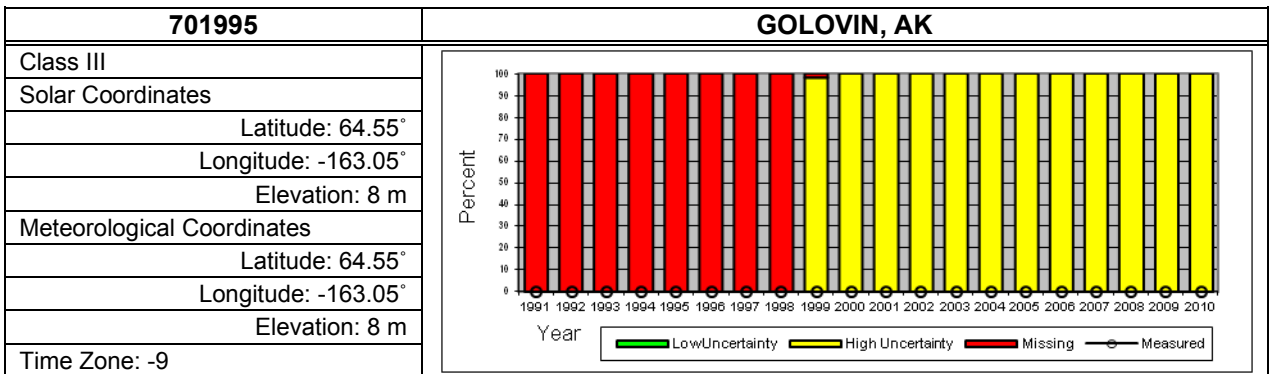
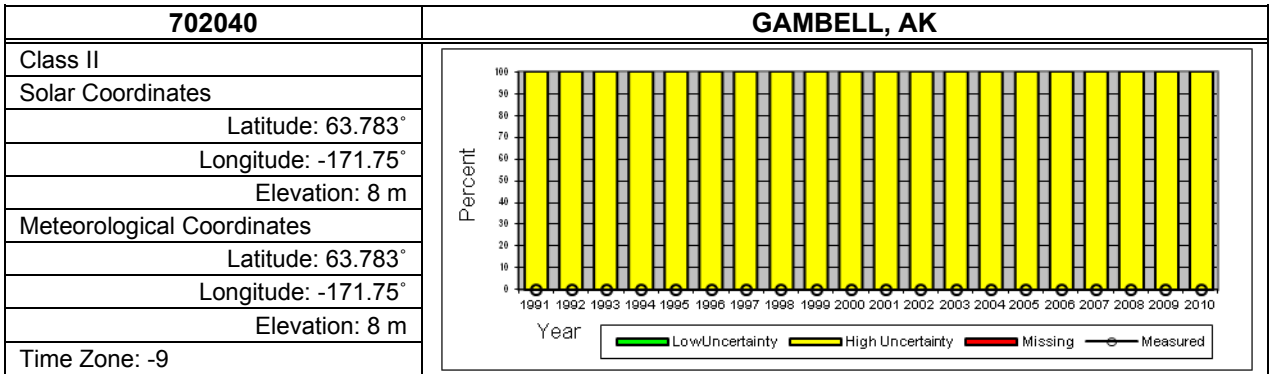
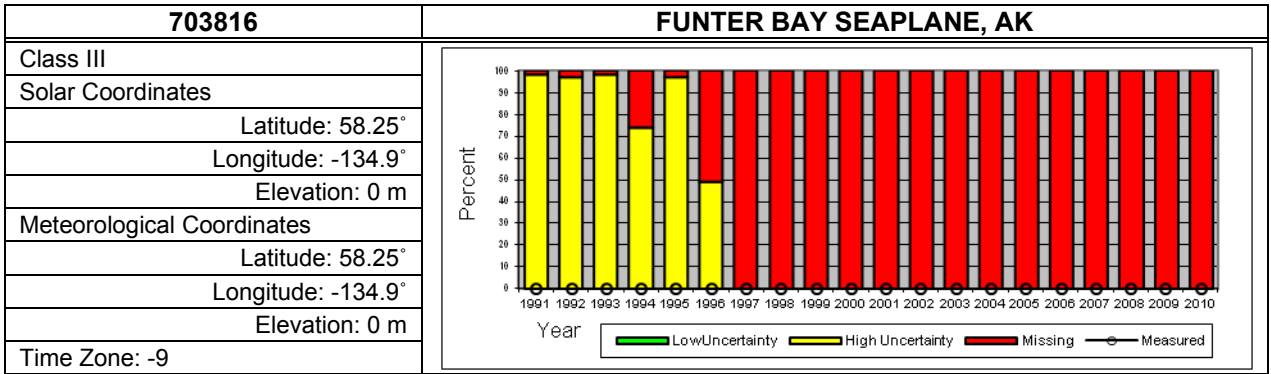
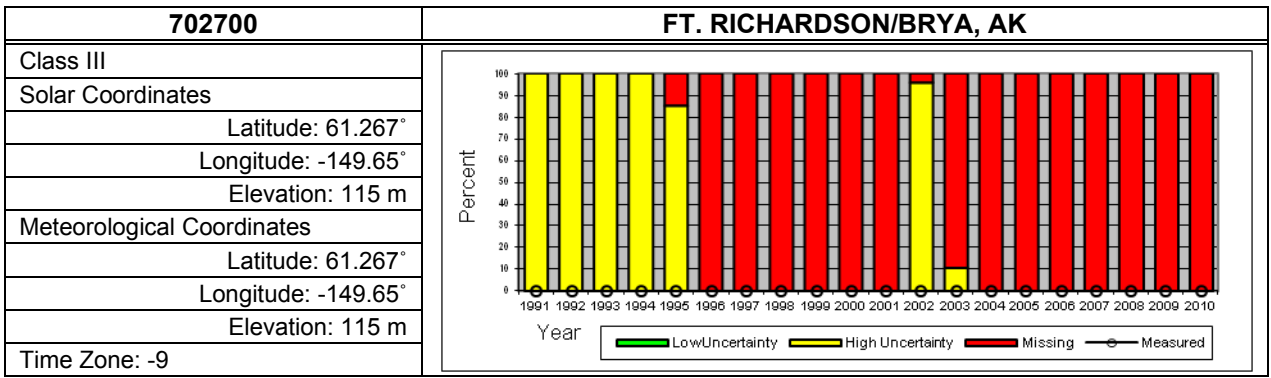


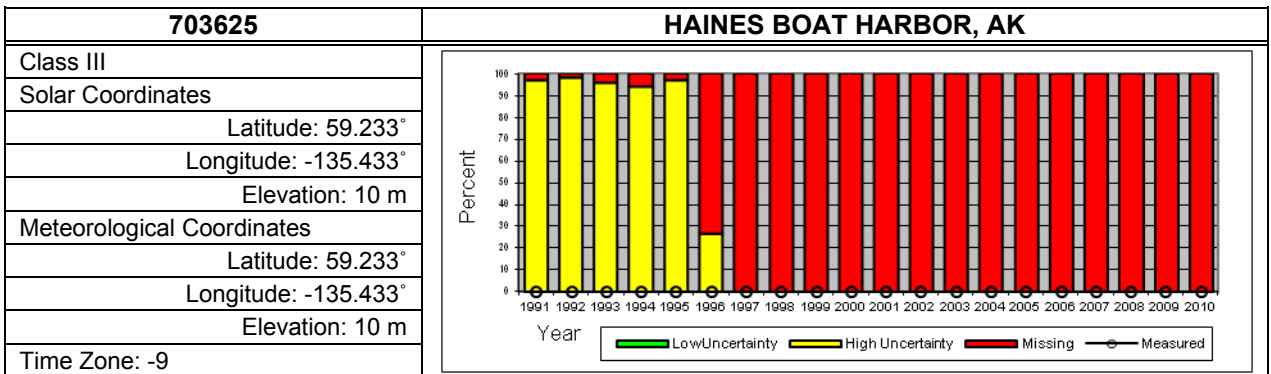
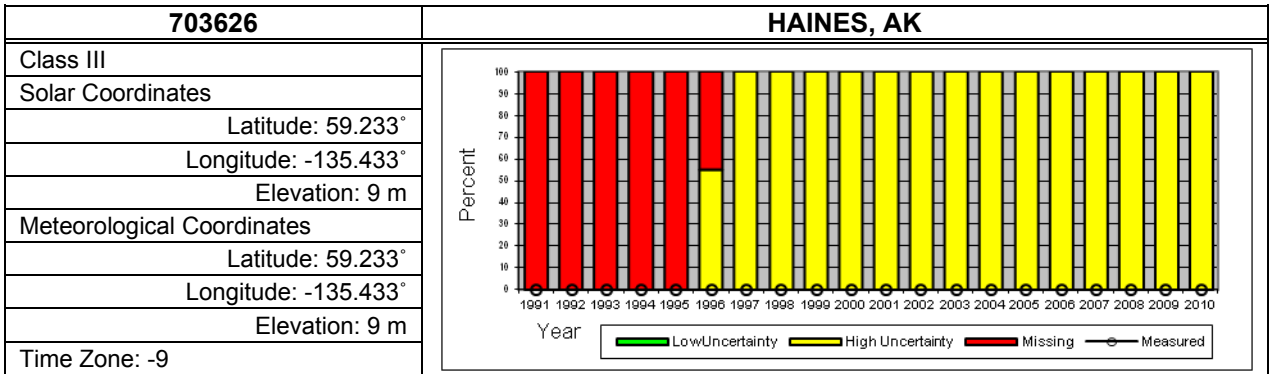
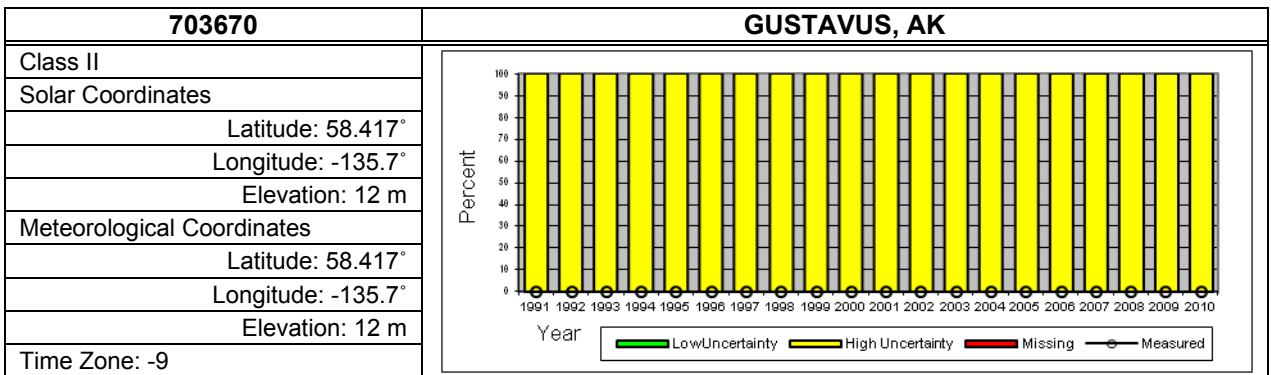
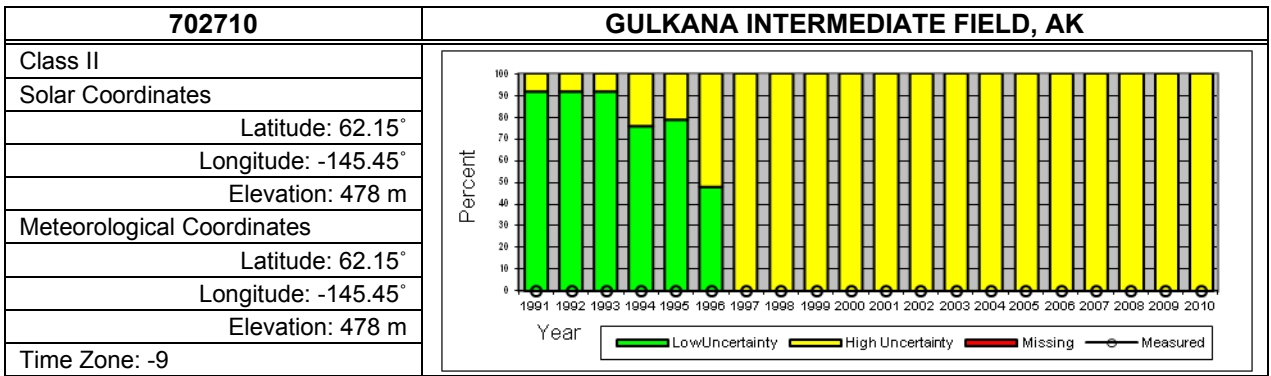


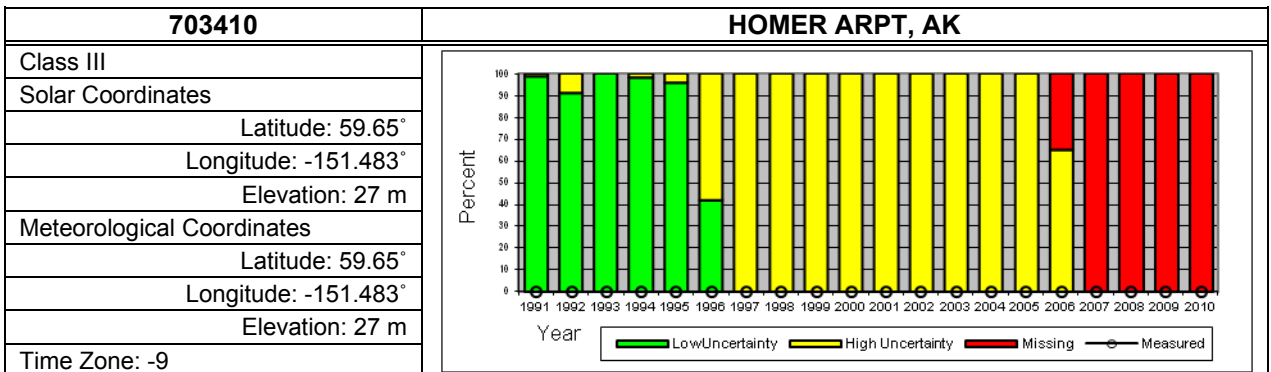
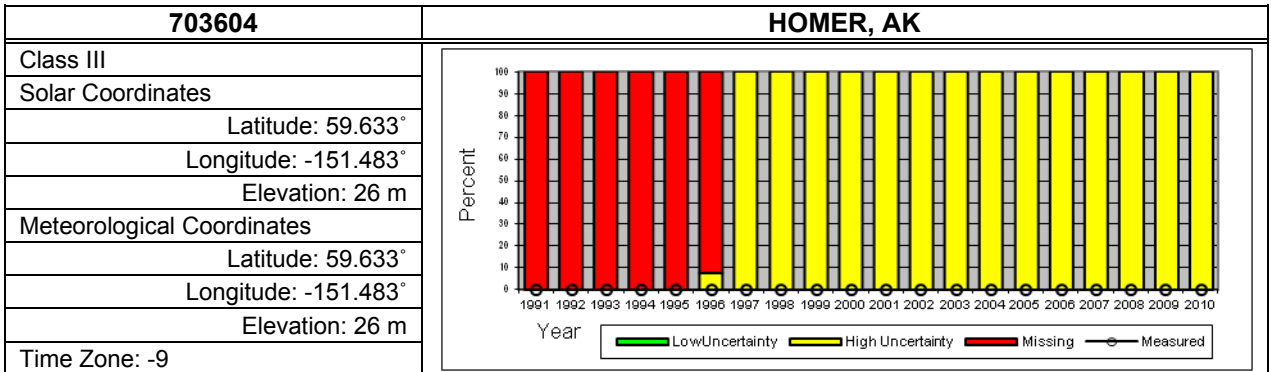
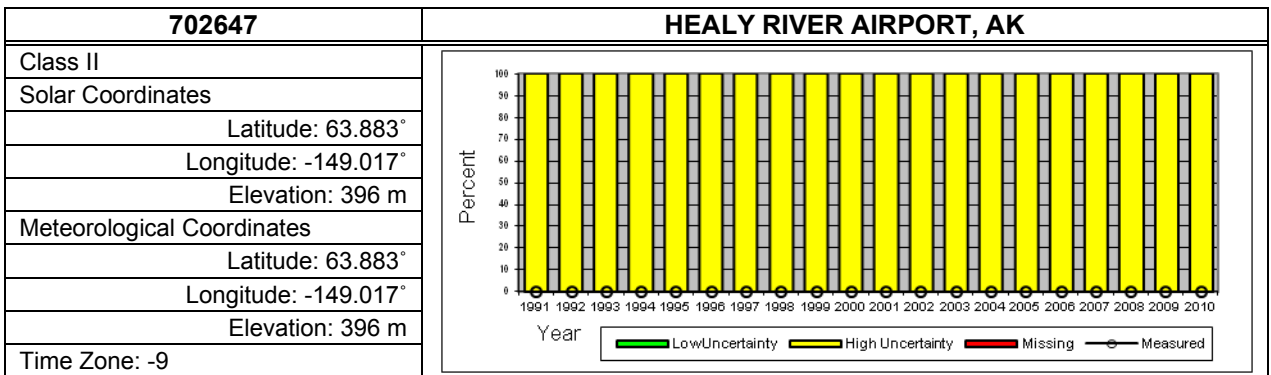
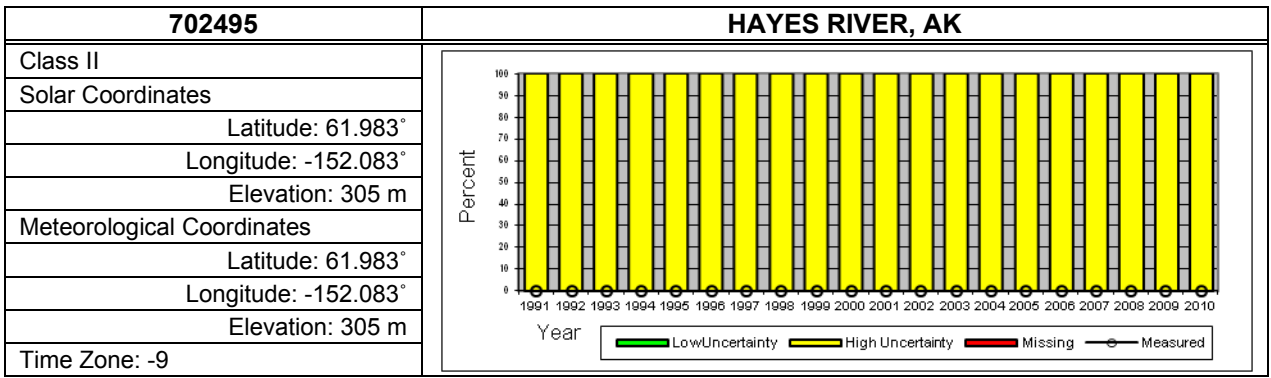


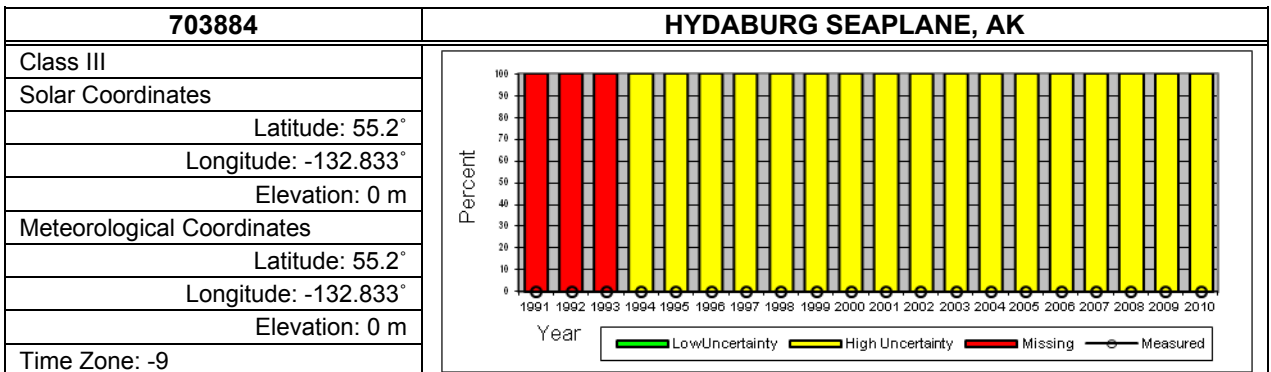
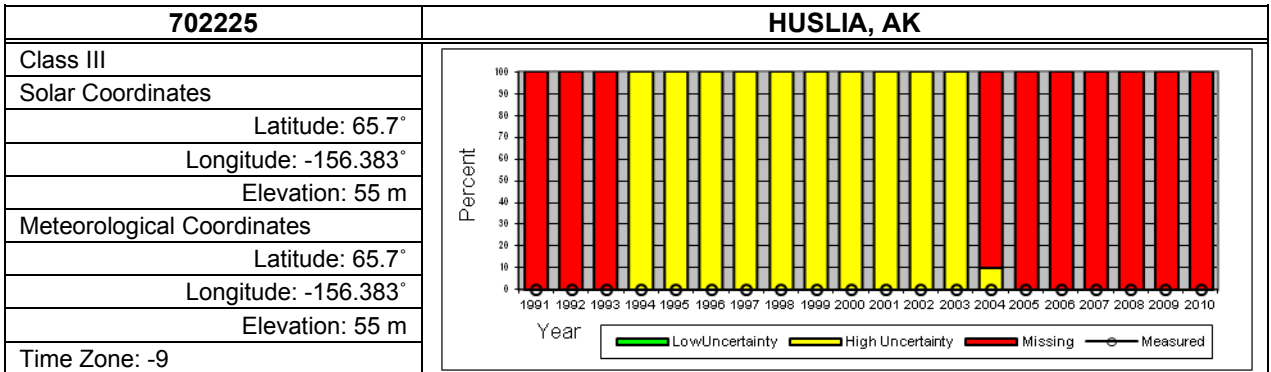
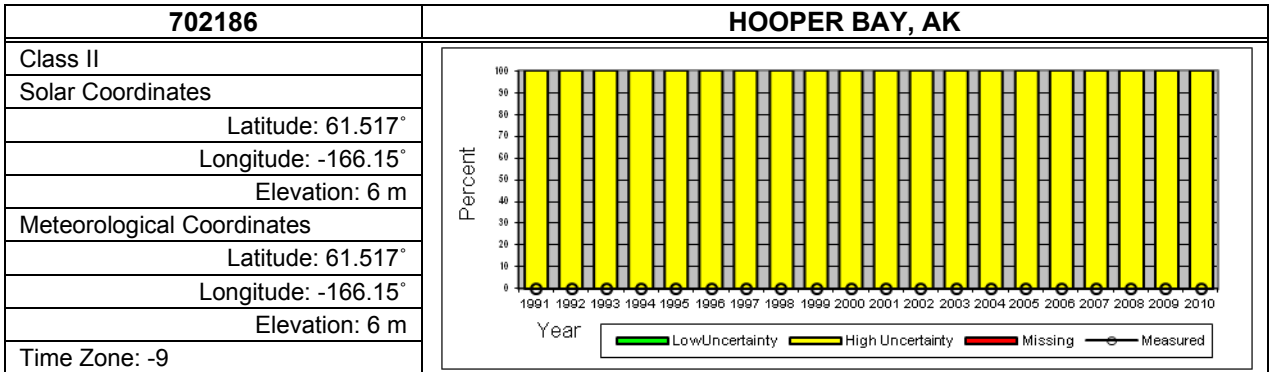
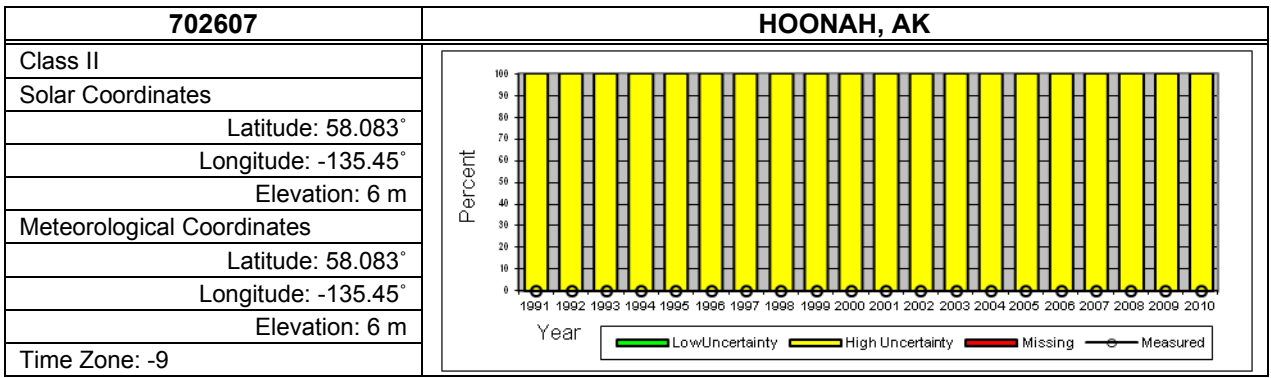


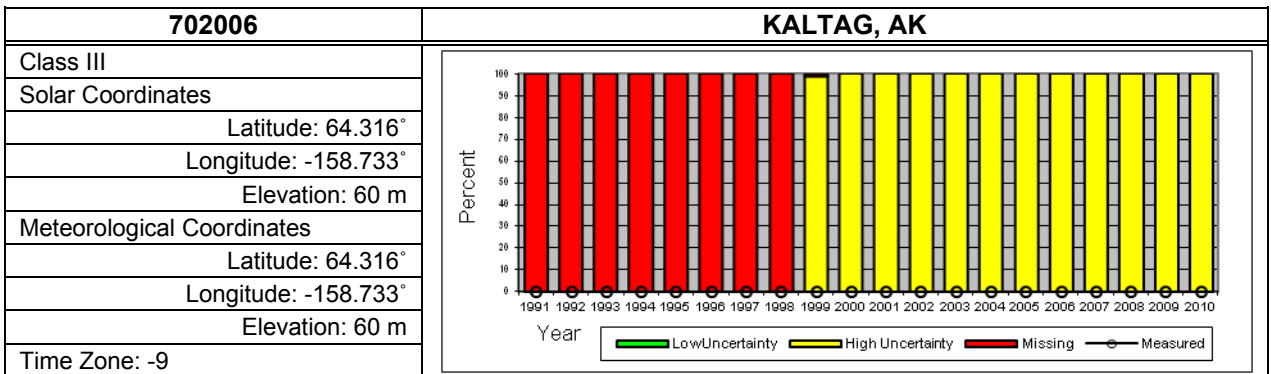
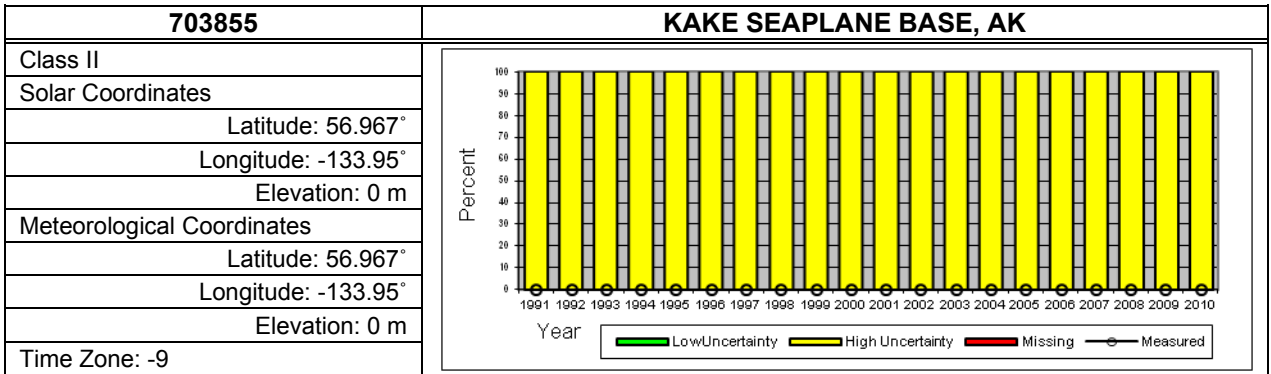
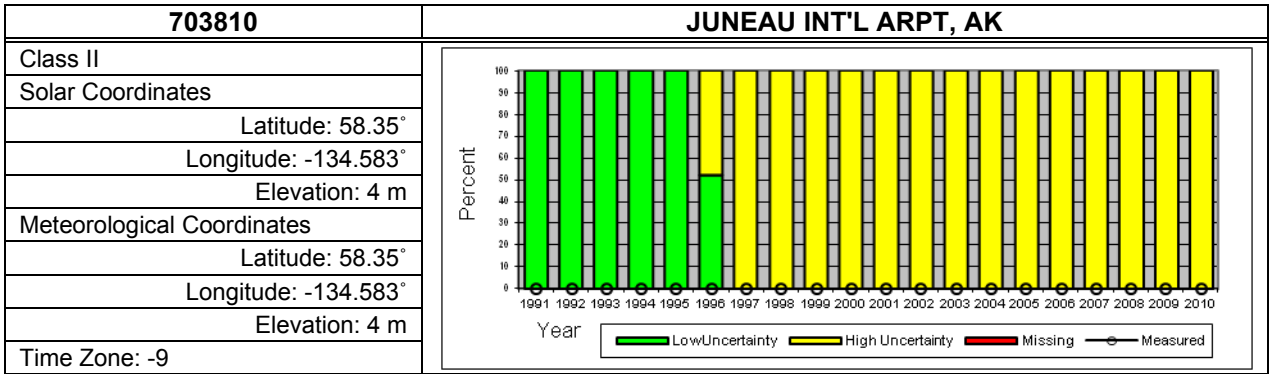
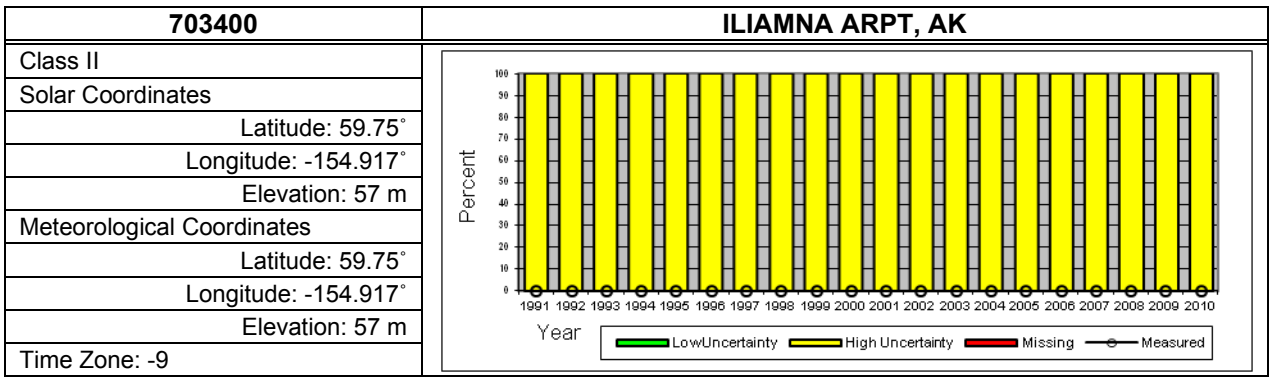


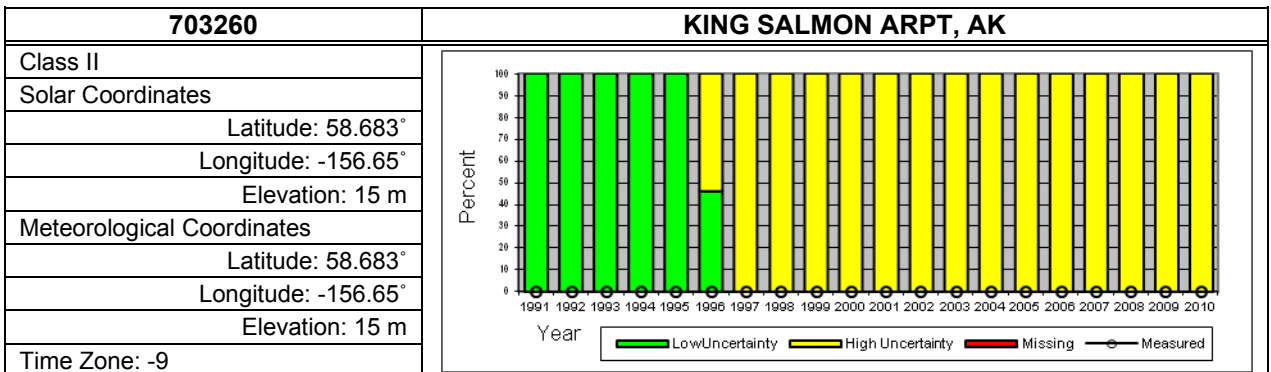
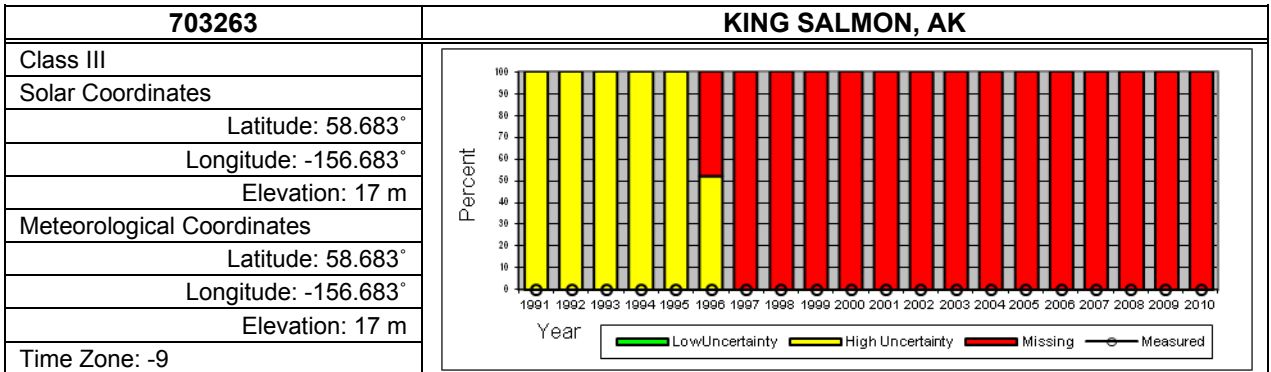
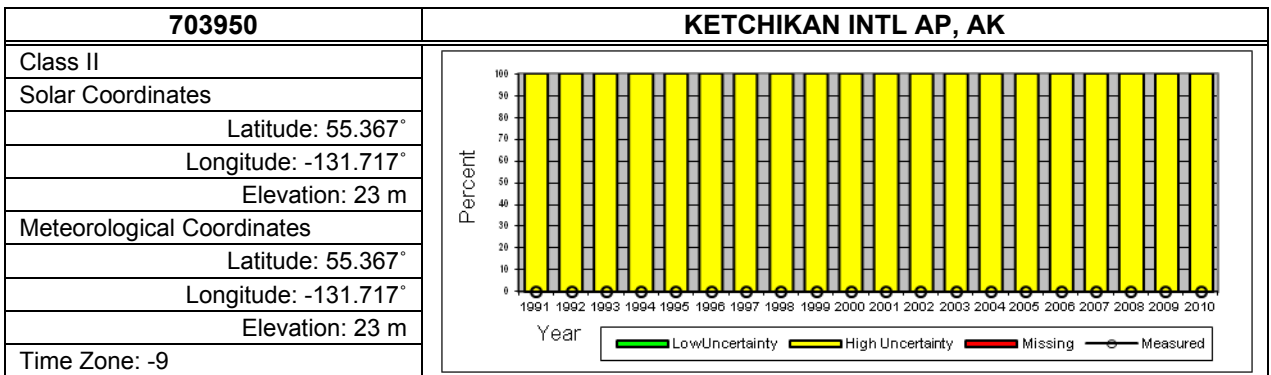
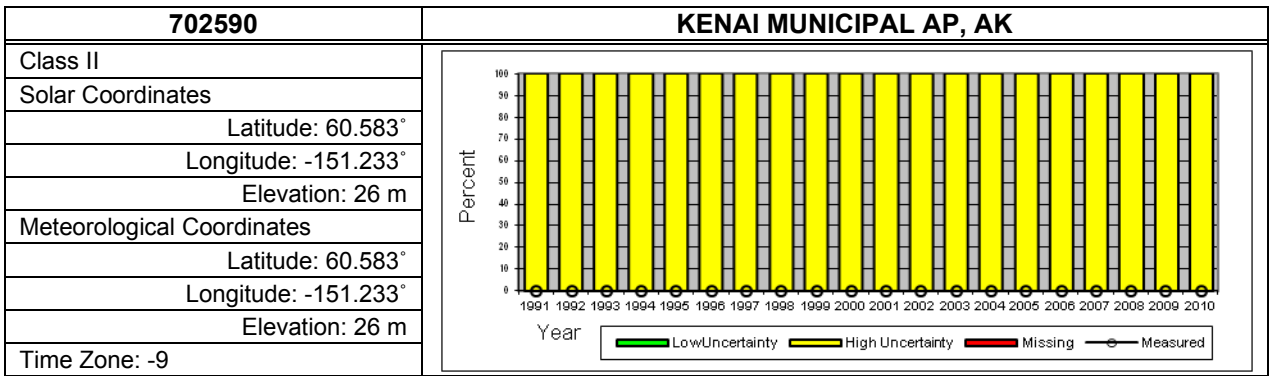


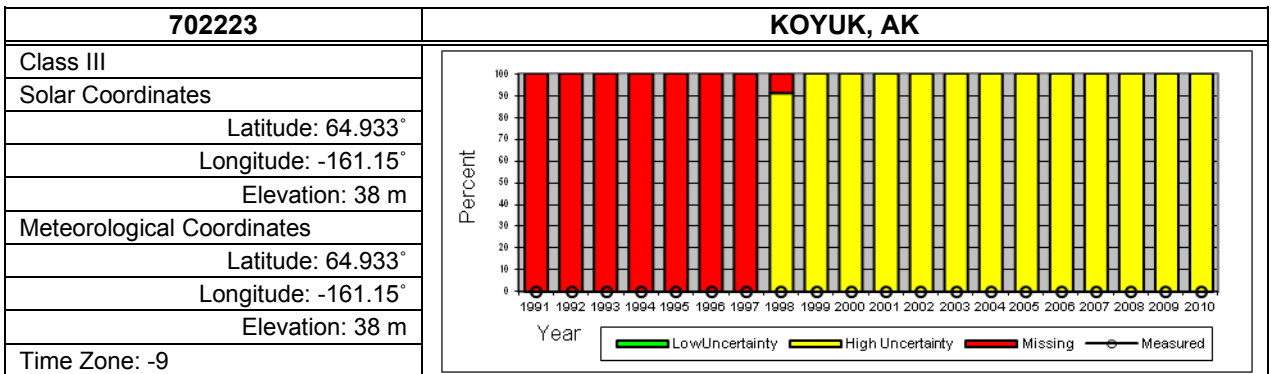
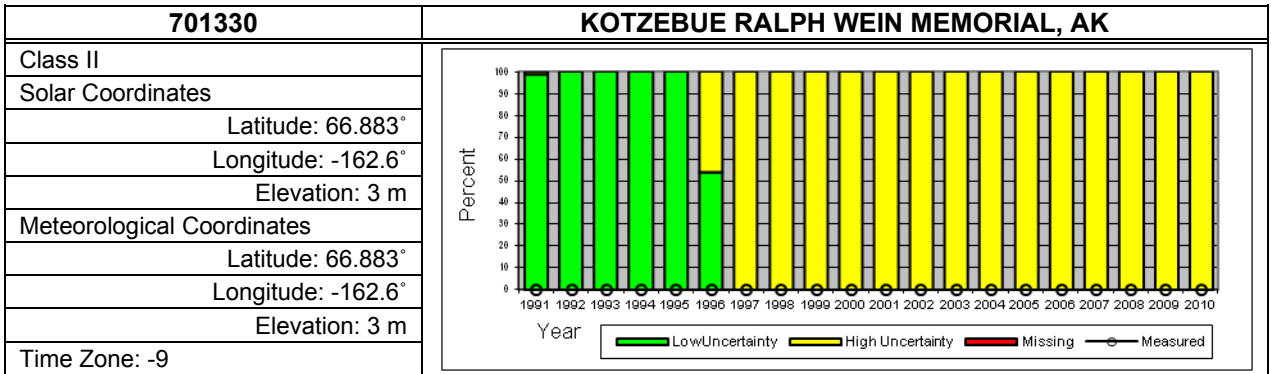
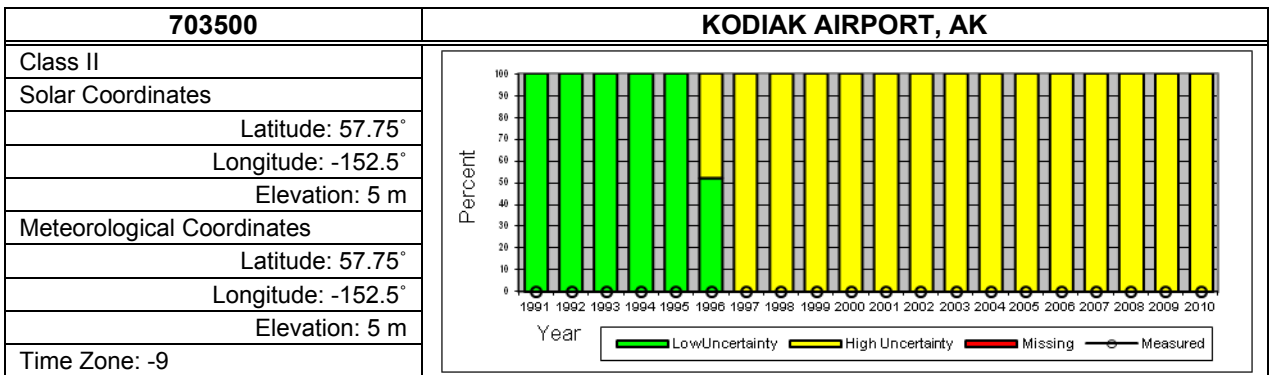
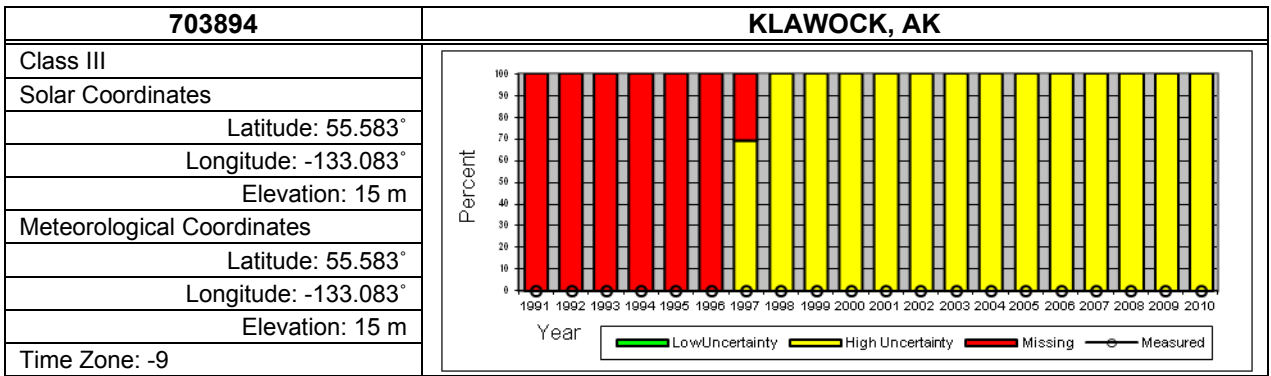


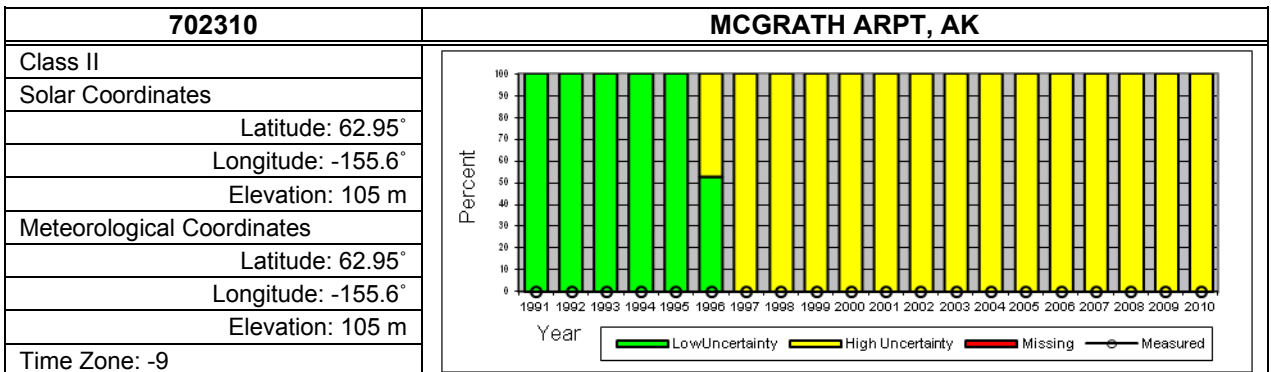
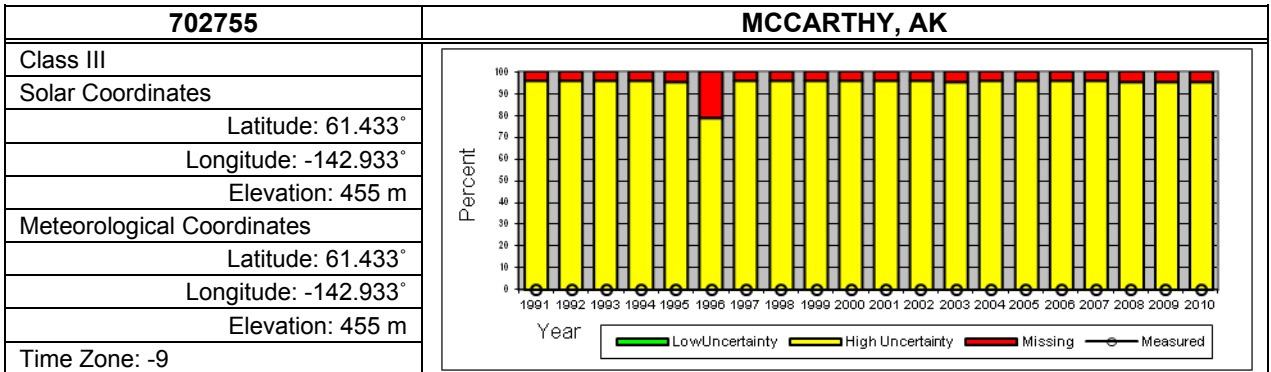
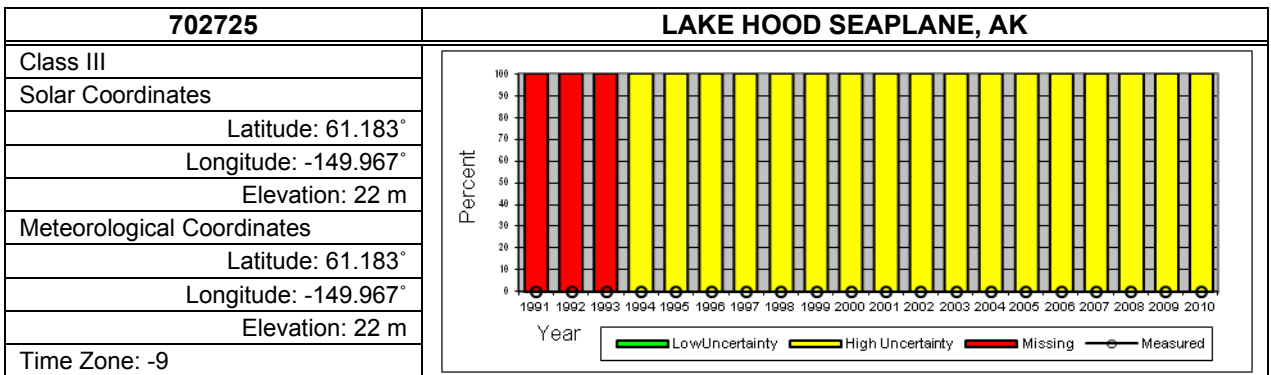
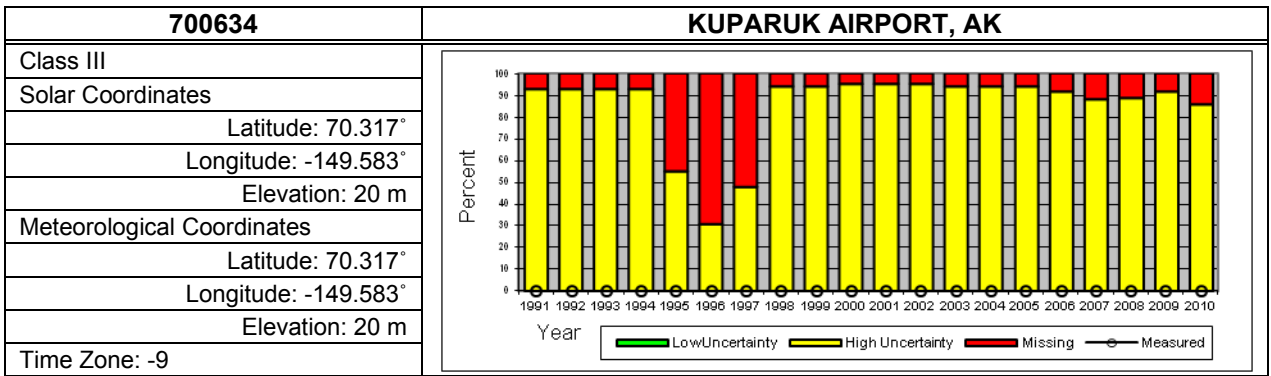




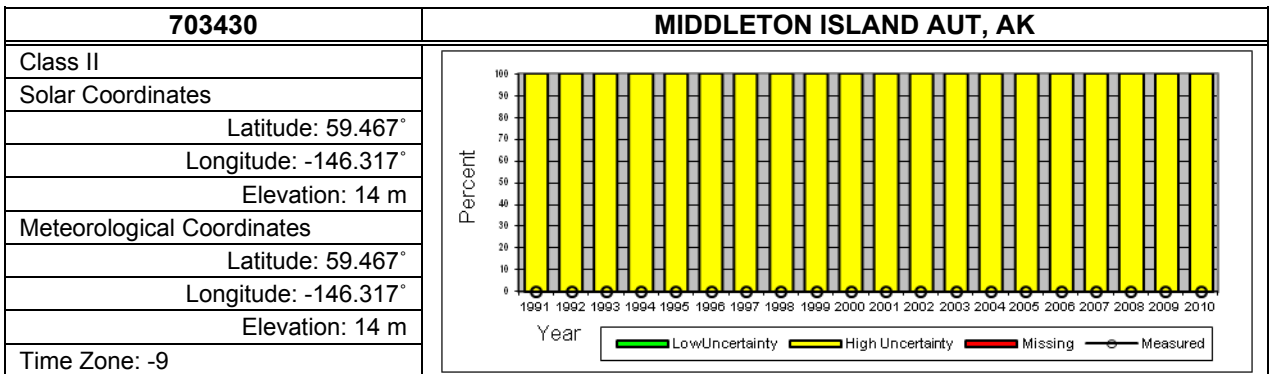
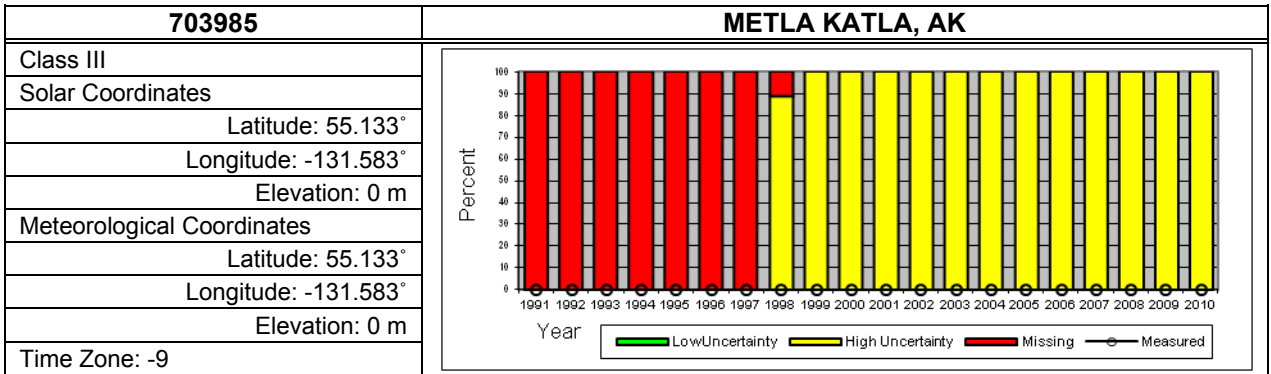
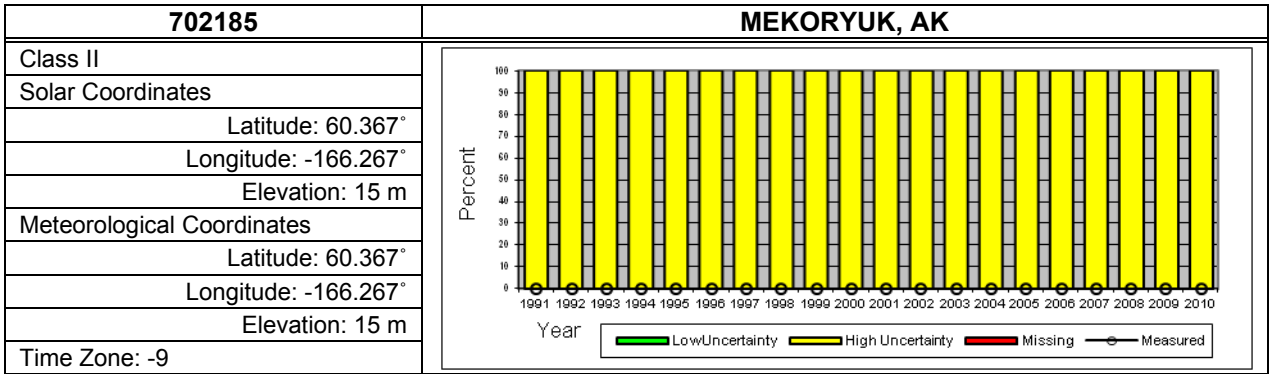
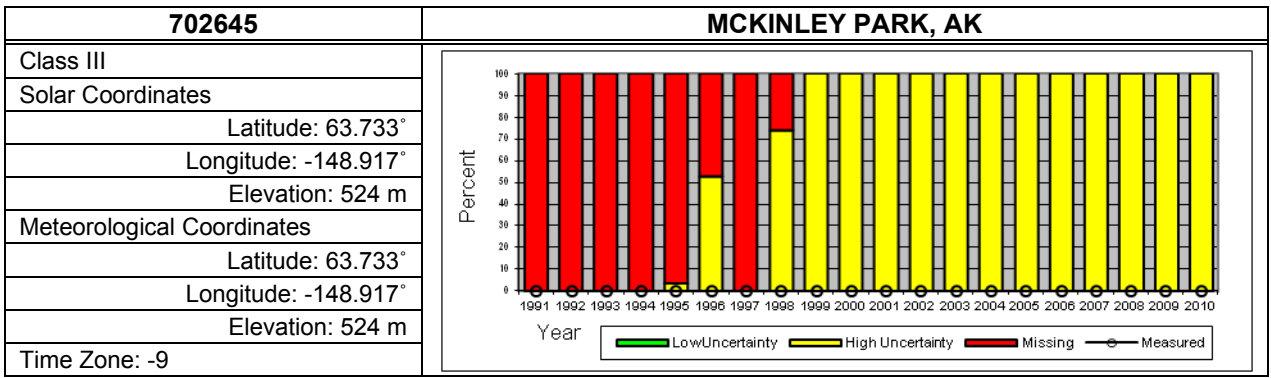


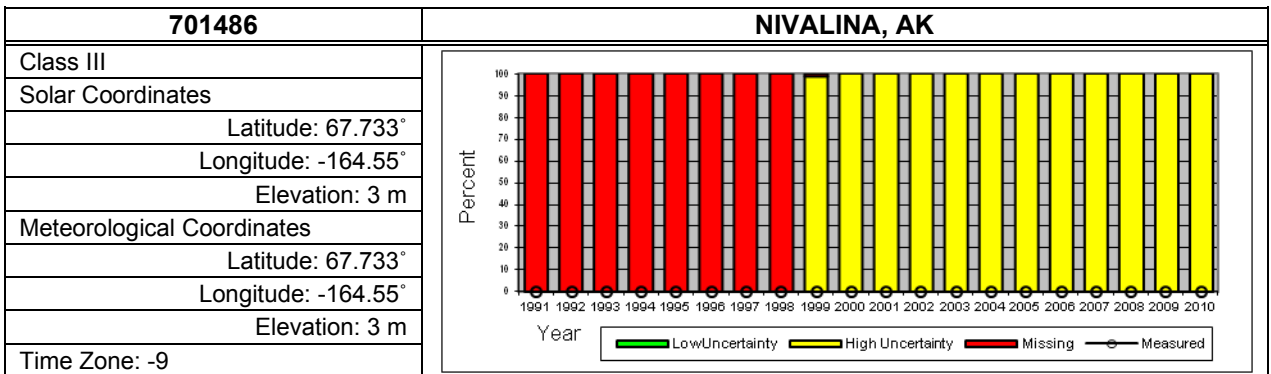
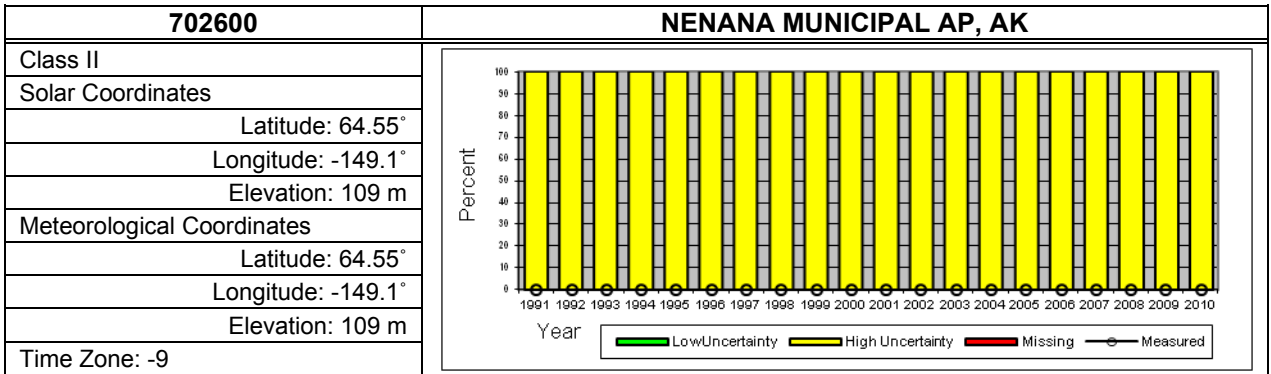
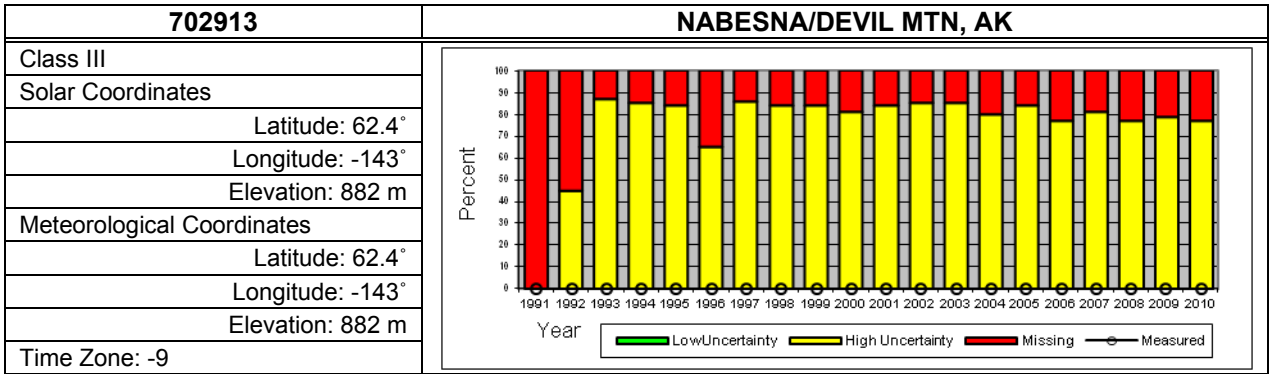
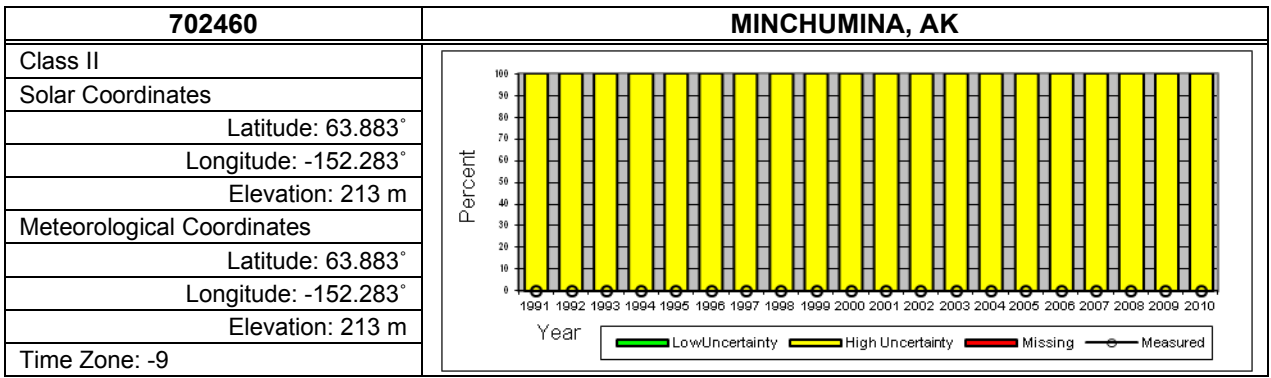


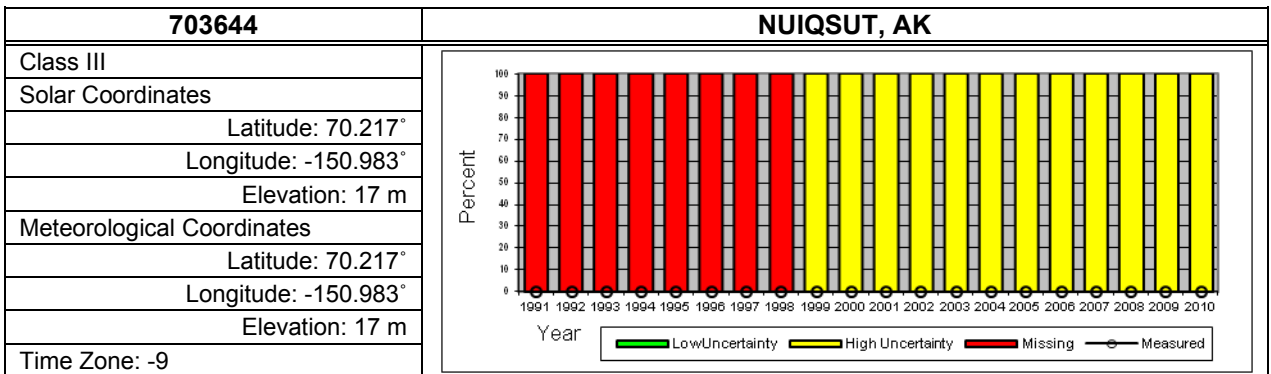
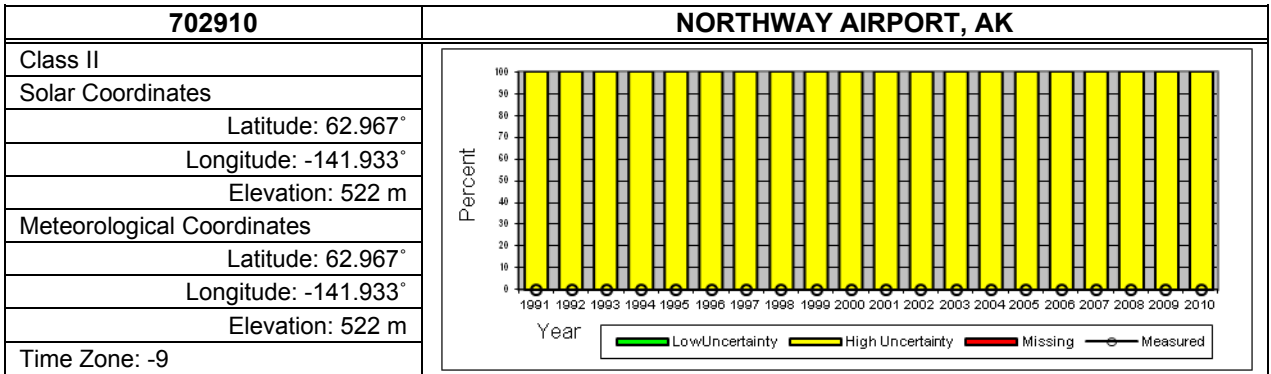
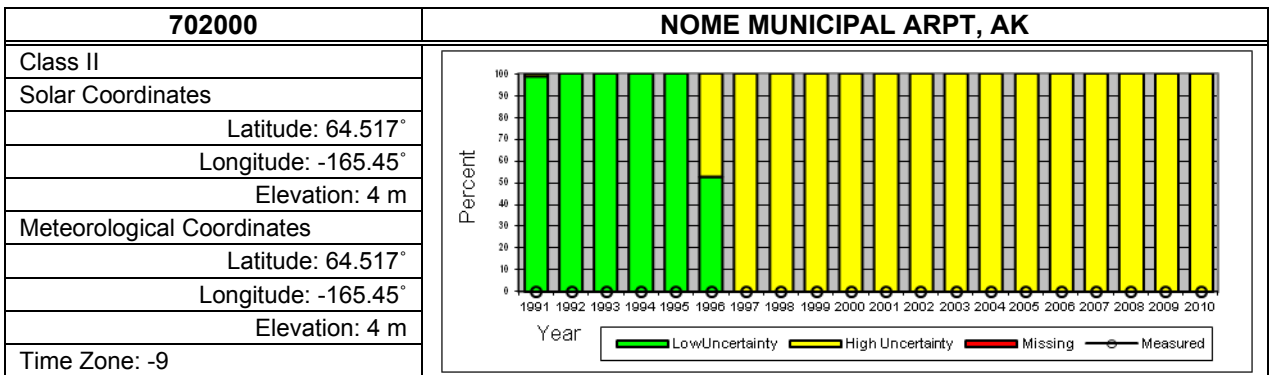
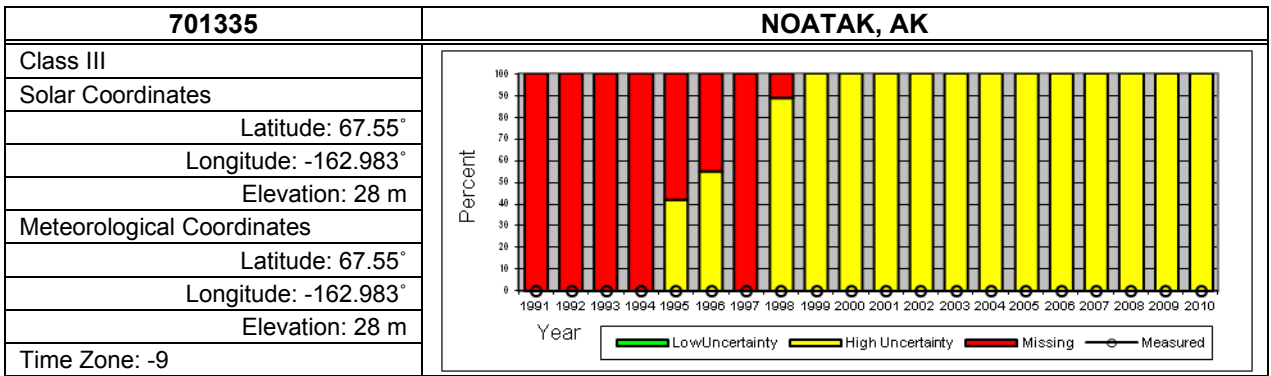


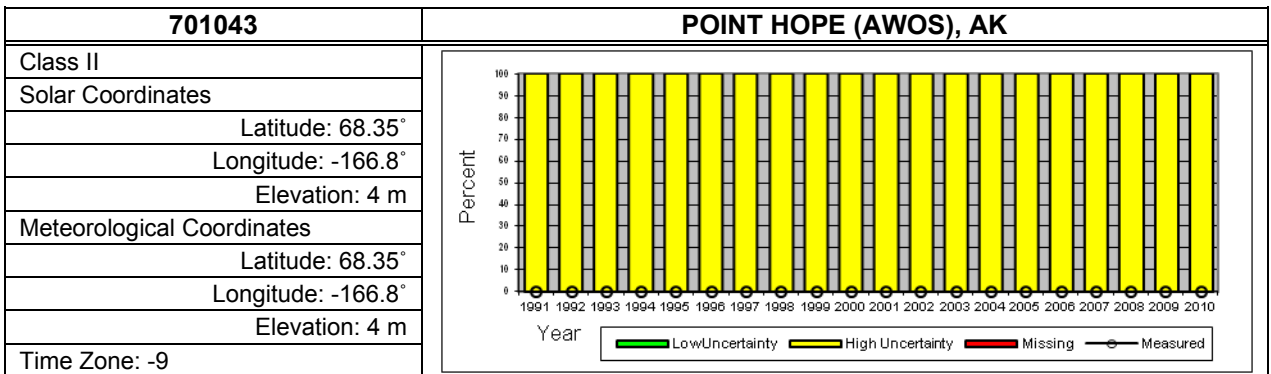
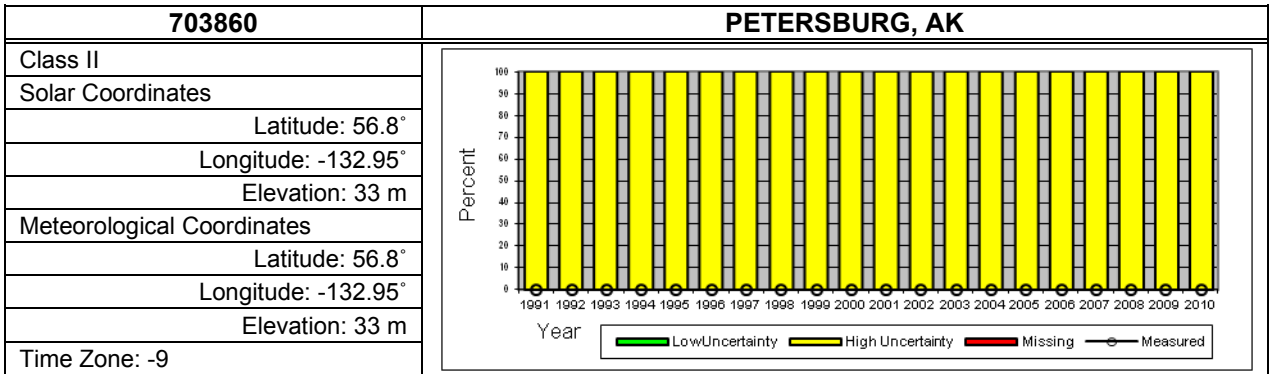
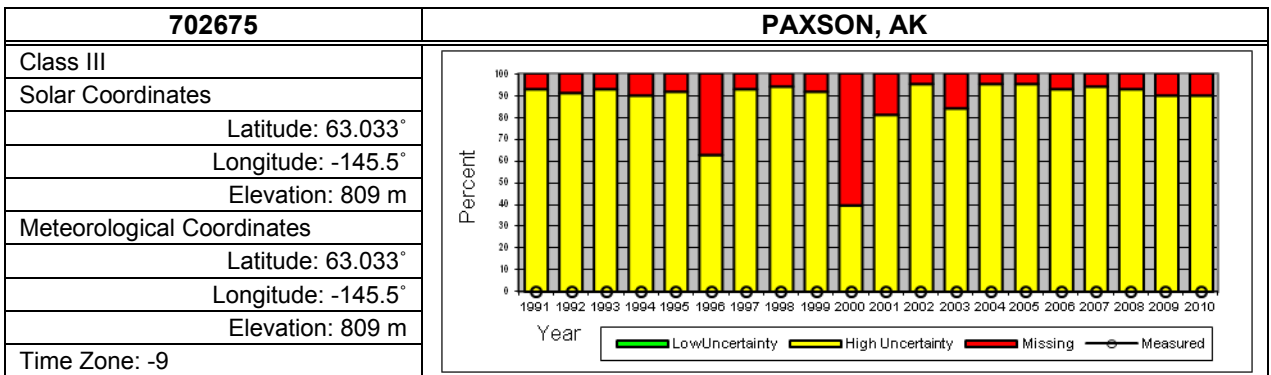
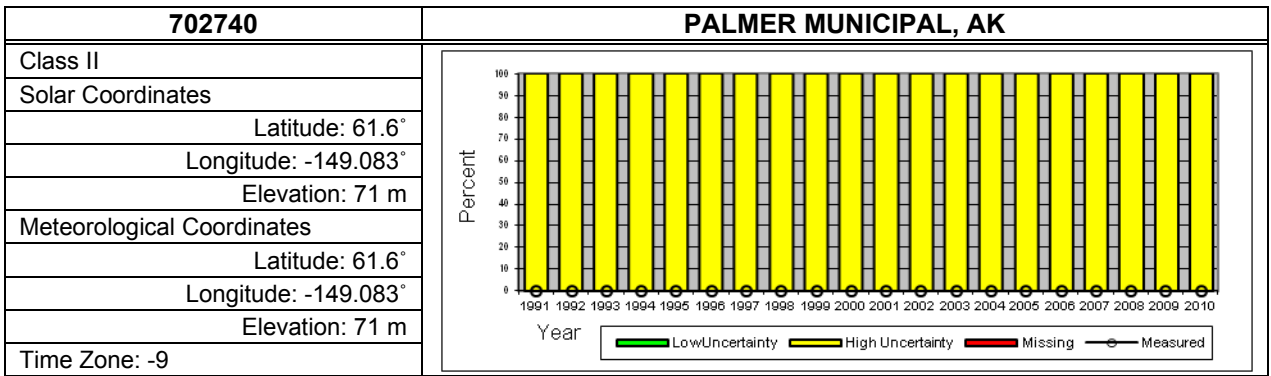


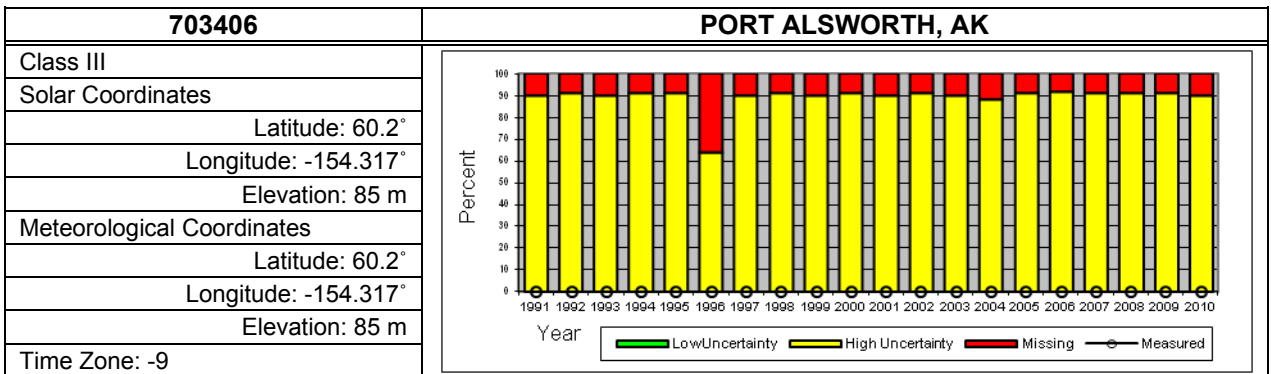
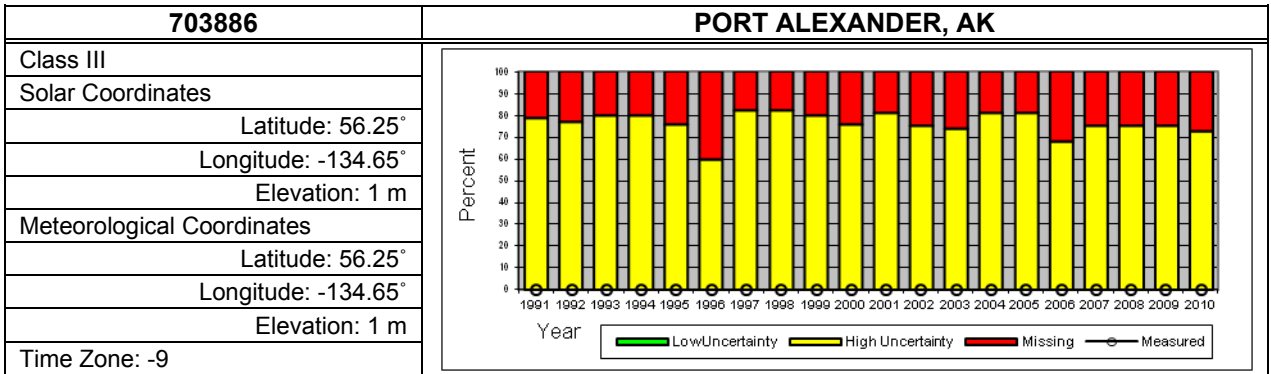
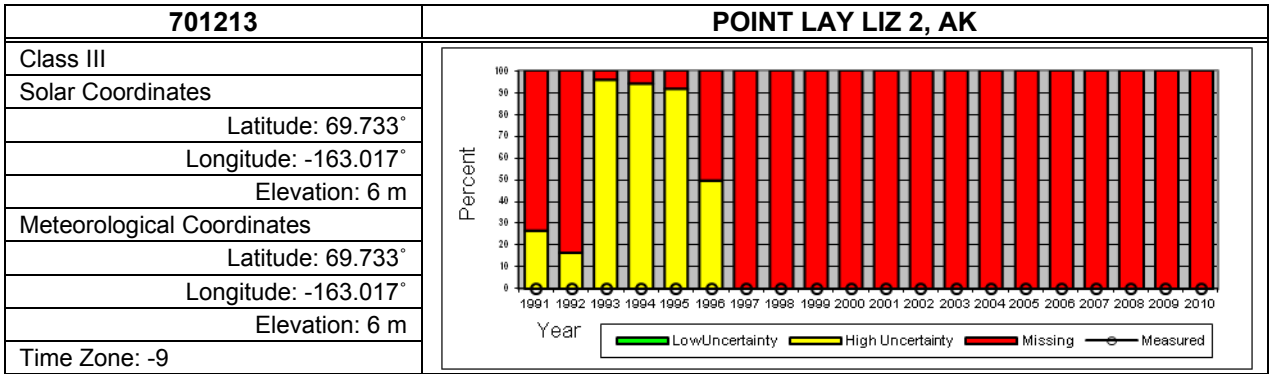
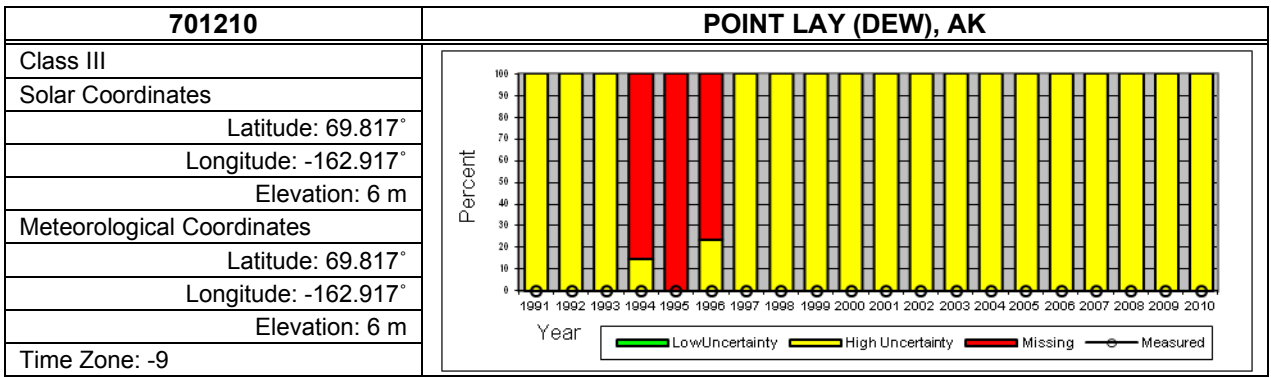


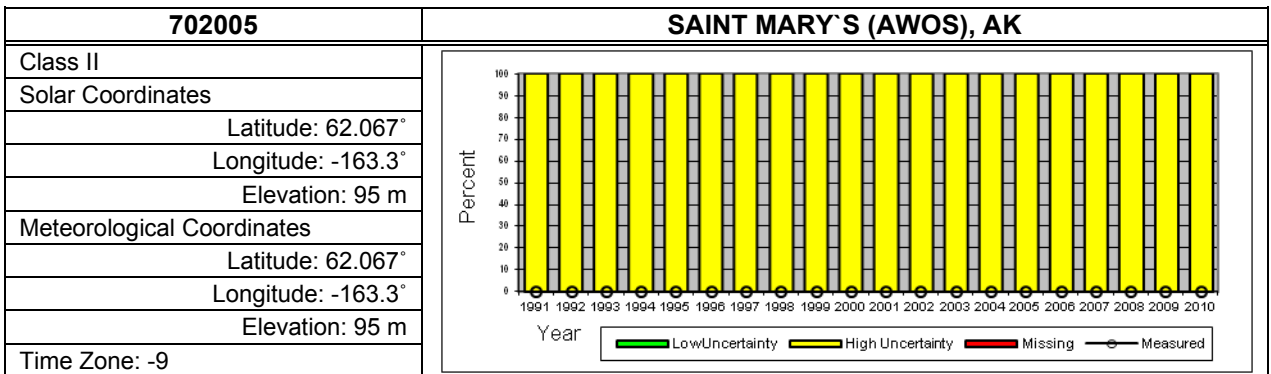
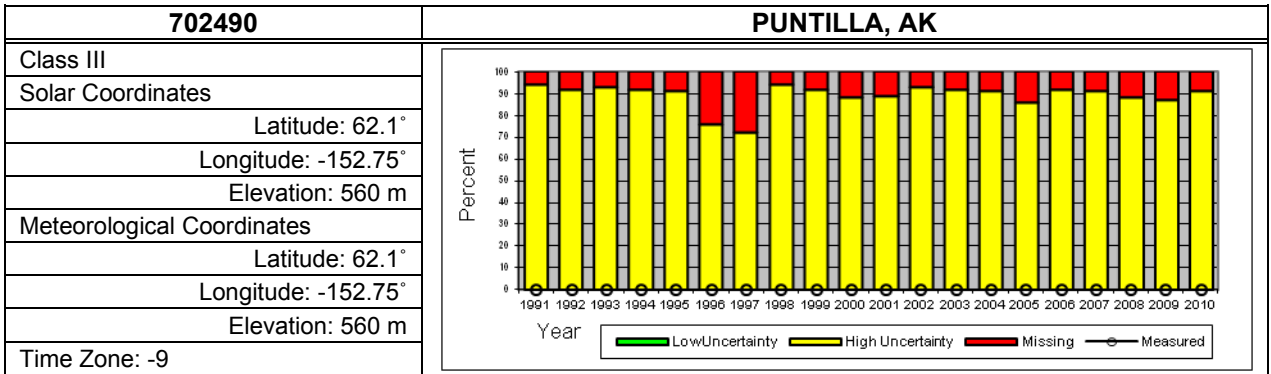
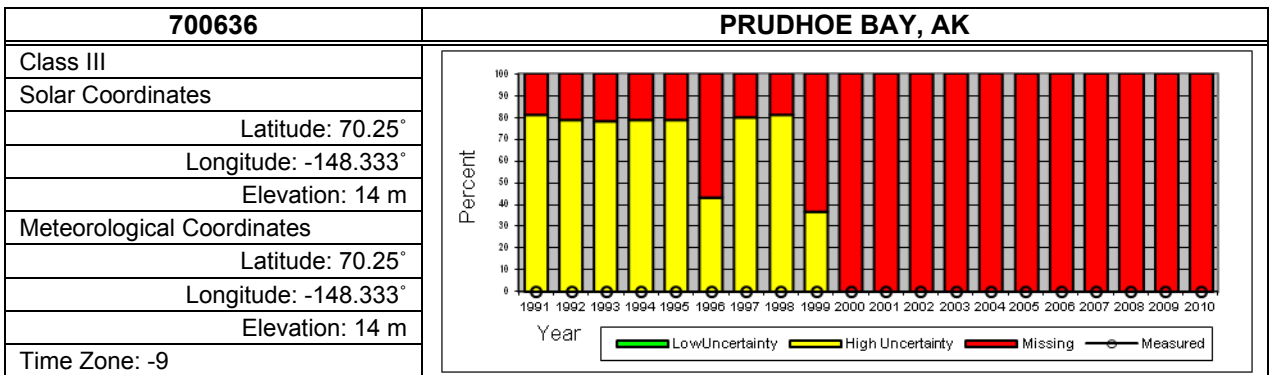
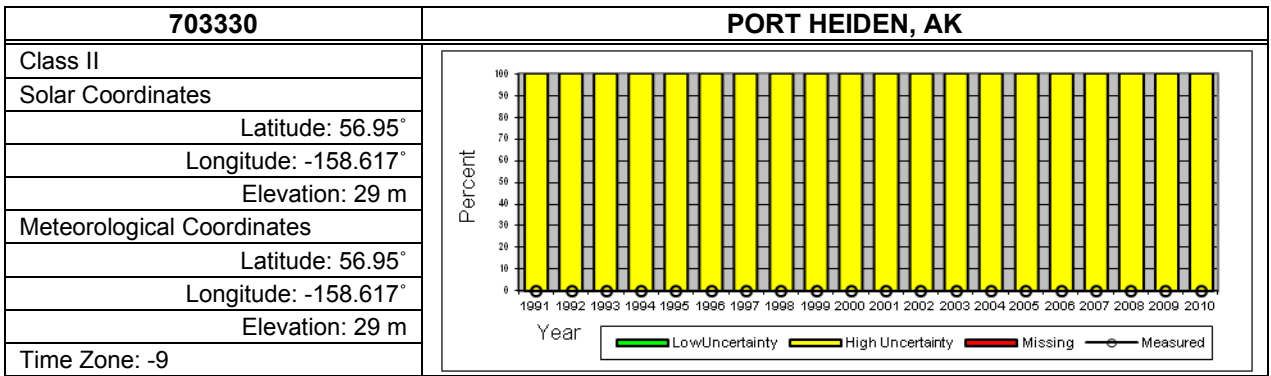


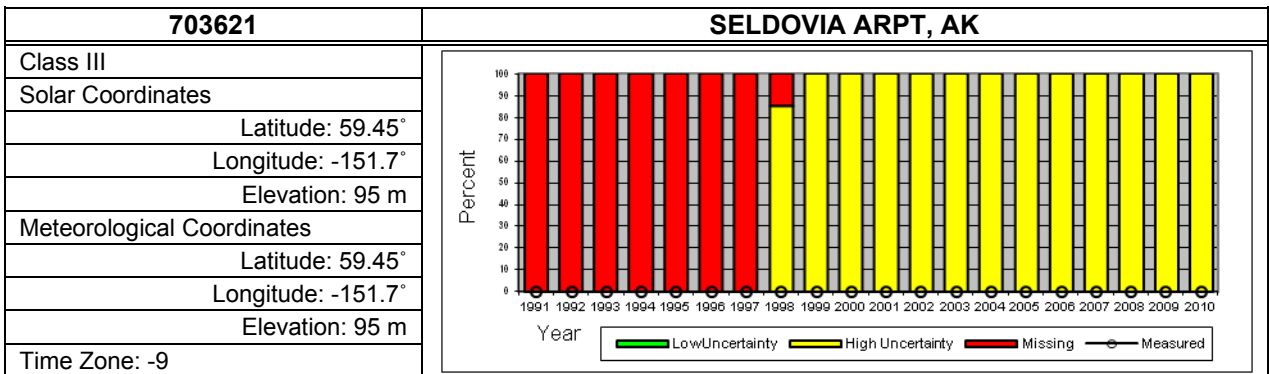
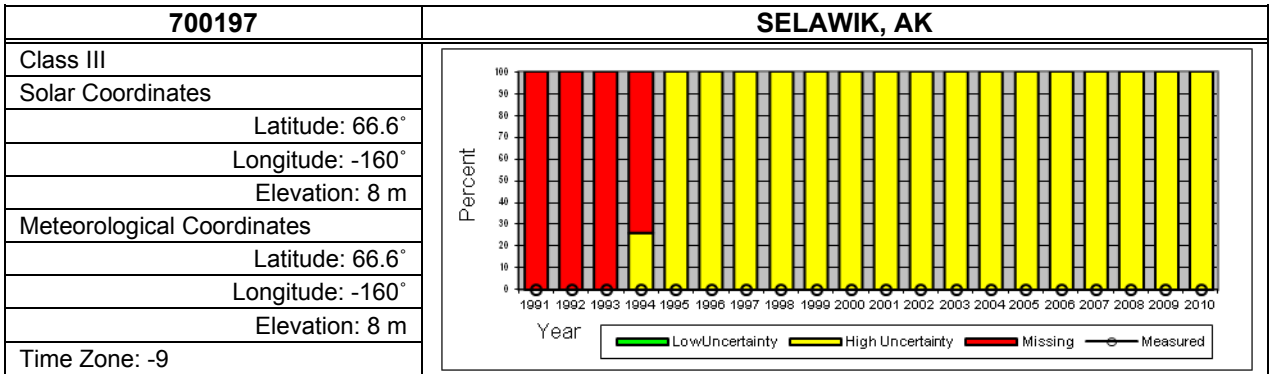
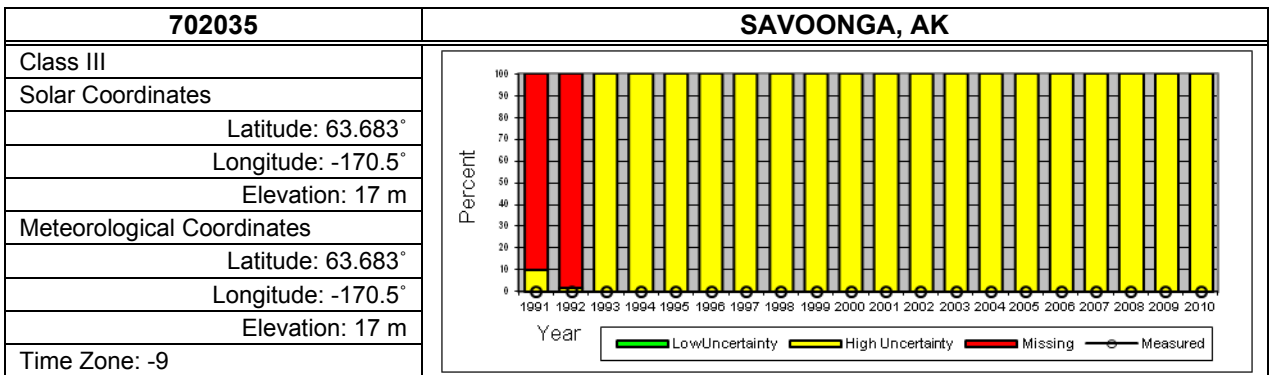
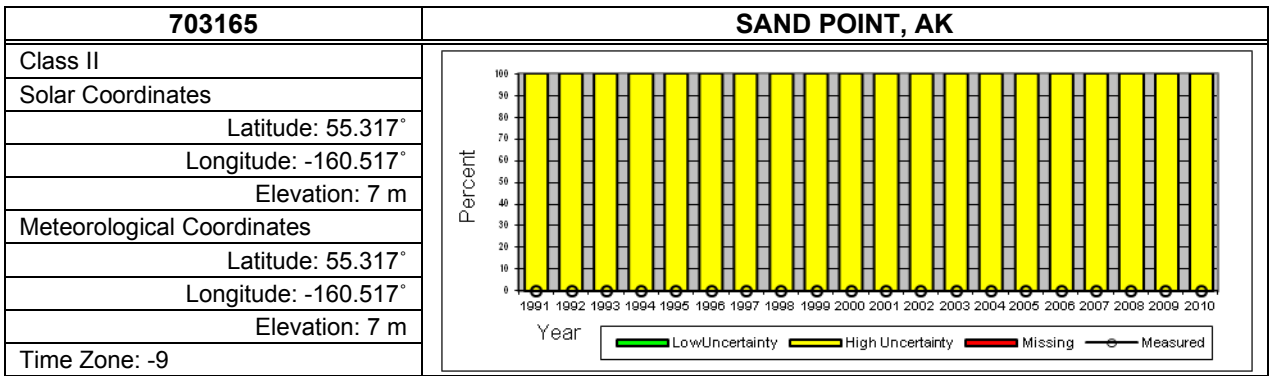


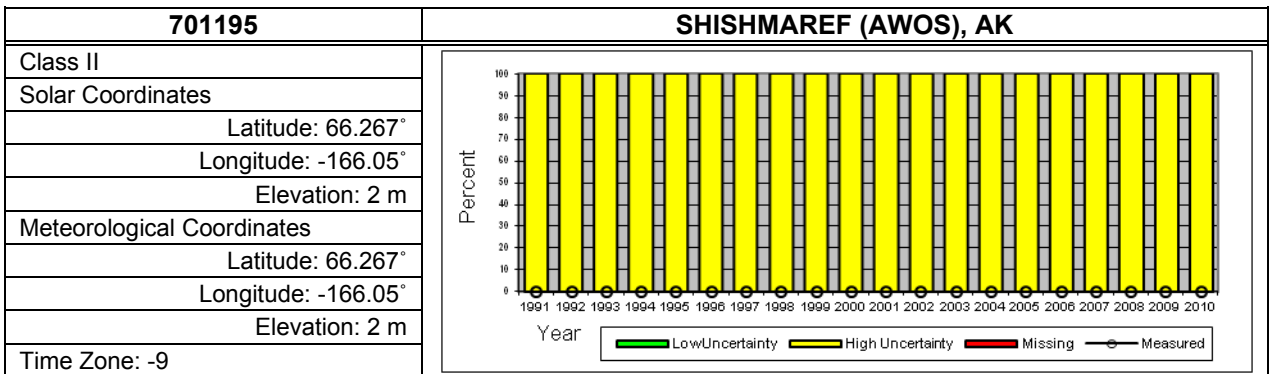
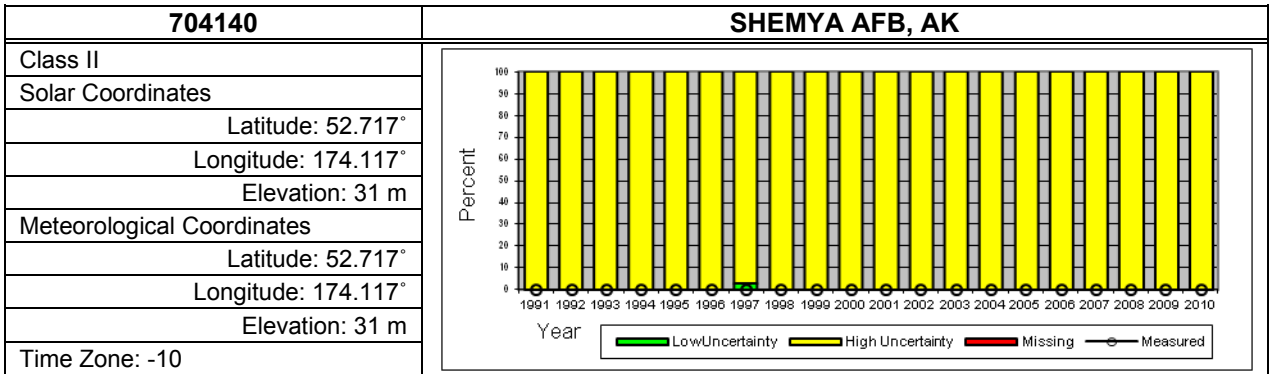
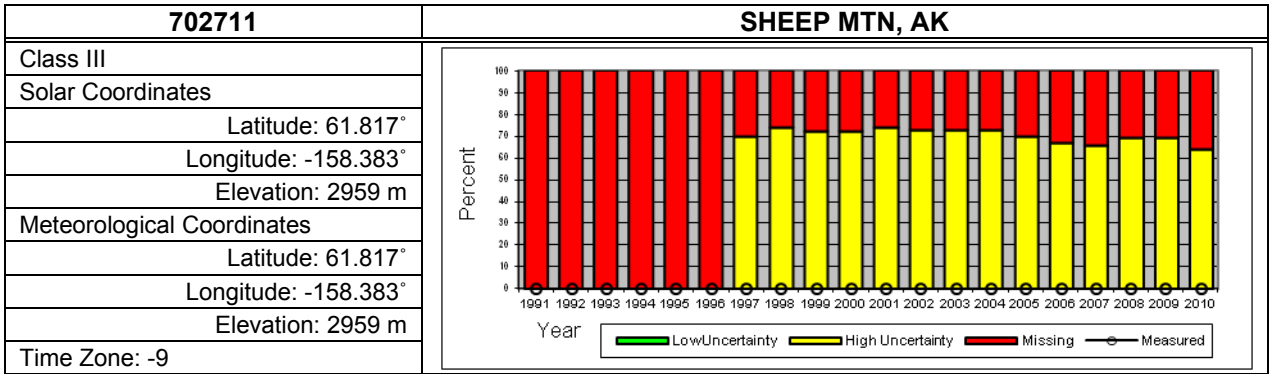
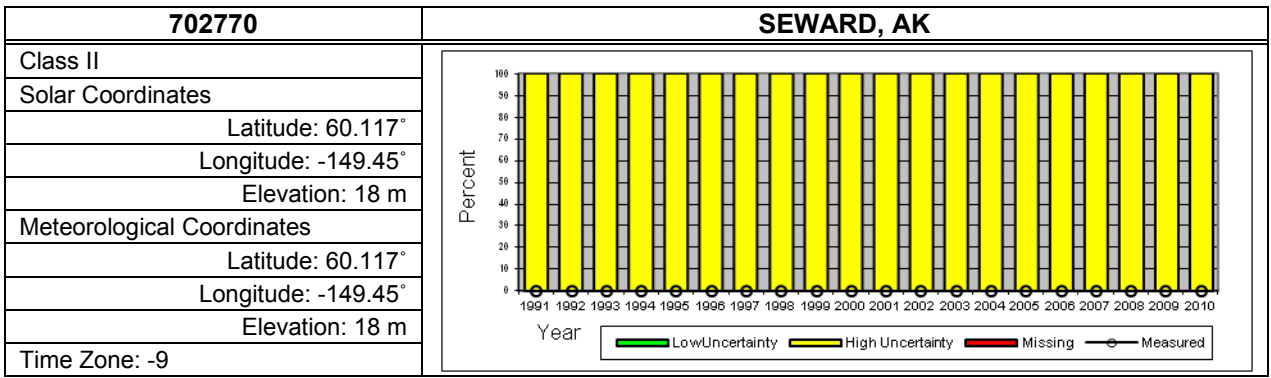




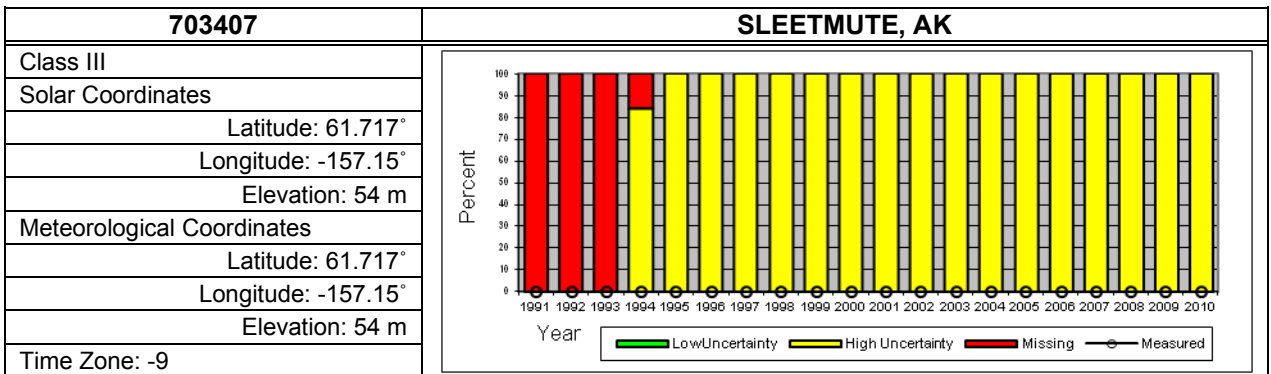
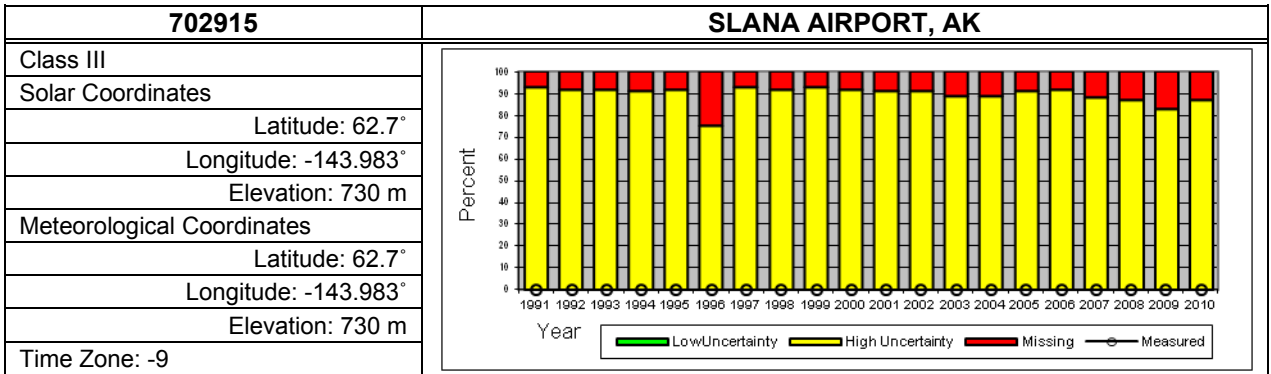
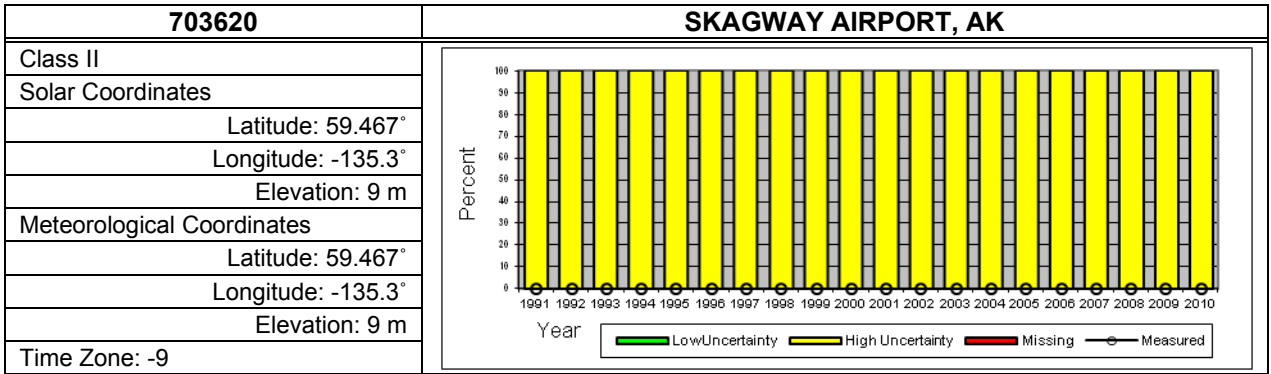
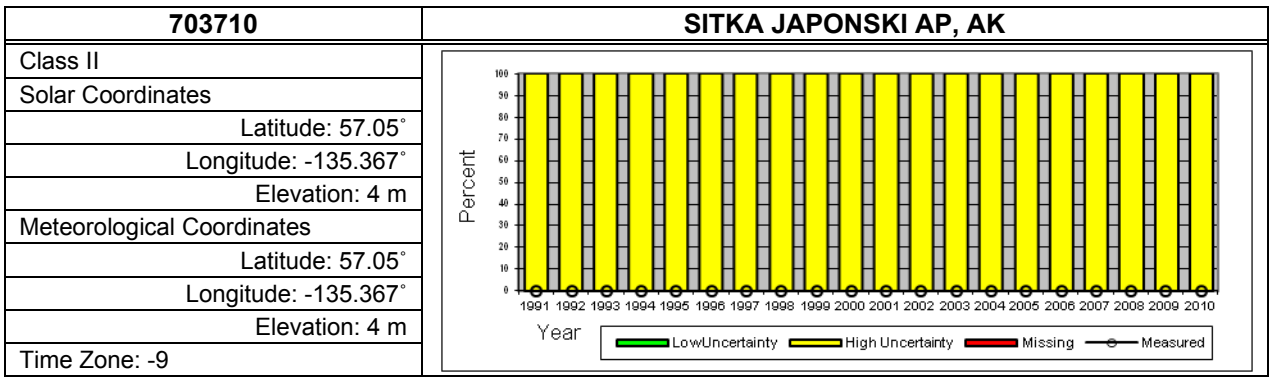


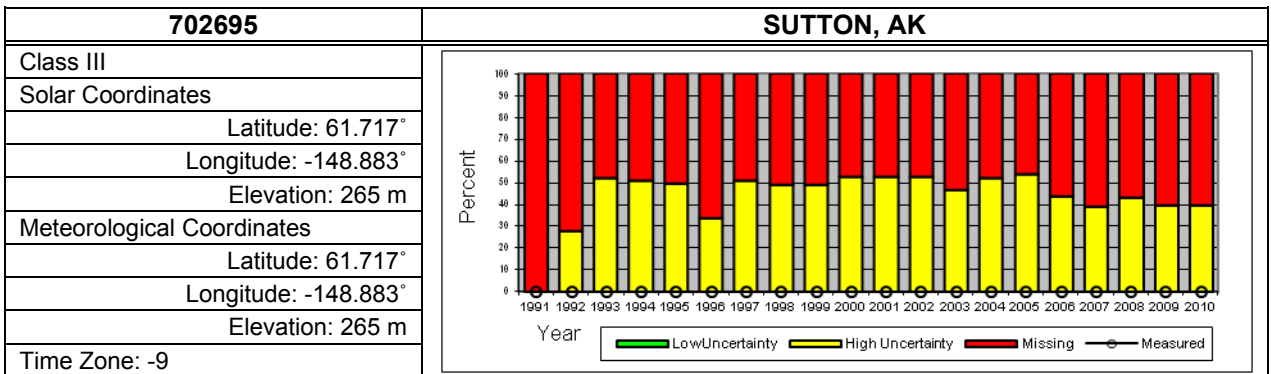
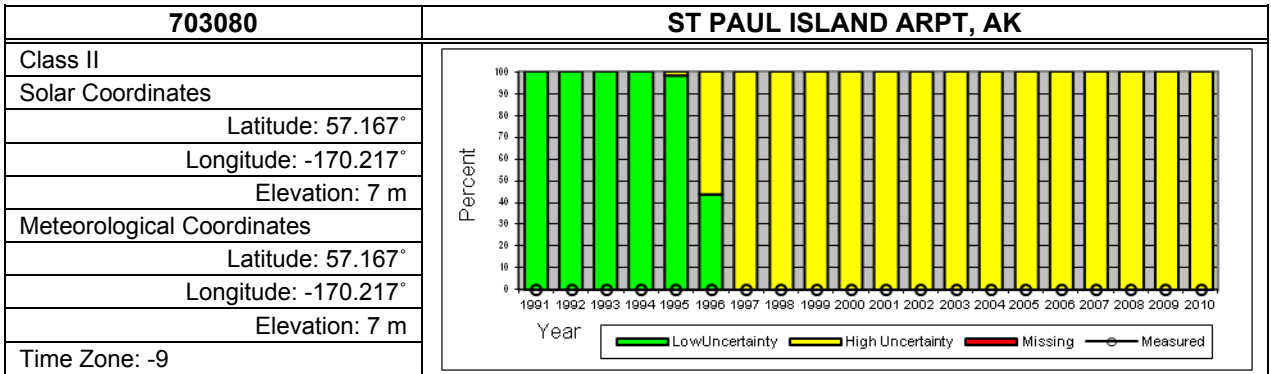
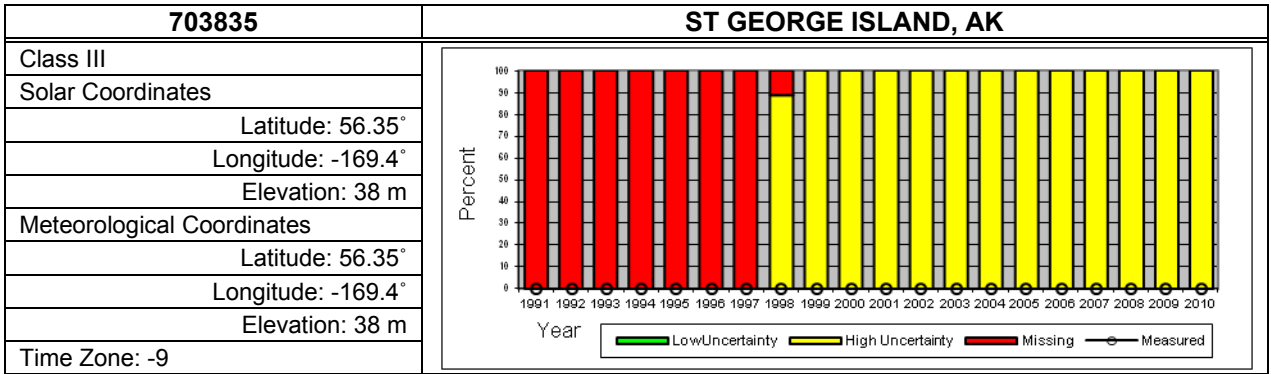
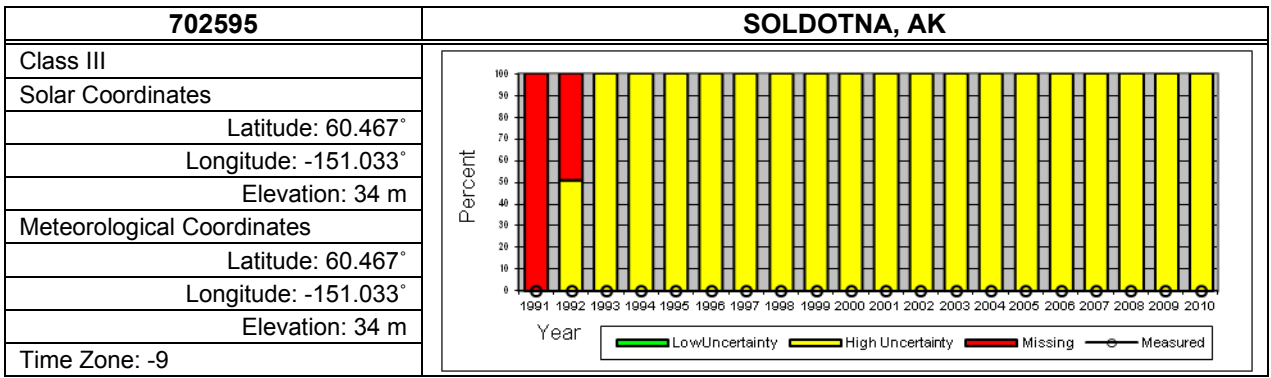


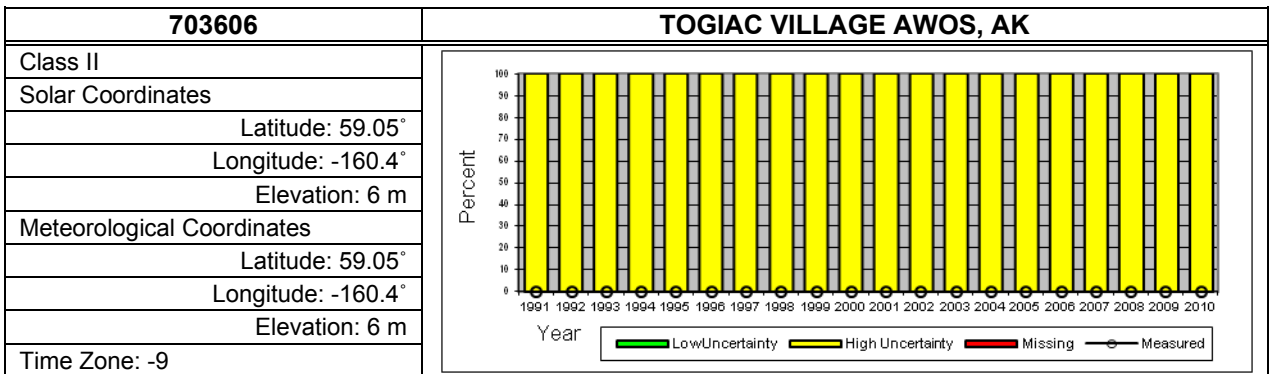
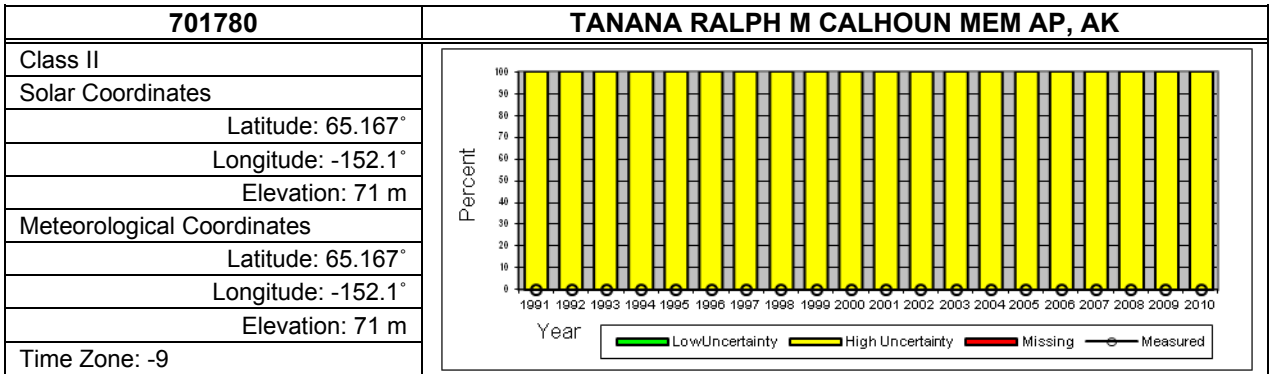
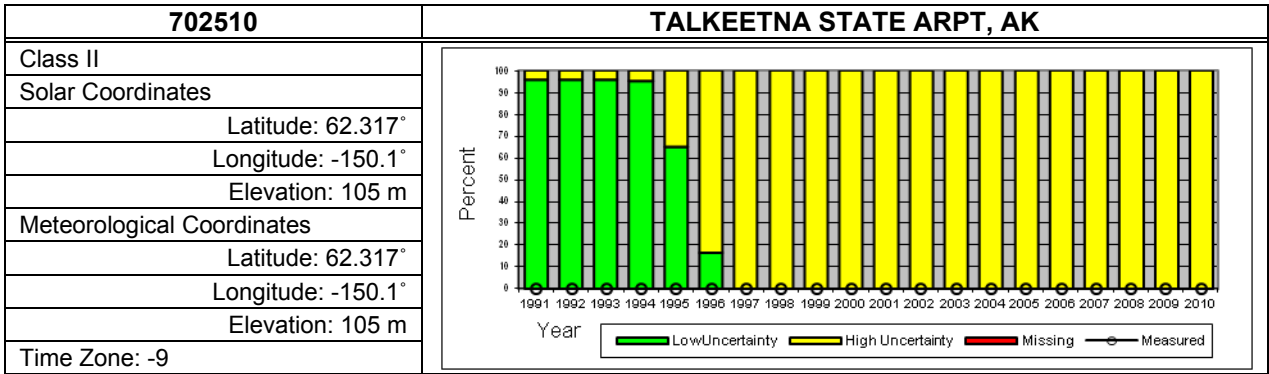
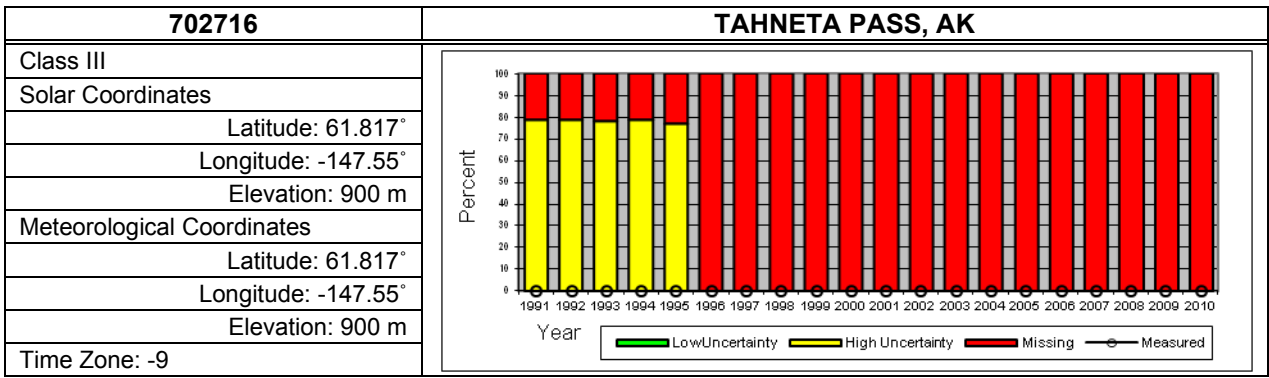


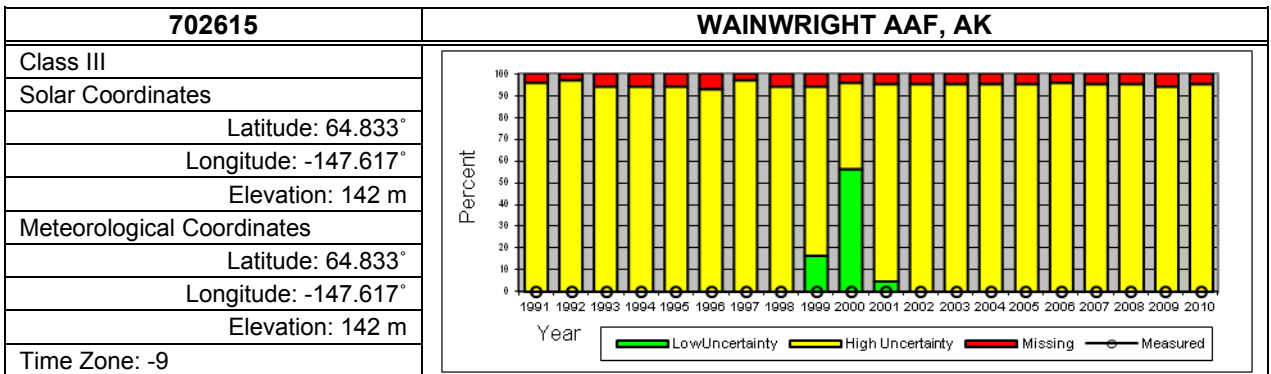
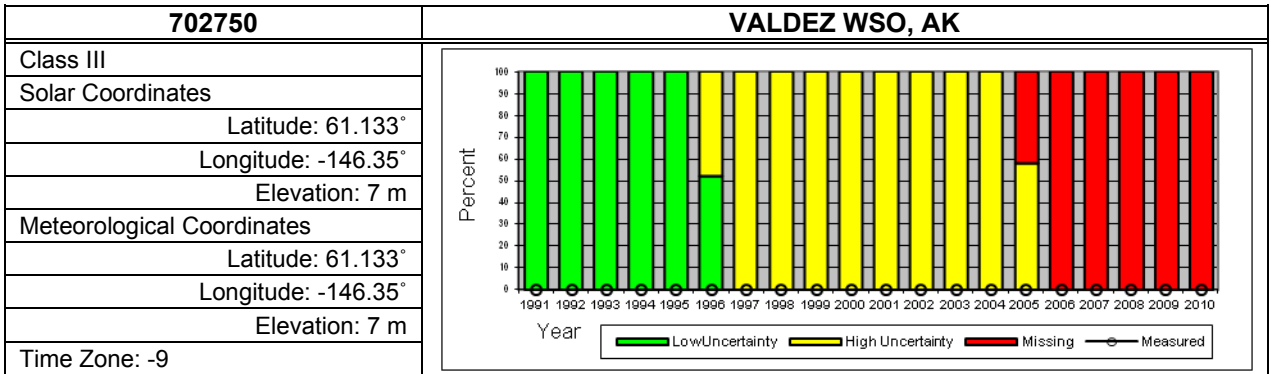
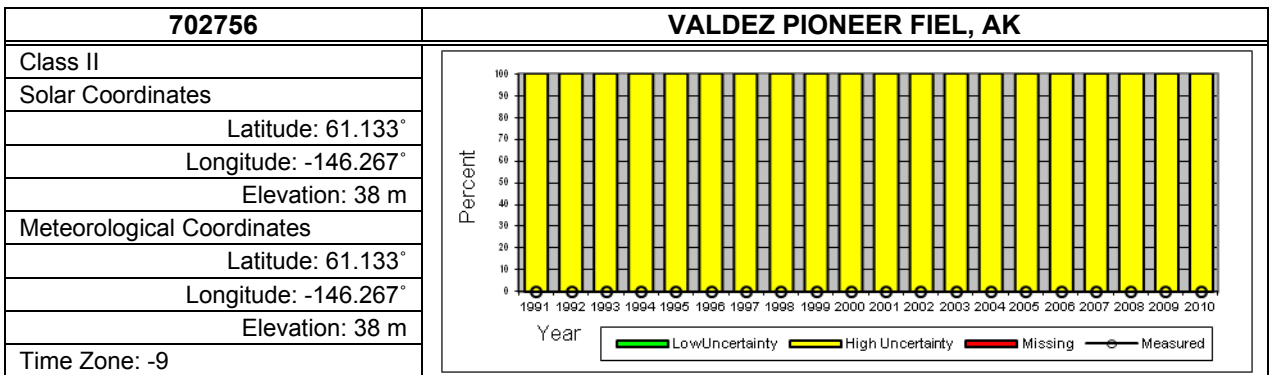
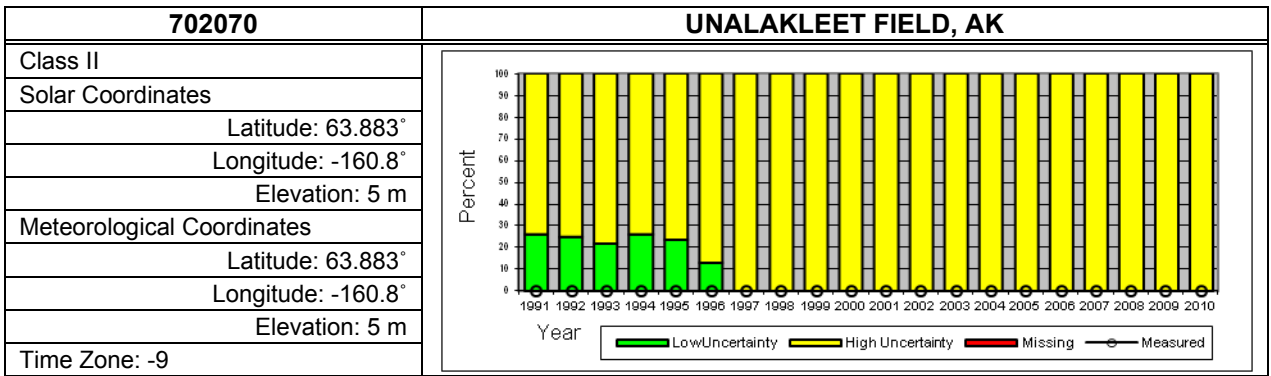


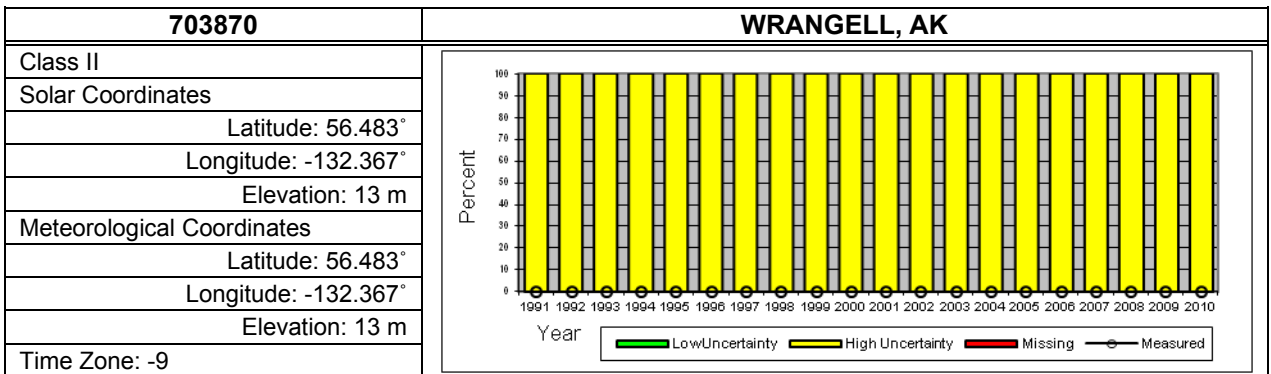
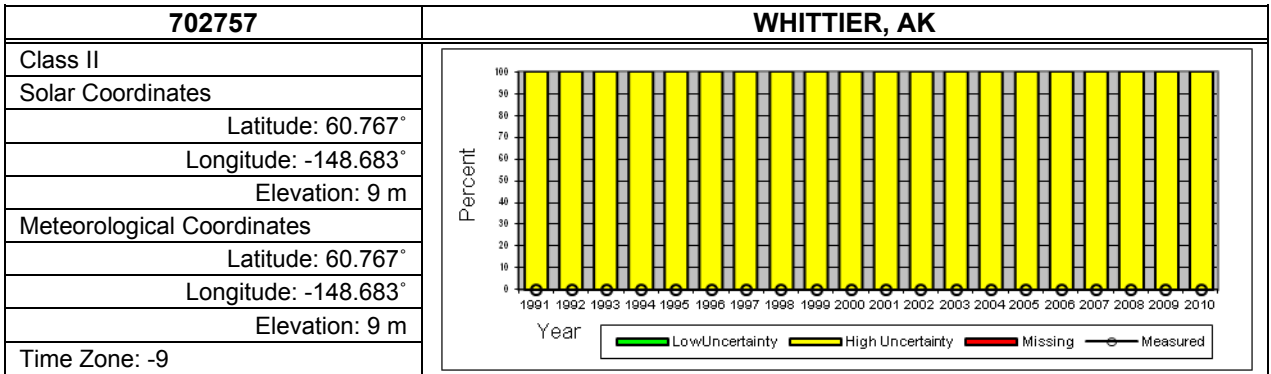
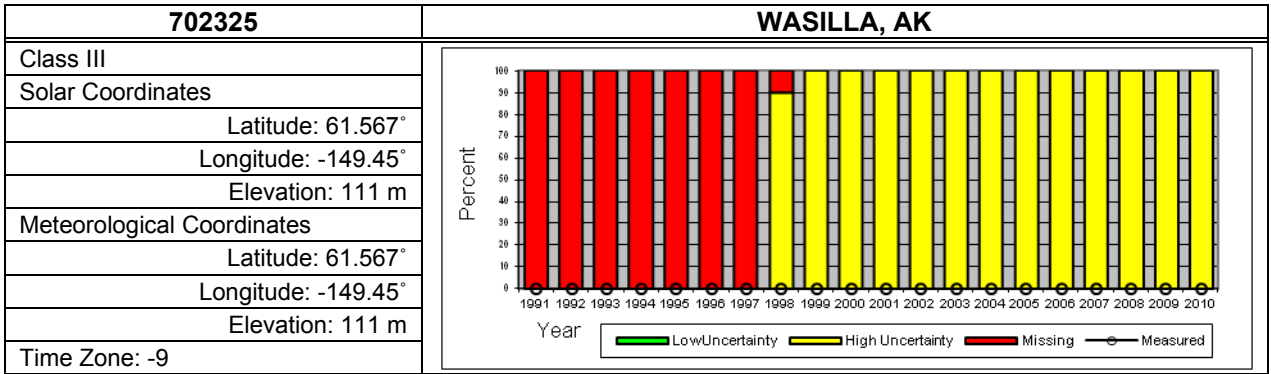
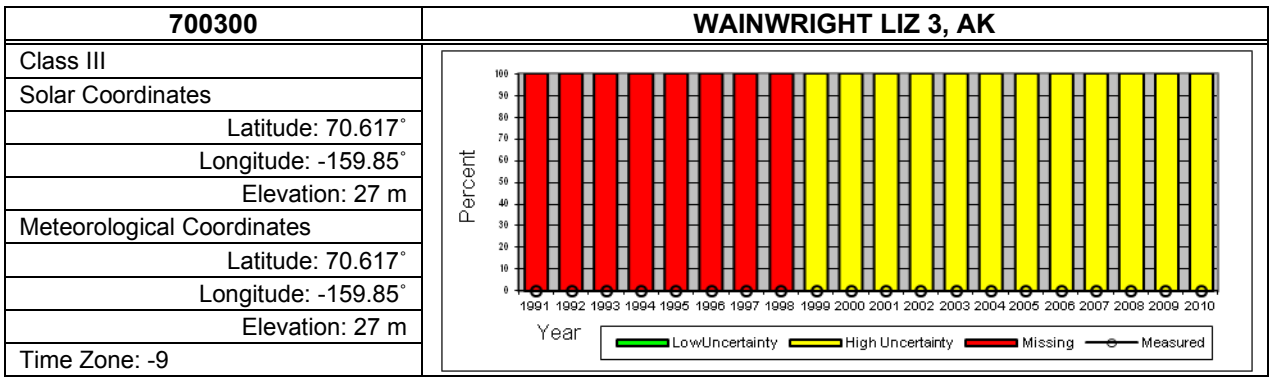


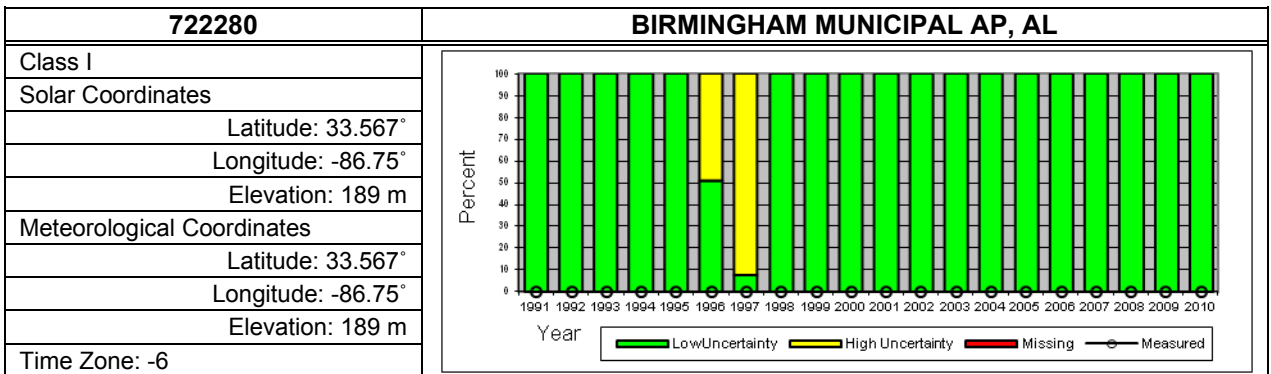
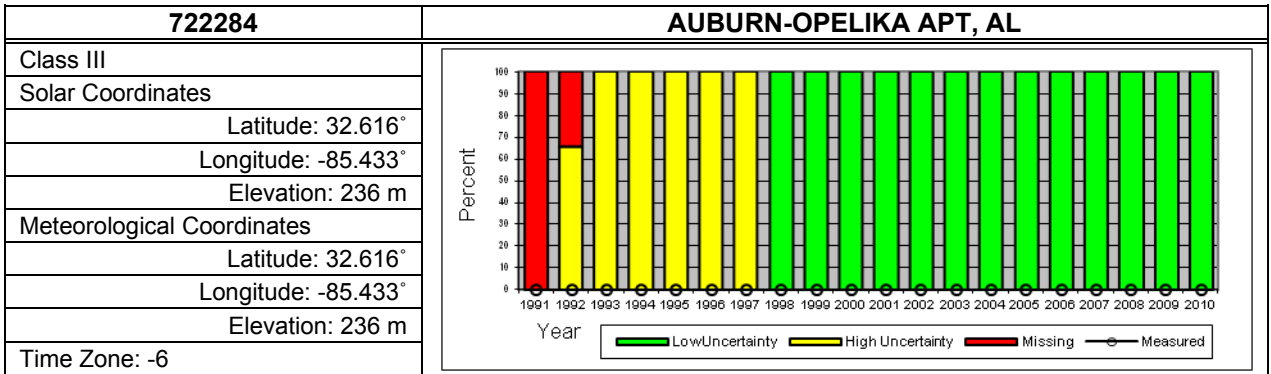
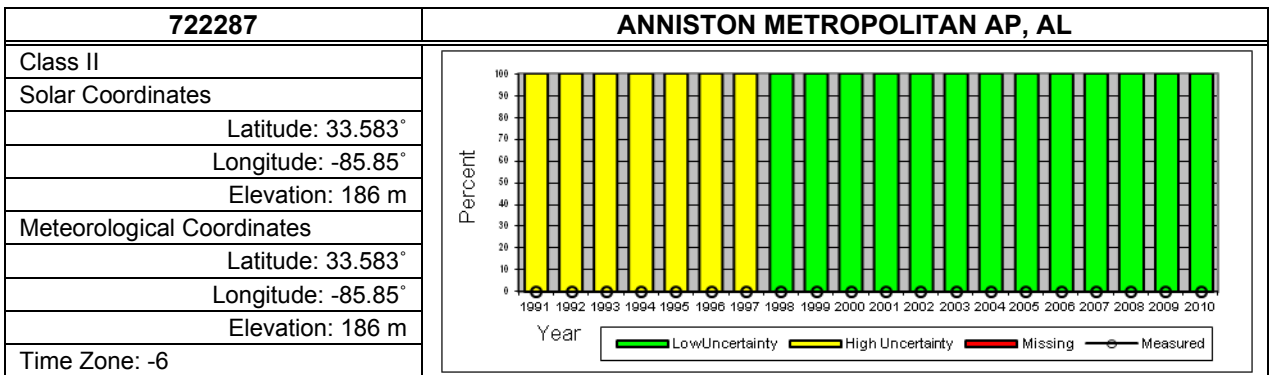
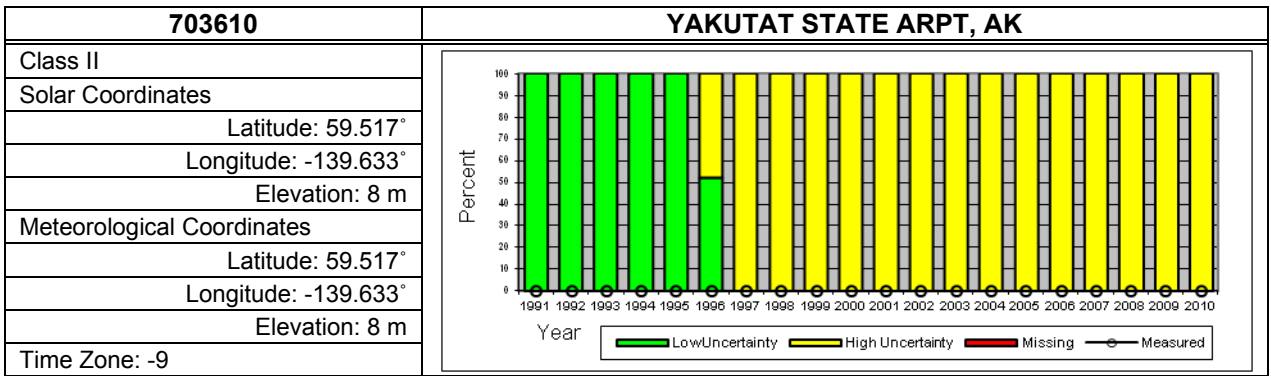


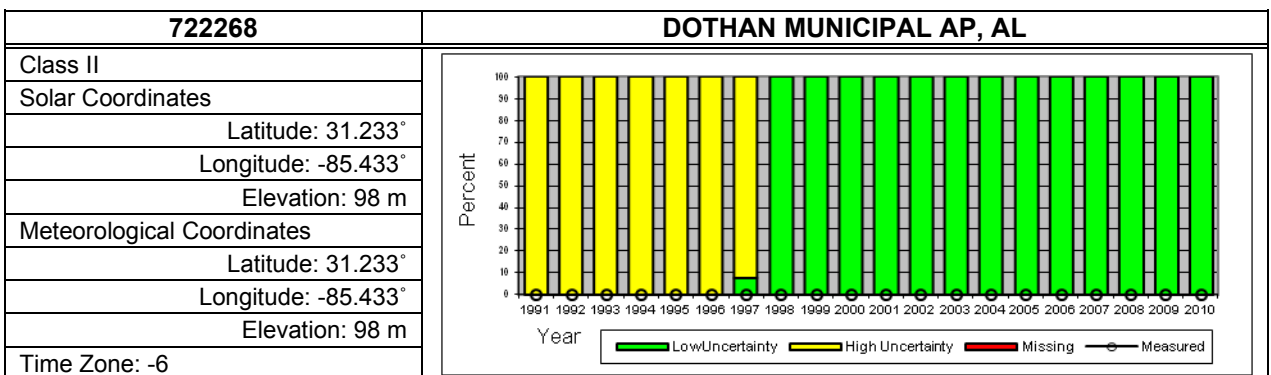
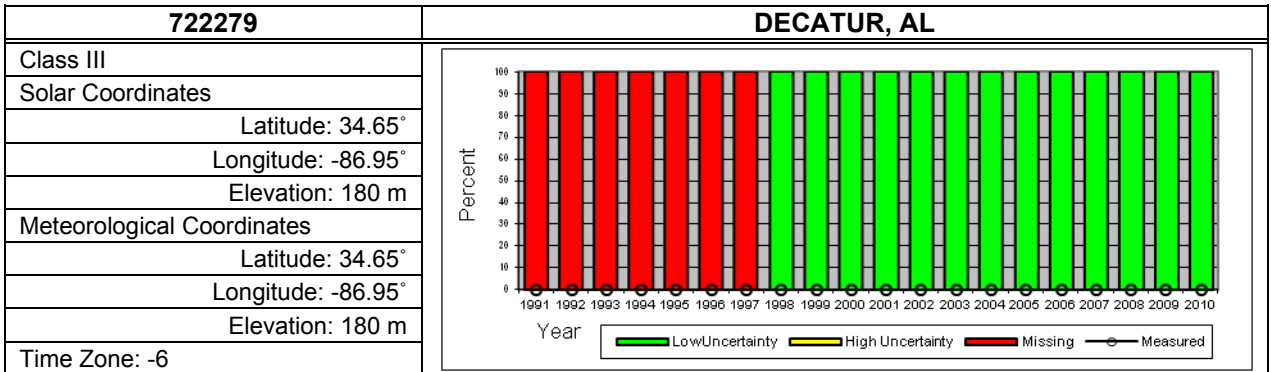
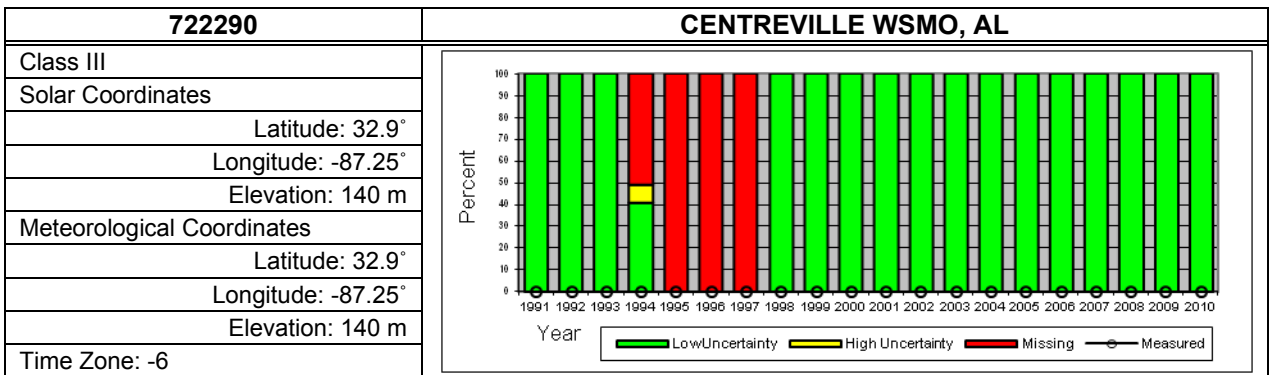
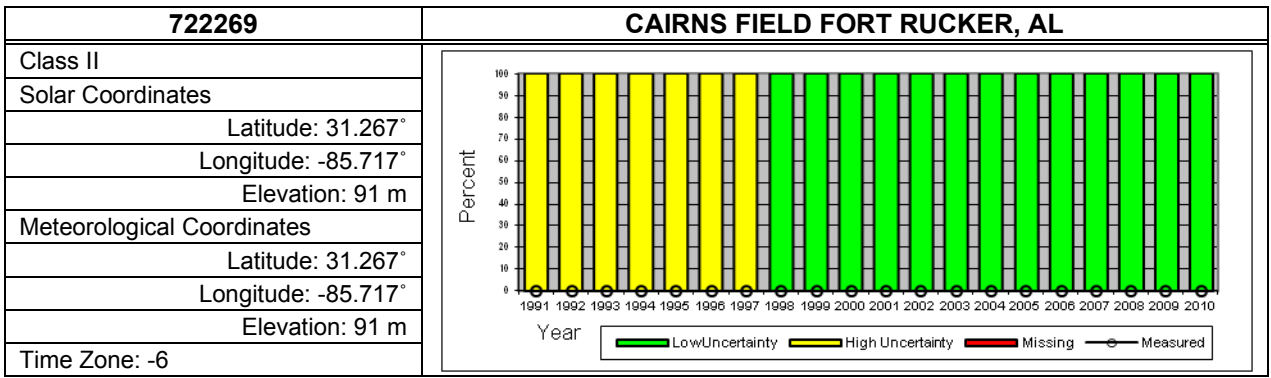


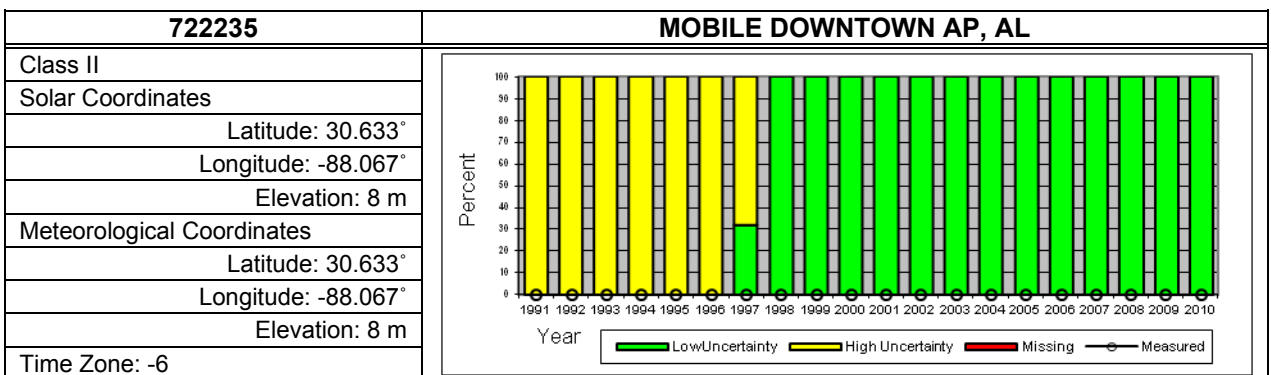
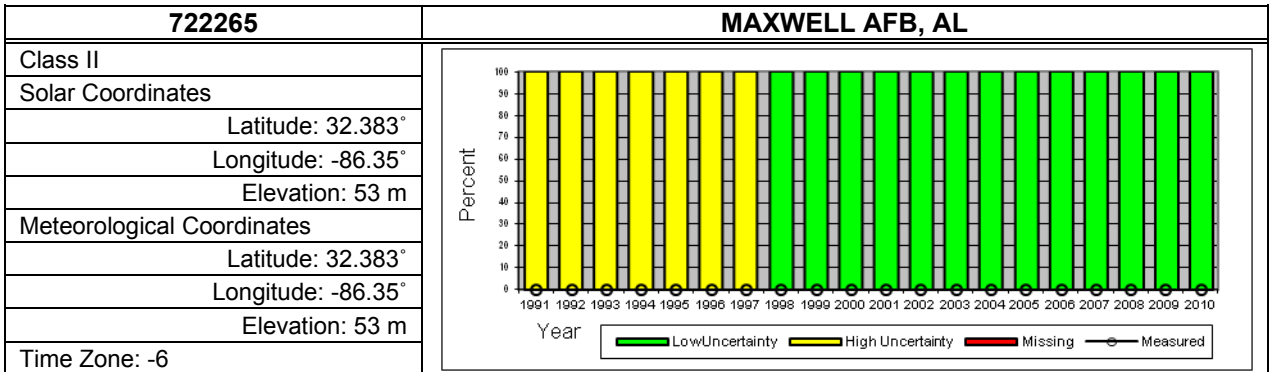
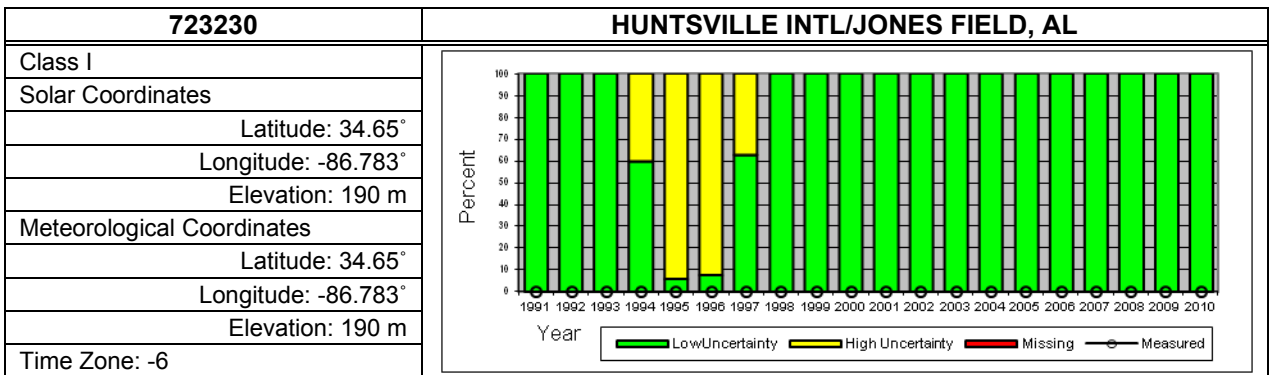
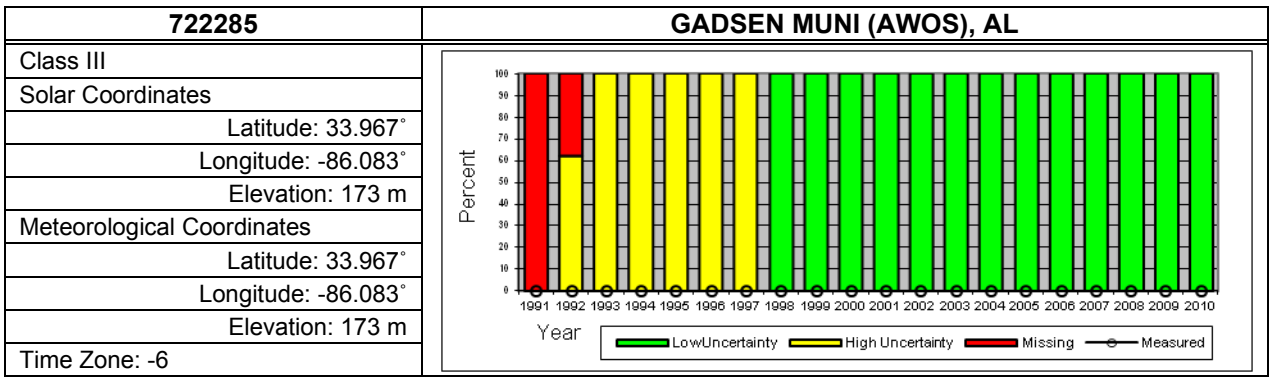




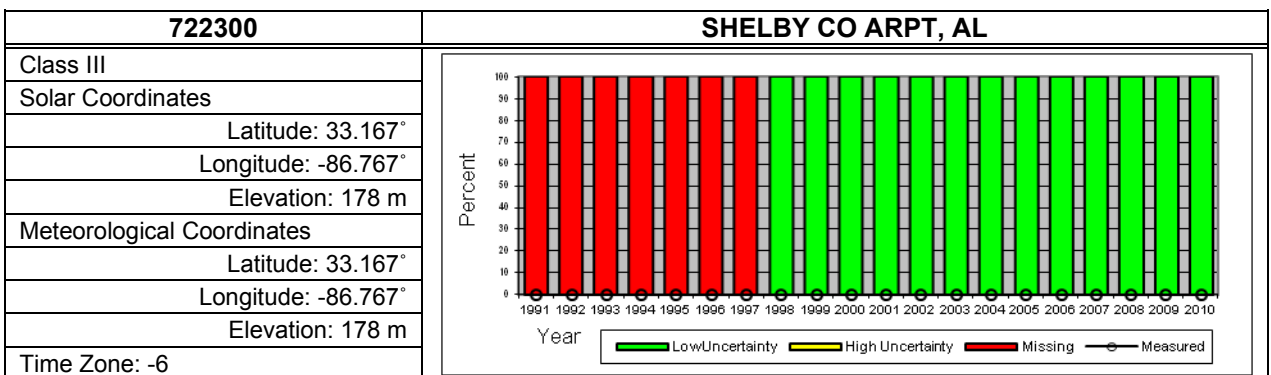
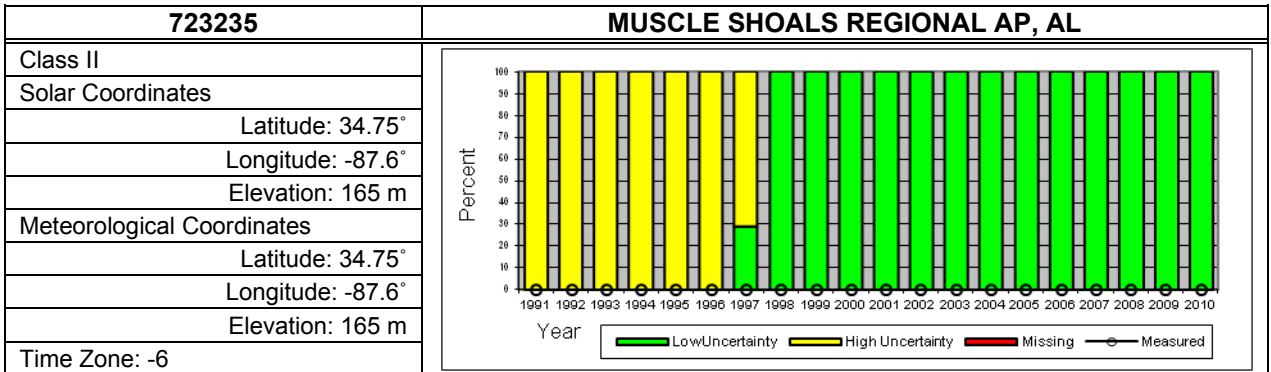
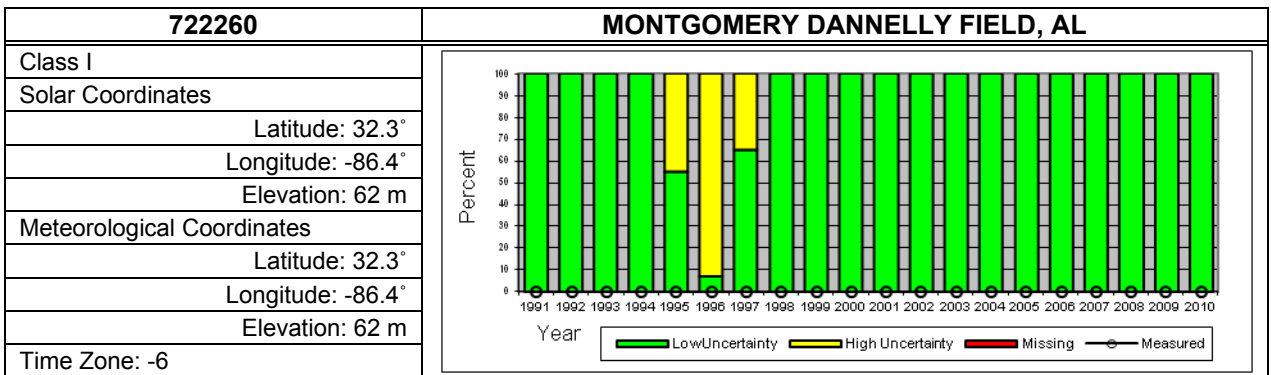
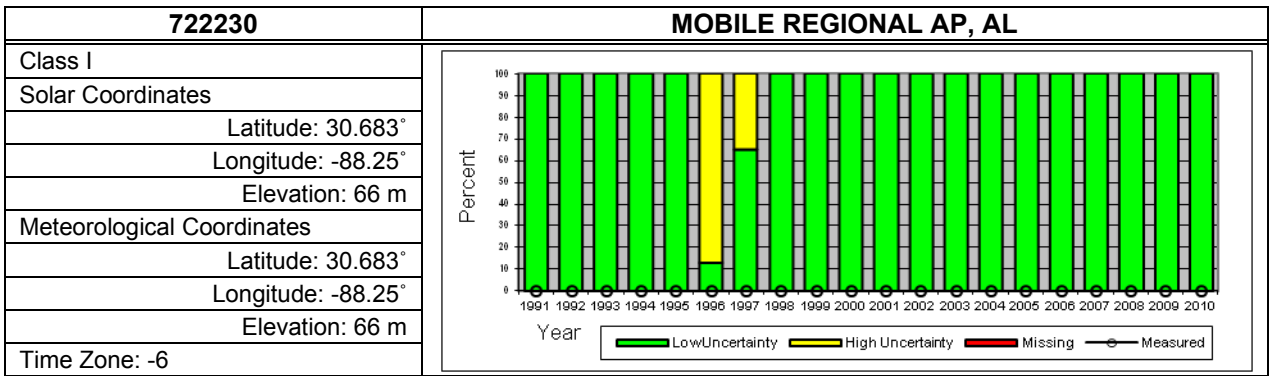


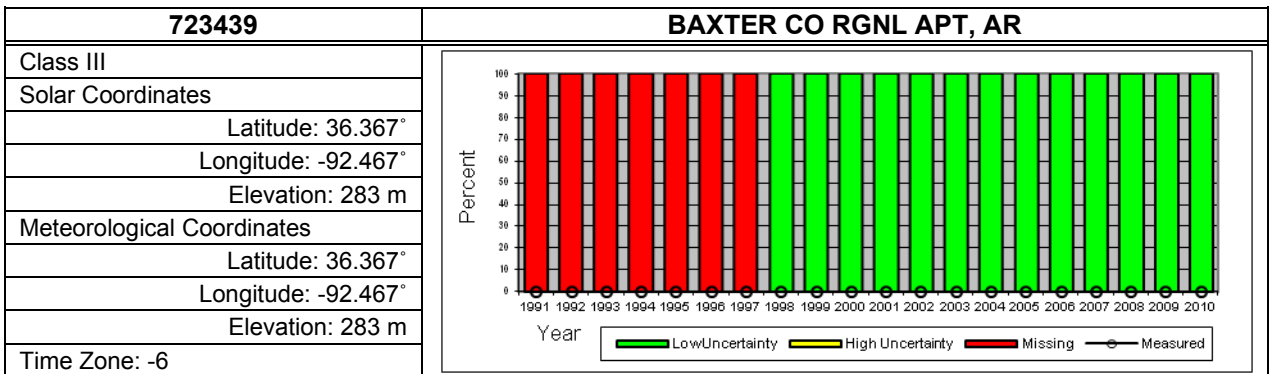
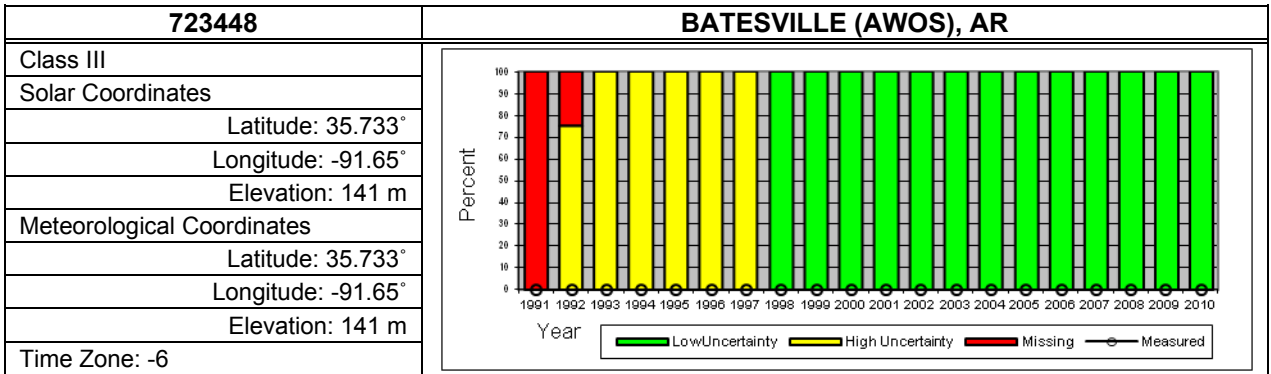
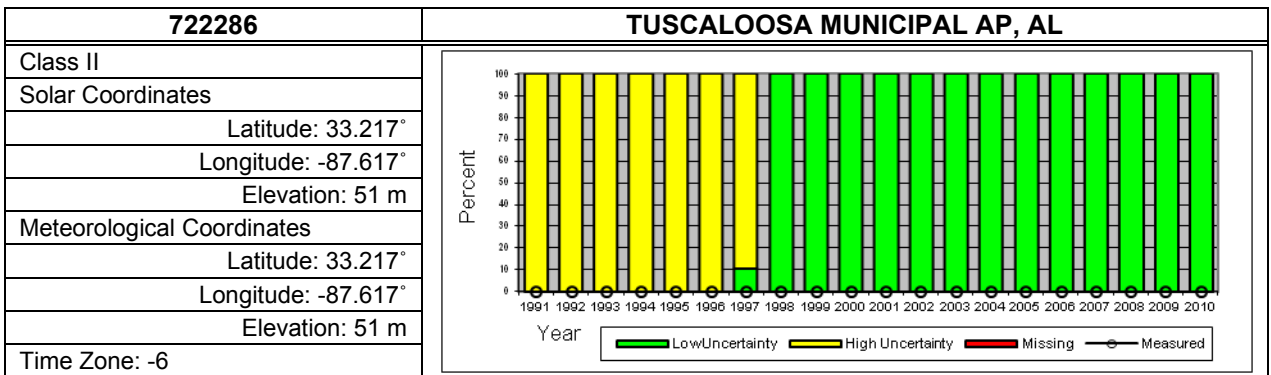
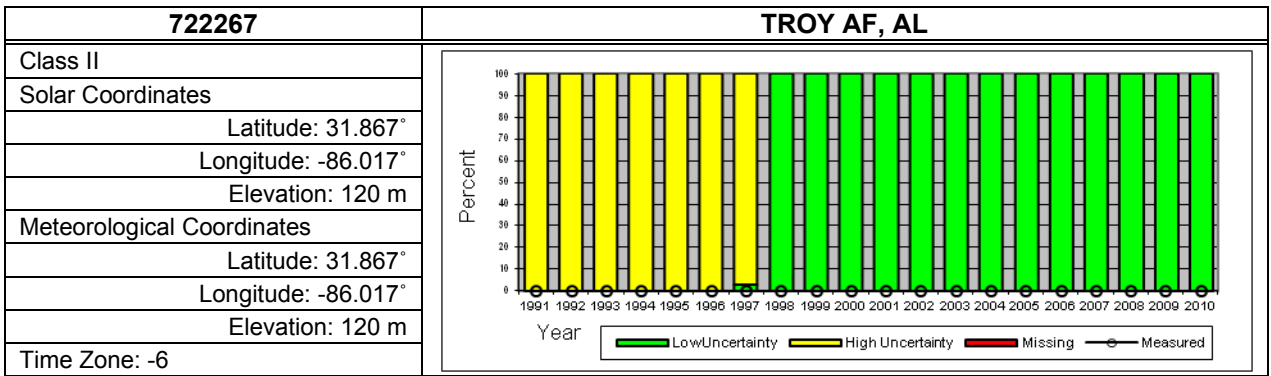


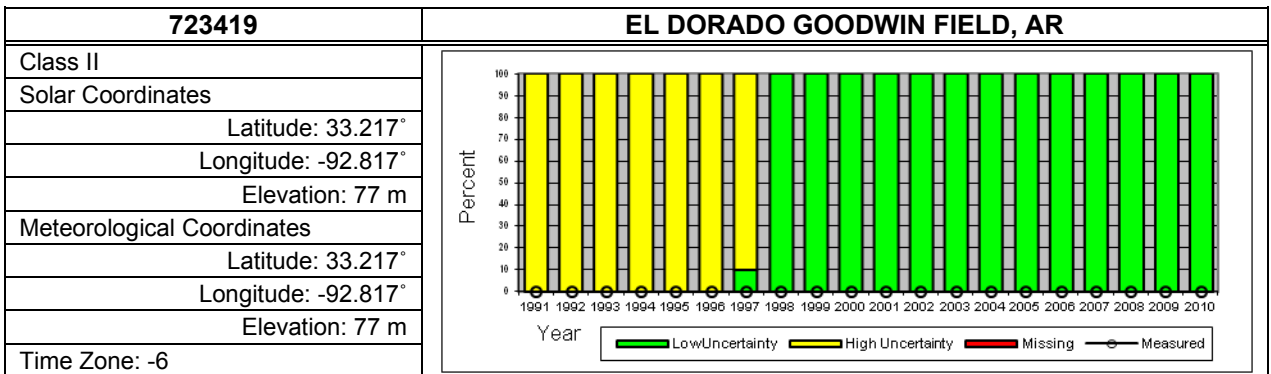
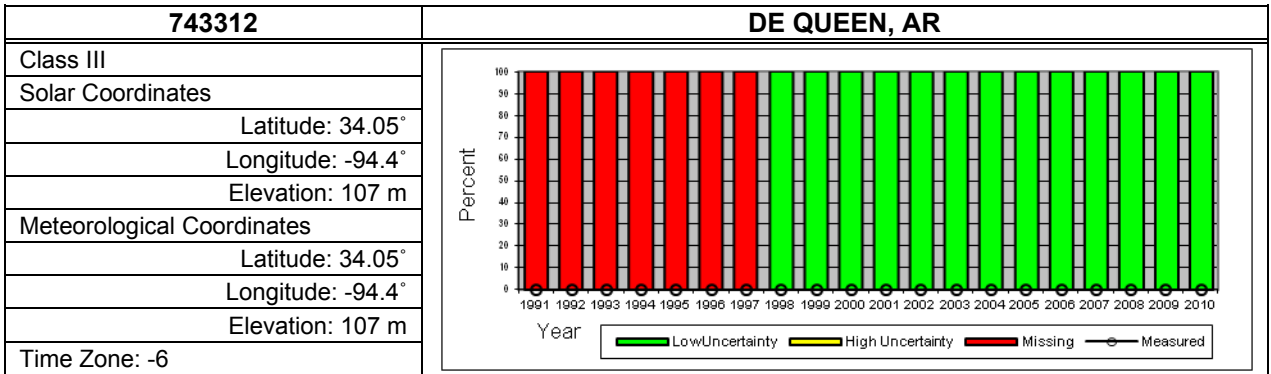
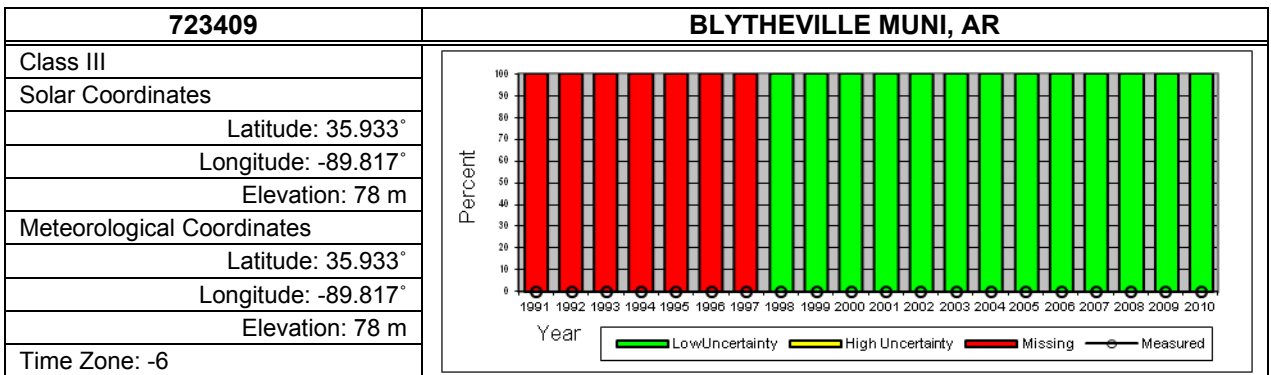
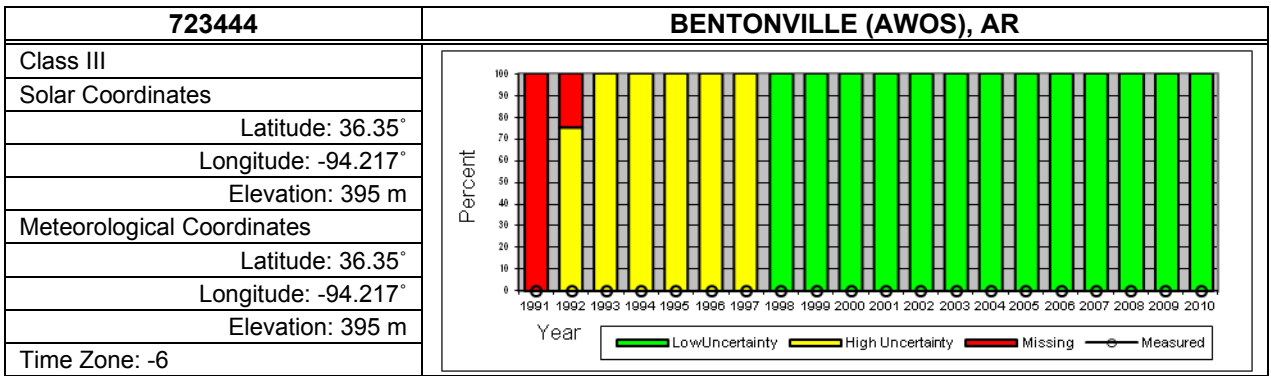


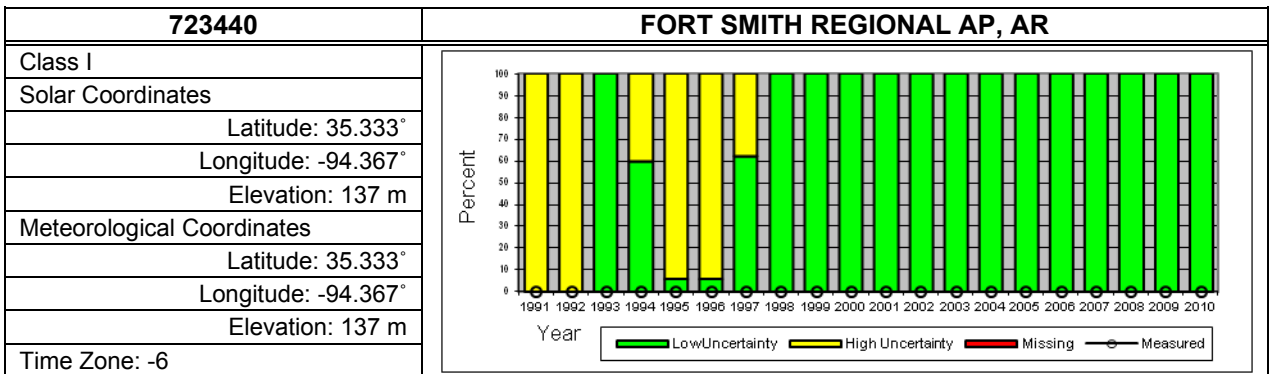
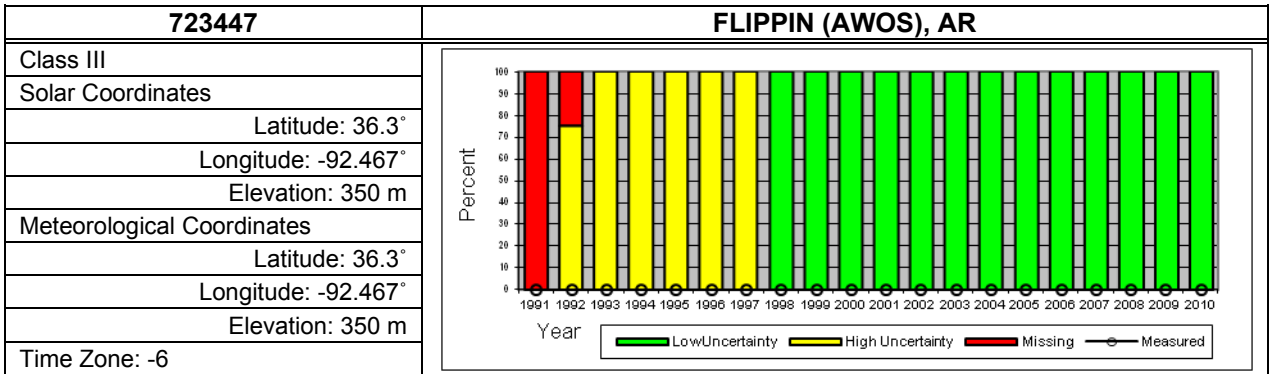
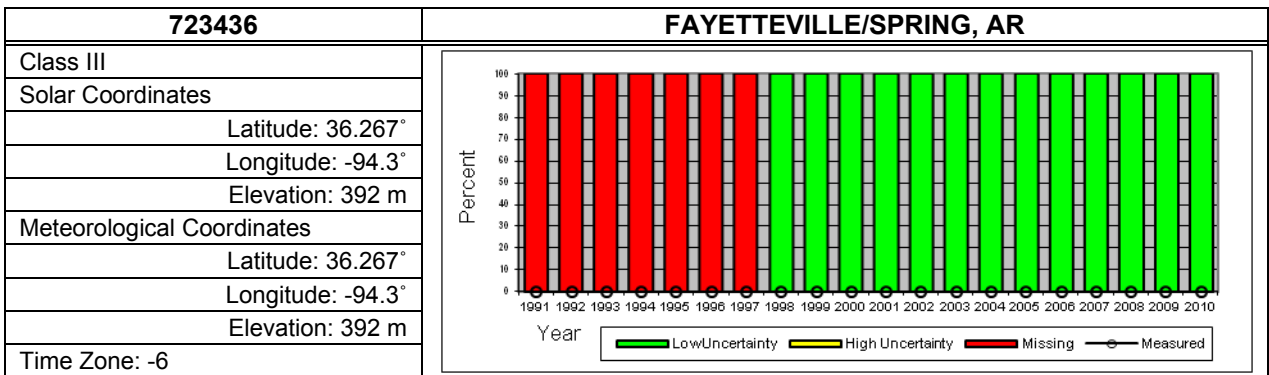
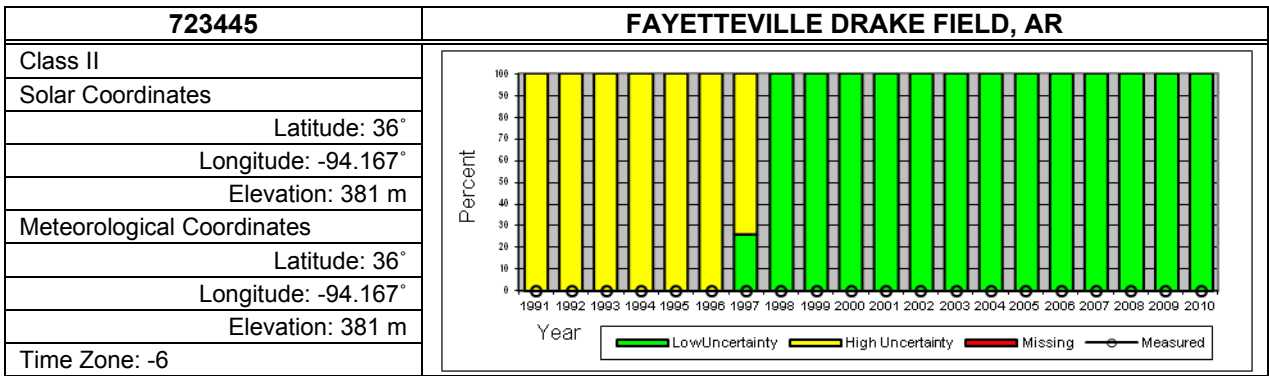


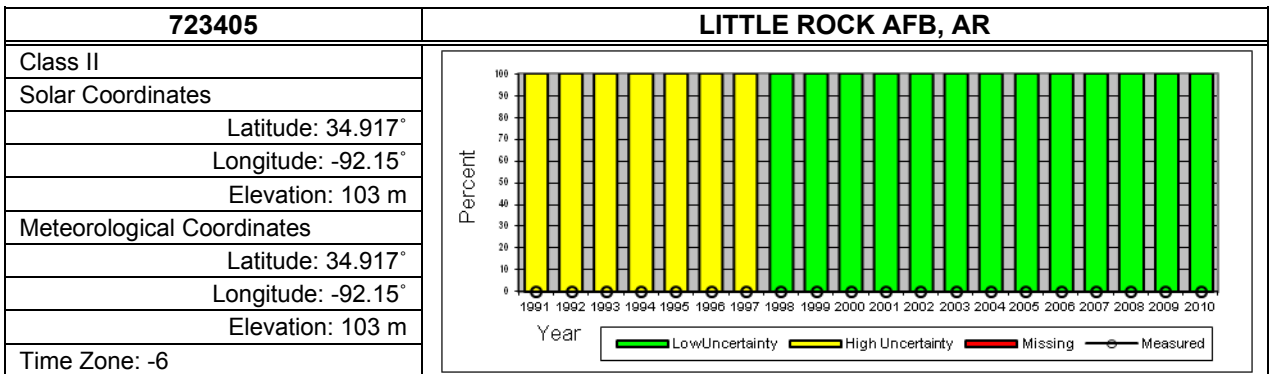
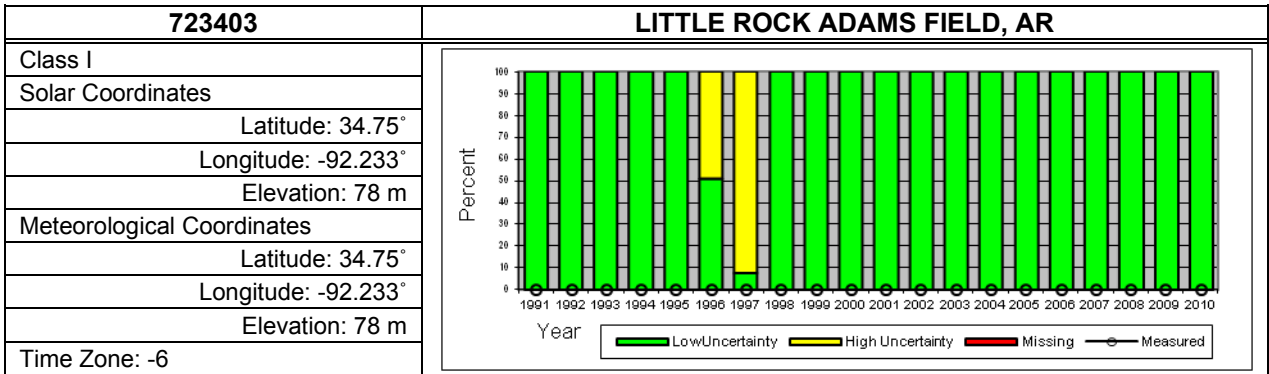
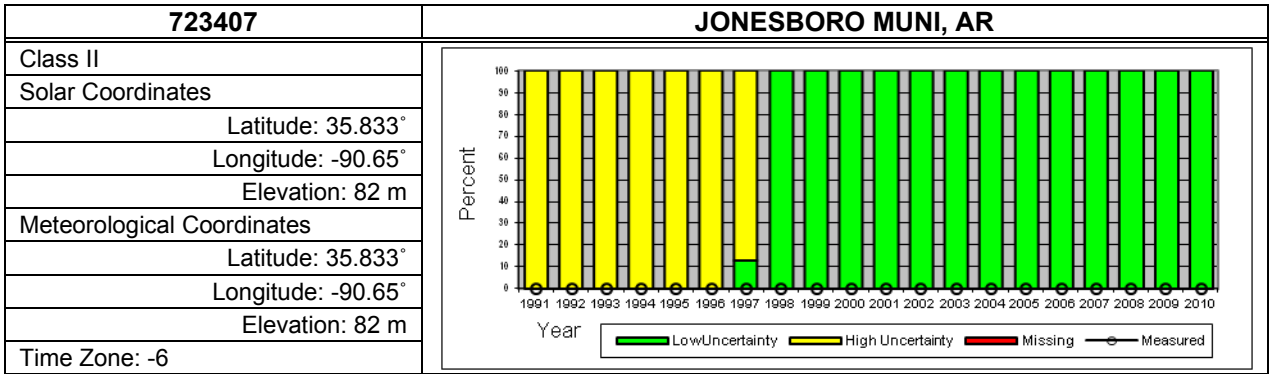
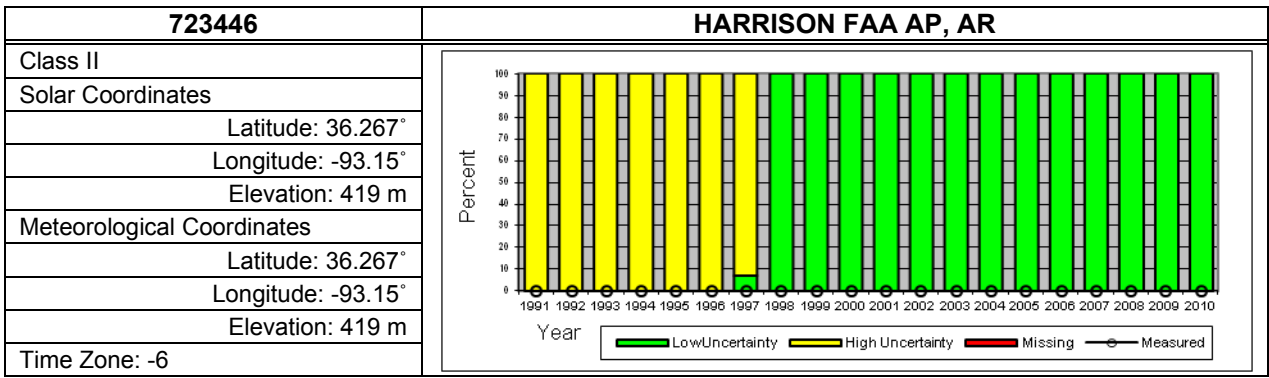


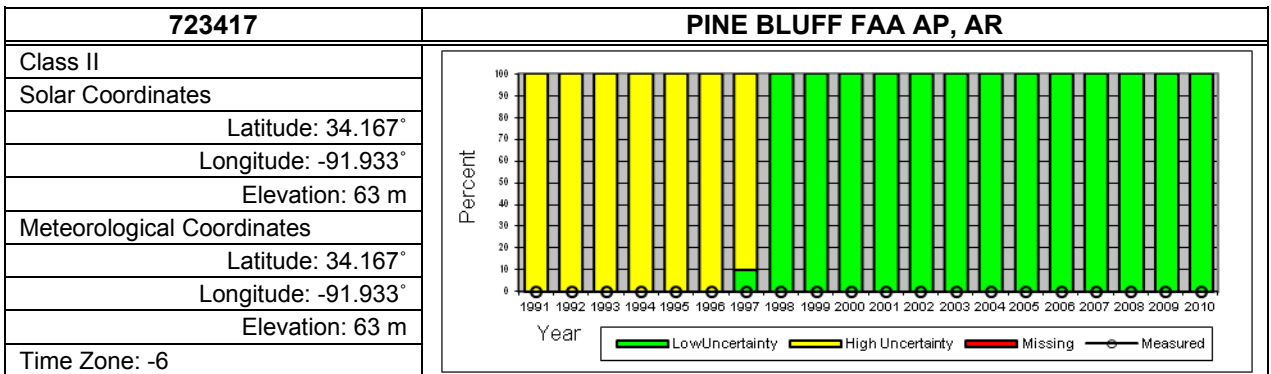
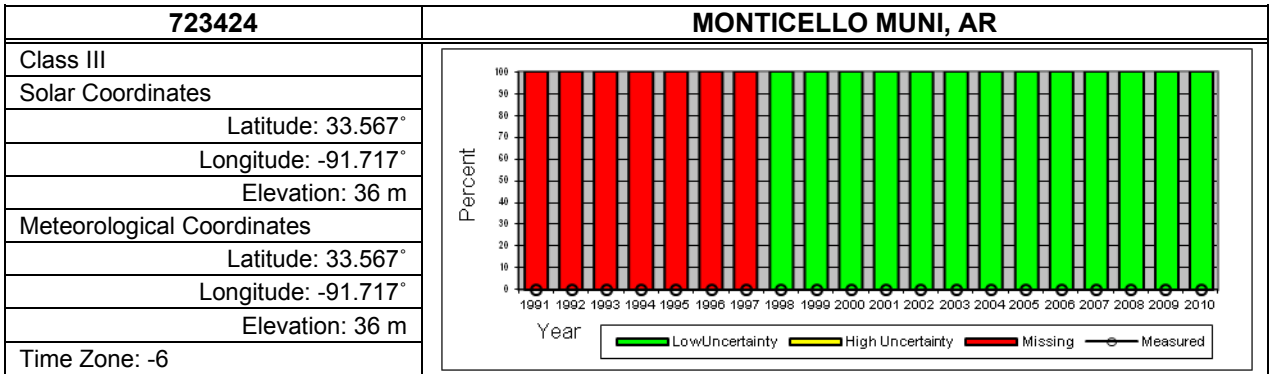
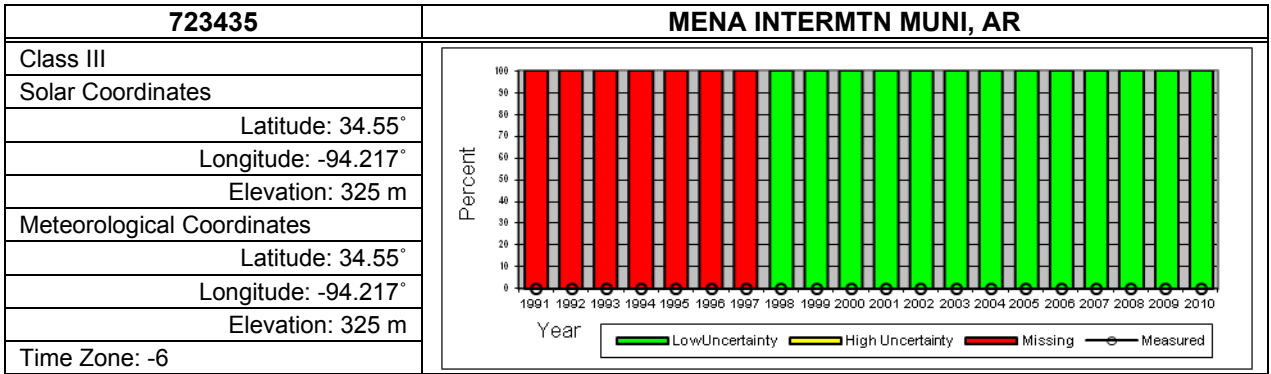
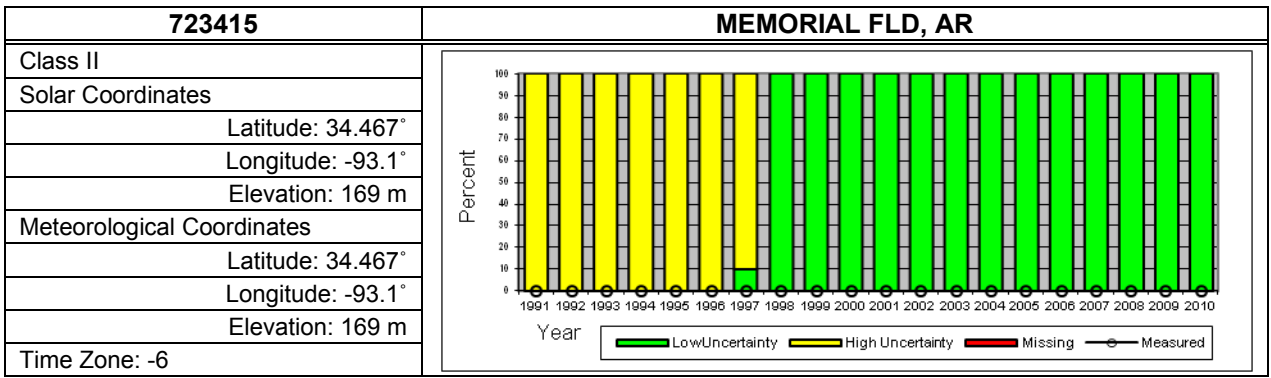


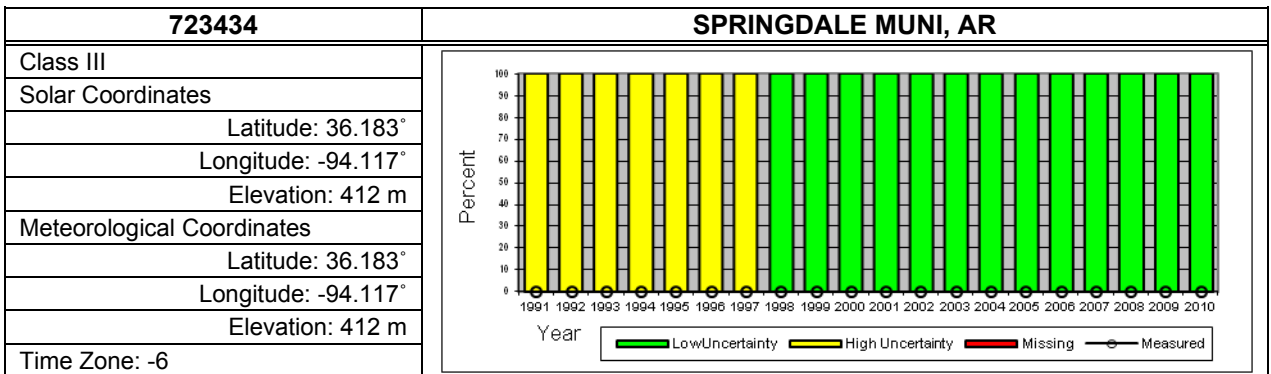
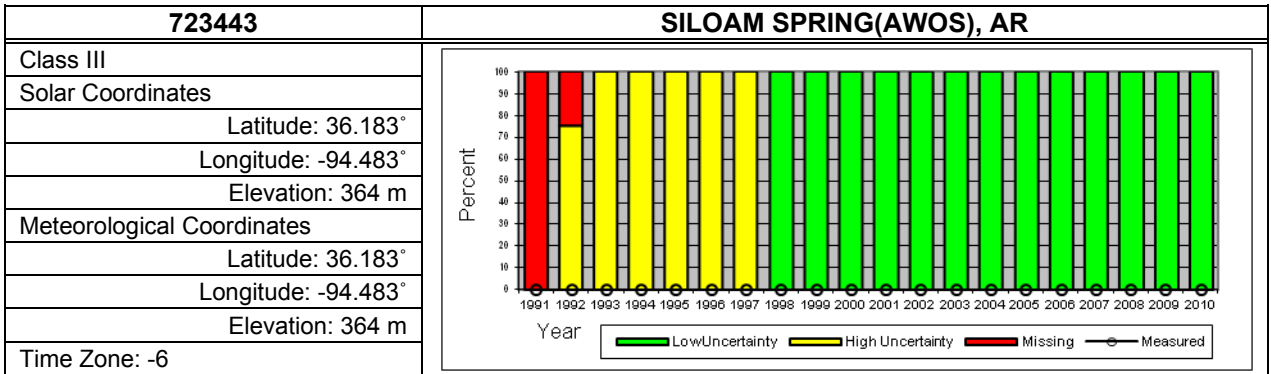
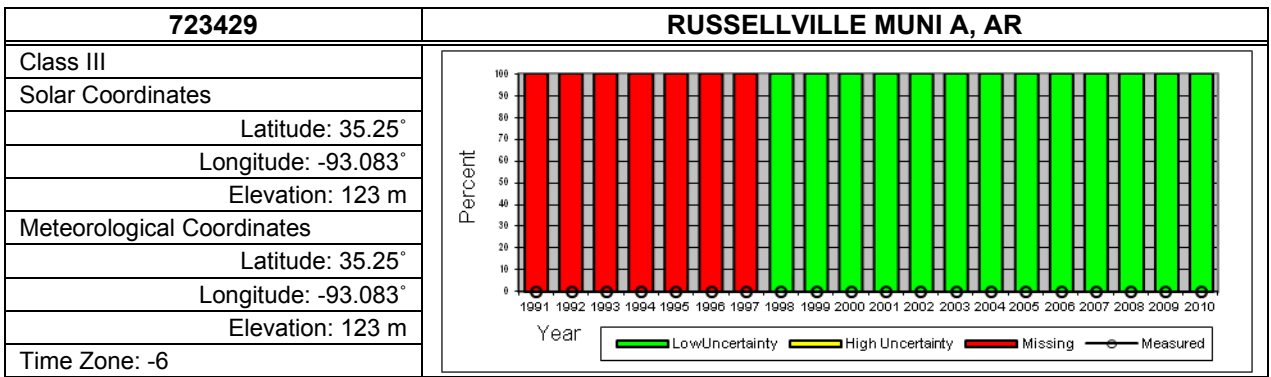
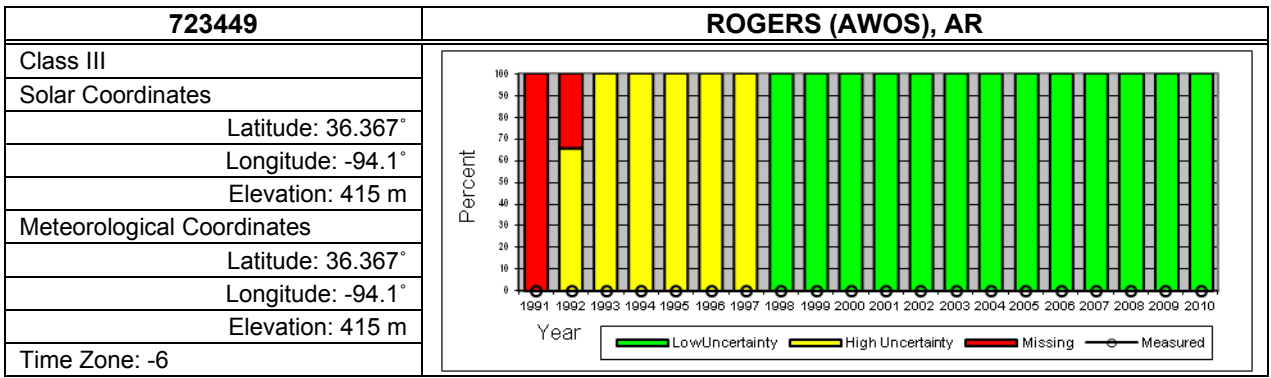


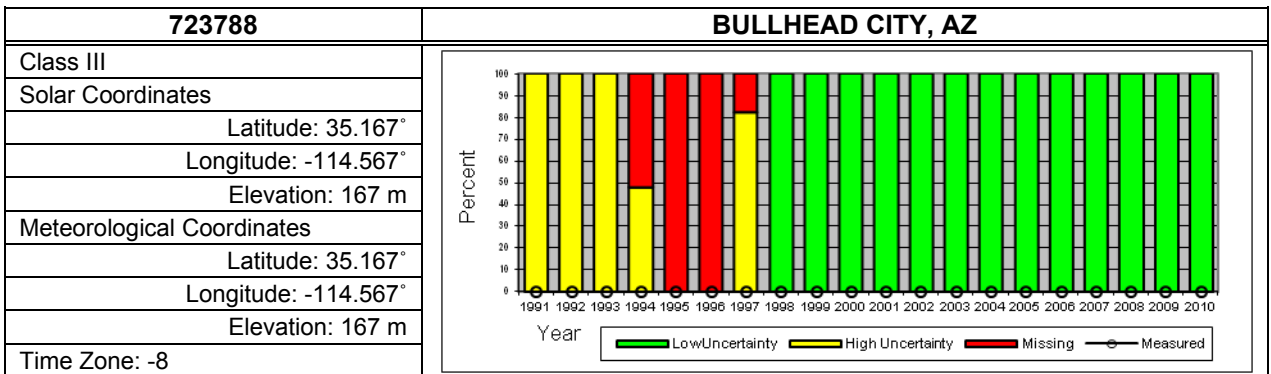
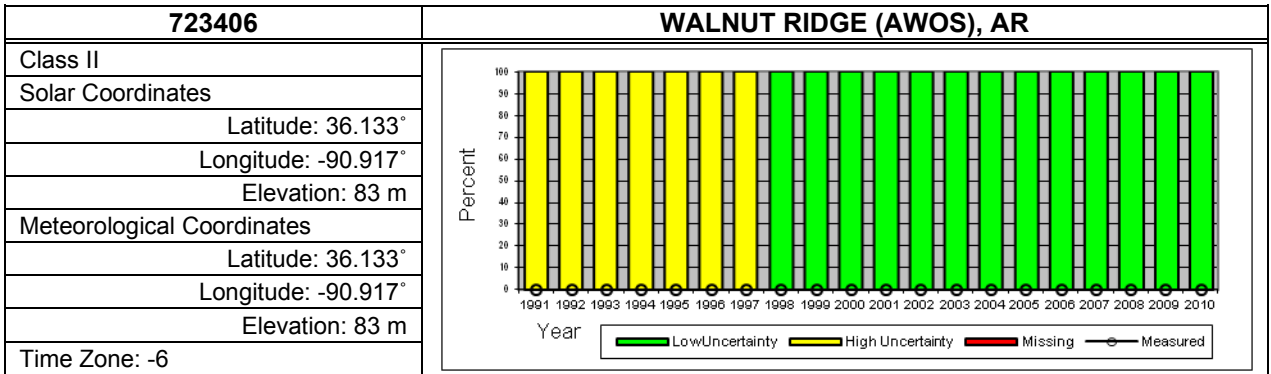
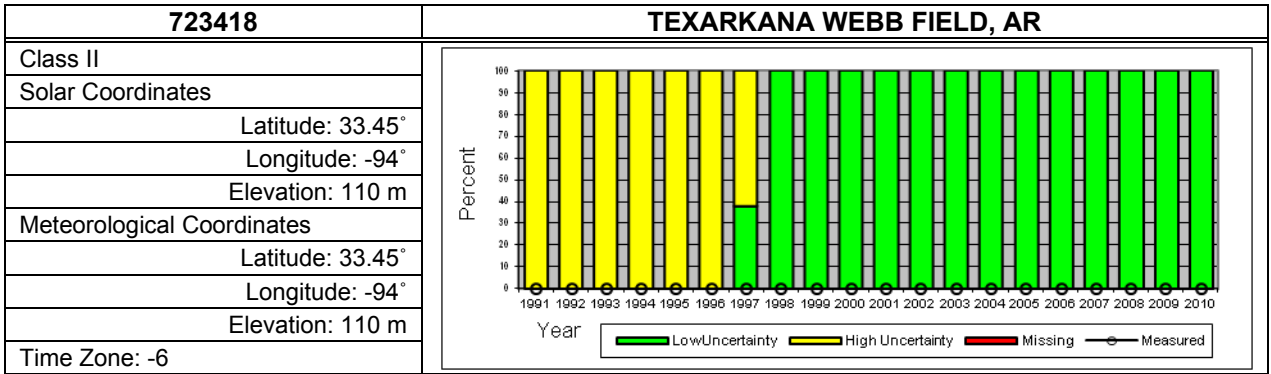
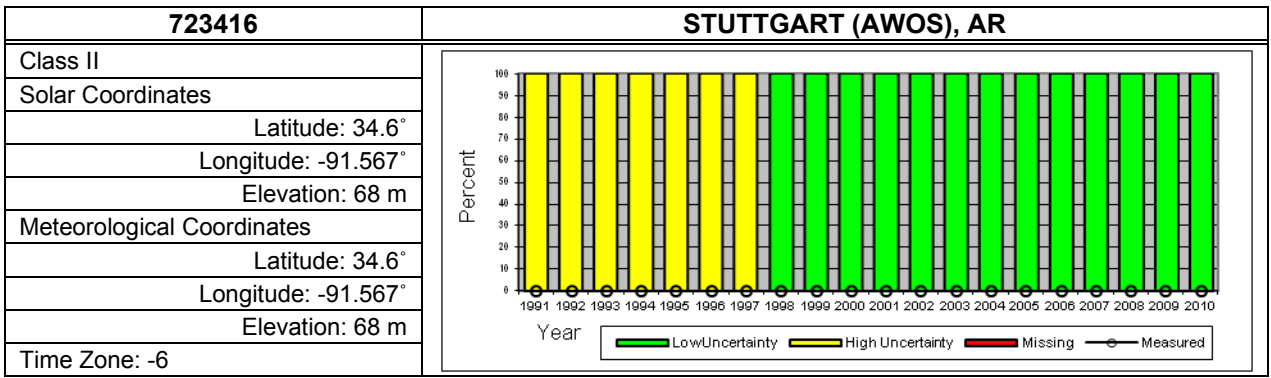




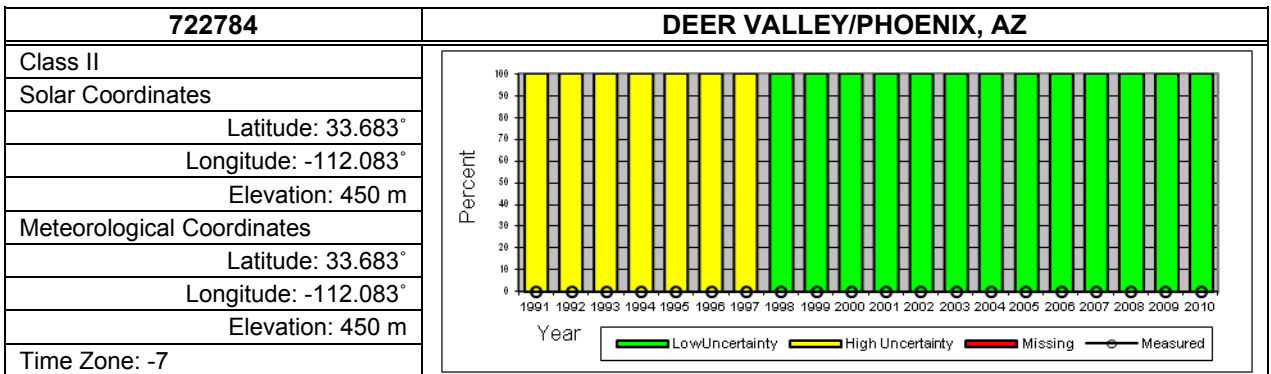
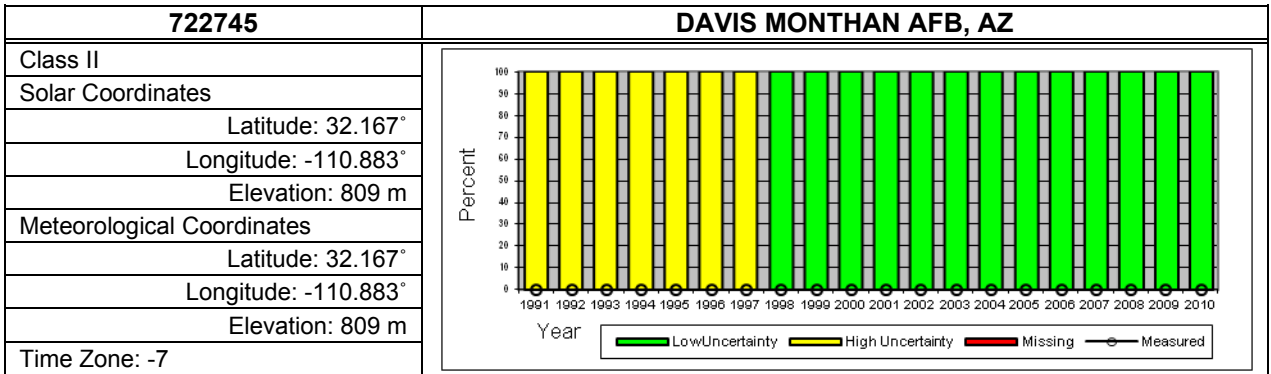
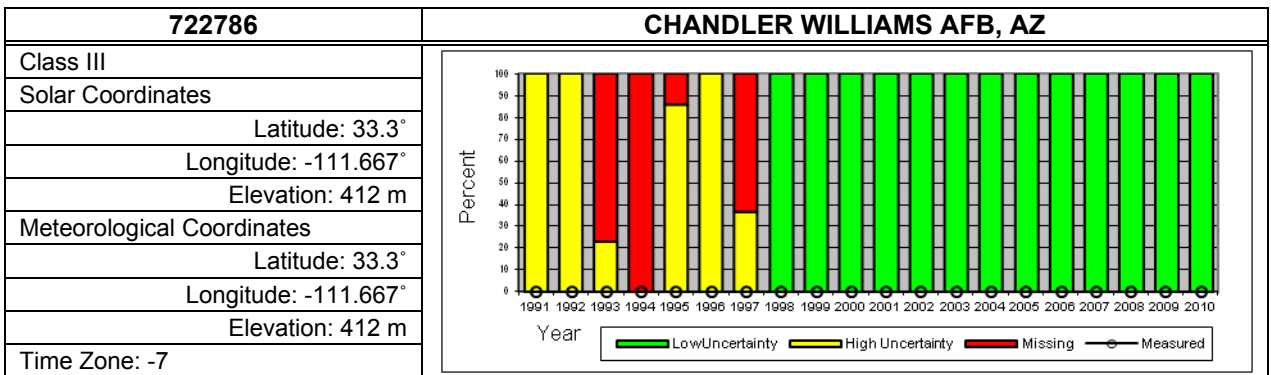
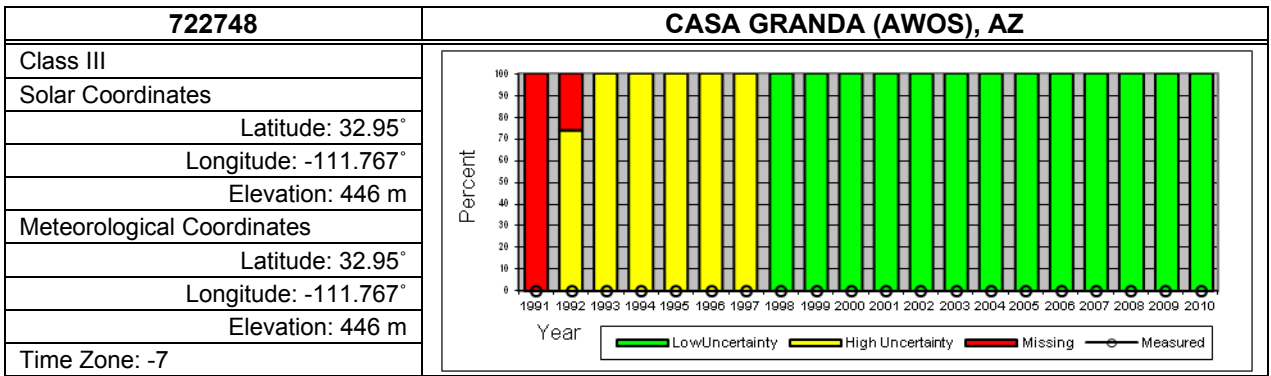


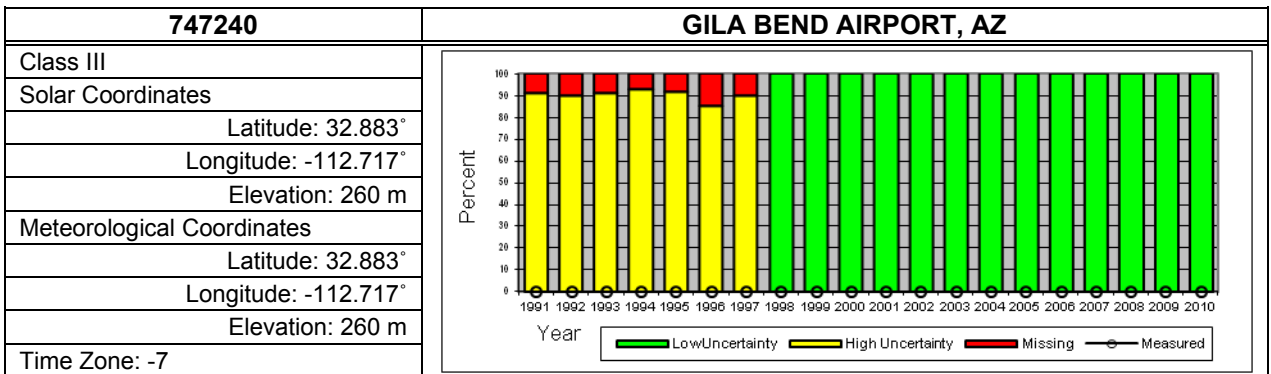
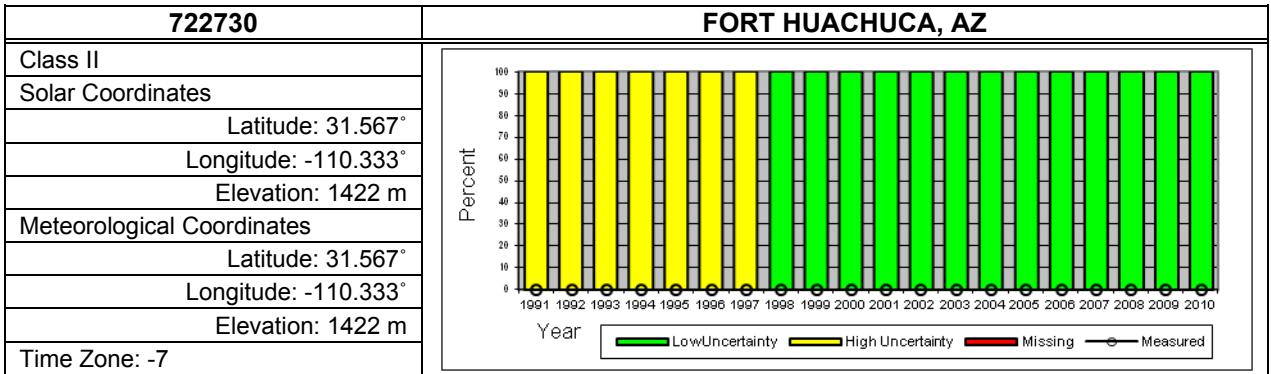
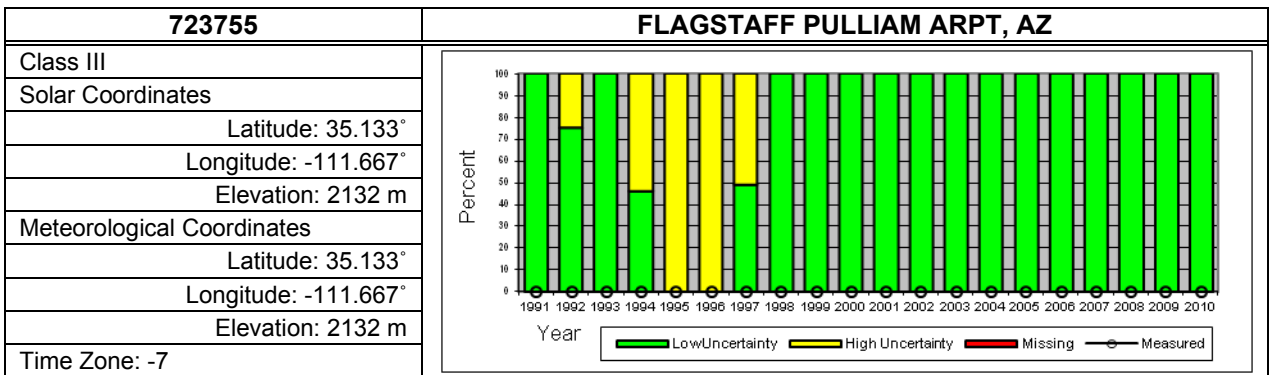
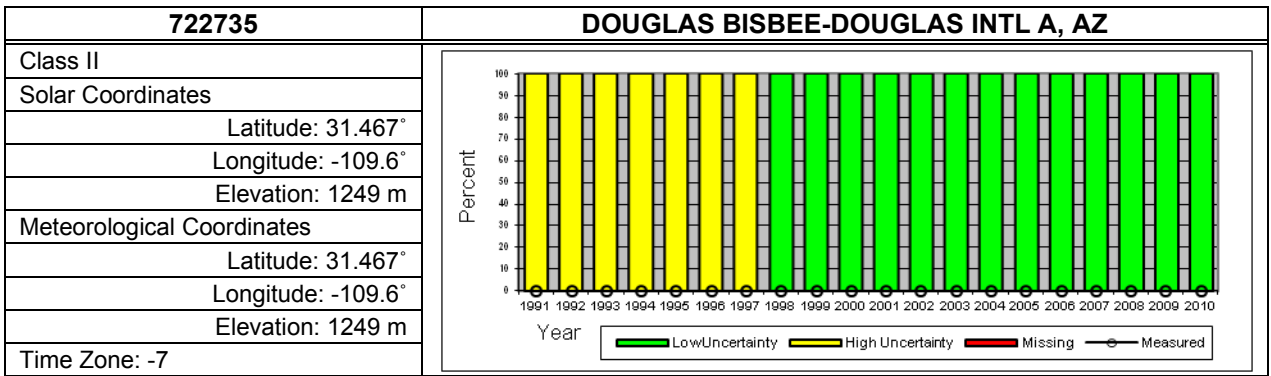


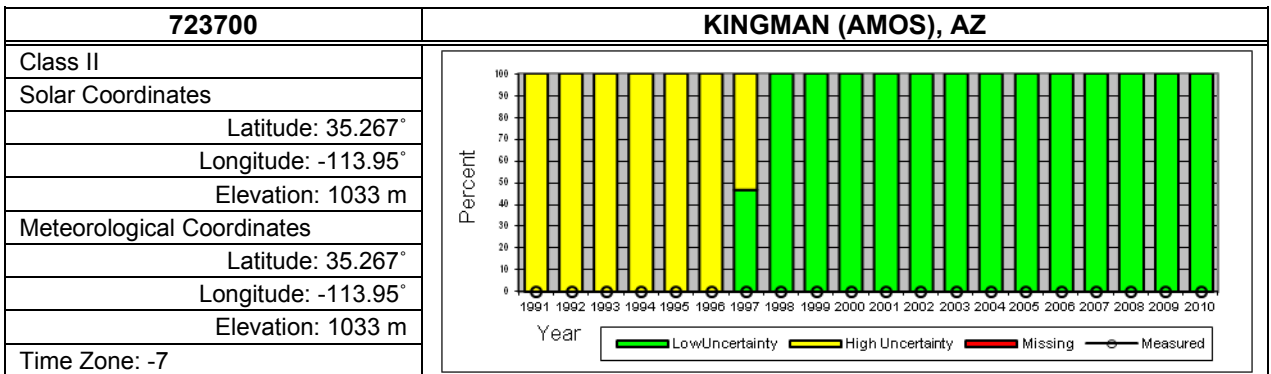
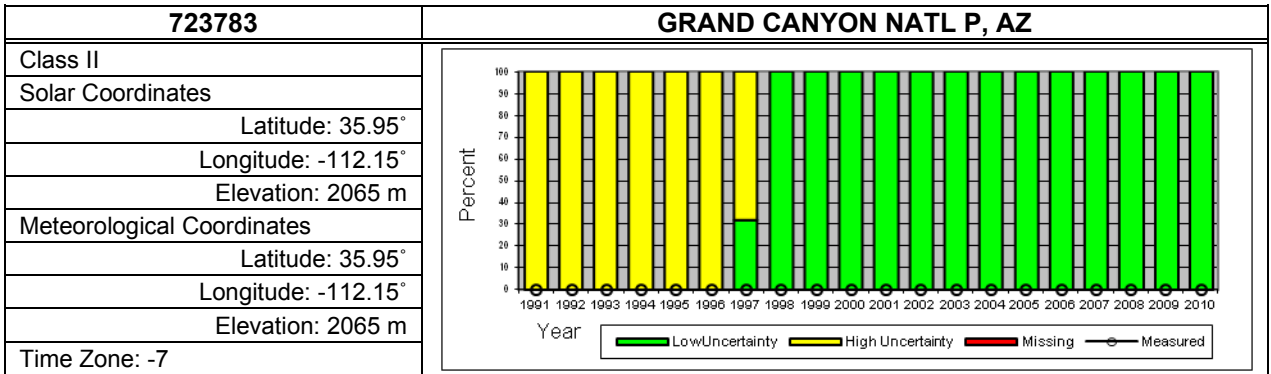
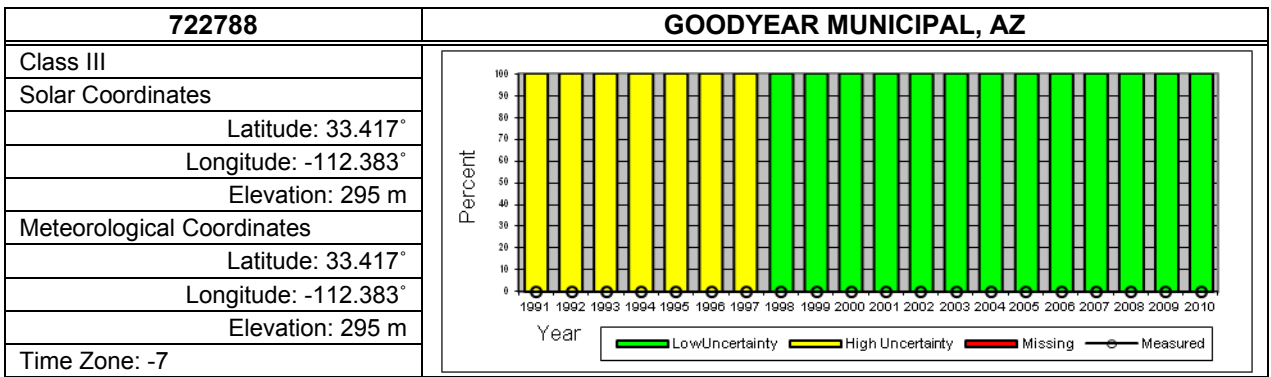
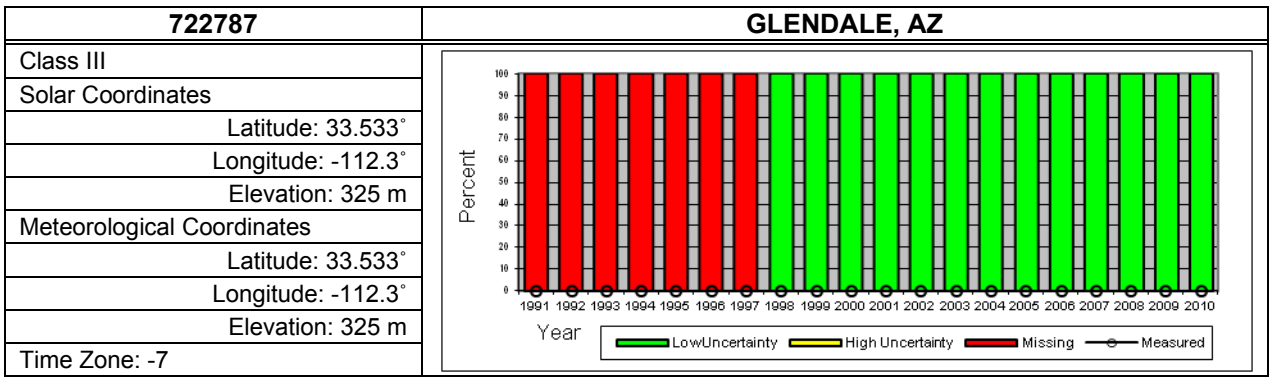


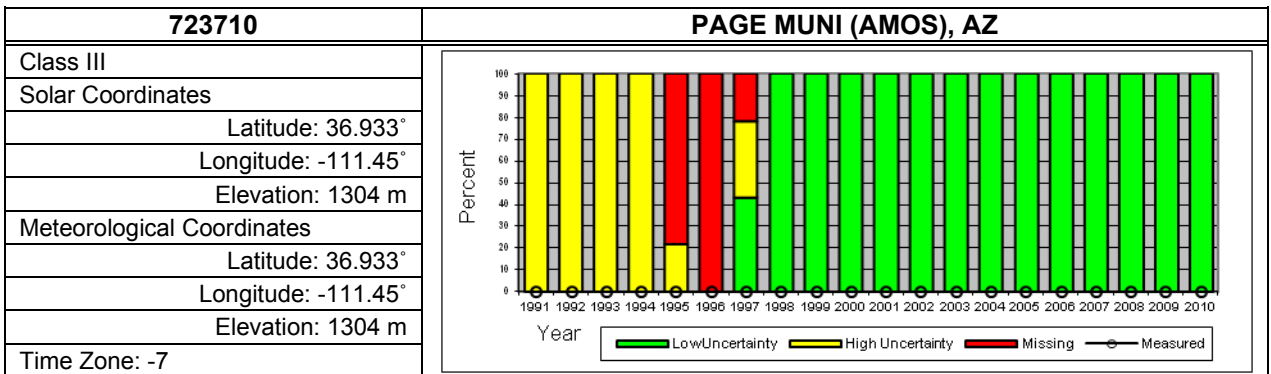
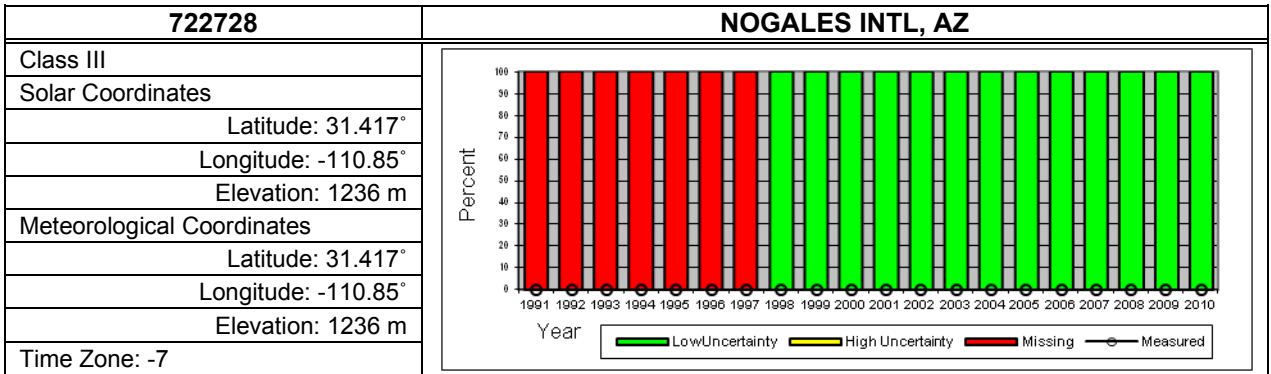
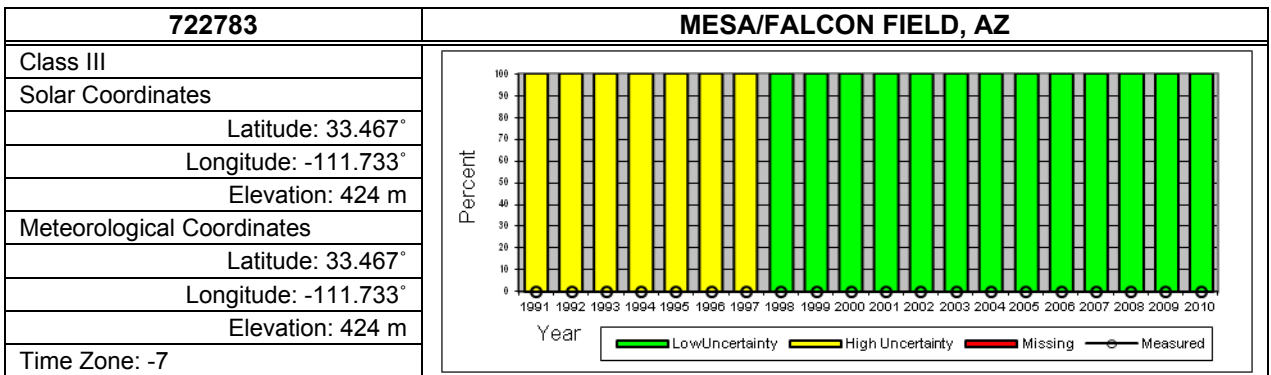
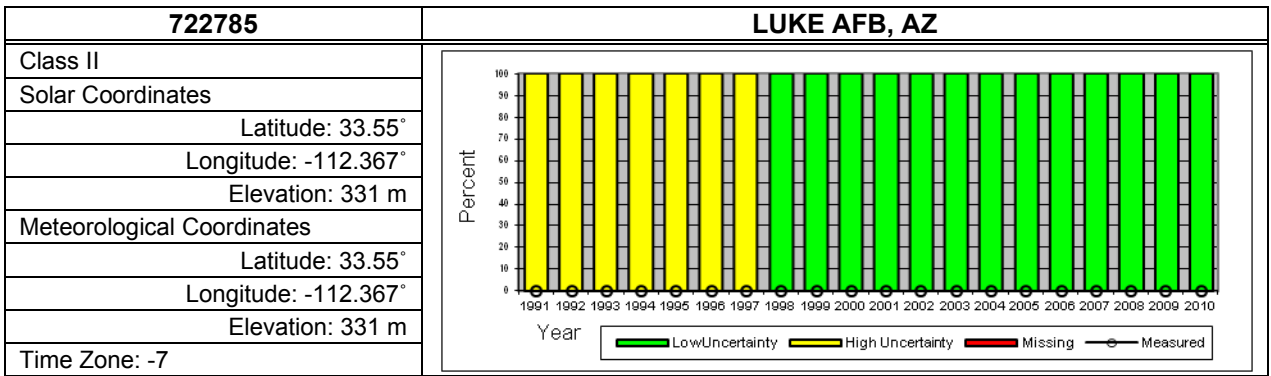


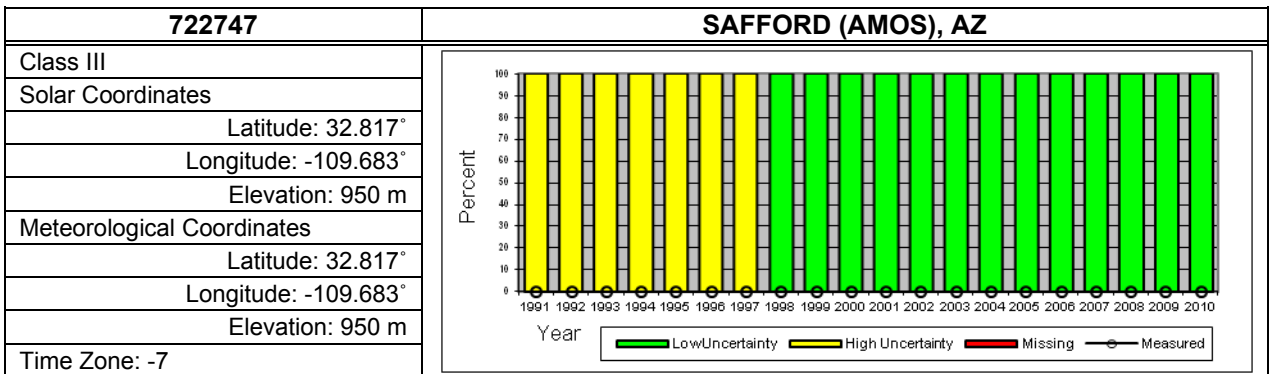
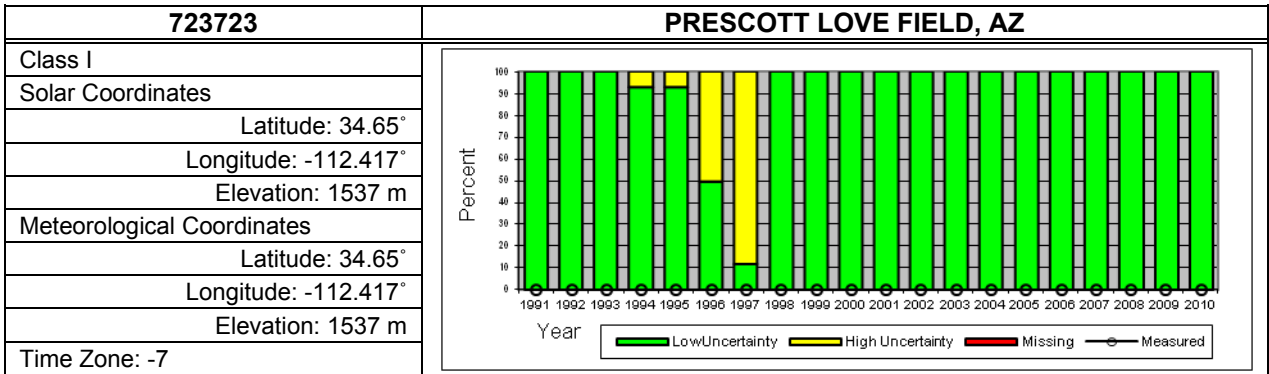
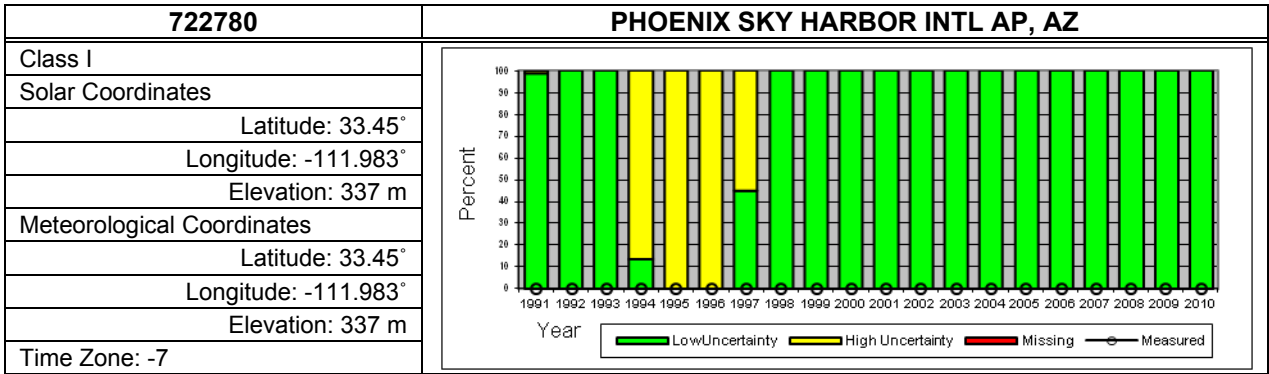
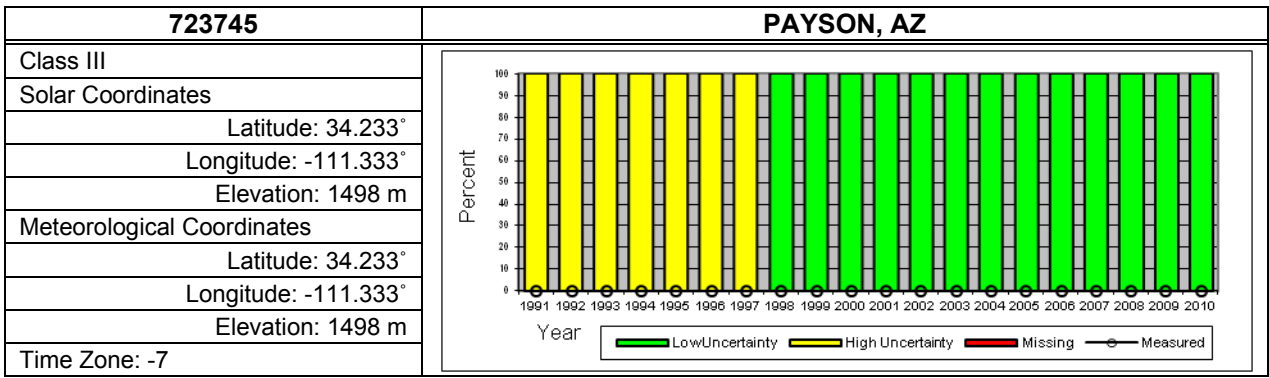


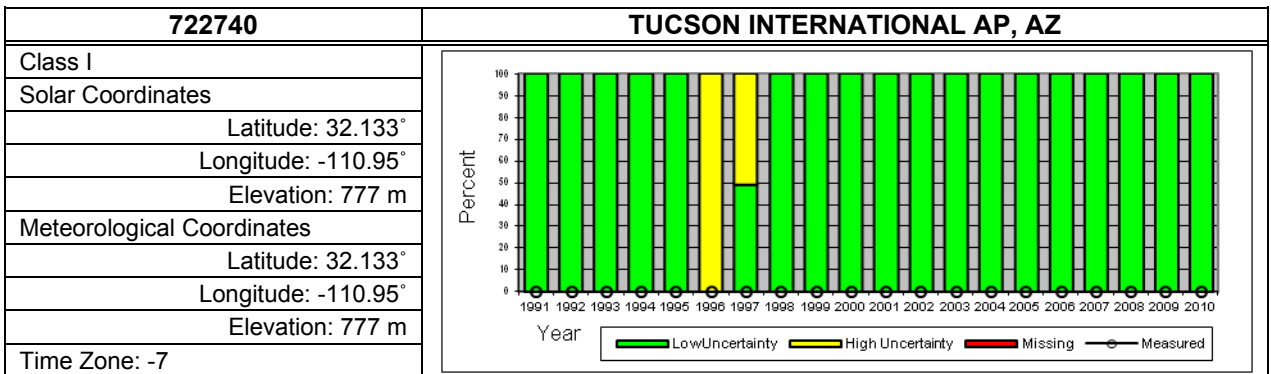
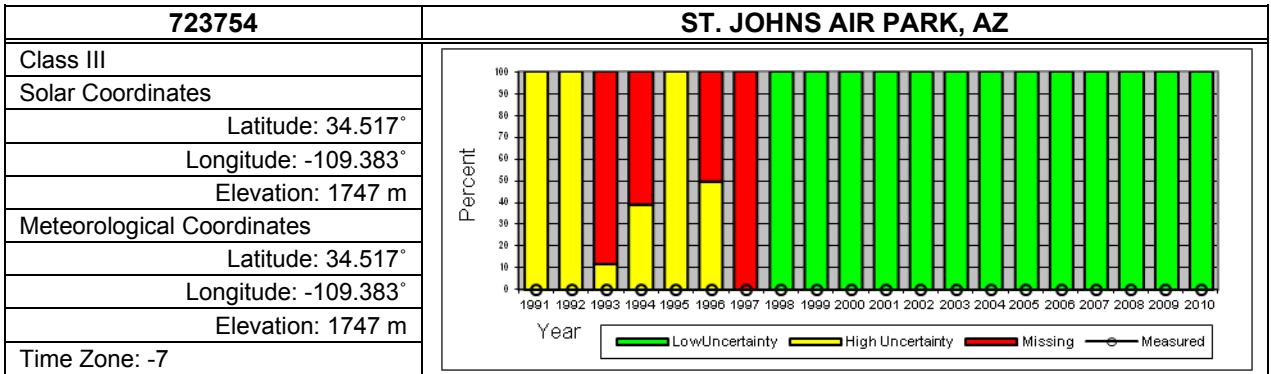
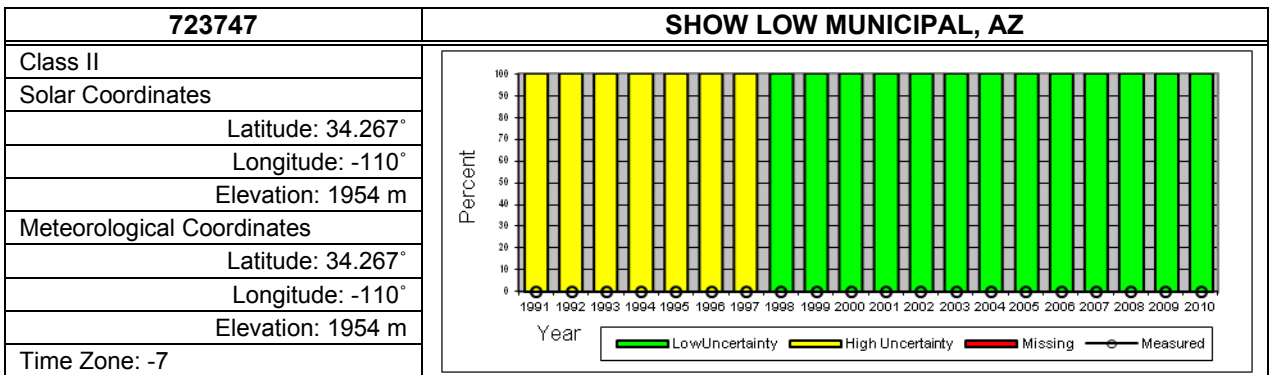
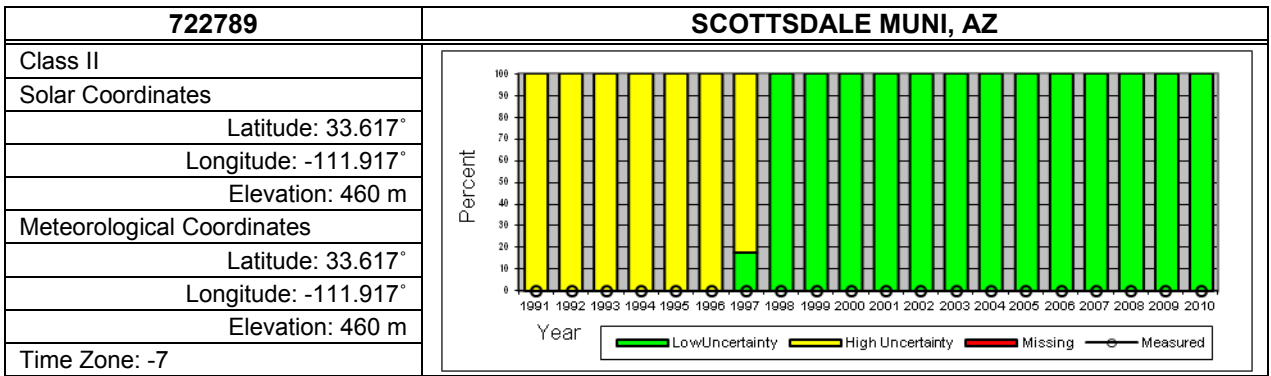


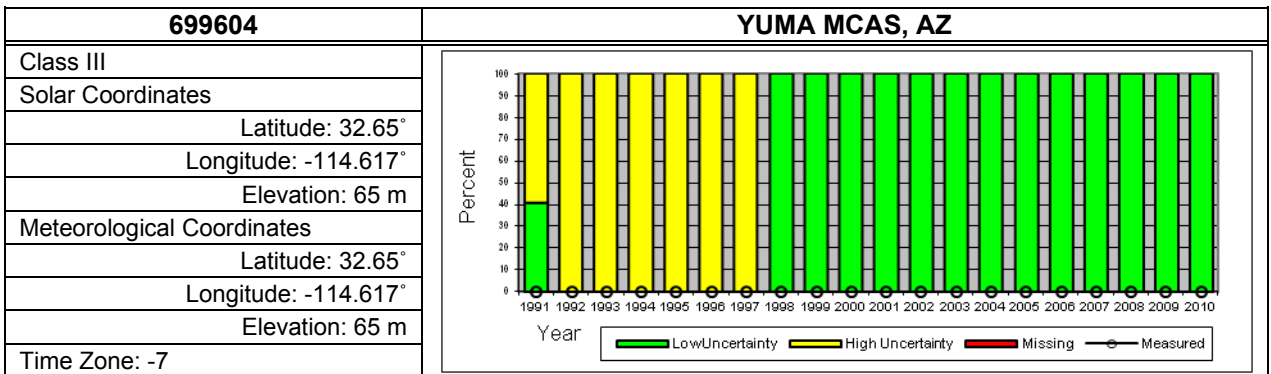
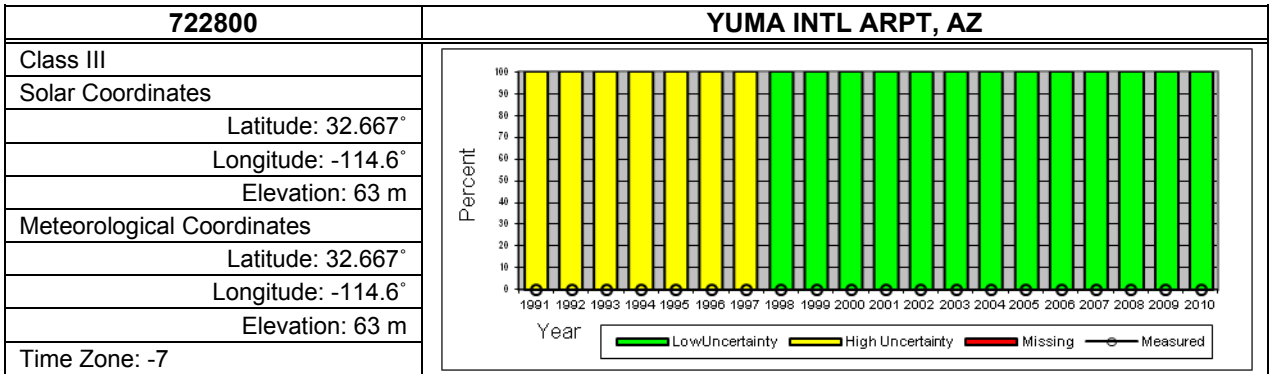
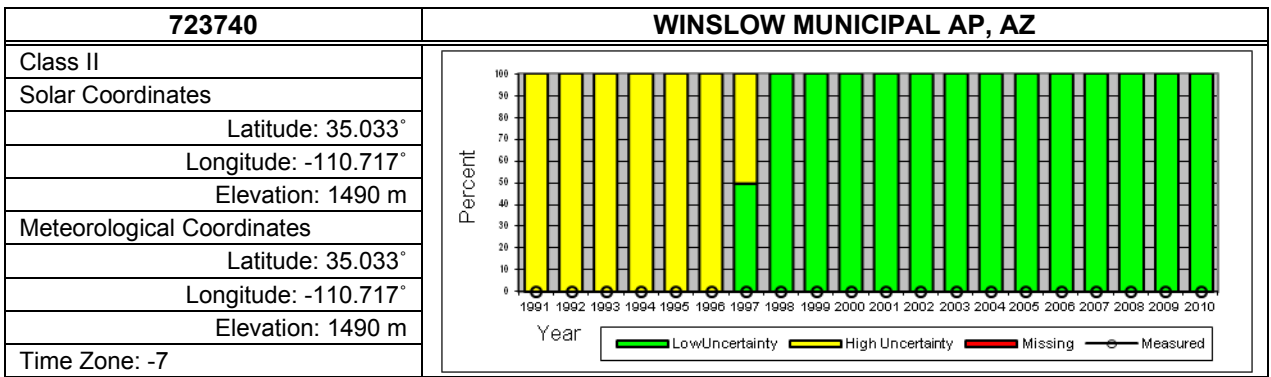
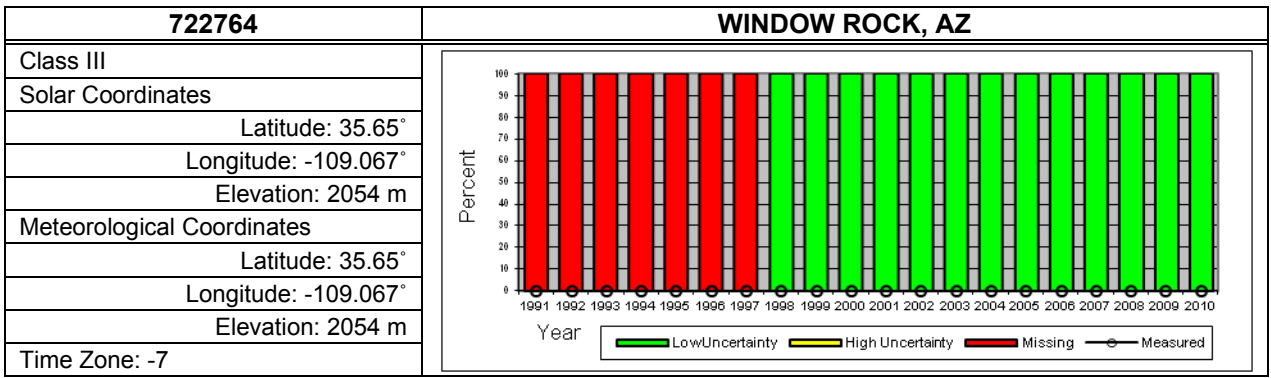


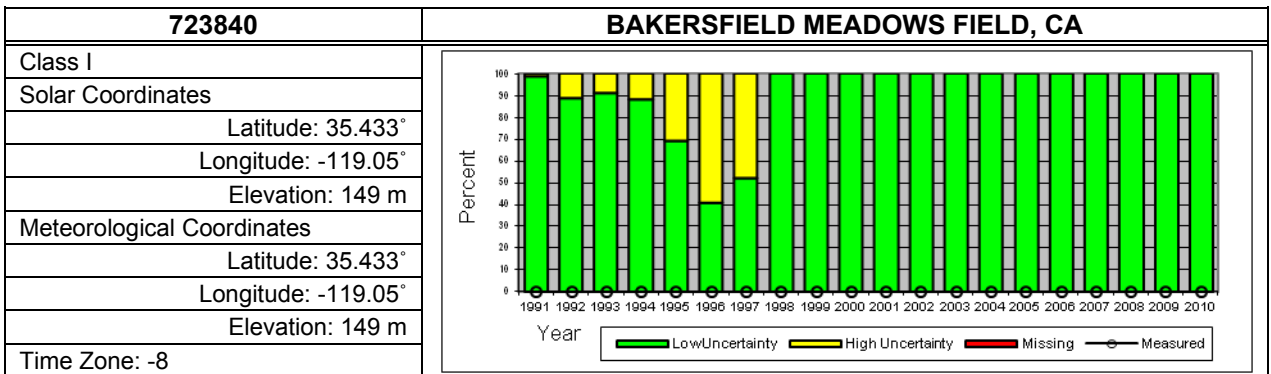
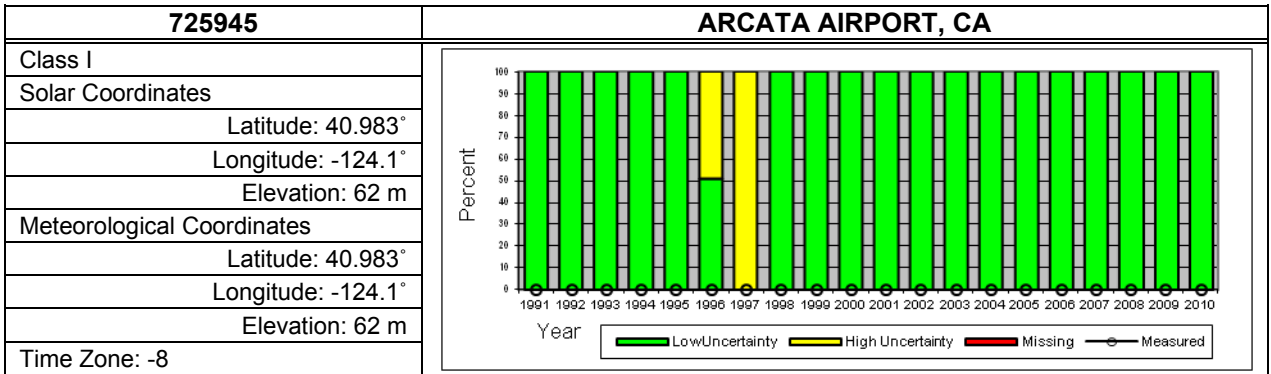
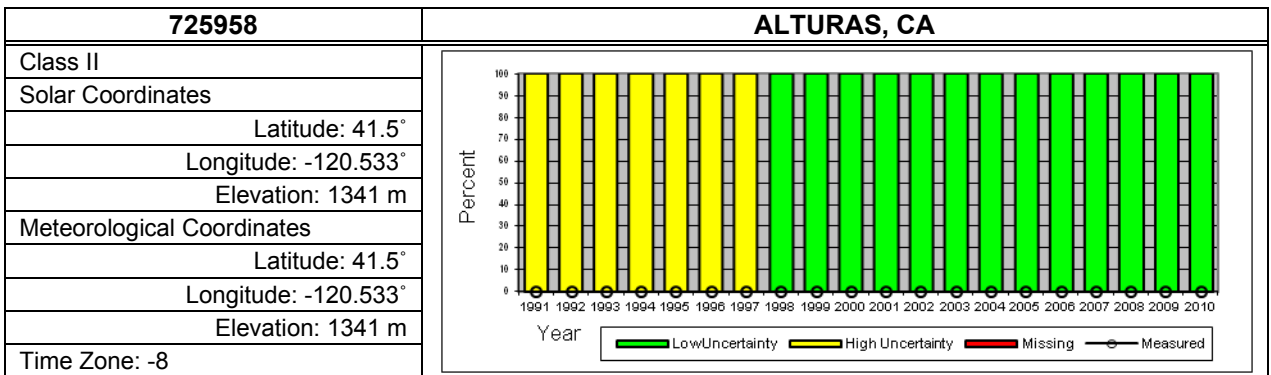
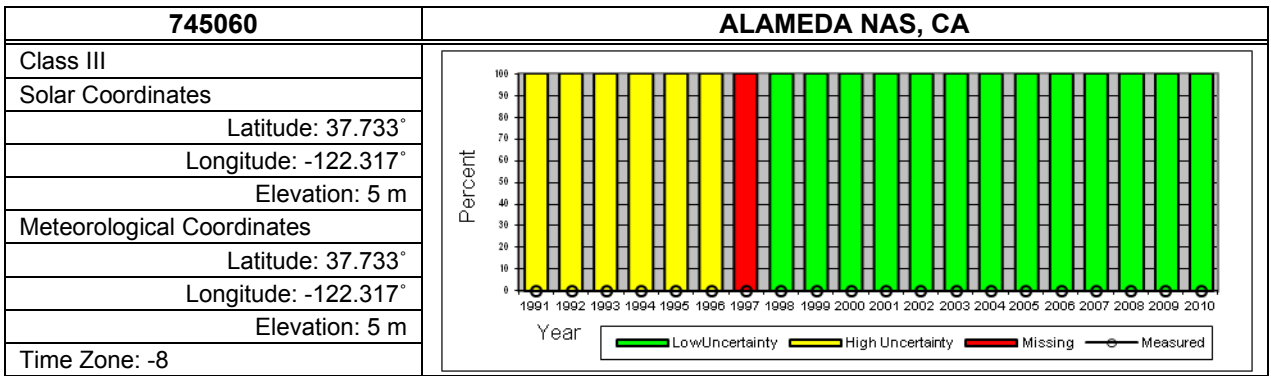




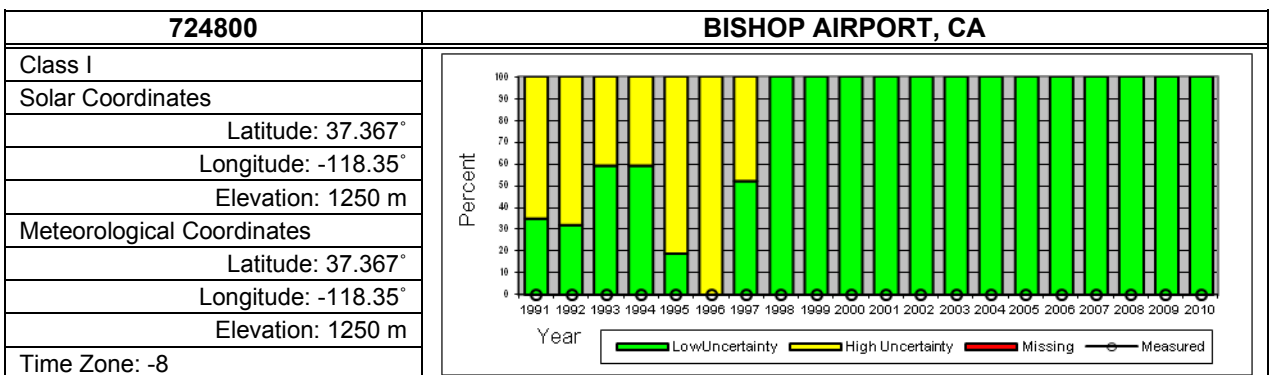
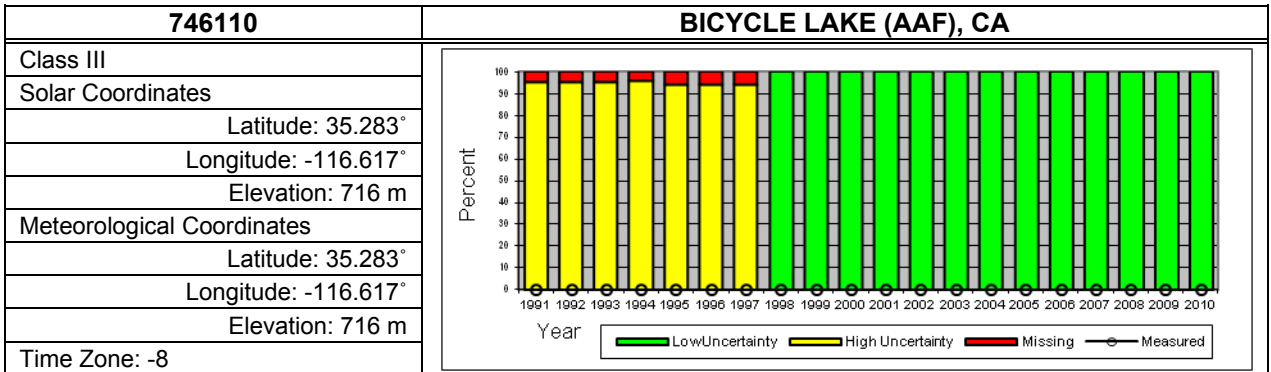
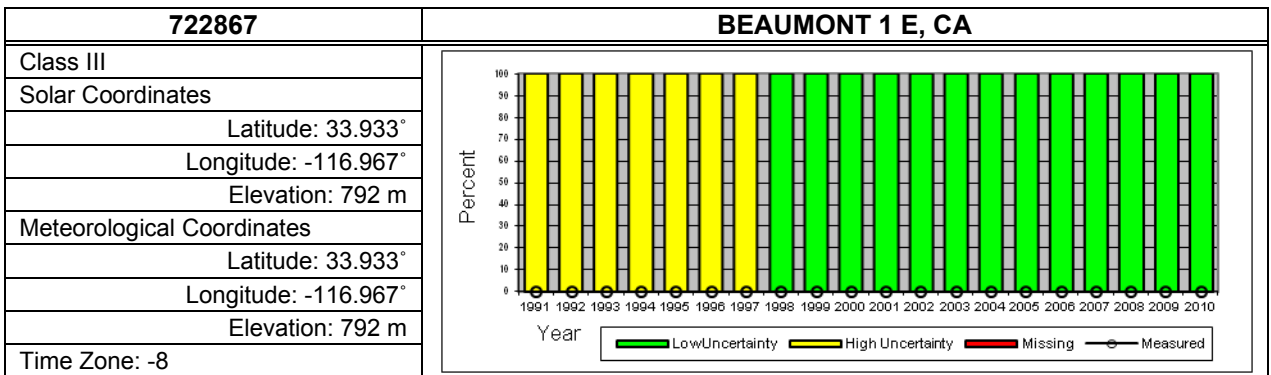
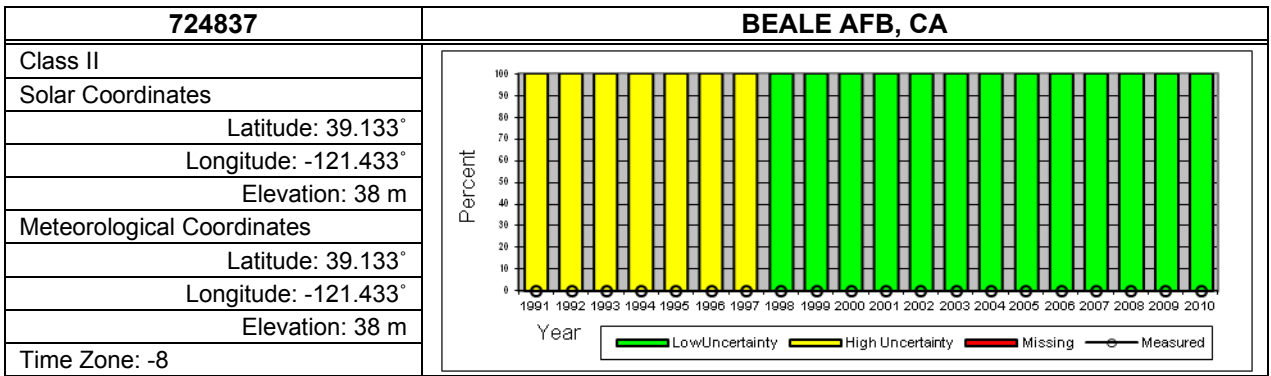


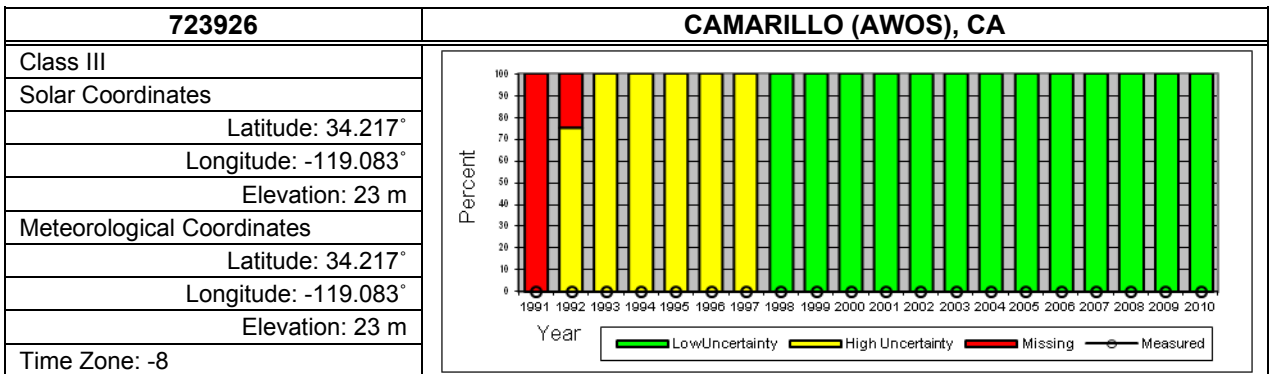
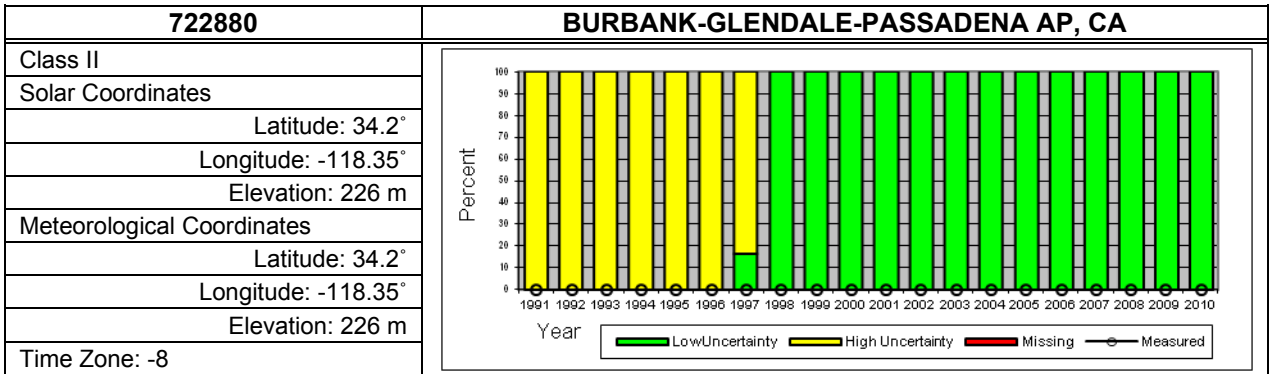
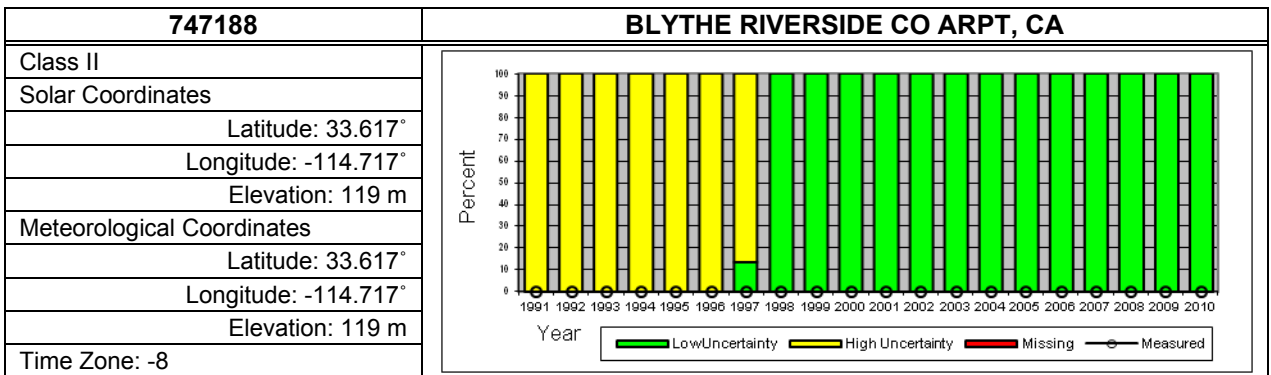
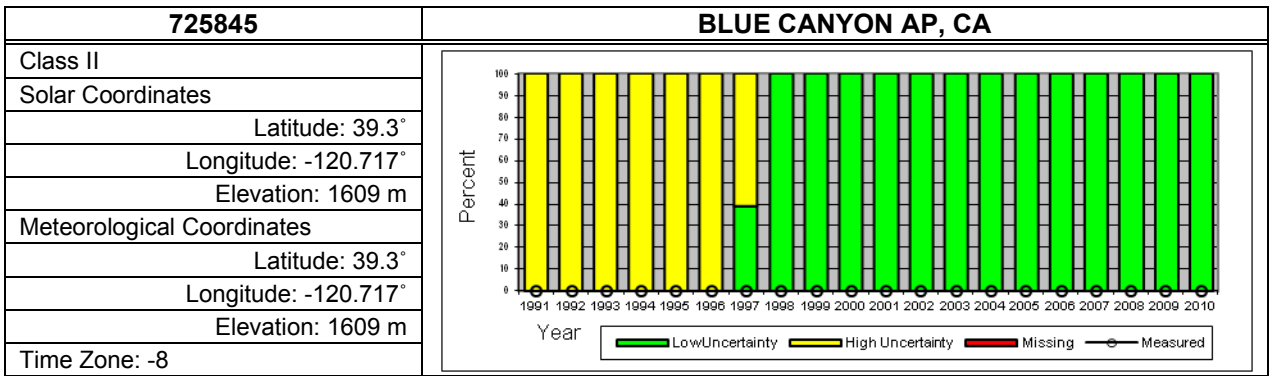


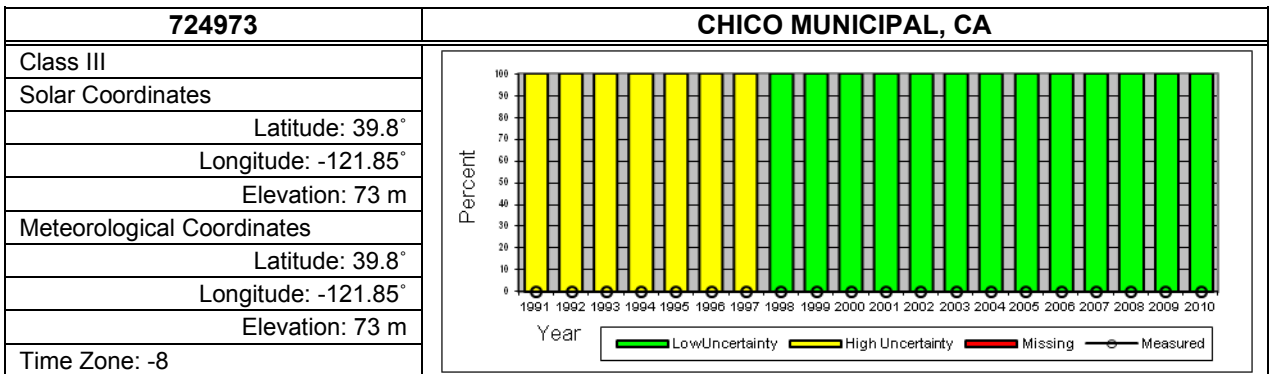
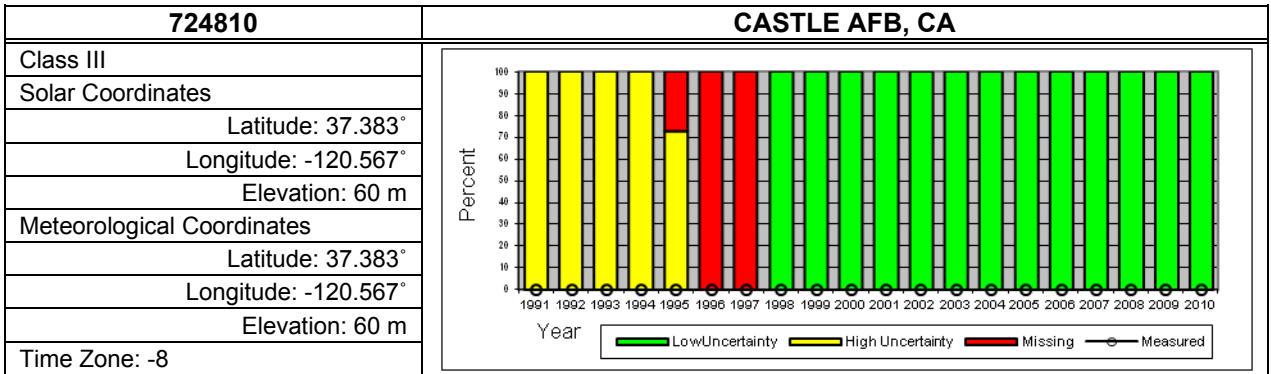
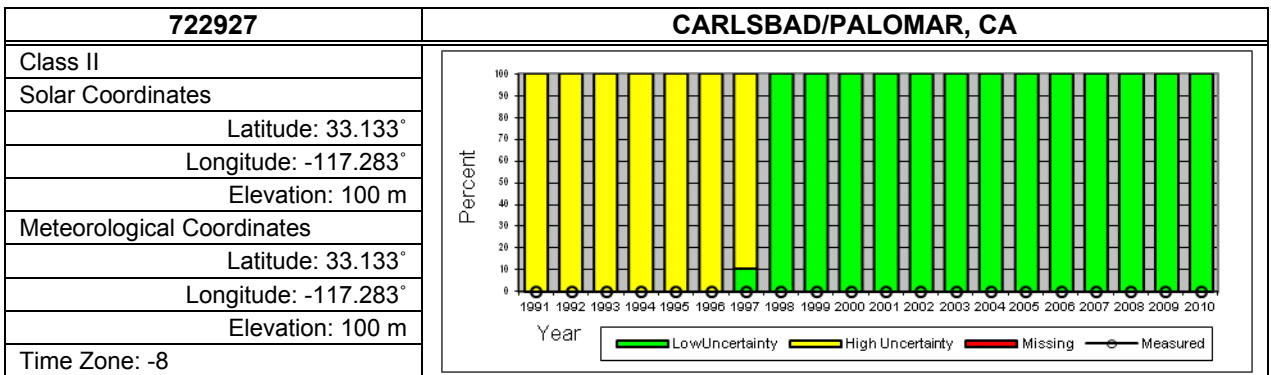
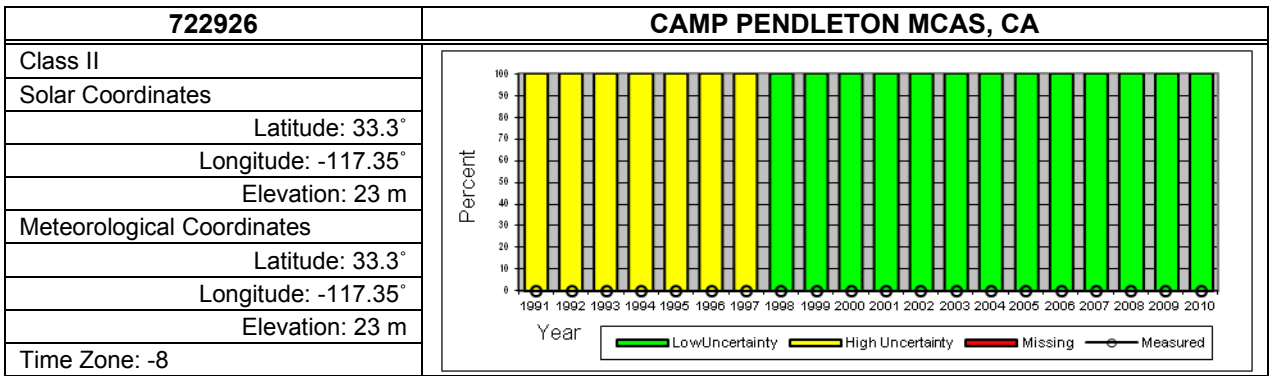


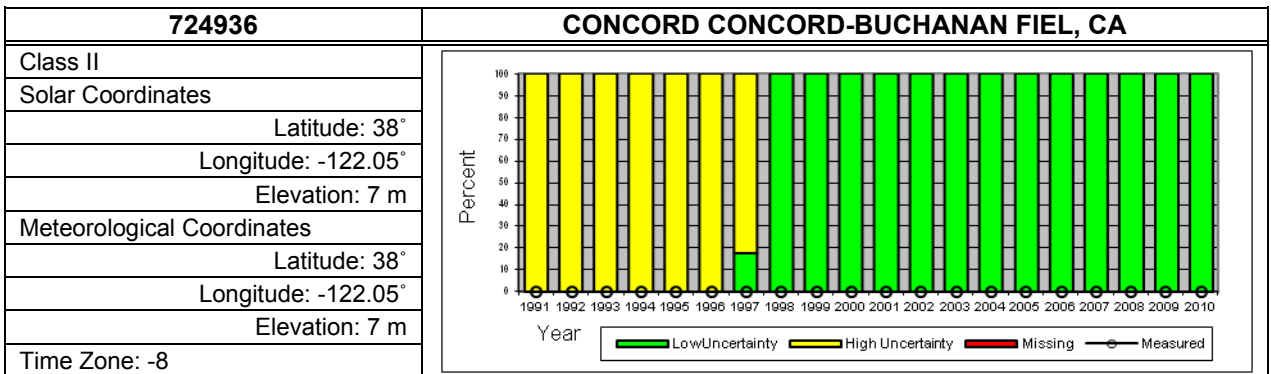
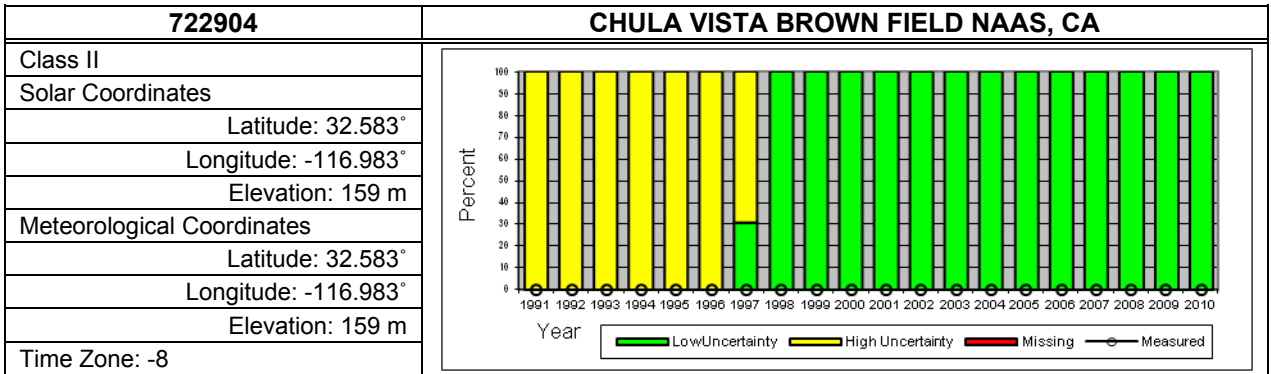
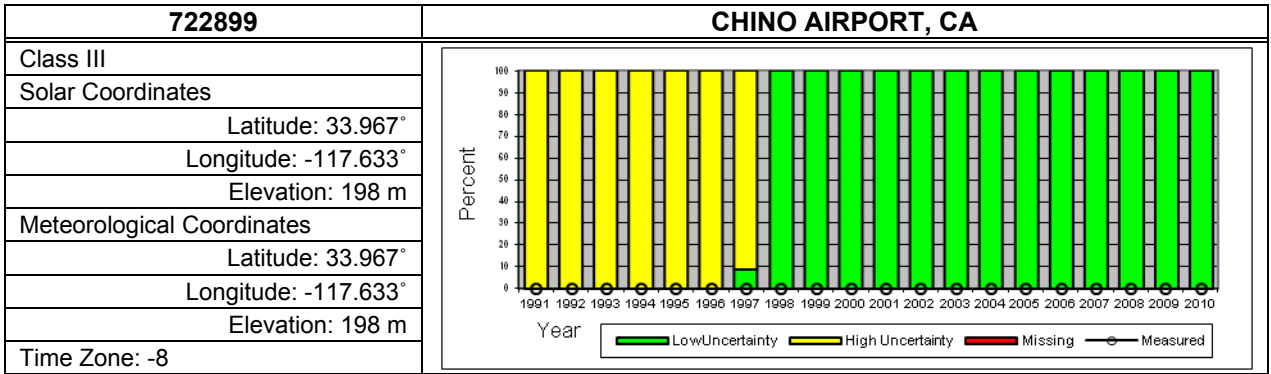
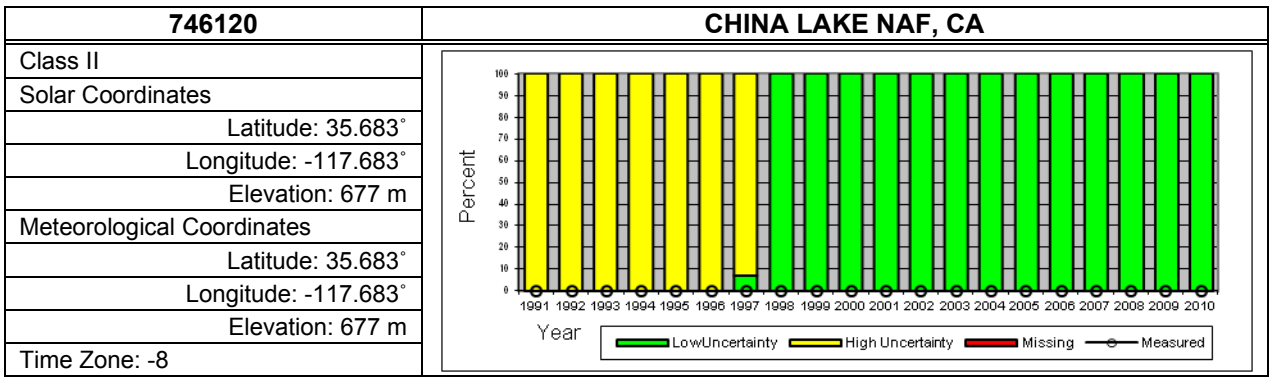


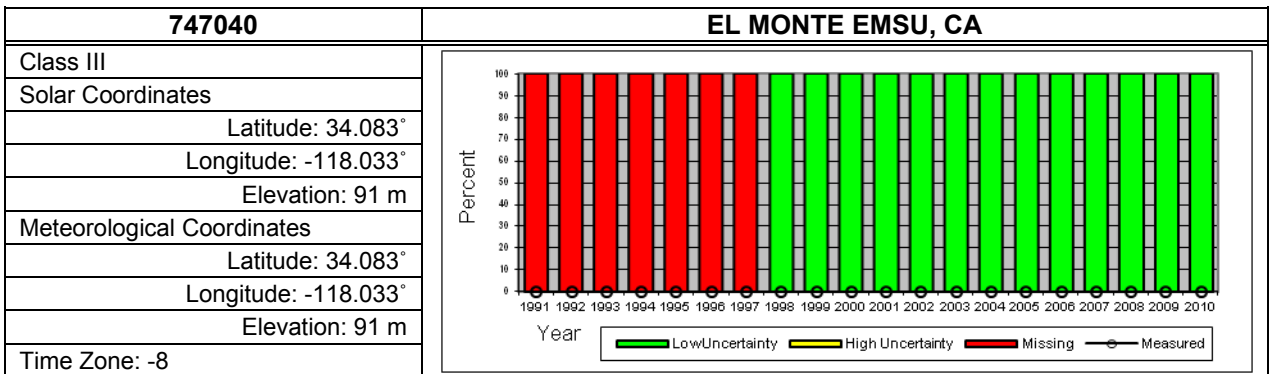
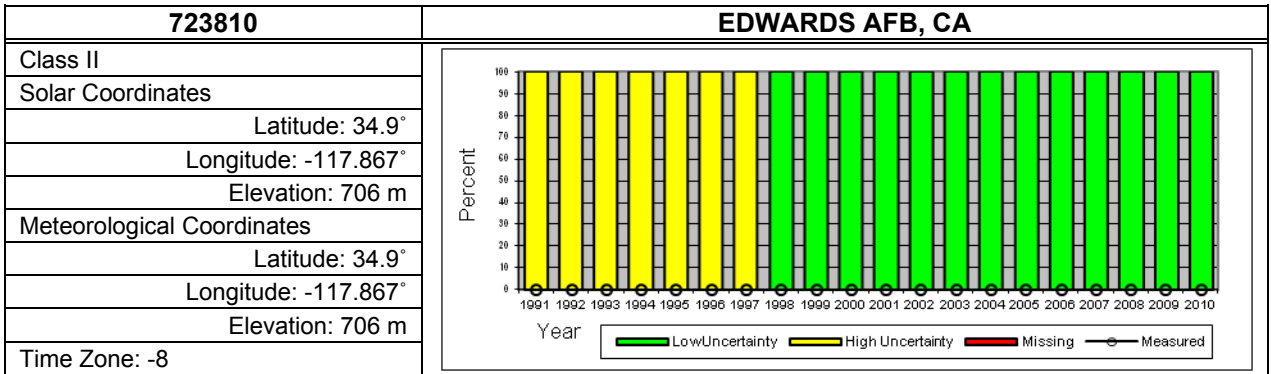
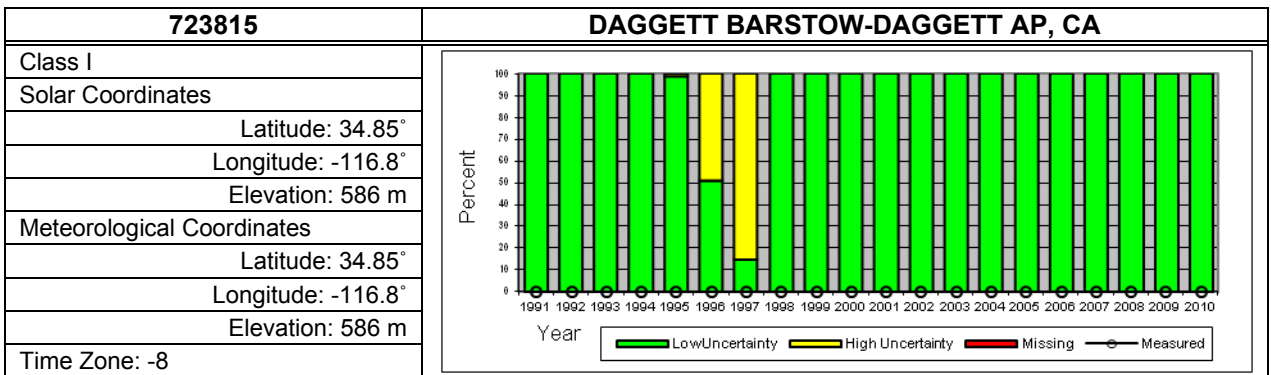
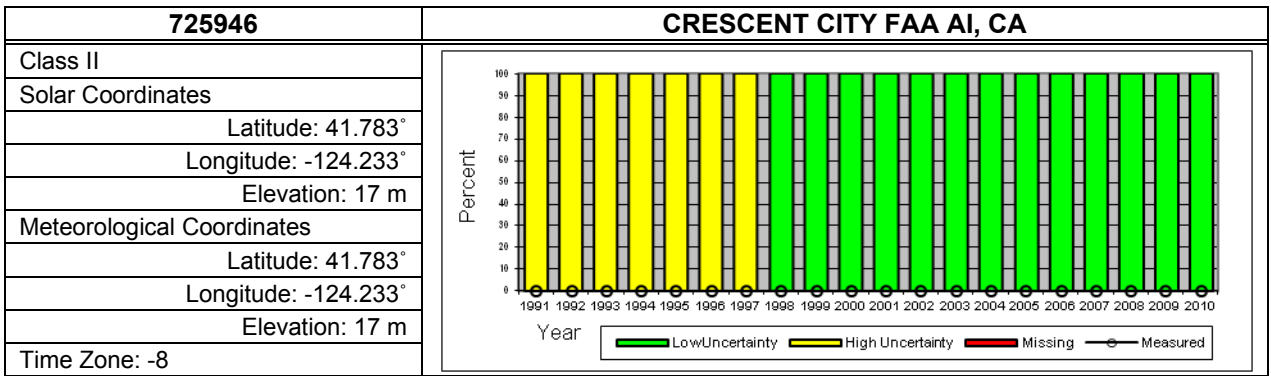


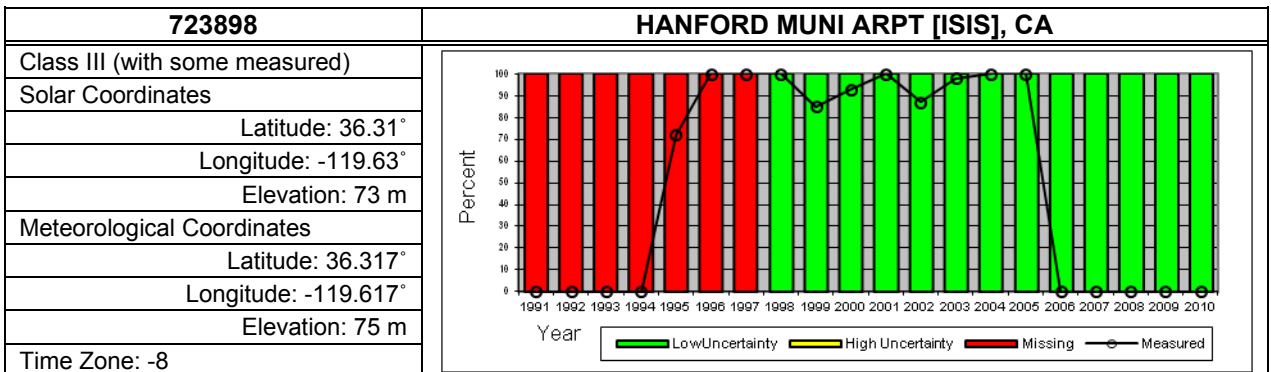
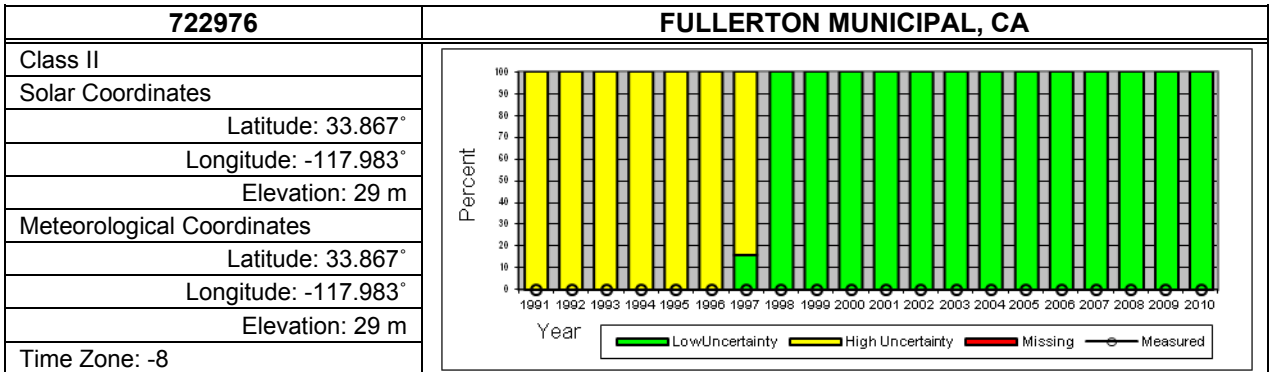
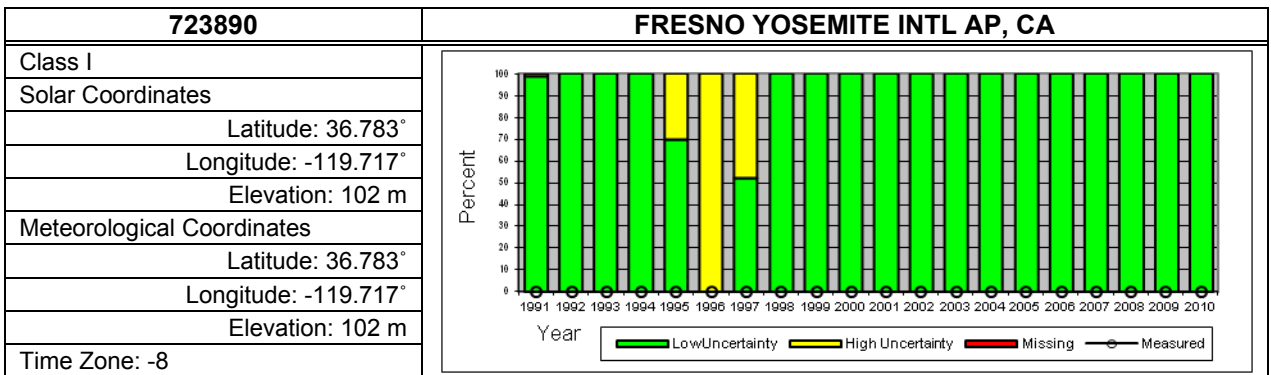
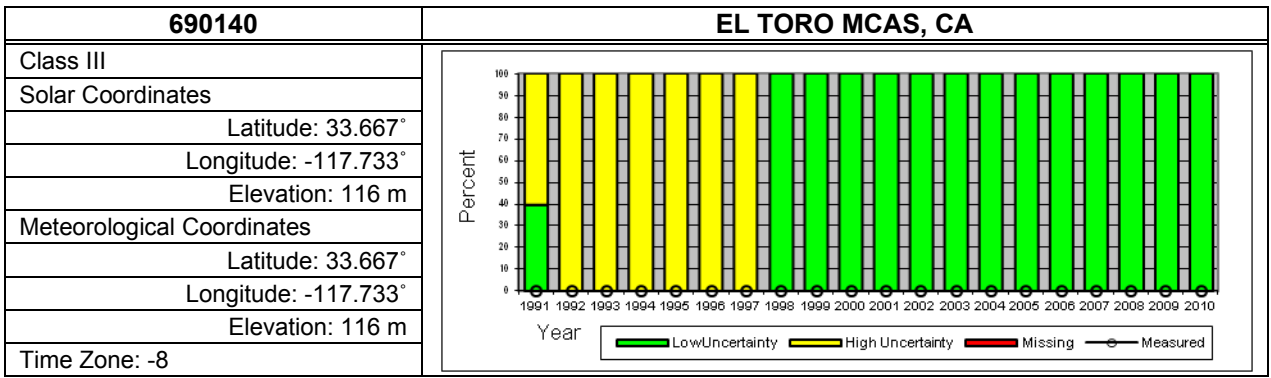


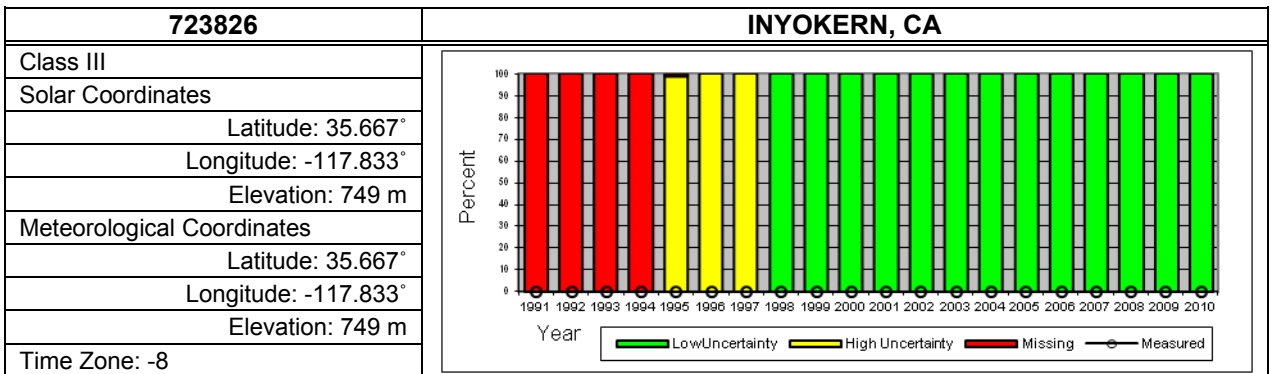
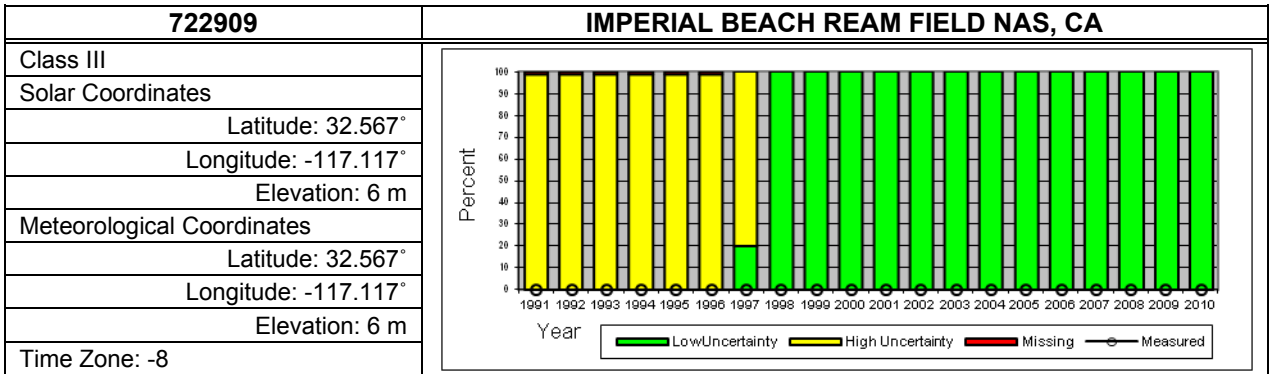
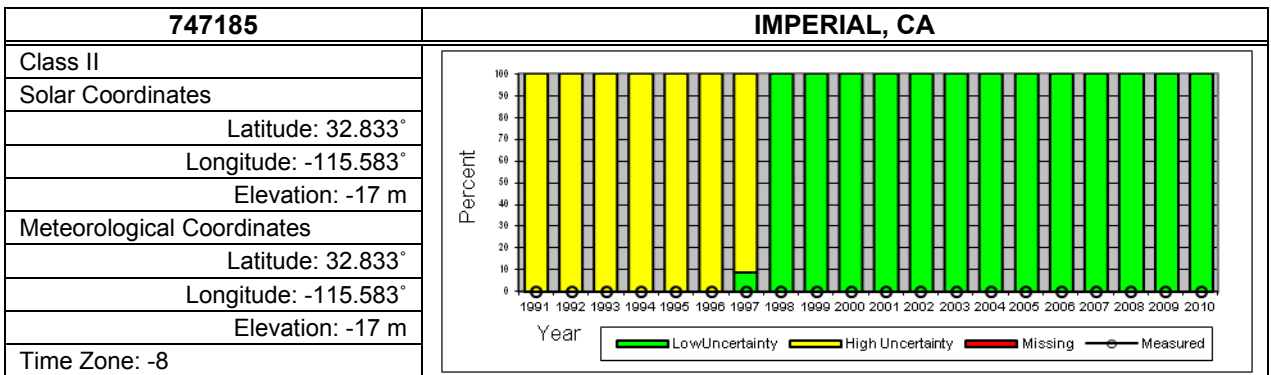
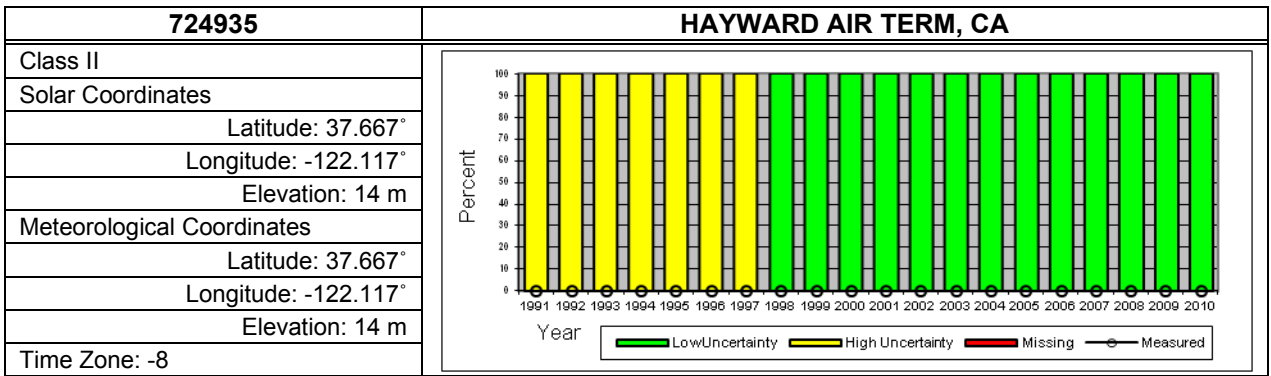


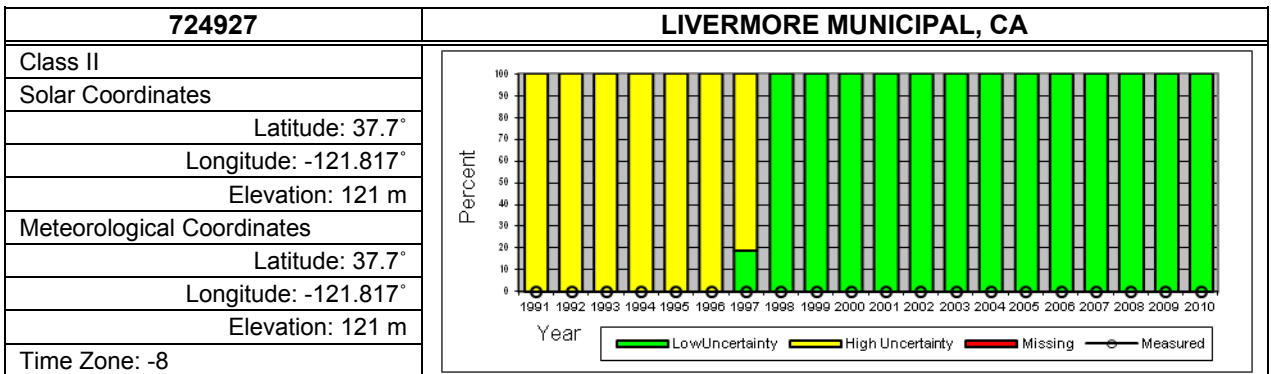
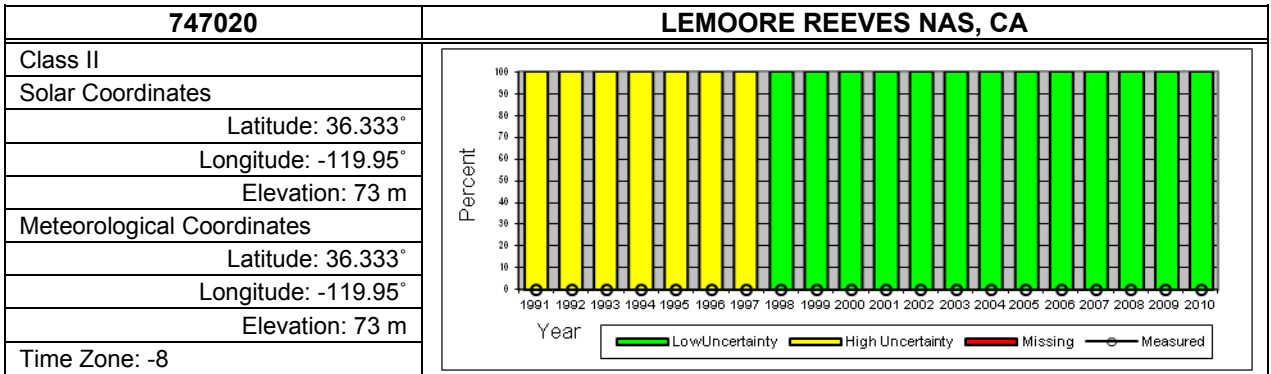
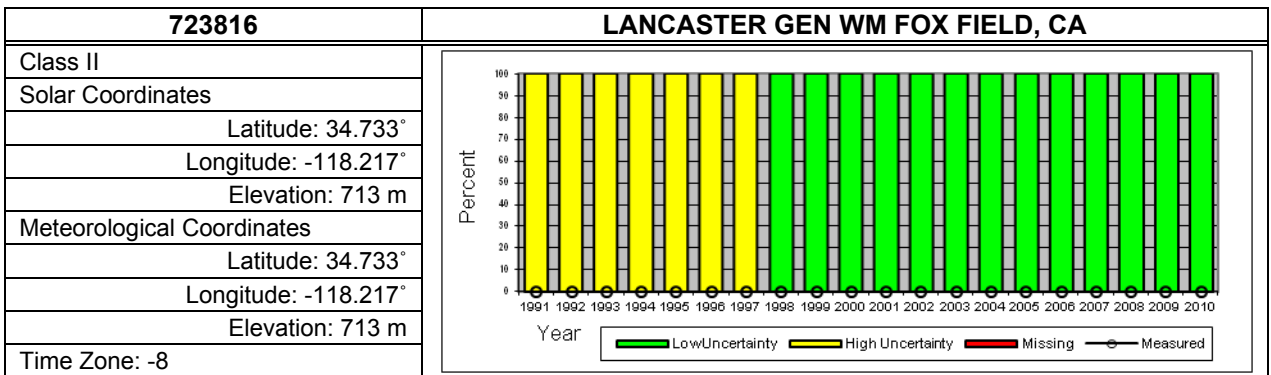
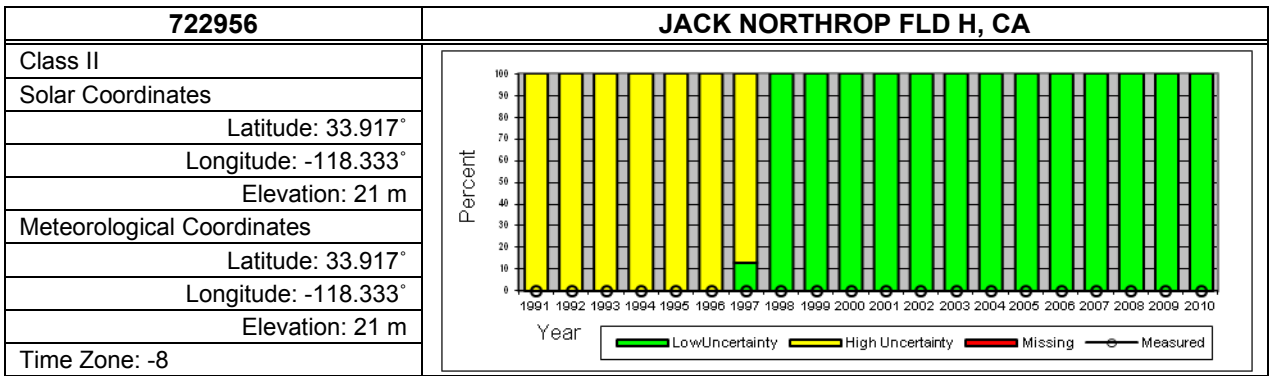




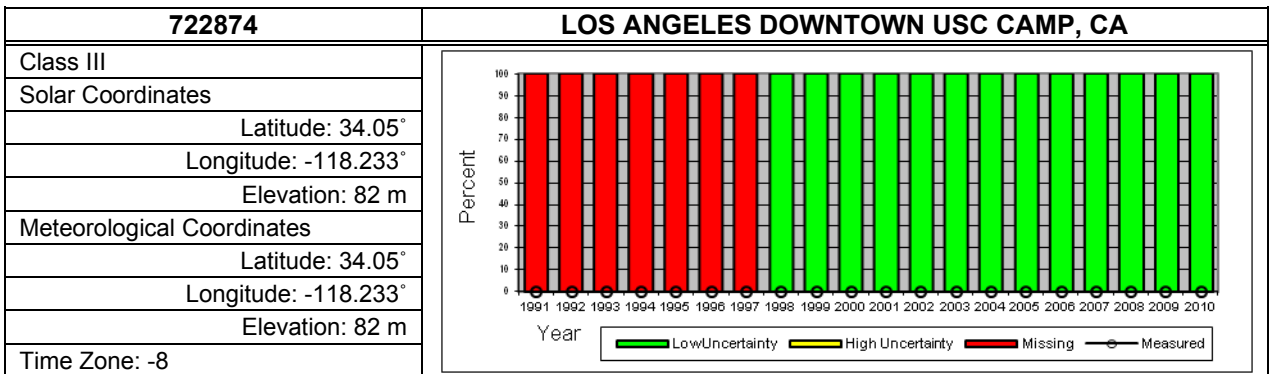
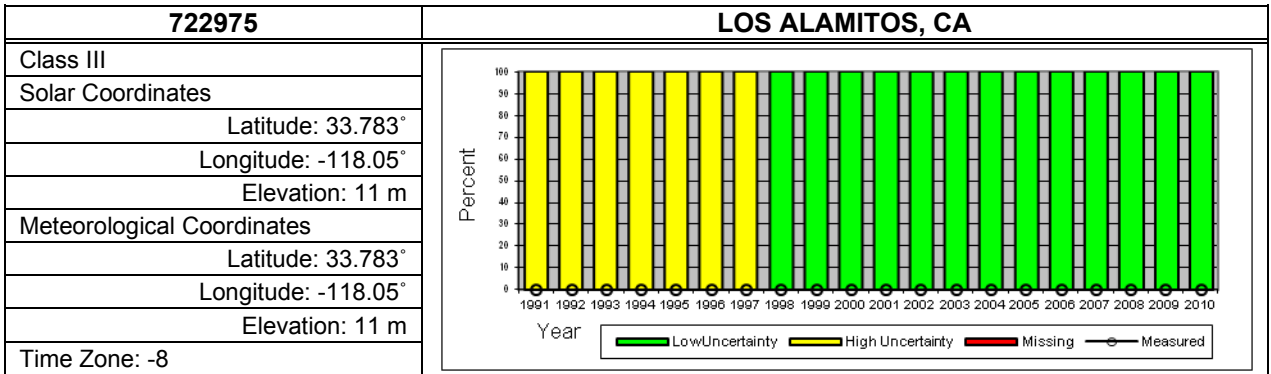
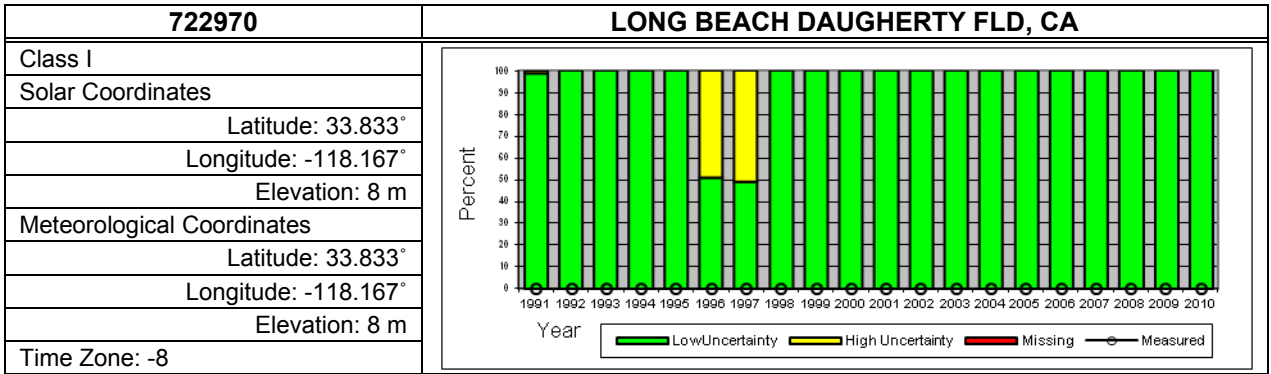
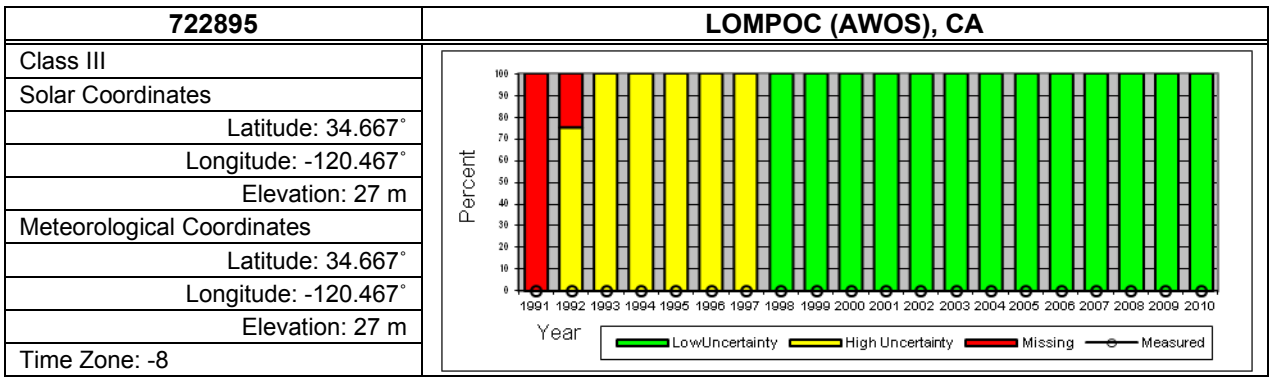


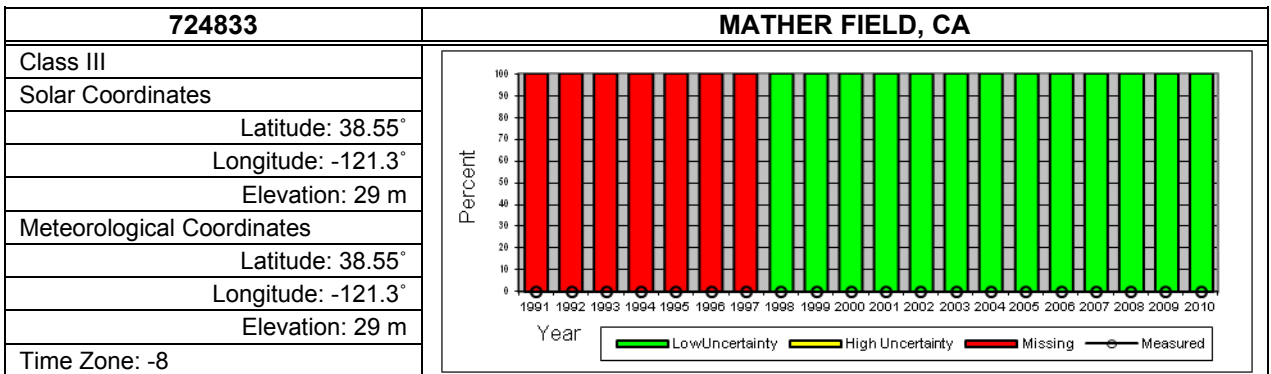
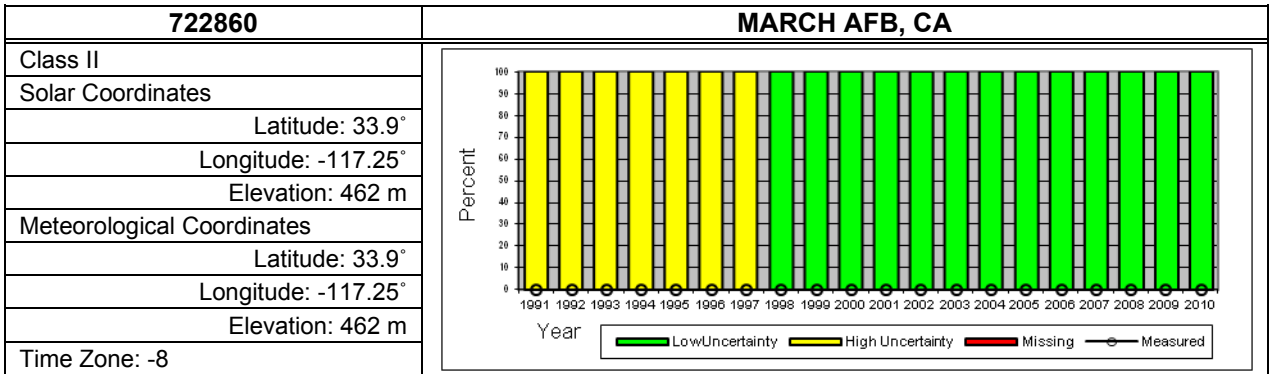
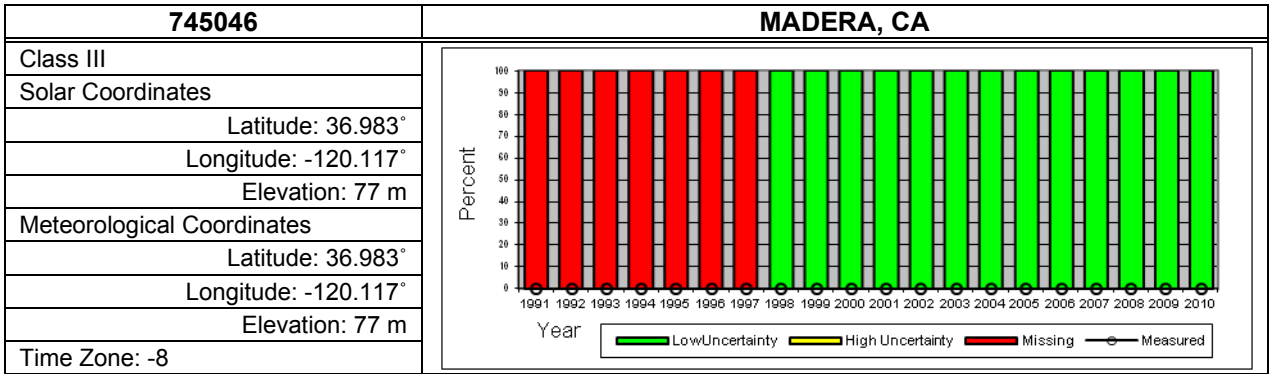
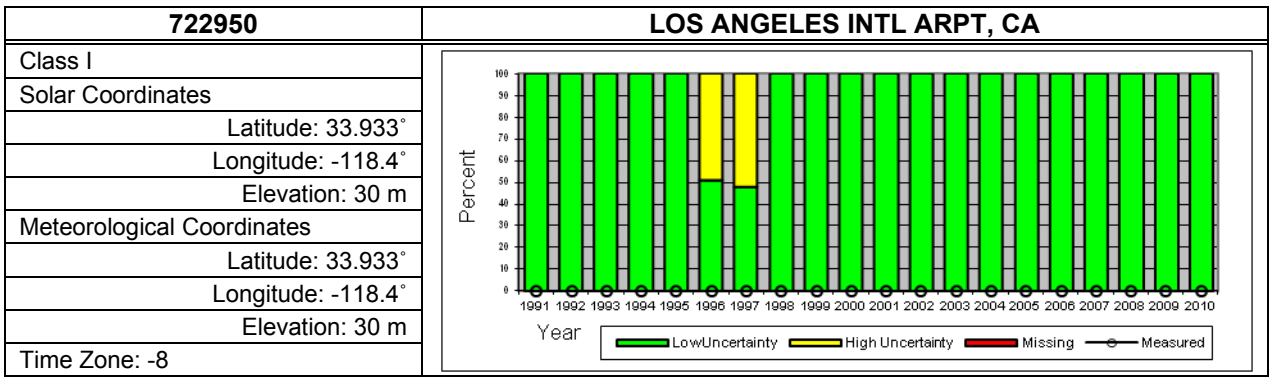


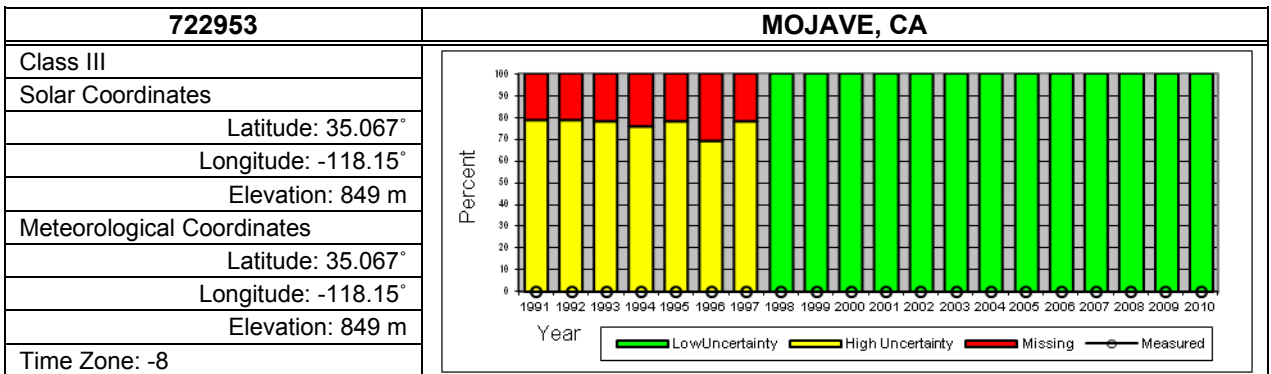
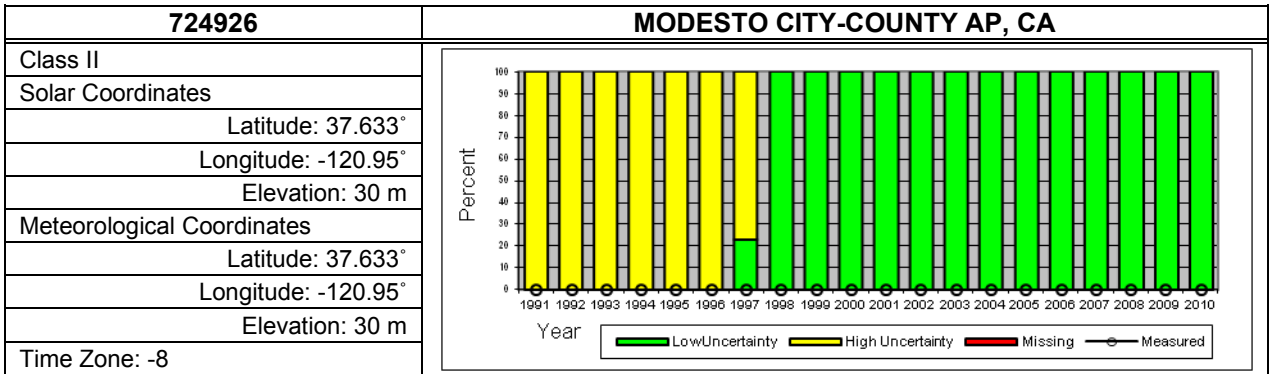
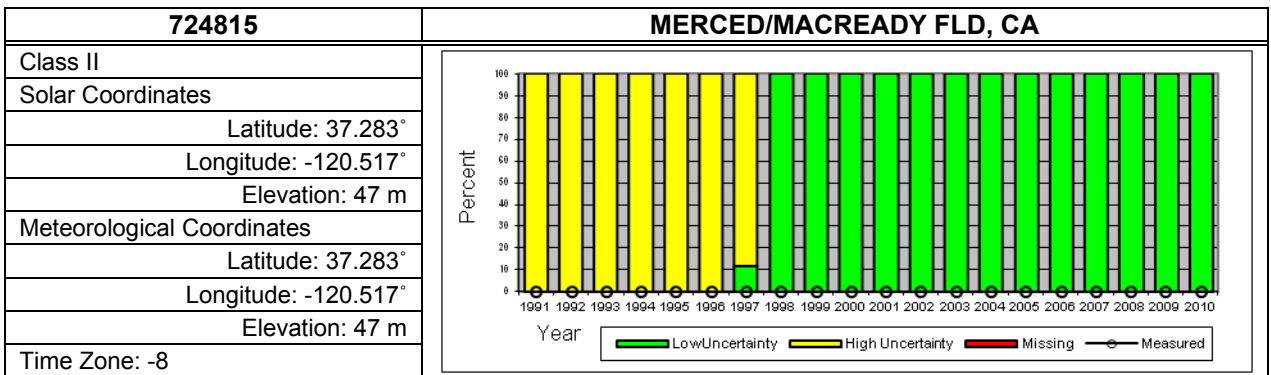
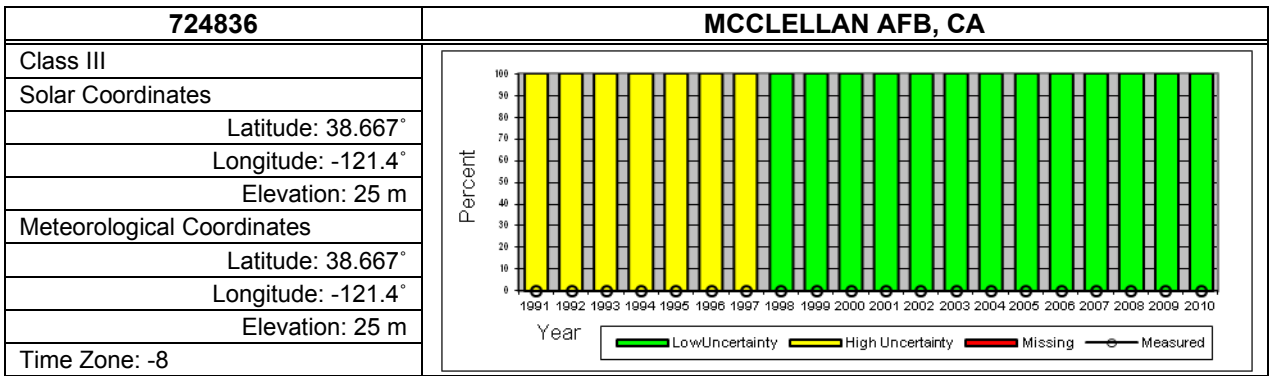


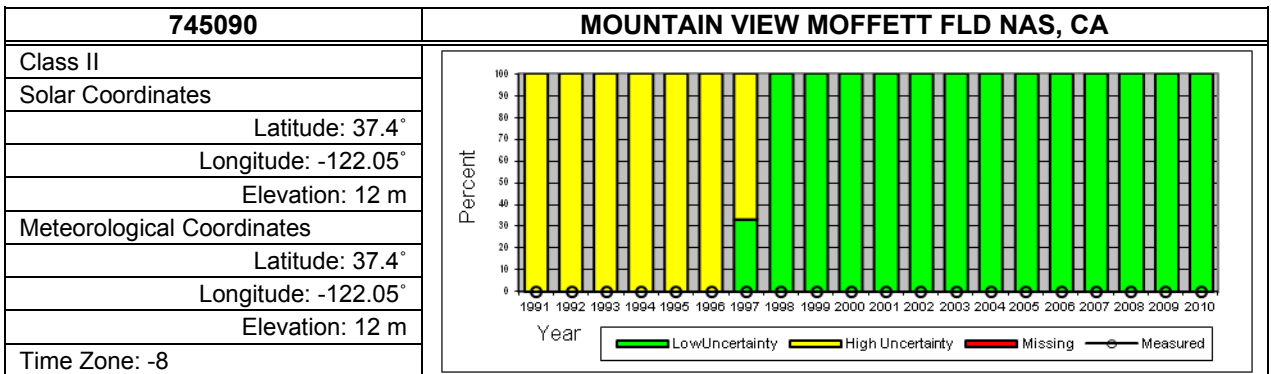
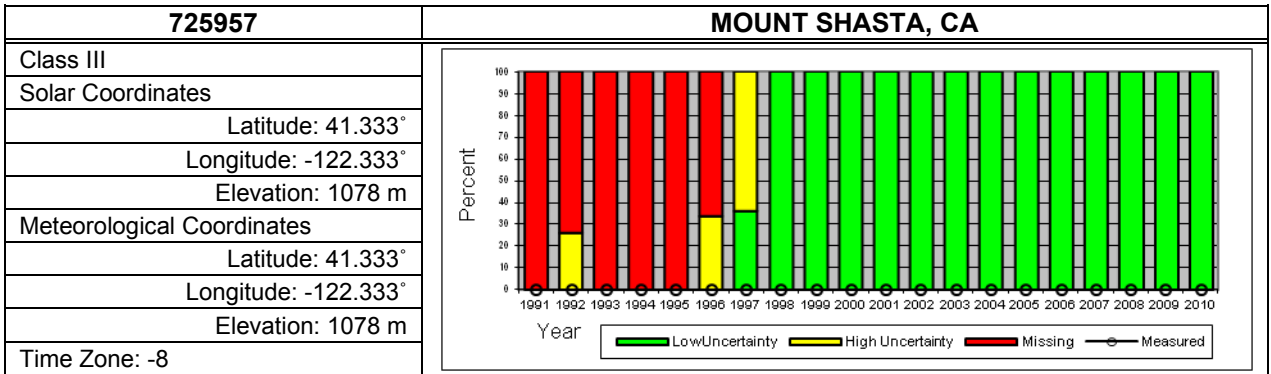
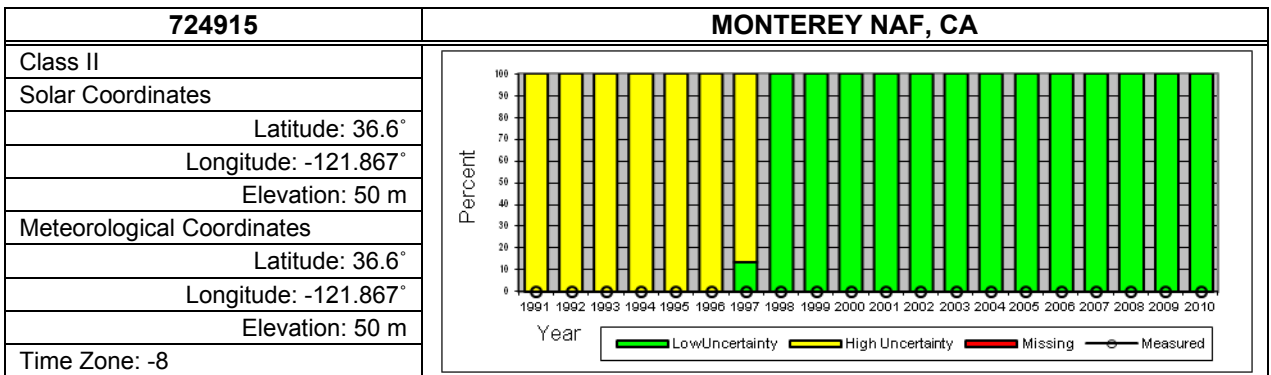
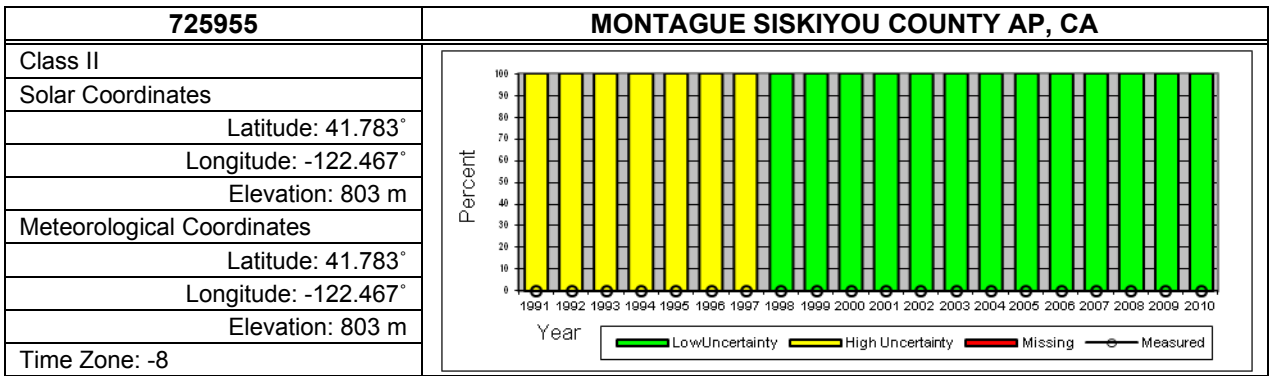


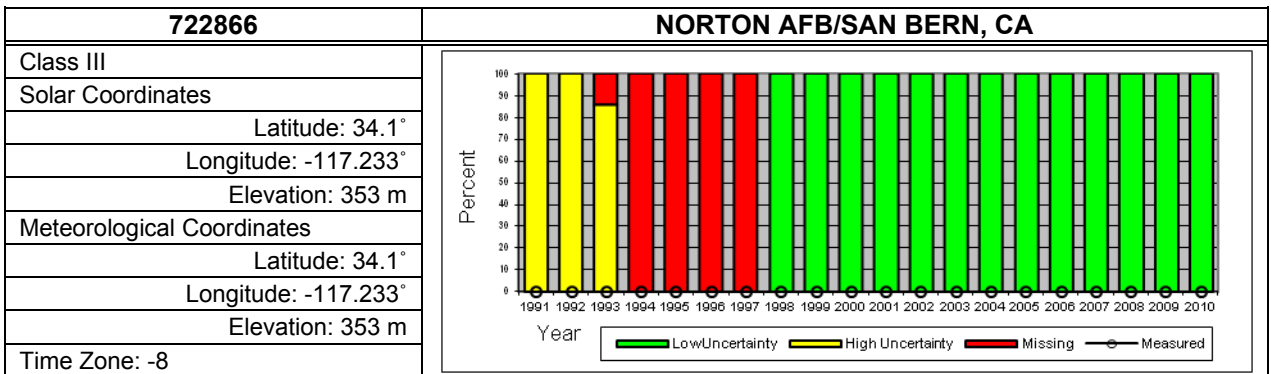
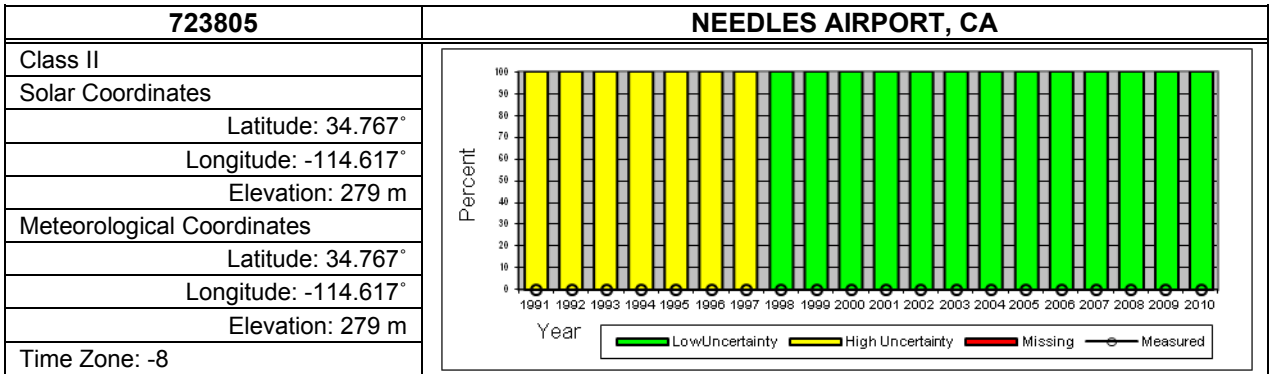
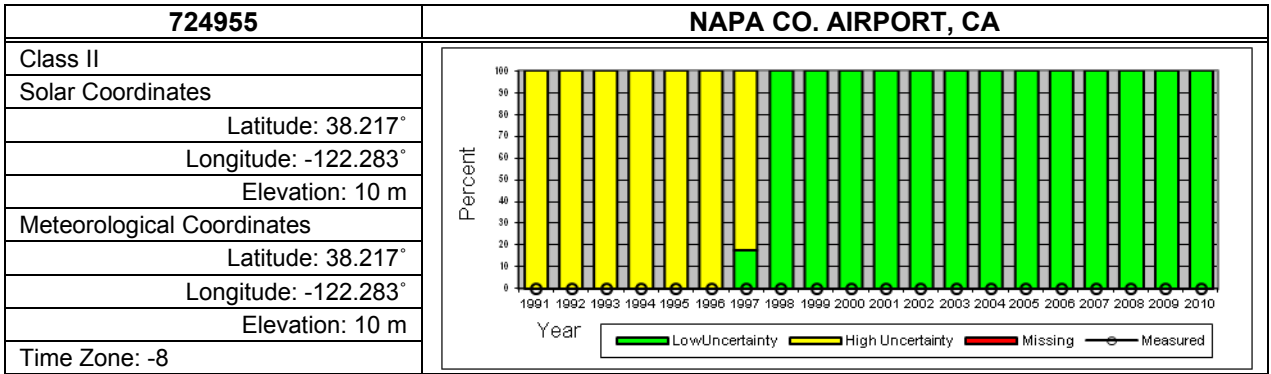
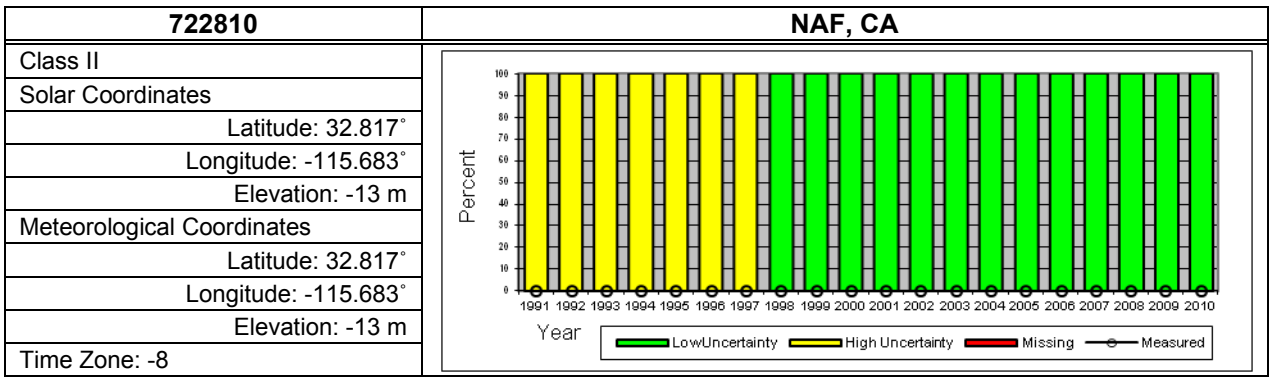


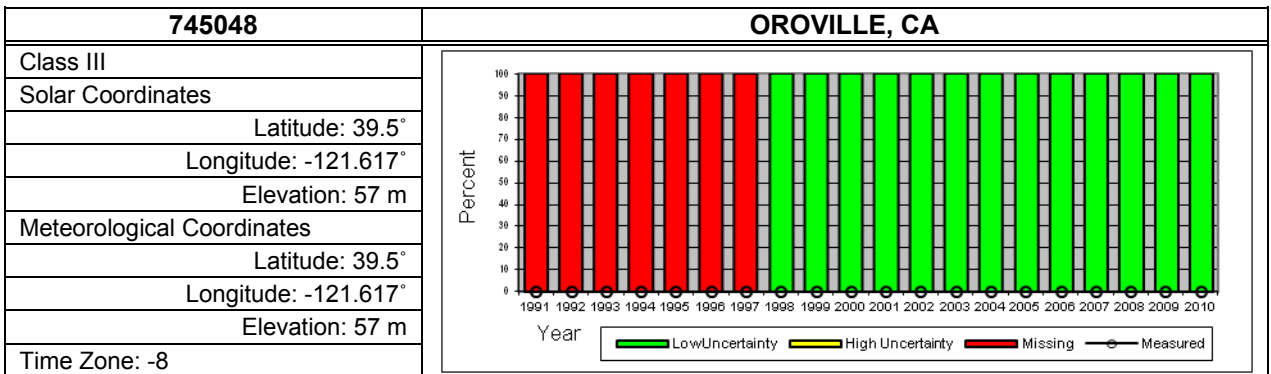
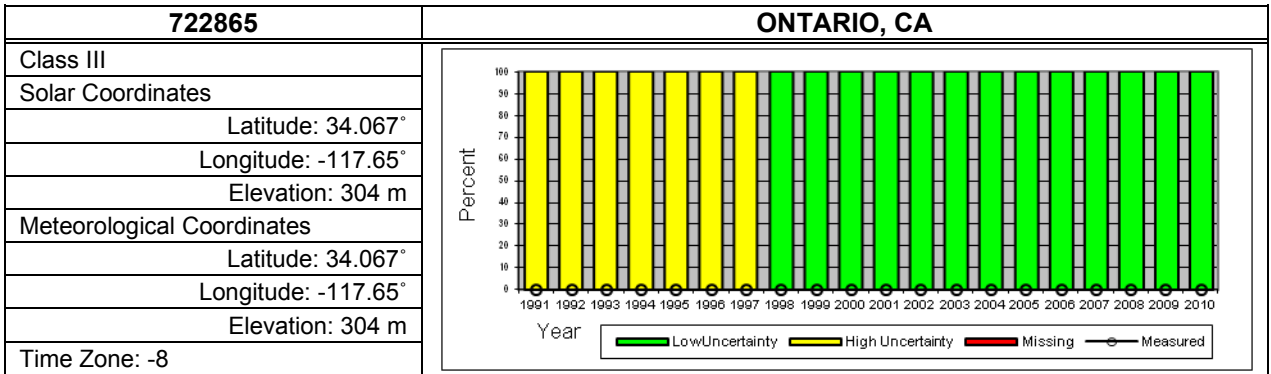
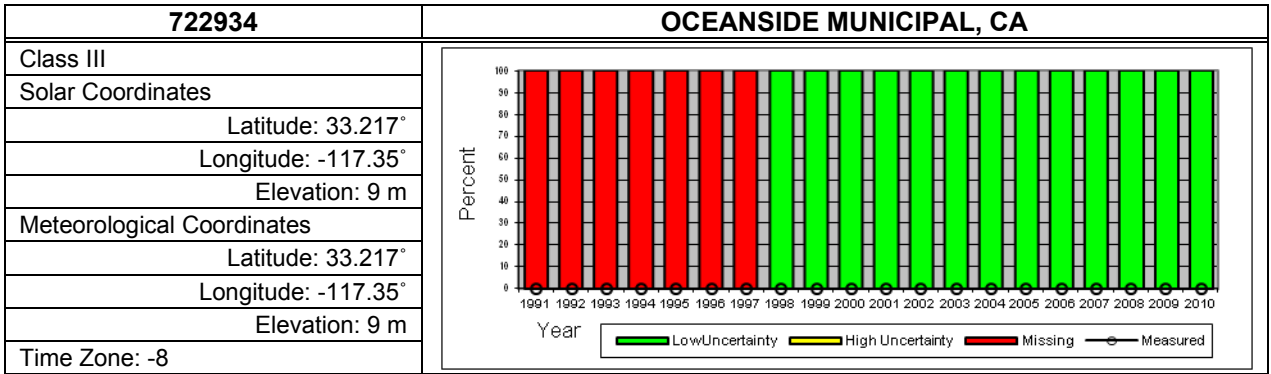
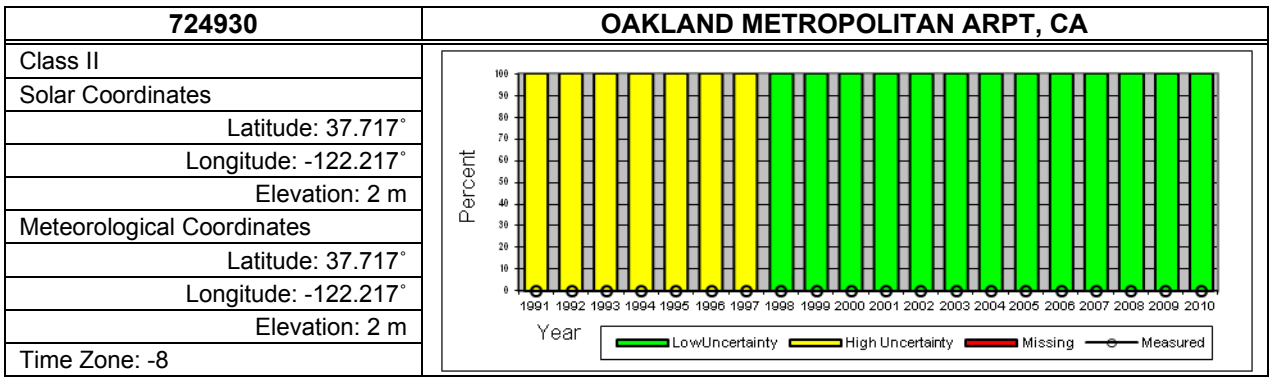


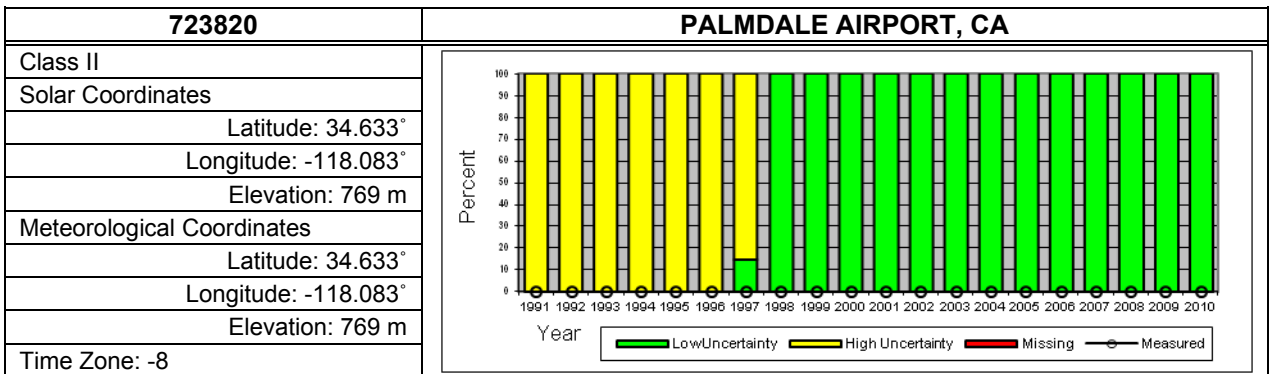
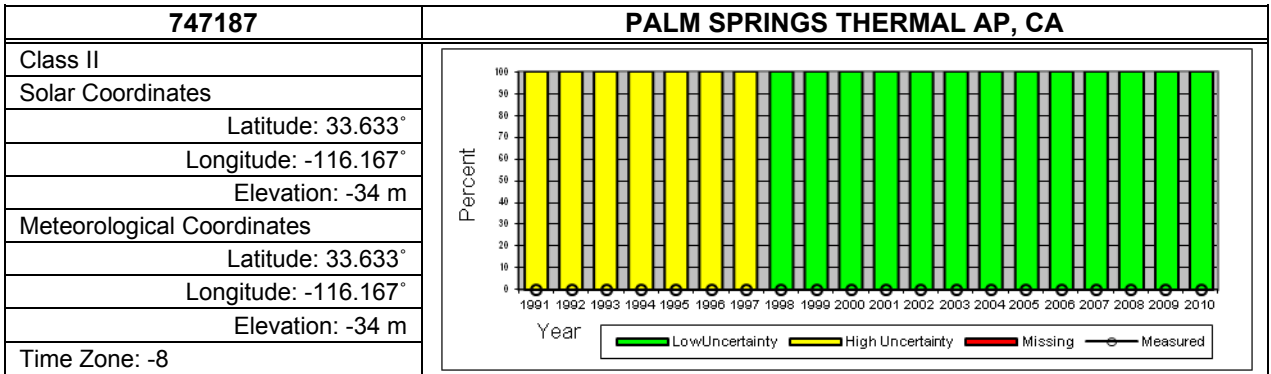
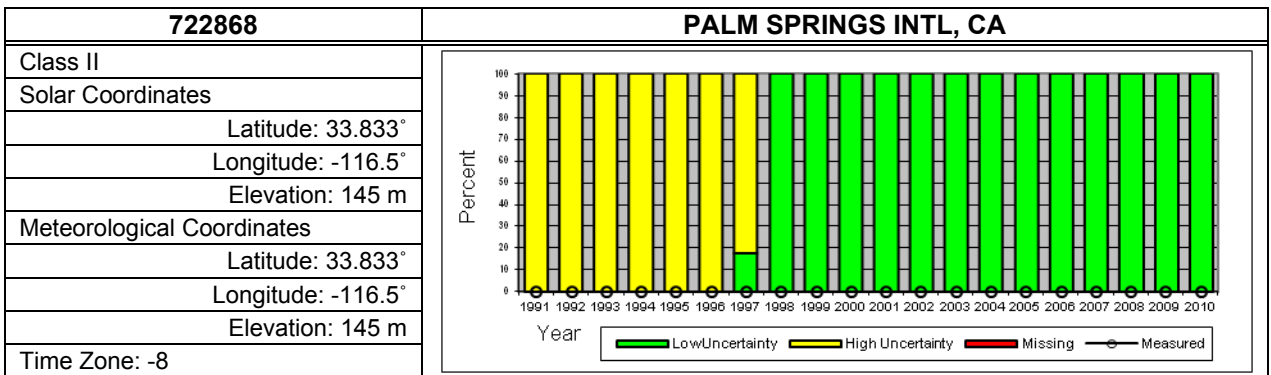
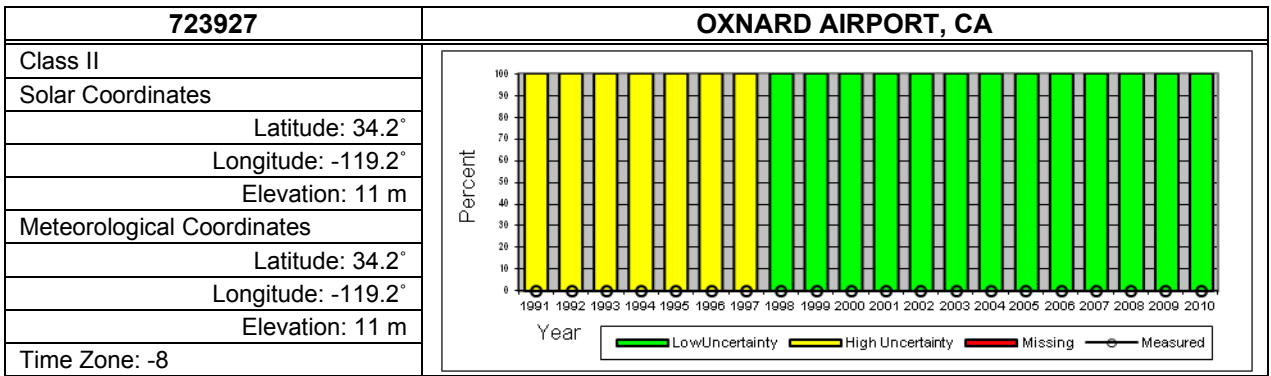


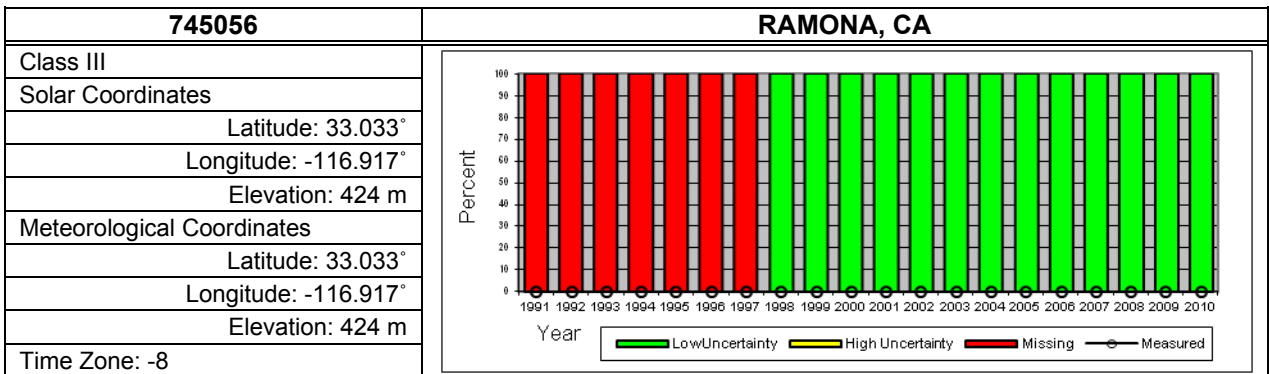
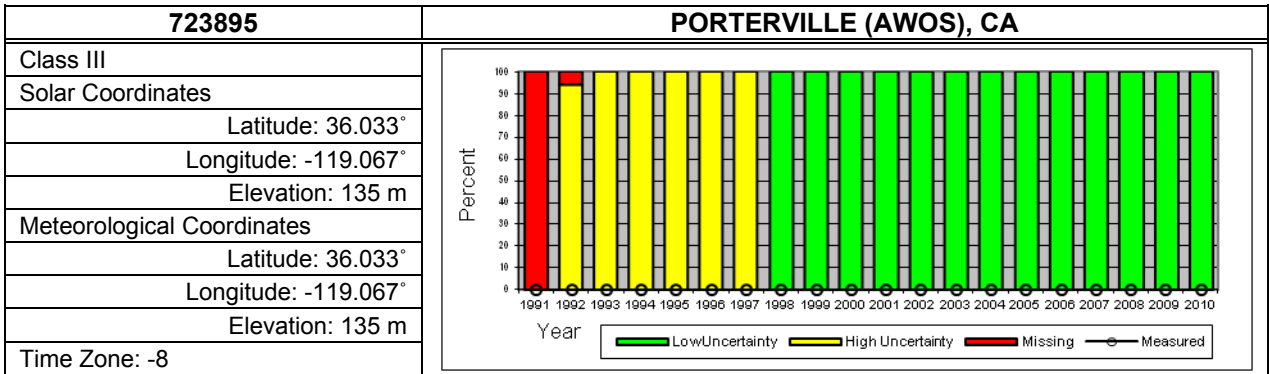
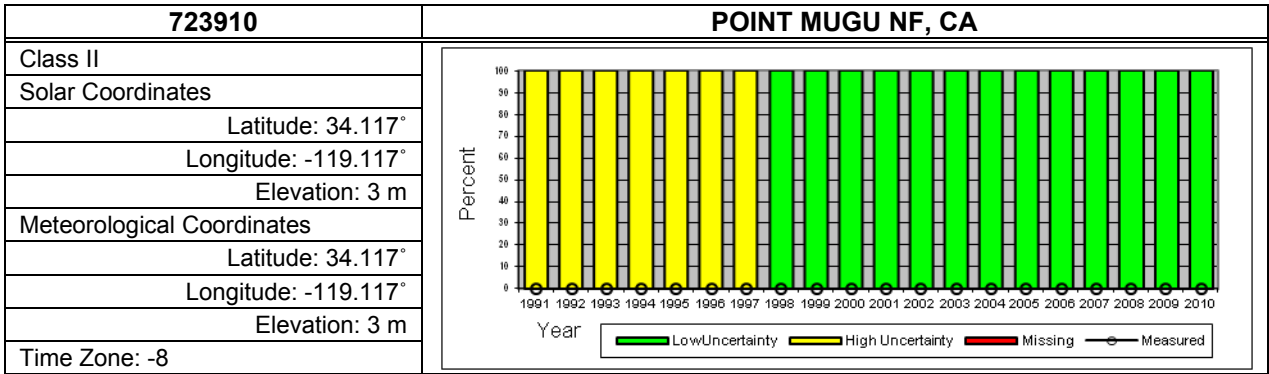
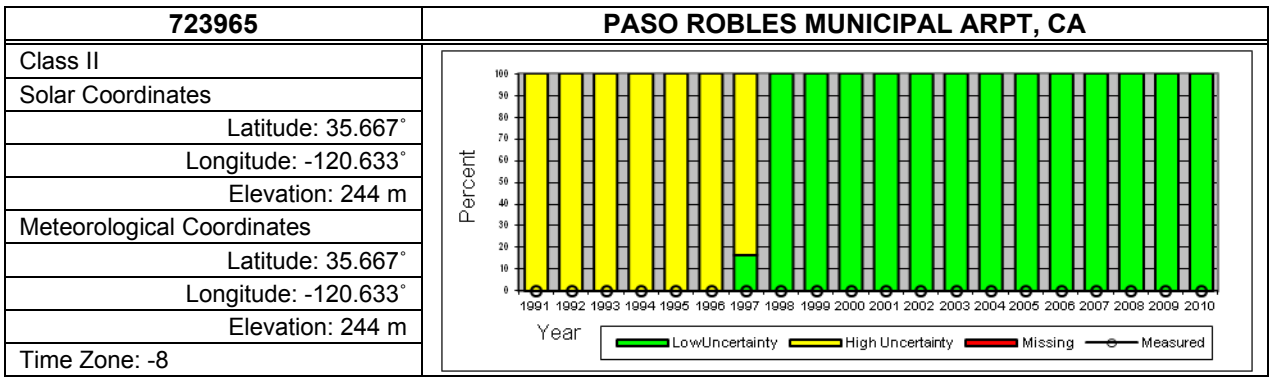




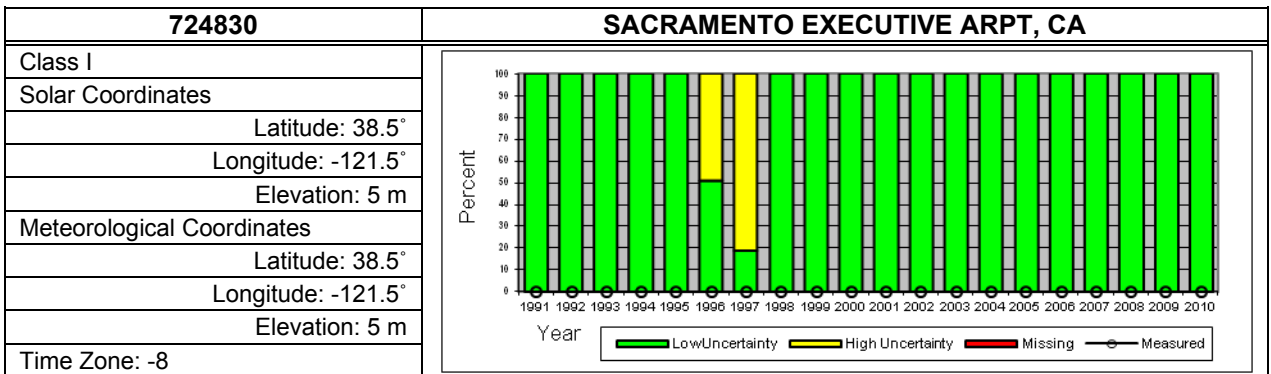
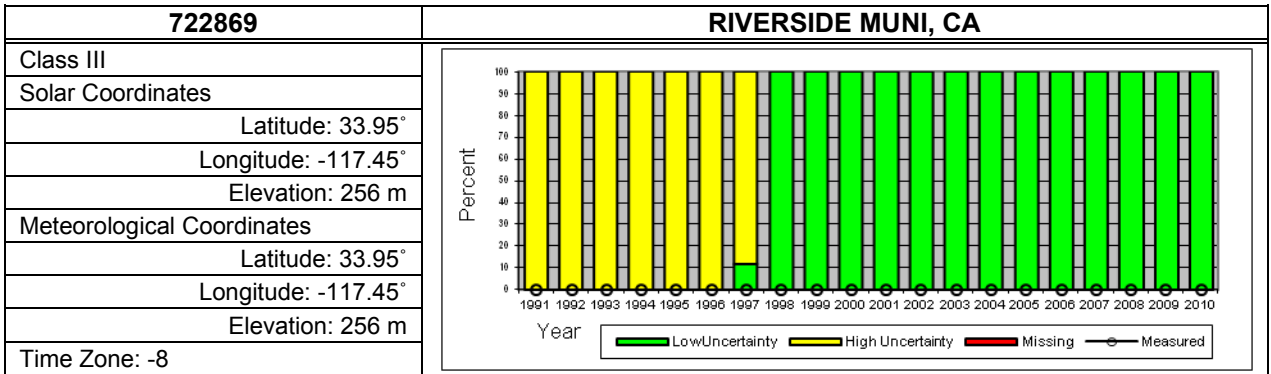
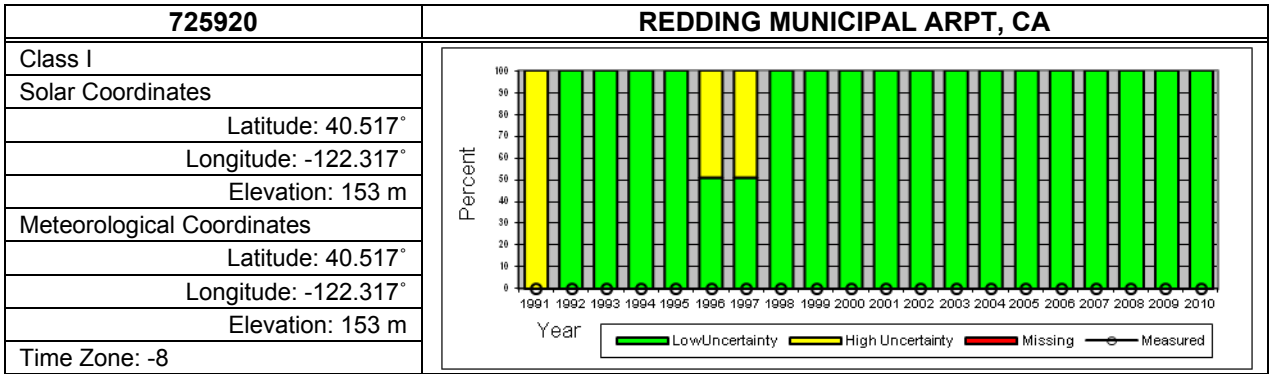
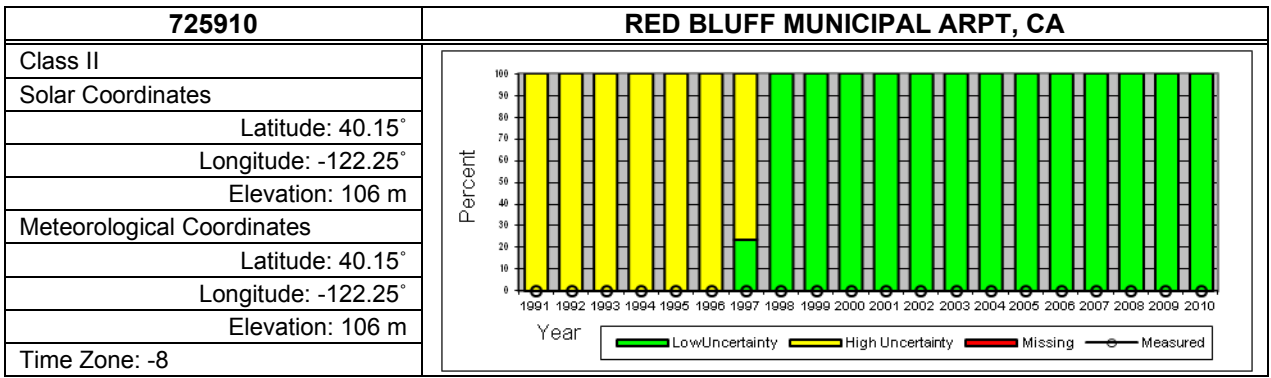


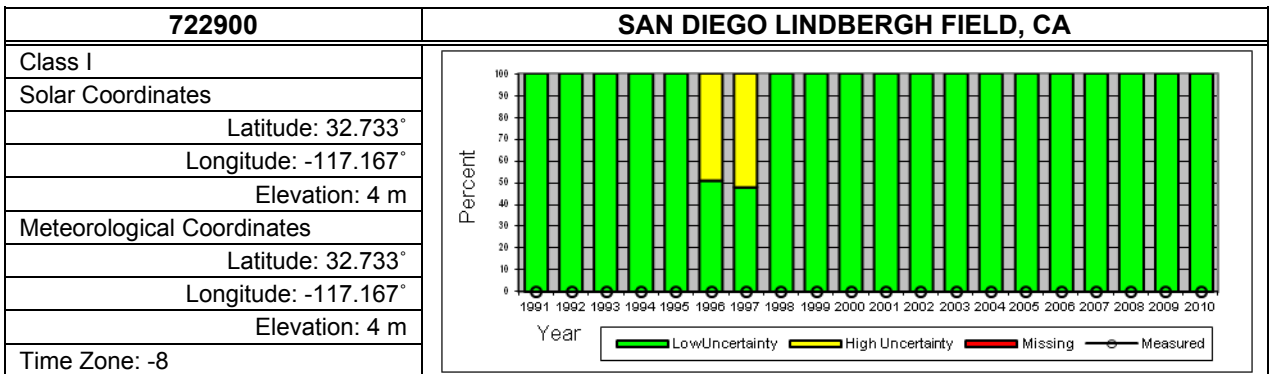
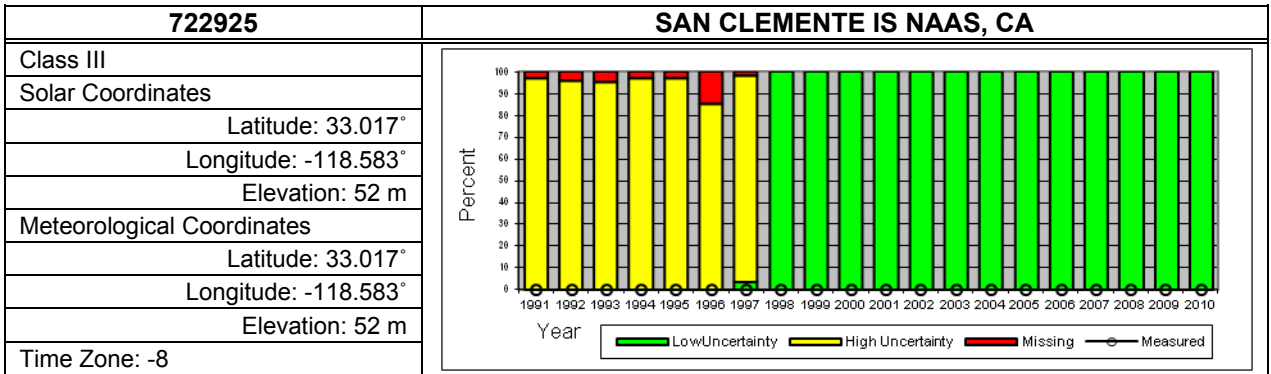
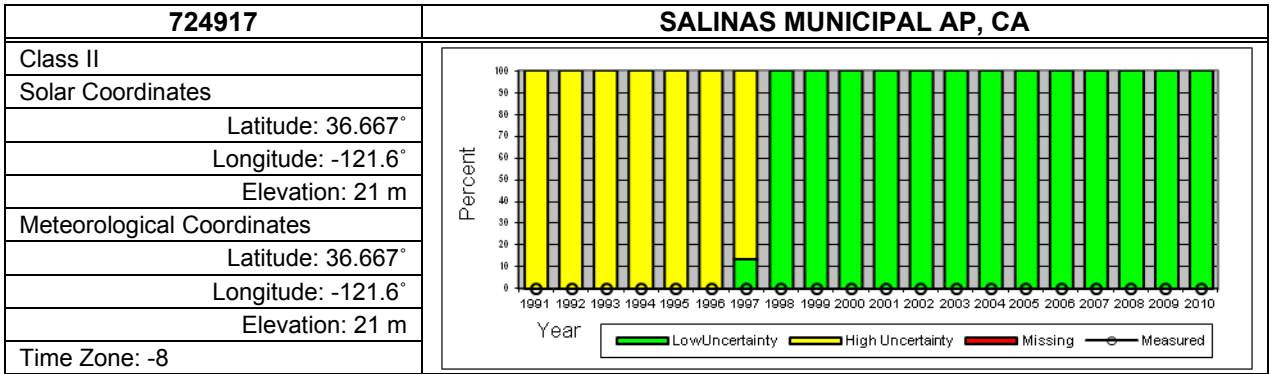
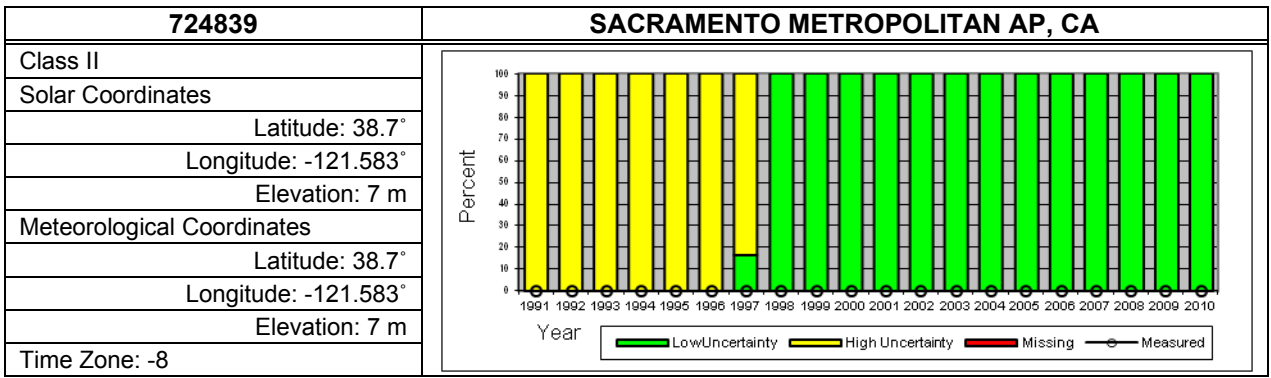


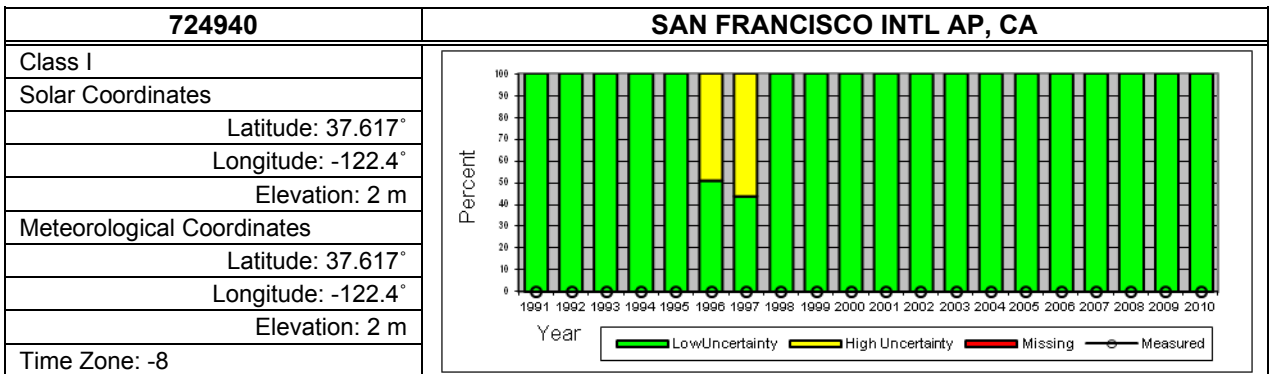
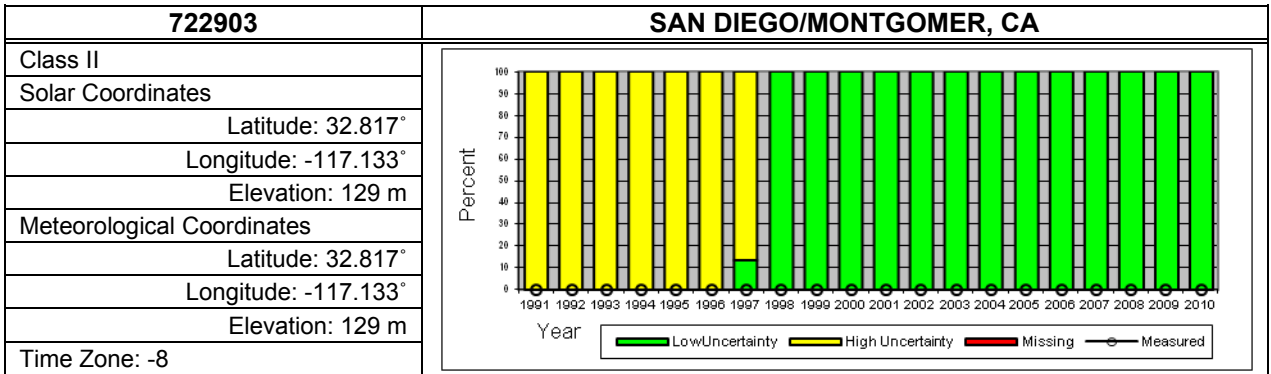
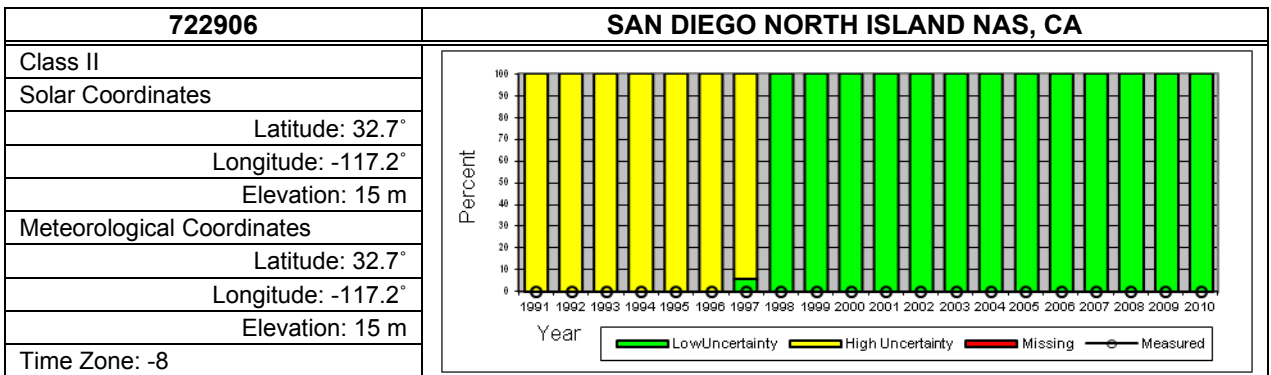
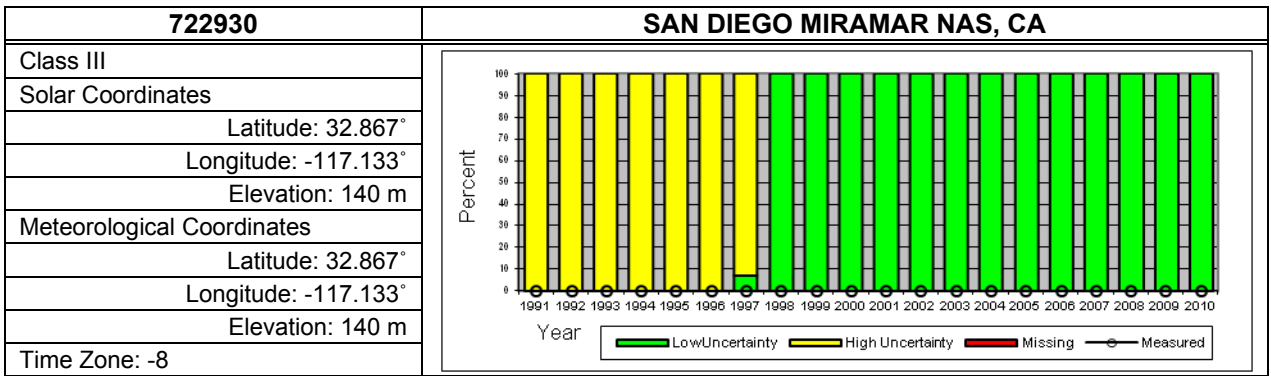


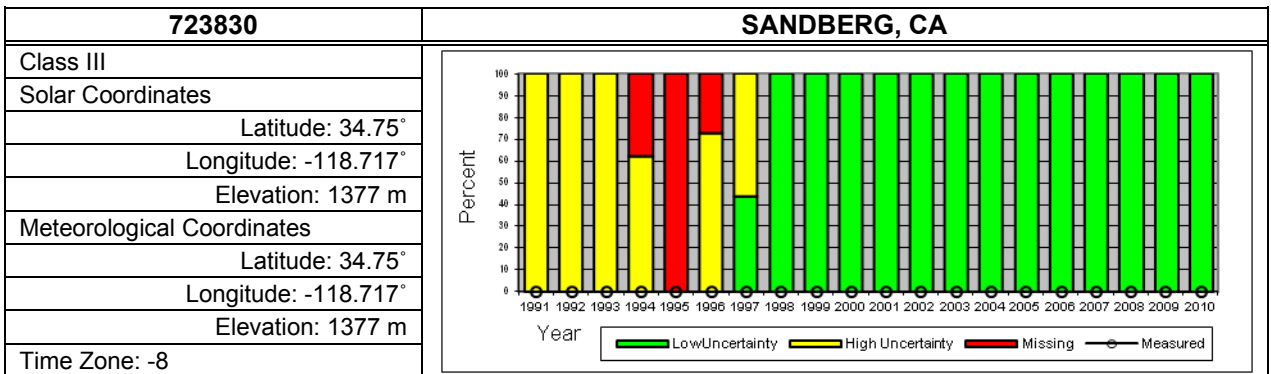
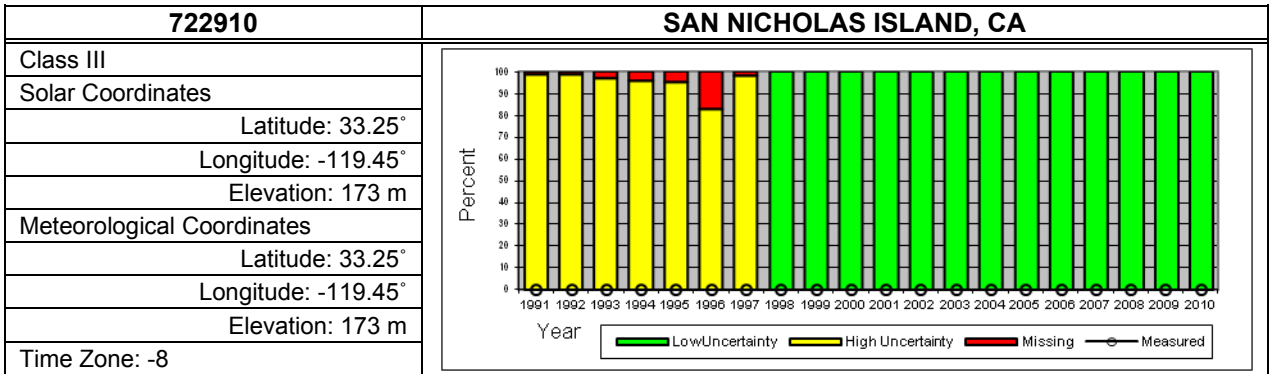
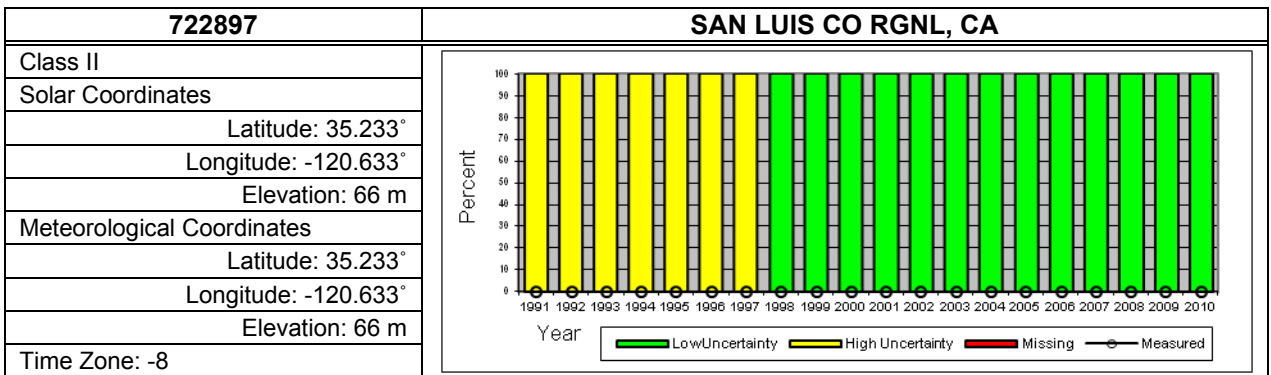
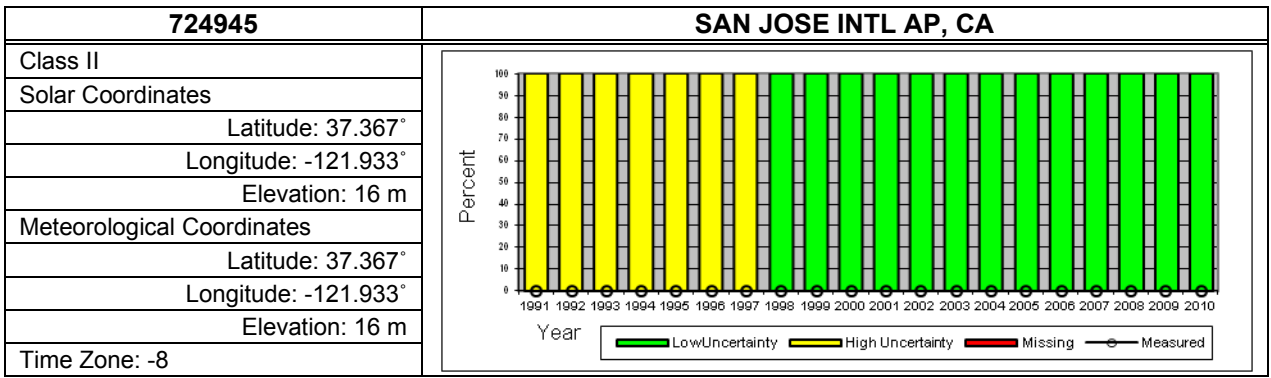


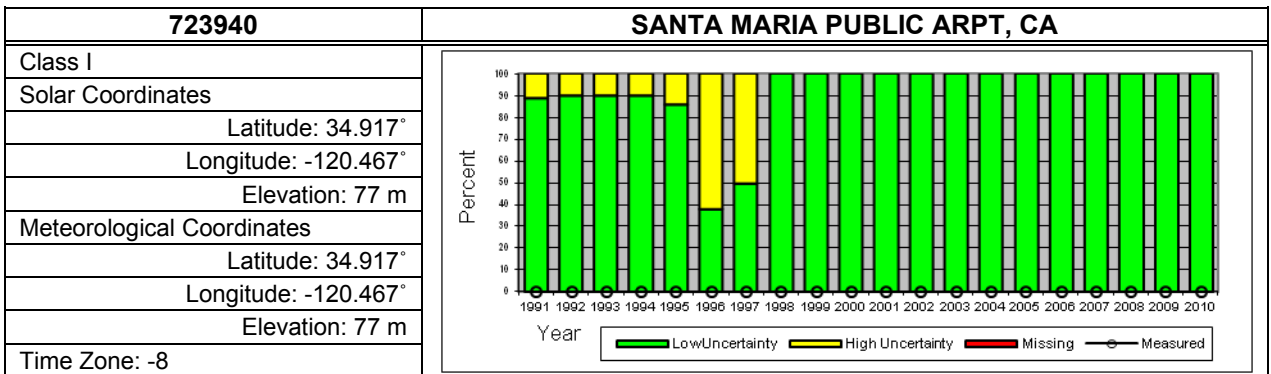
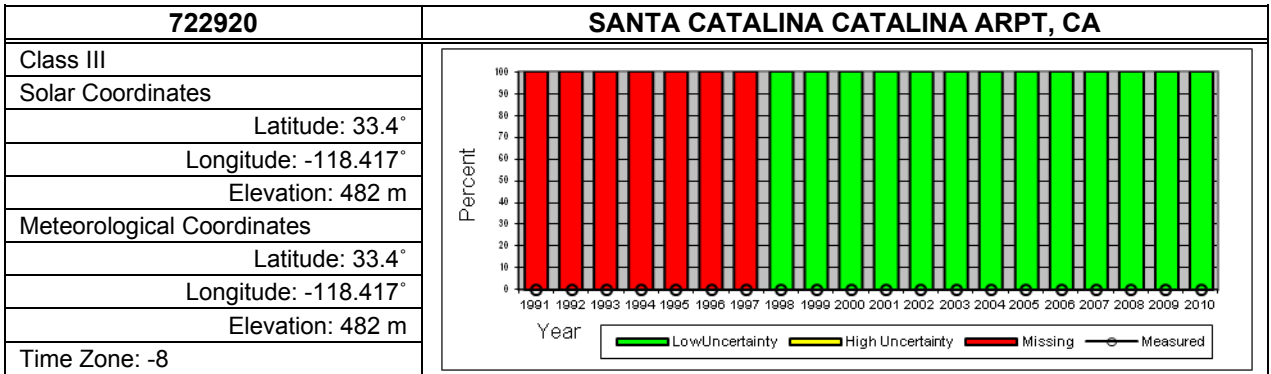
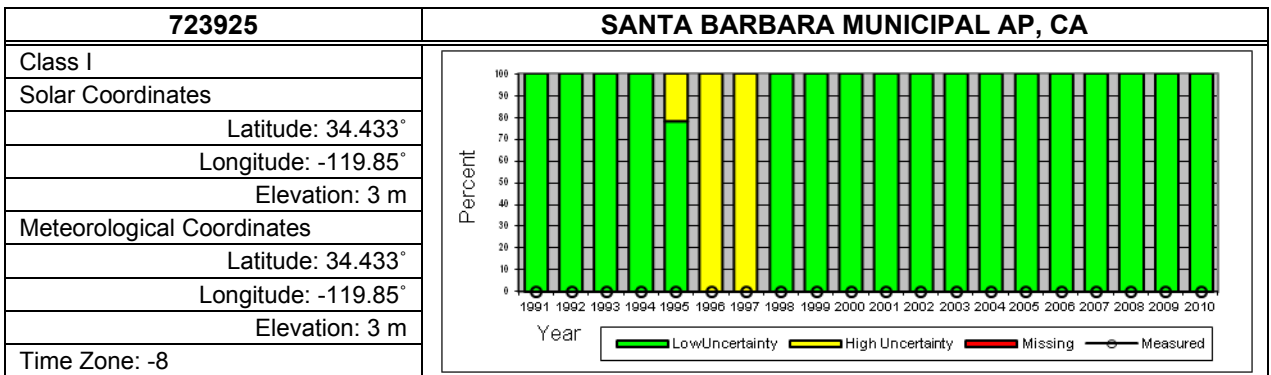
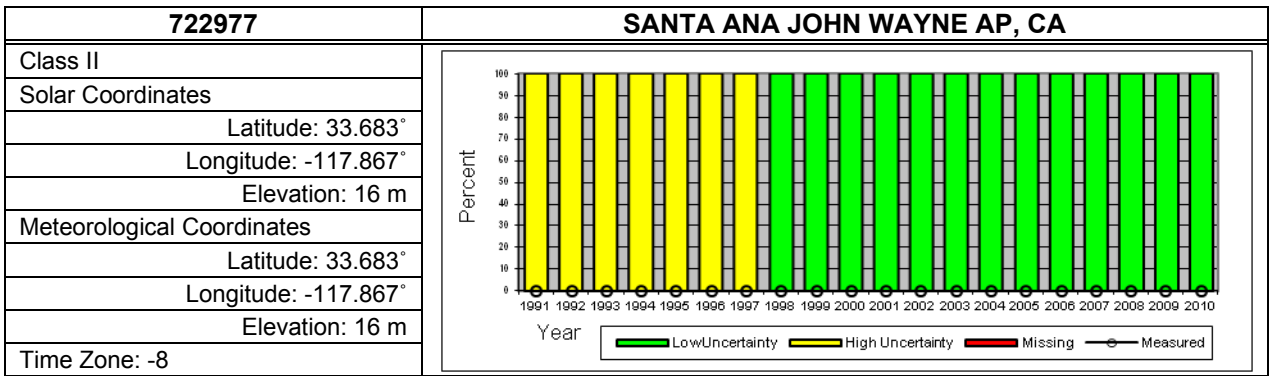


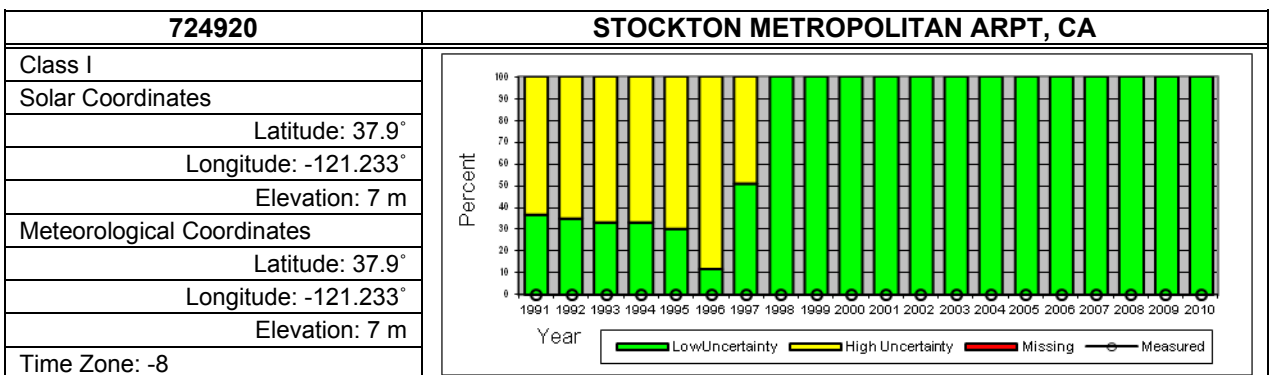
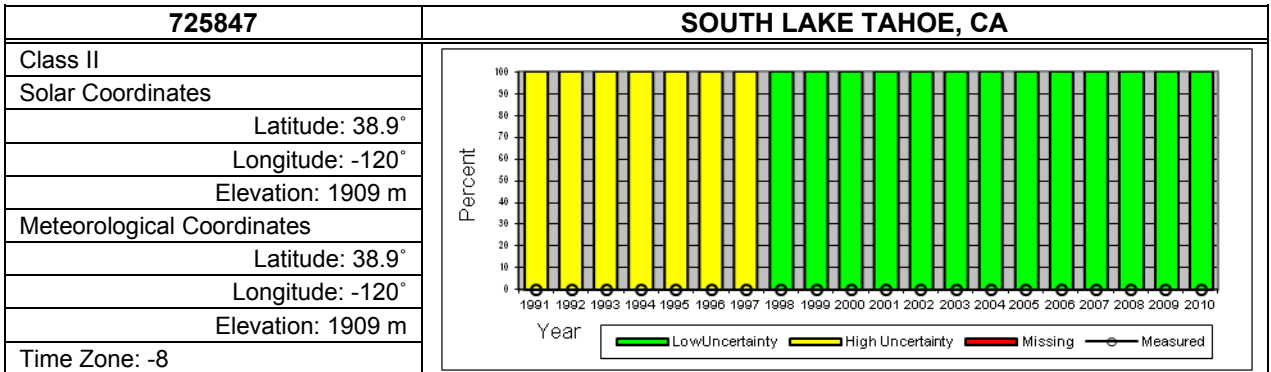
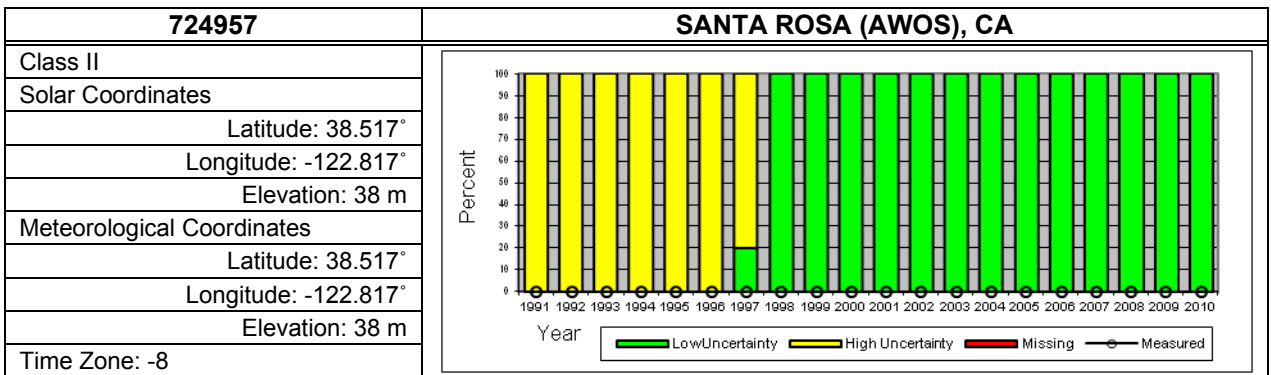
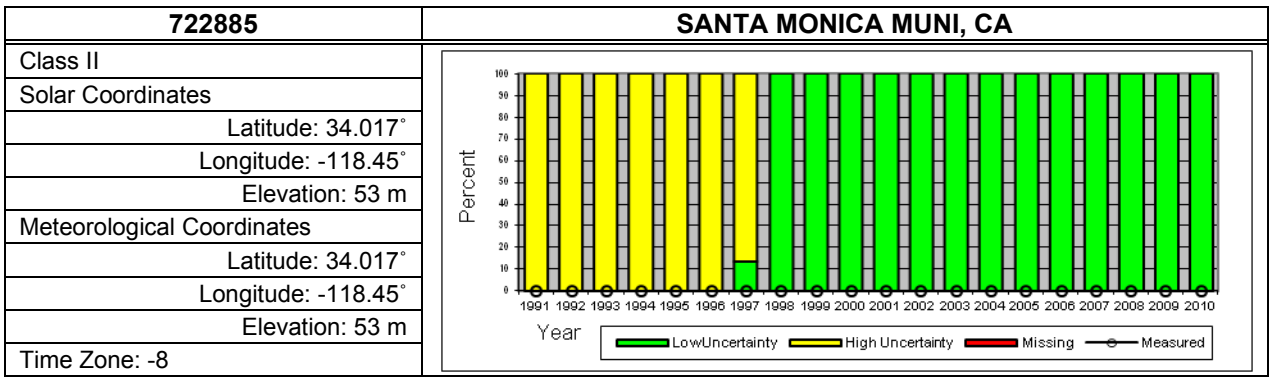


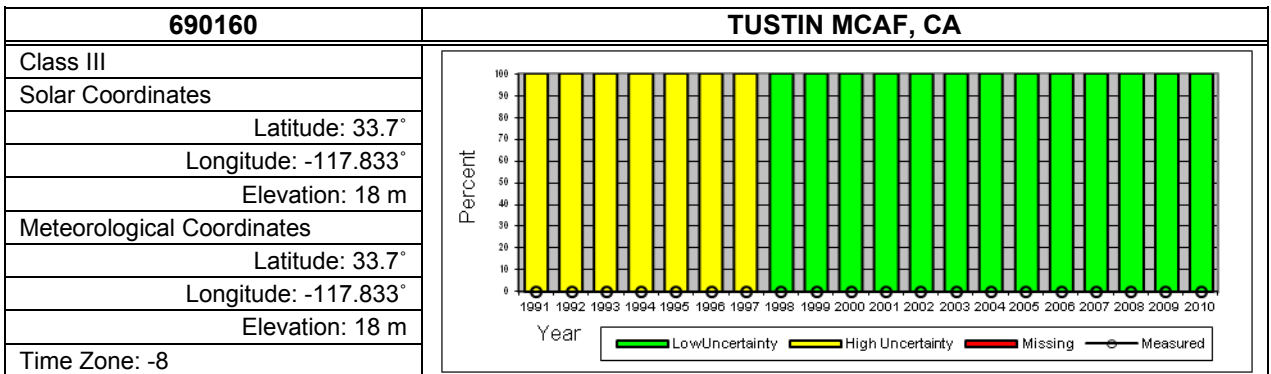
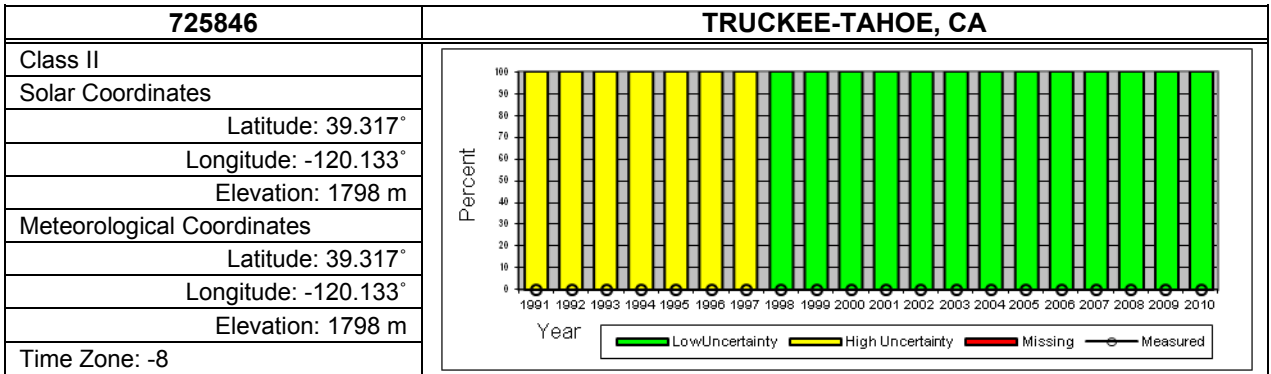
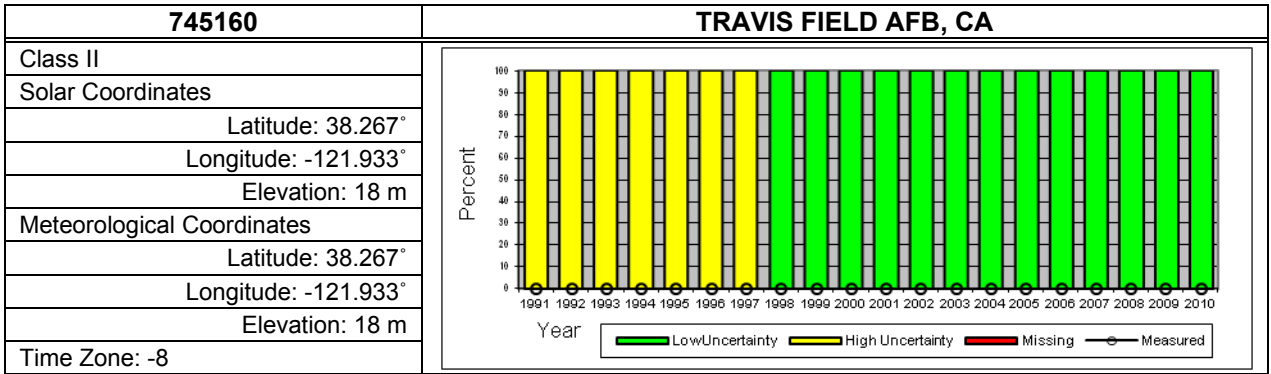
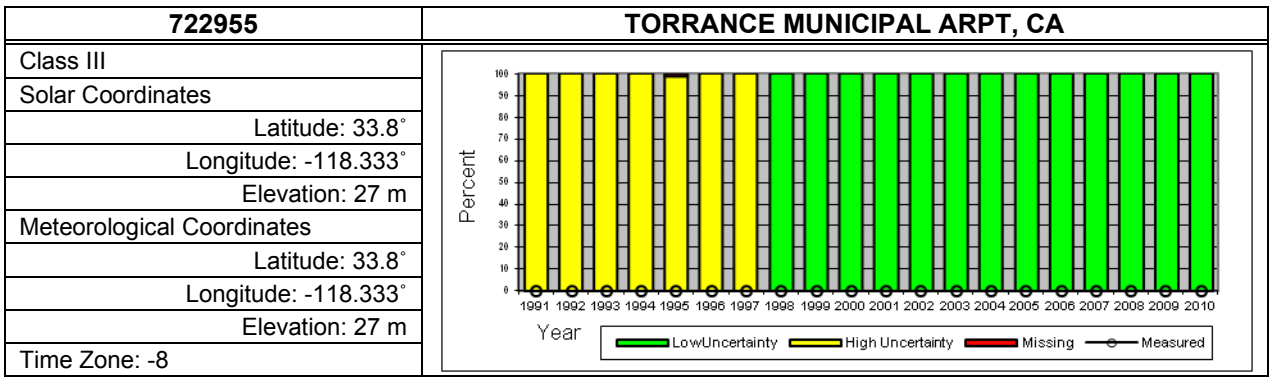


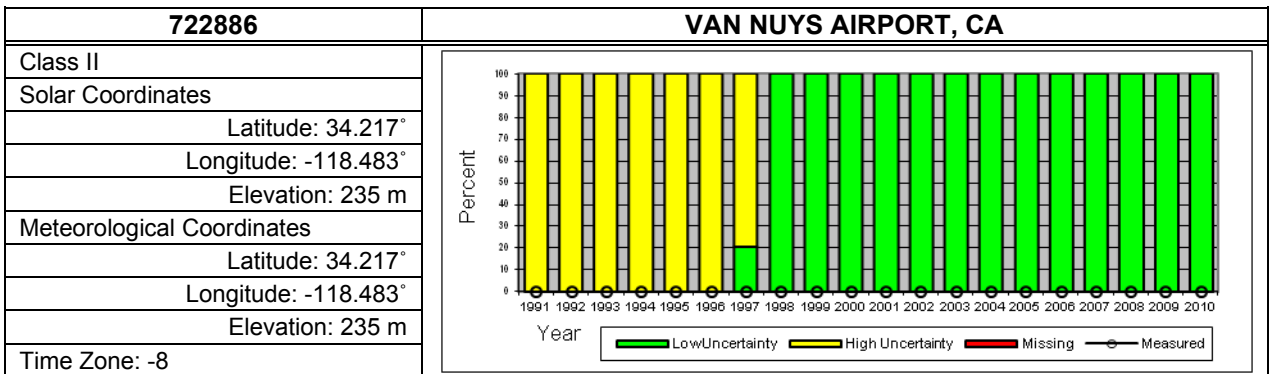
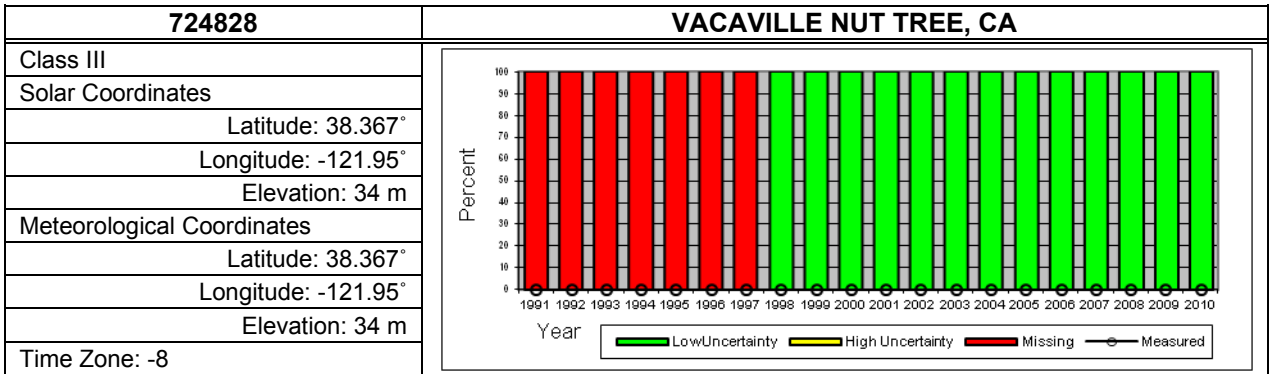
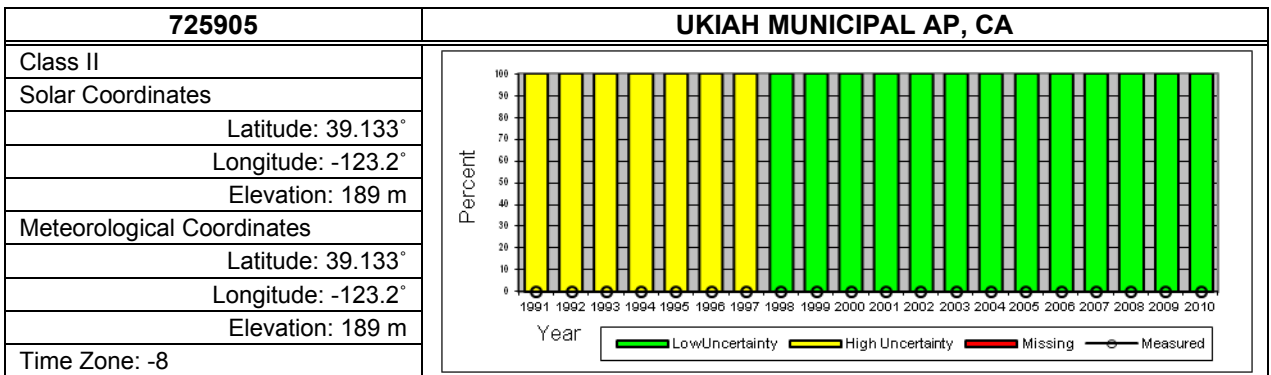
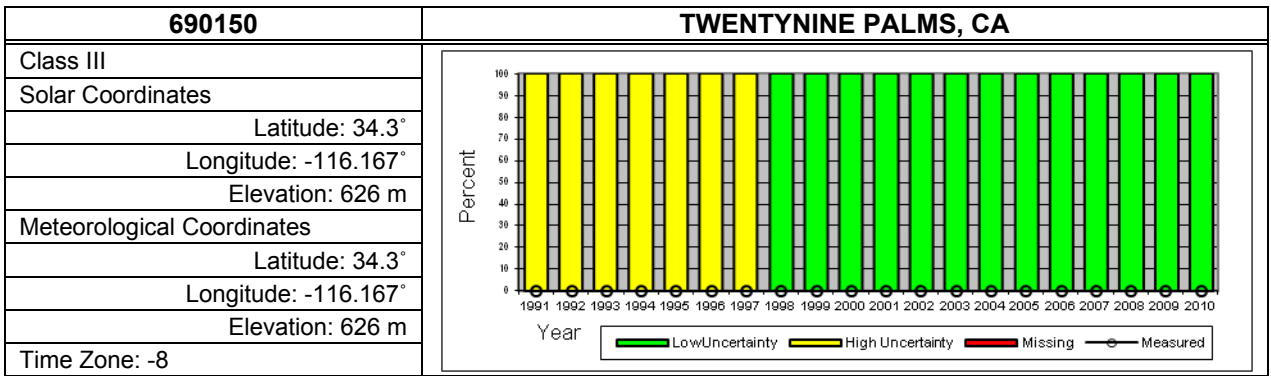




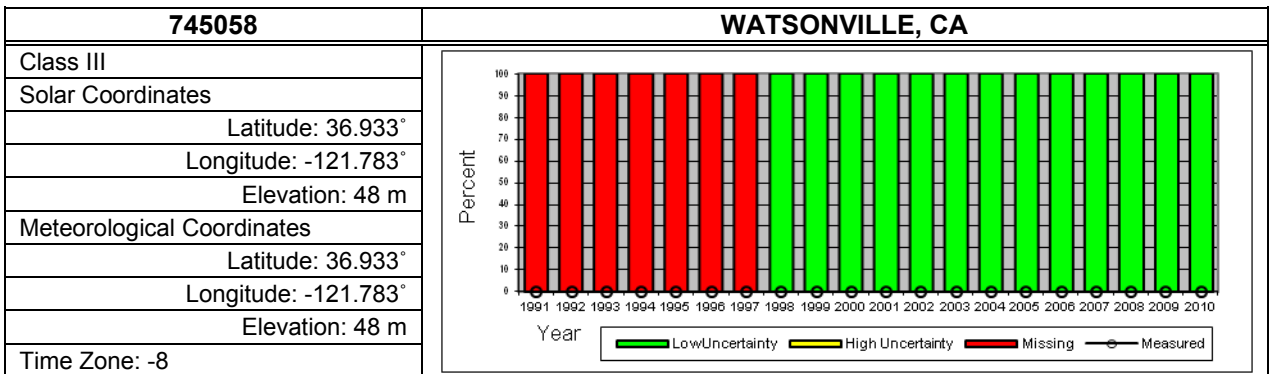
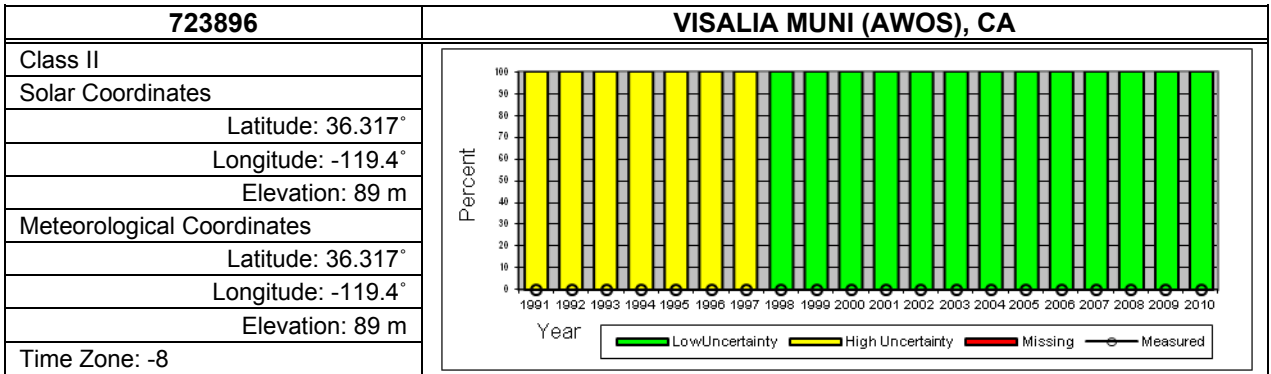
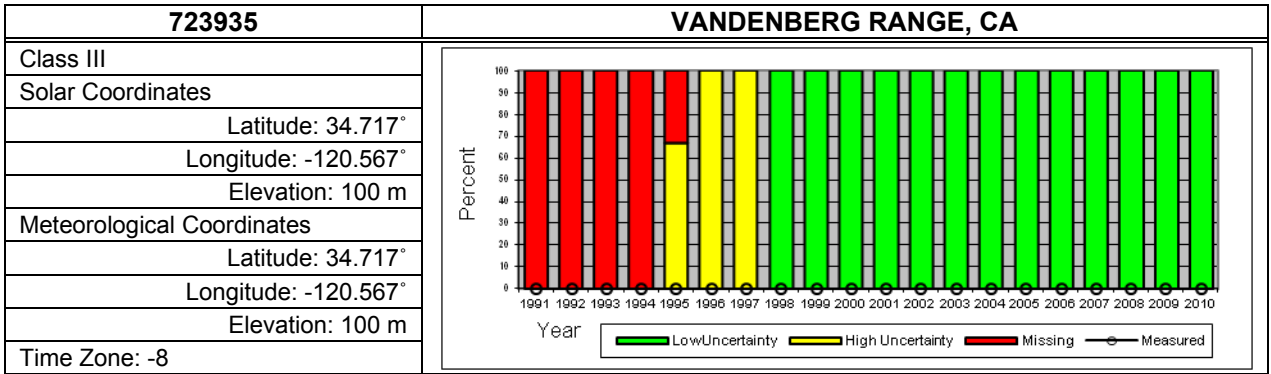
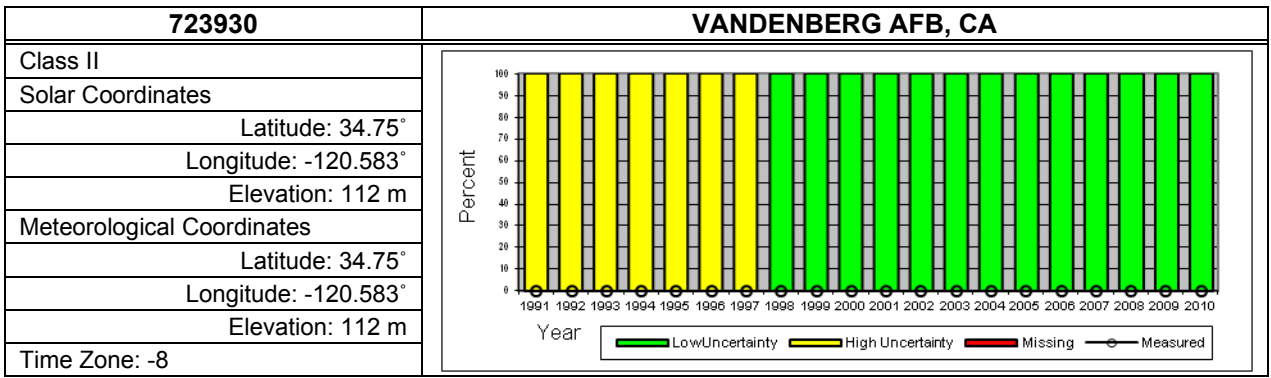


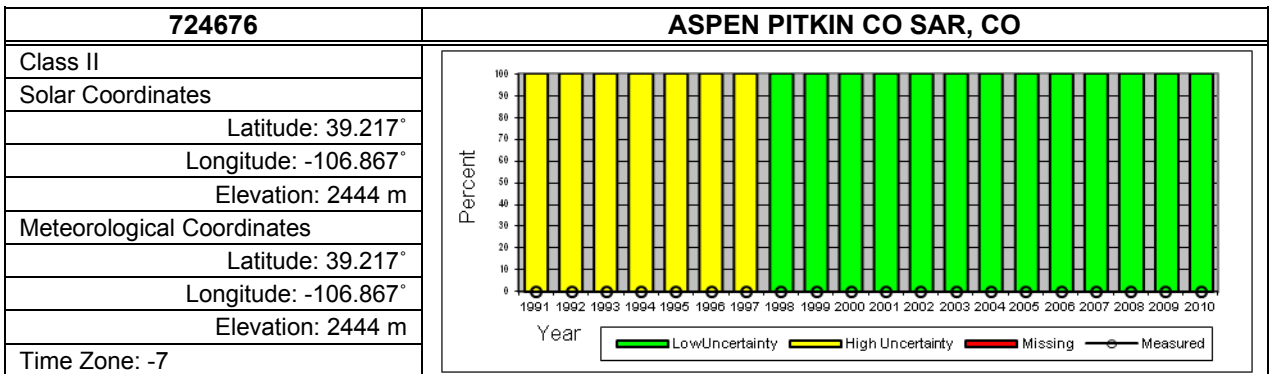
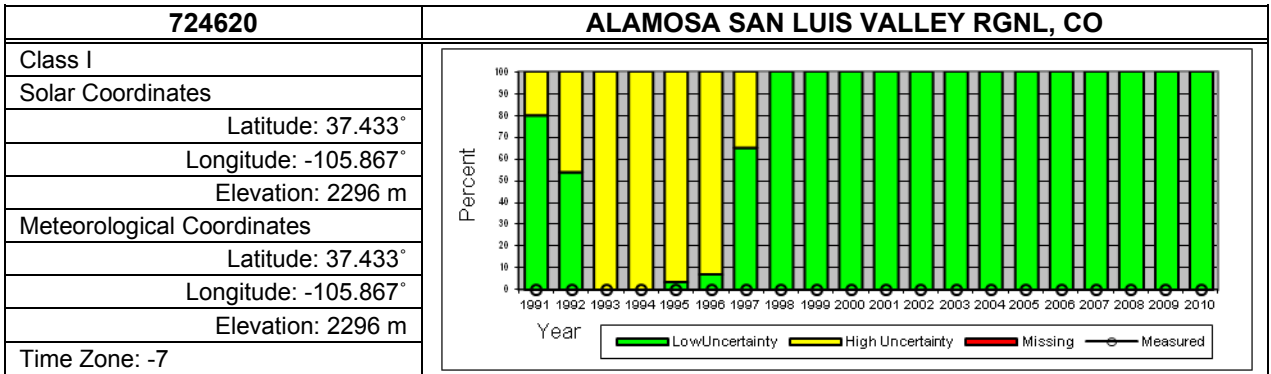
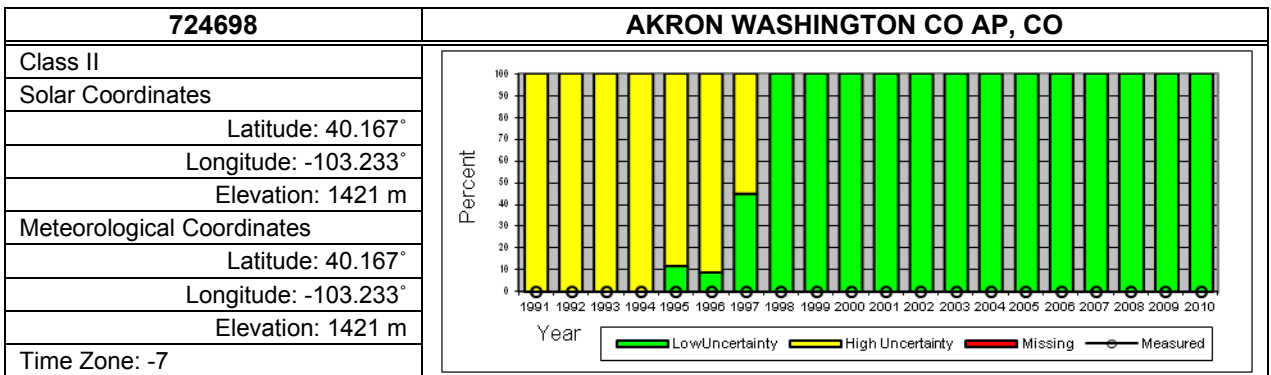
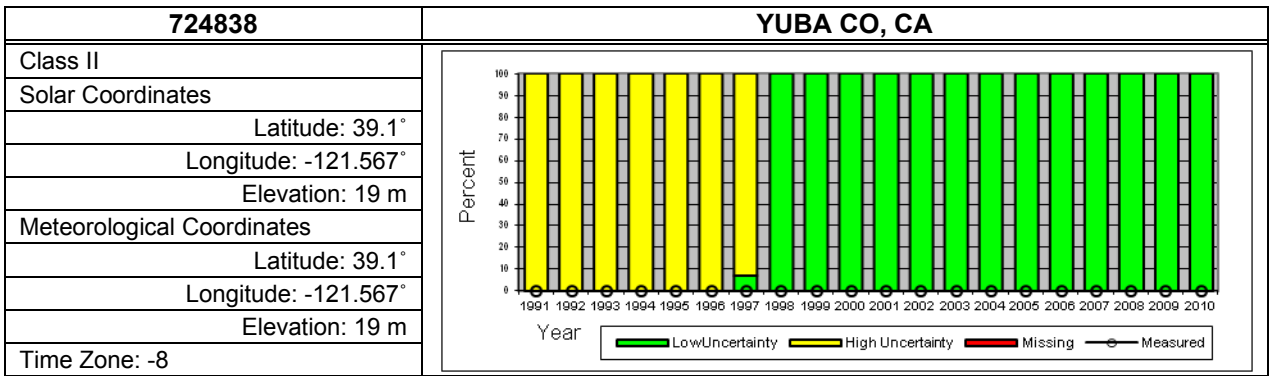


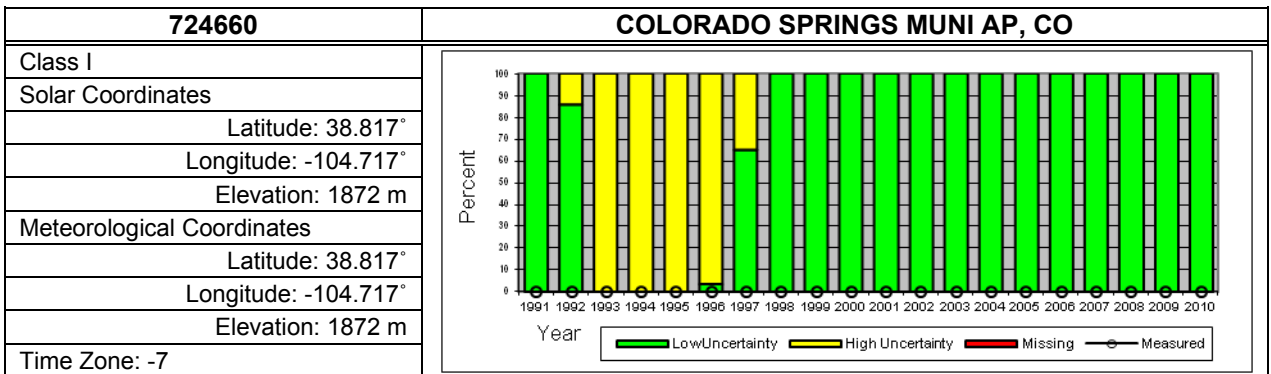
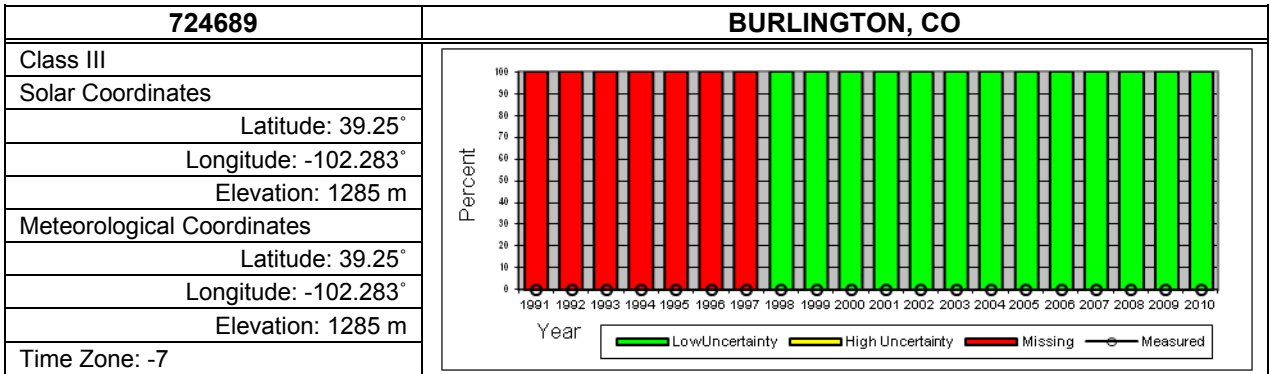
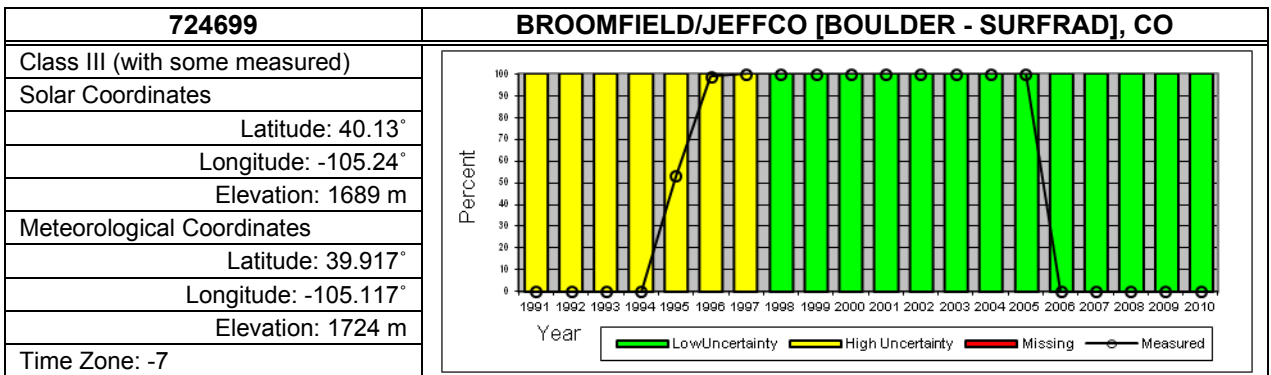
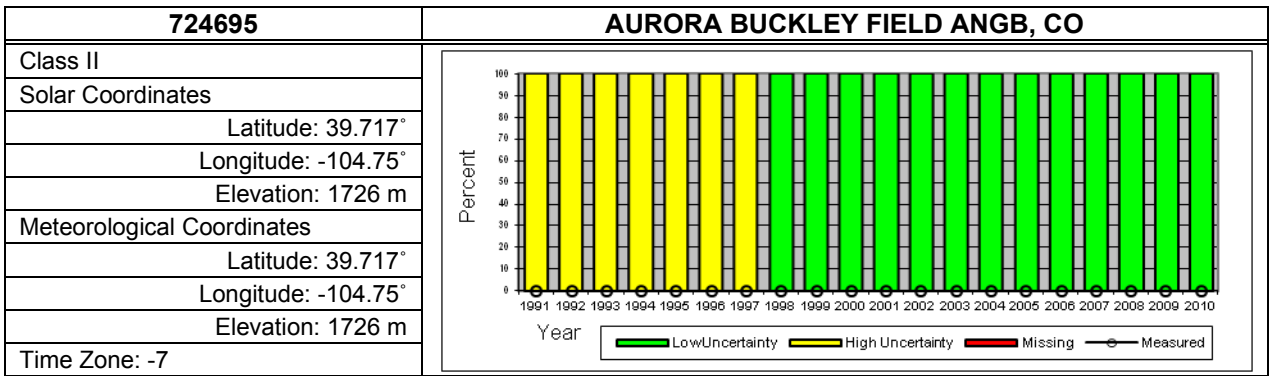


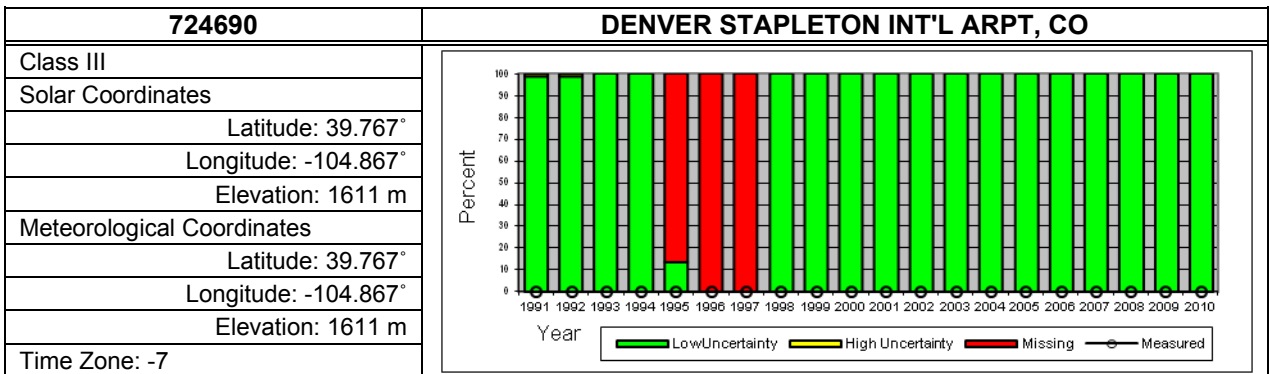
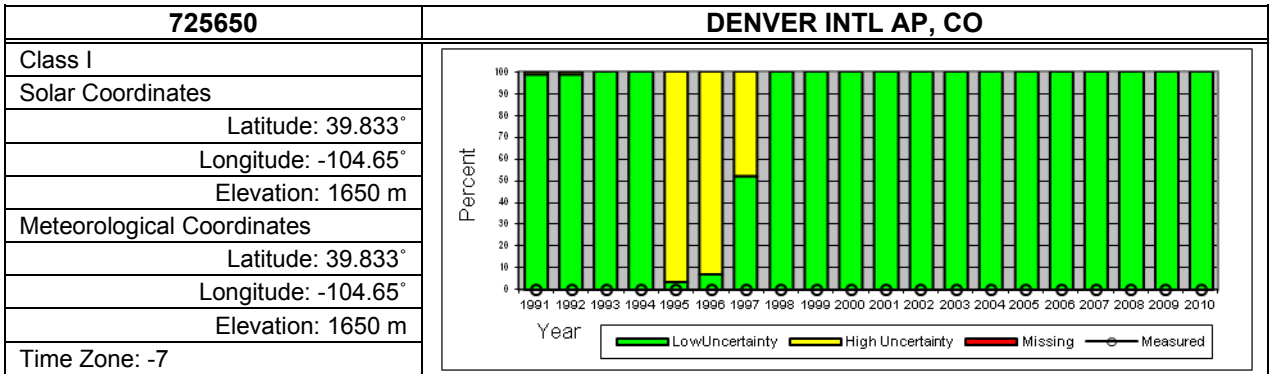
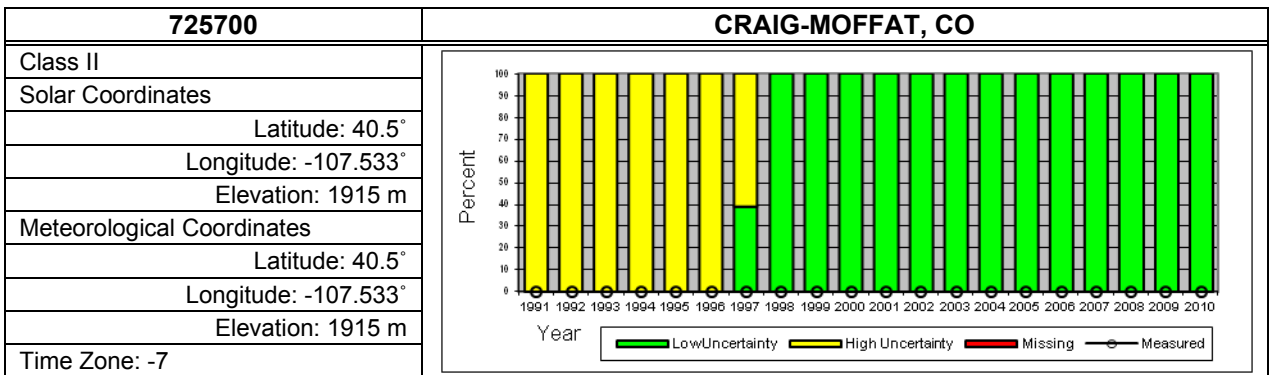
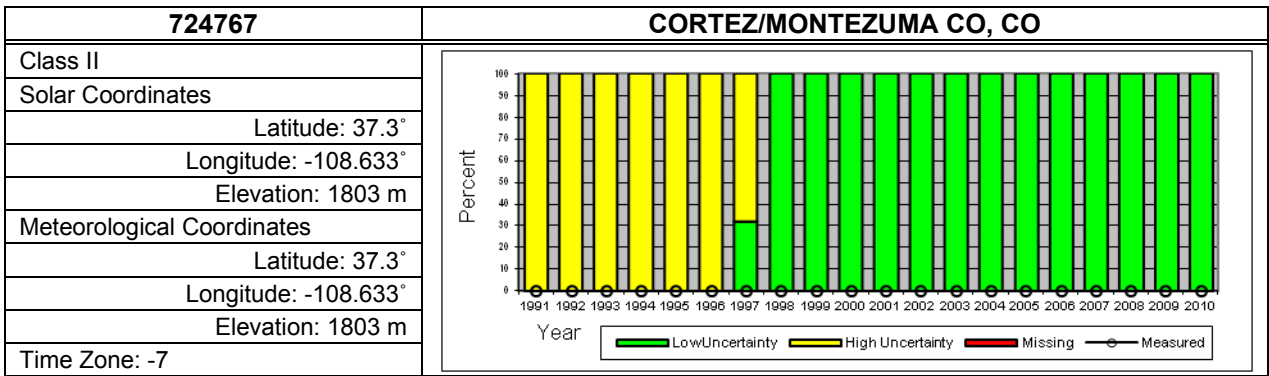


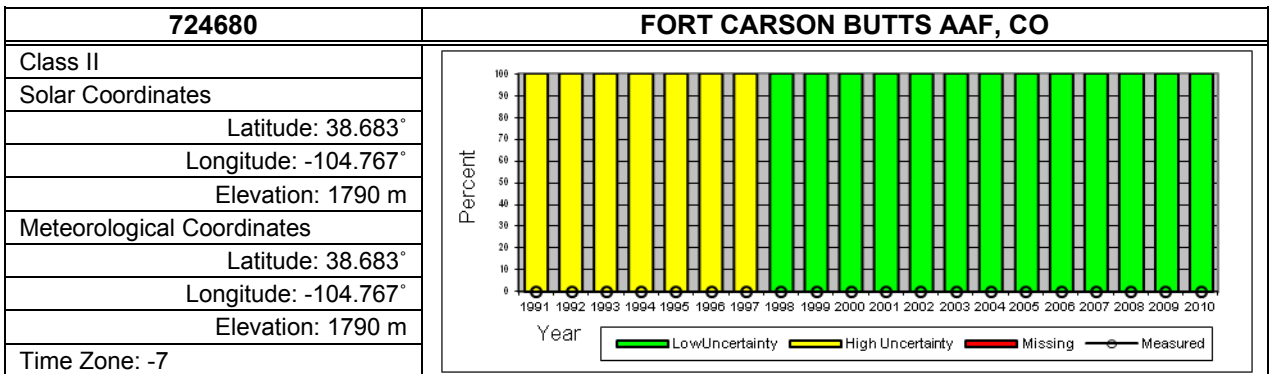
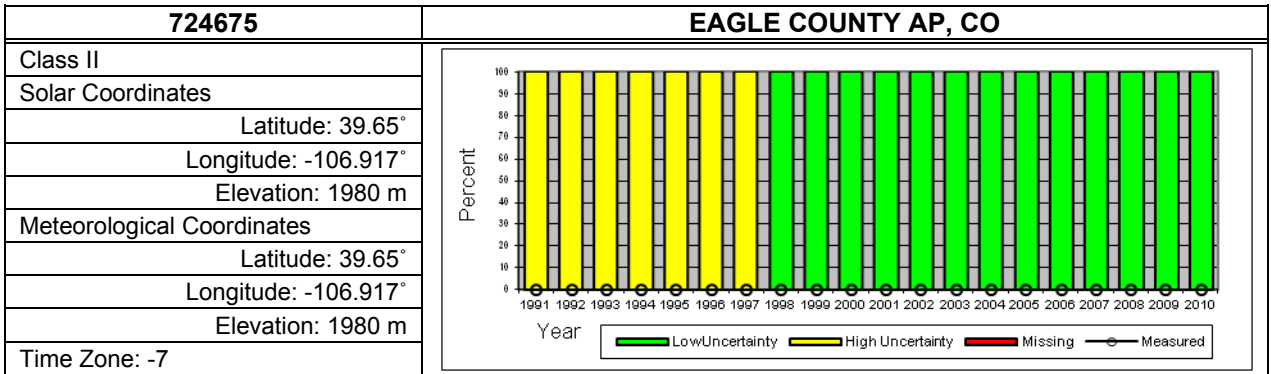
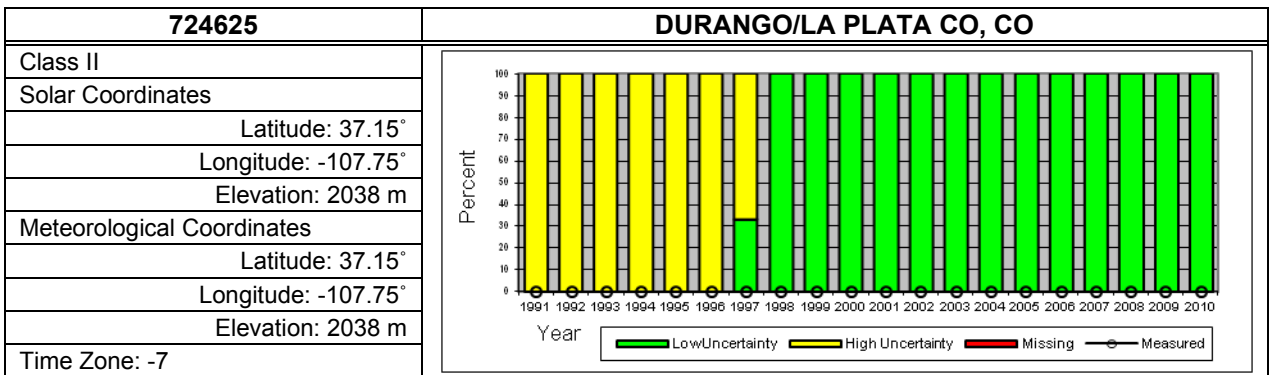
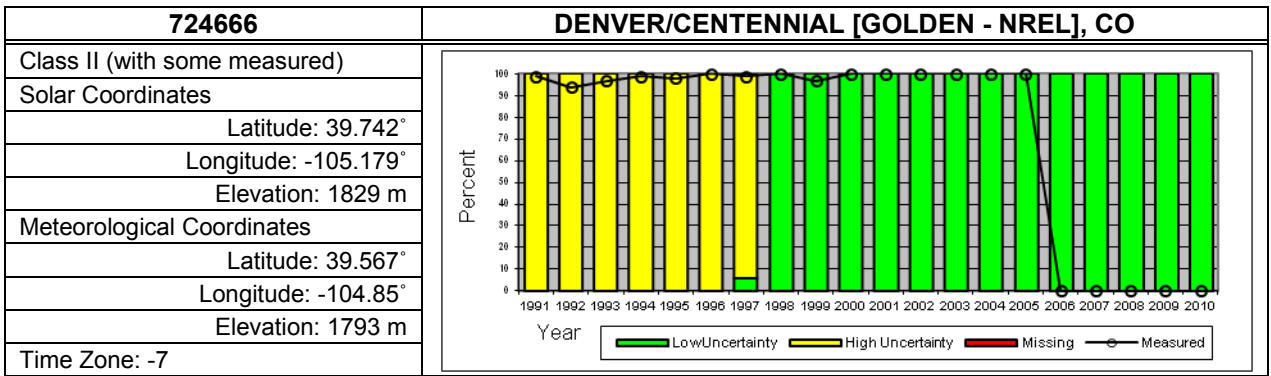


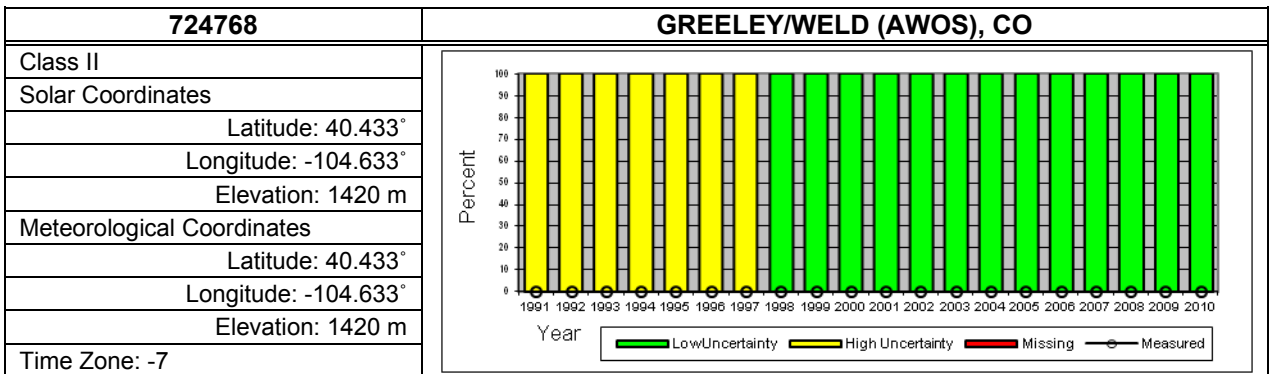
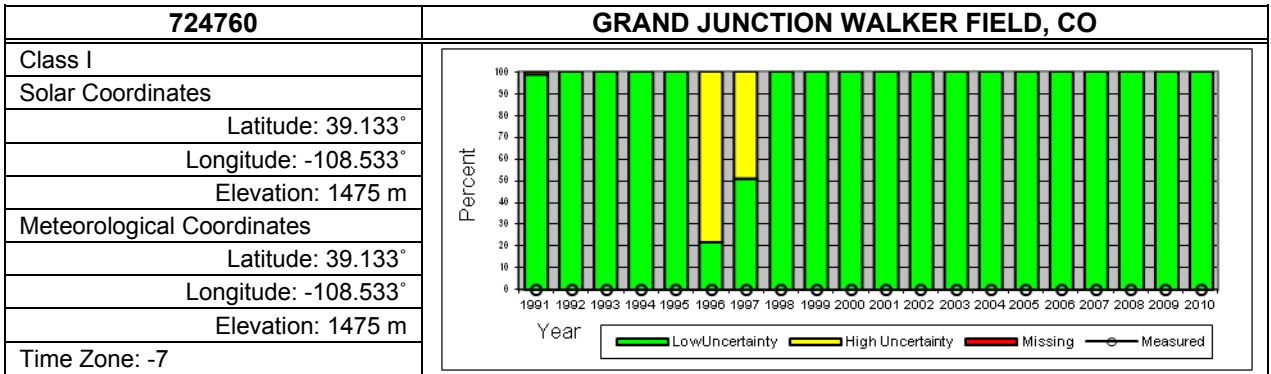
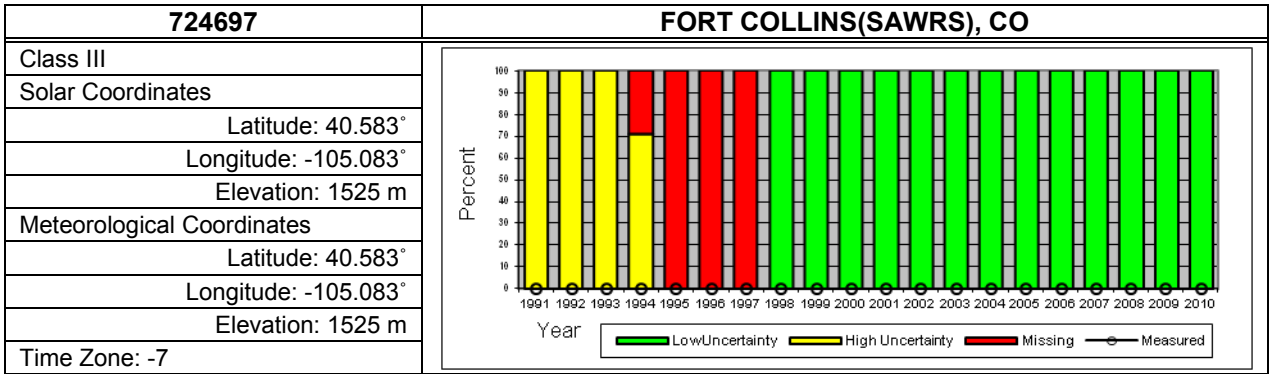
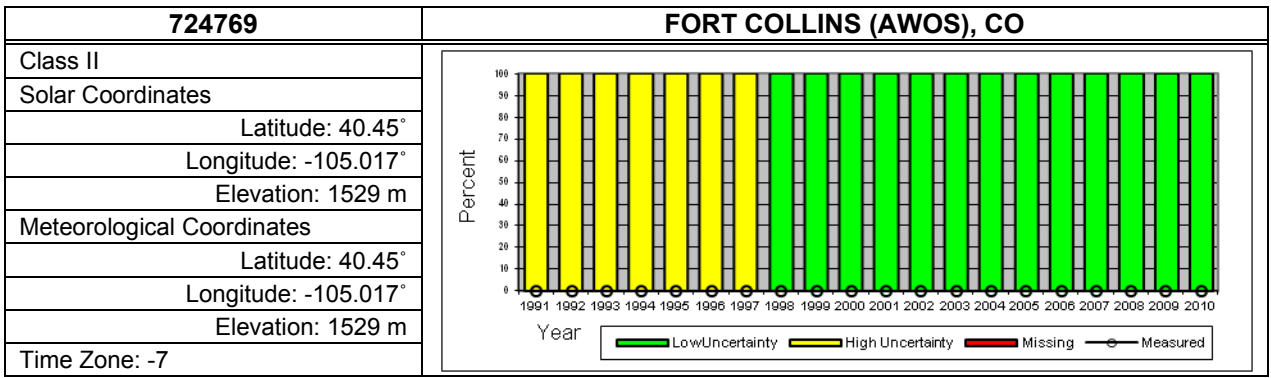


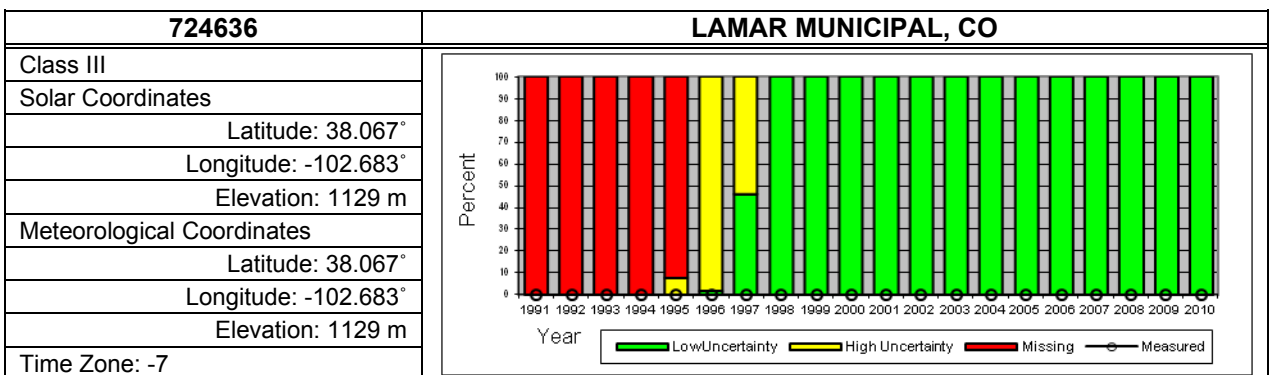
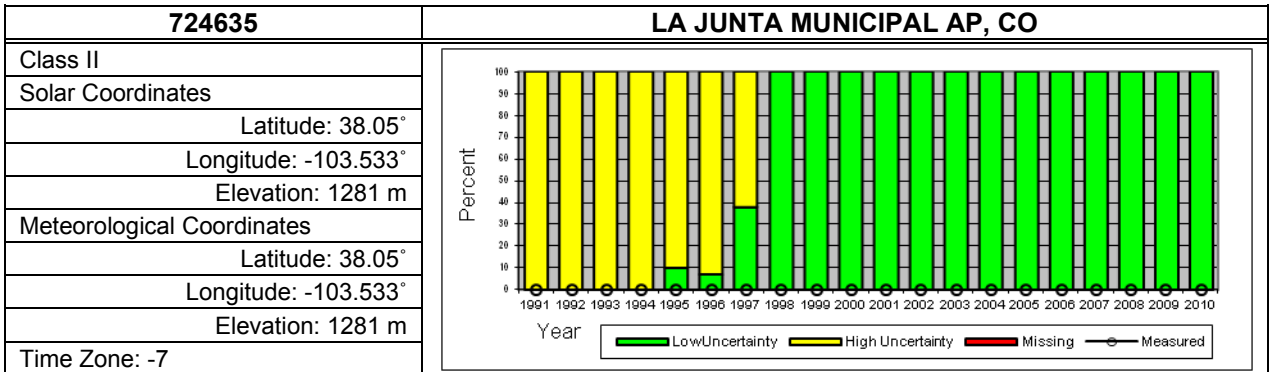
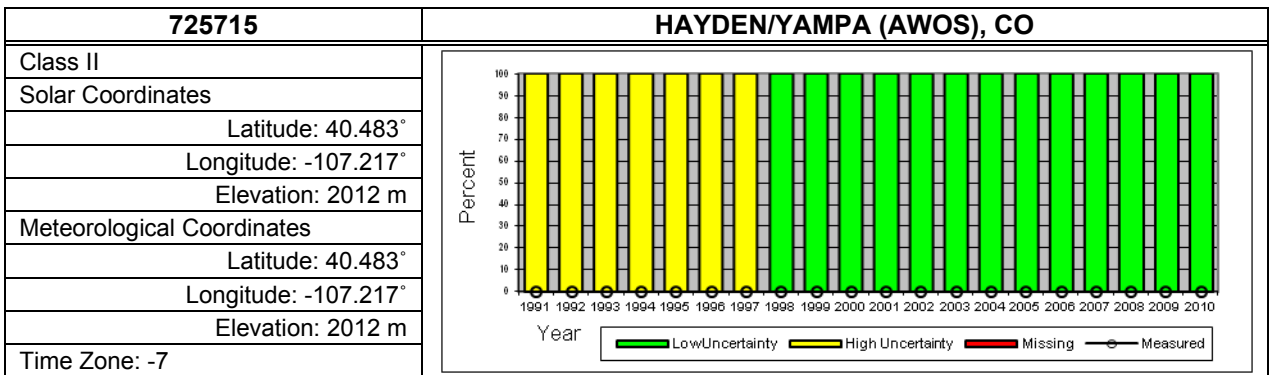
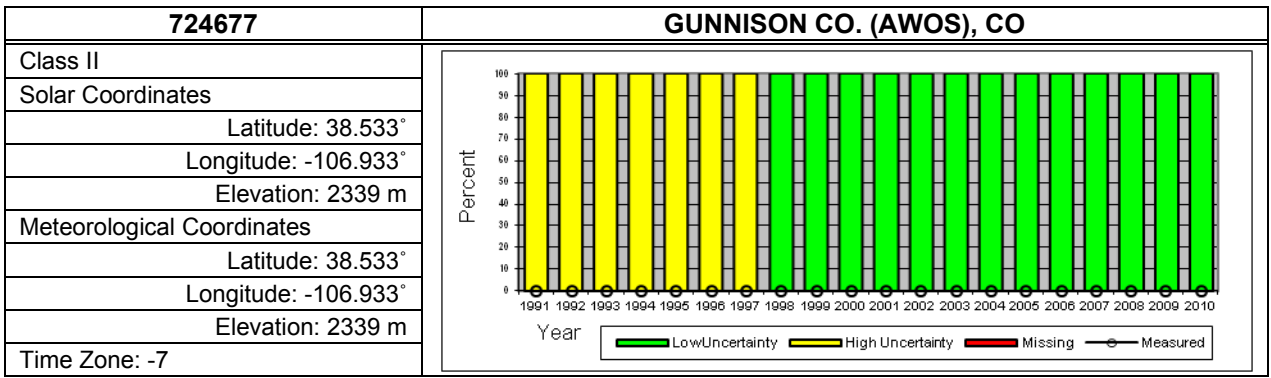


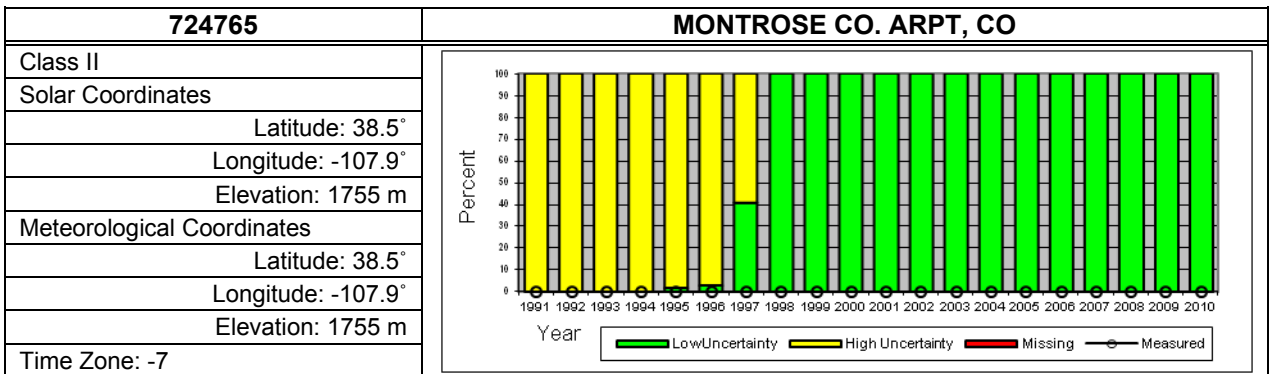
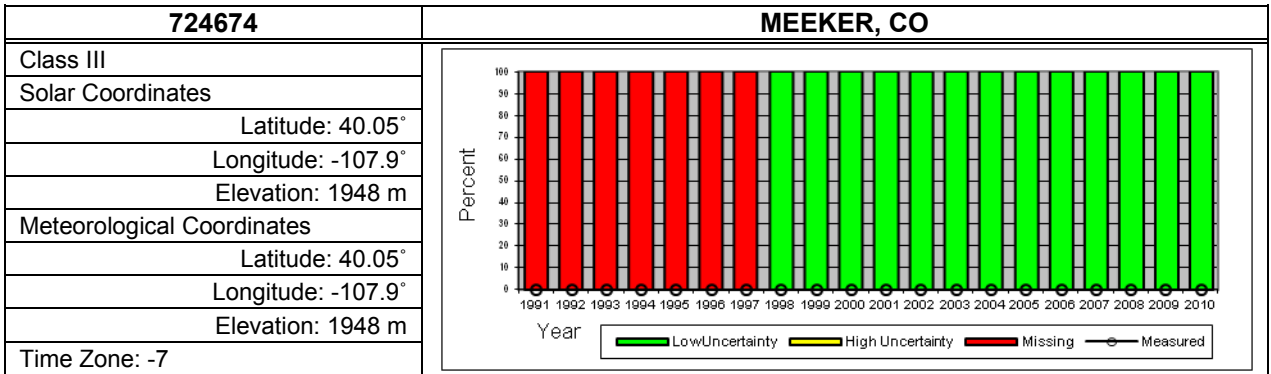
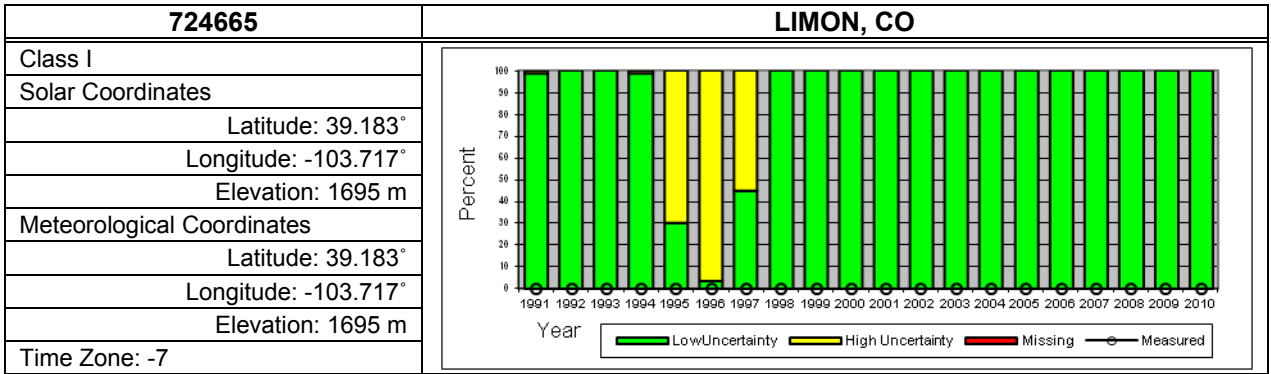
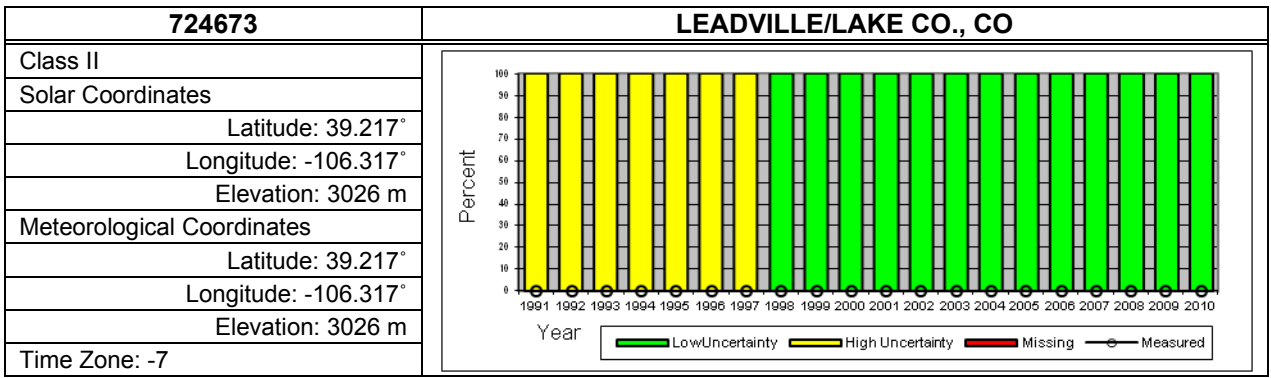




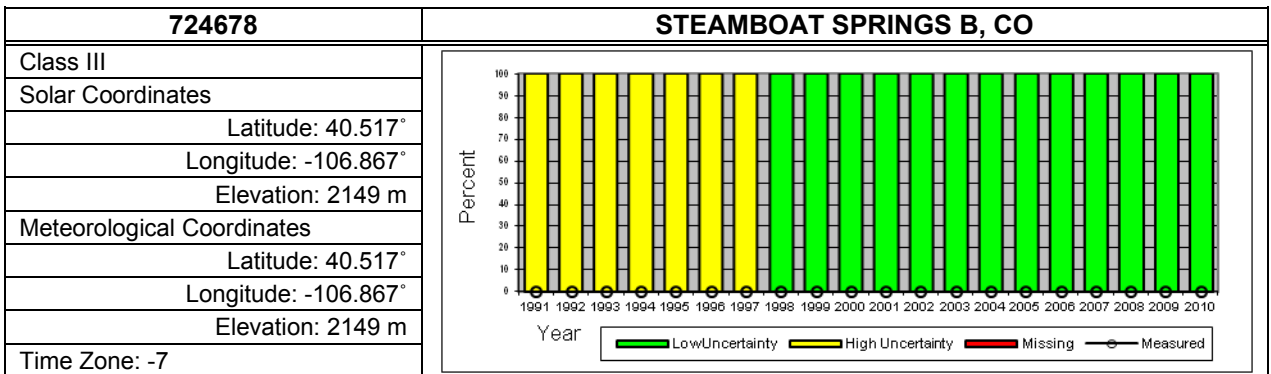
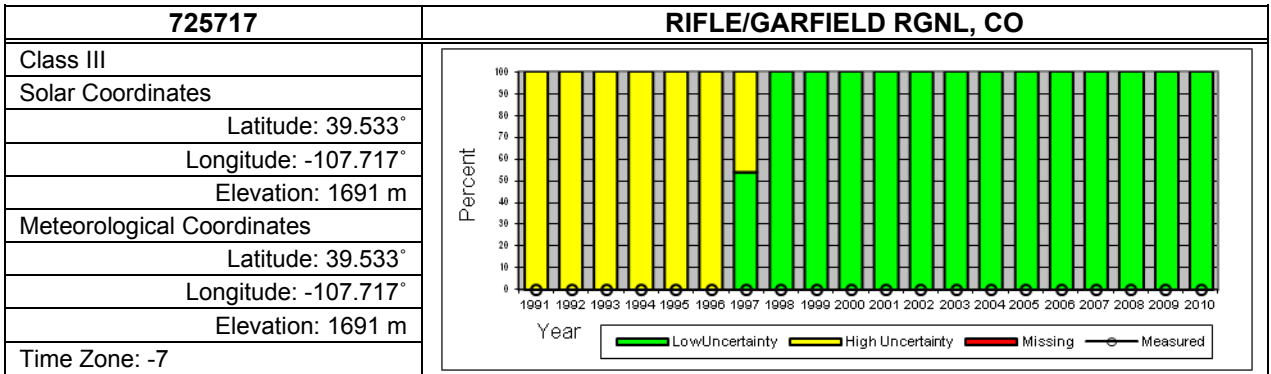
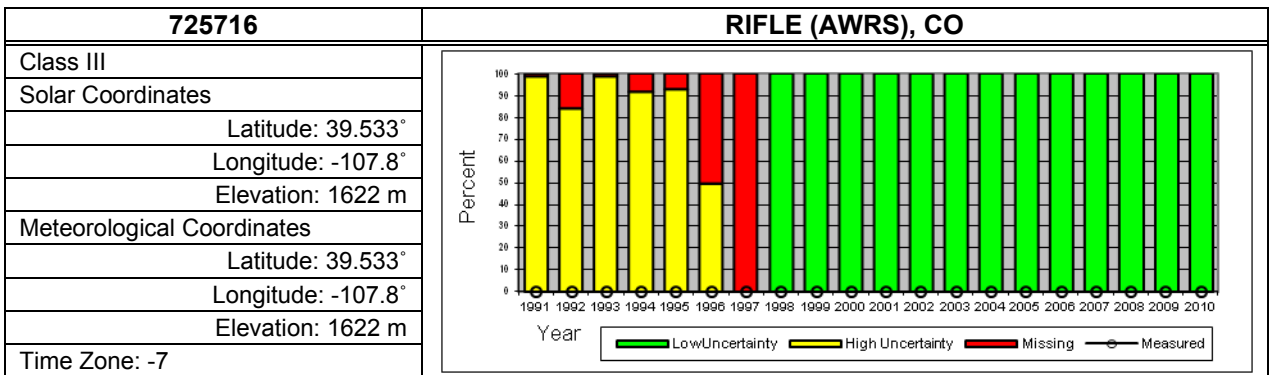
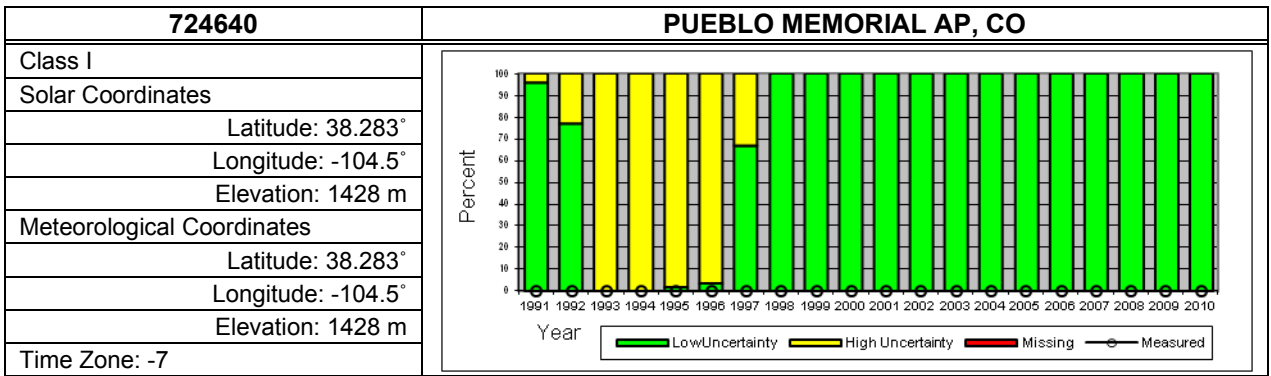


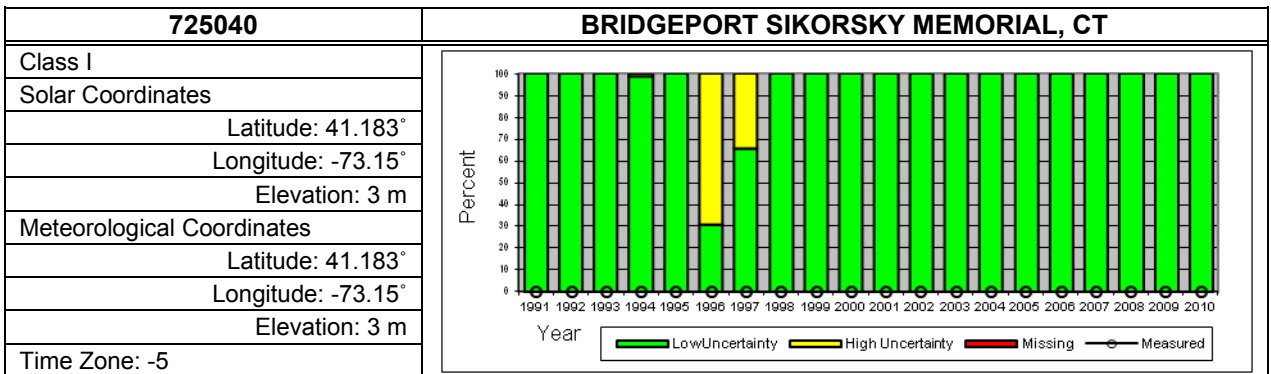
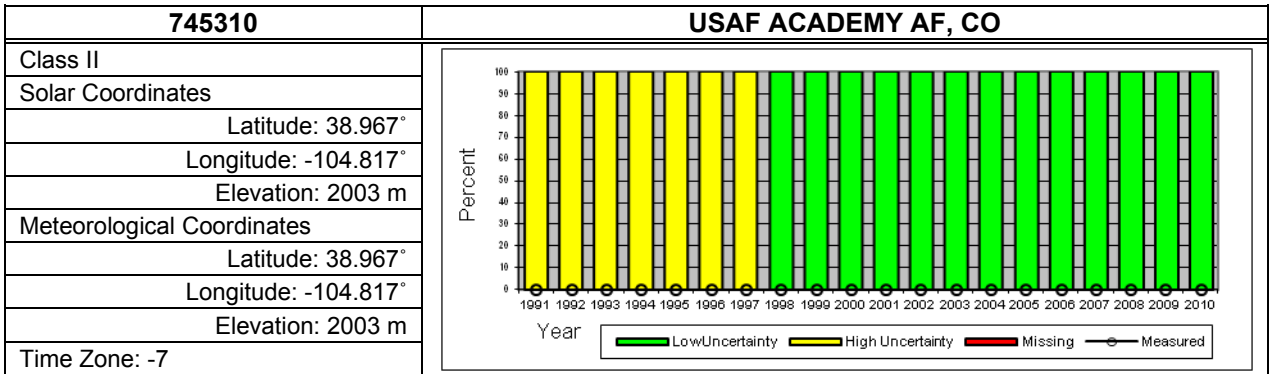
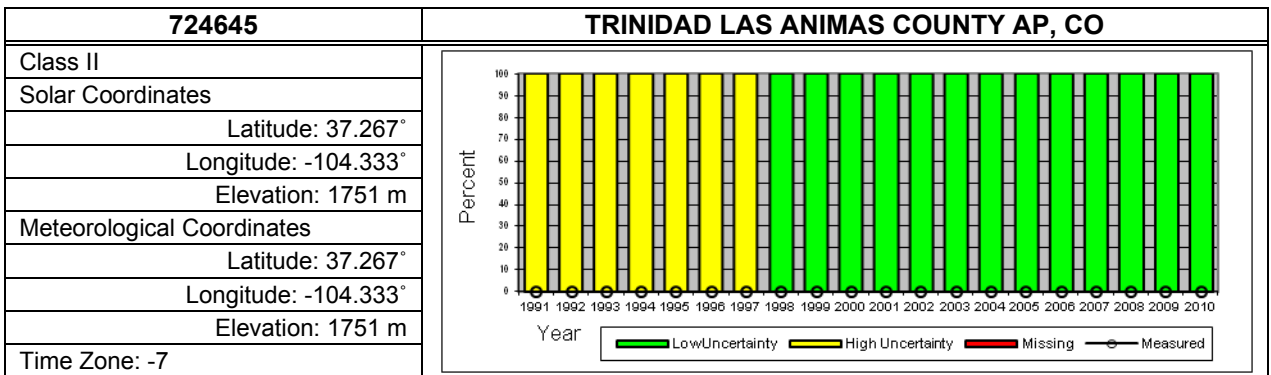
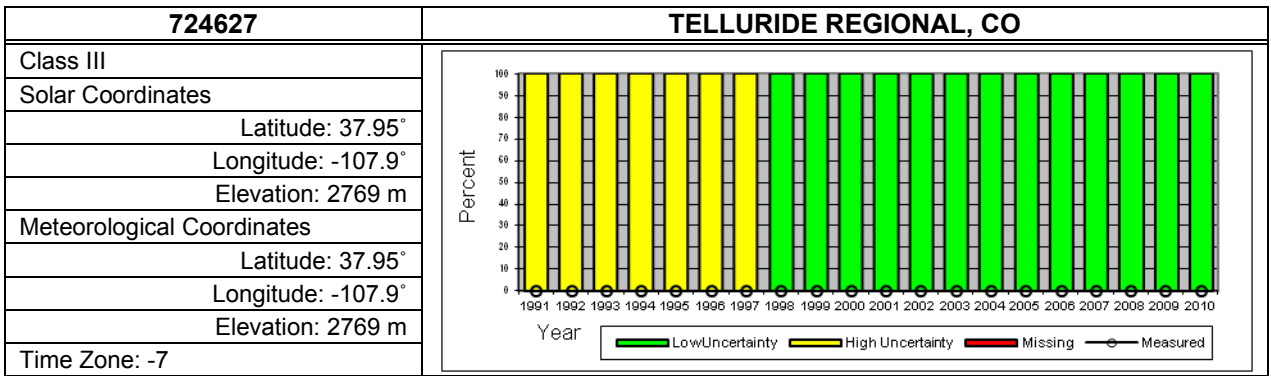


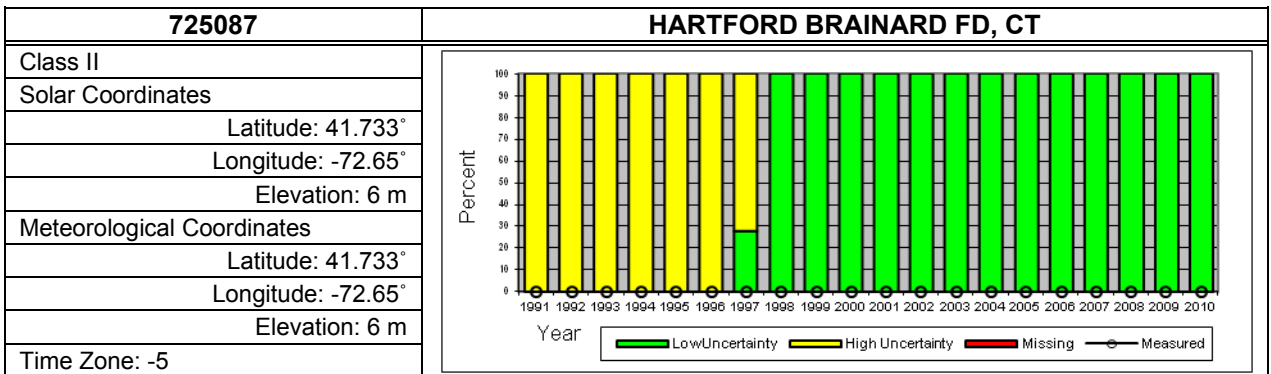
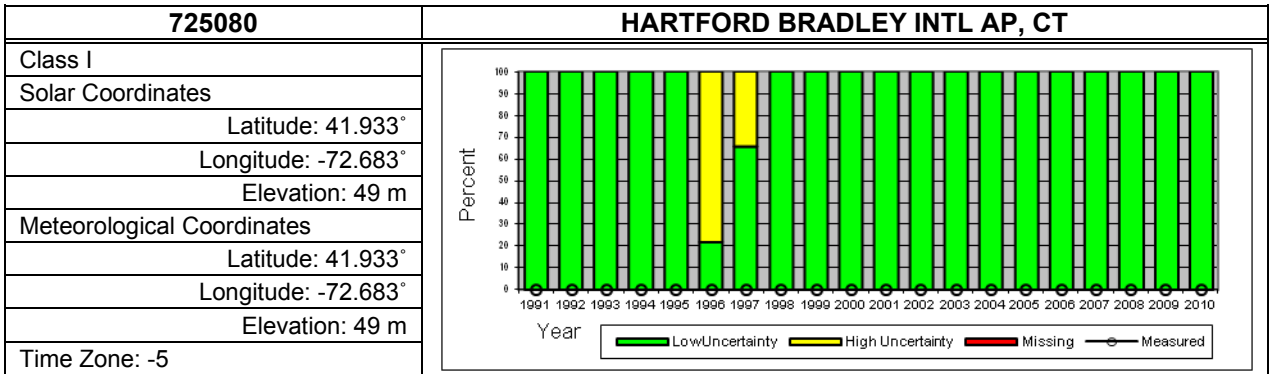
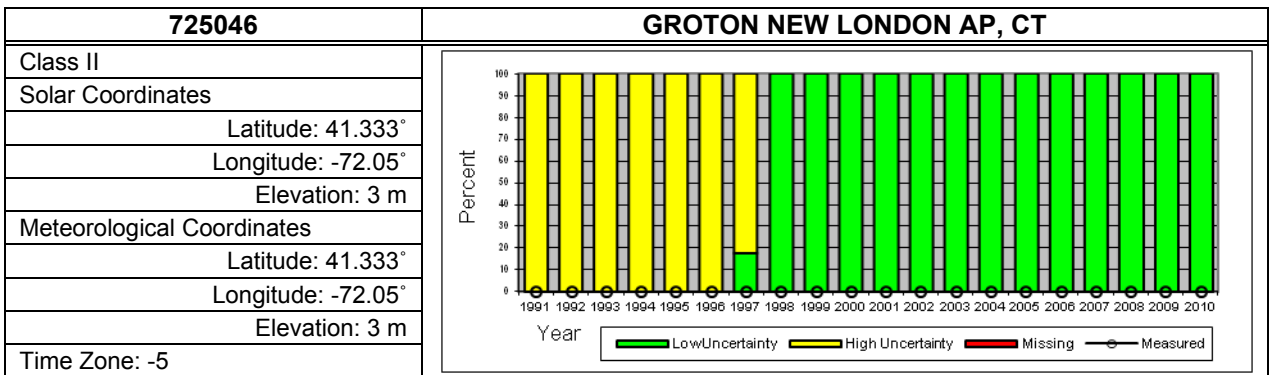
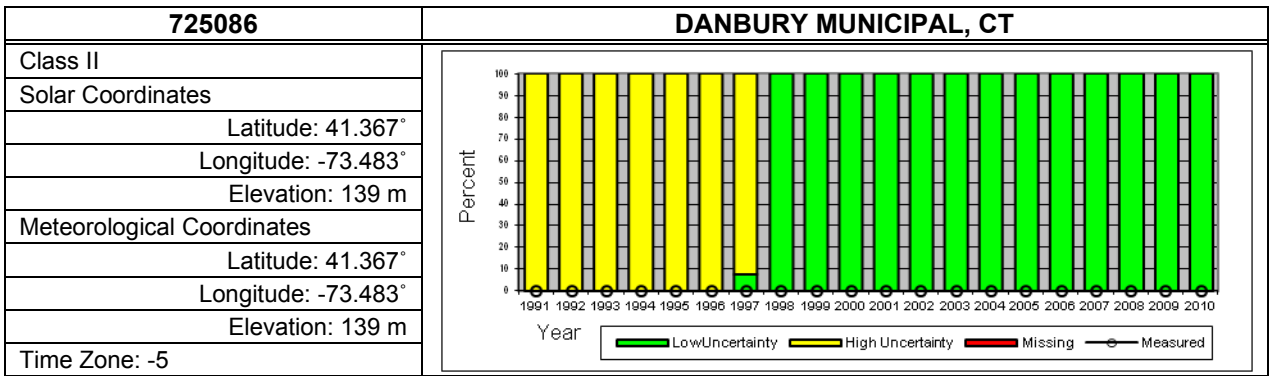


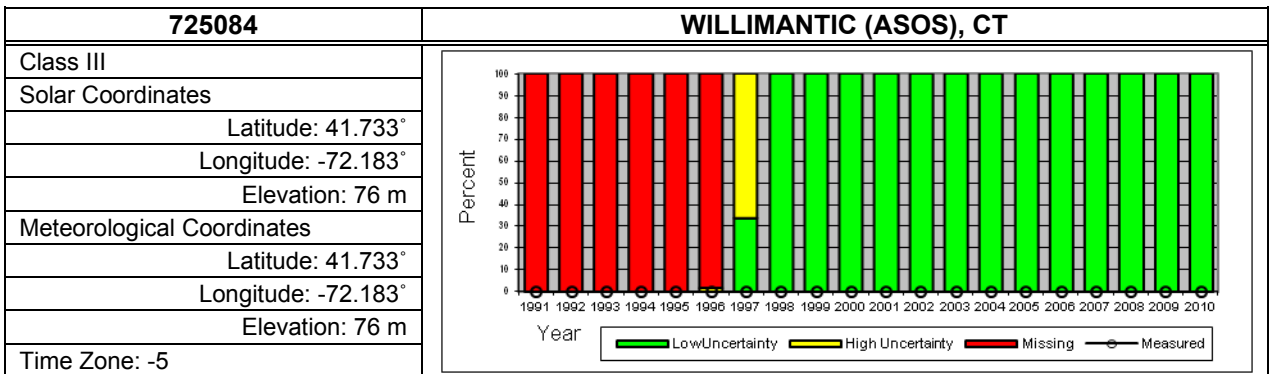
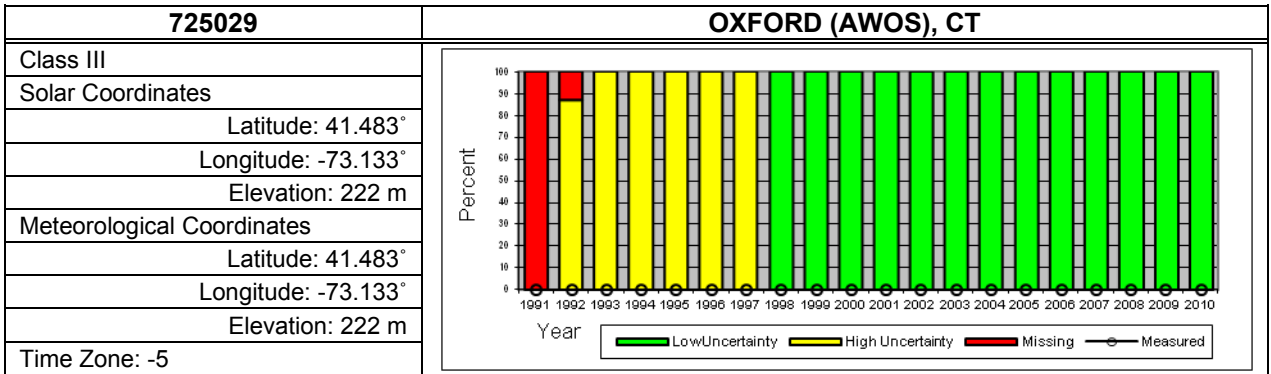
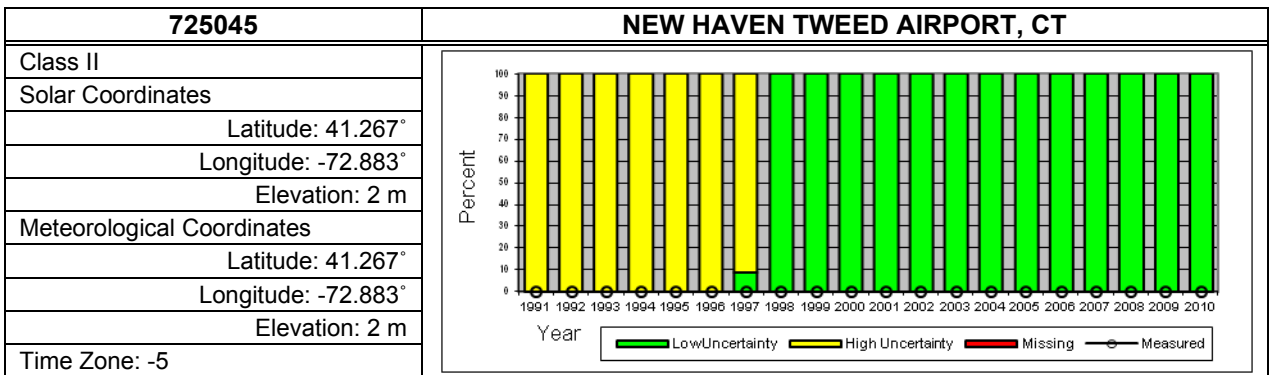
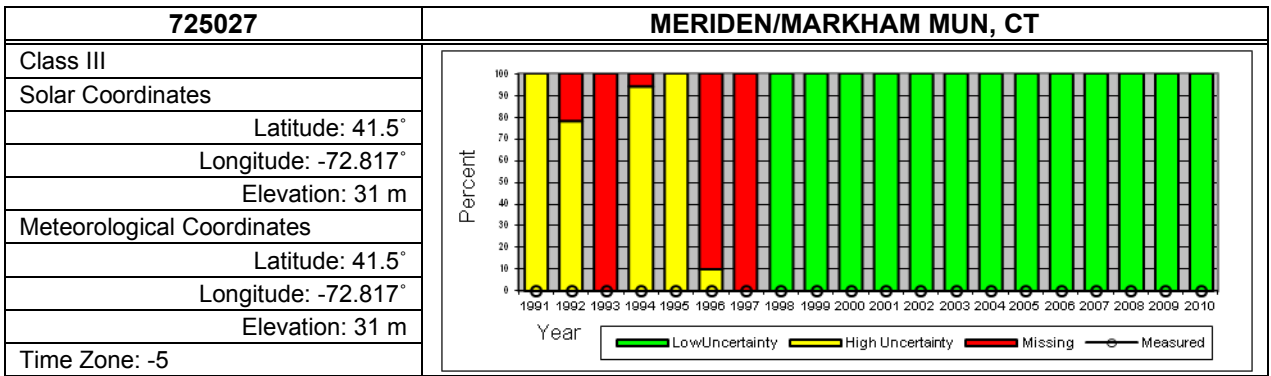


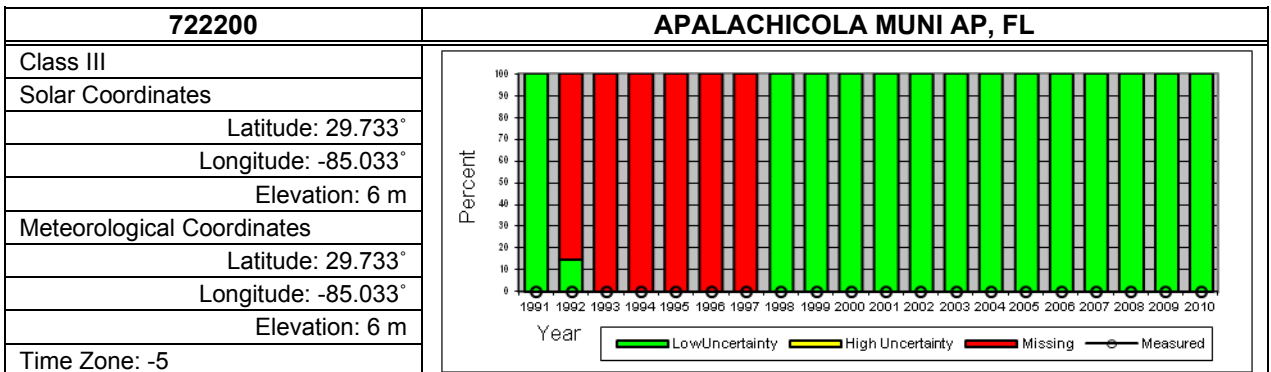
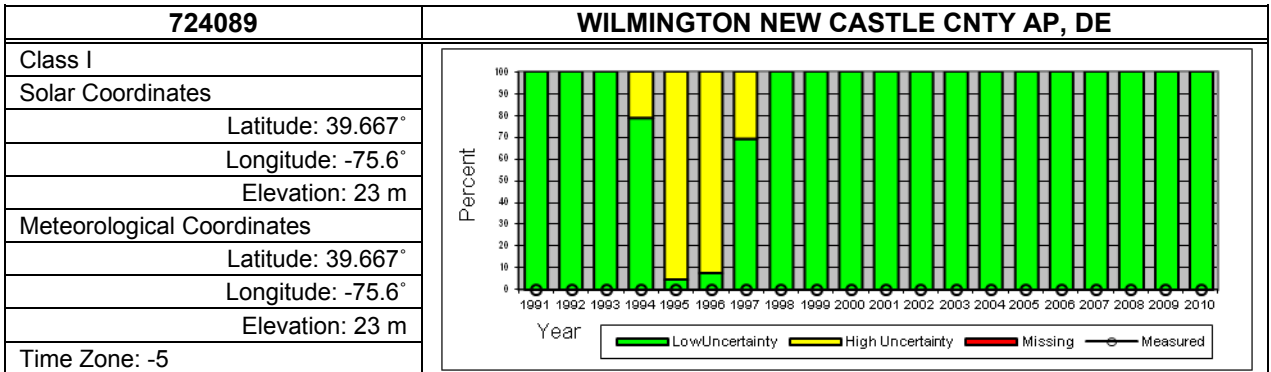
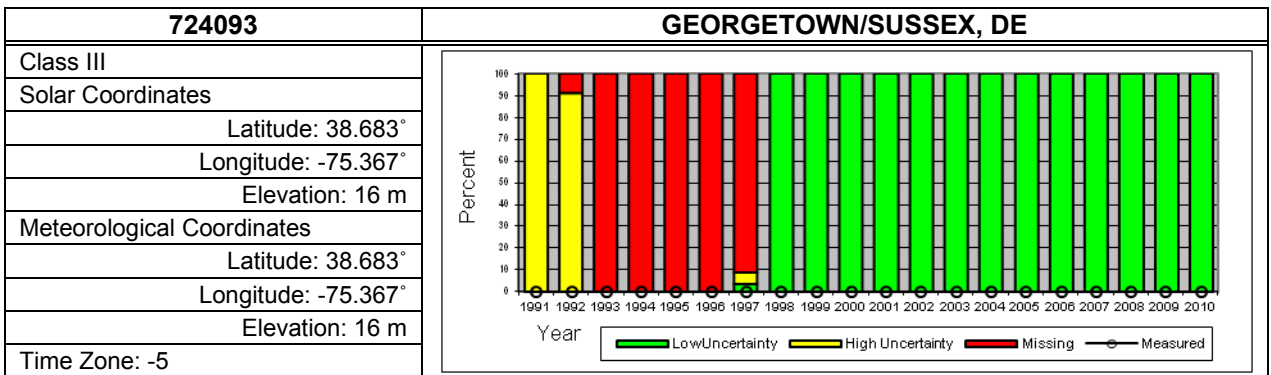
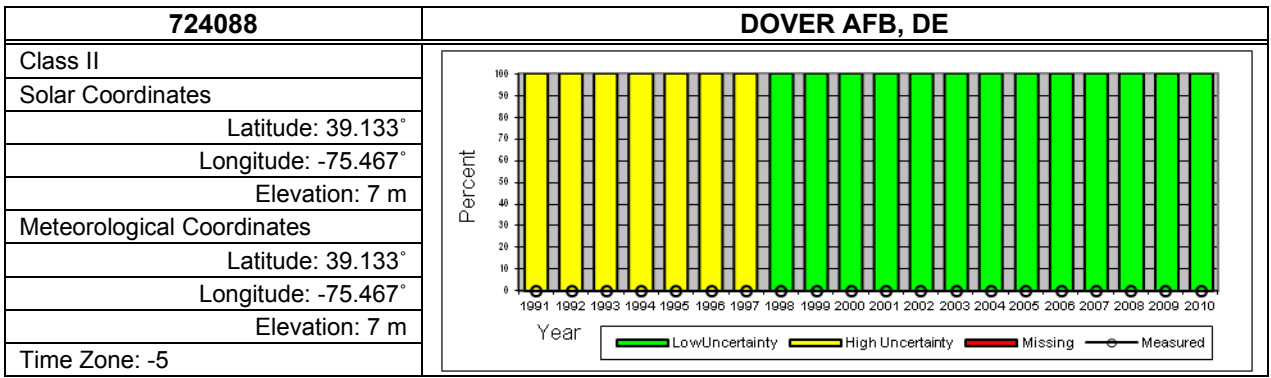


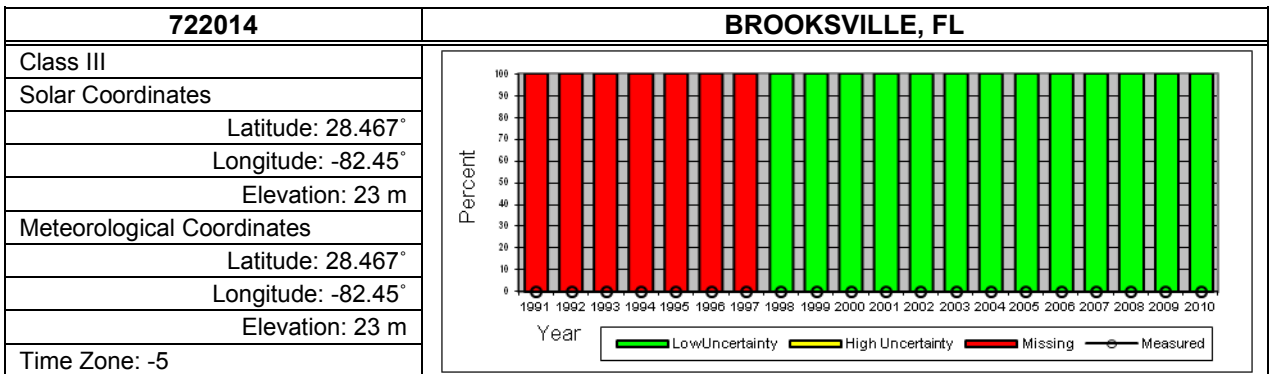
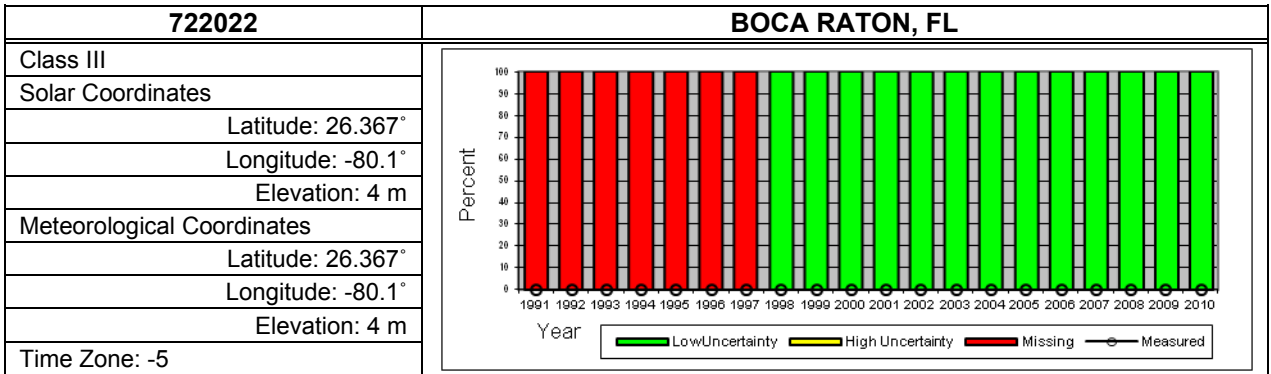
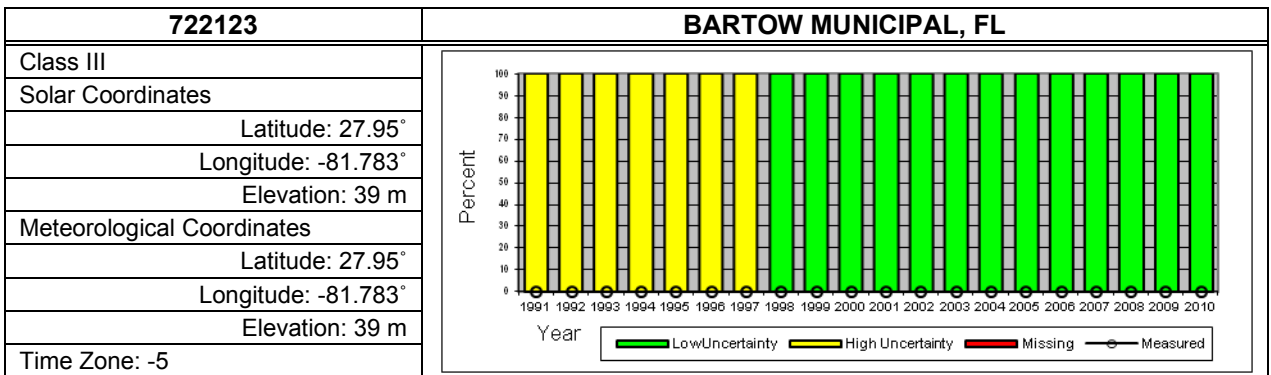
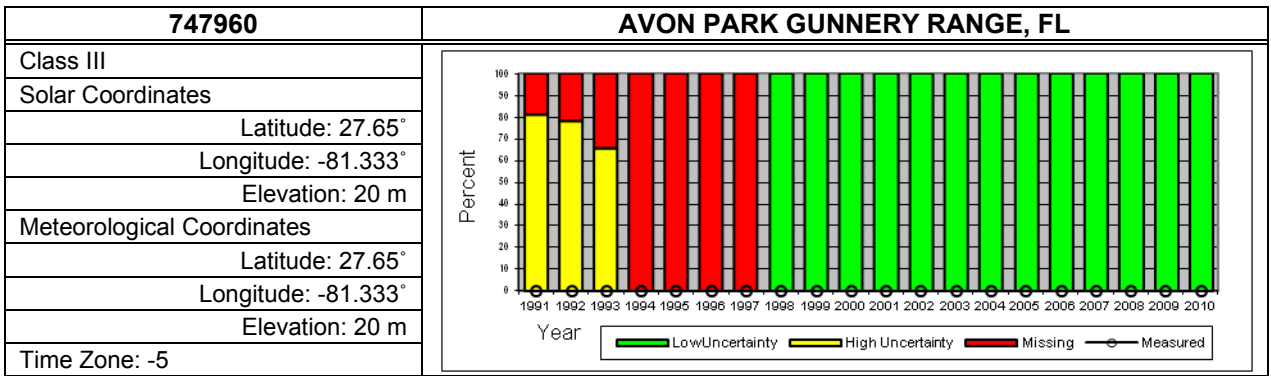


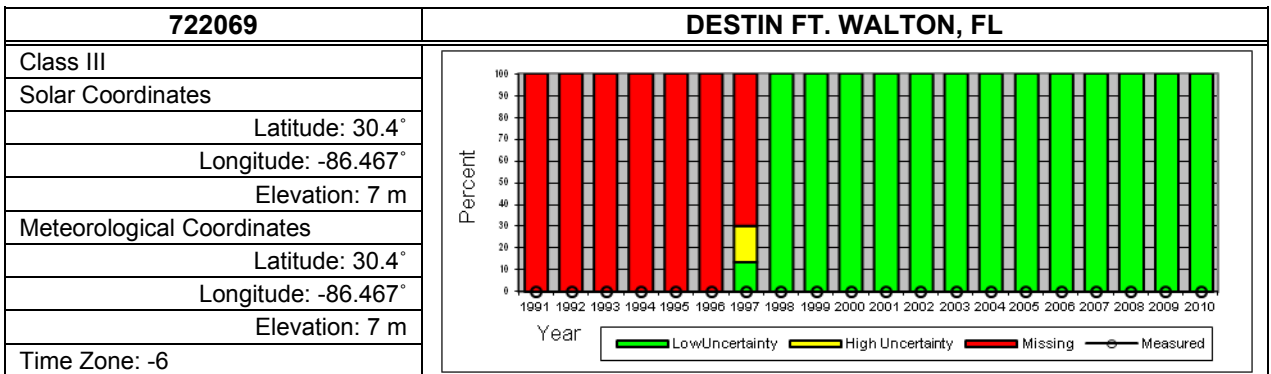
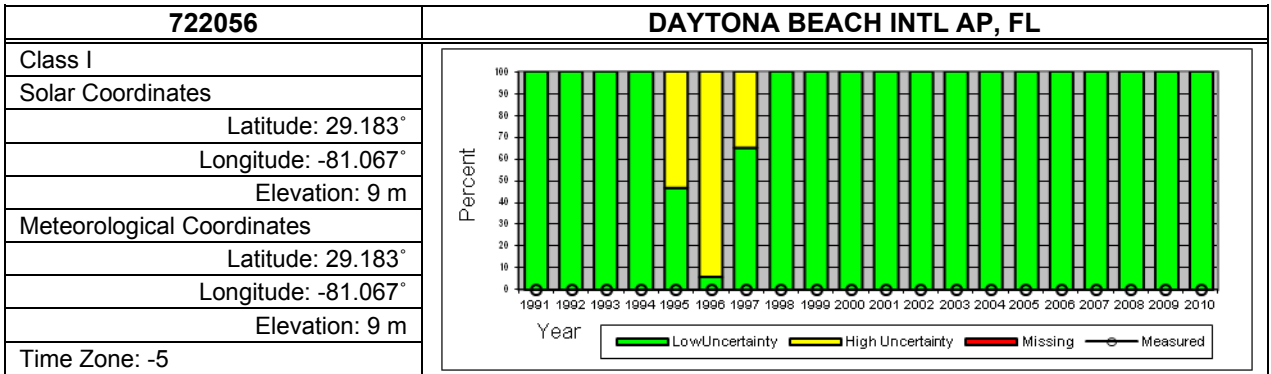
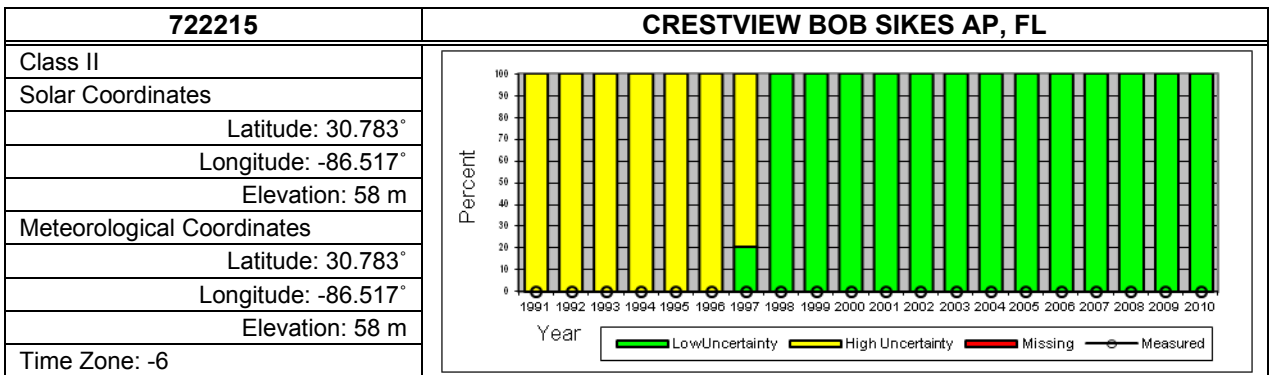
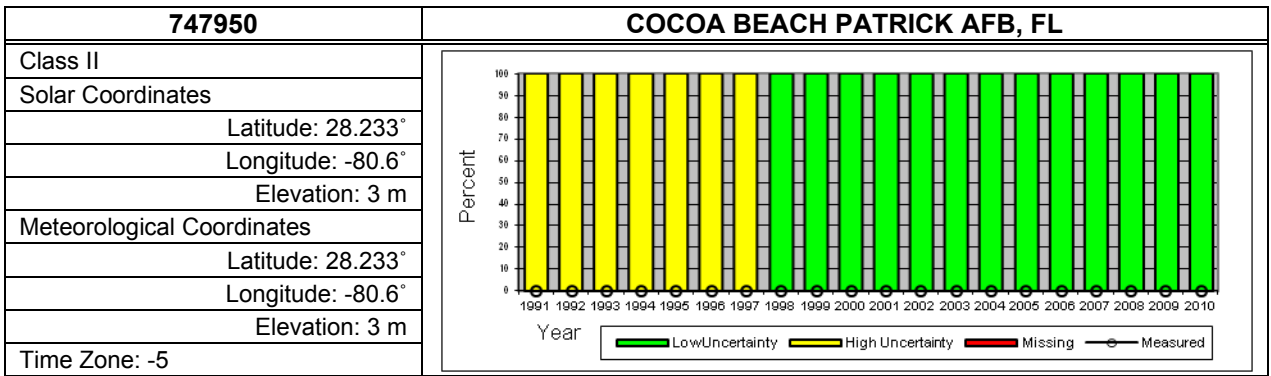


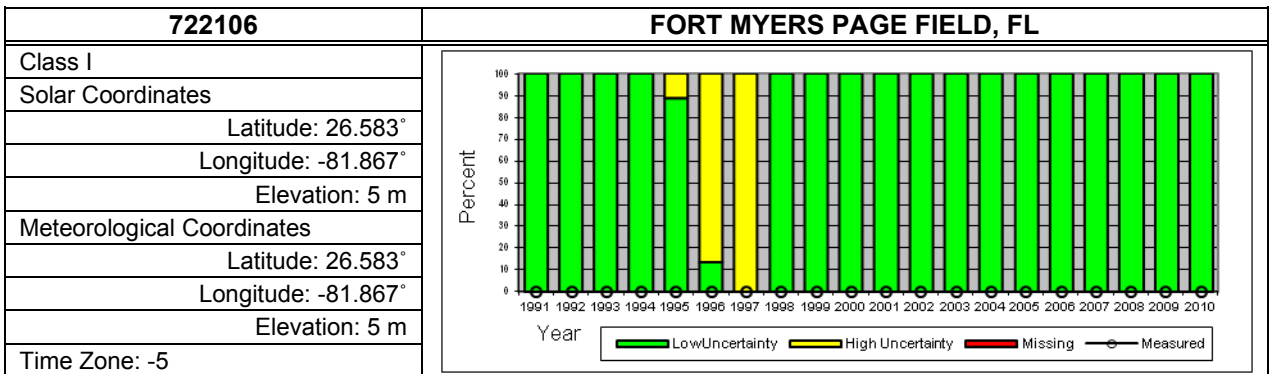
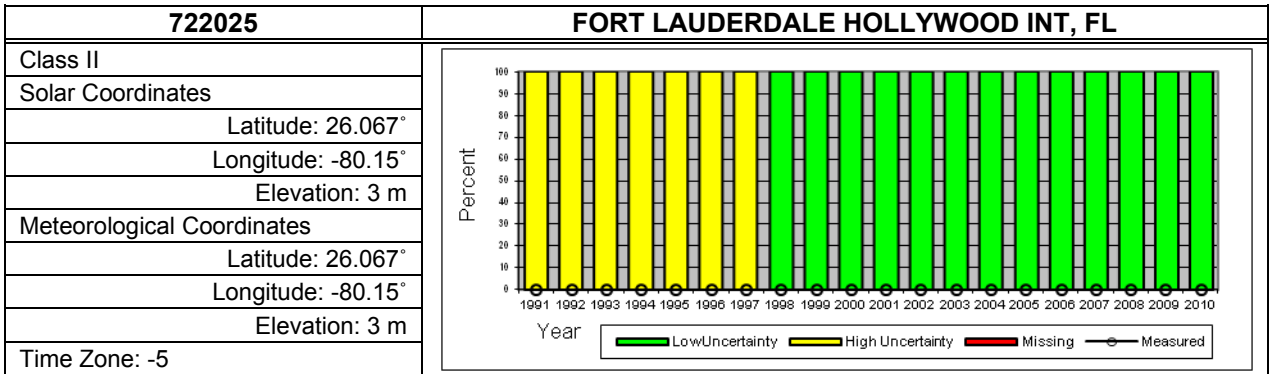
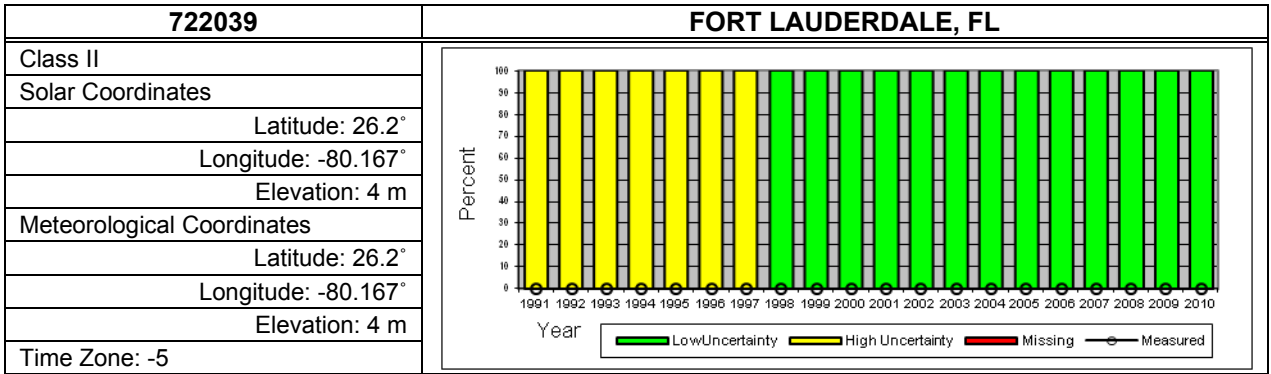
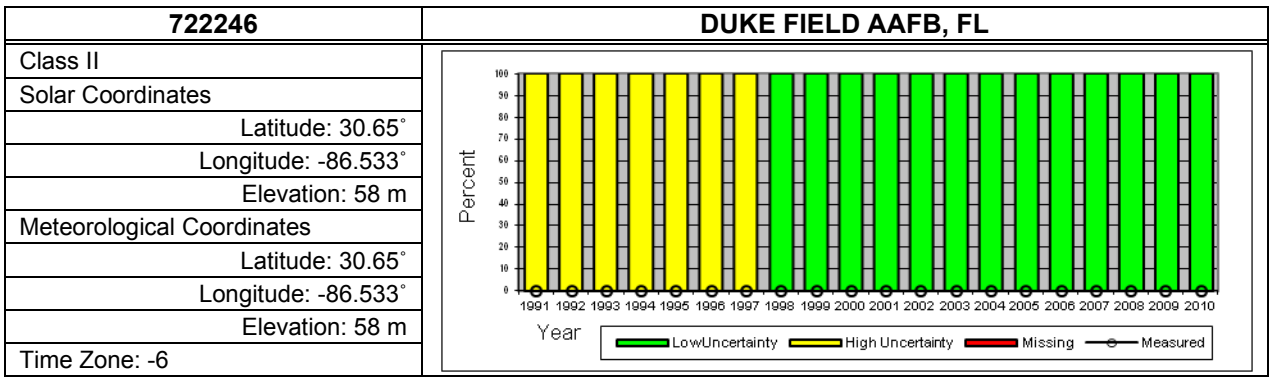




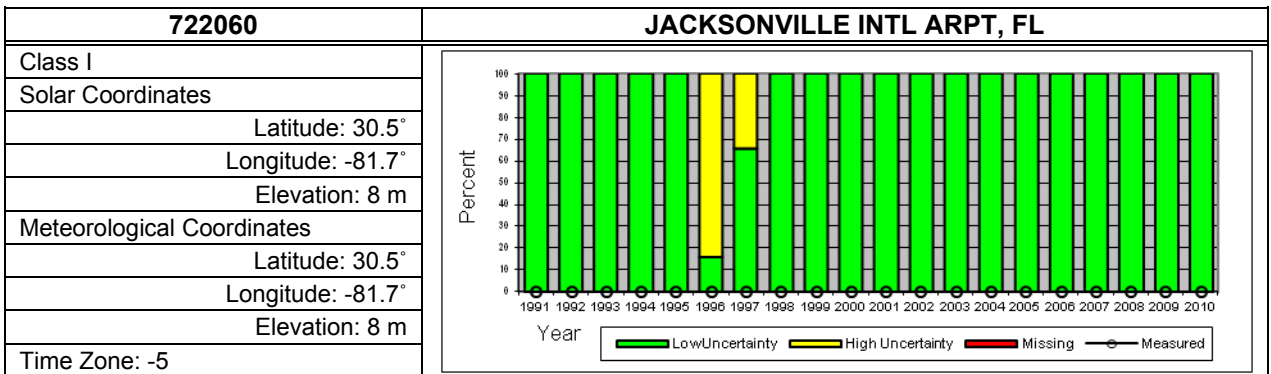
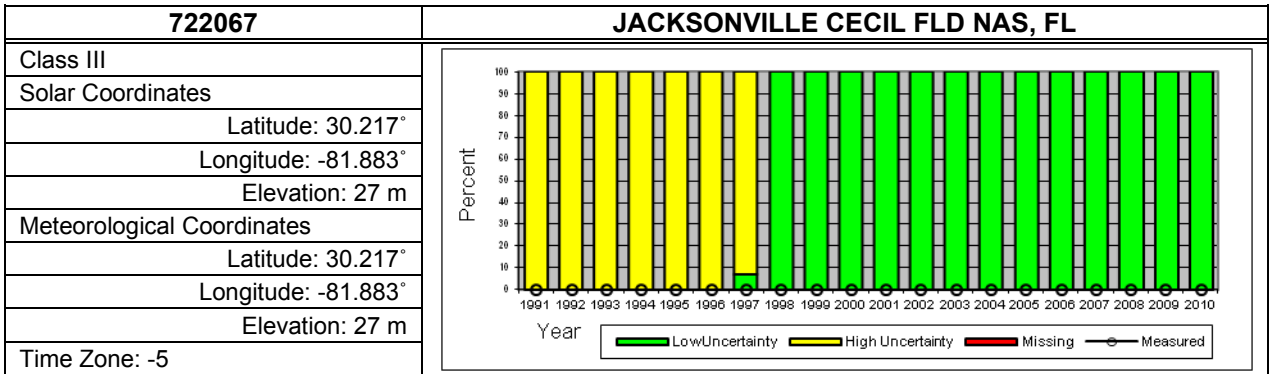
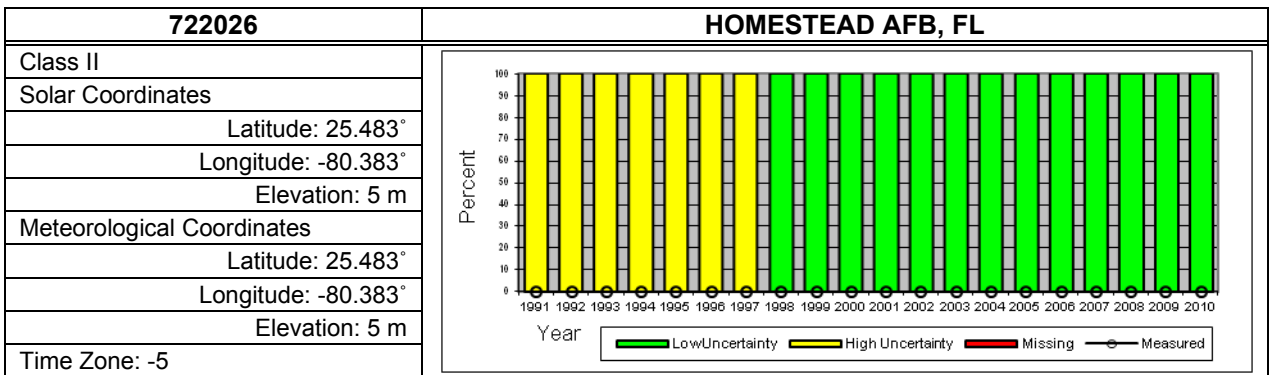
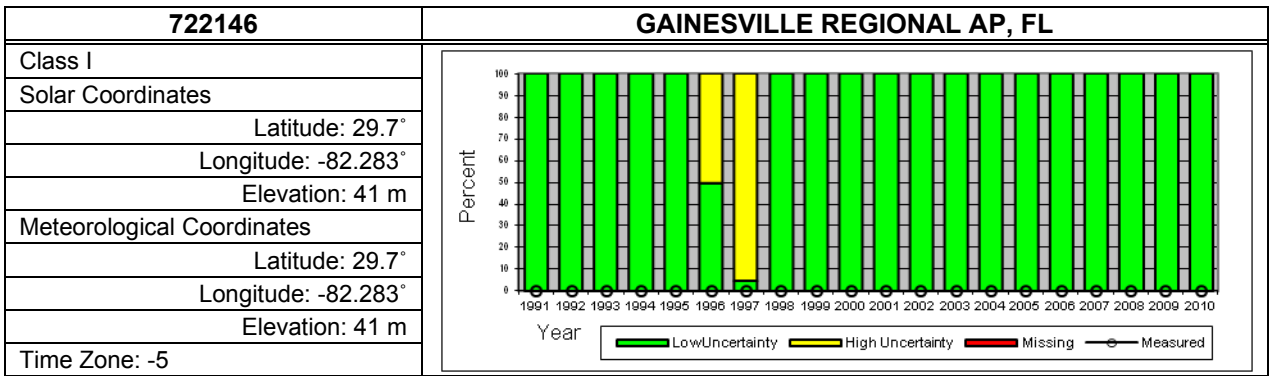


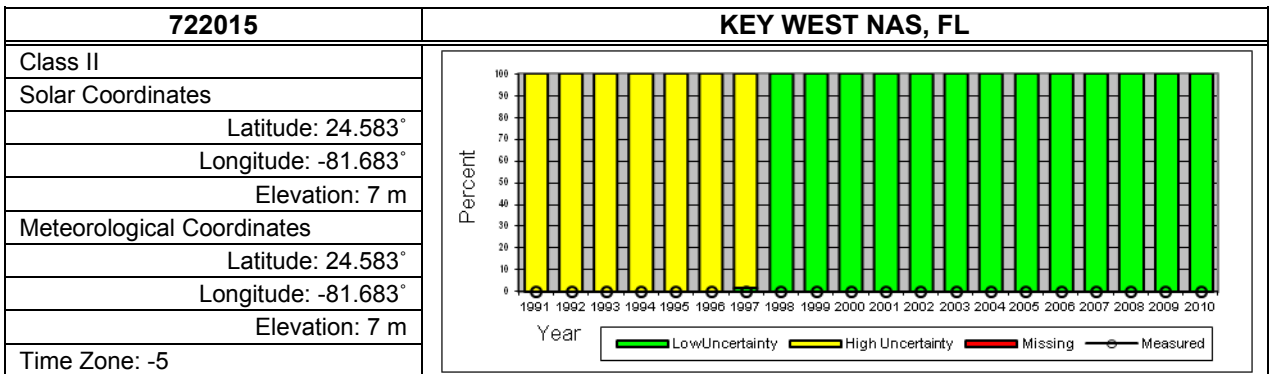
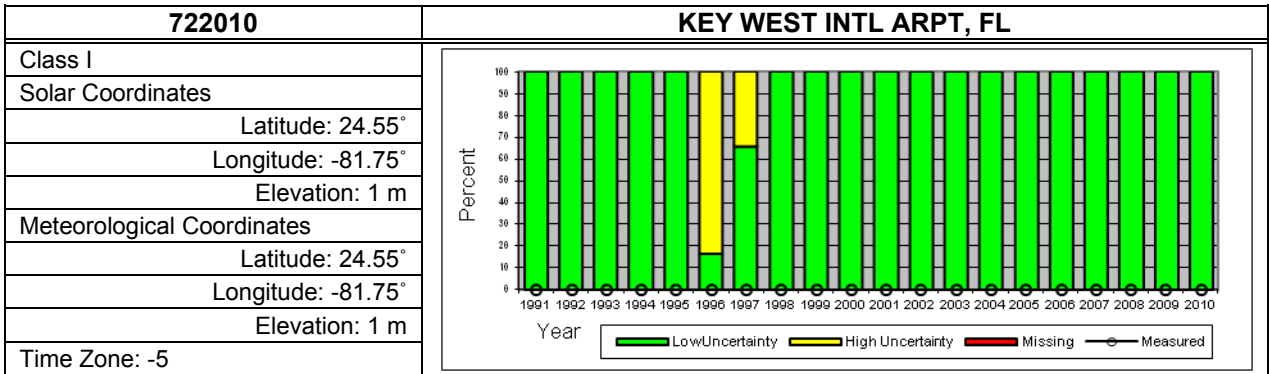
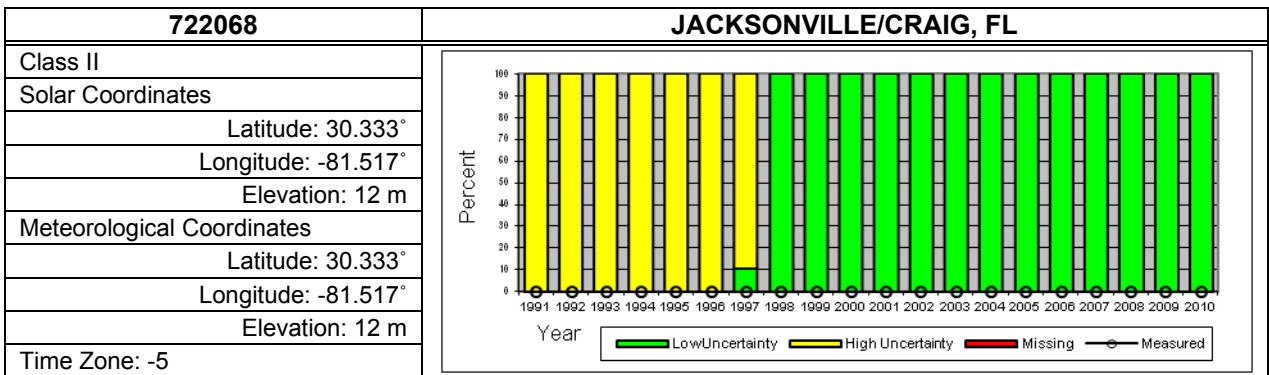
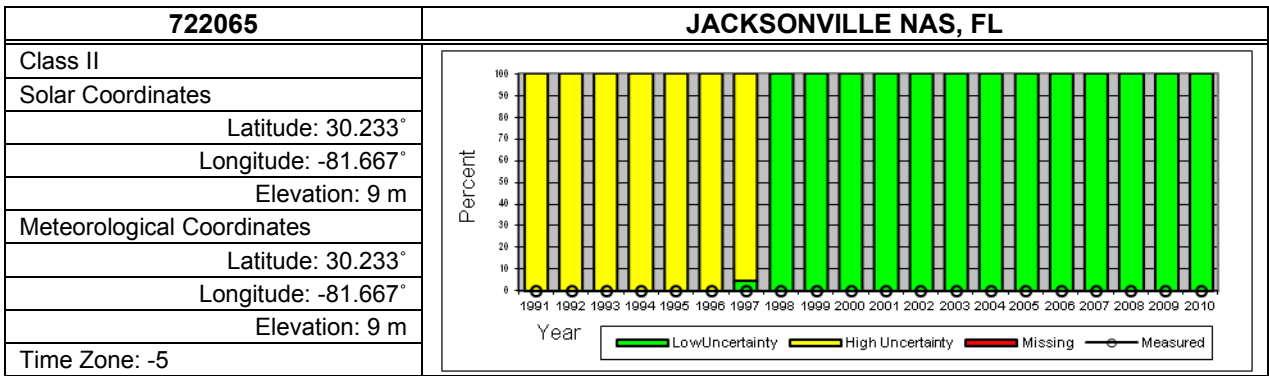


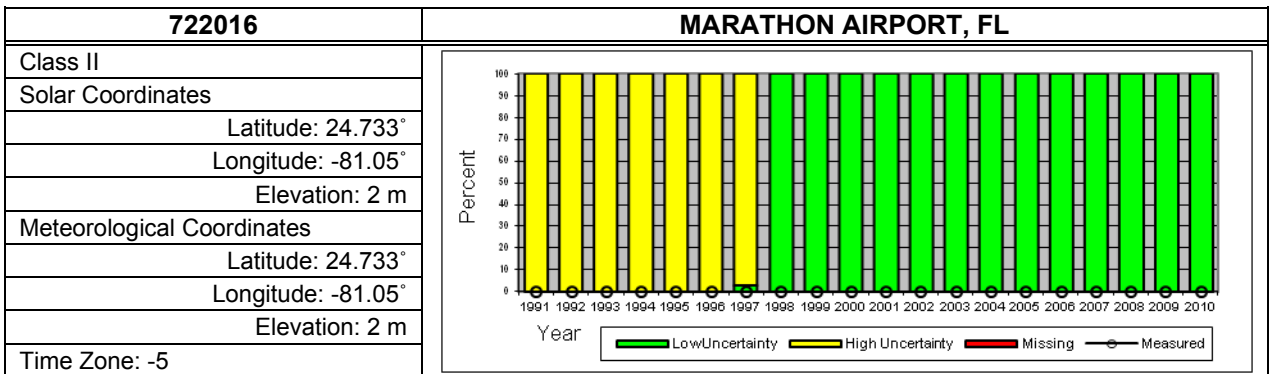
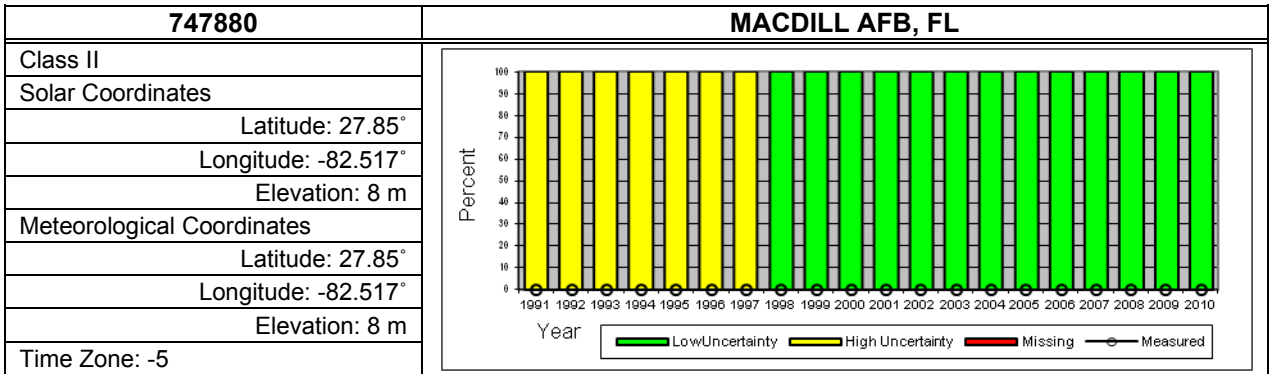
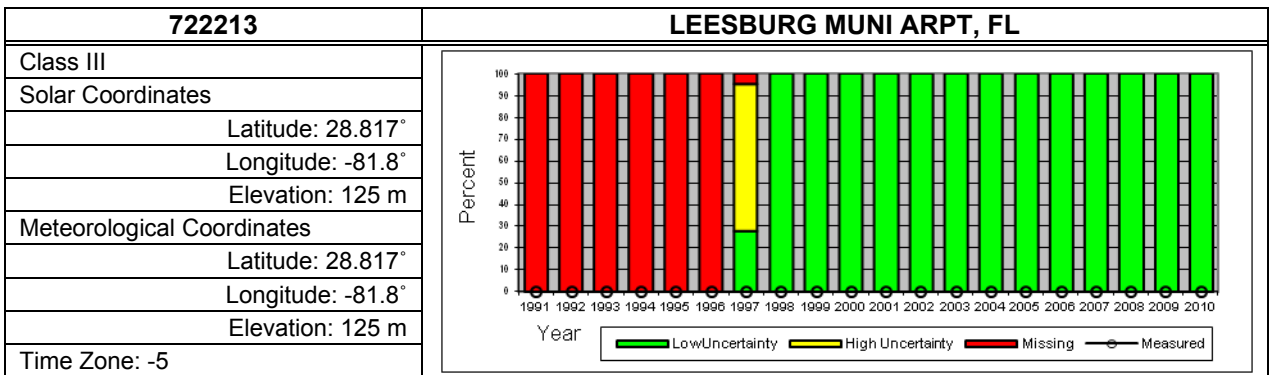
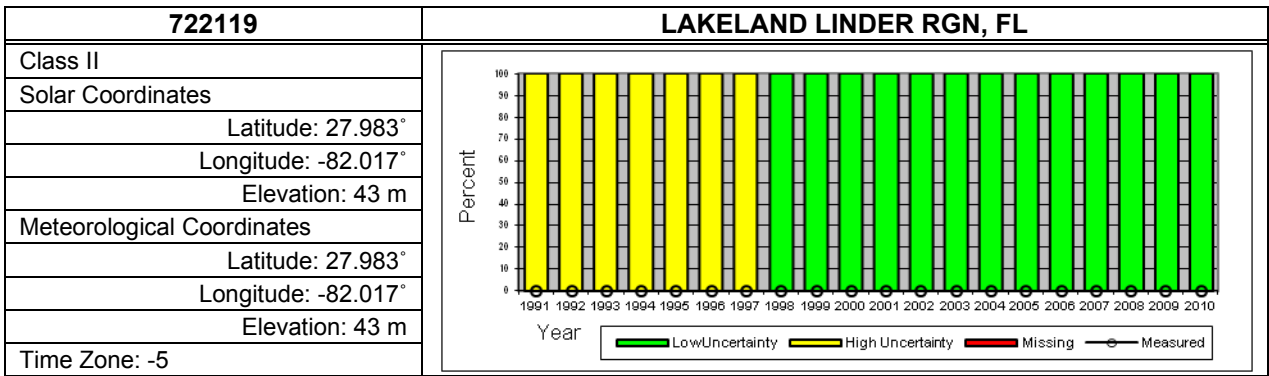


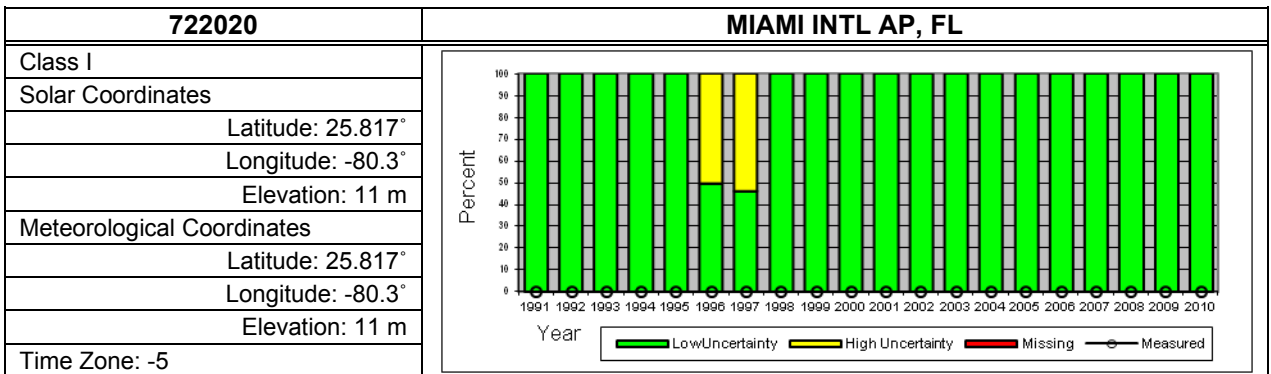
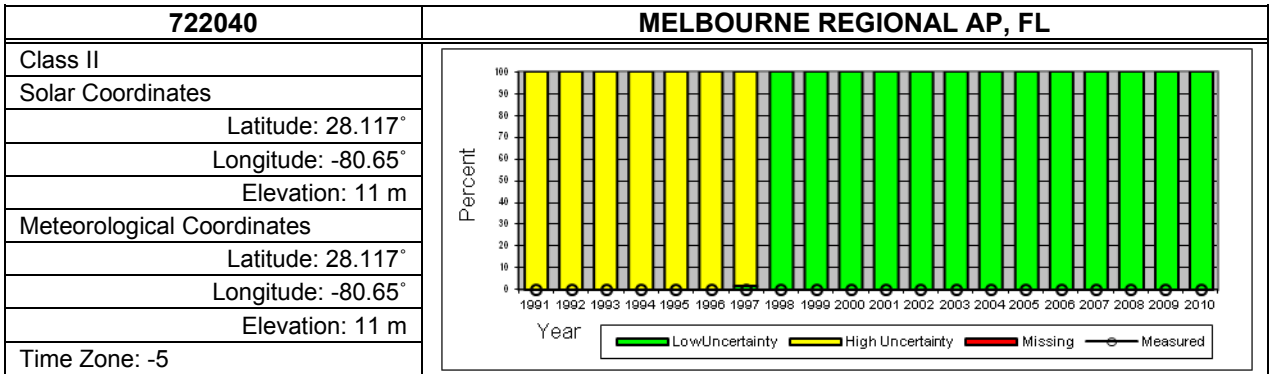
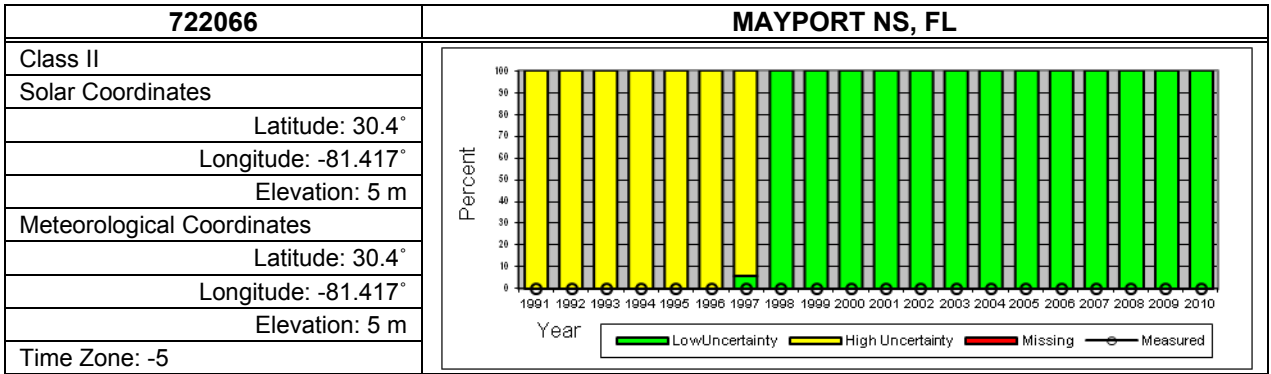
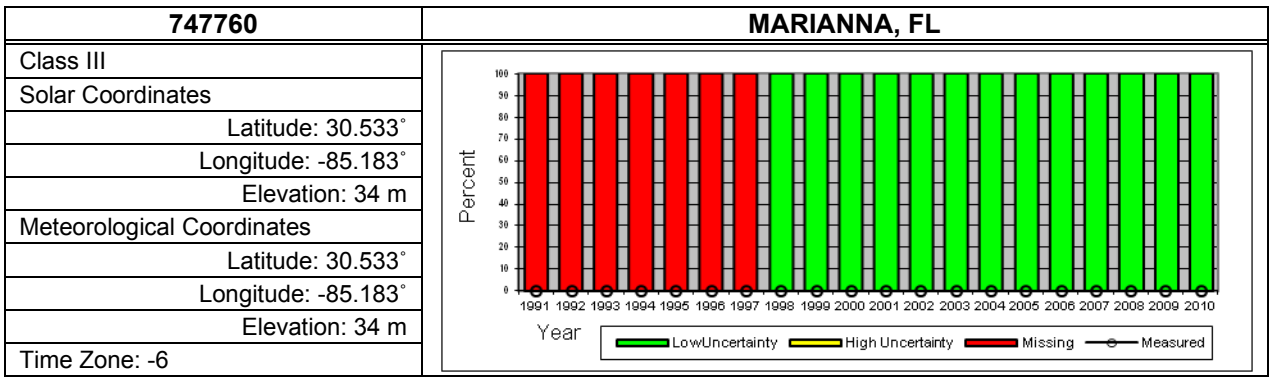


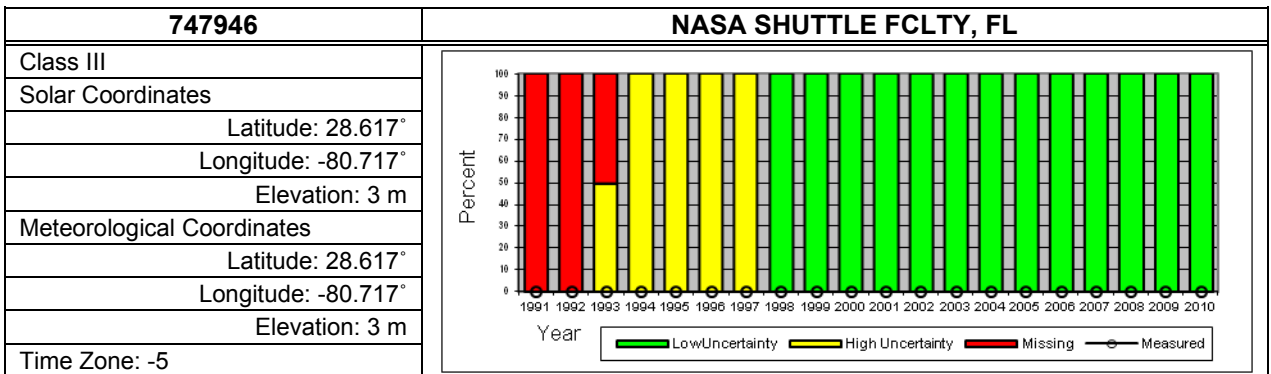
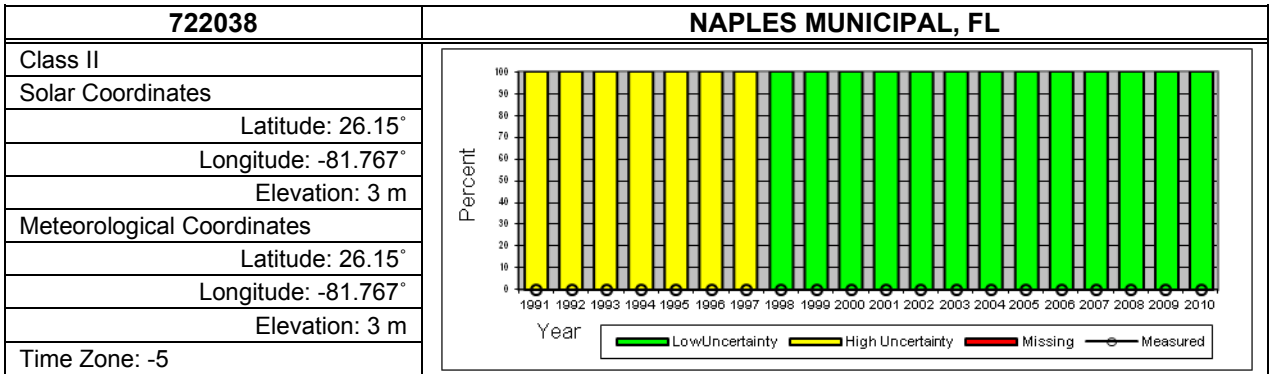
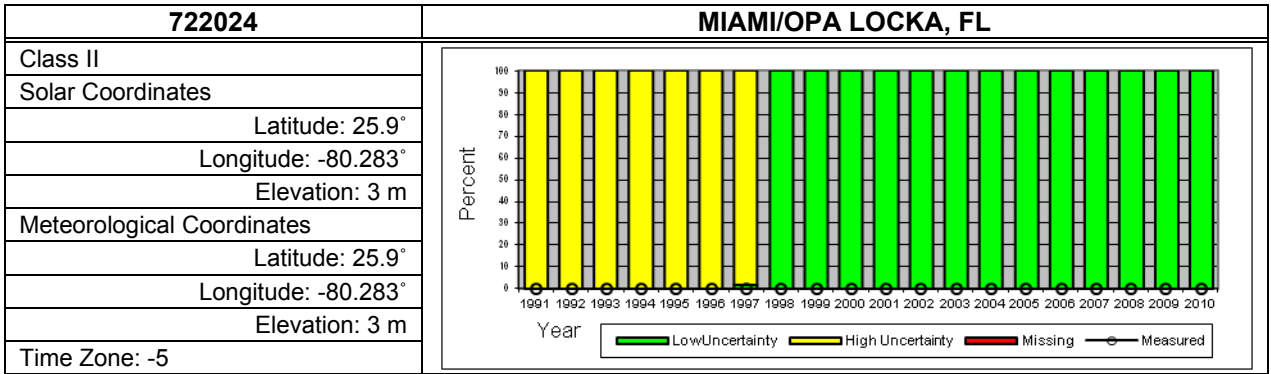
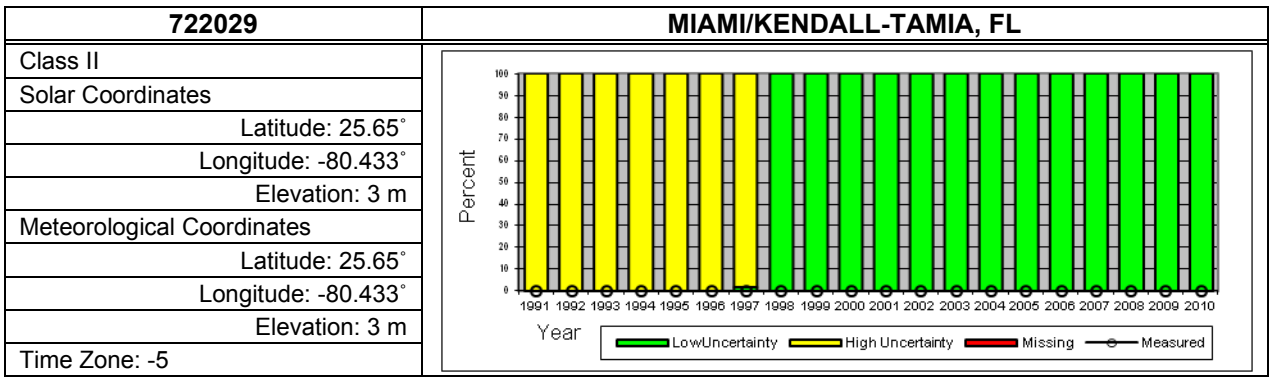










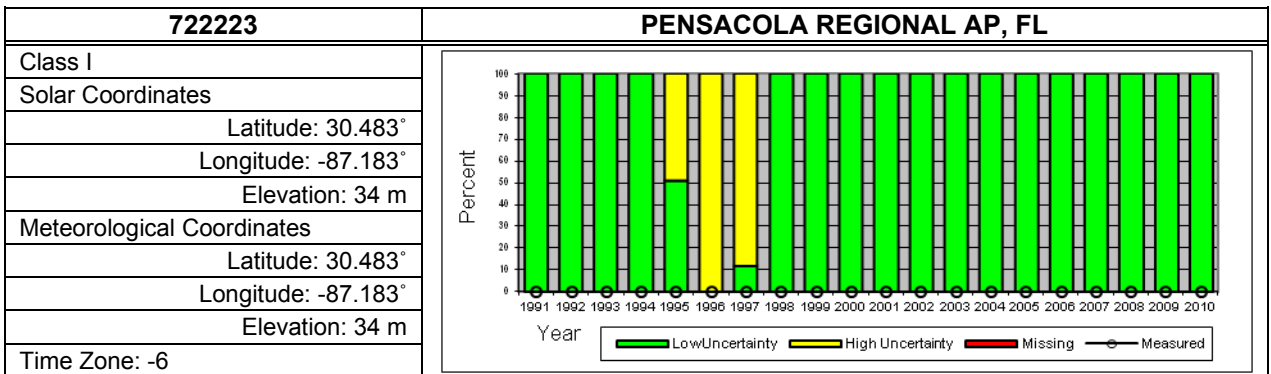
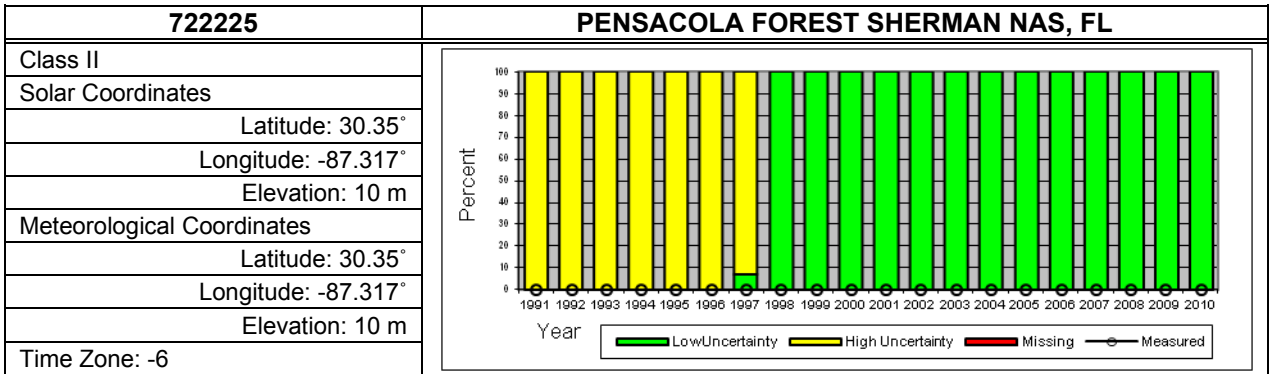
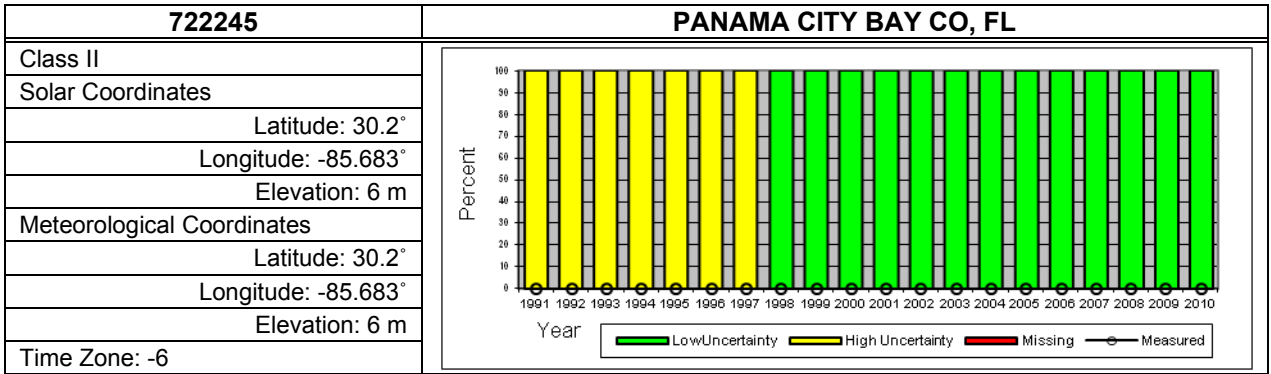
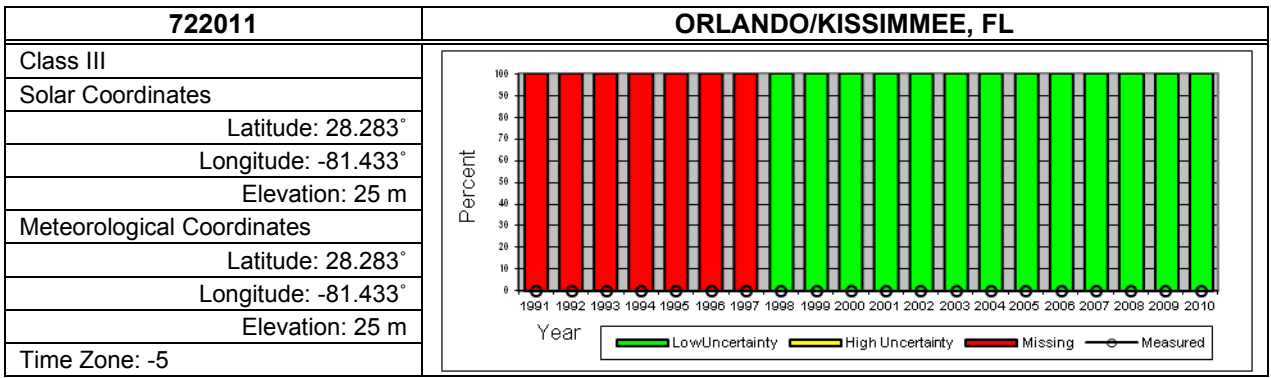


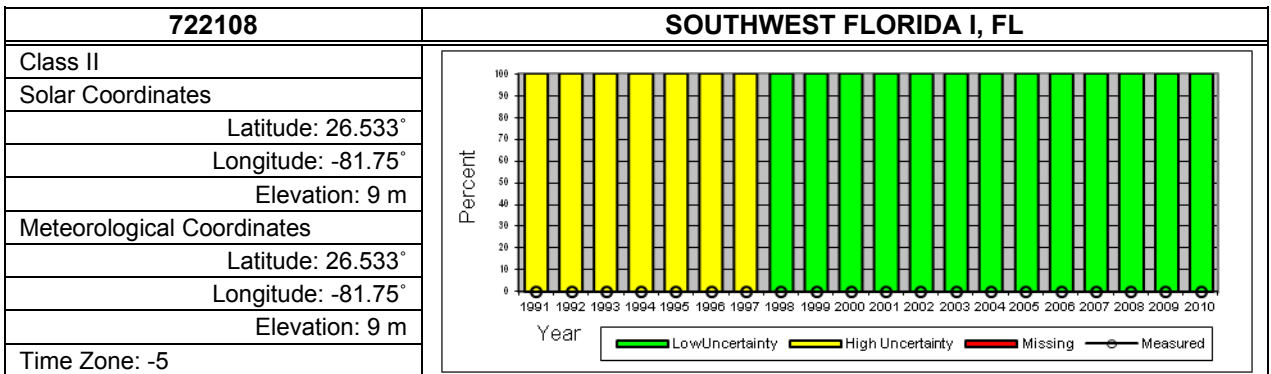
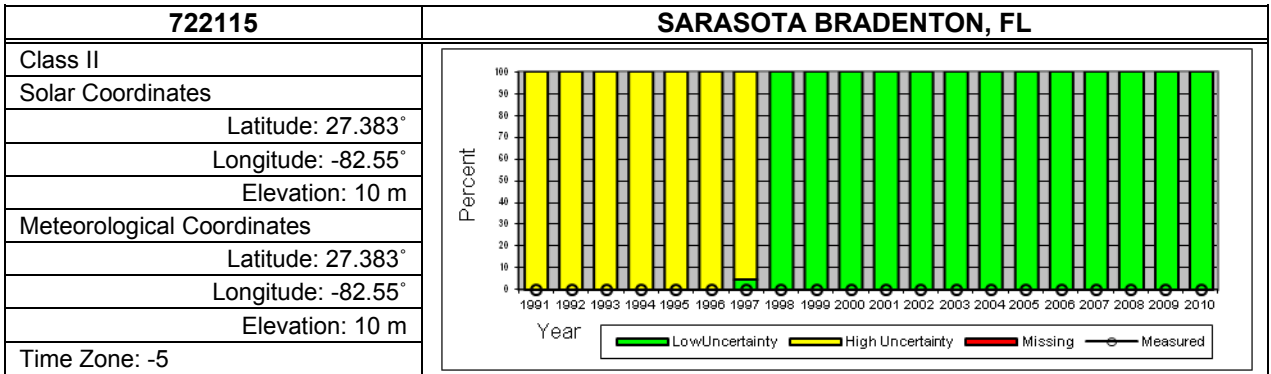
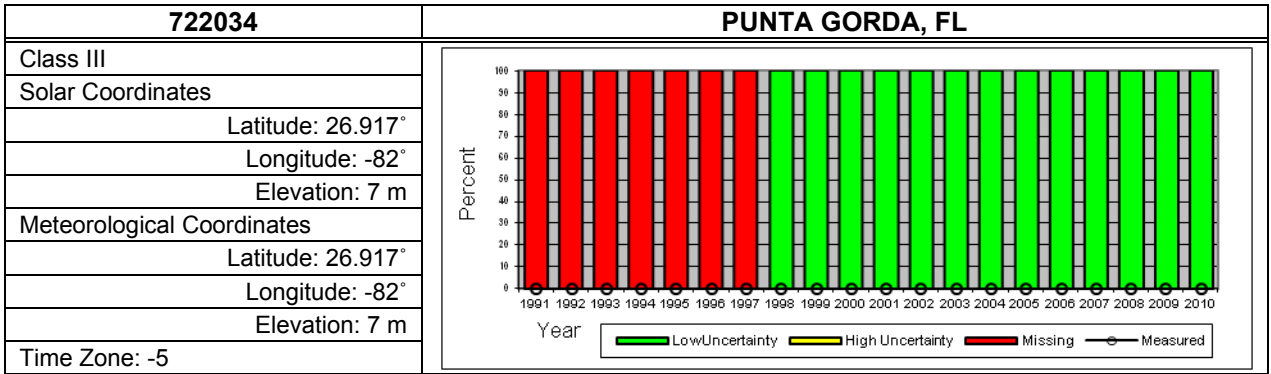
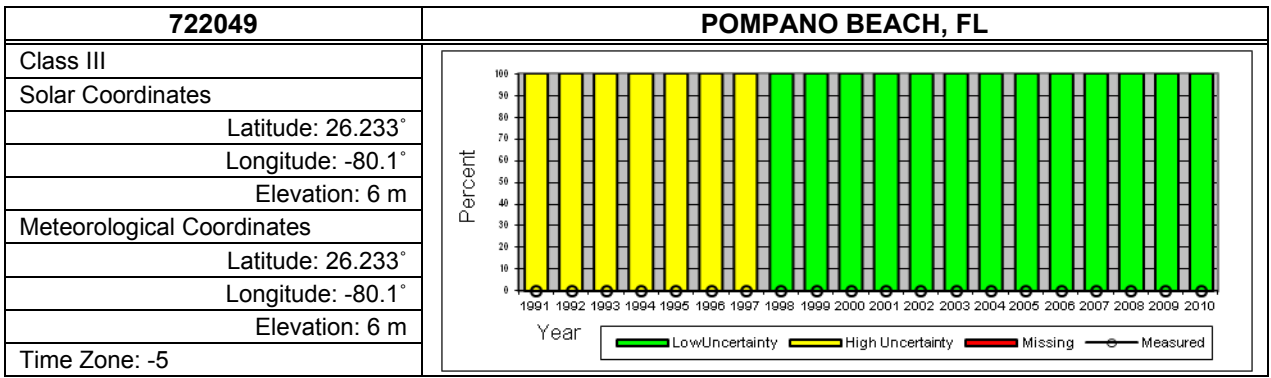
722055	OCALA MUNI (AWOS), FL
Class II	
Solar Coordinates	
Latitude: 29.167°	
Longitude: -82.217°	
Elevation: 27 m	
Meteorological Coordinates	
Latitude: 29.167°	
Longitude: -82.217°	
Elevation: 27 m	
Time Zone: -5	

722053	ORLANDO EXECUTIVE AP, FL
Class II	
Solar Coordinates	
Latitude: 28.55°	
Longitude: -81.333°	
Elevation: 33 m	
Meteorological Coordinates	
Latitude: 28.55°	
Longitude: -81.333°	
Elevation: 33 m	
Time Zone: -5	

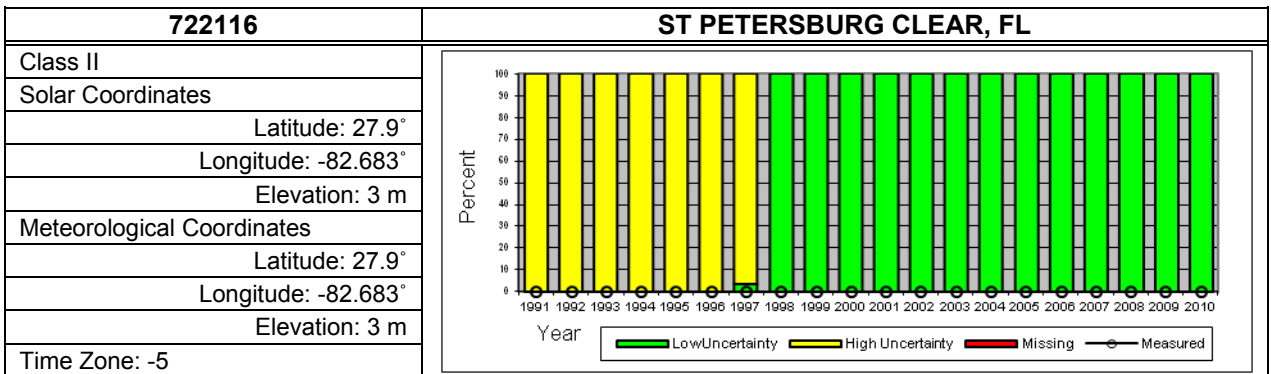
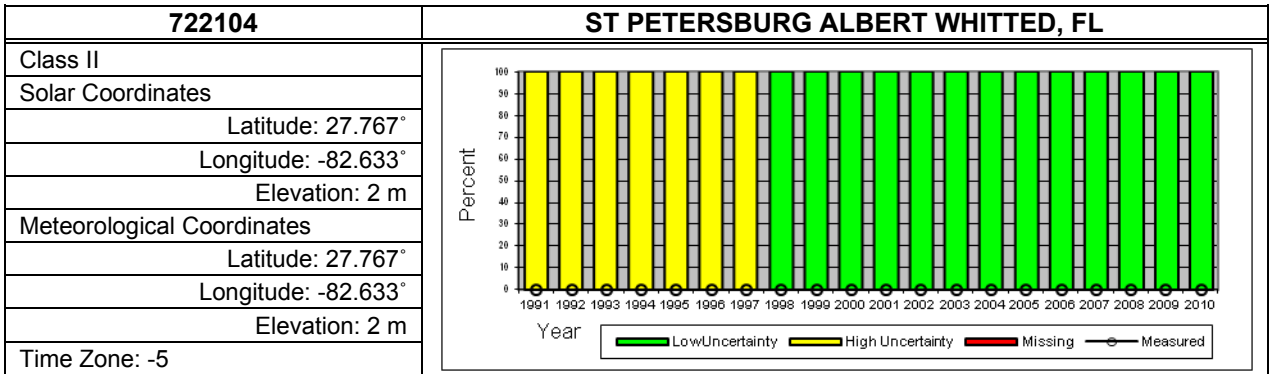
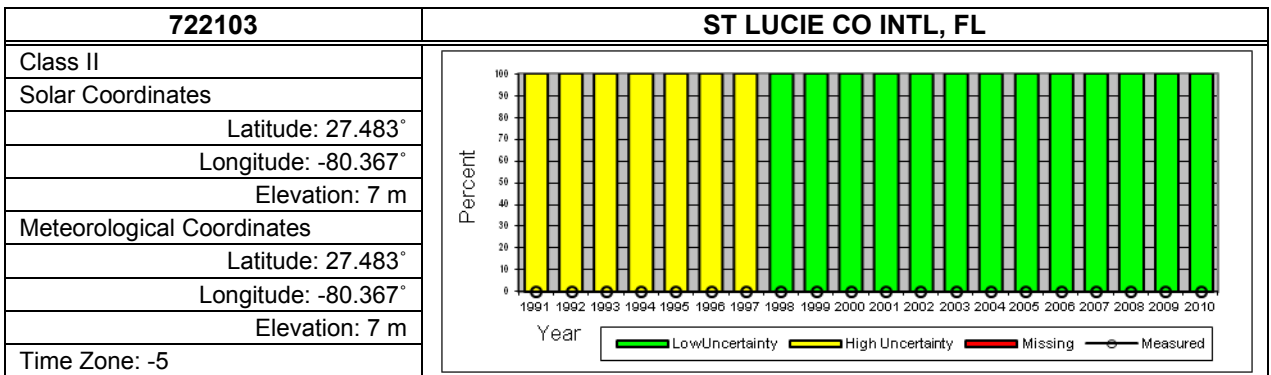
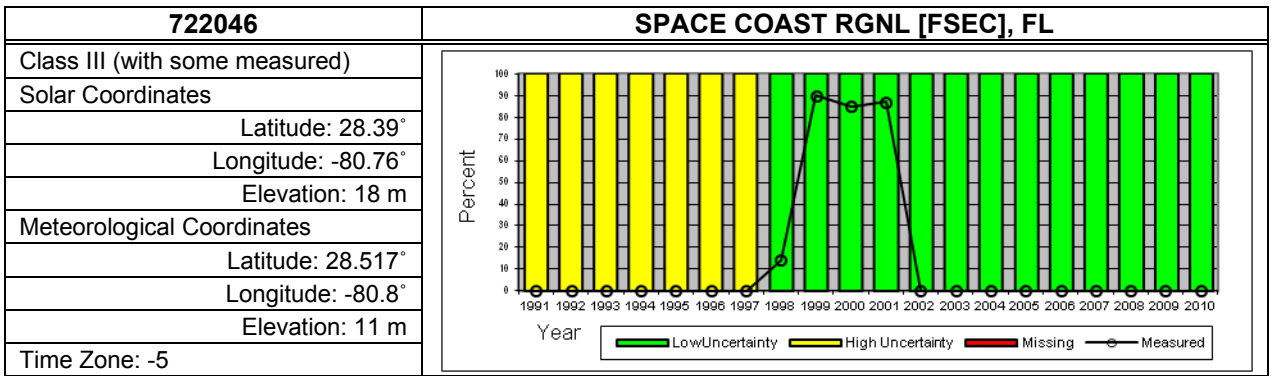
722050	ORLANDO INTL ARPT, FL
Class I	
Solar Coordinates	
Latitude: 28.433°	
Longitude: -81.333°	
Elevation: 29 m	
Meteorological Coordinates	
Latitude: 28.433°	
Longitude: -81.333°	
Elevation: 29 m	
Time Zone: -5	

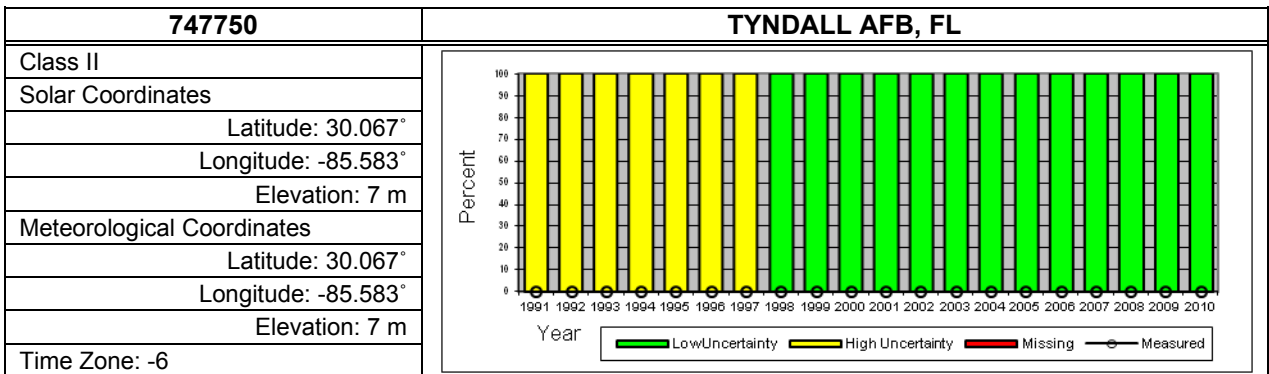
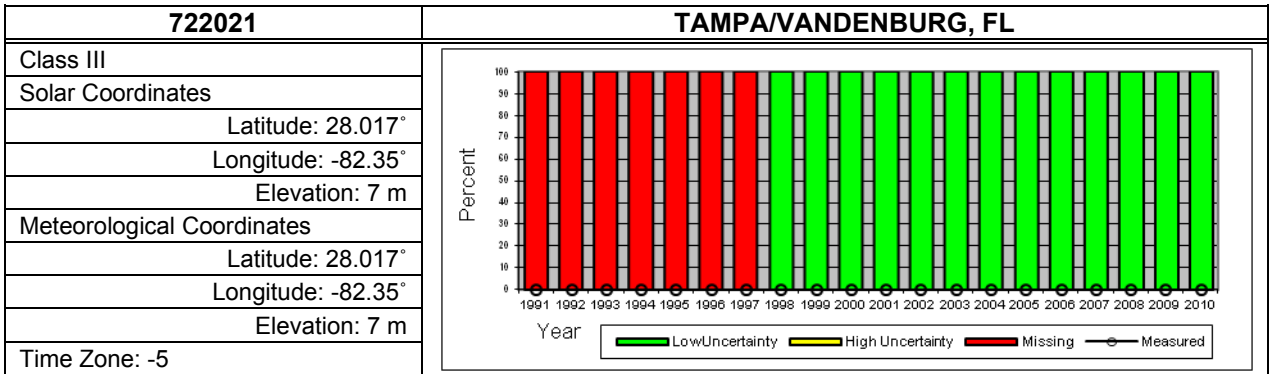
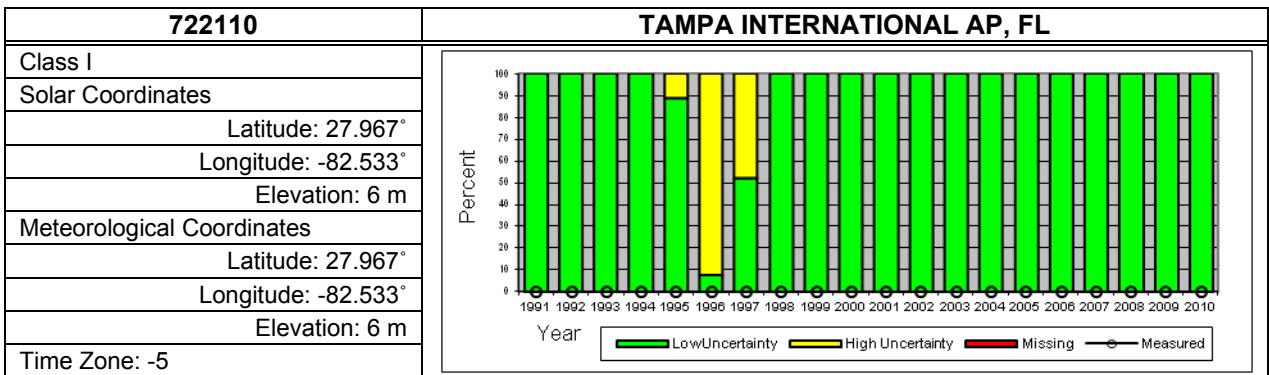
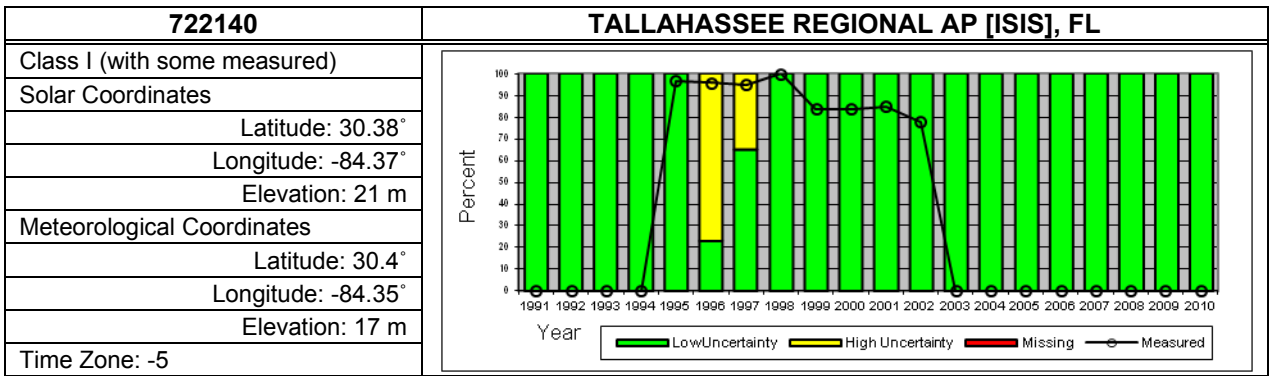
722057	ORLANDO SANFORD AIRPORT, FL
Class II	
Solar Coordinates	
Latitude: 28.783°	
Longitude: -81.25°	
Elevation: 17 m	
Meteorological Coordinates	
Latitude: 28.783°	
Longitude: -81.25°	
Elevation: 17 m	
Time Zone: -5	

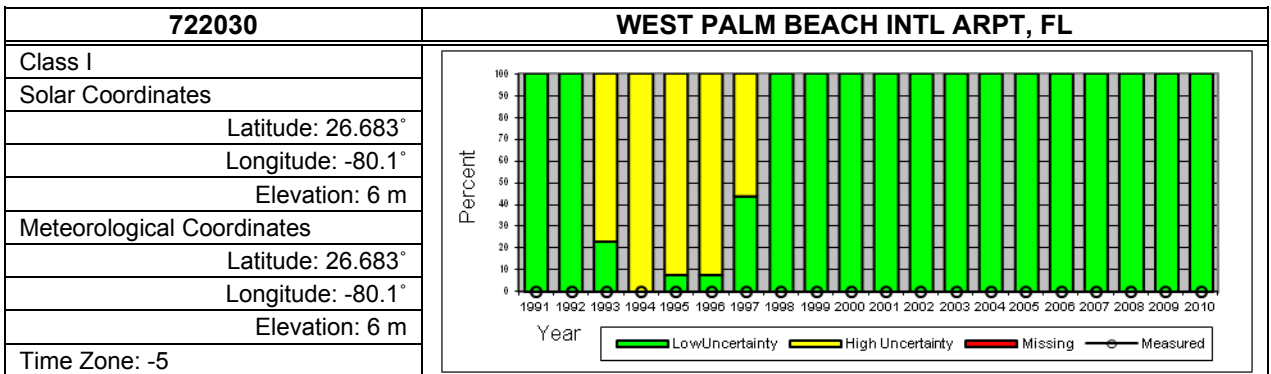
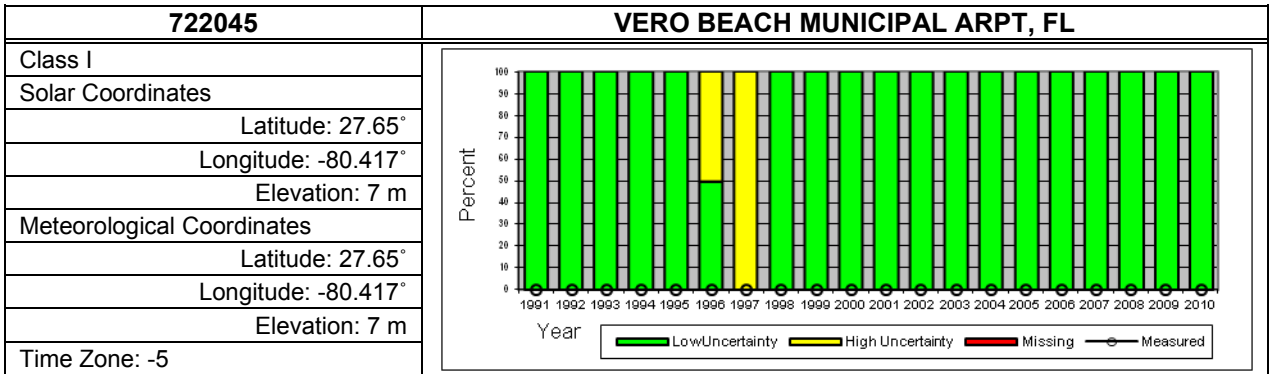
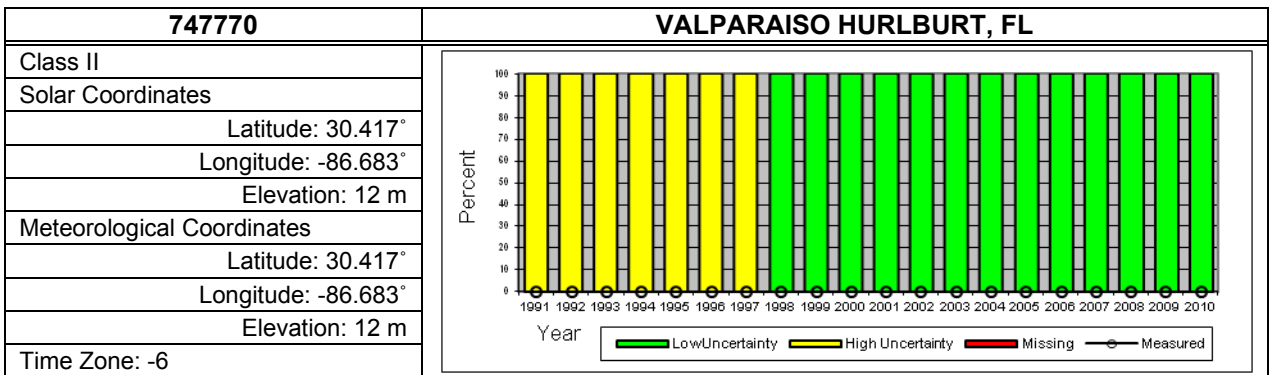
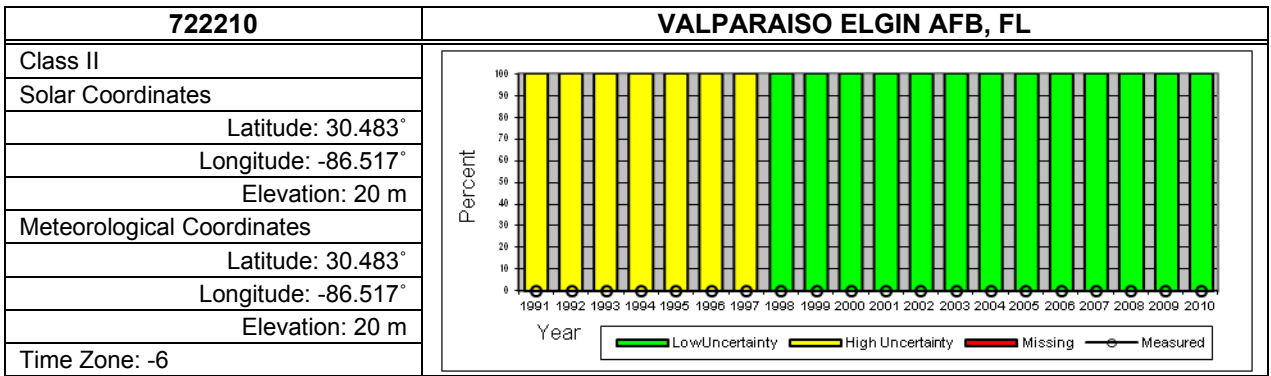


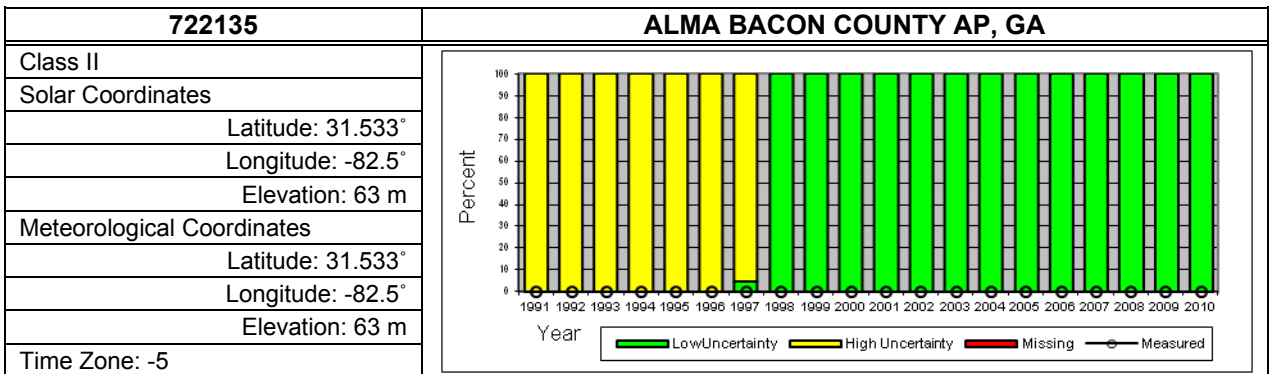
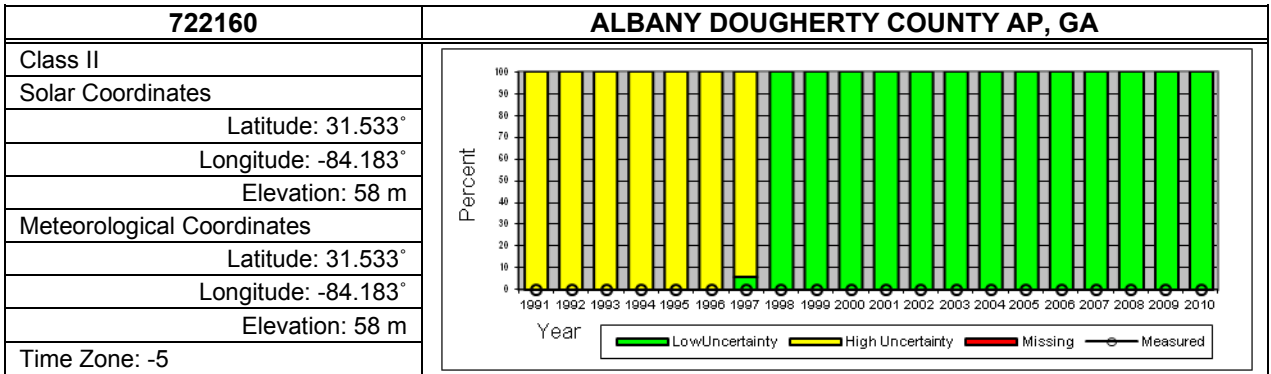
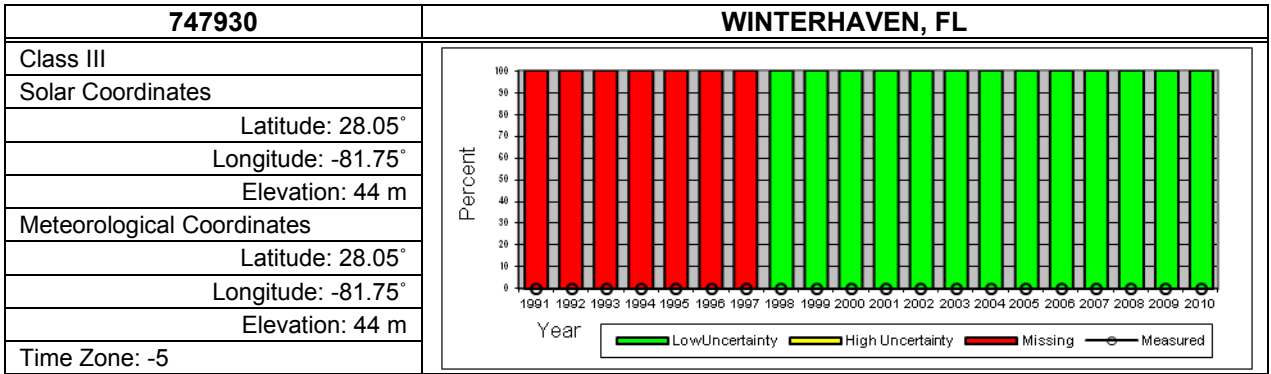
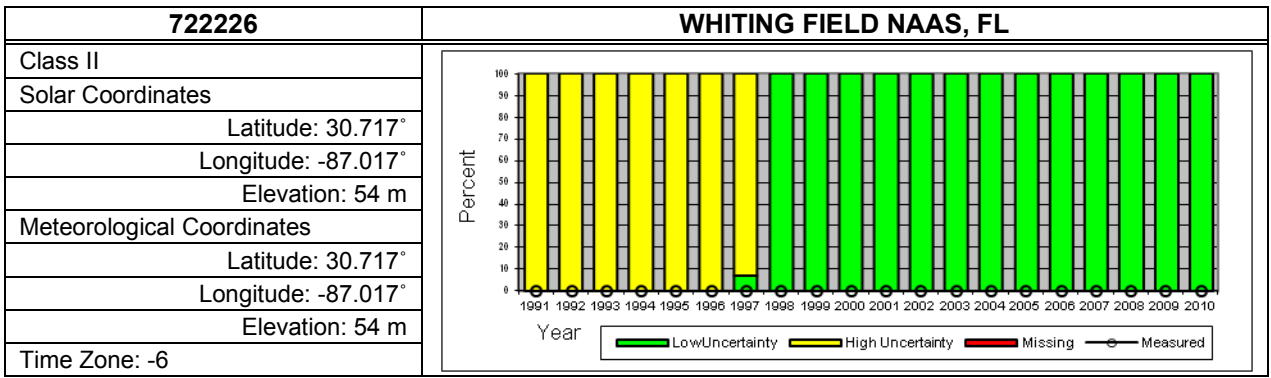


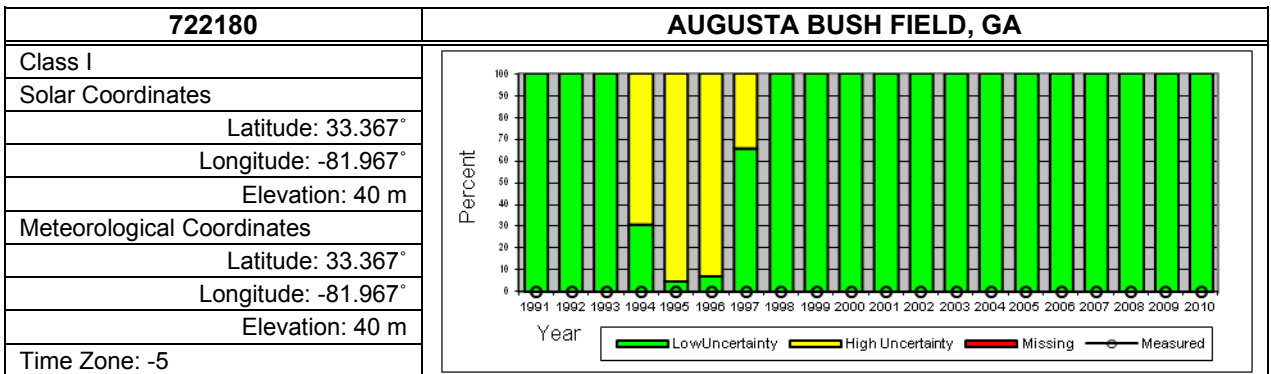
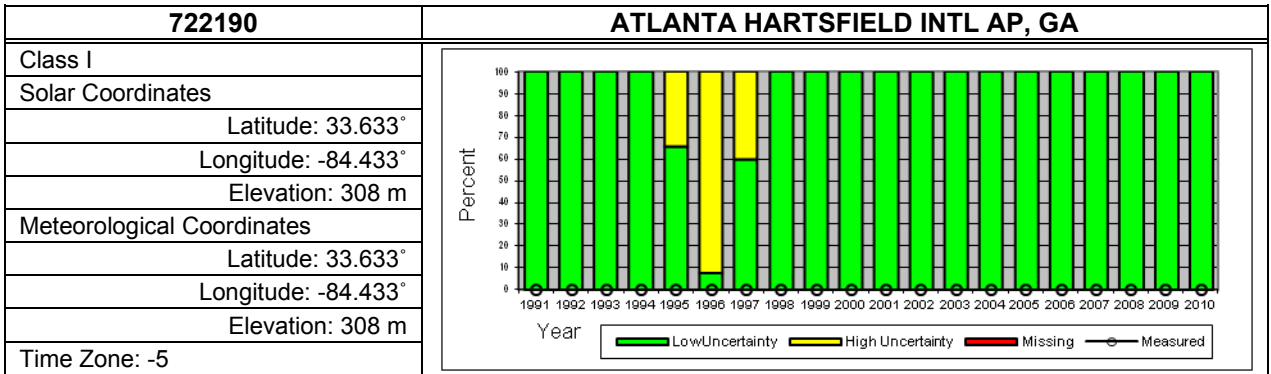
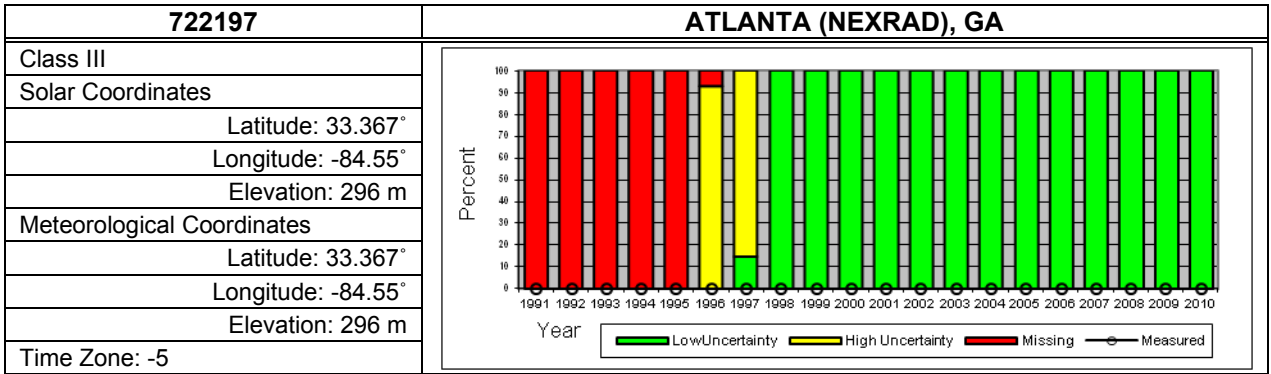
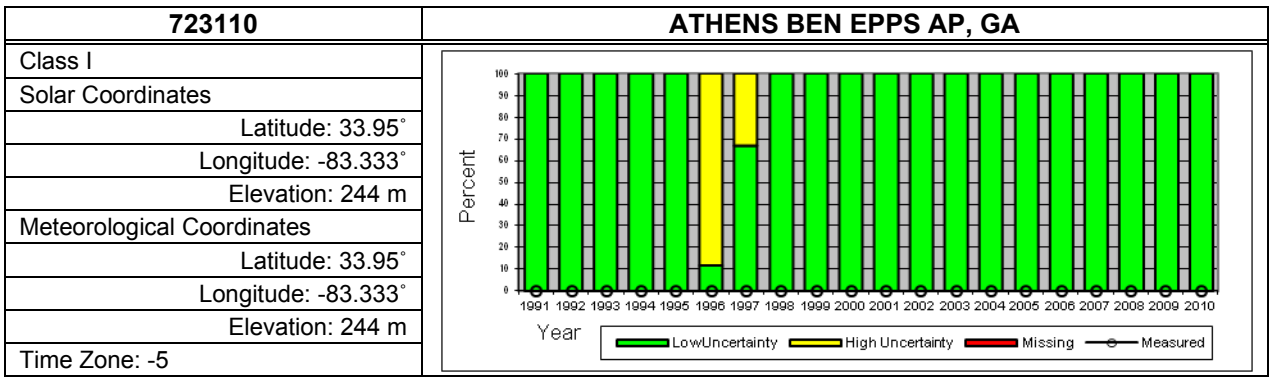


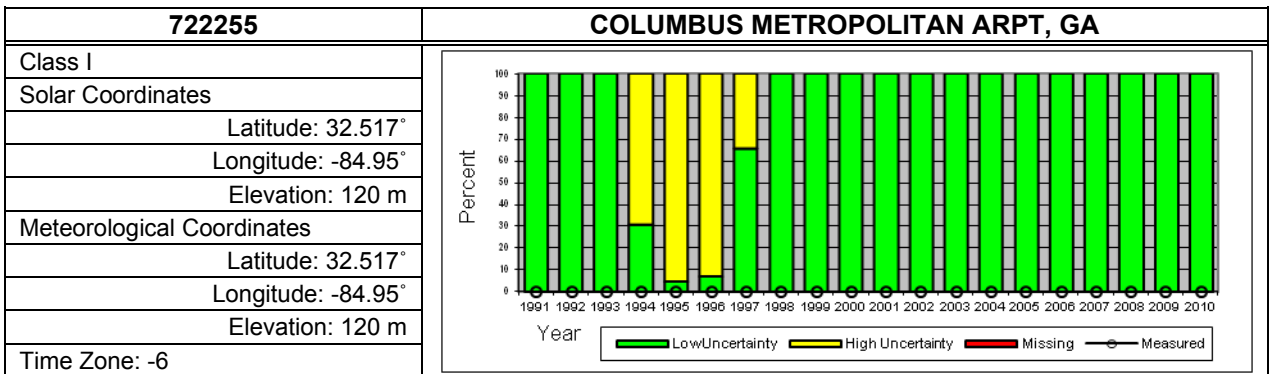
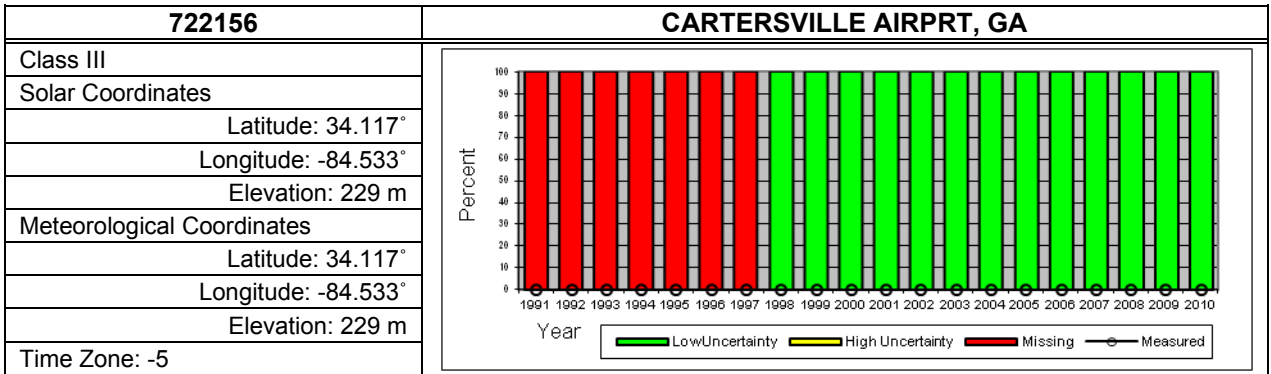
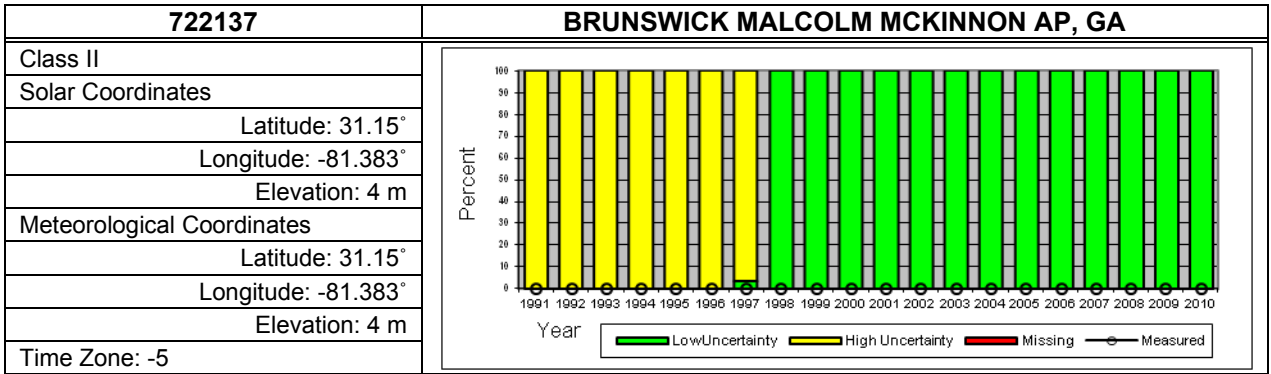
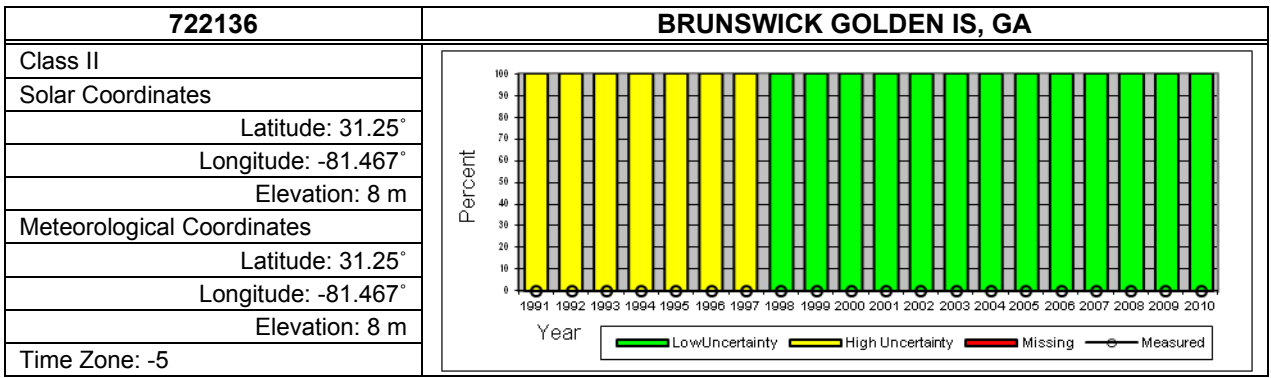


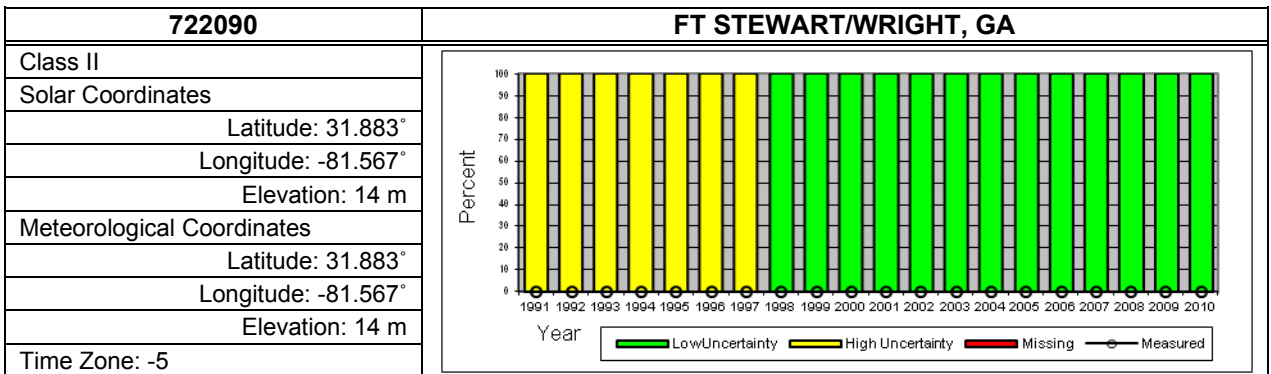
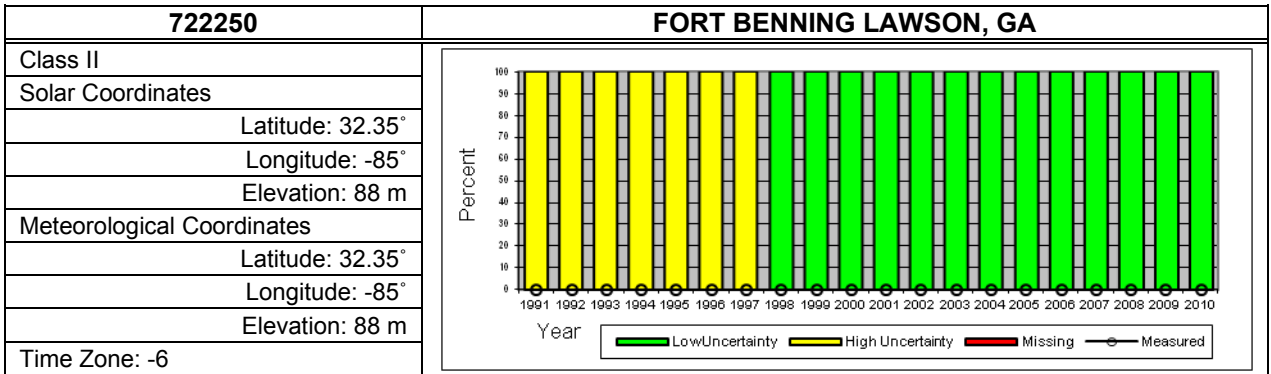
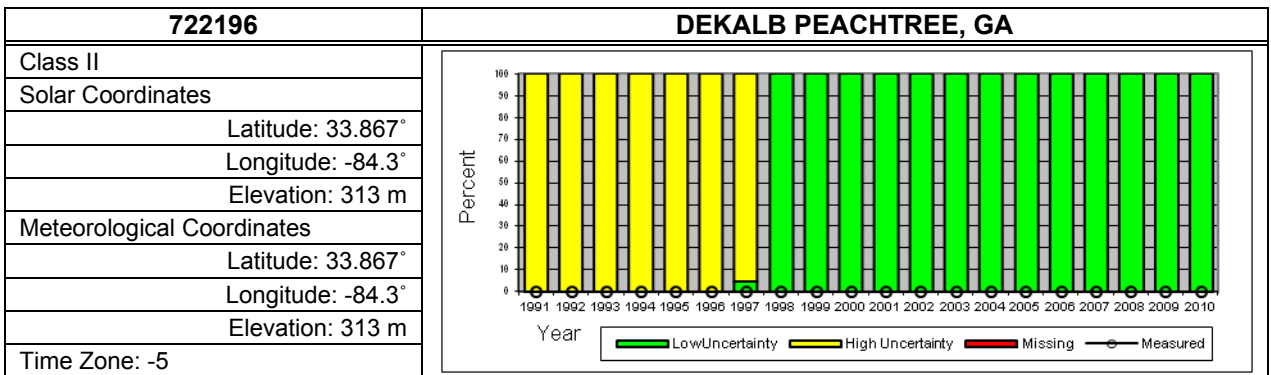
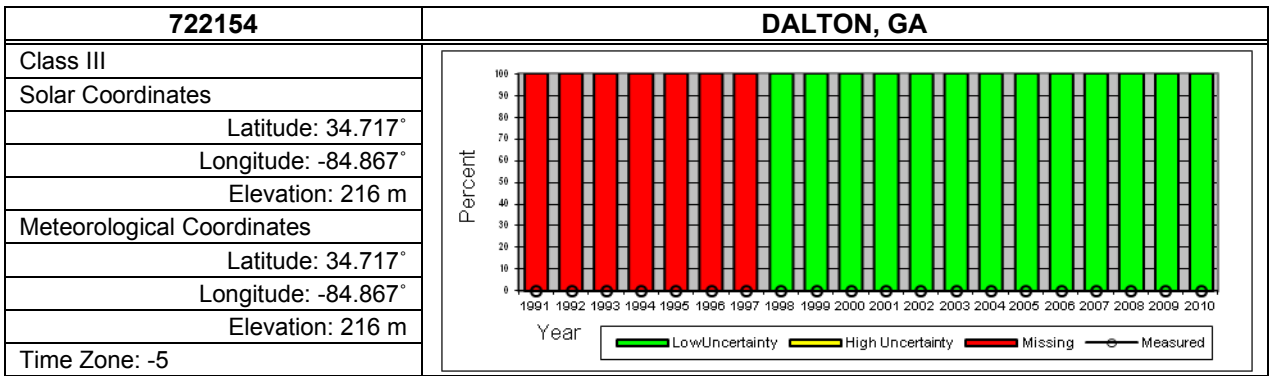


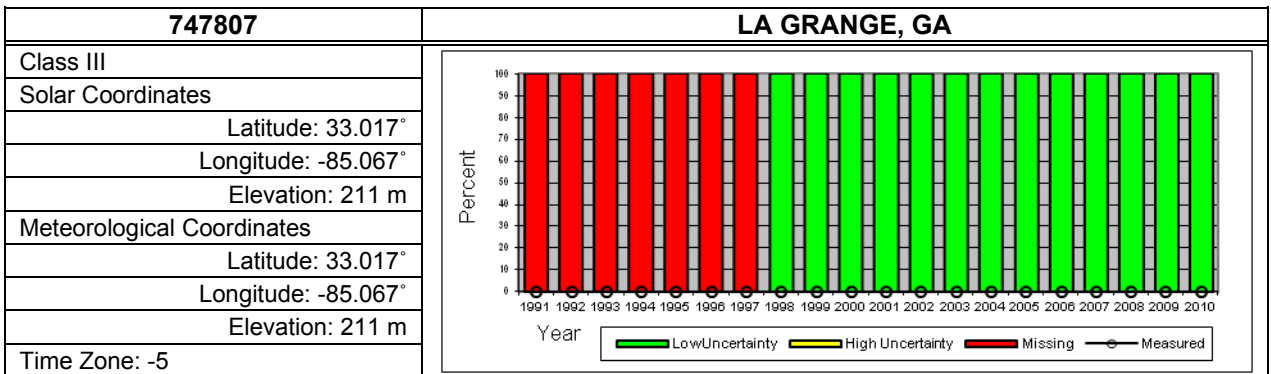
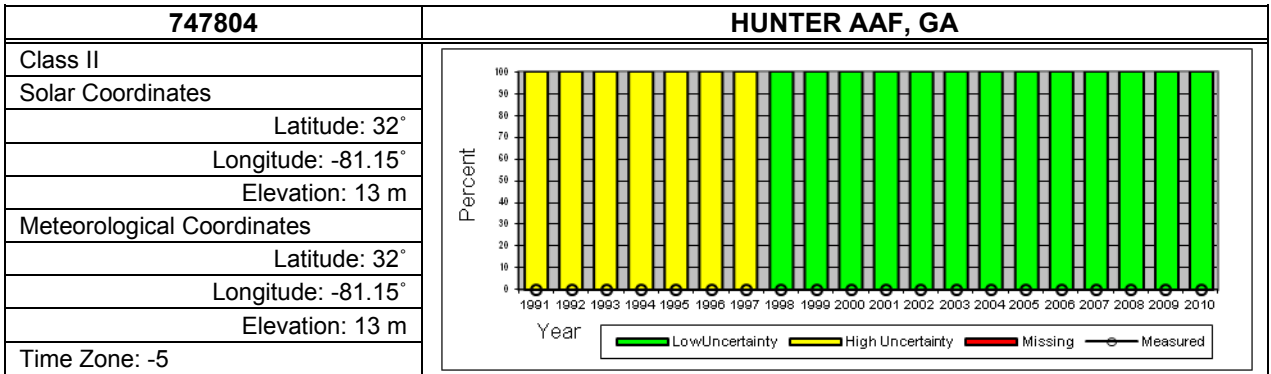
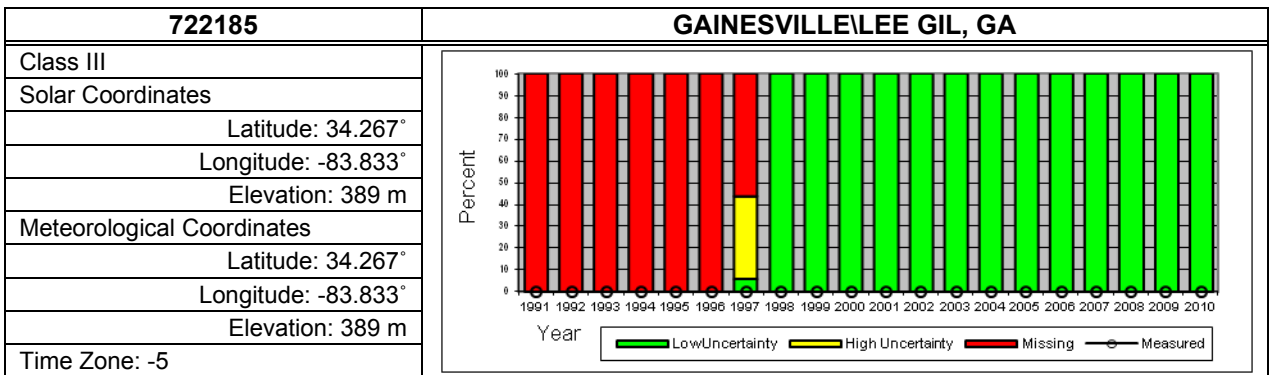
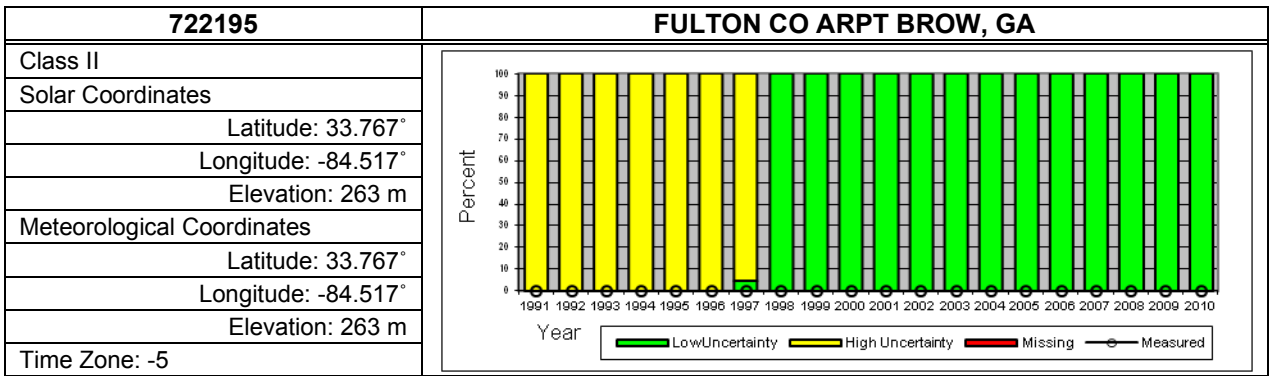




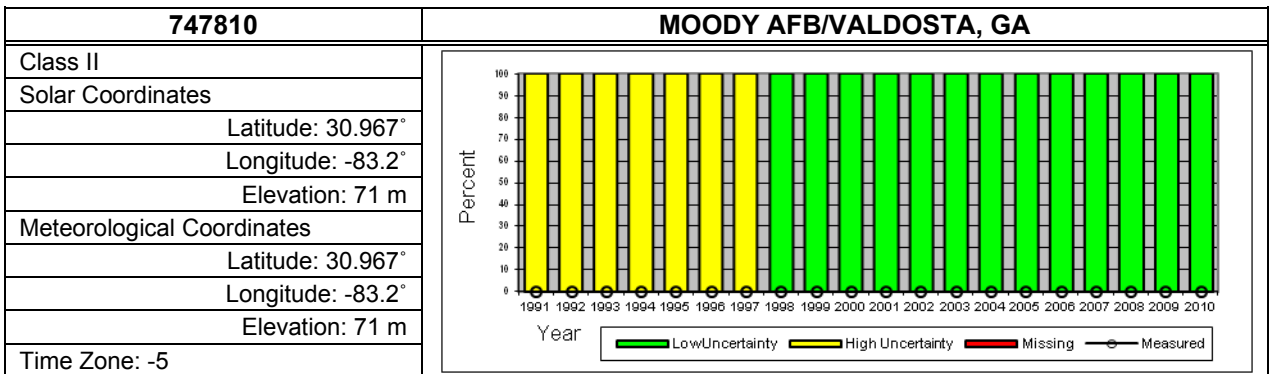
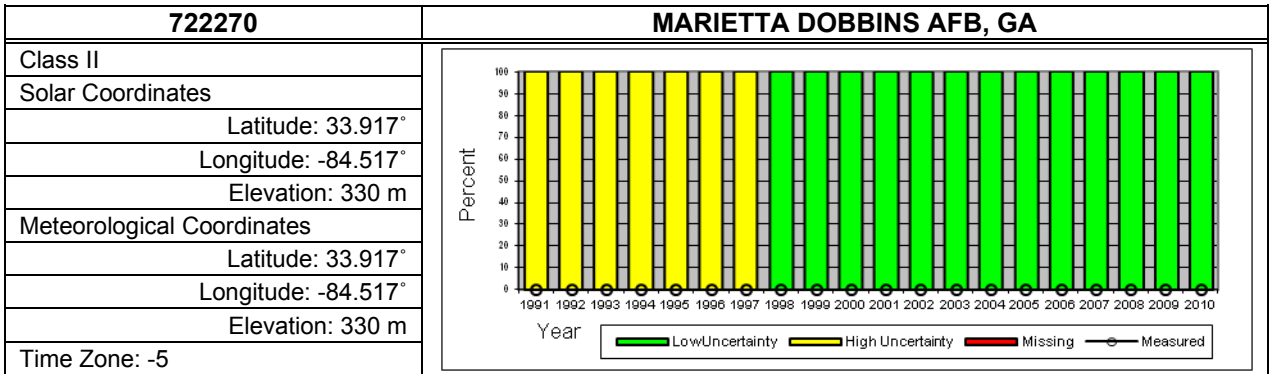
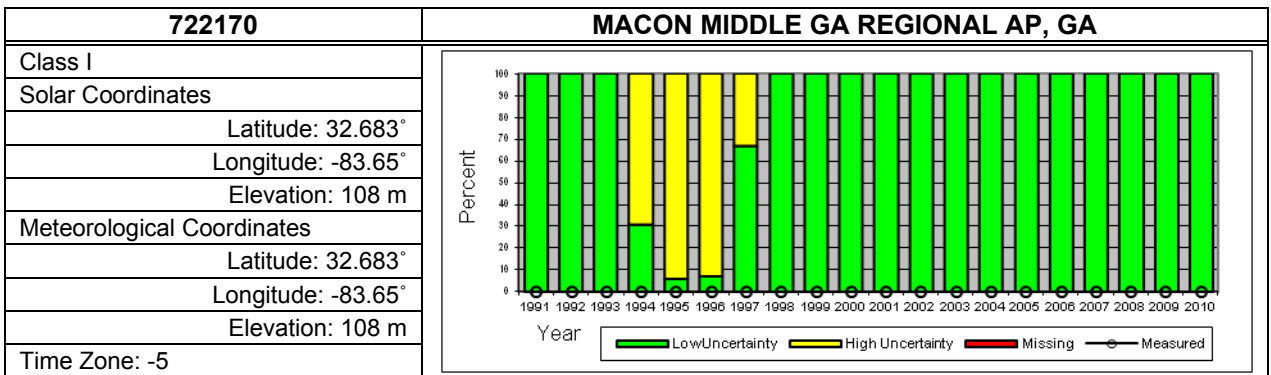
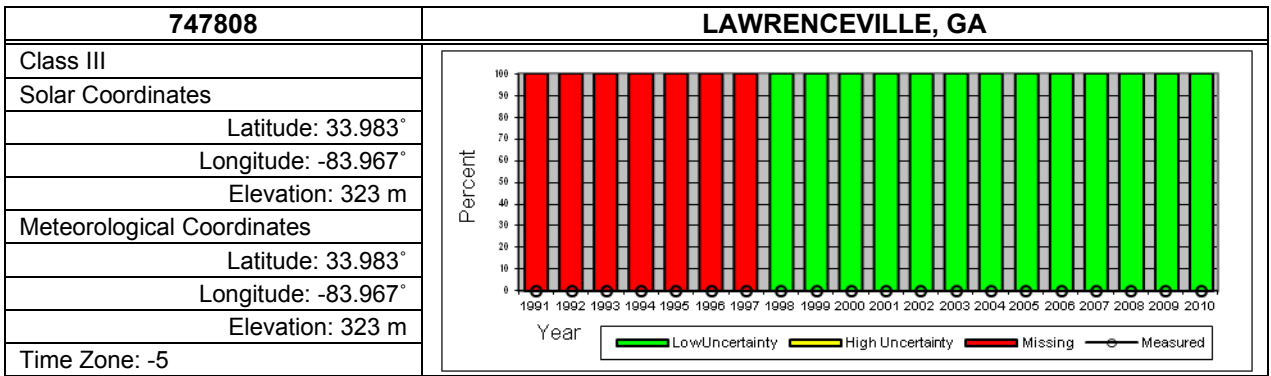


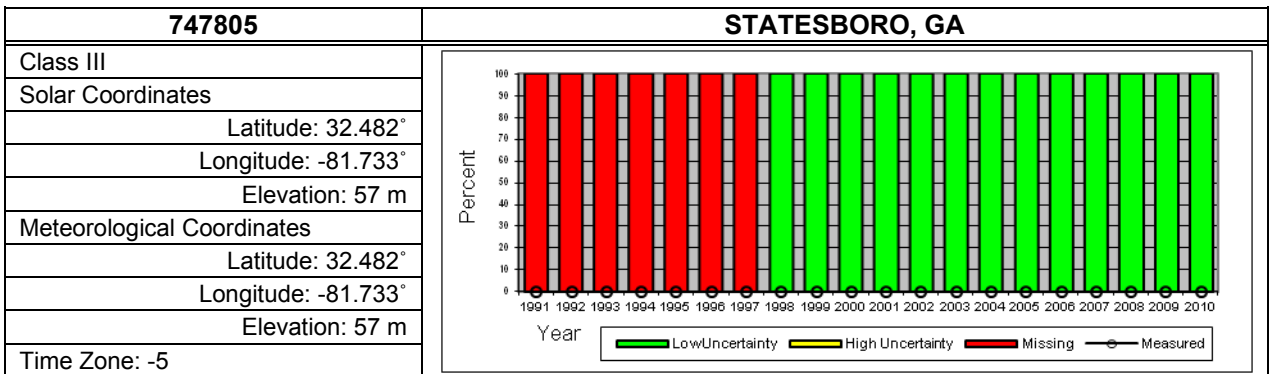
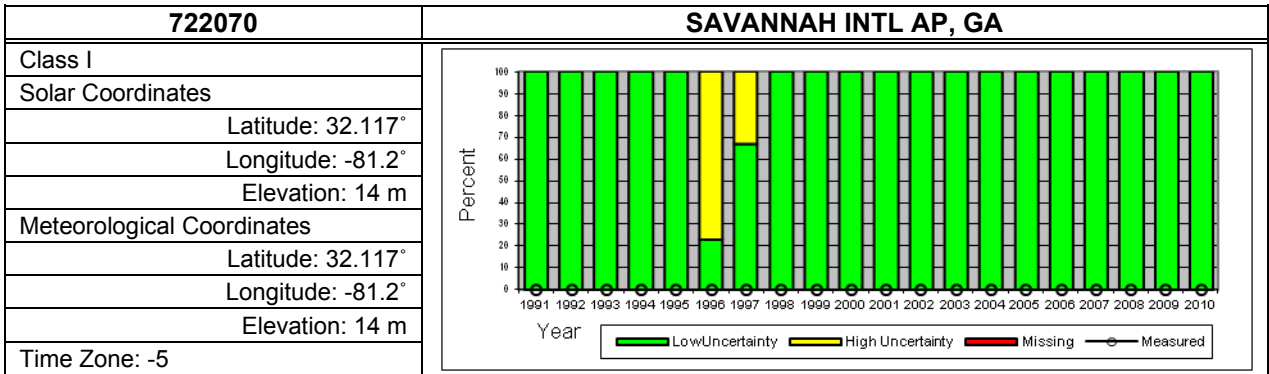
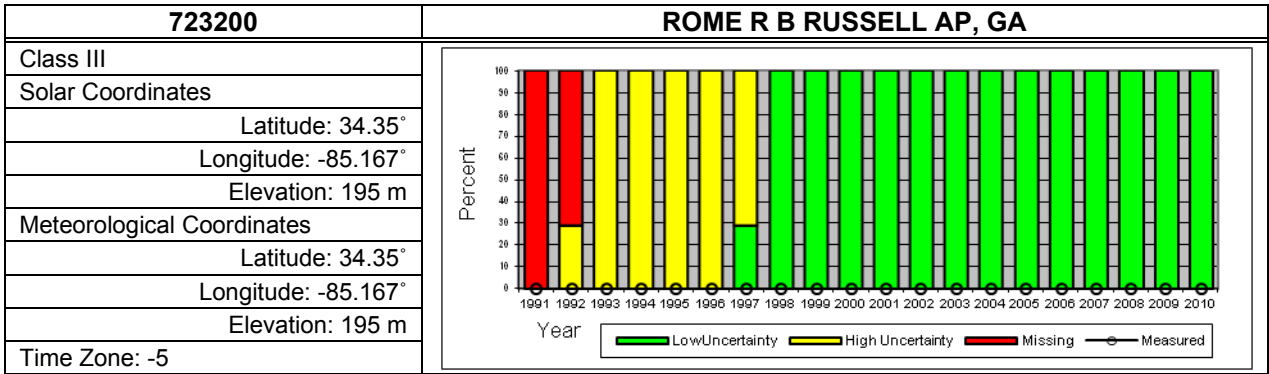
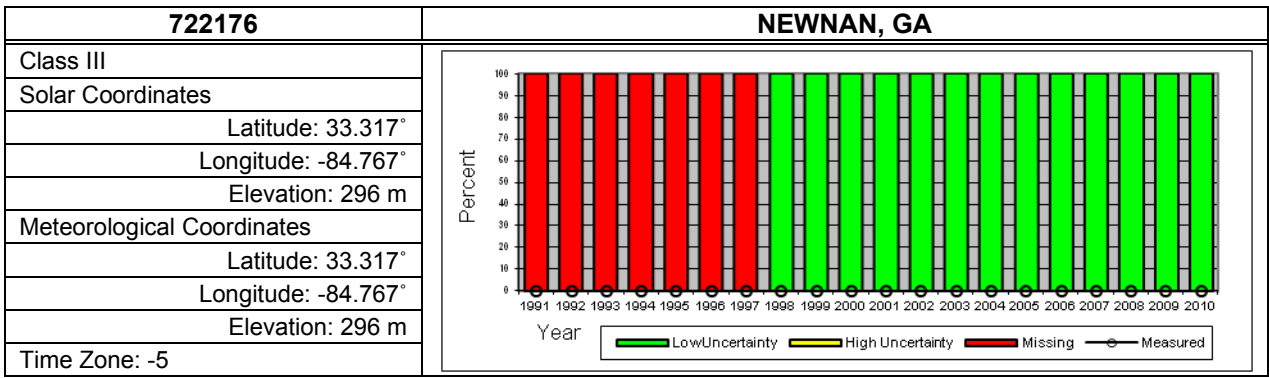


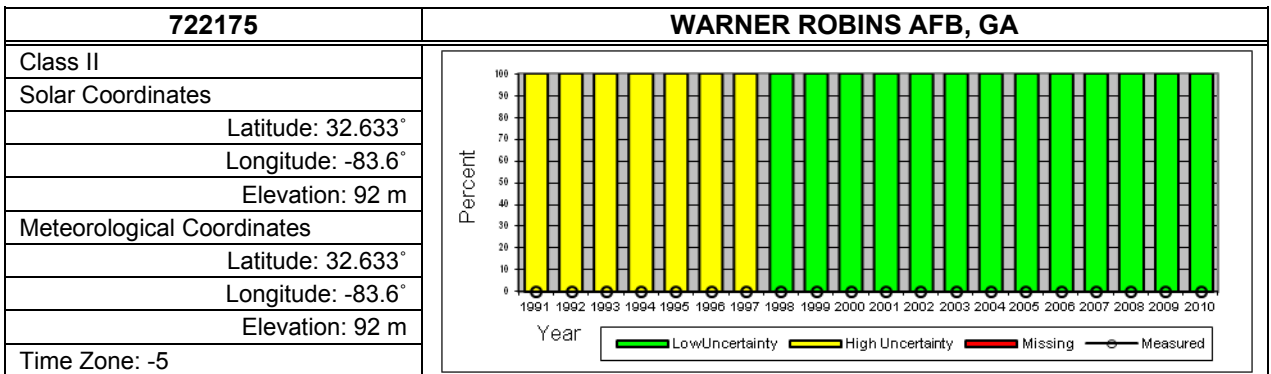
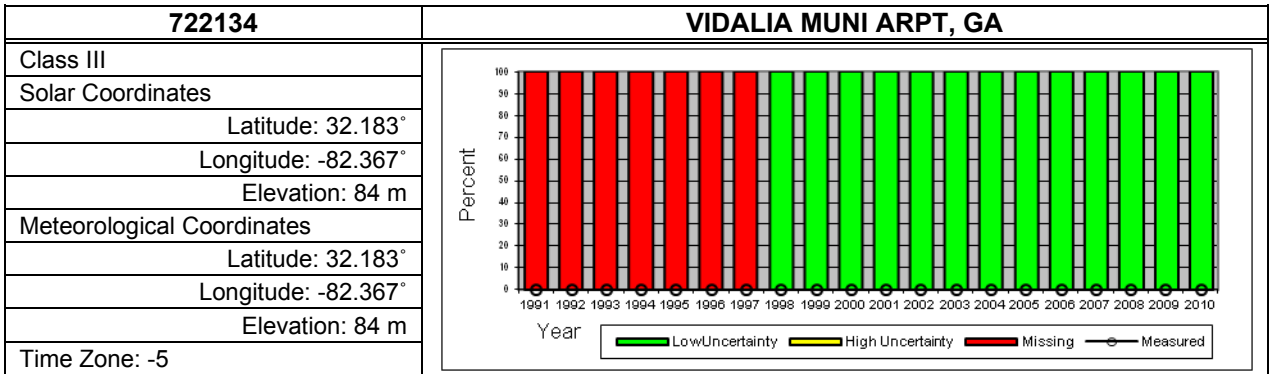
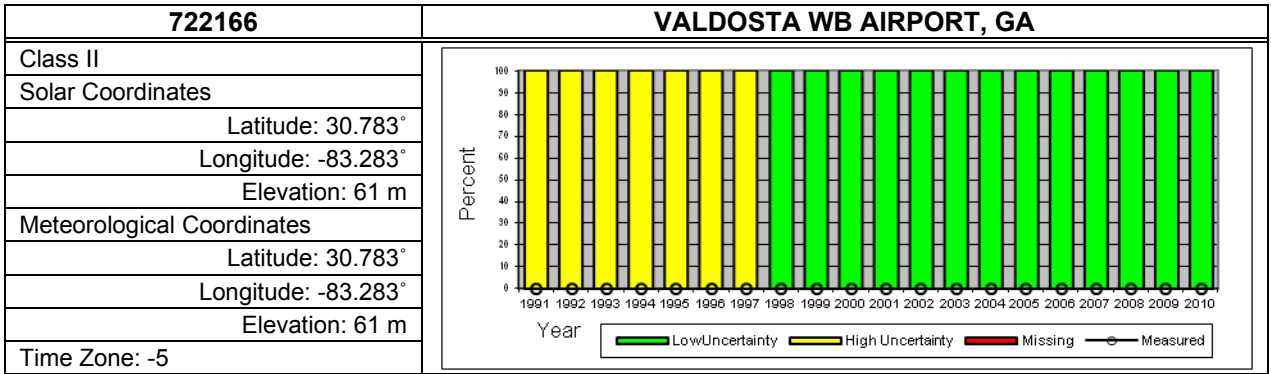
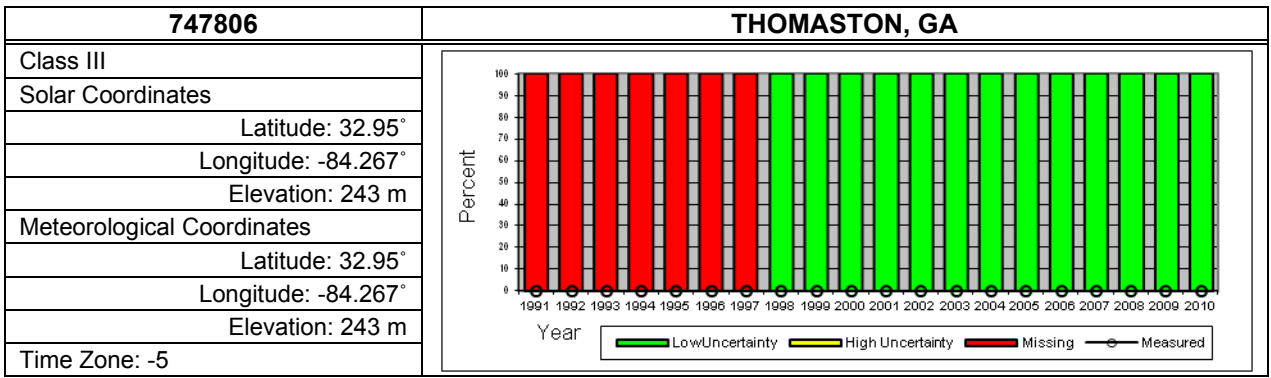


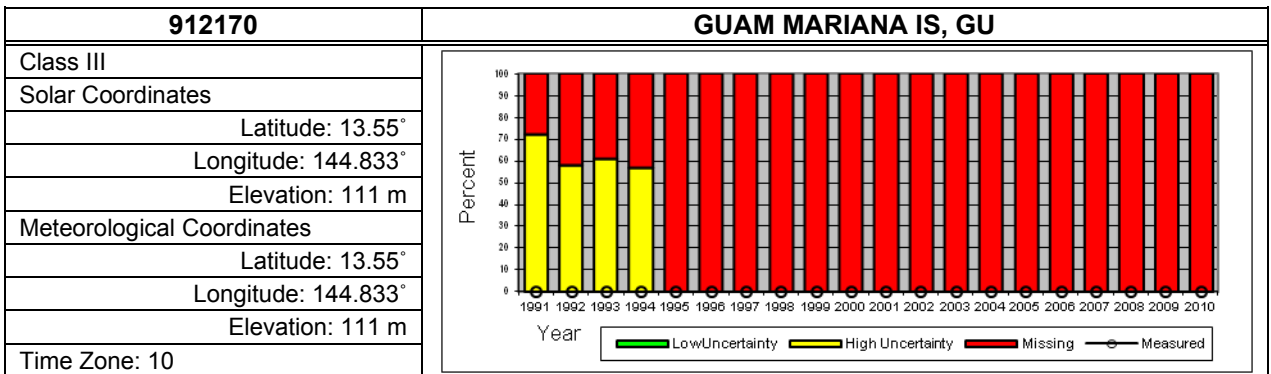
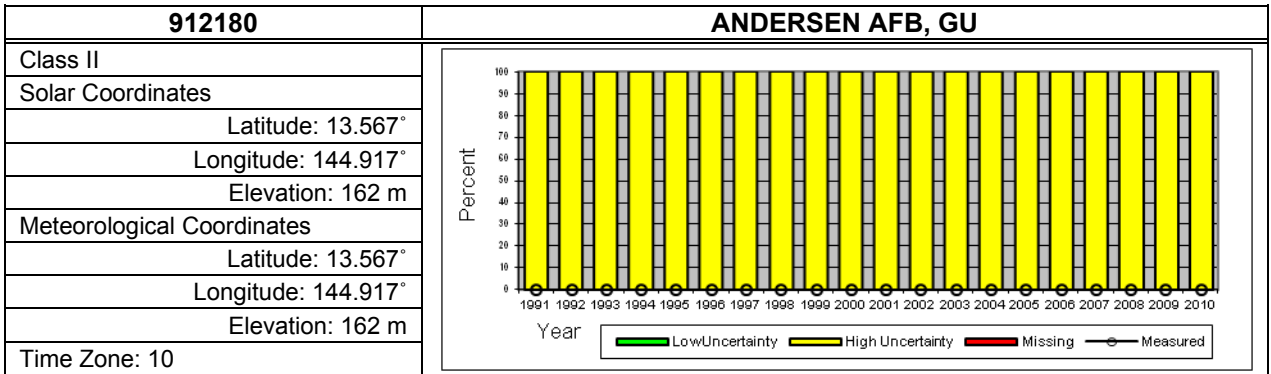
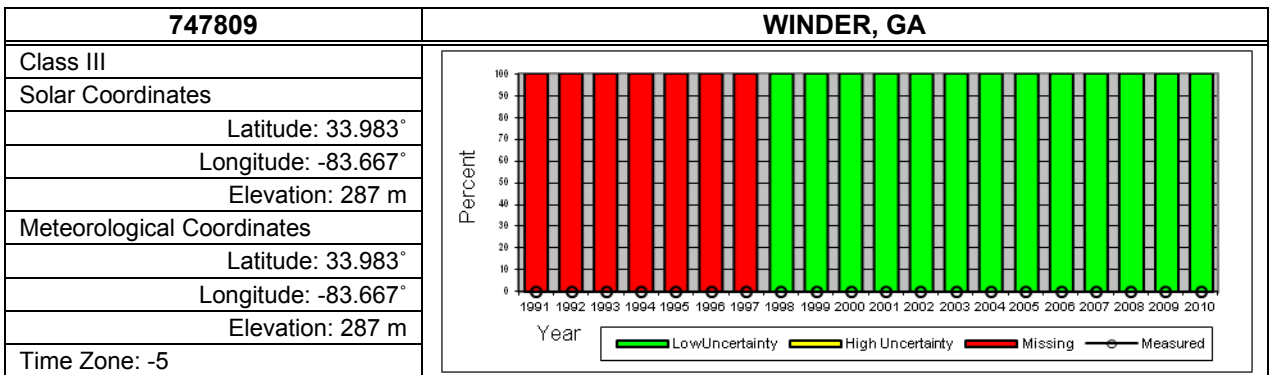
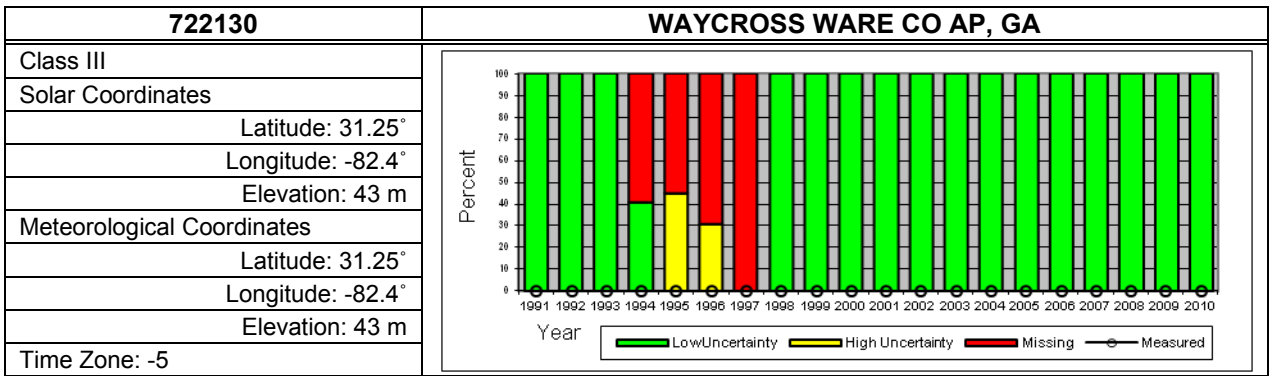


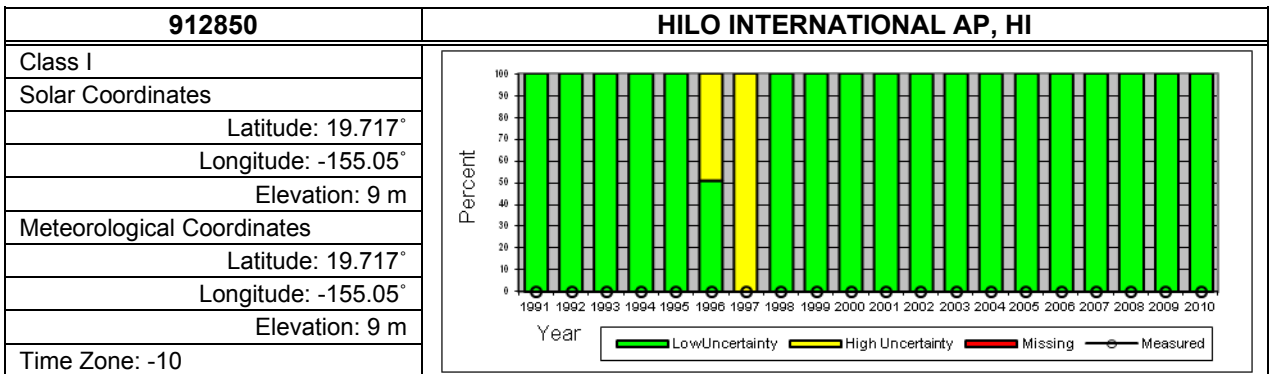
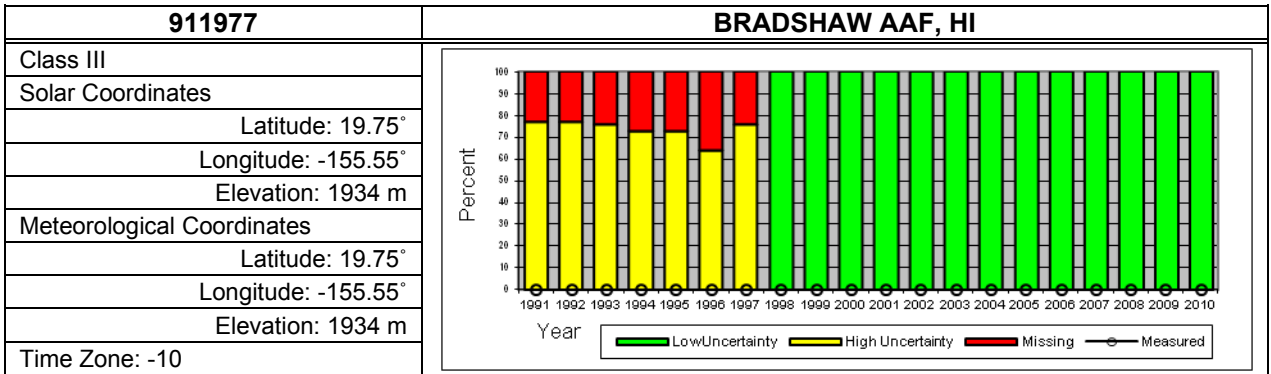
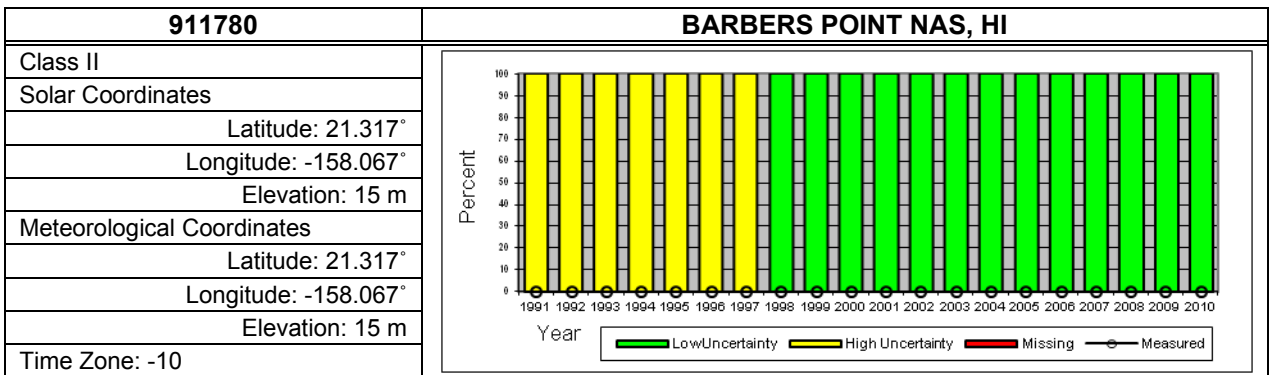
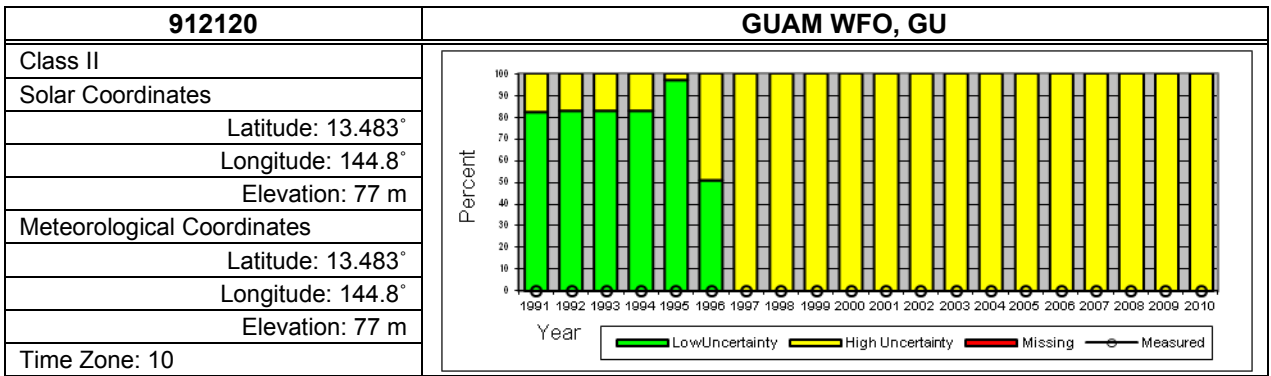


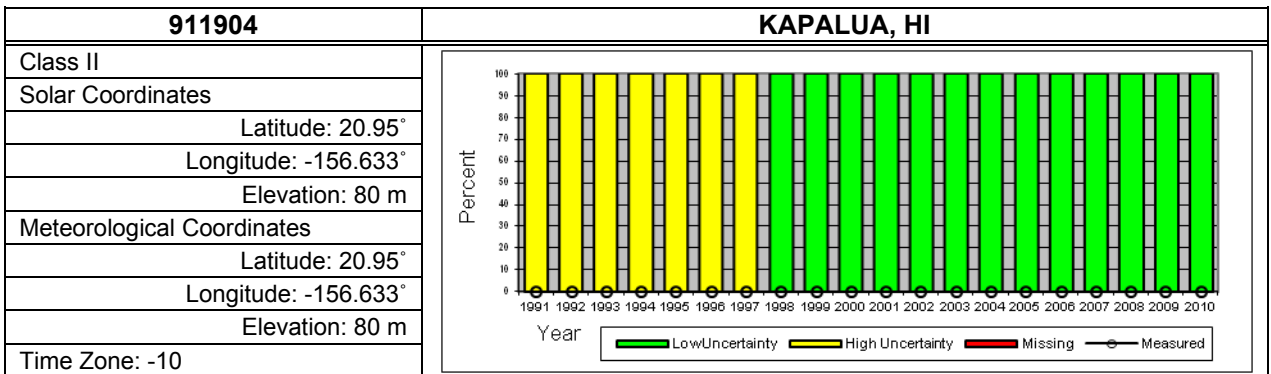
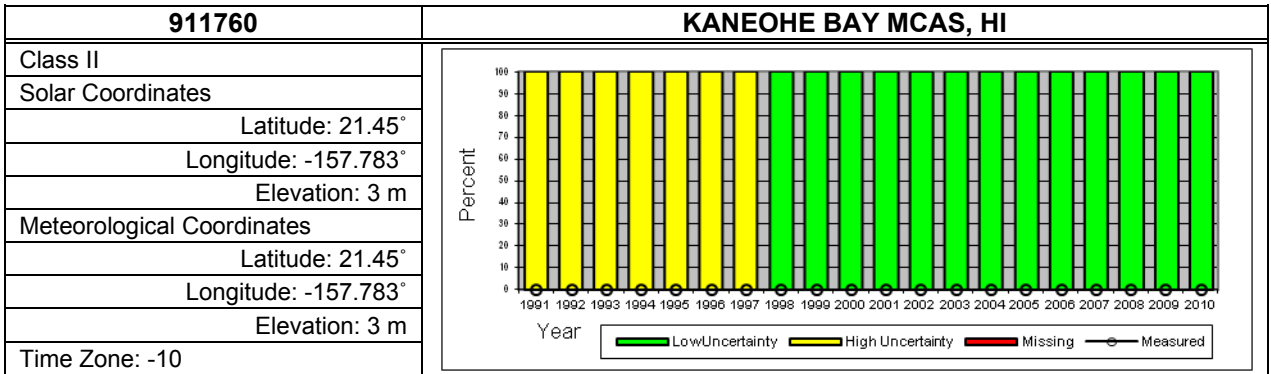
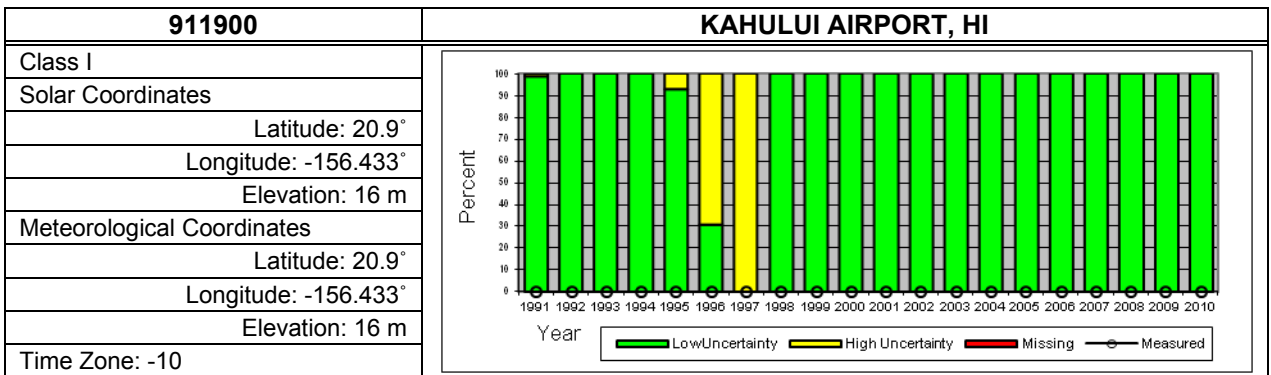
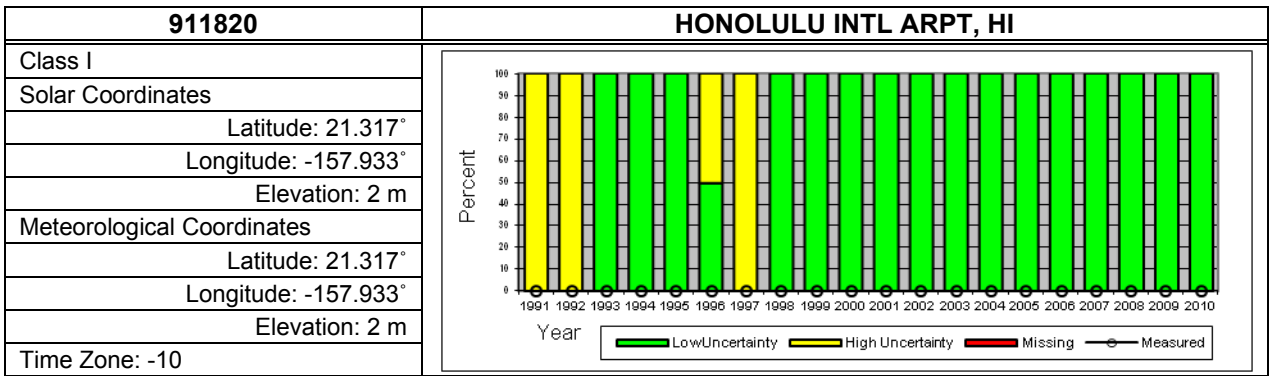


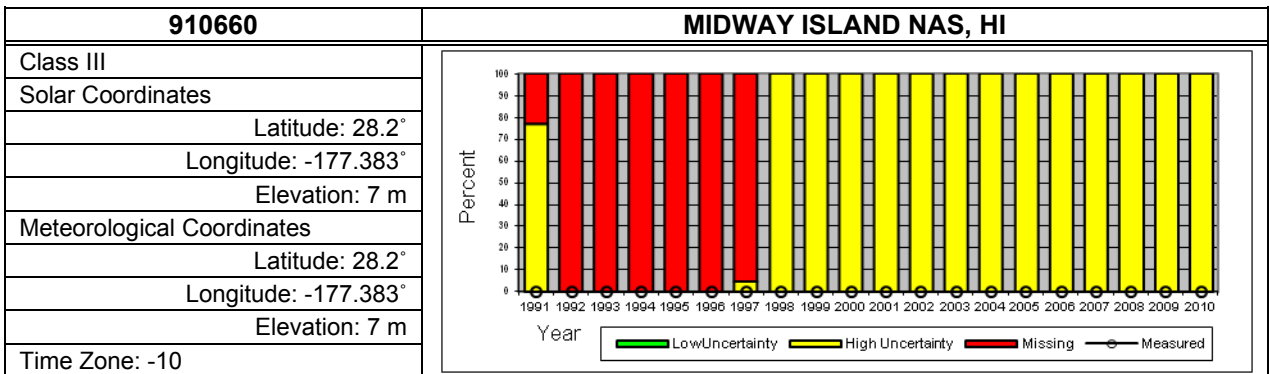
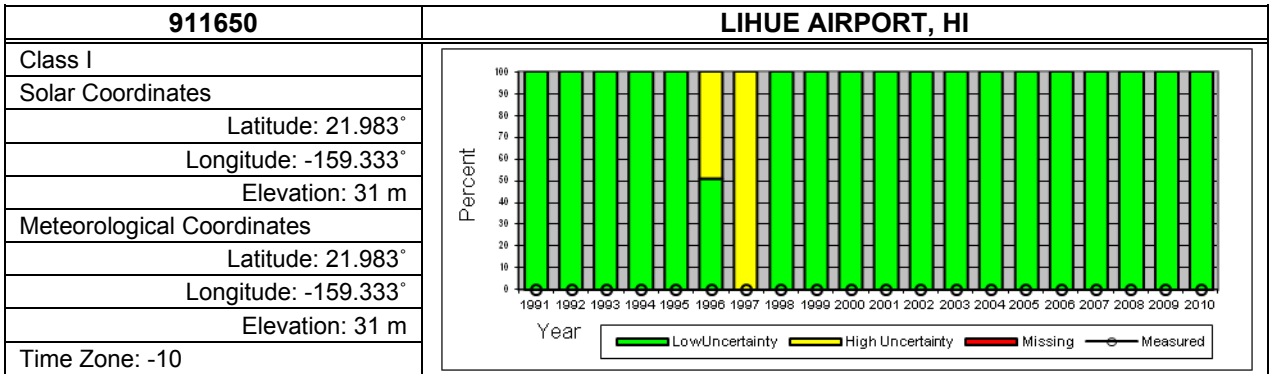
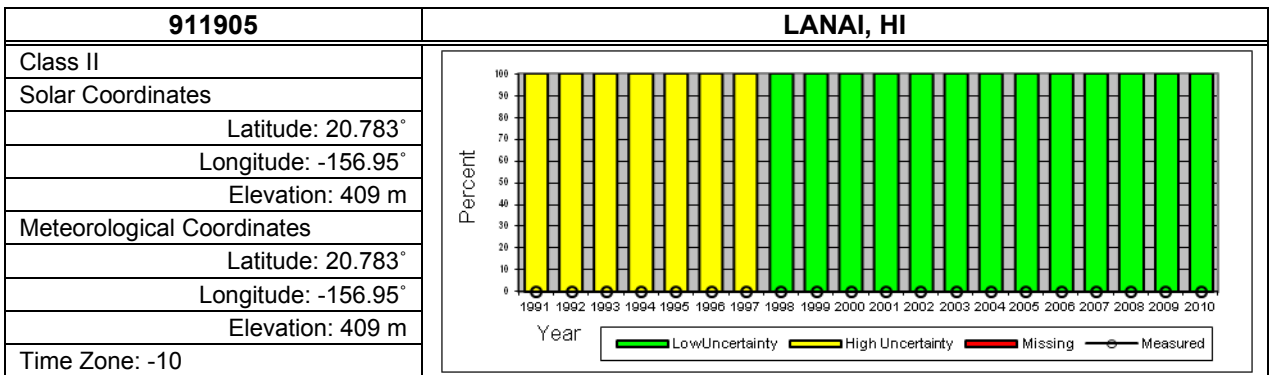
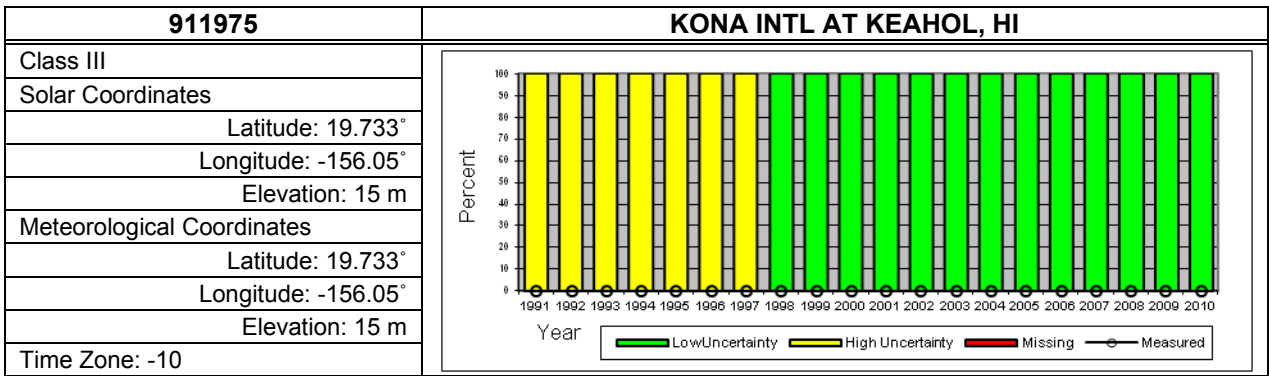


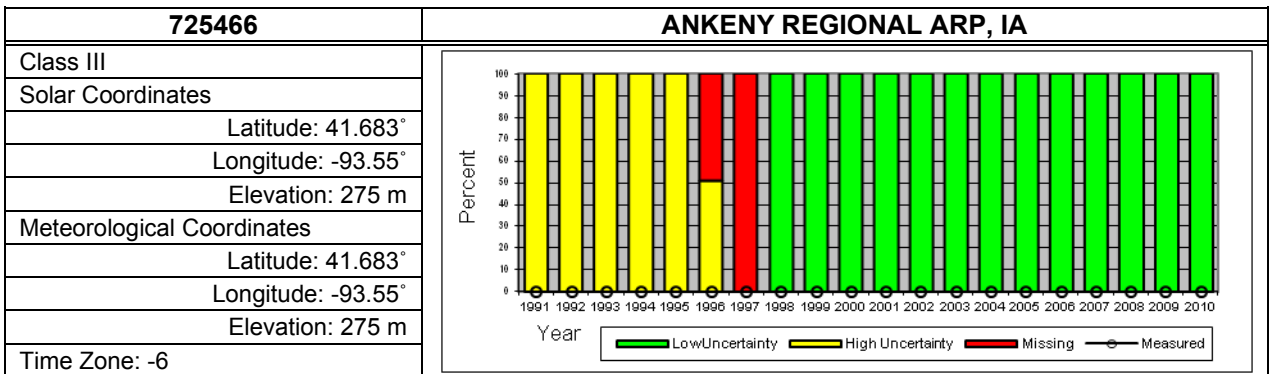
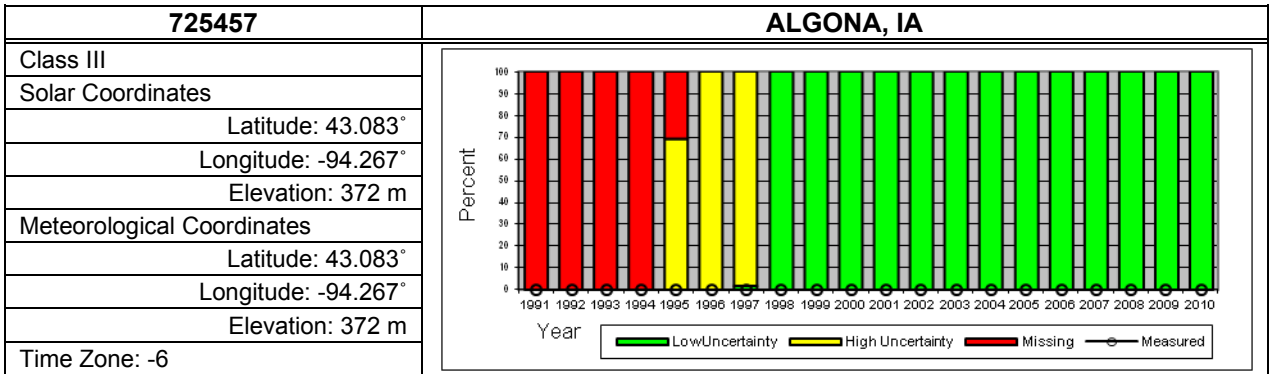
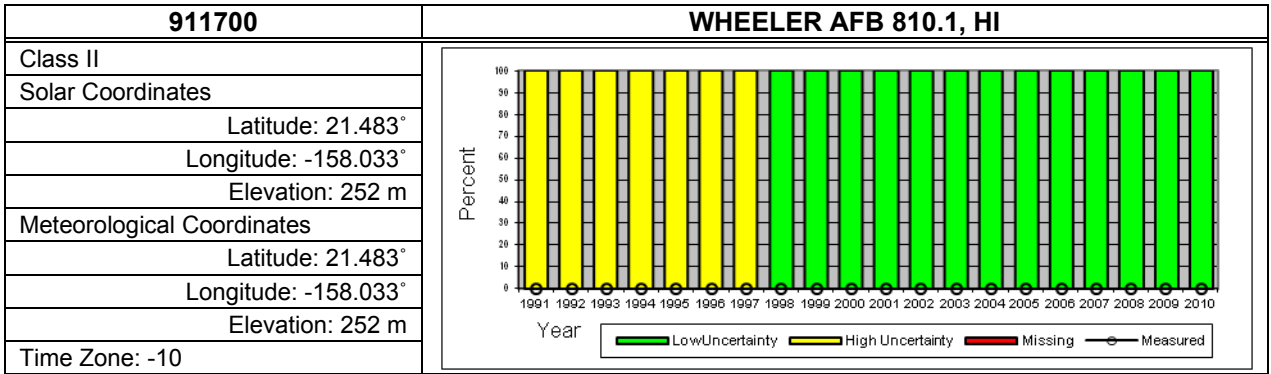
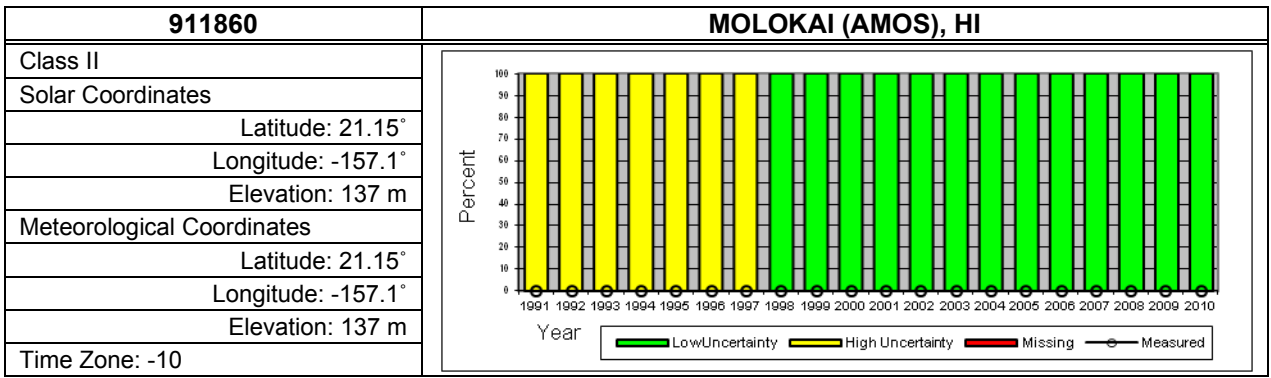




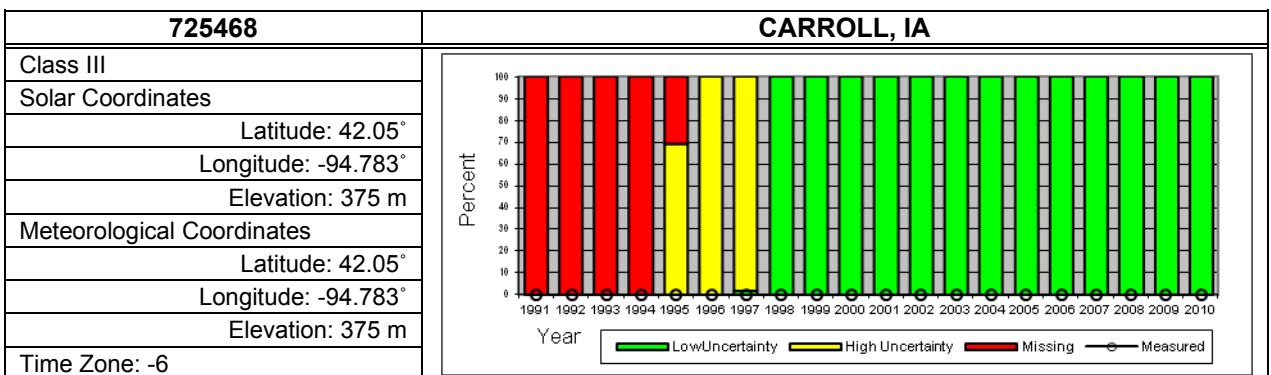
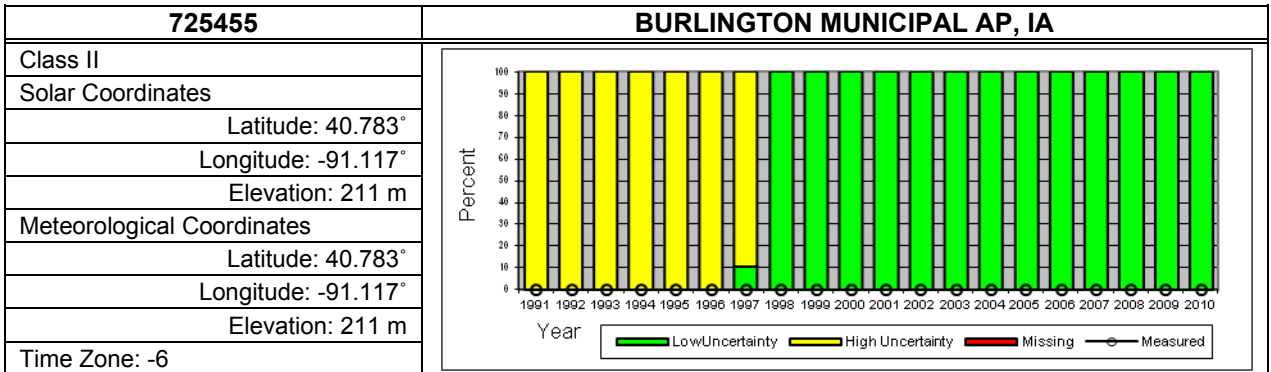
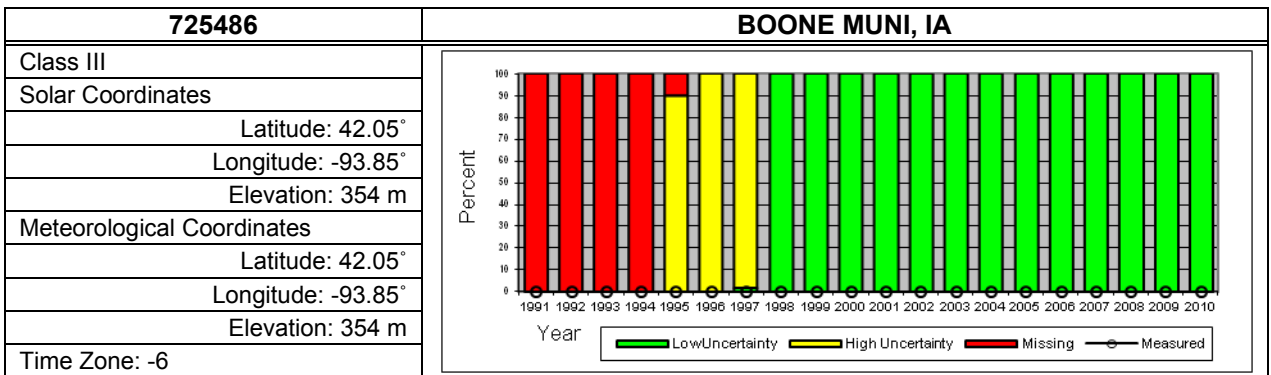
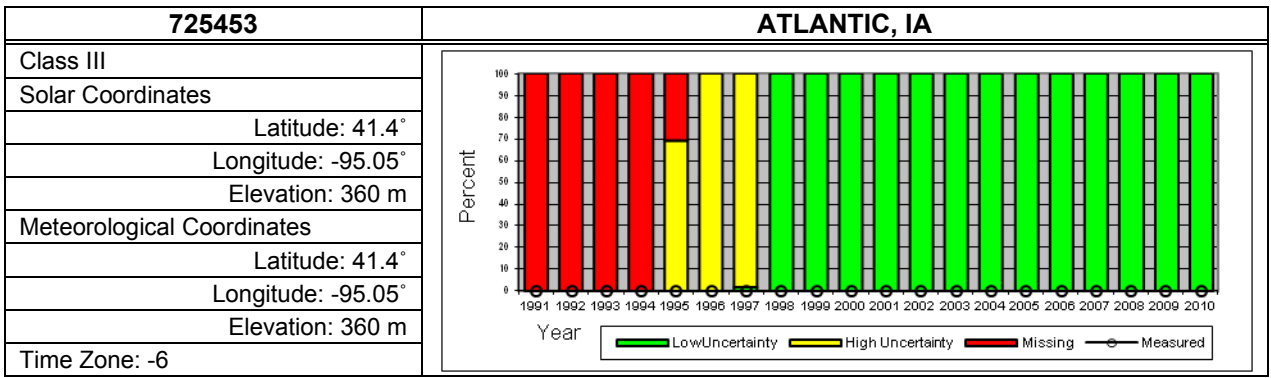


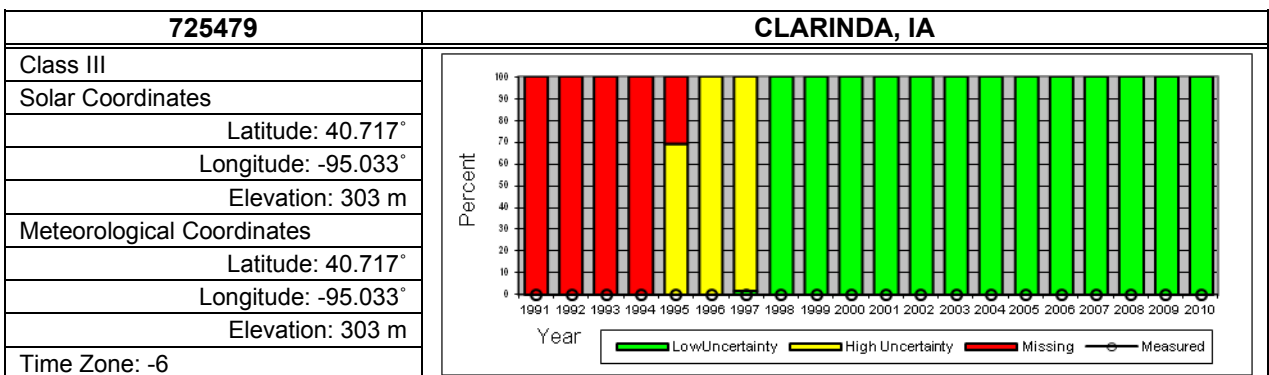
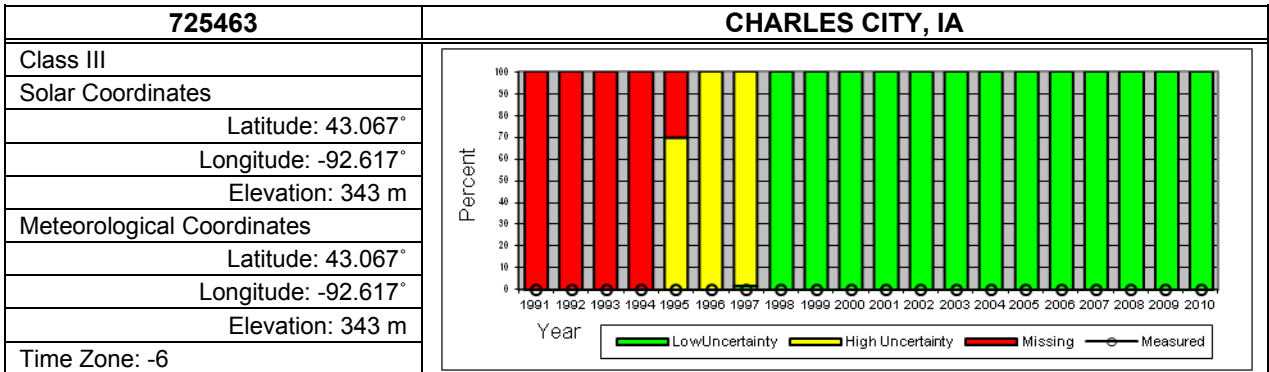
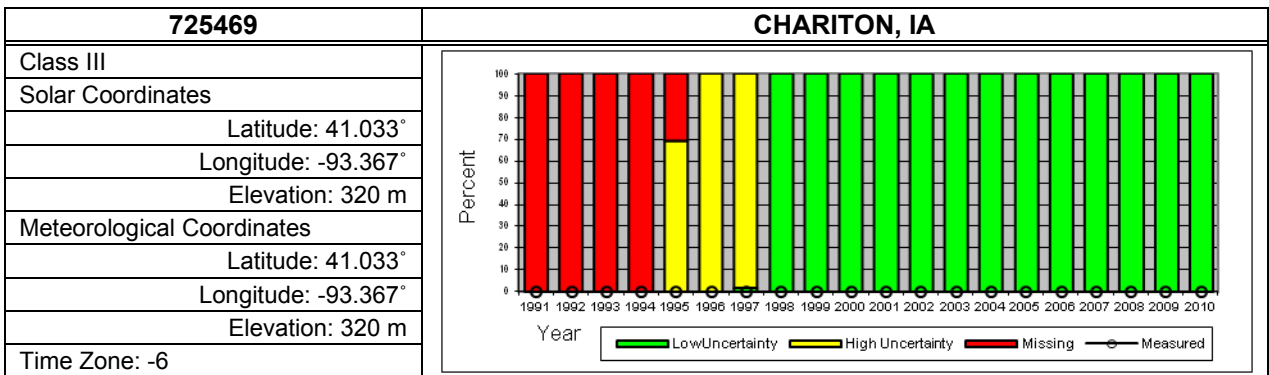
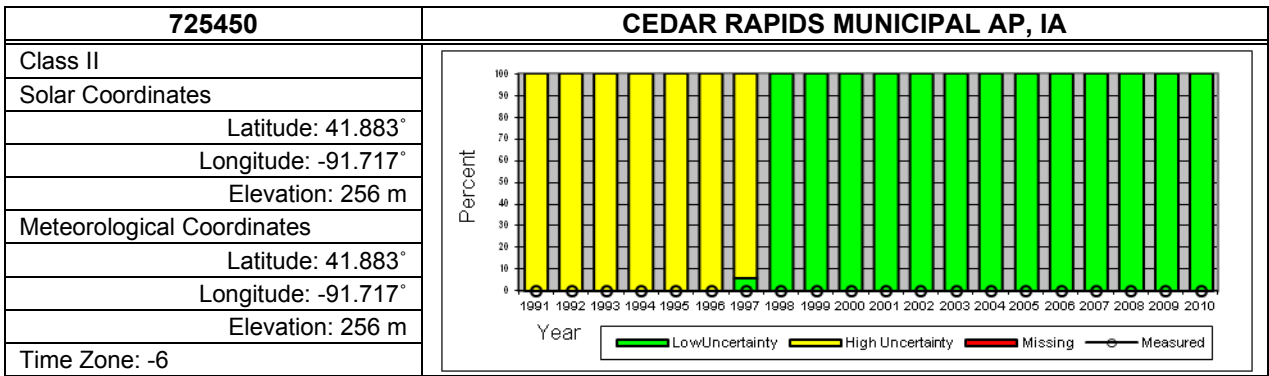


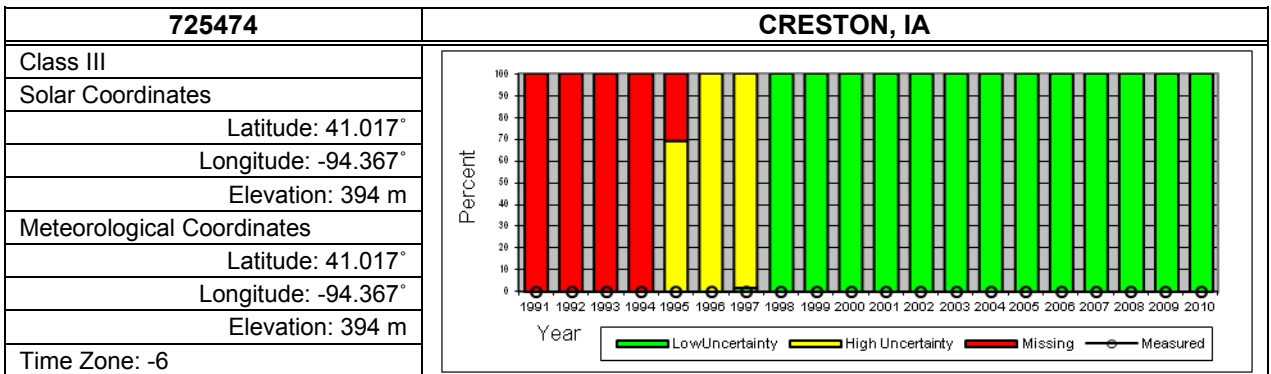
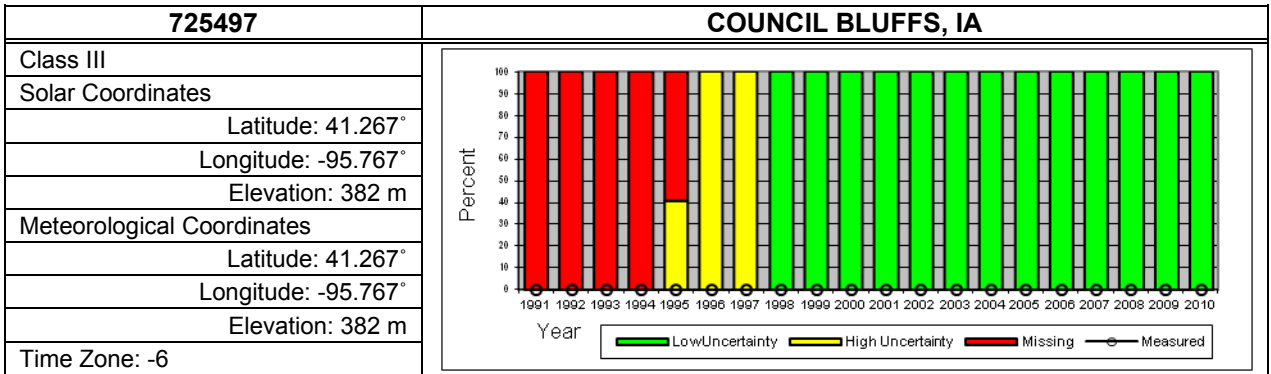
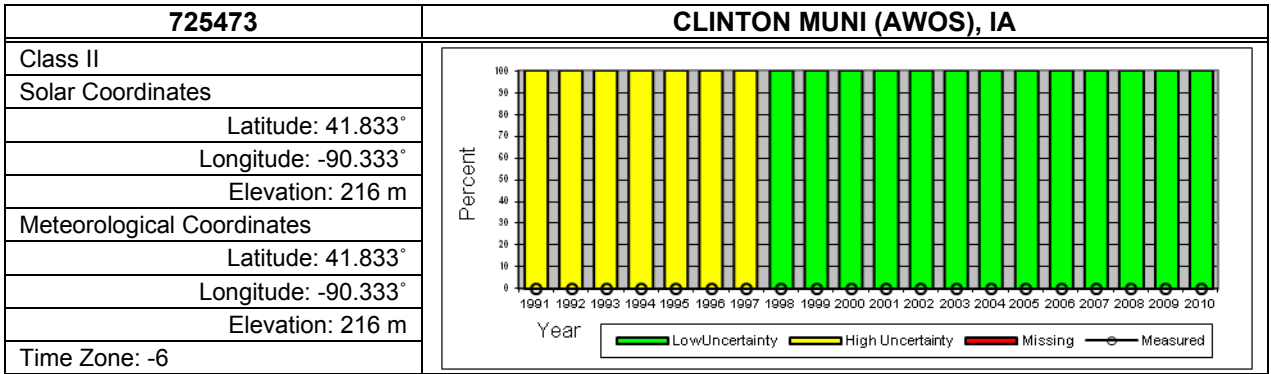
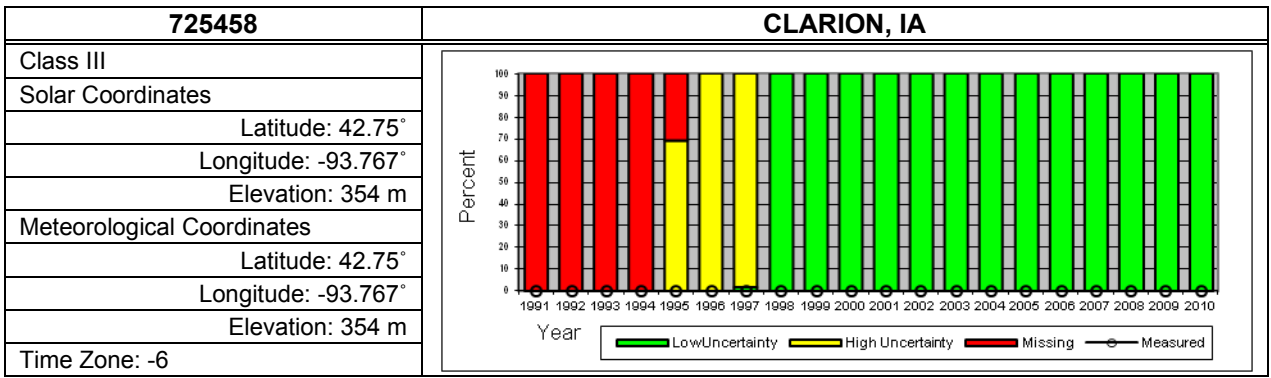


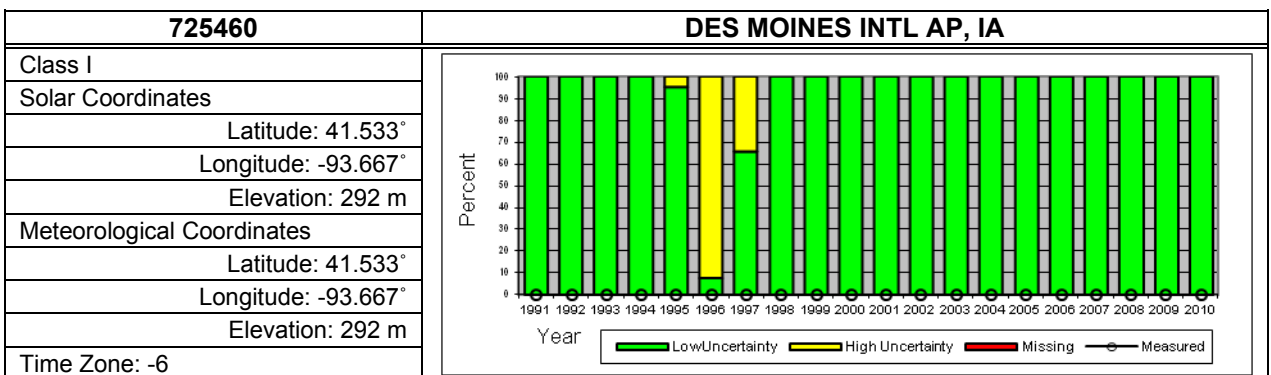
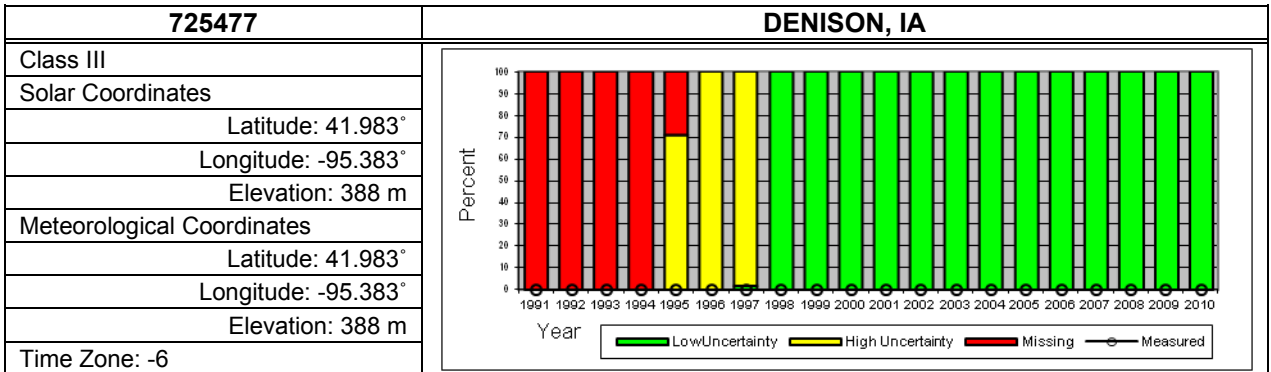
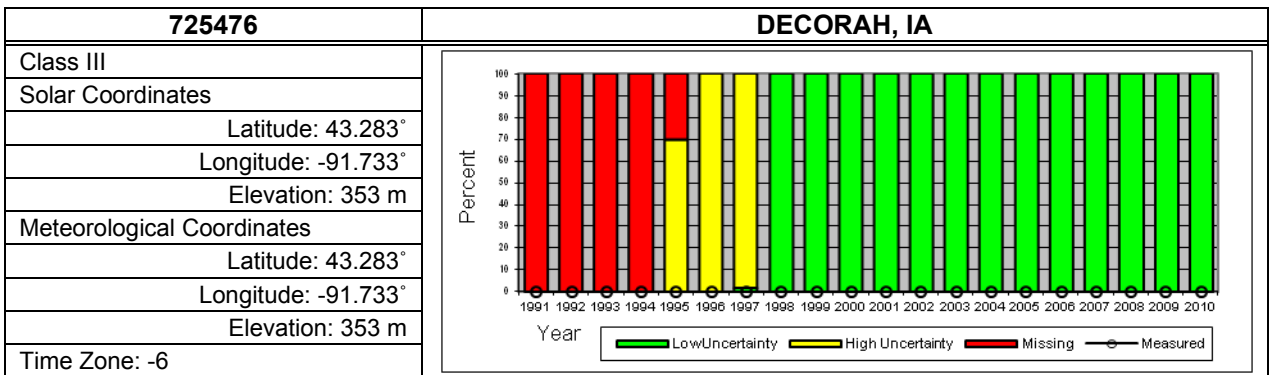
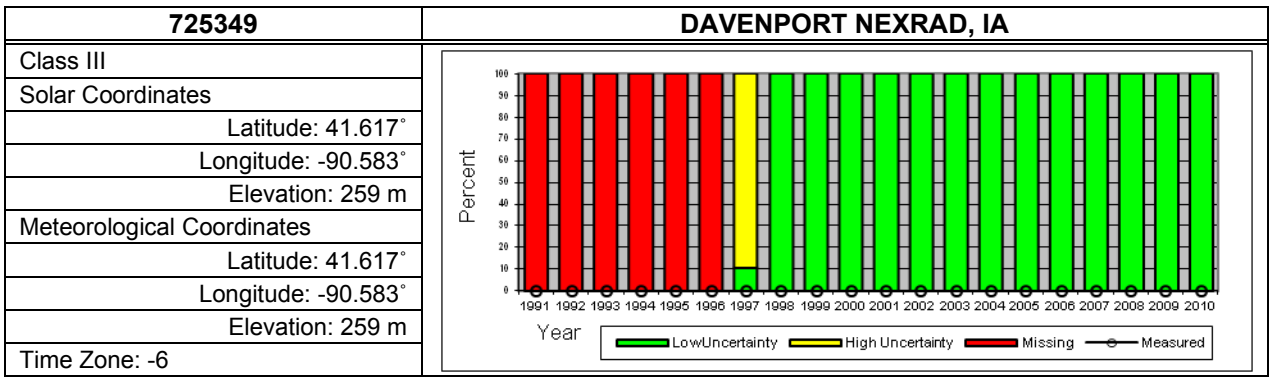


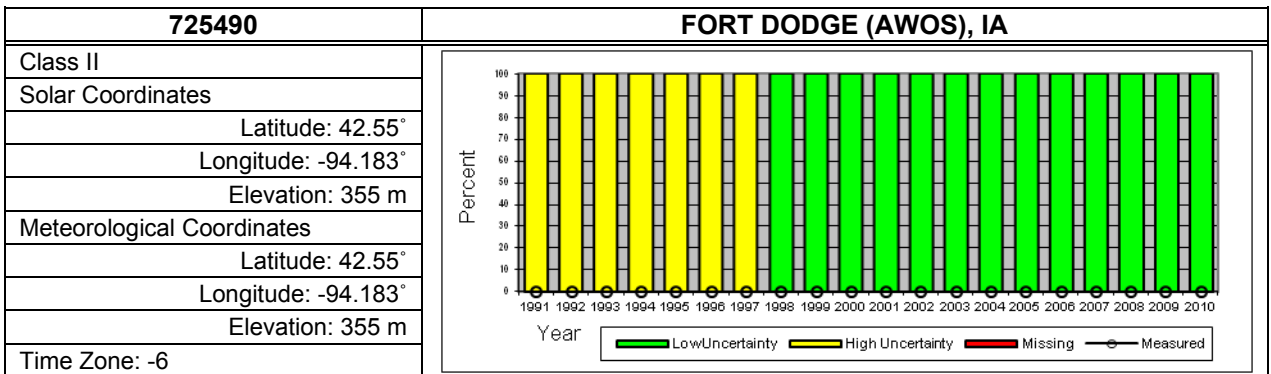
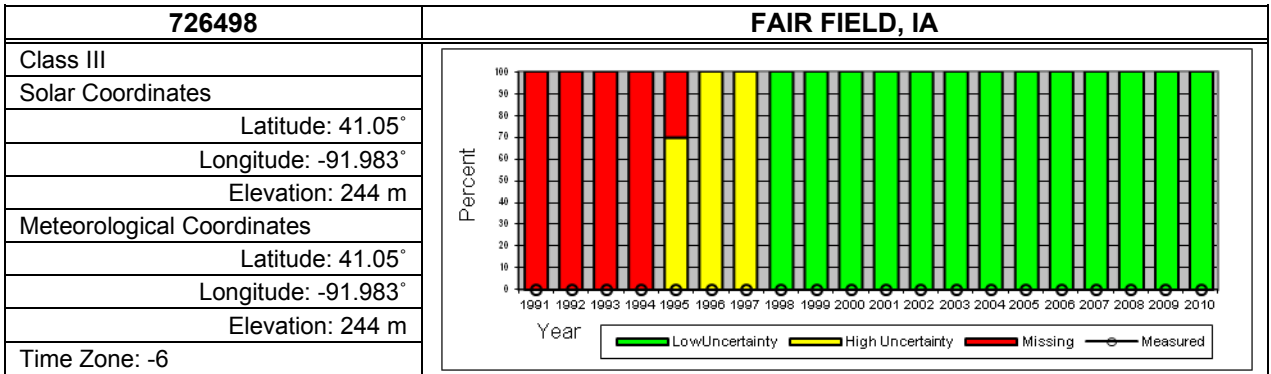
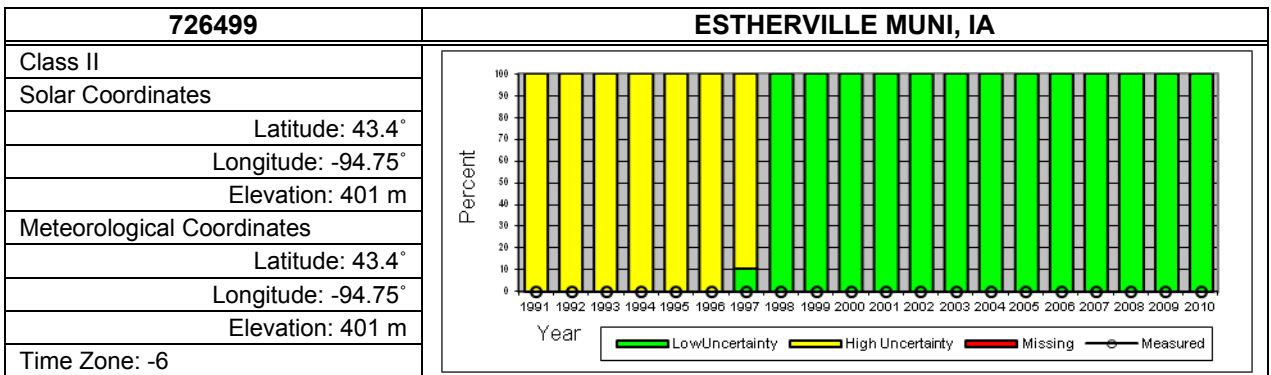
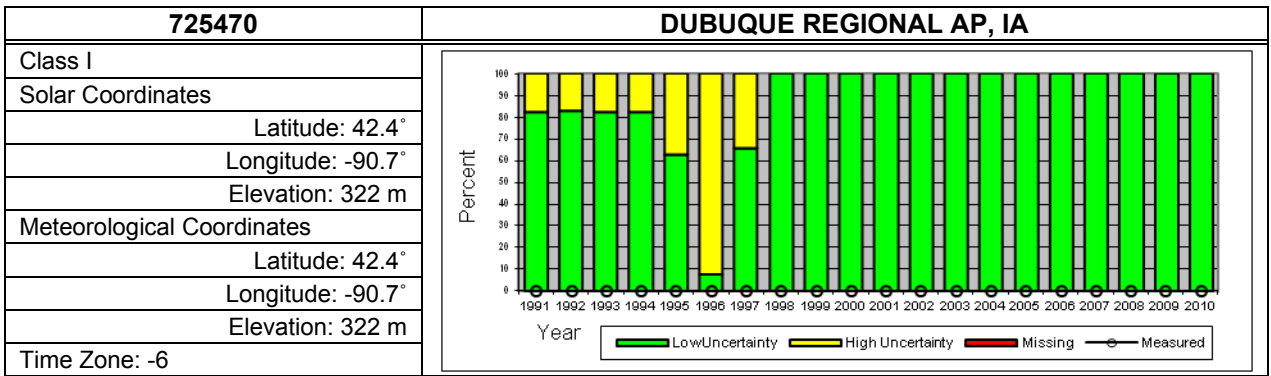


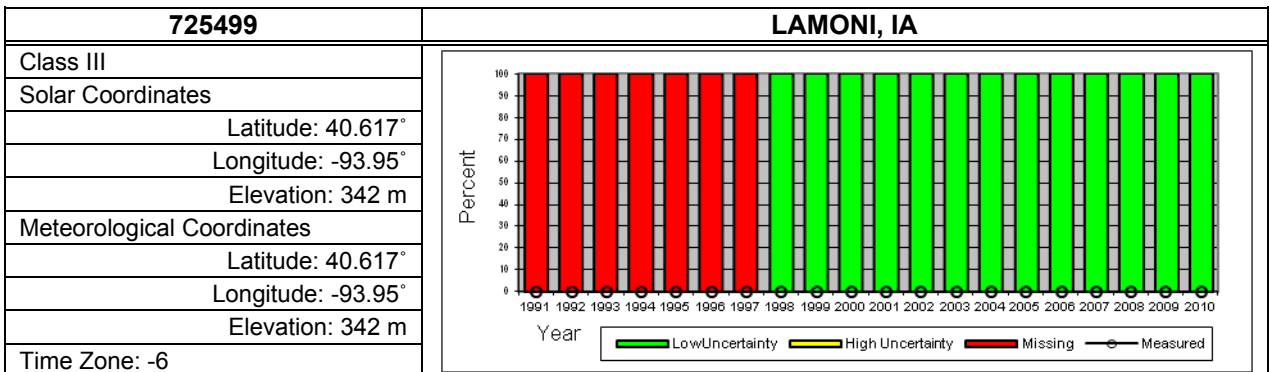
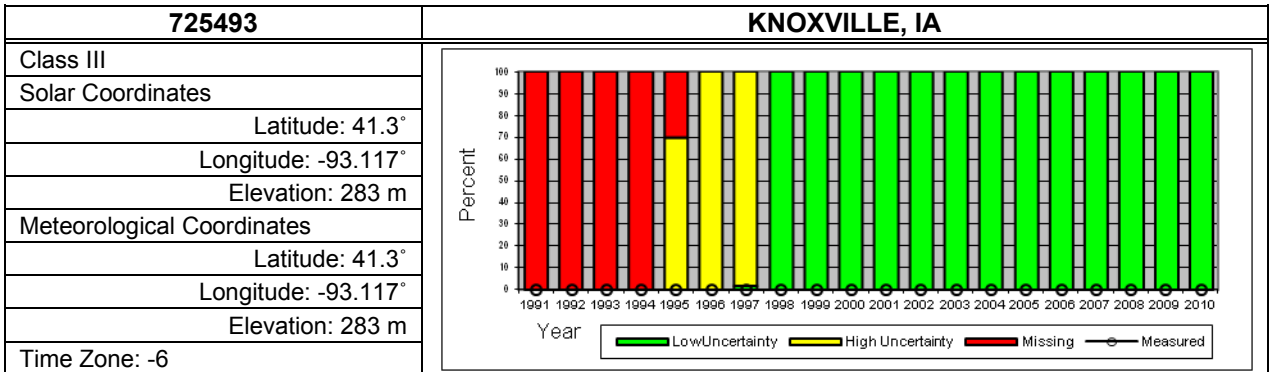
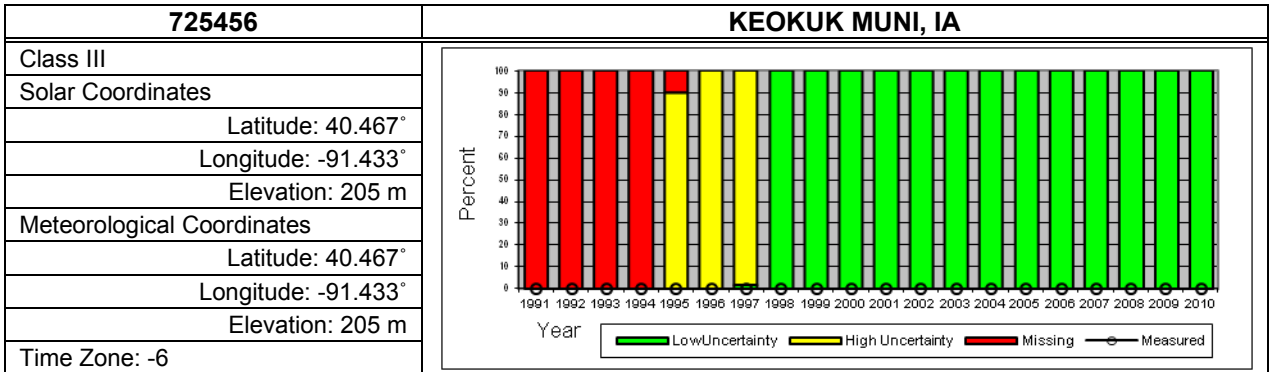
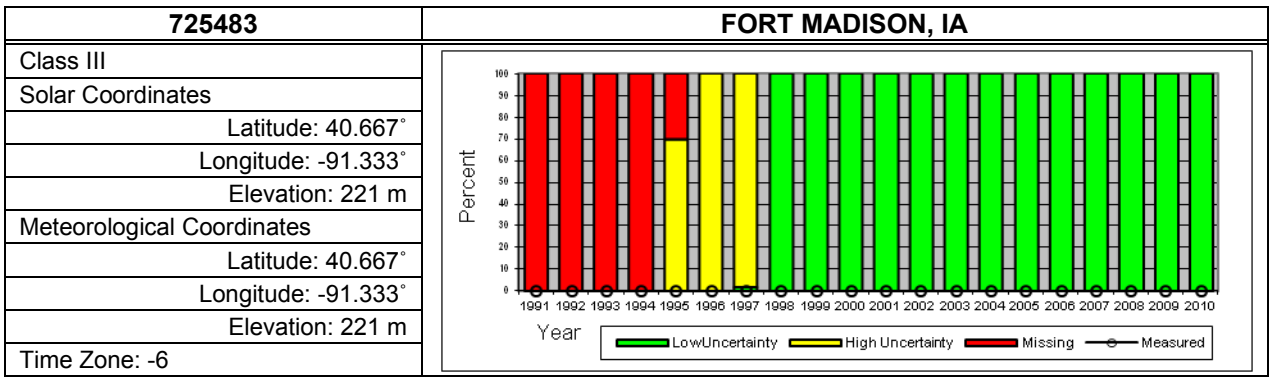


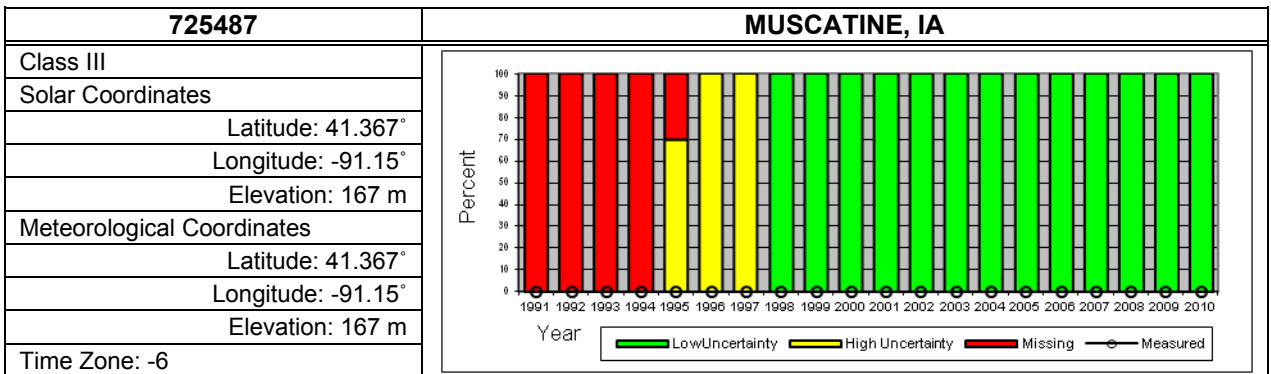
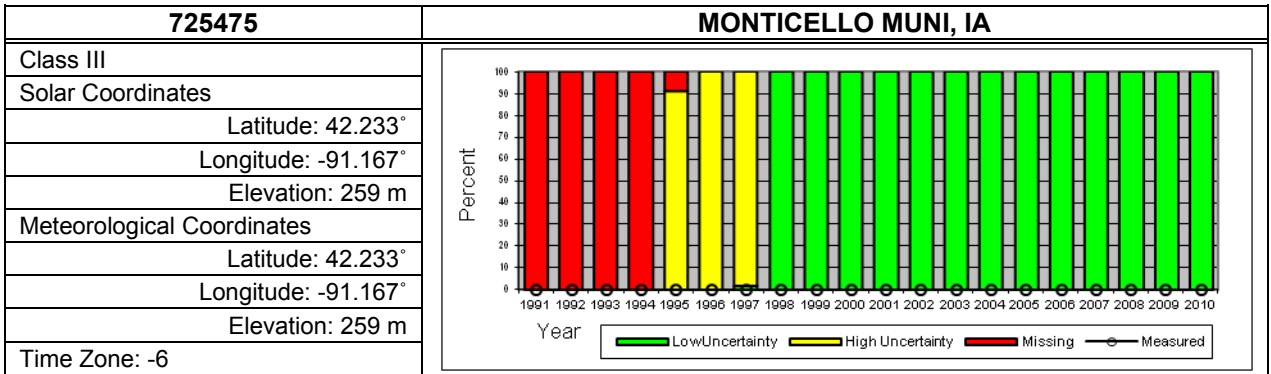
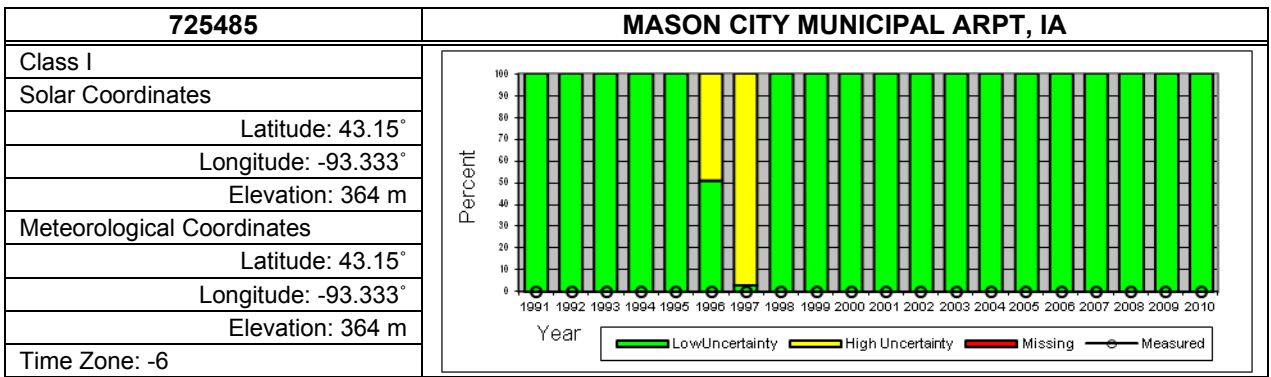
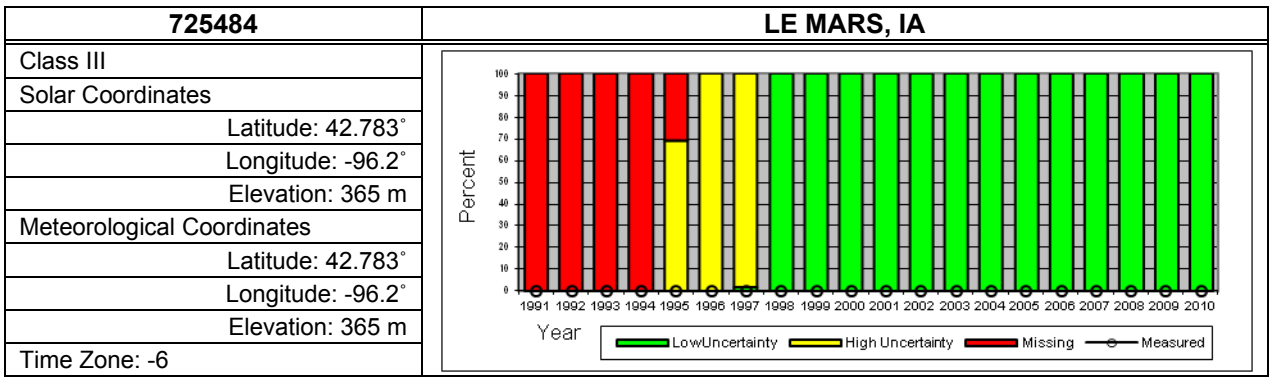


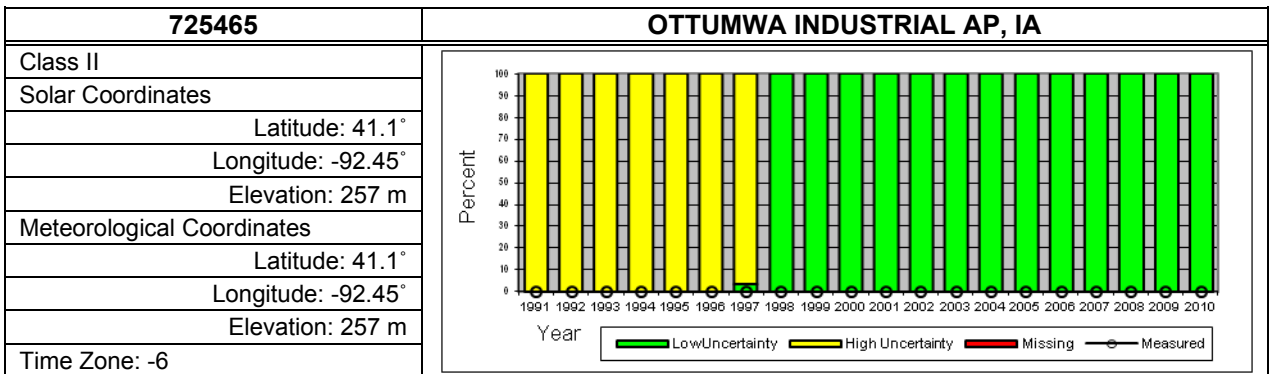
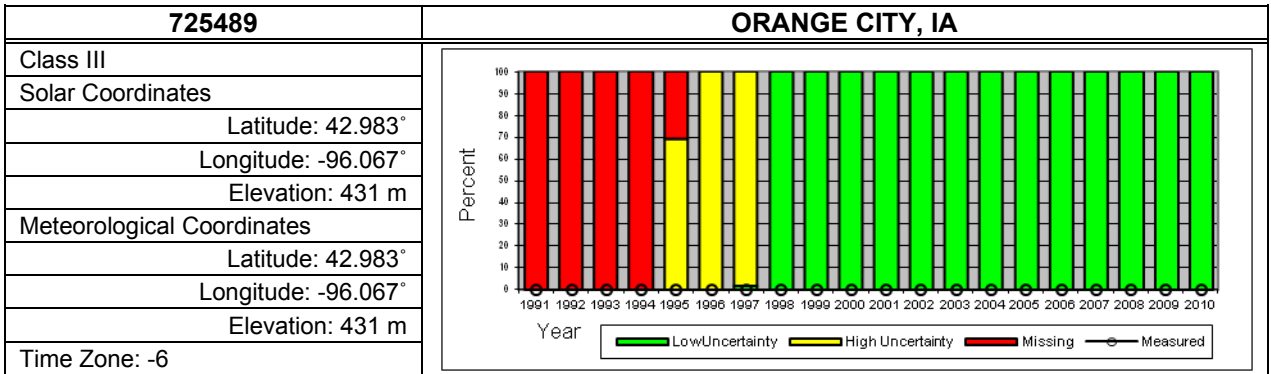
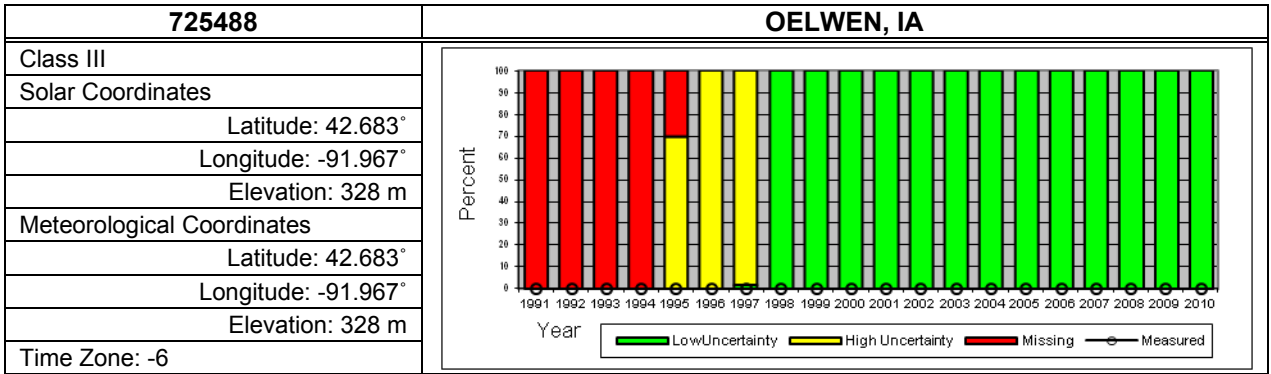
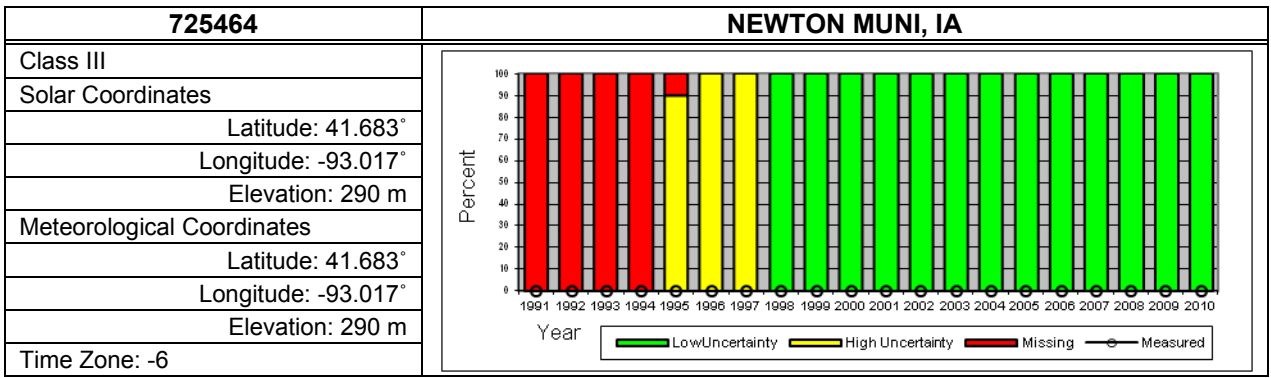




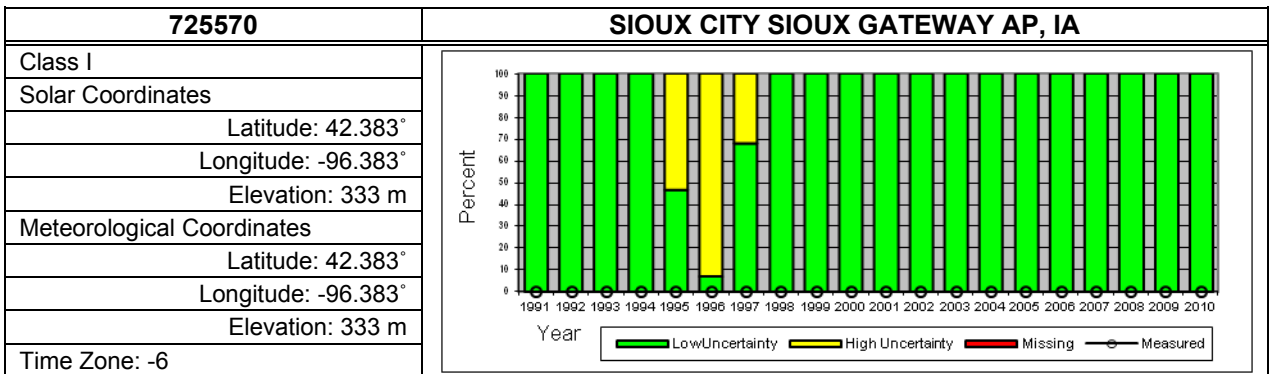
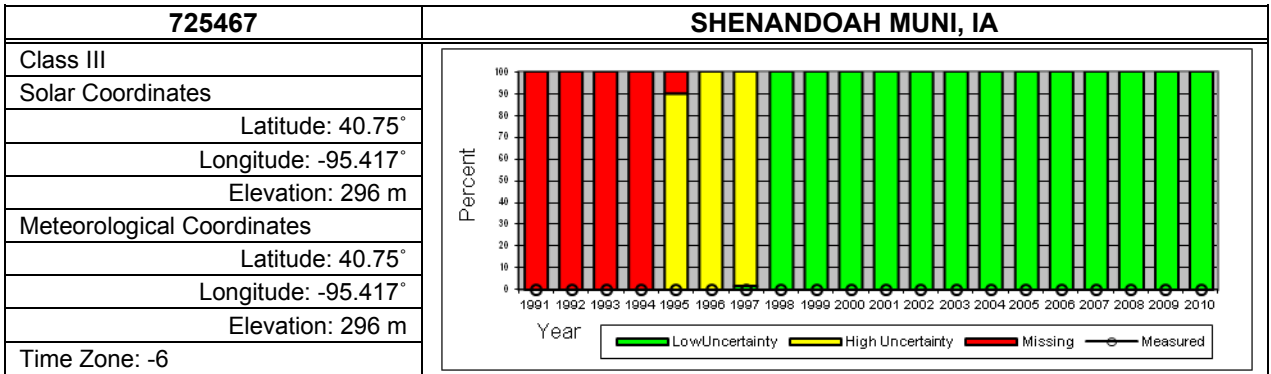
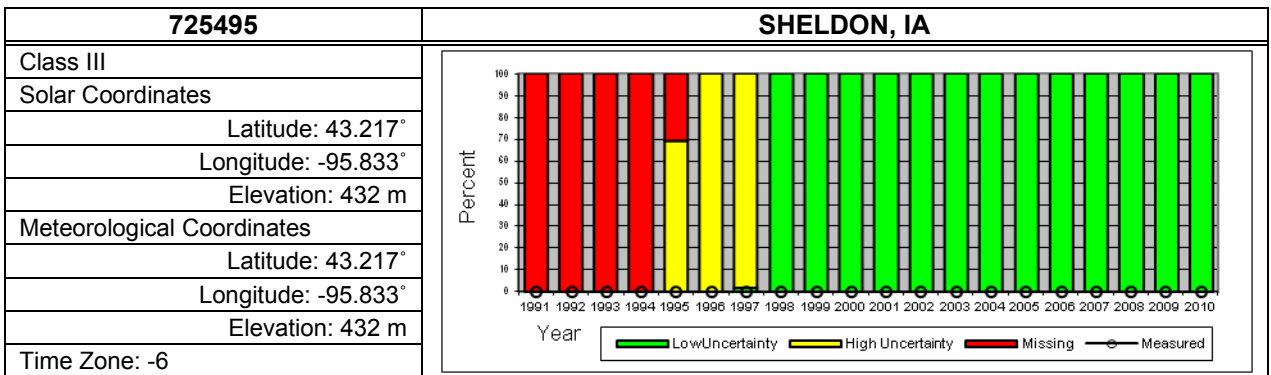
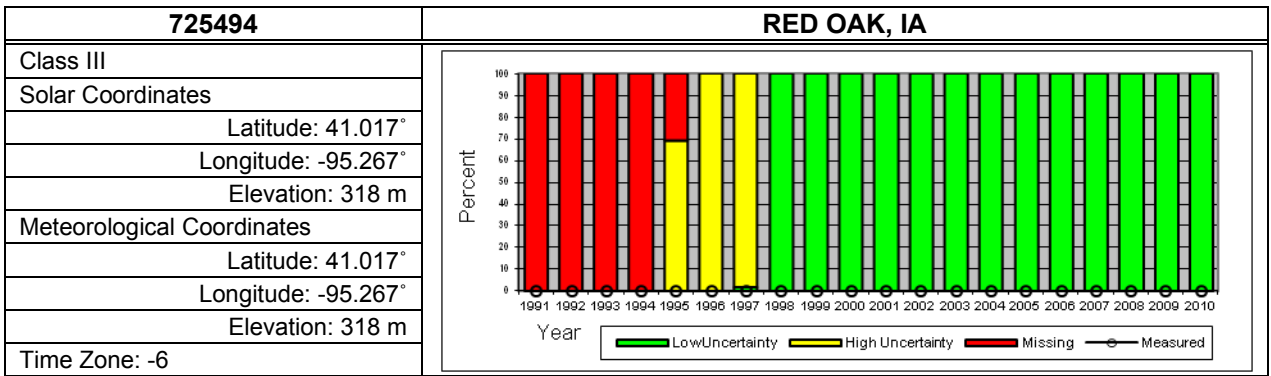


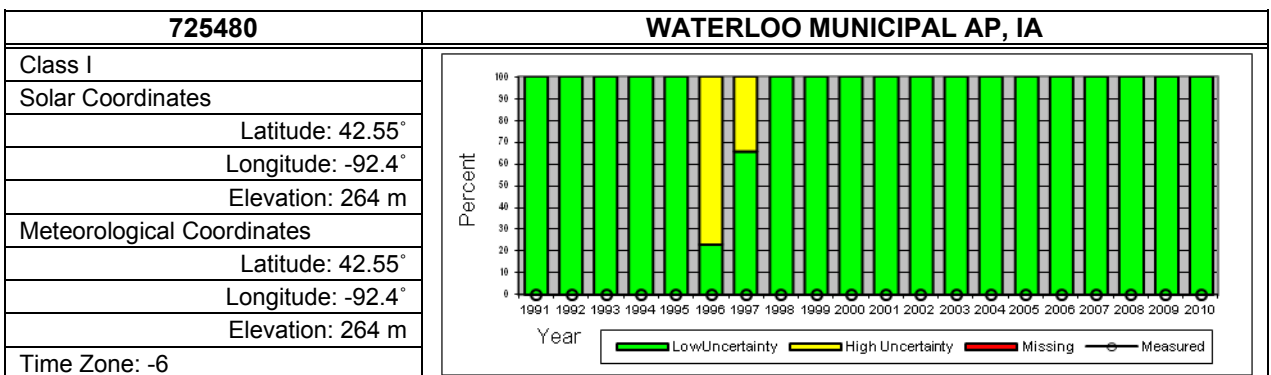
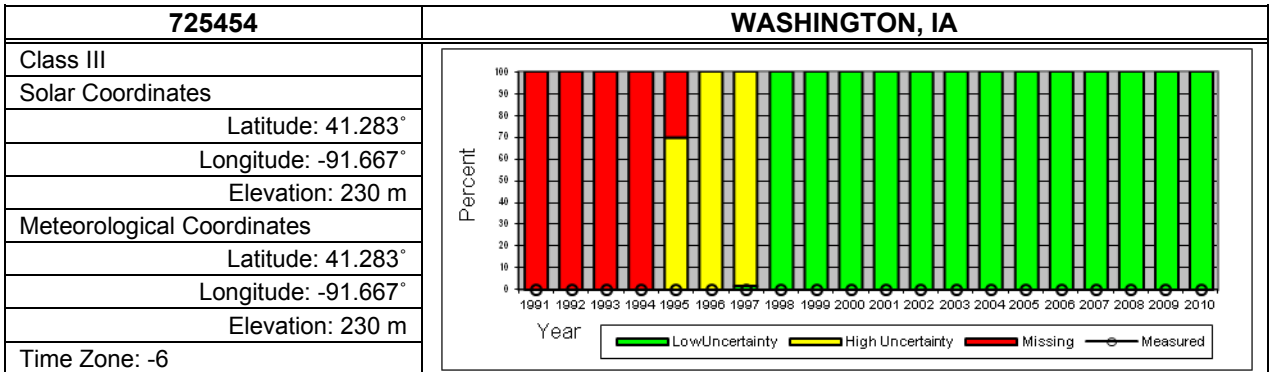
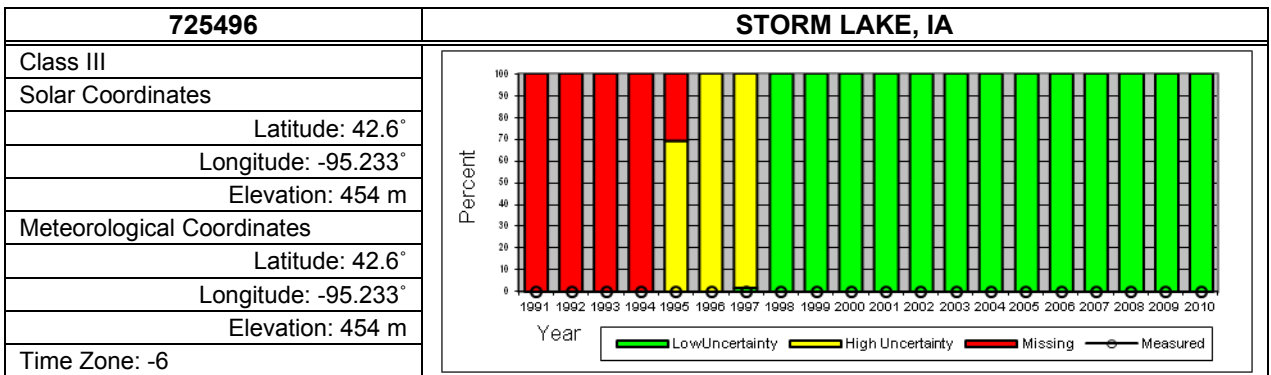
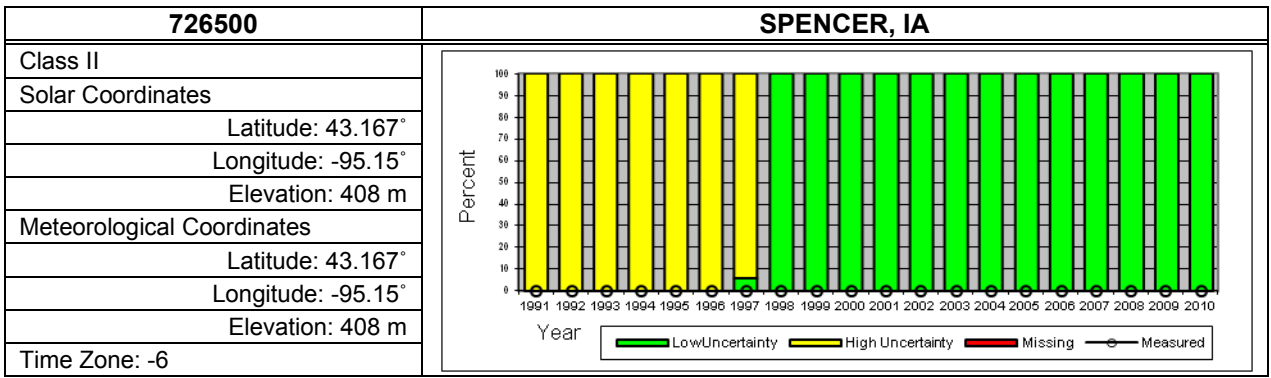


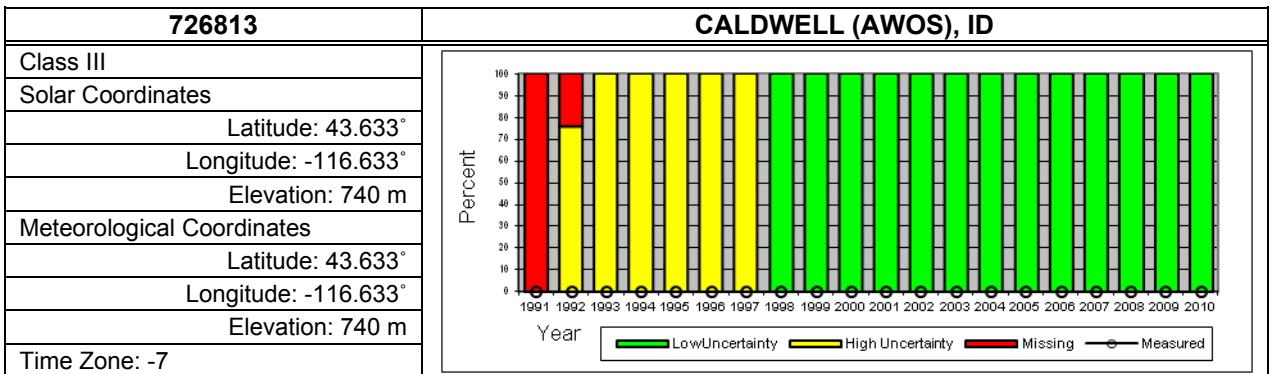
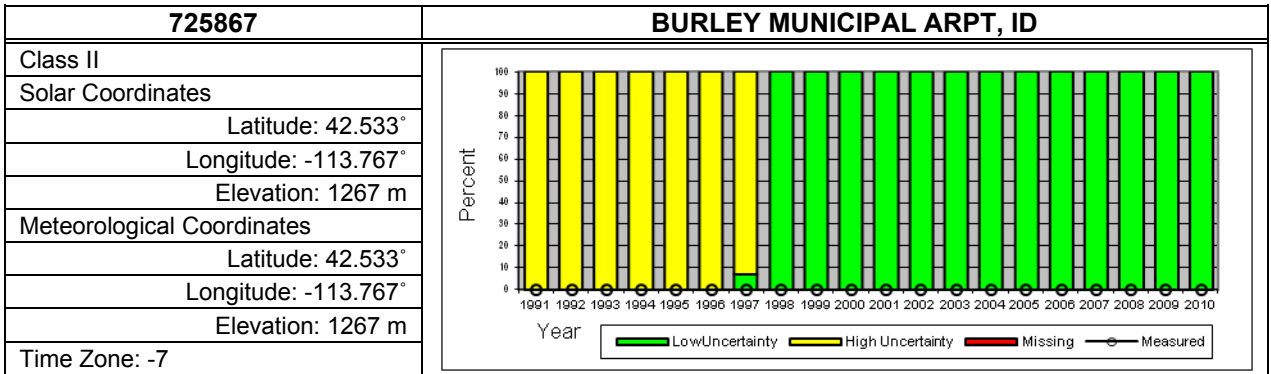
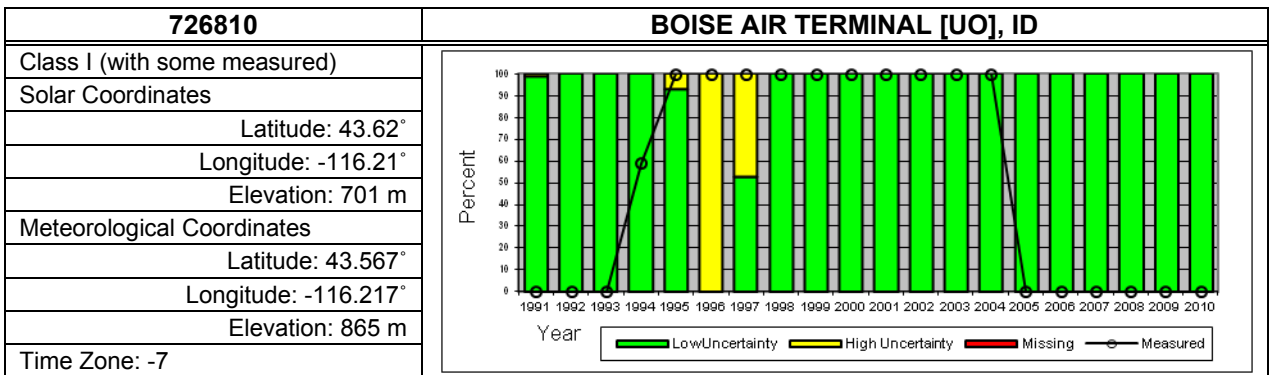
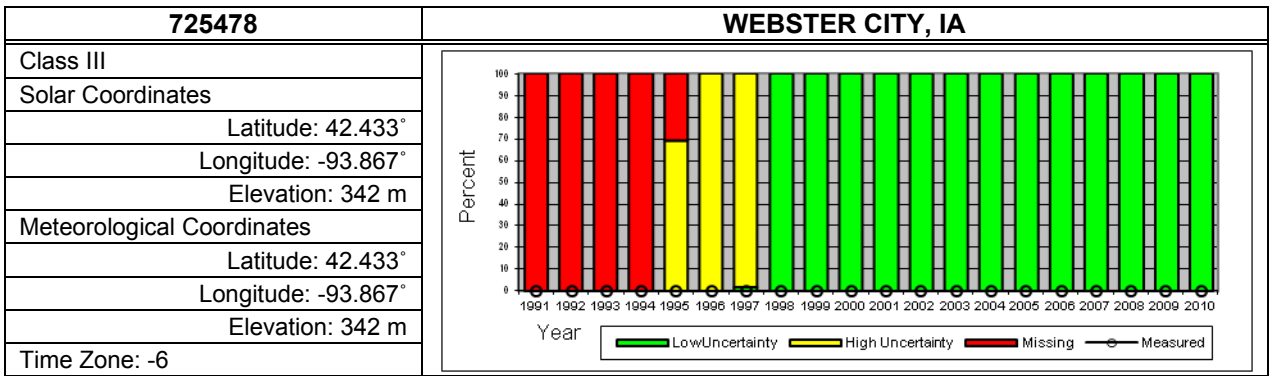


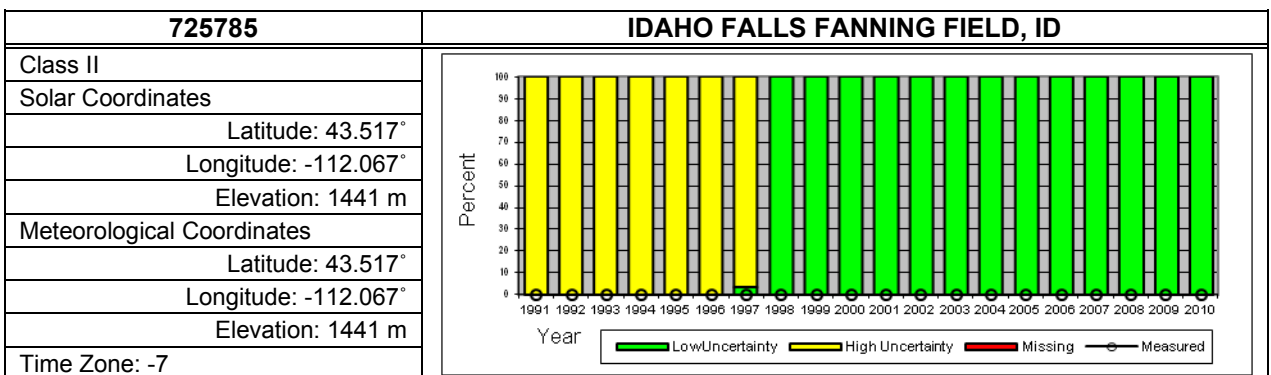
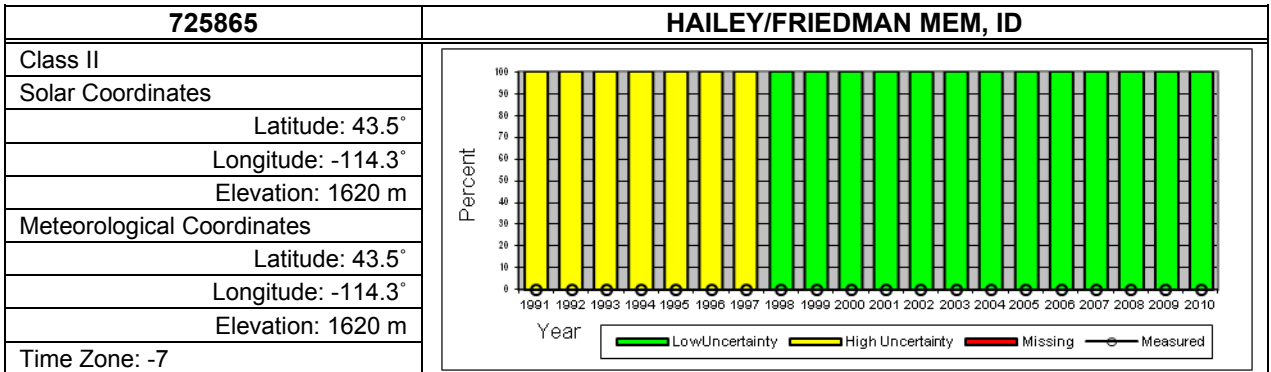
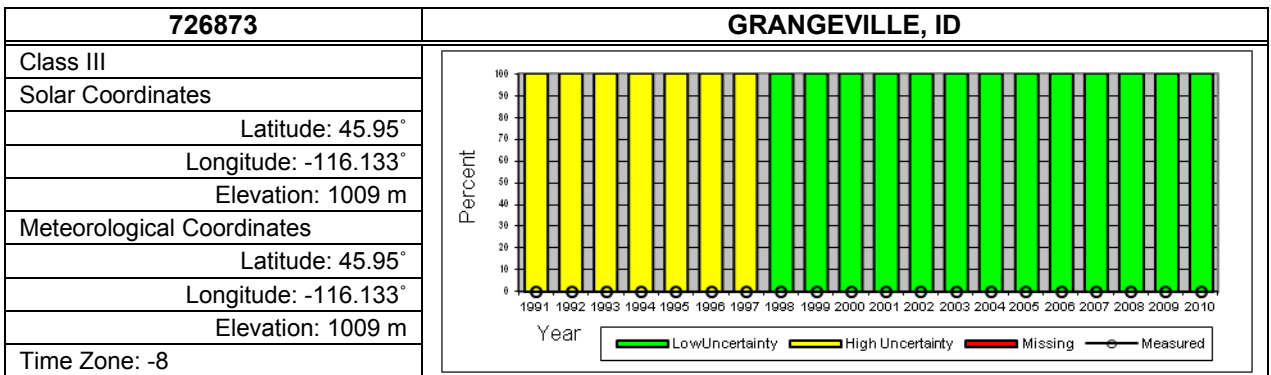
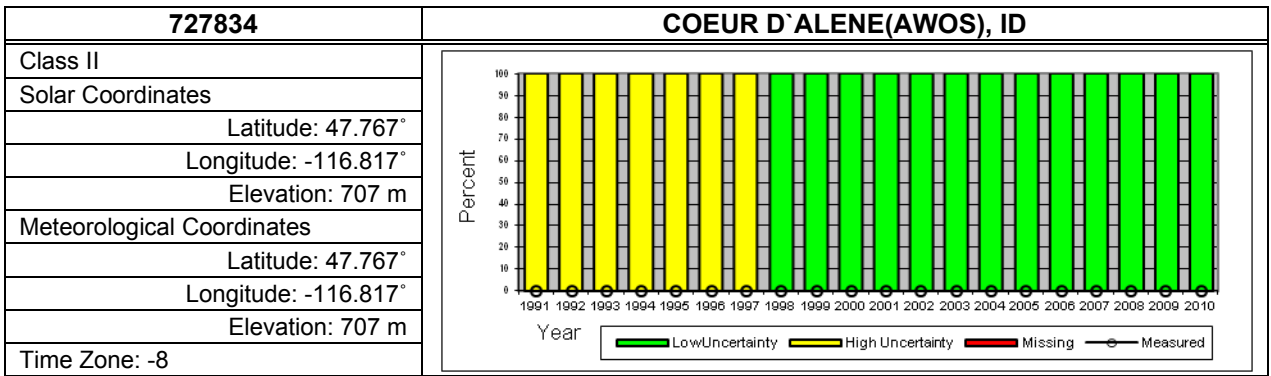


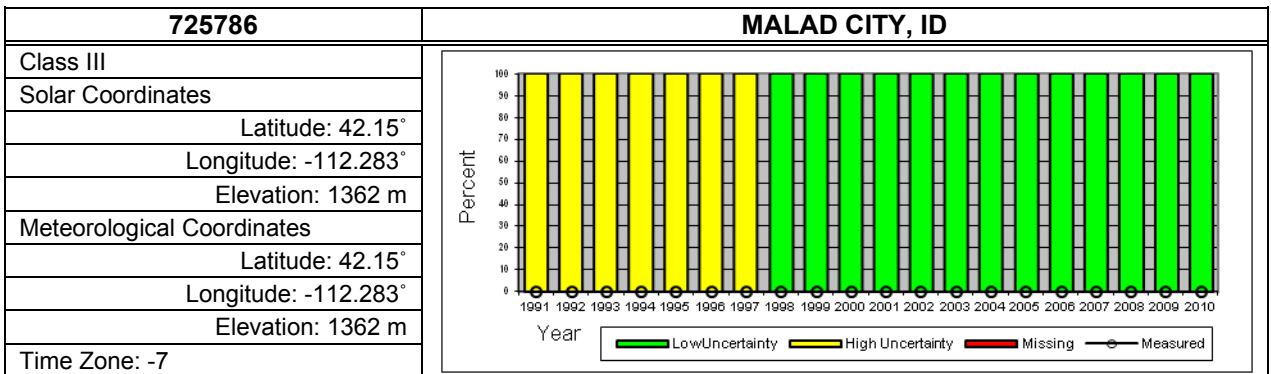
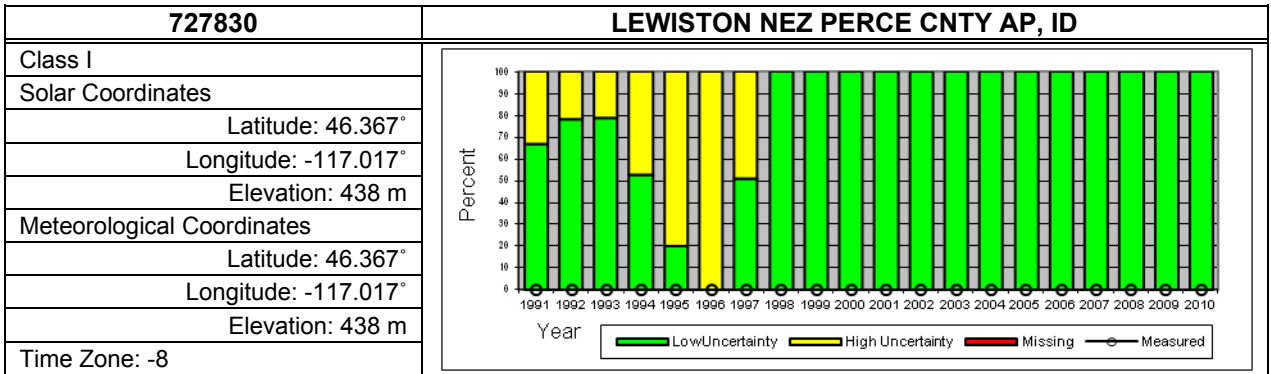
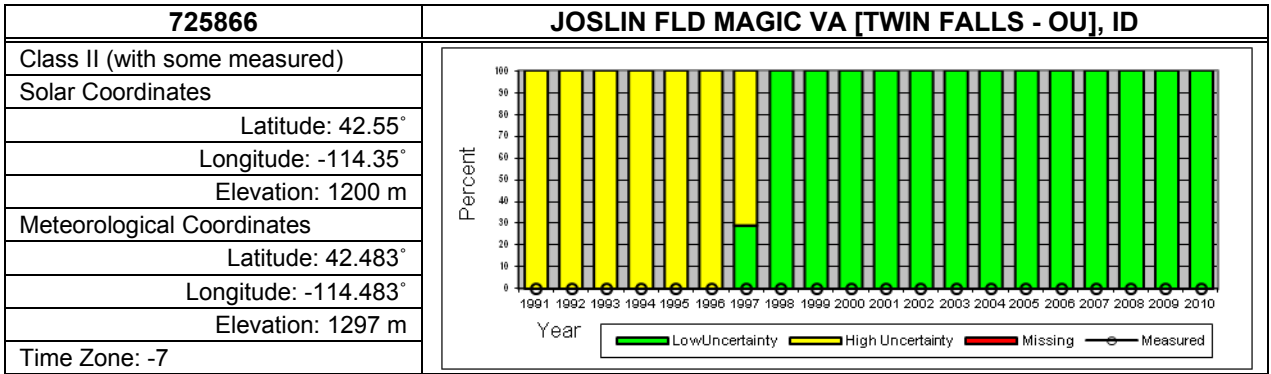
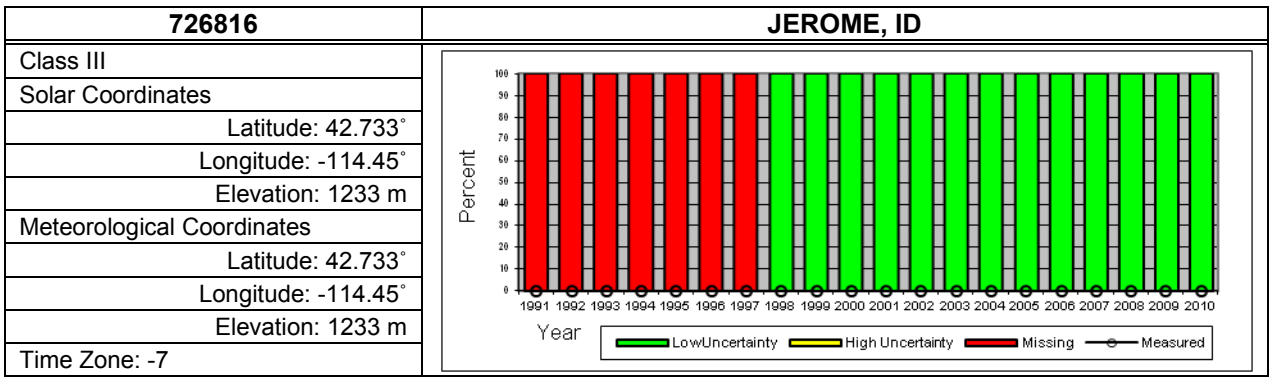


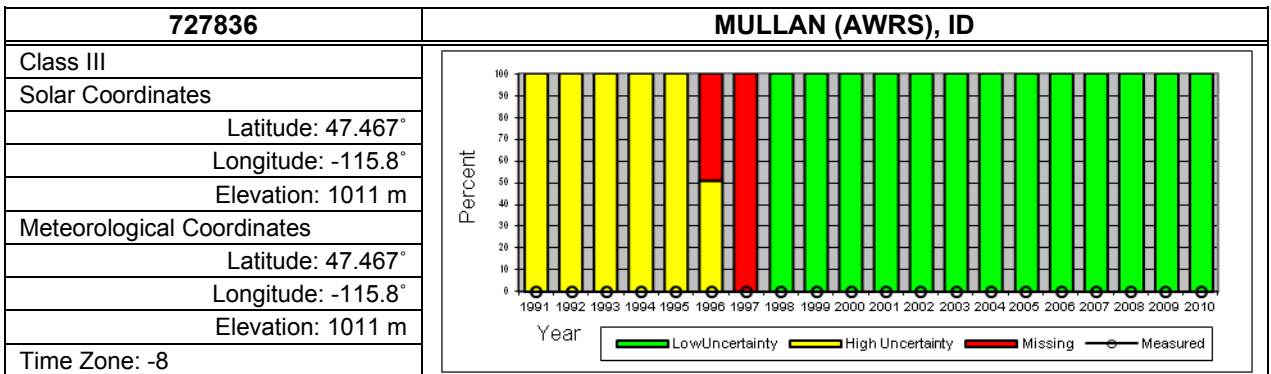
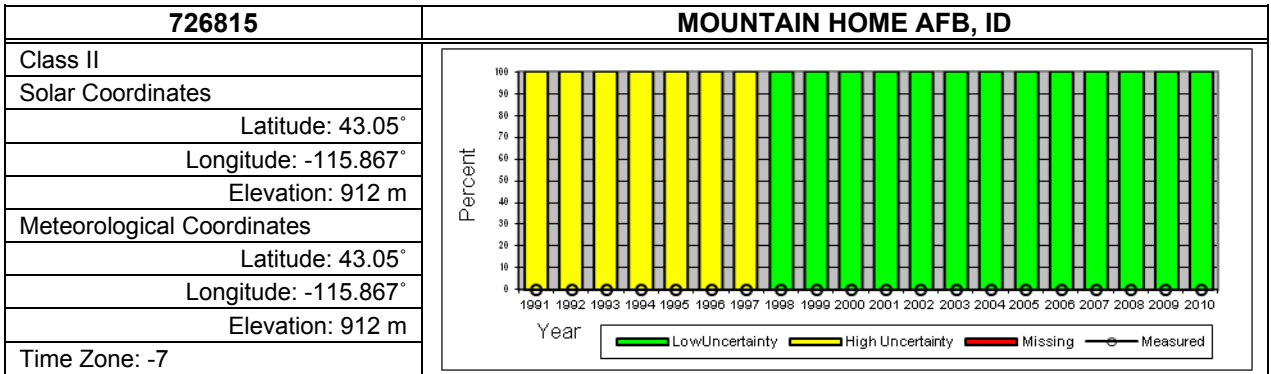
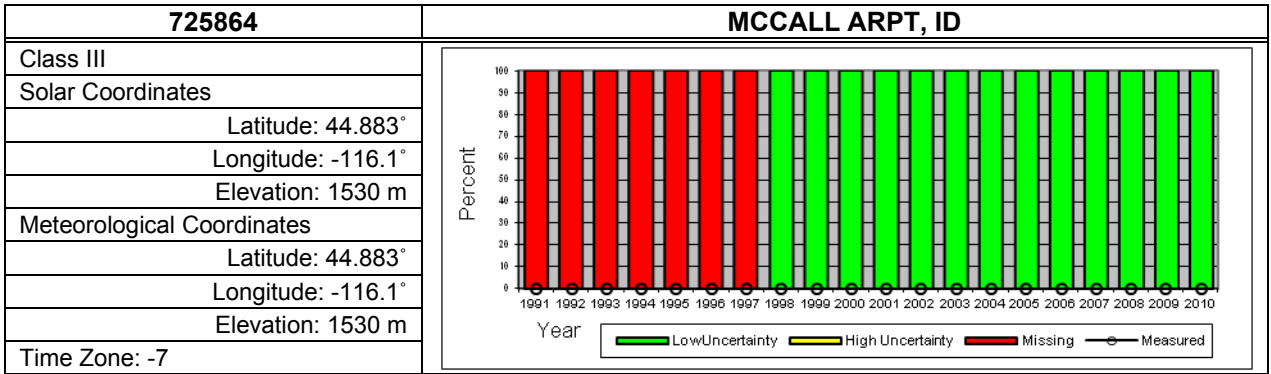
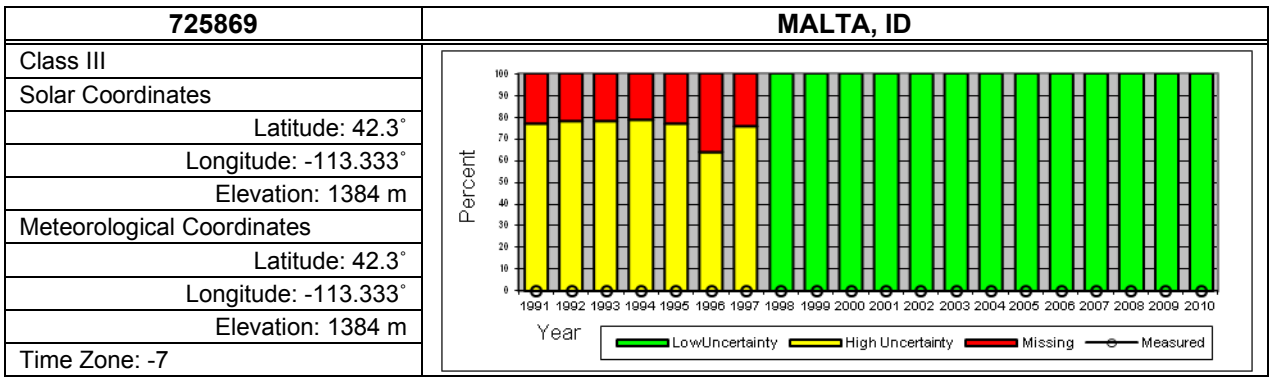


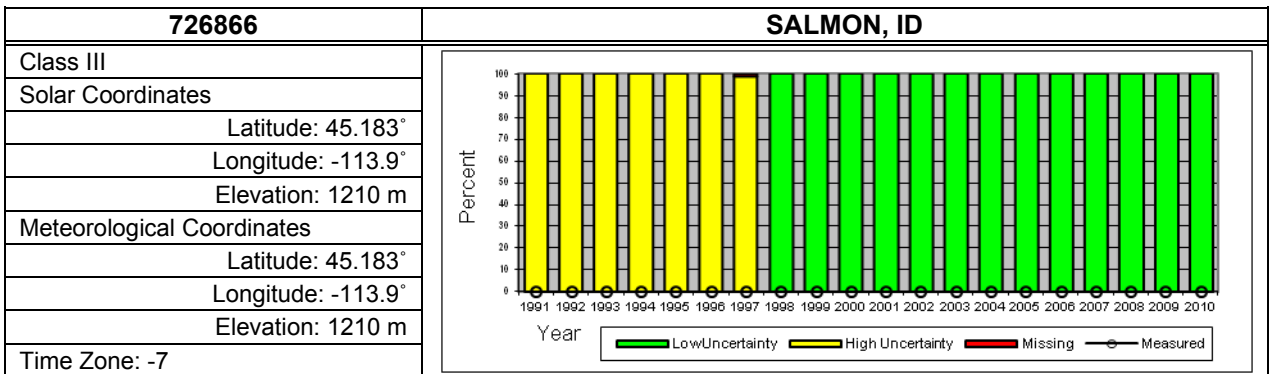
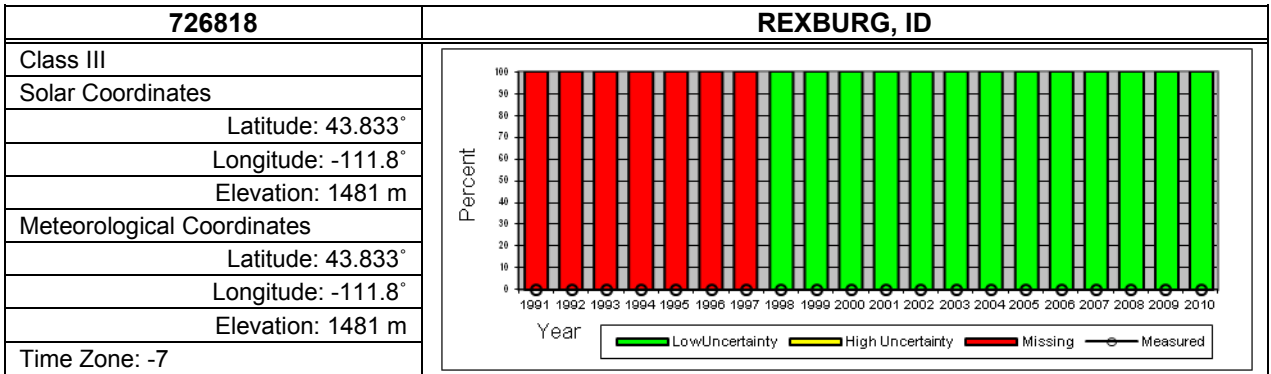
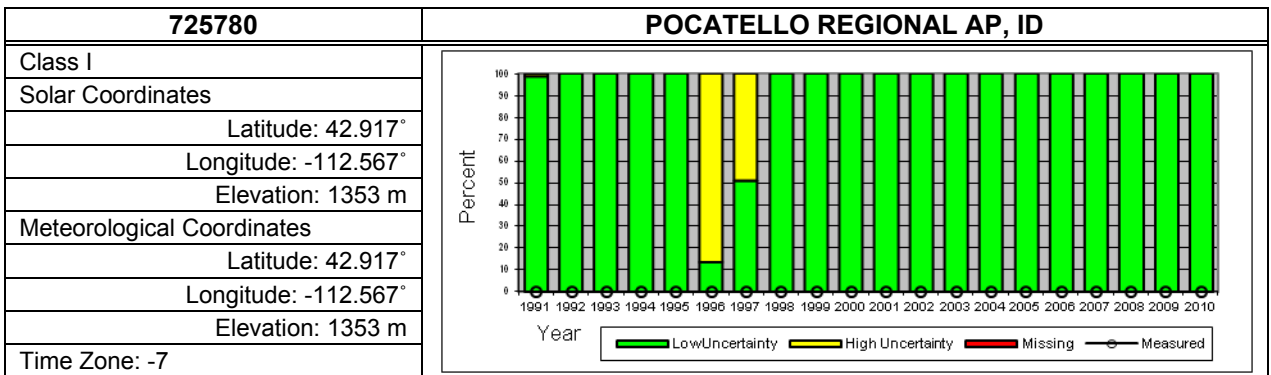
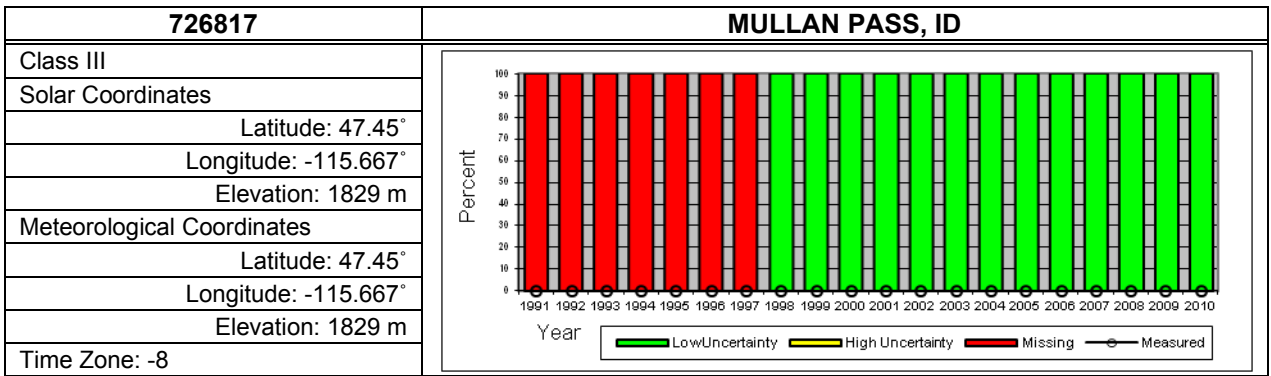


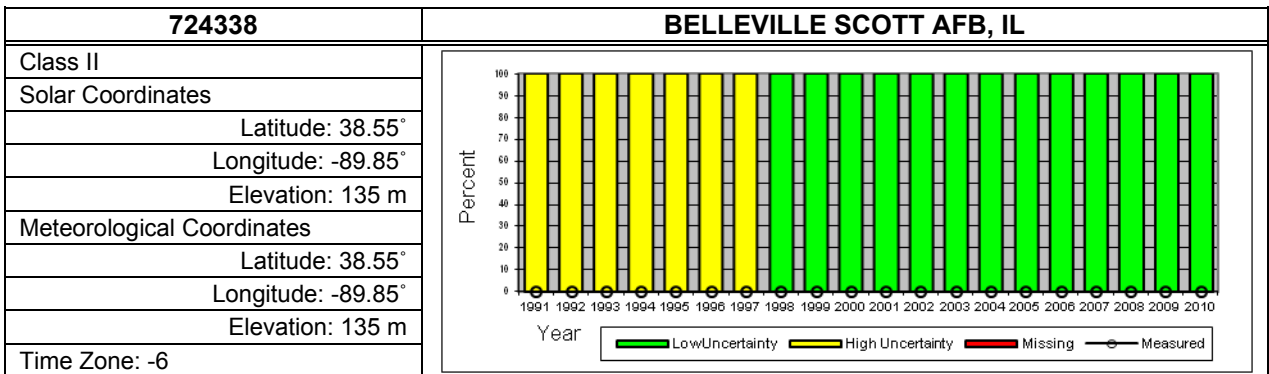
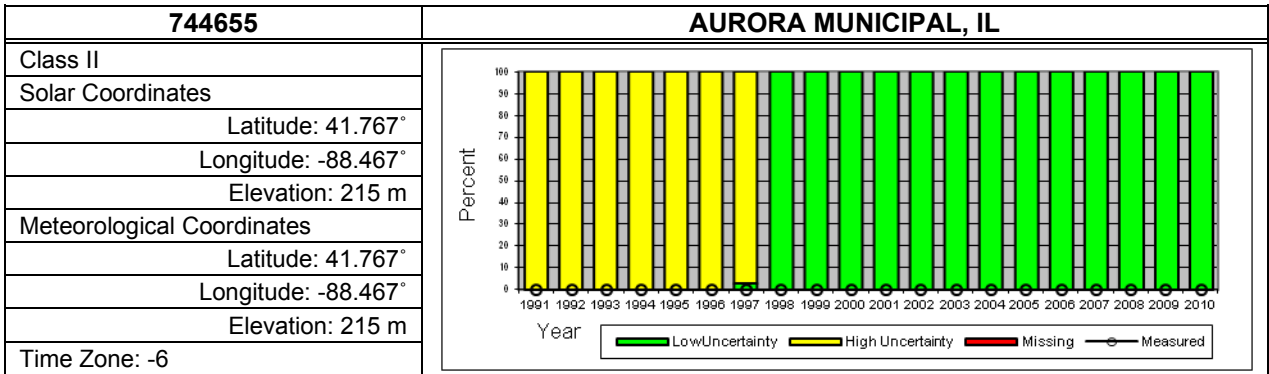
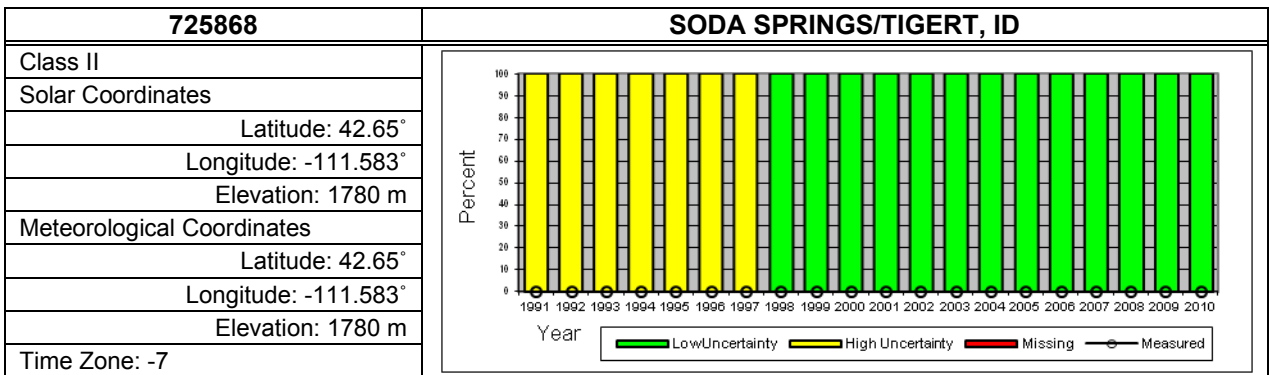
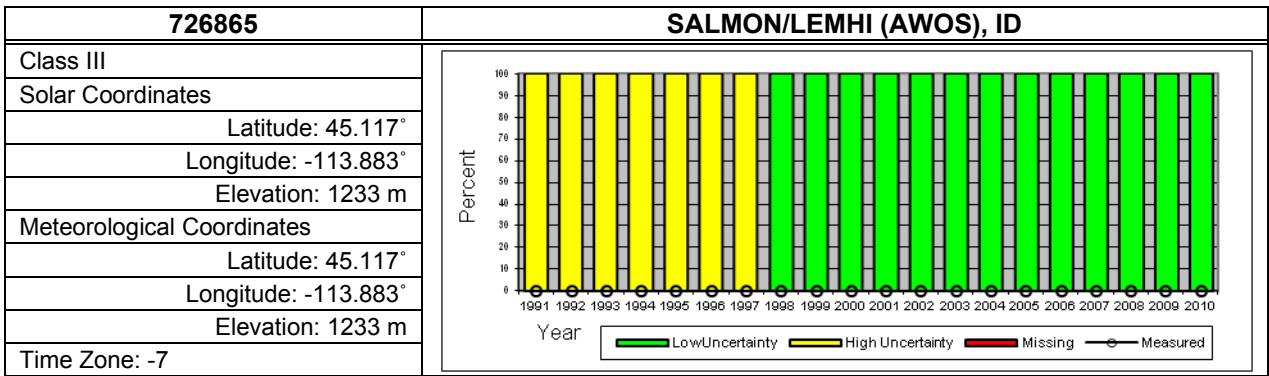




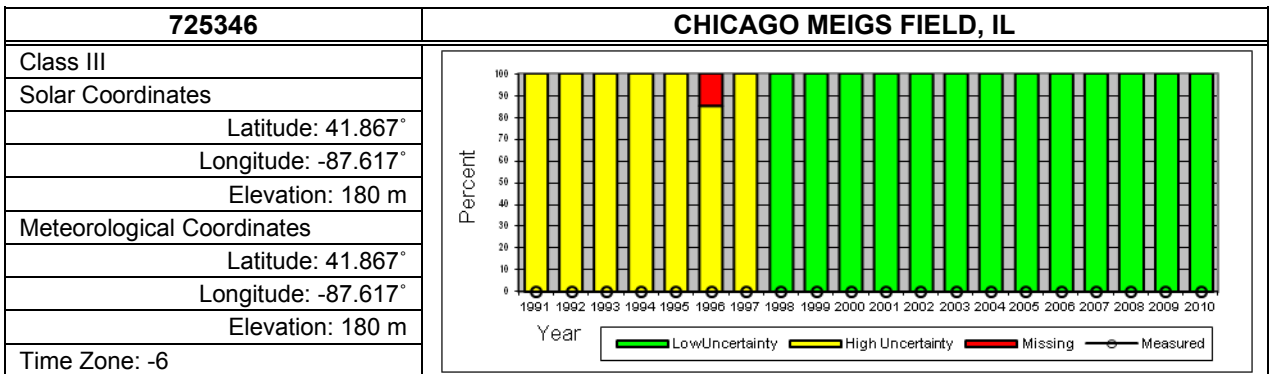
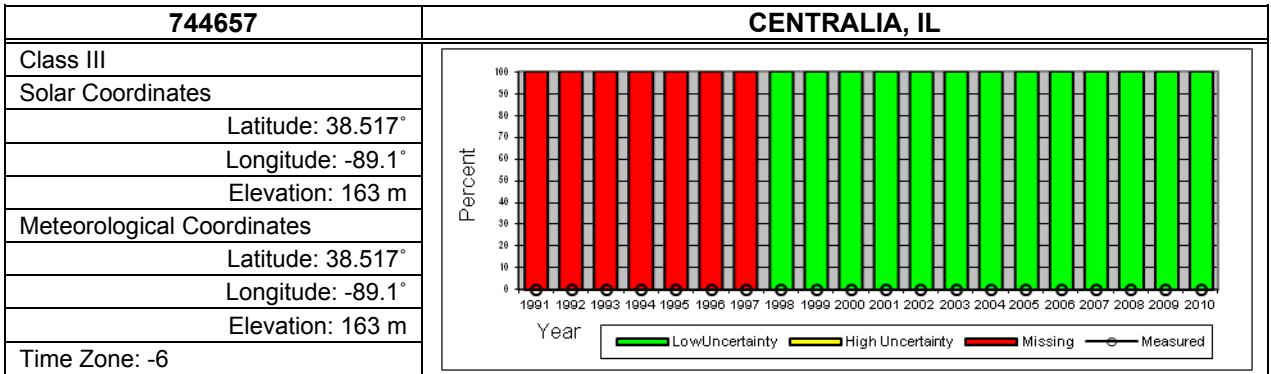
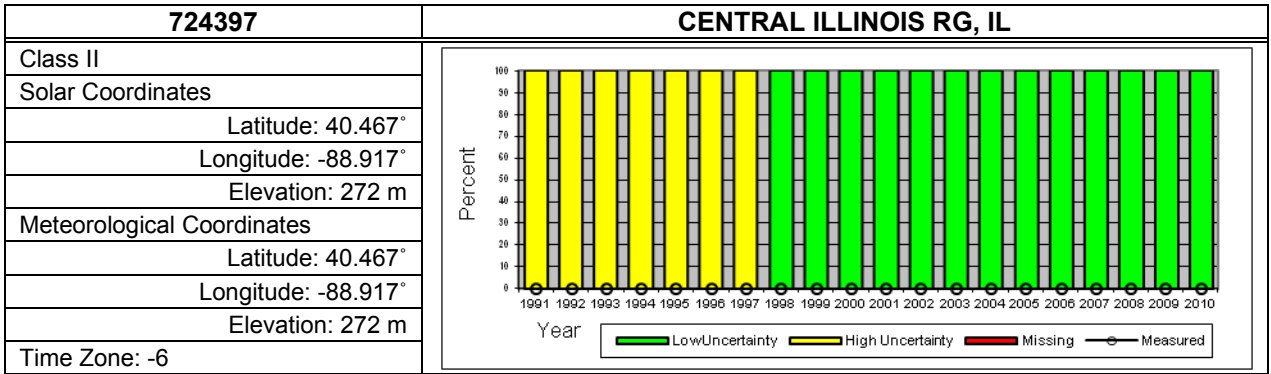
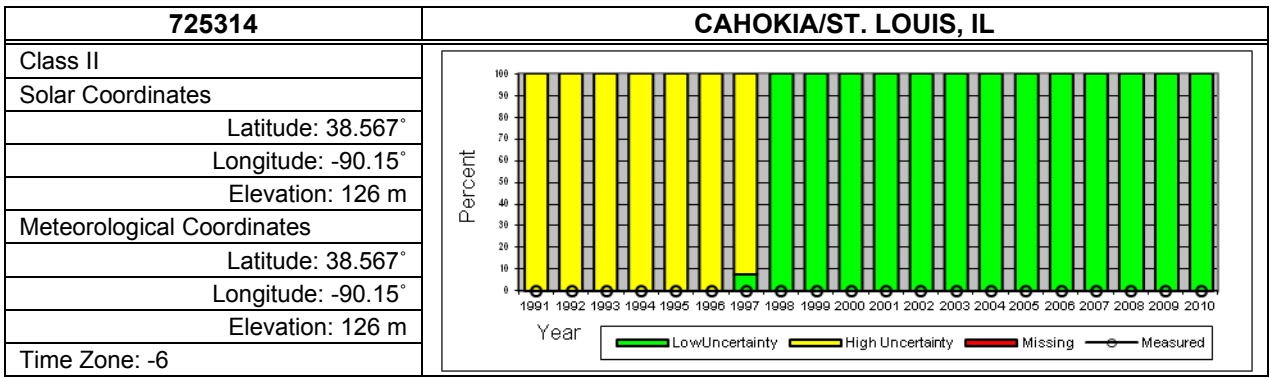


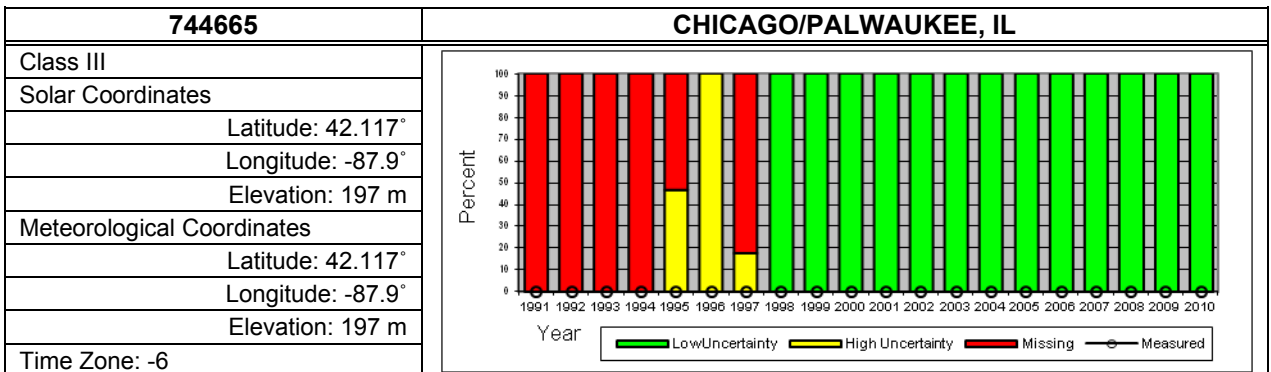
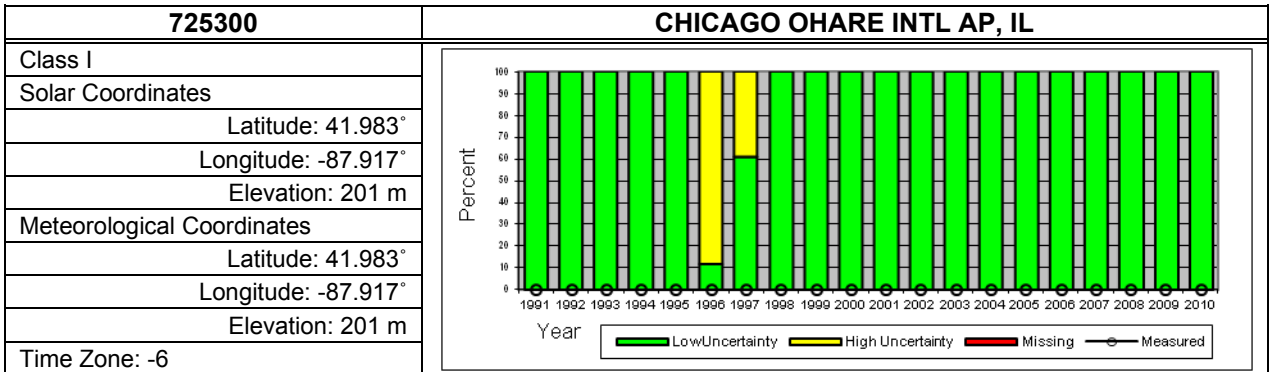
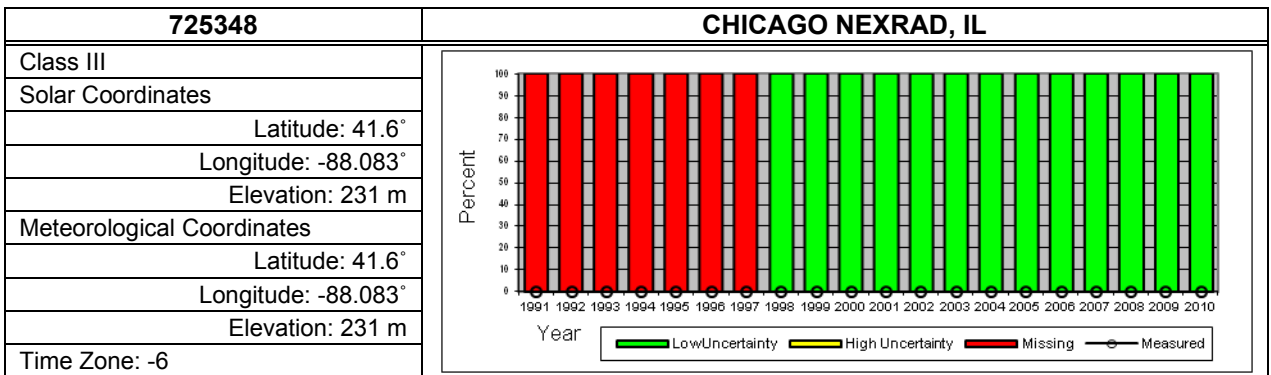
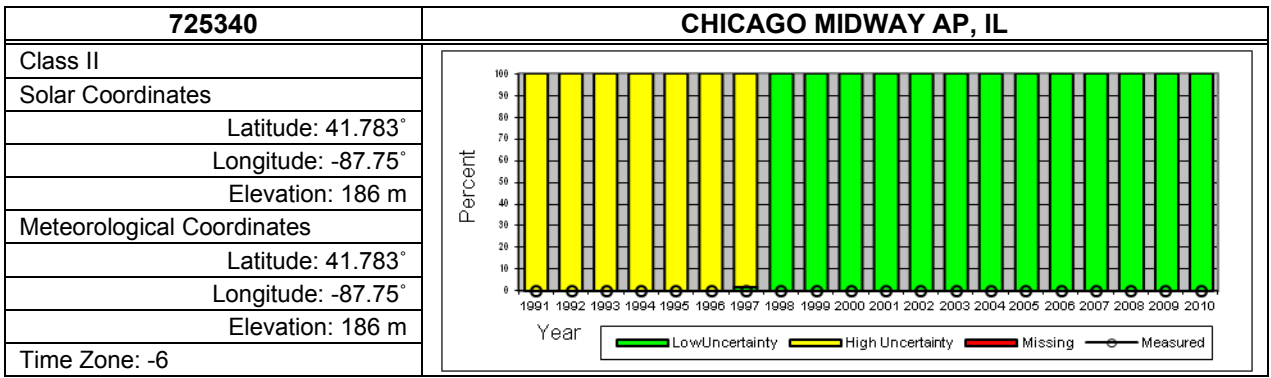


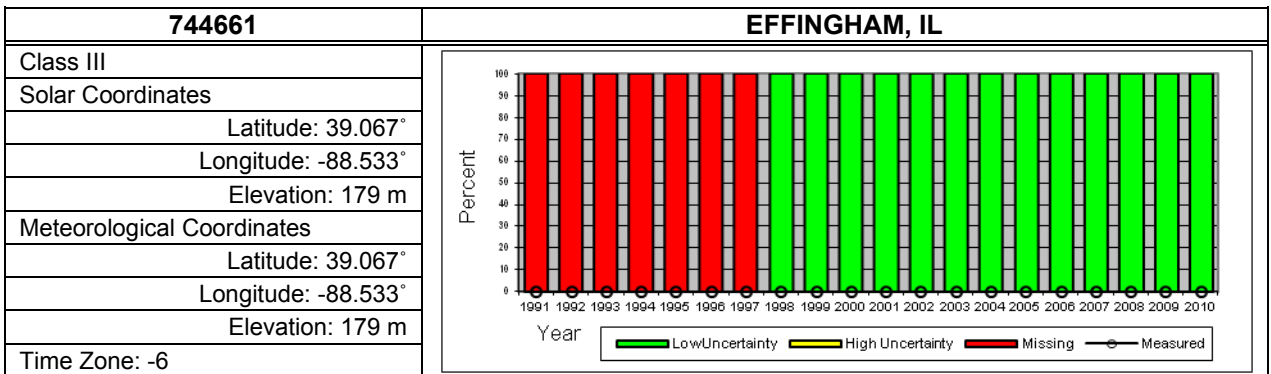
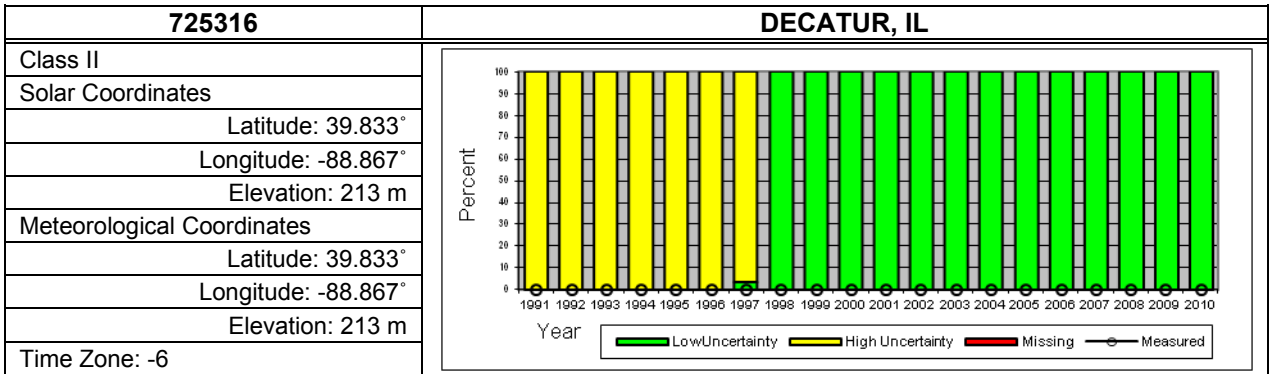
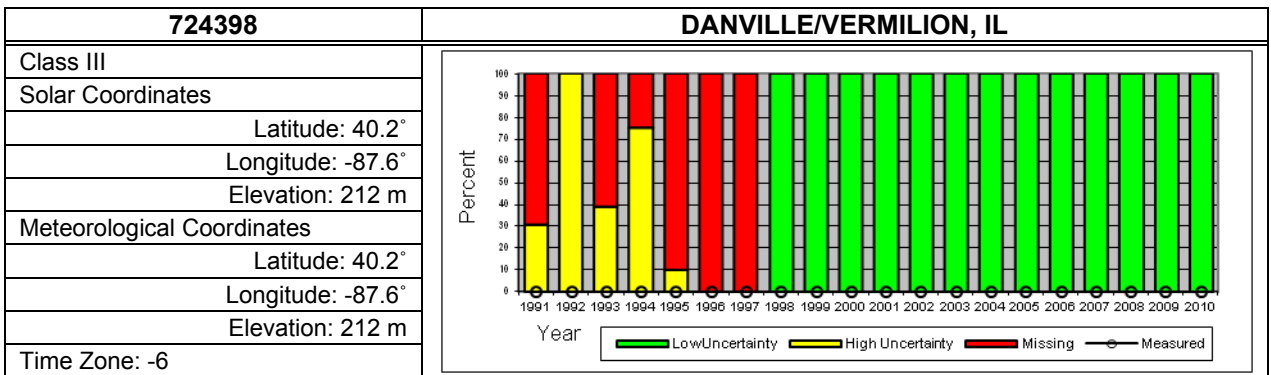
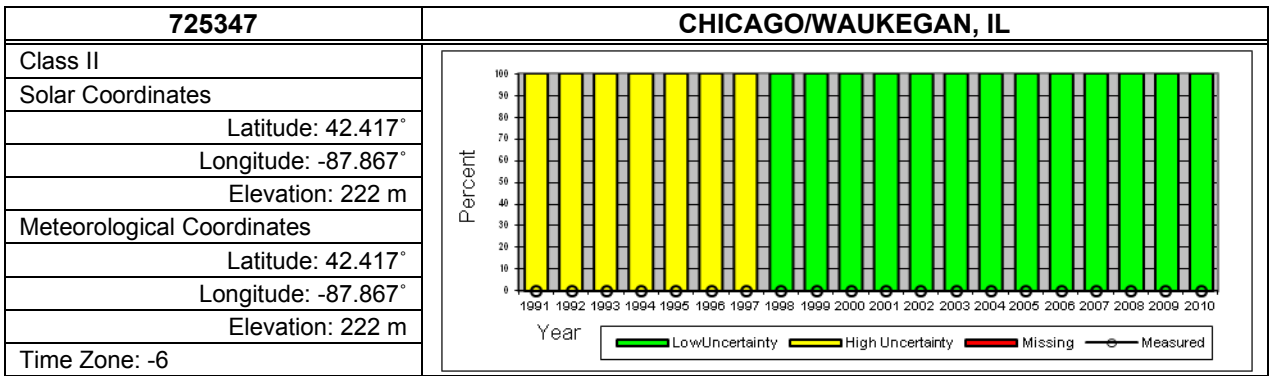


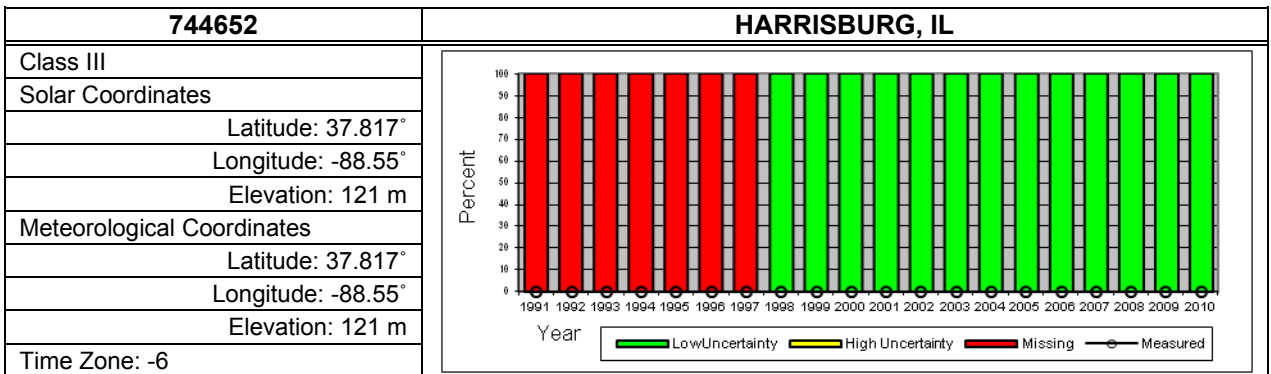
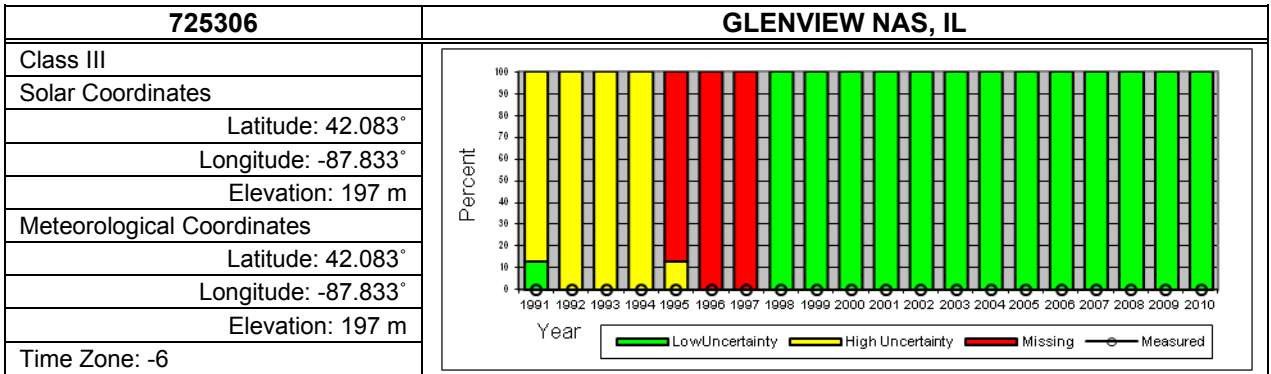
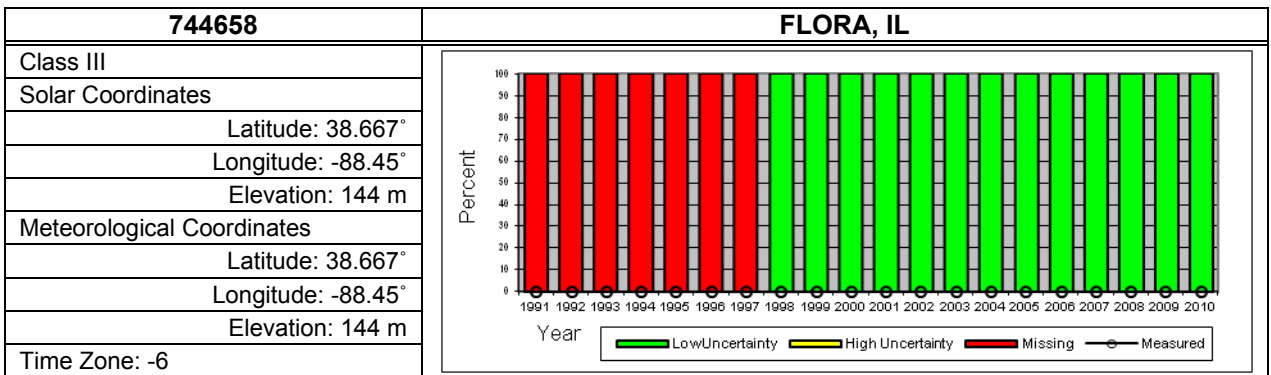
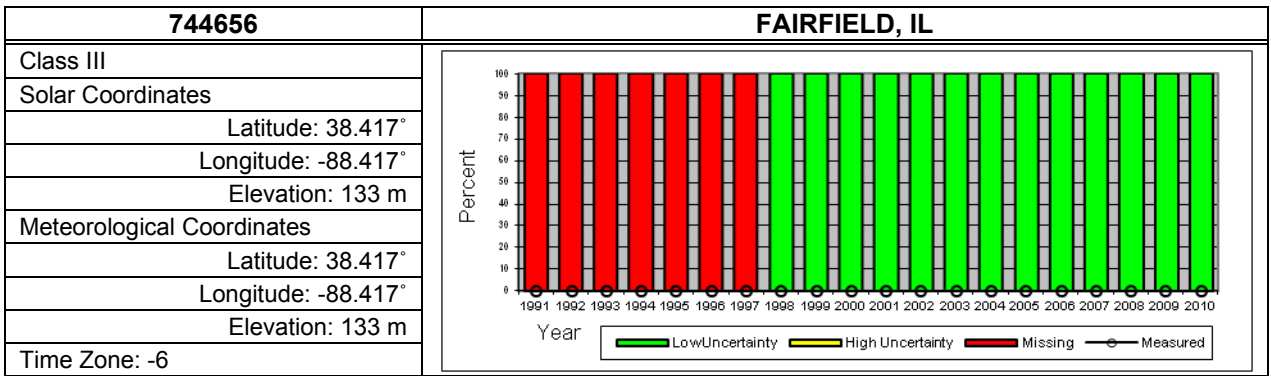


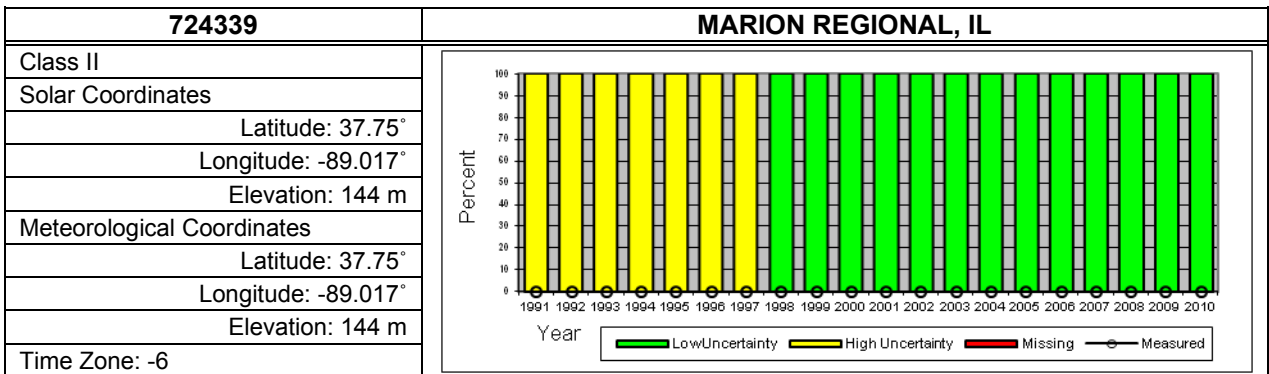
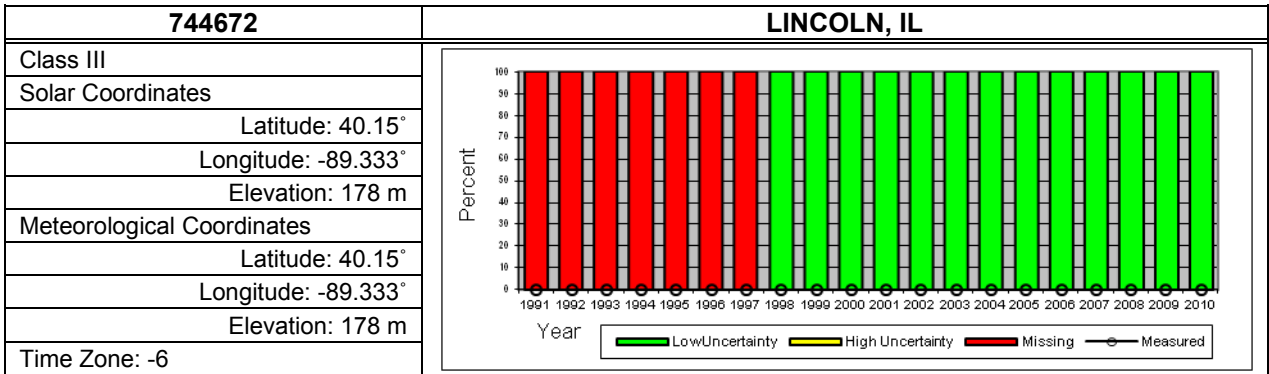
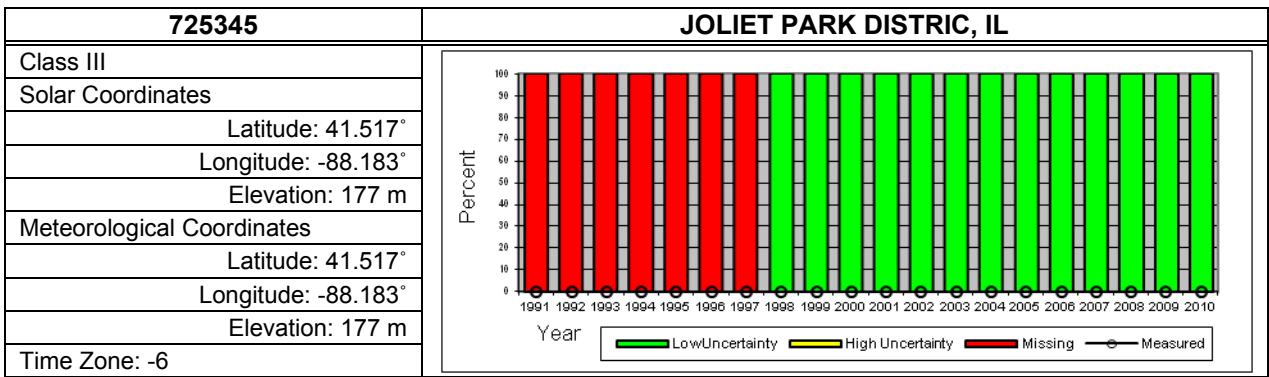
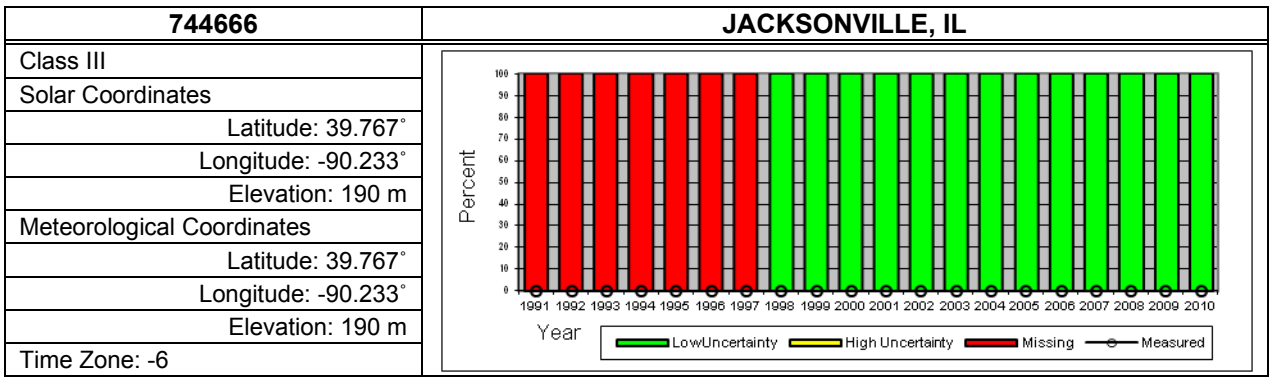


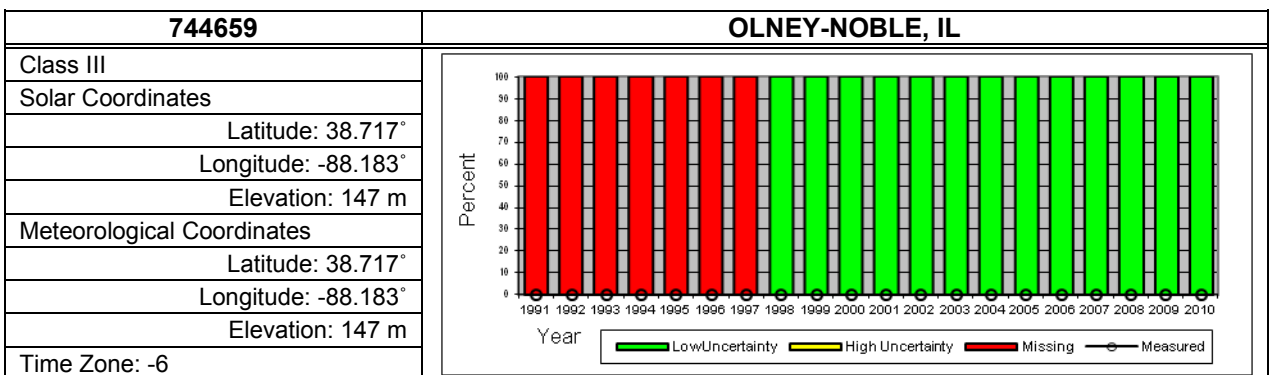
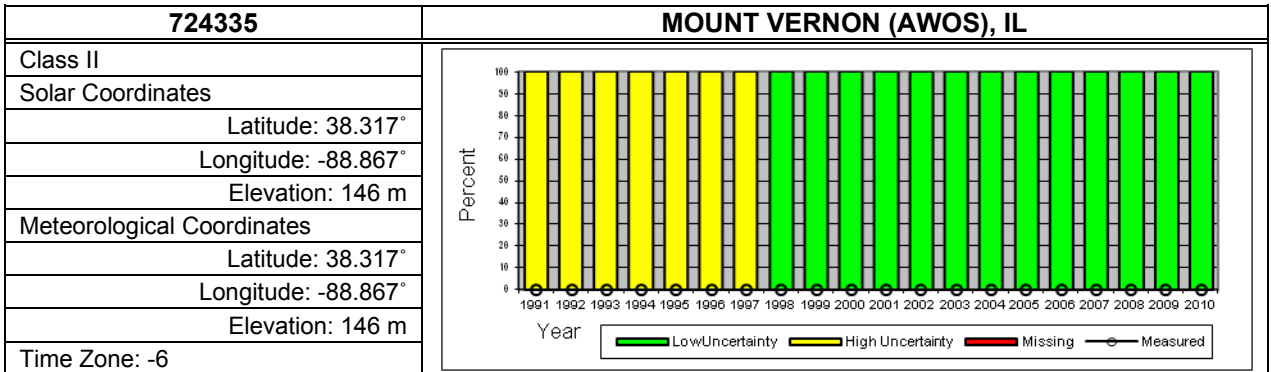
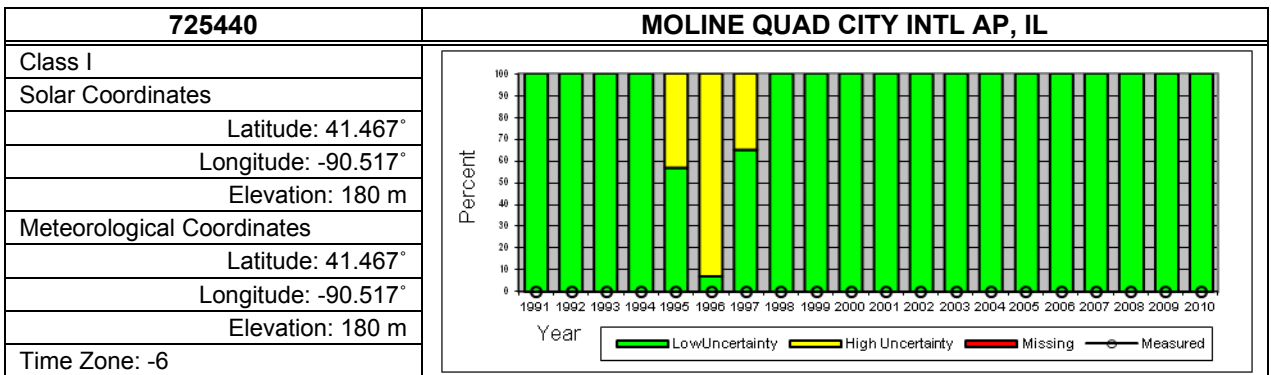
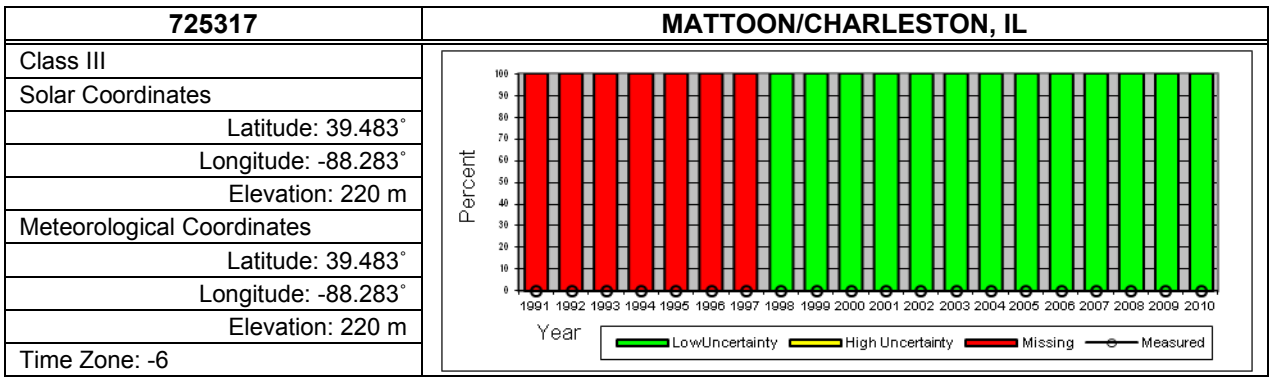


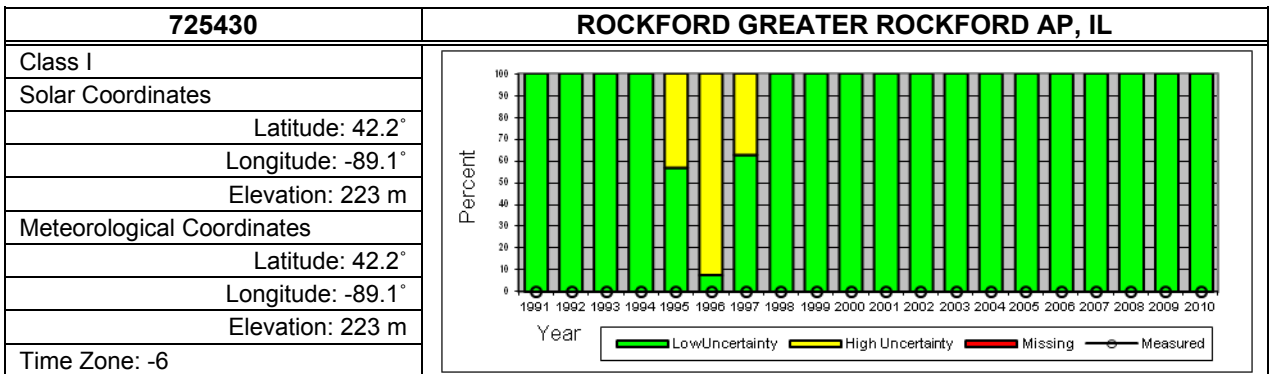
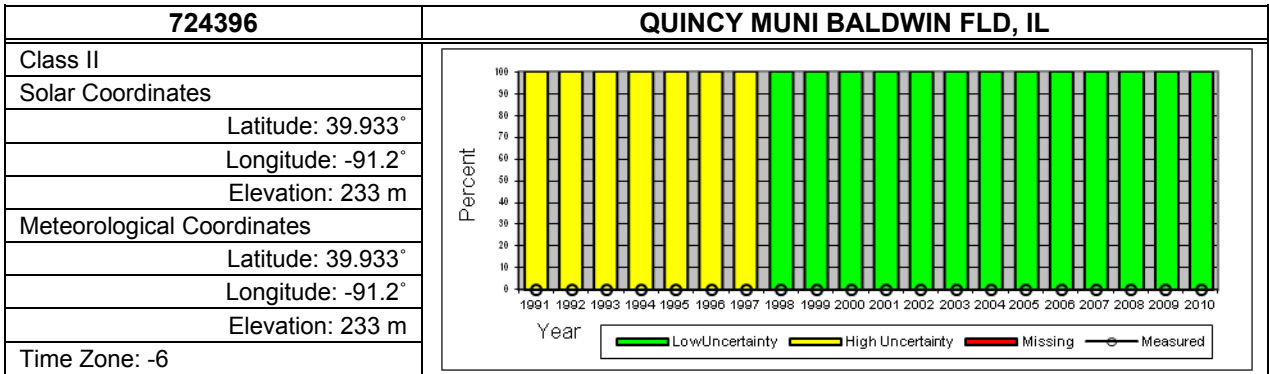
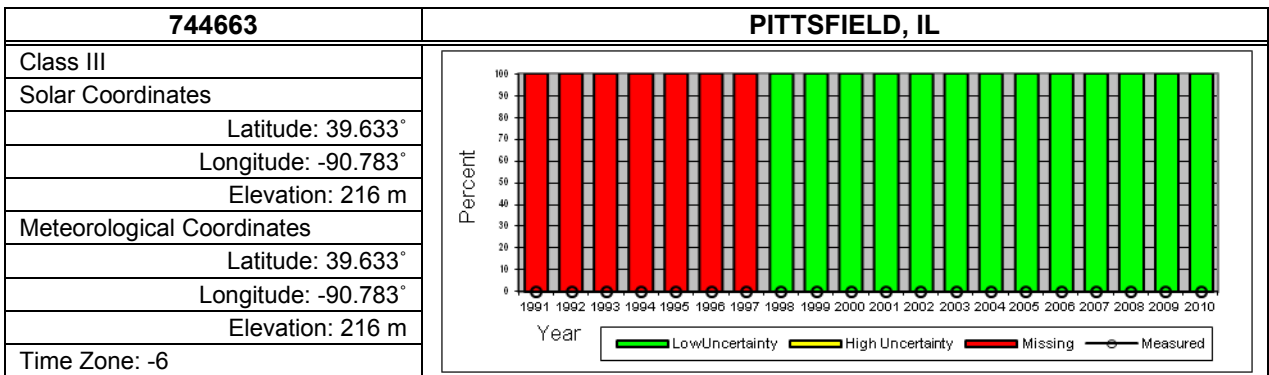
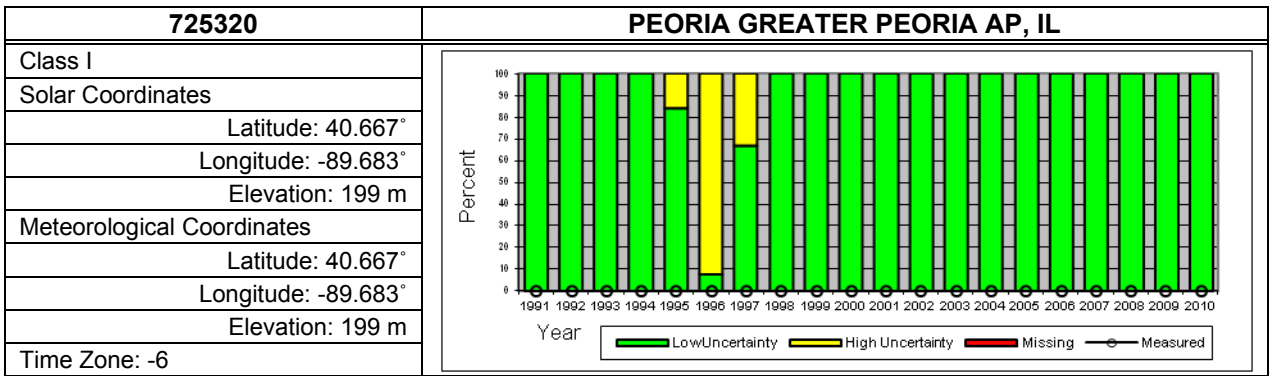


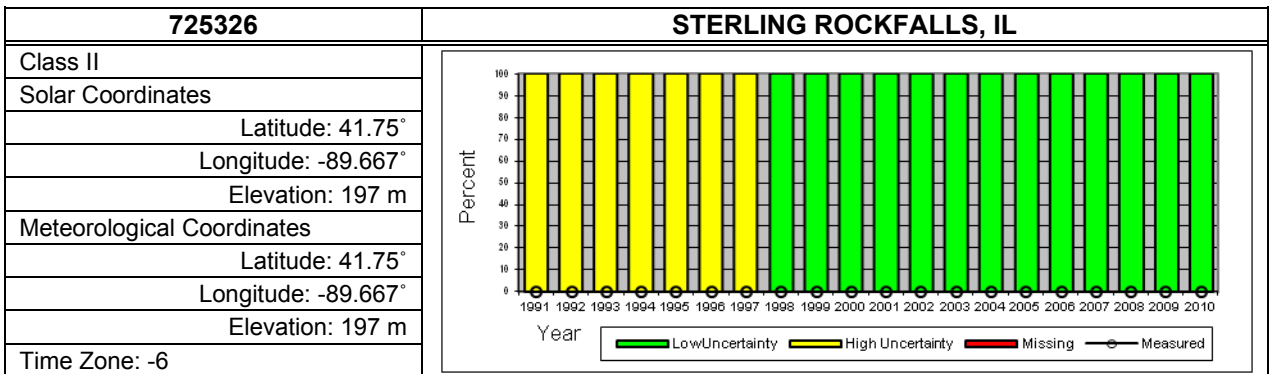
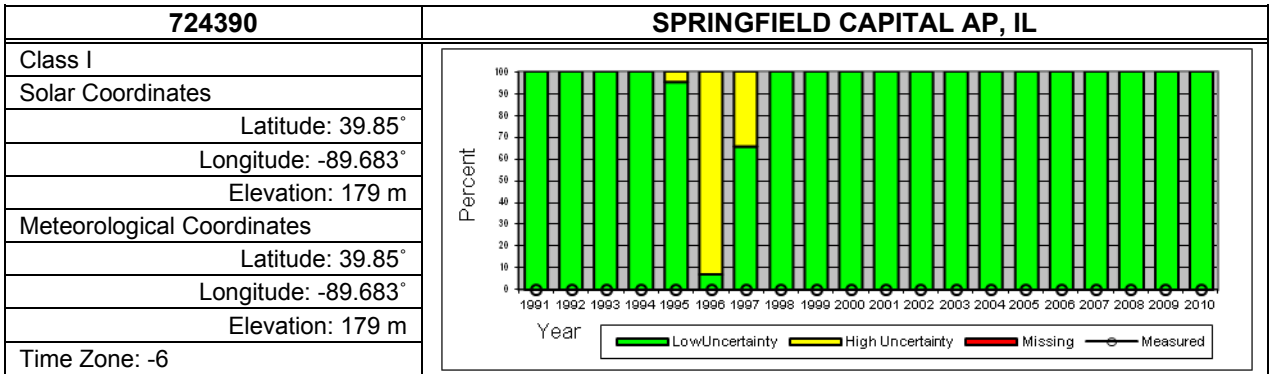
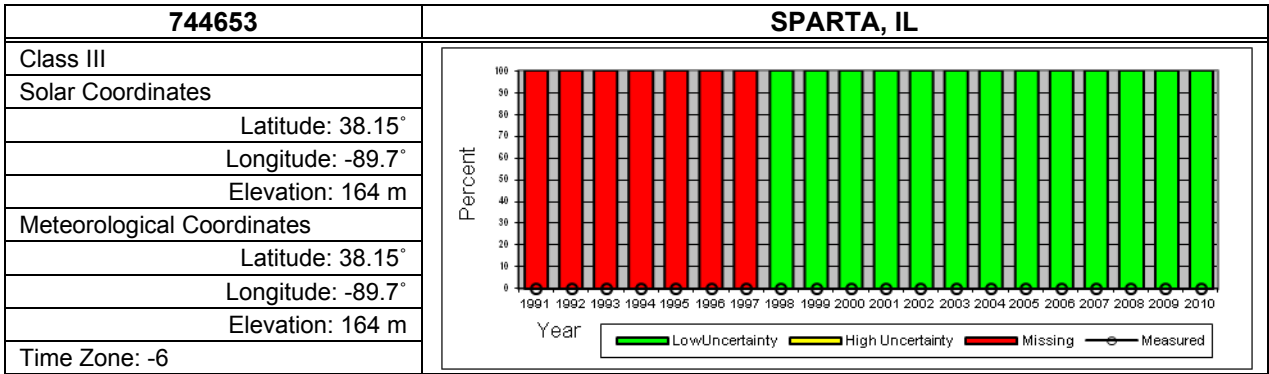
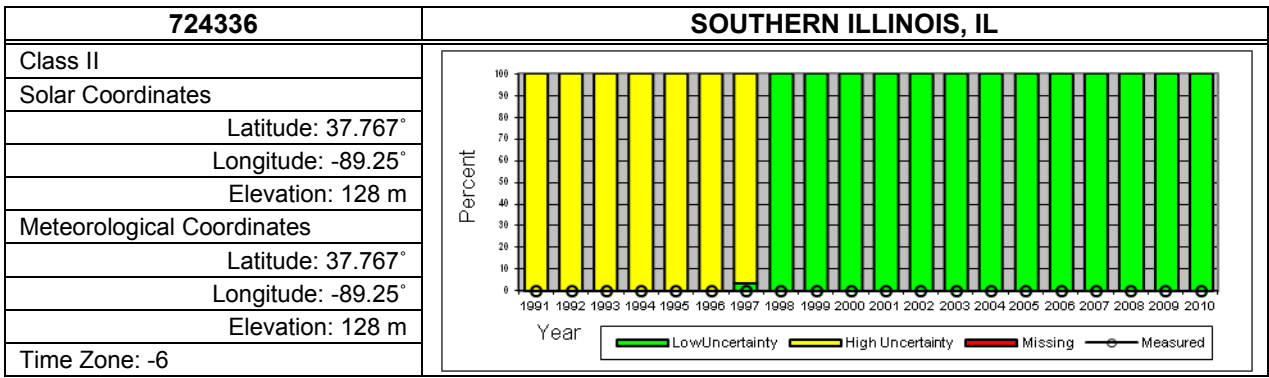




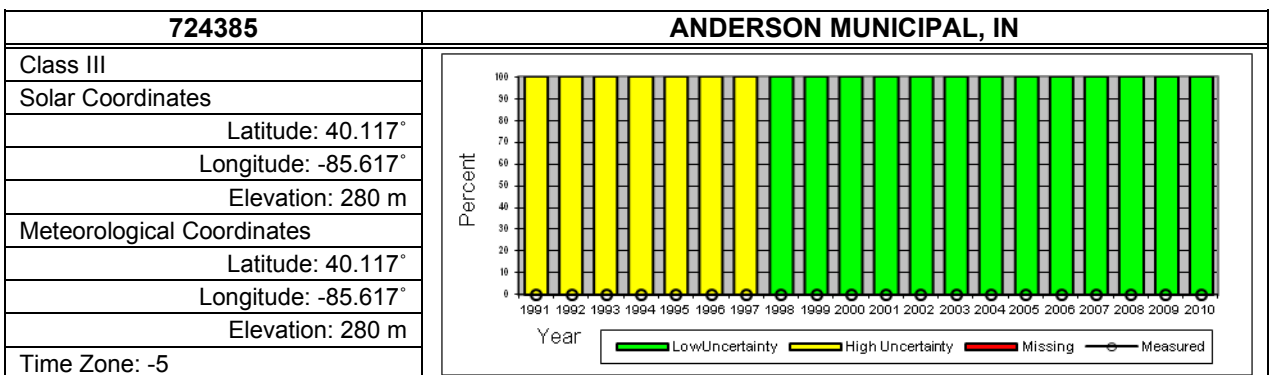
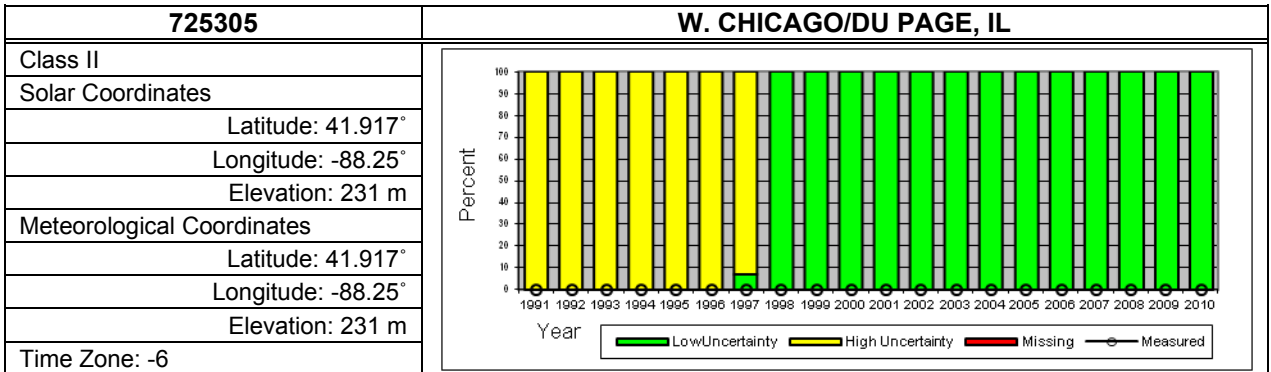
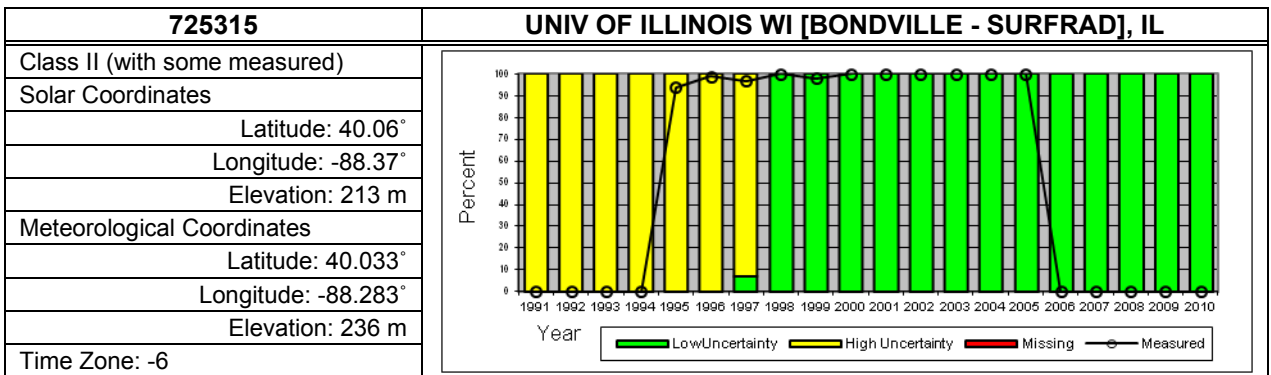
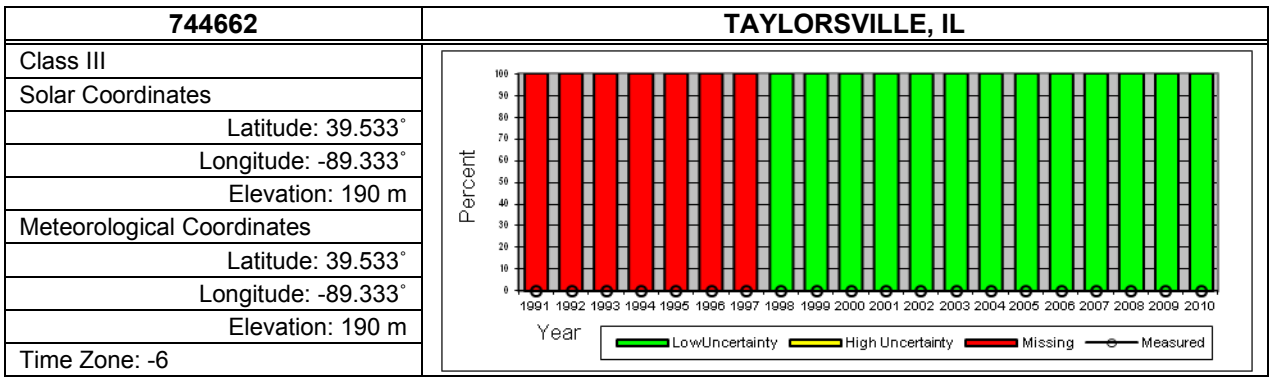


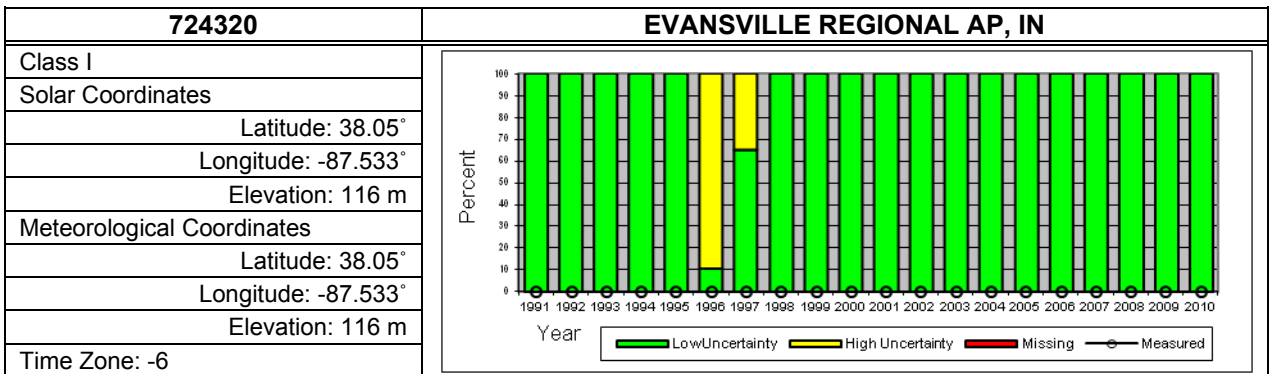
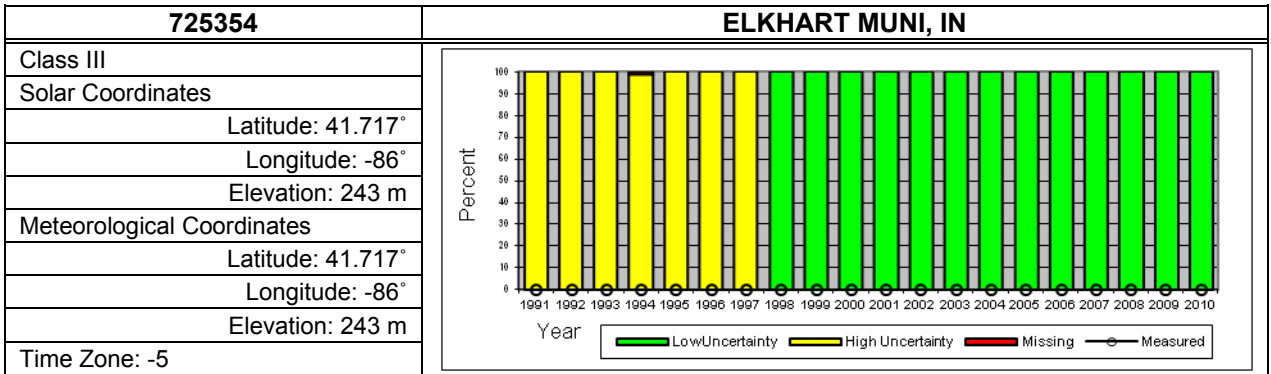
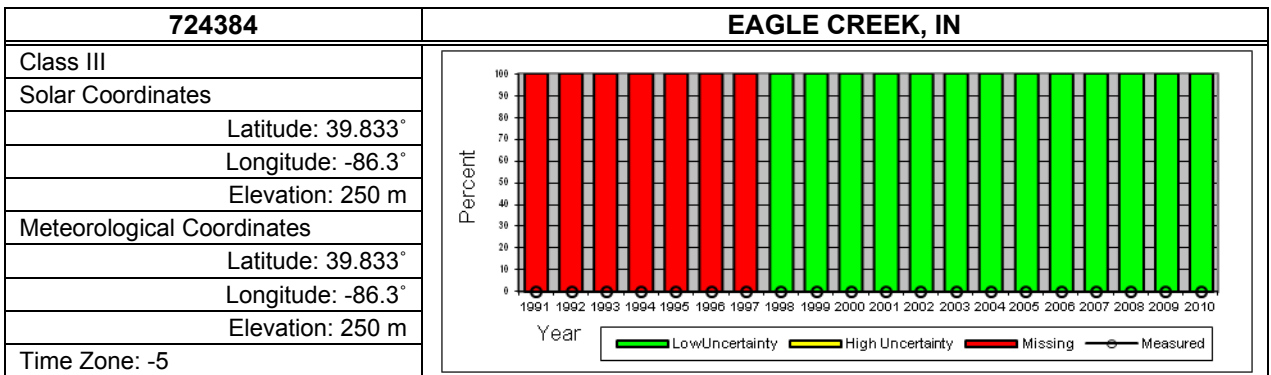
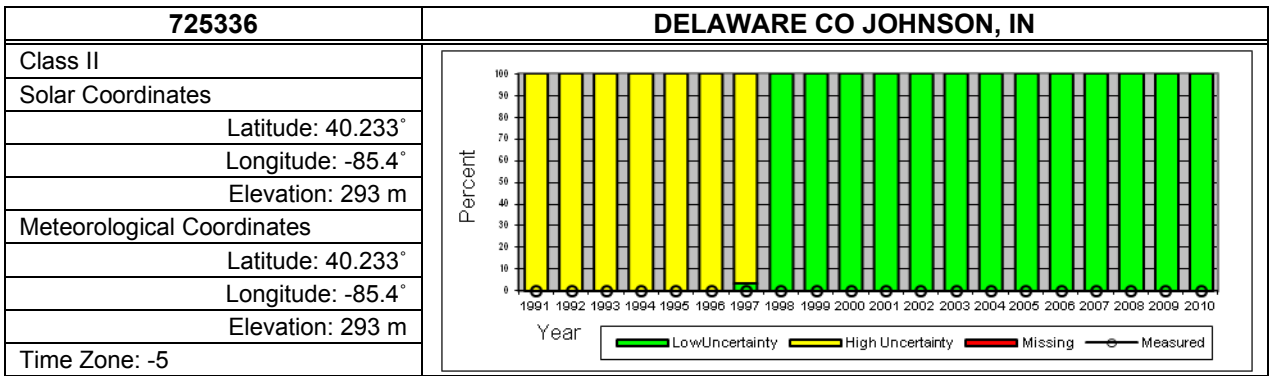


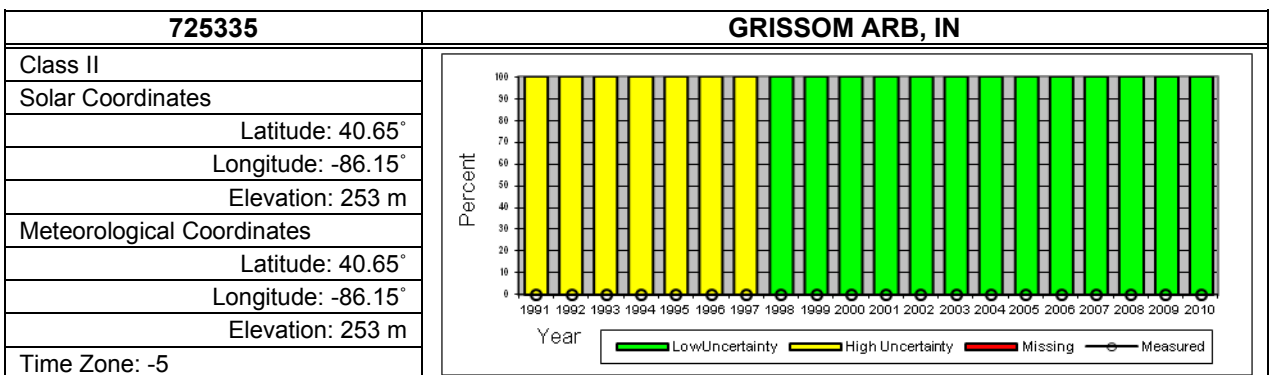
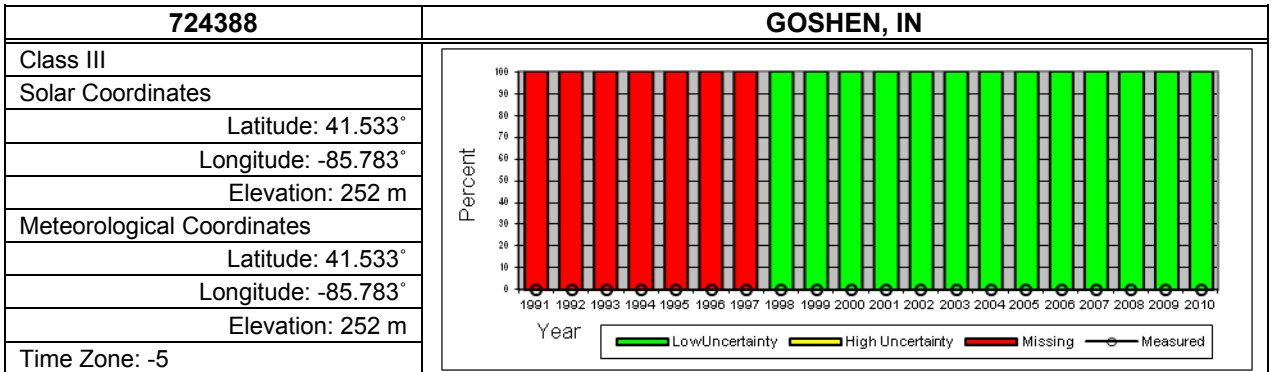
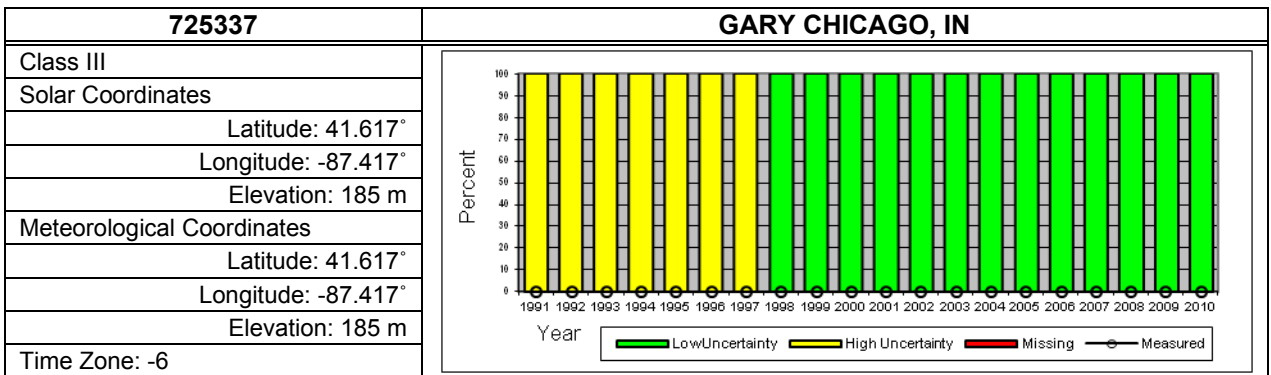
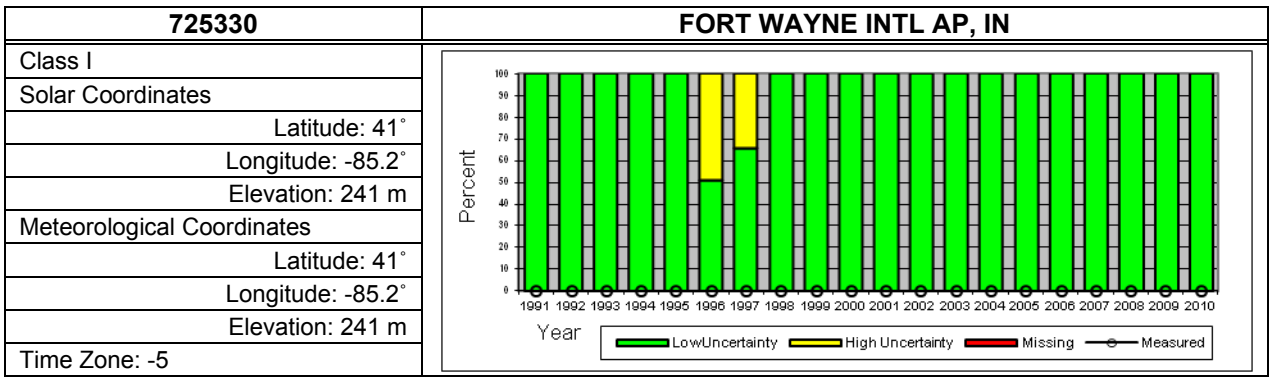


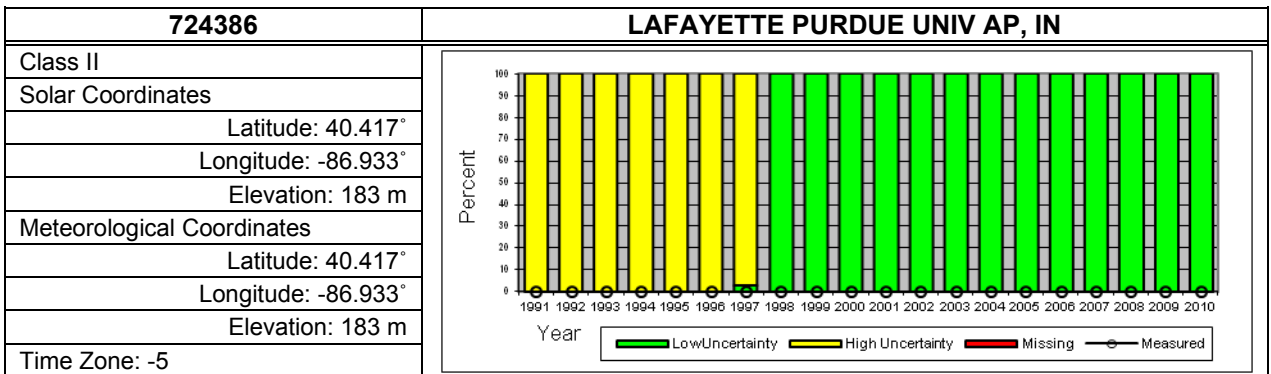
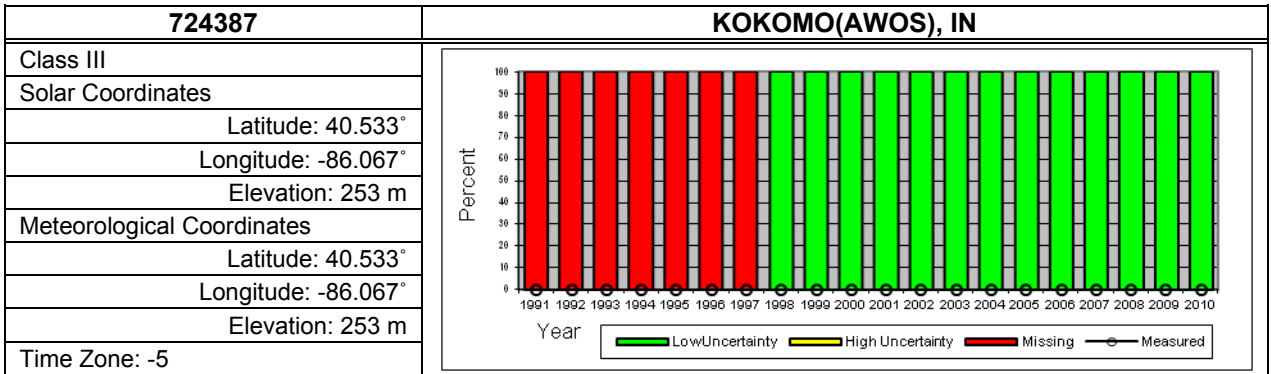
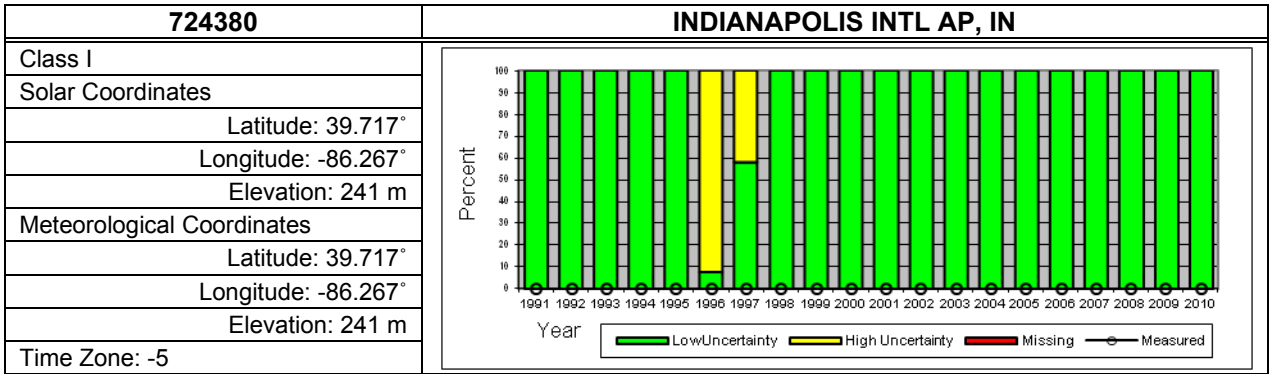
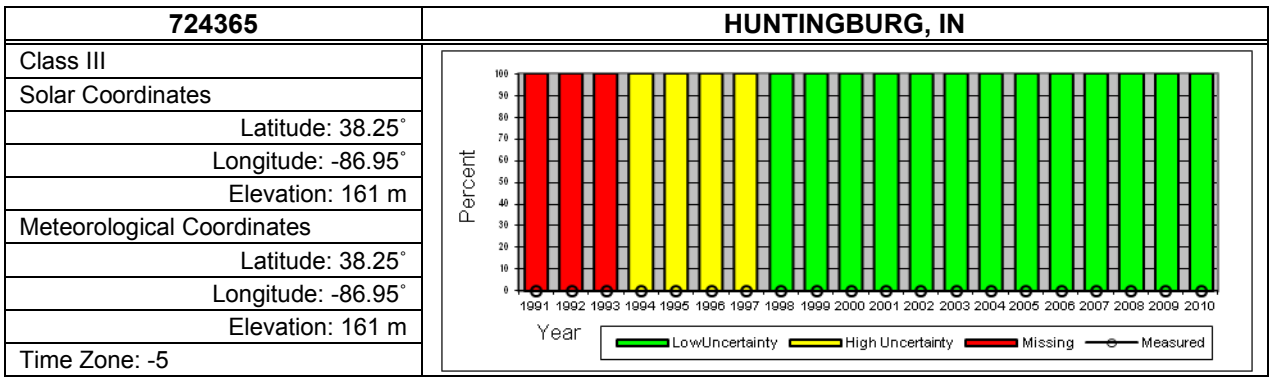


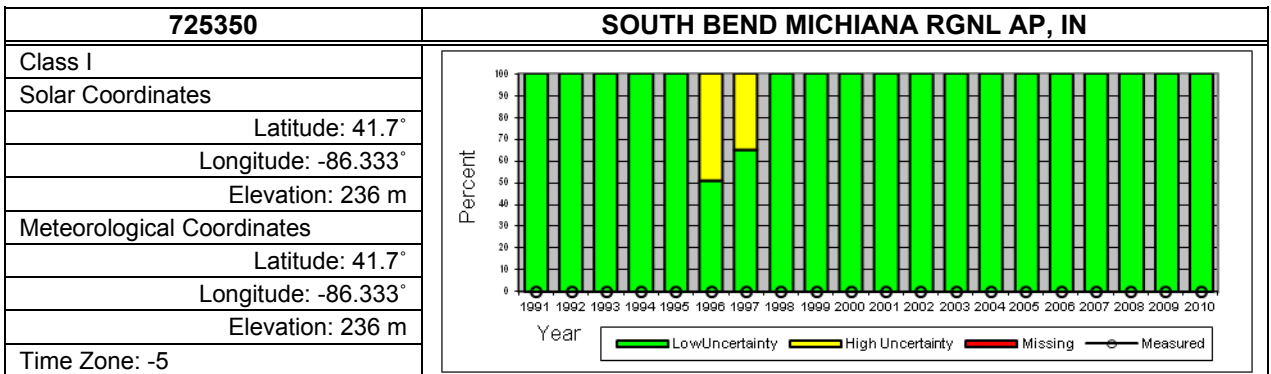
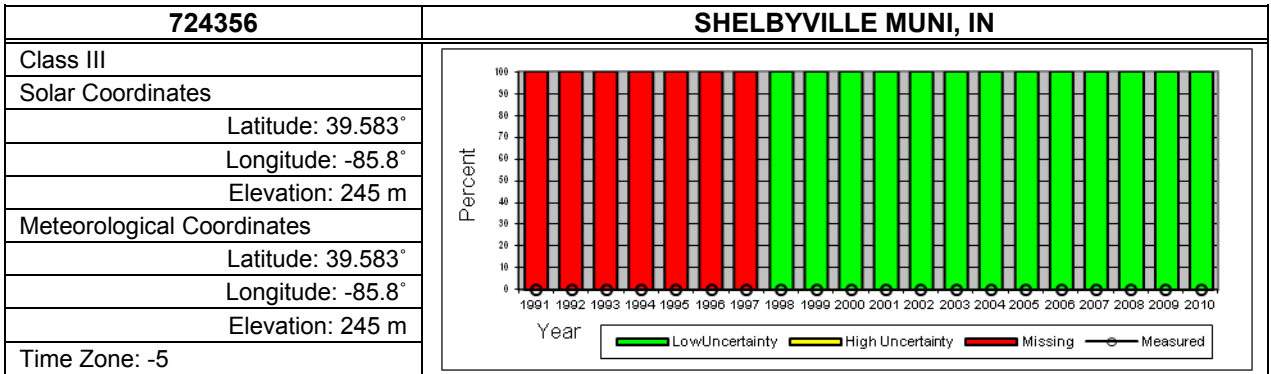
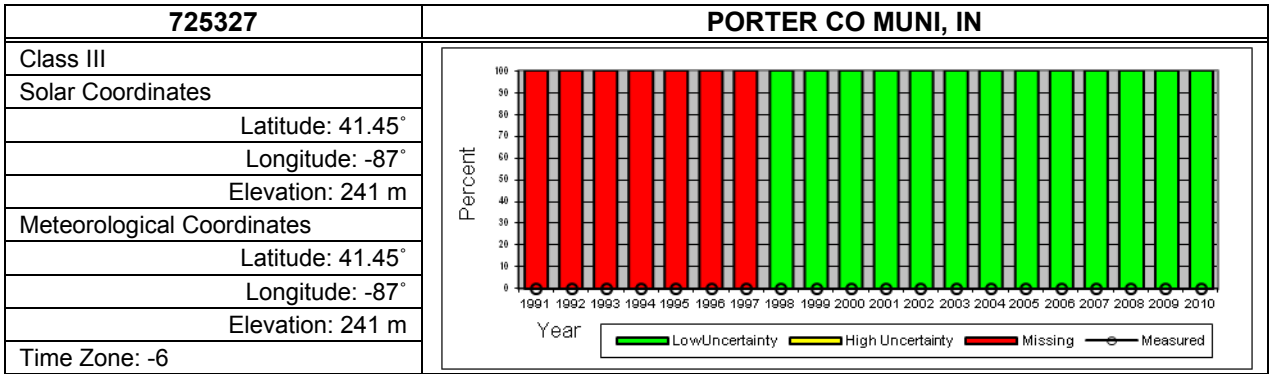
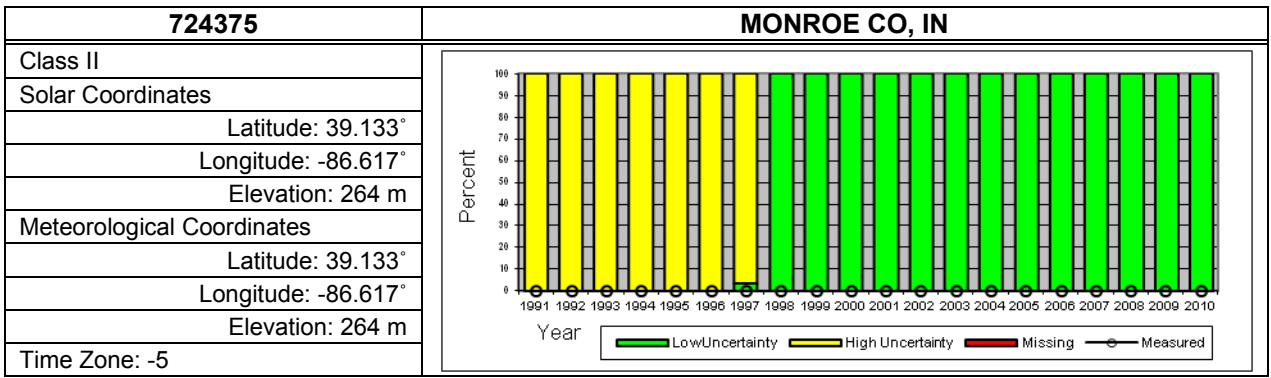


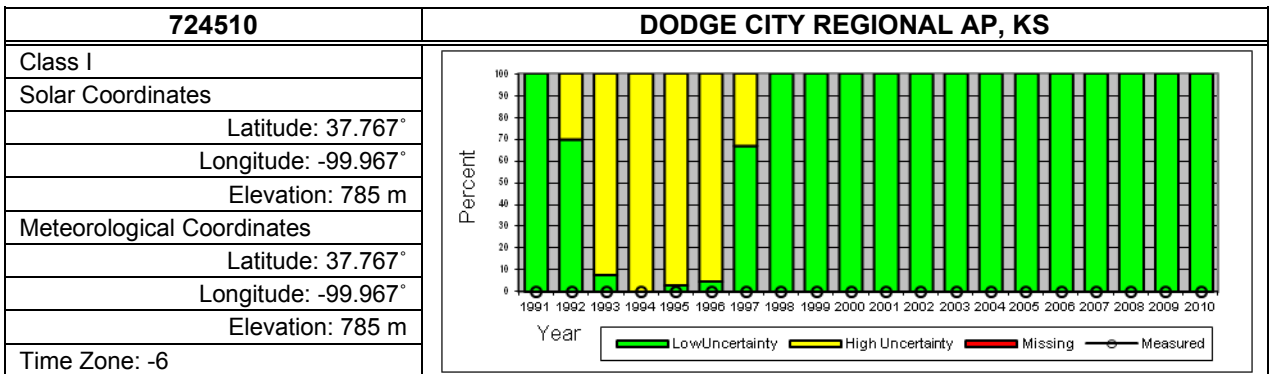
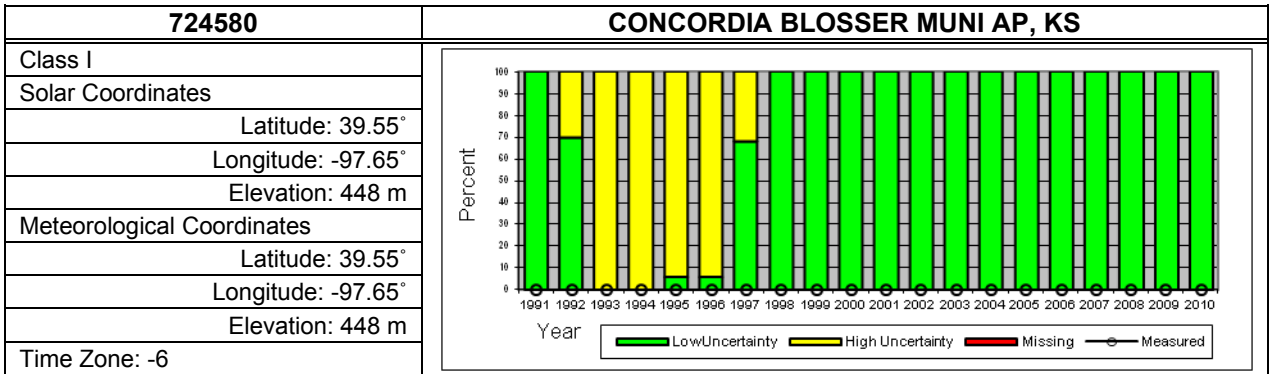
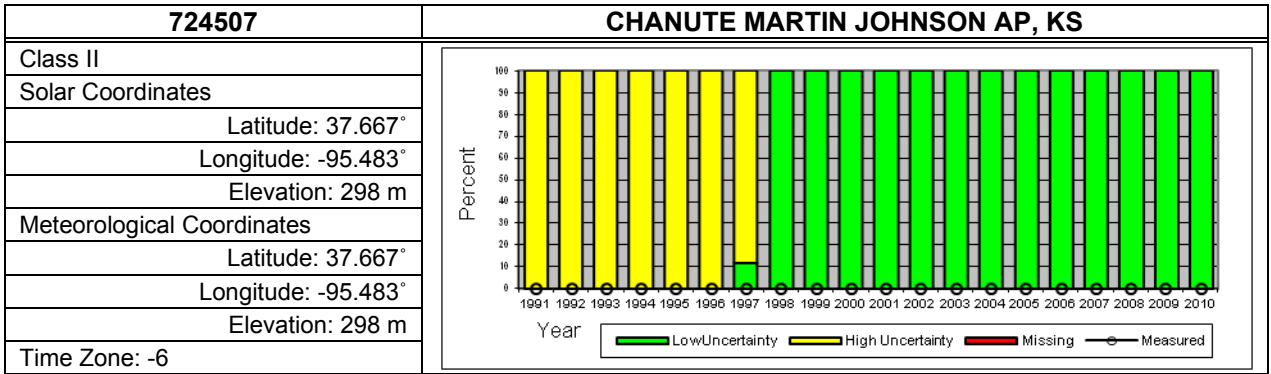
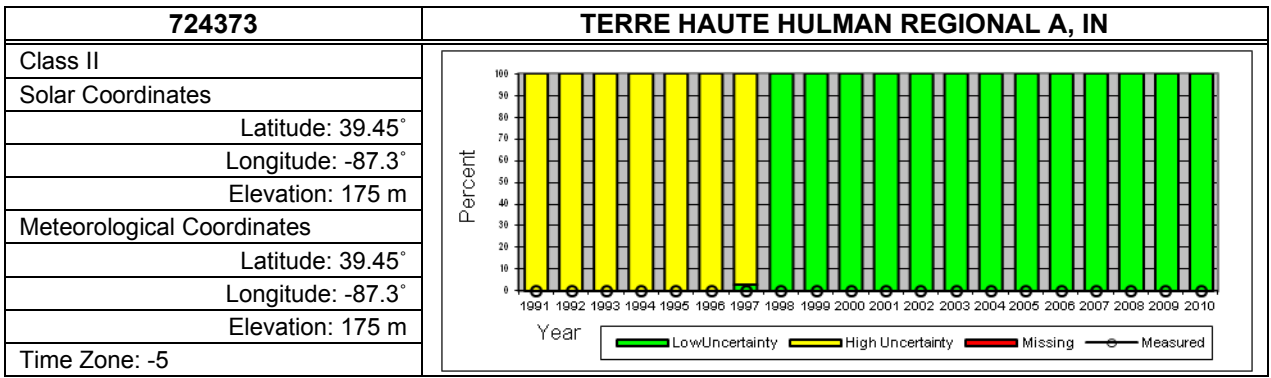


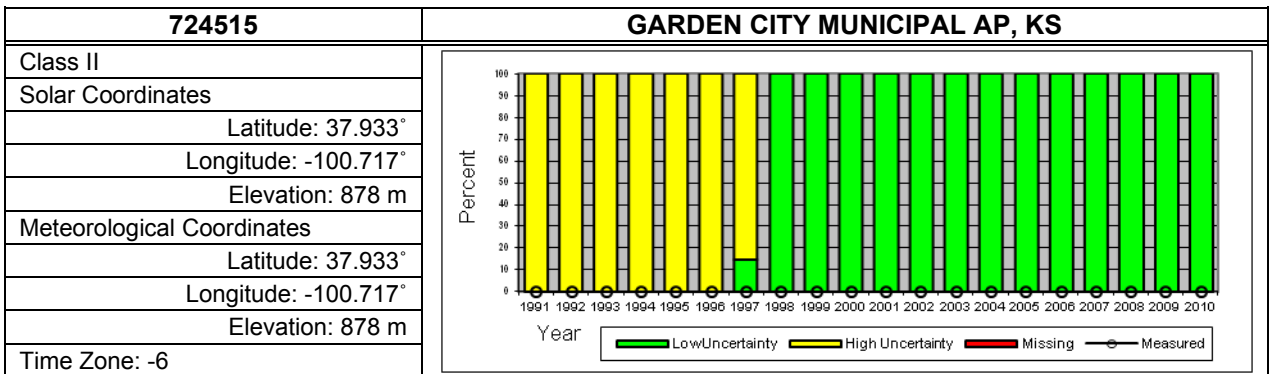
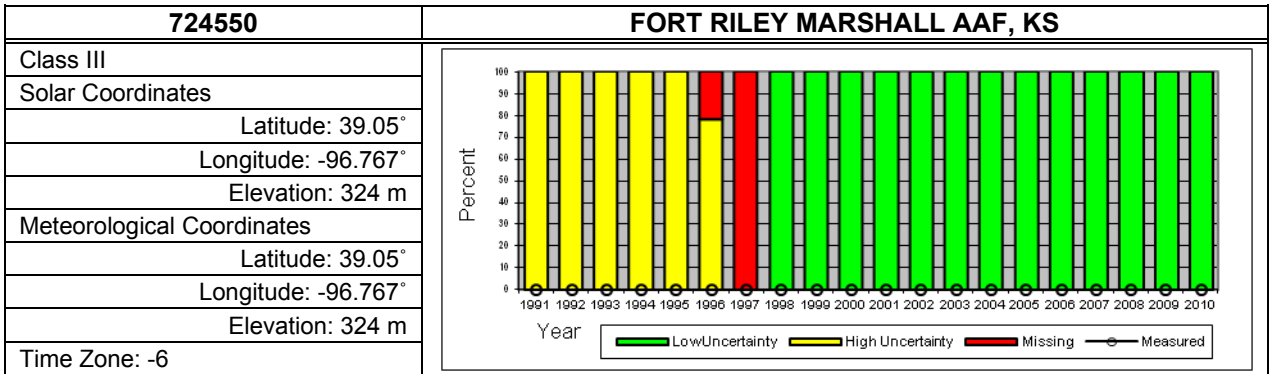
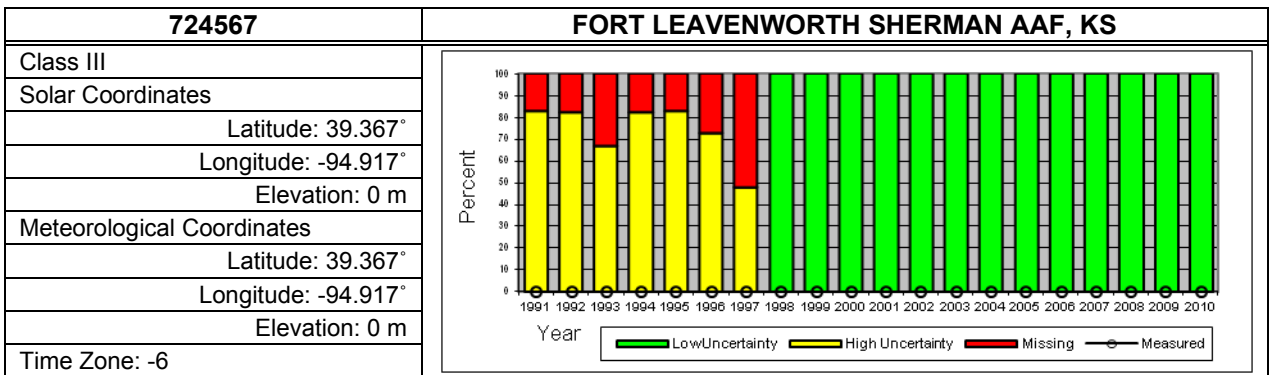
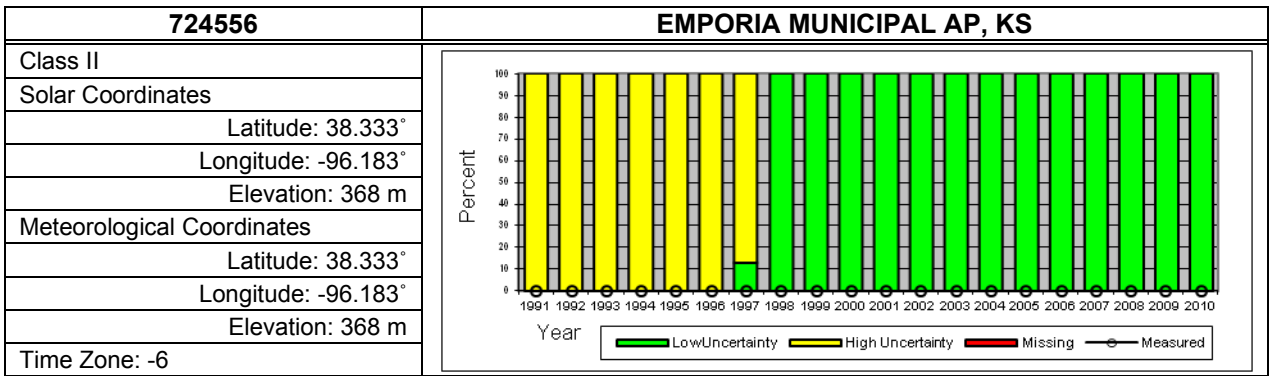


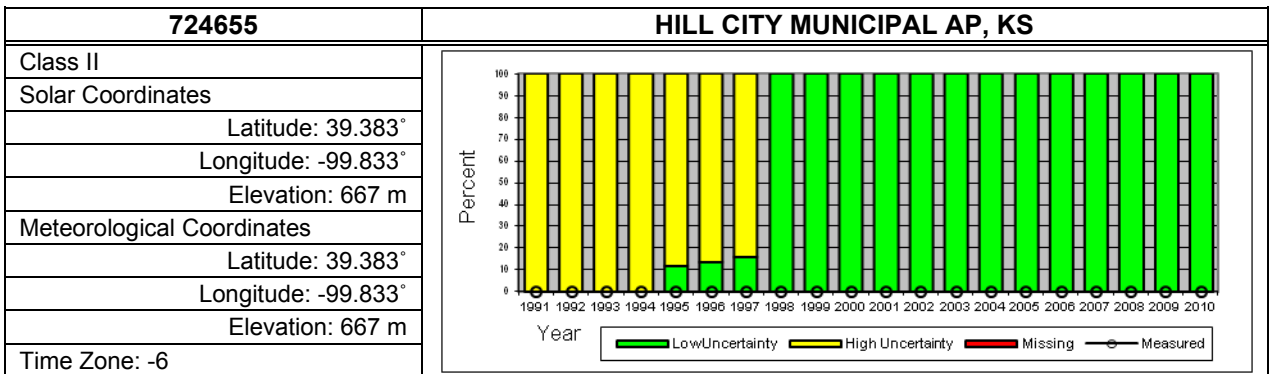
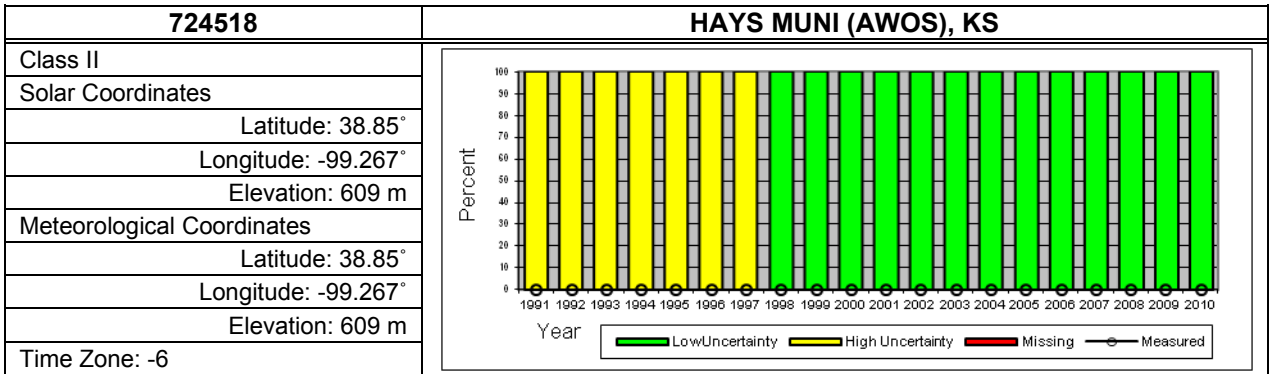
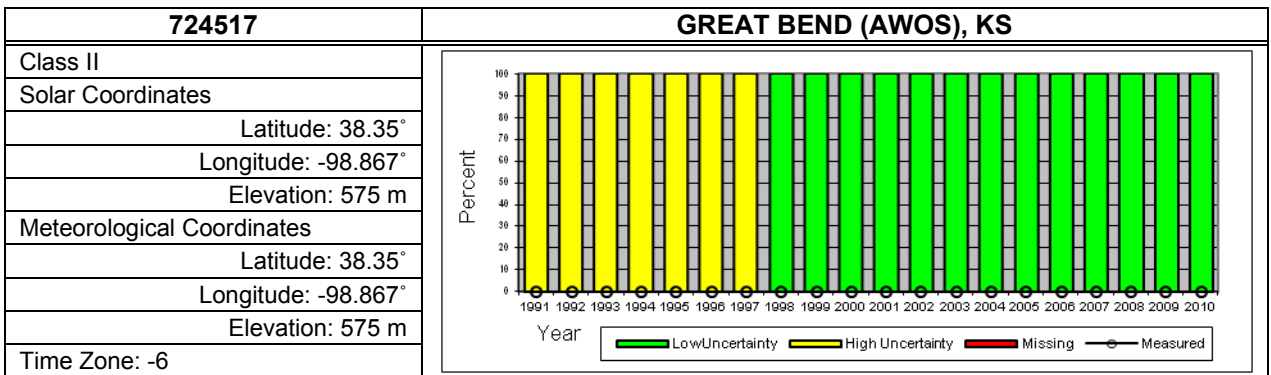
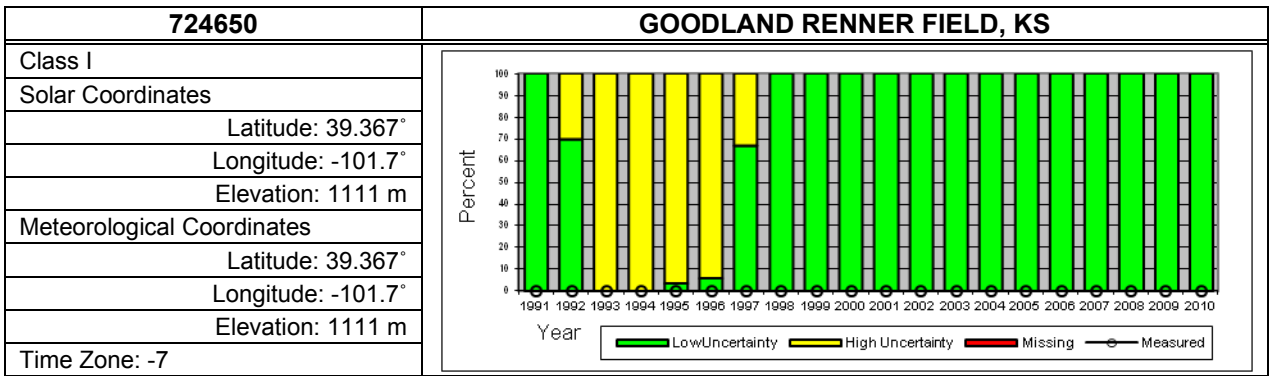




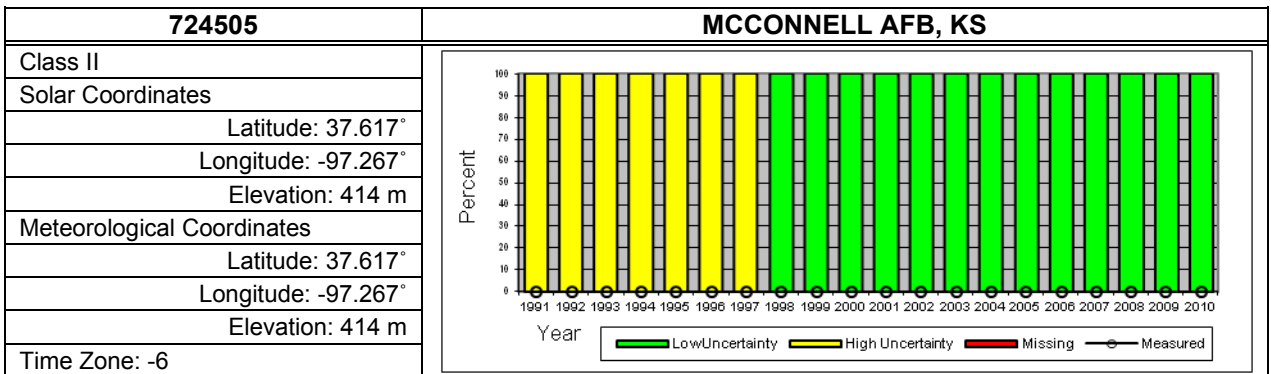
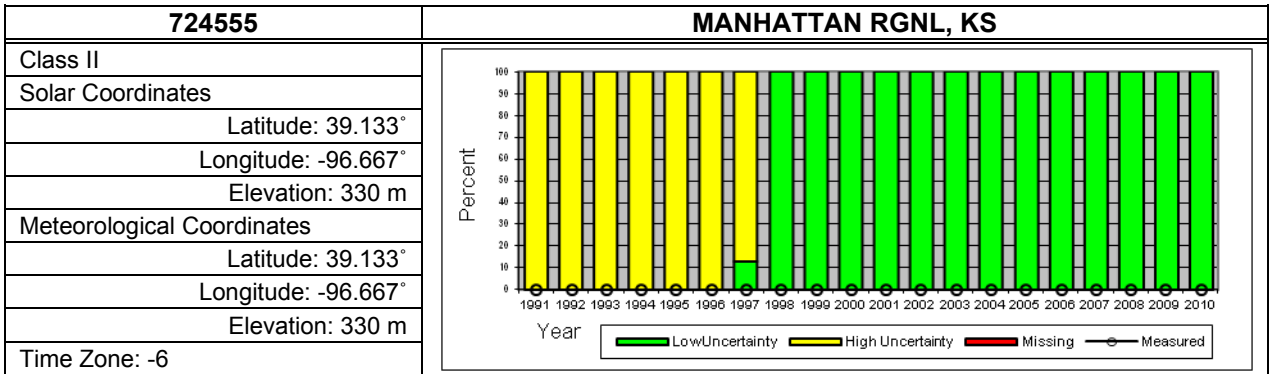
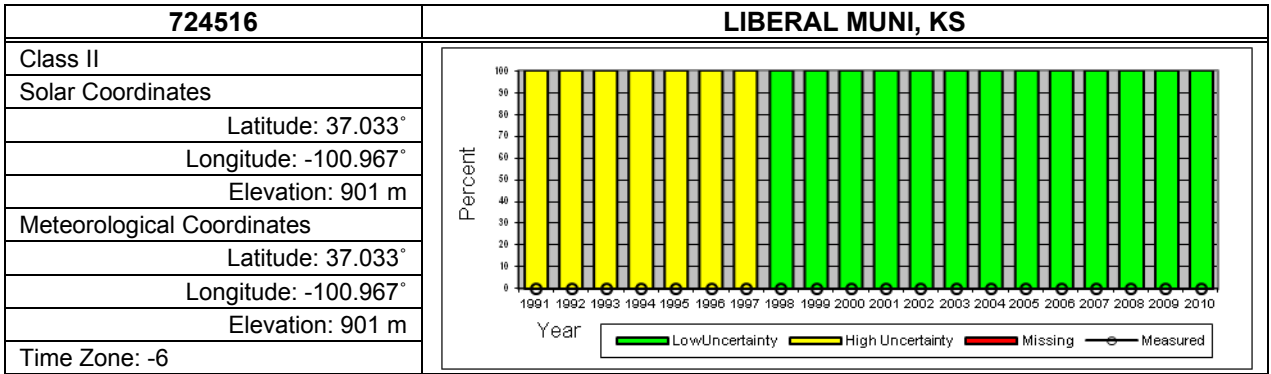
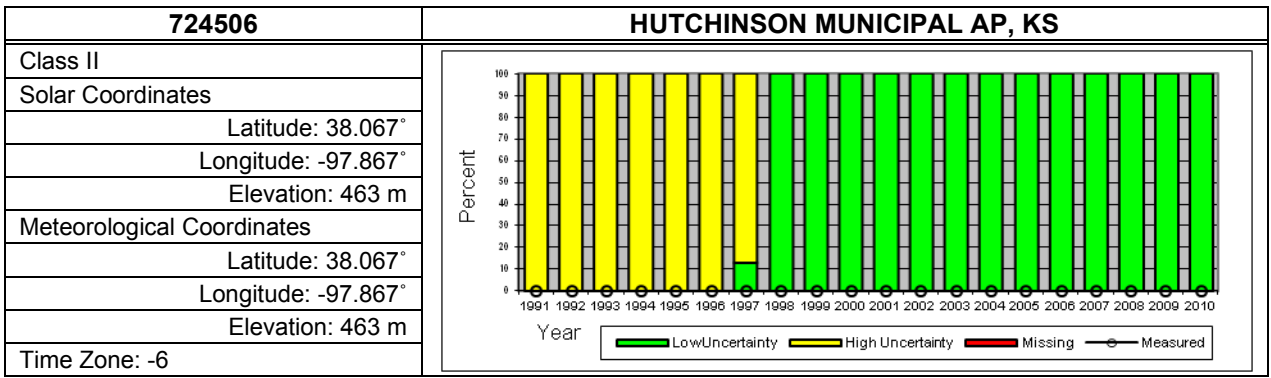


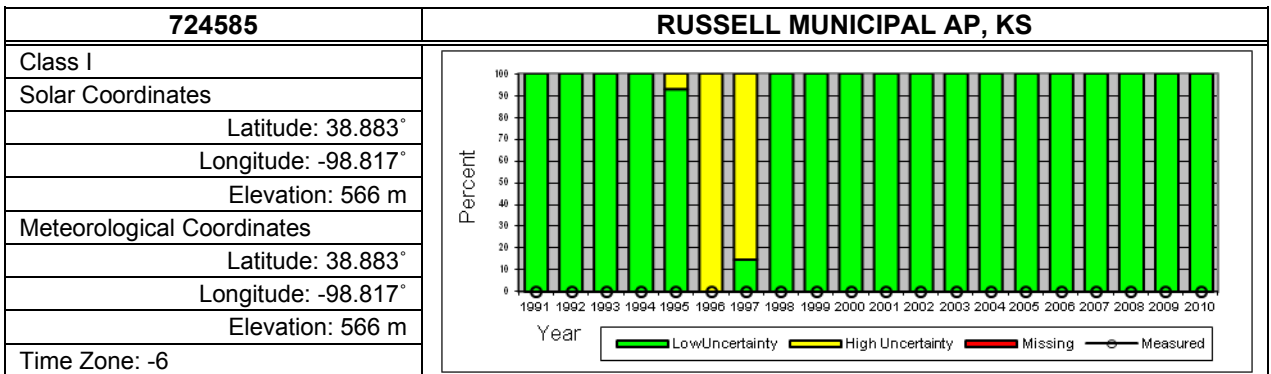
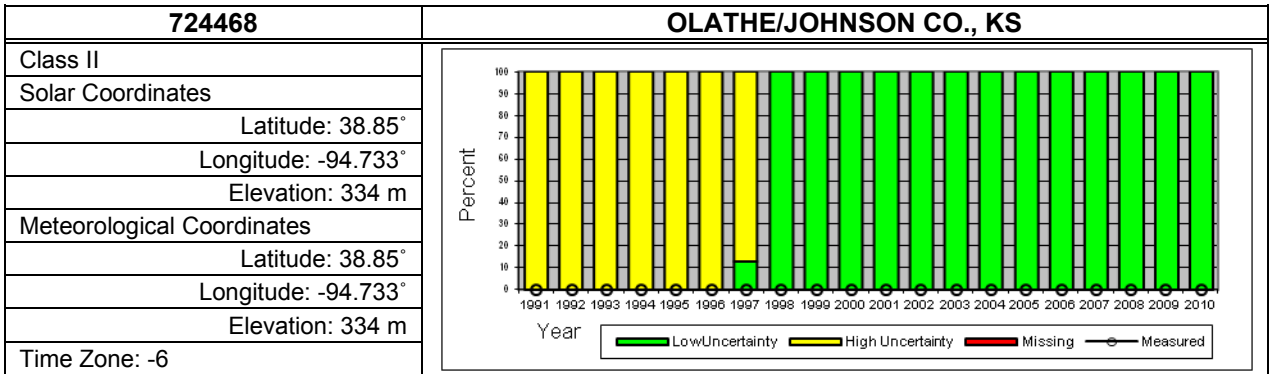
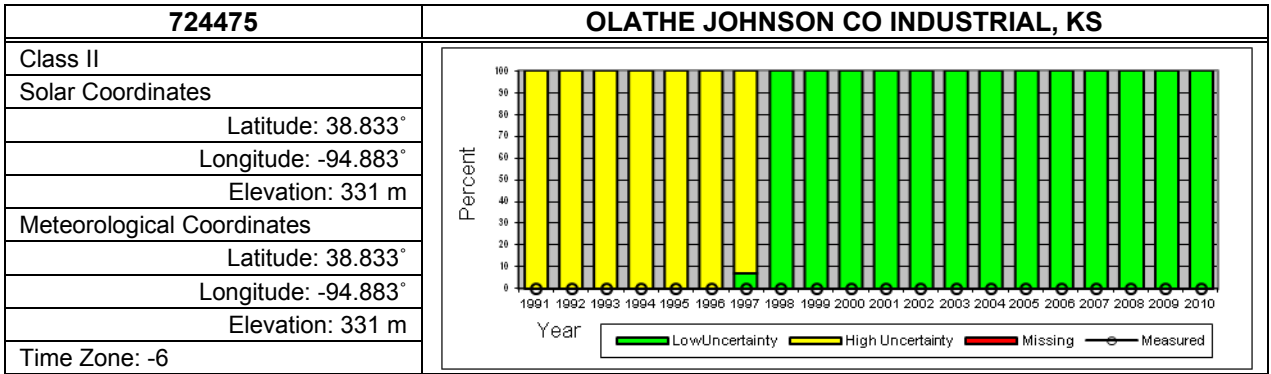
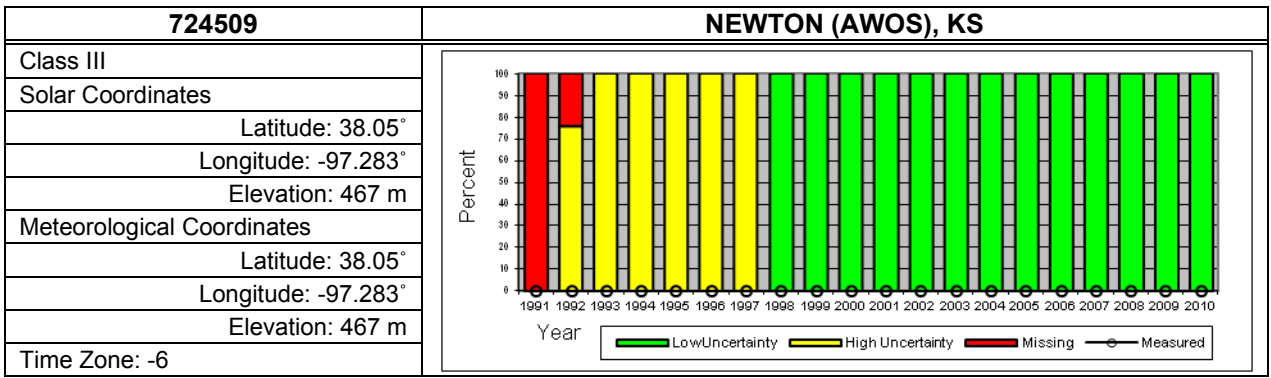


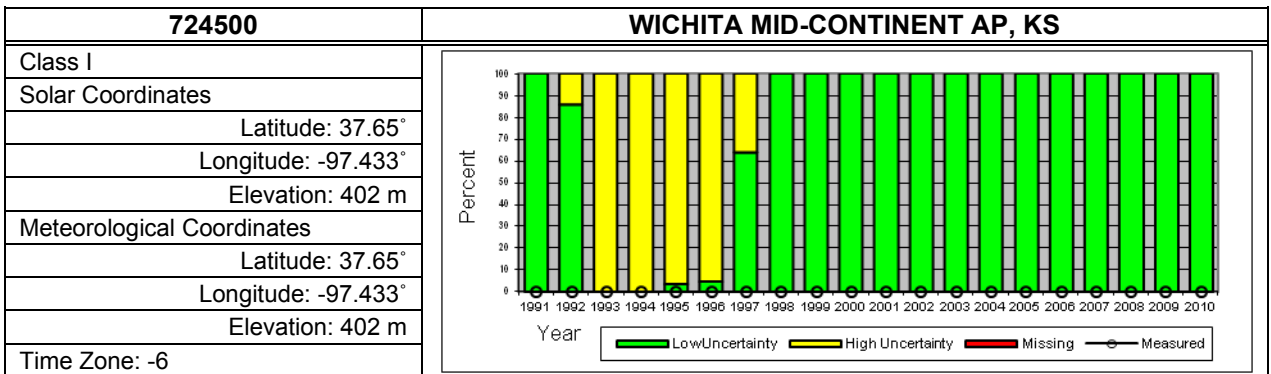
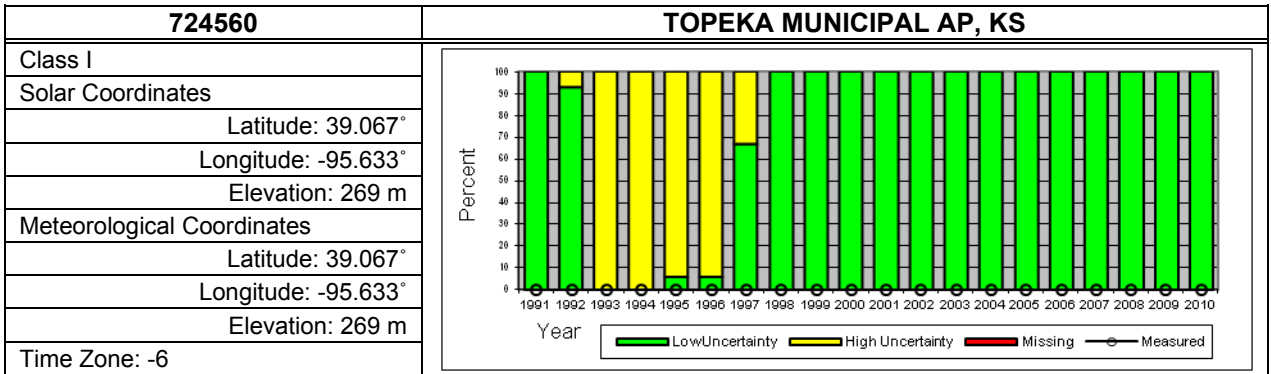
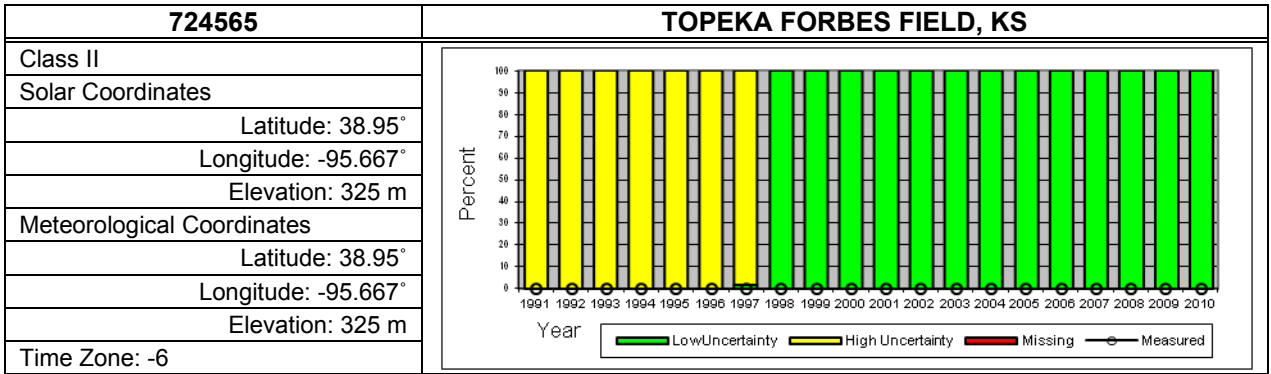
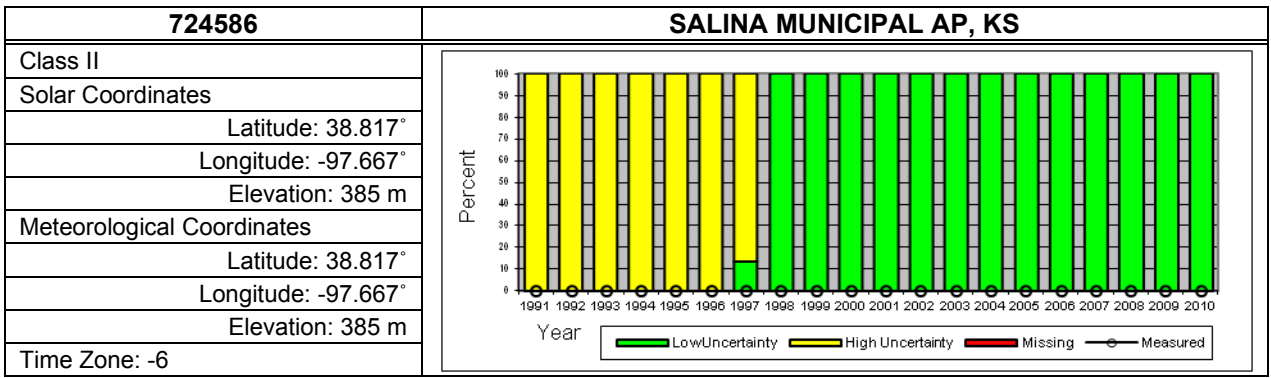


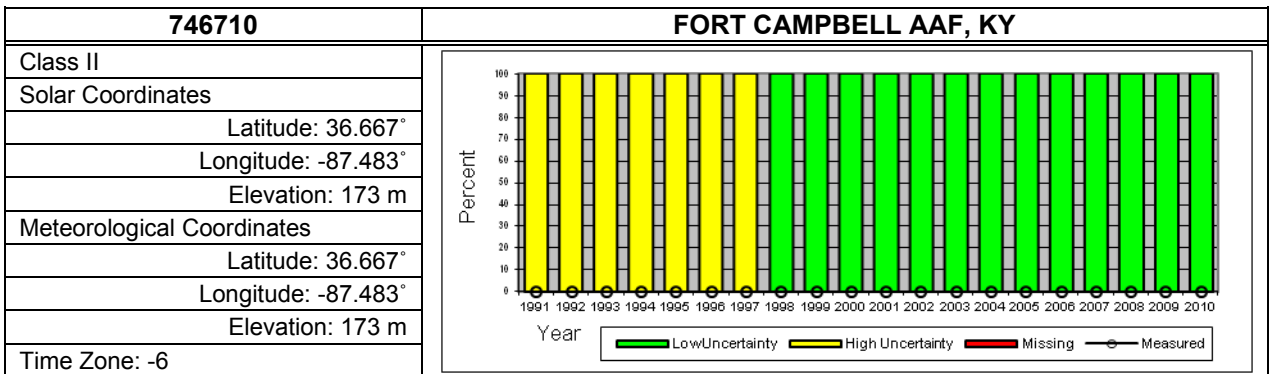
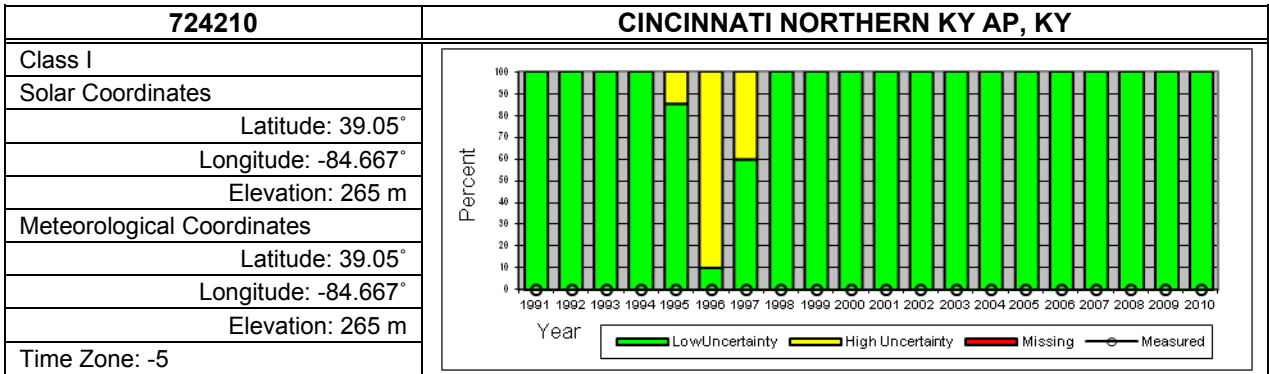
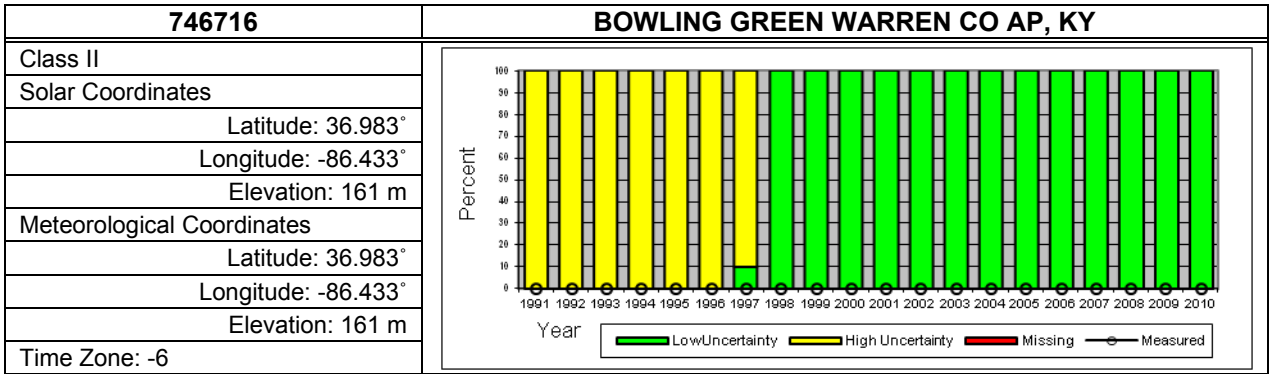
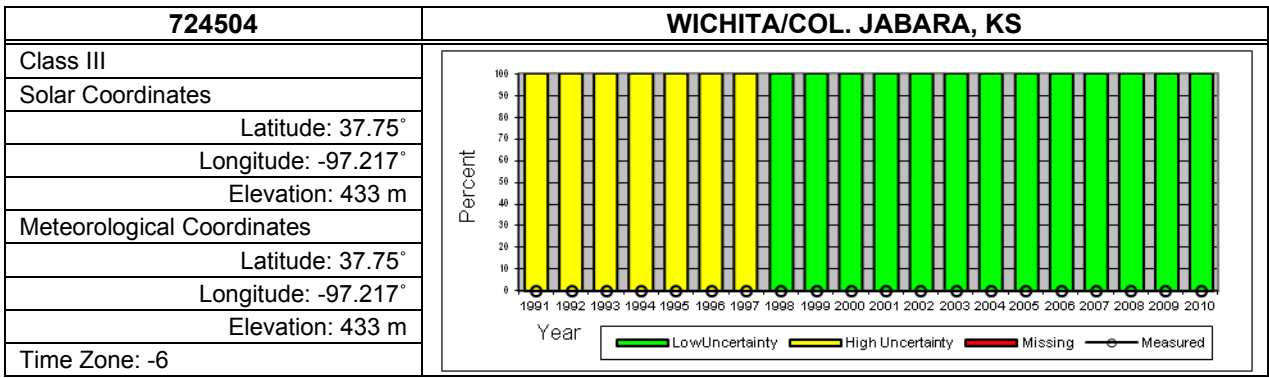


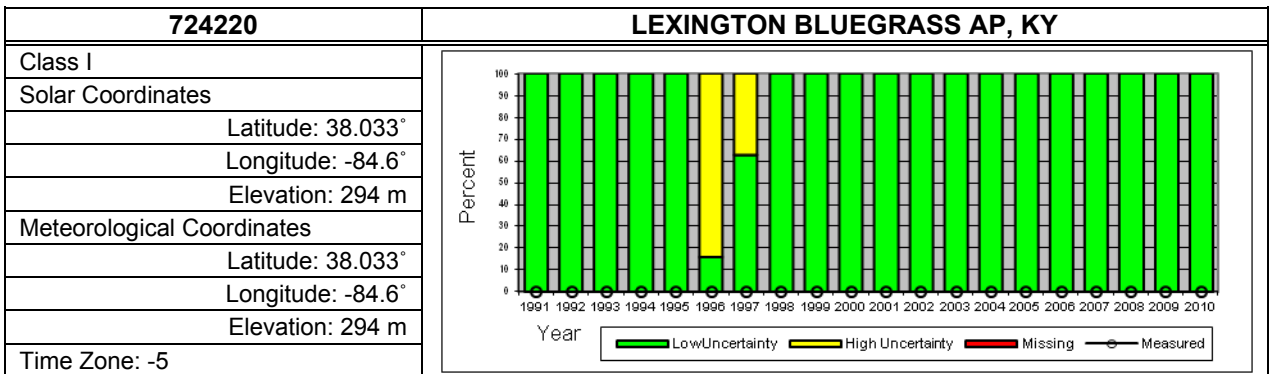
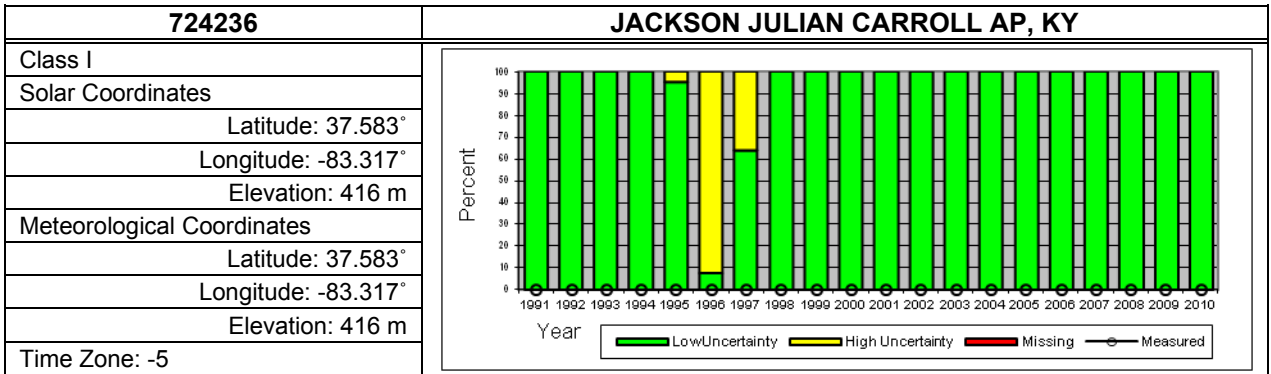
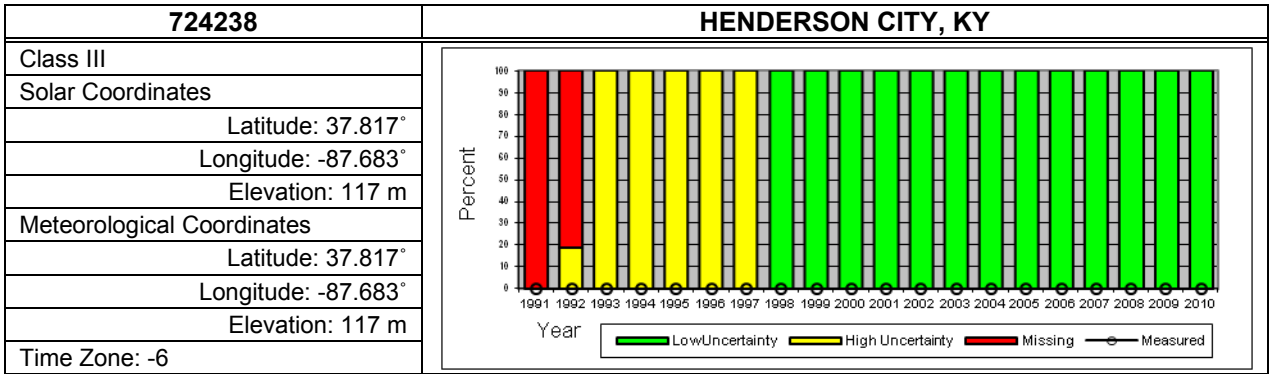
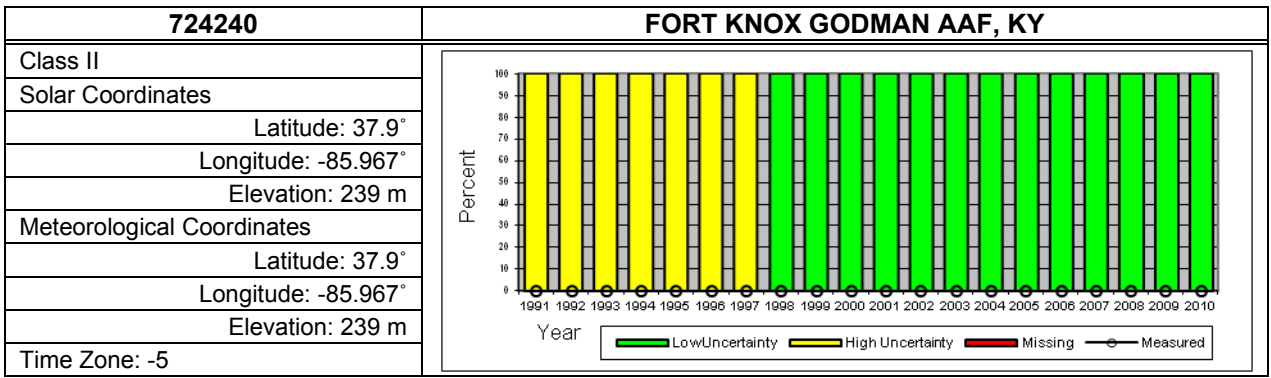


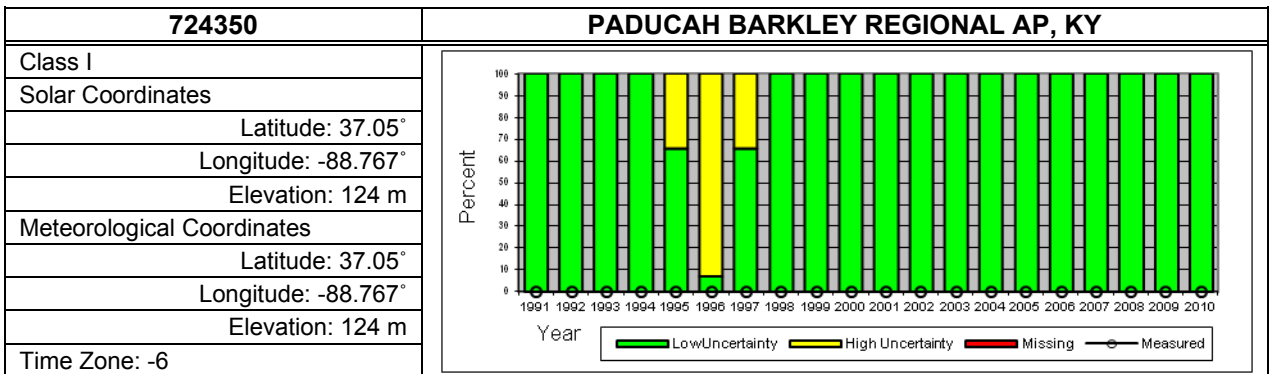
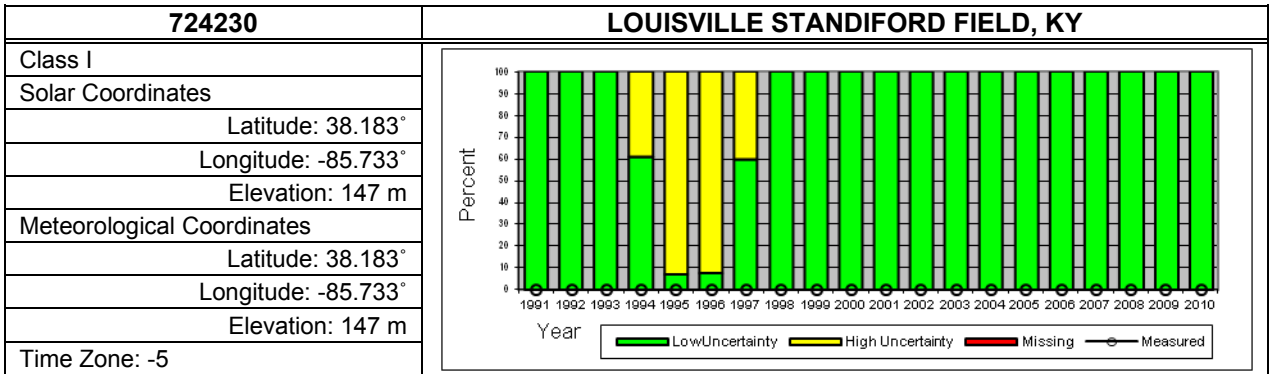
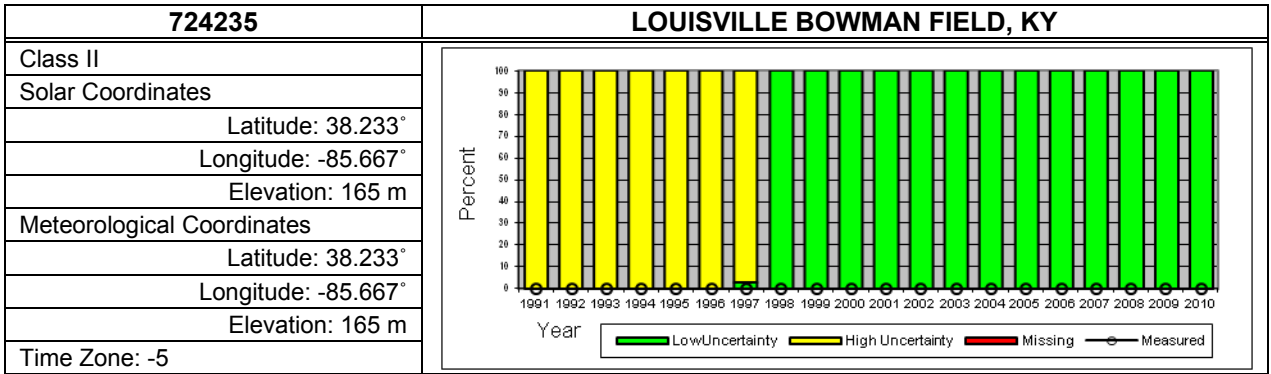
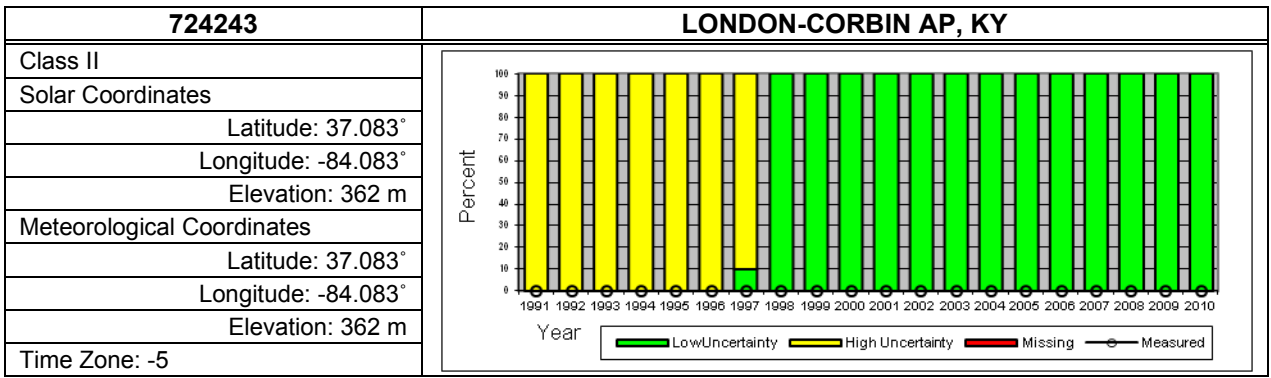


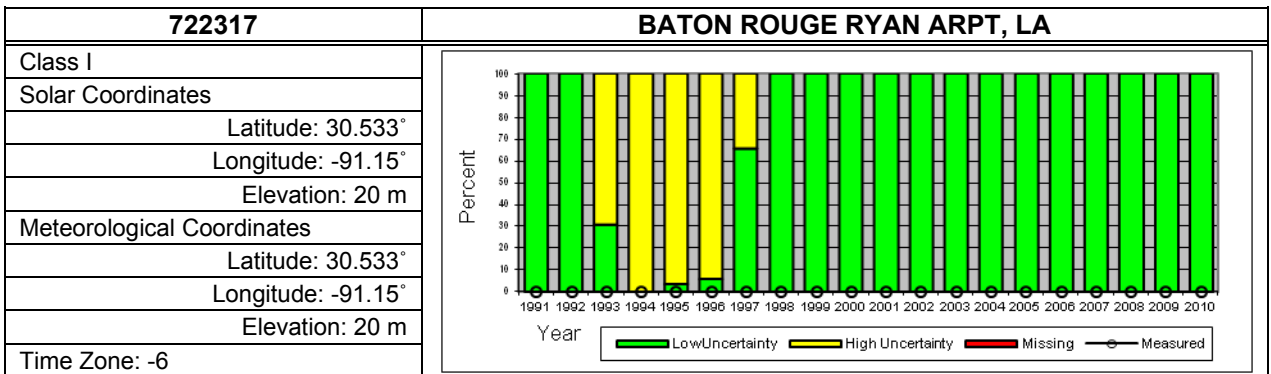
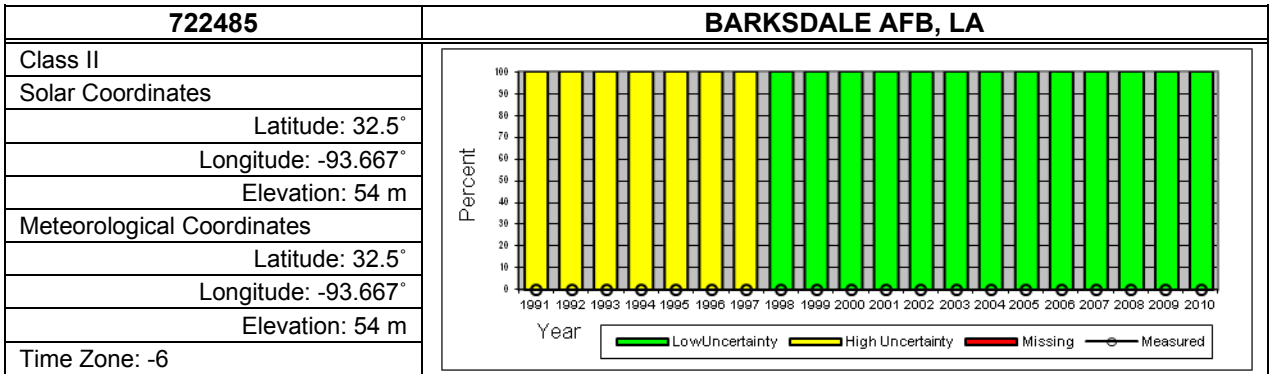
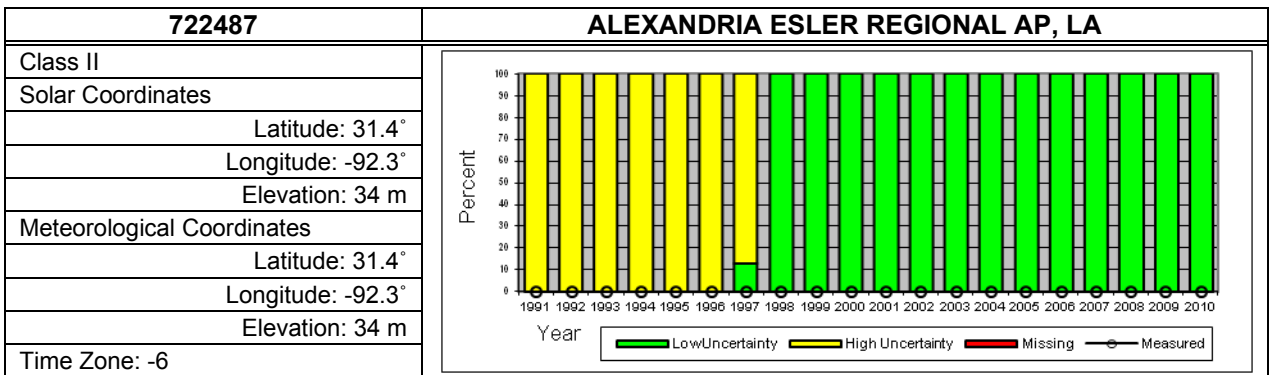
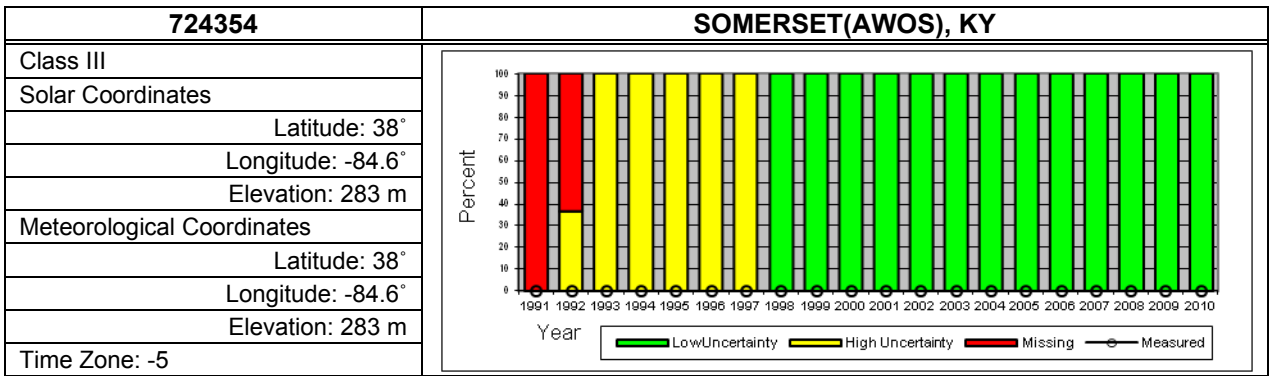


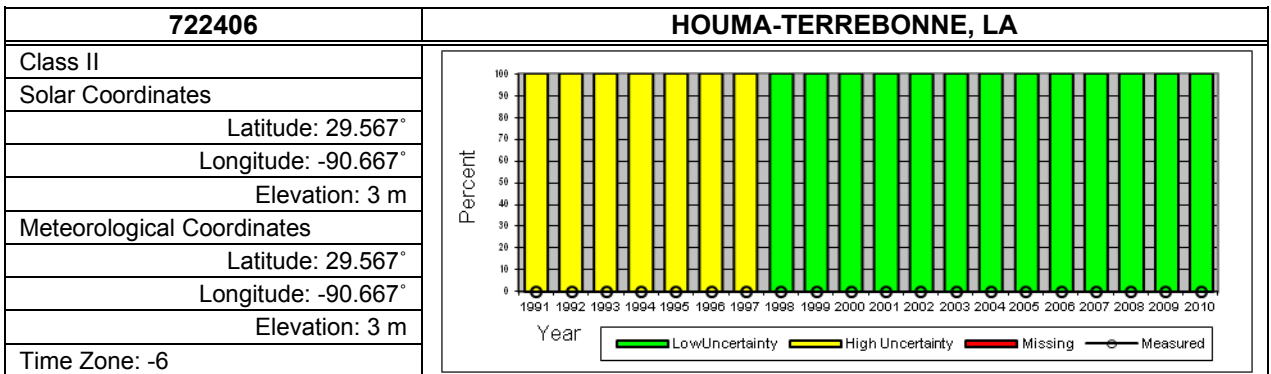
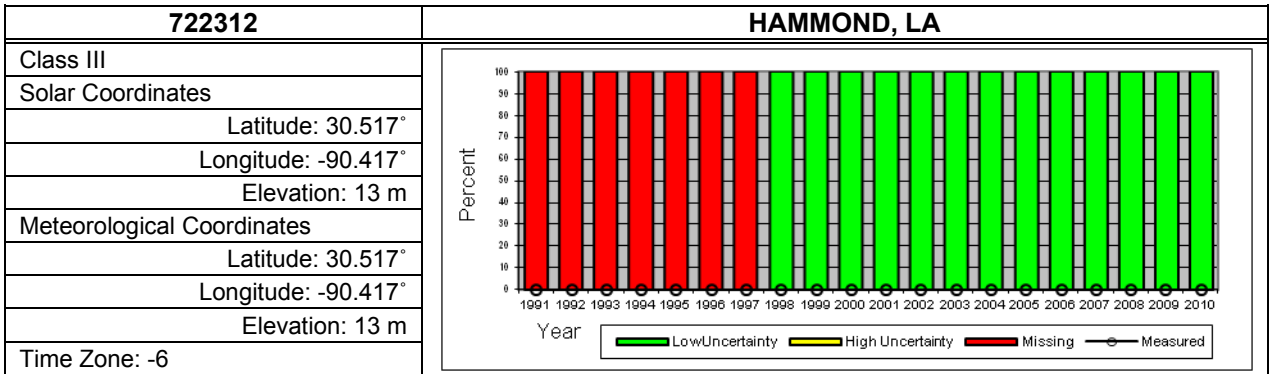
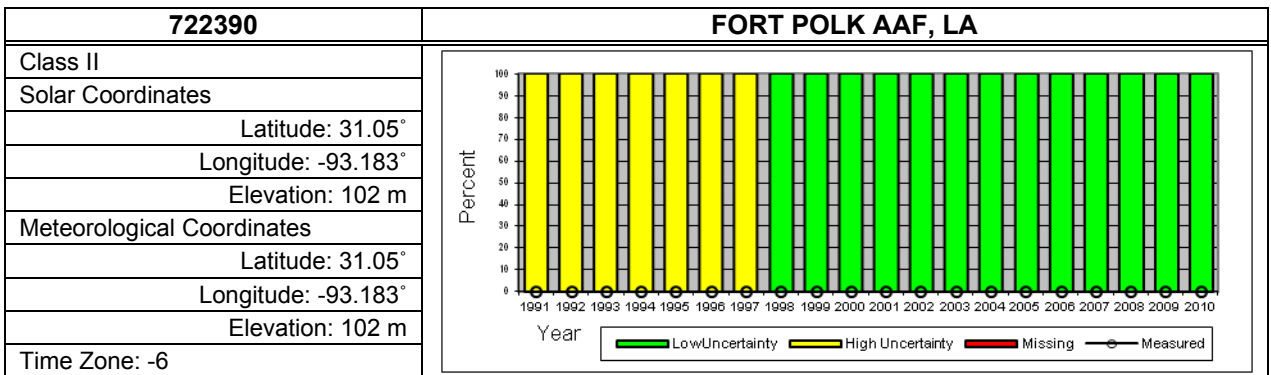
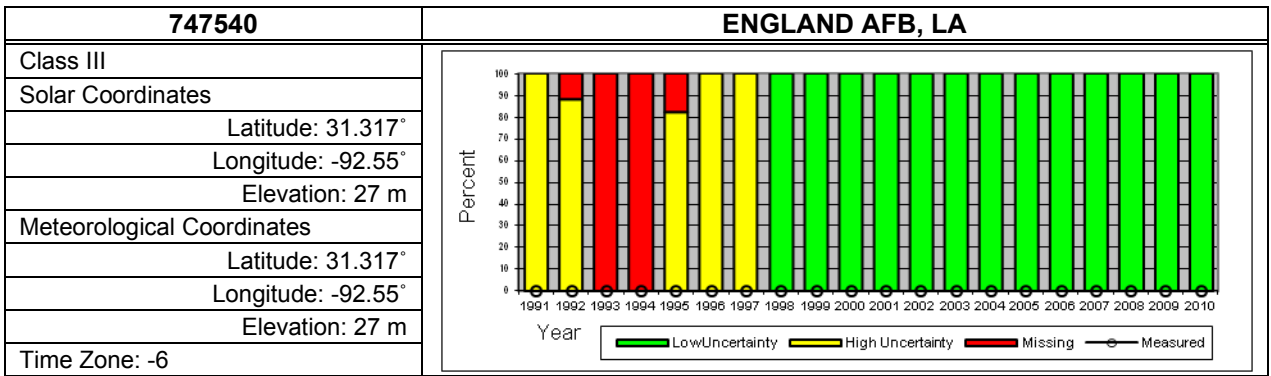




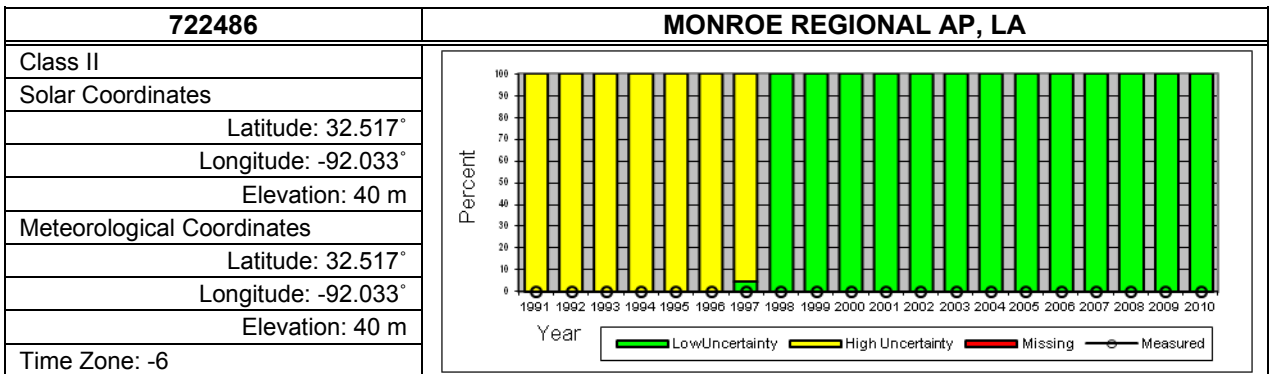
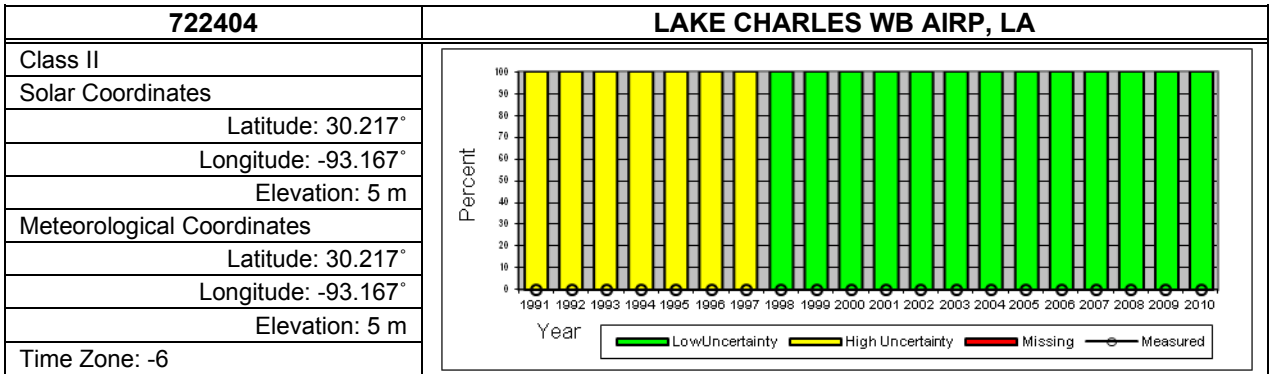
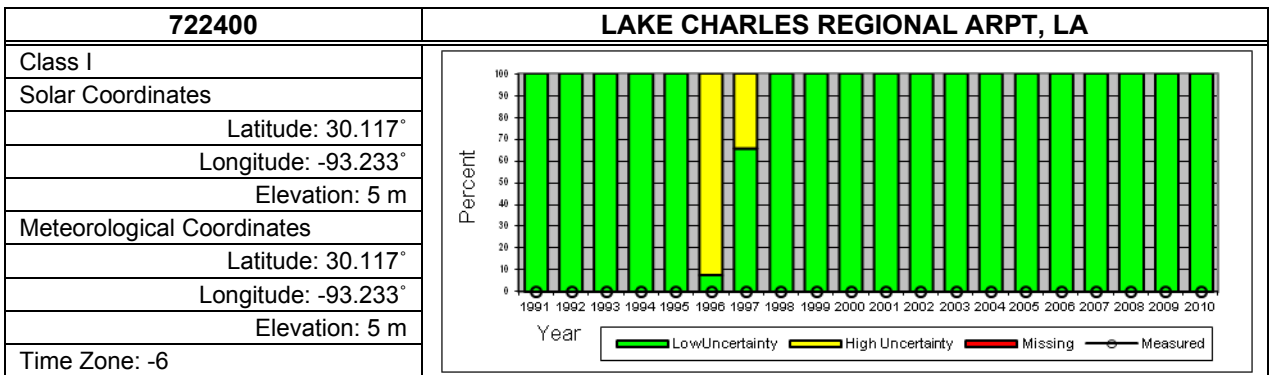
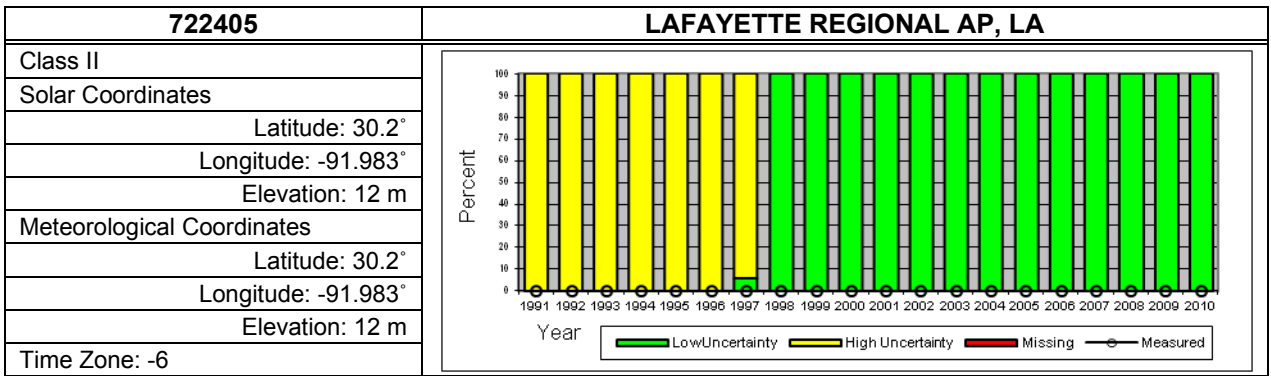


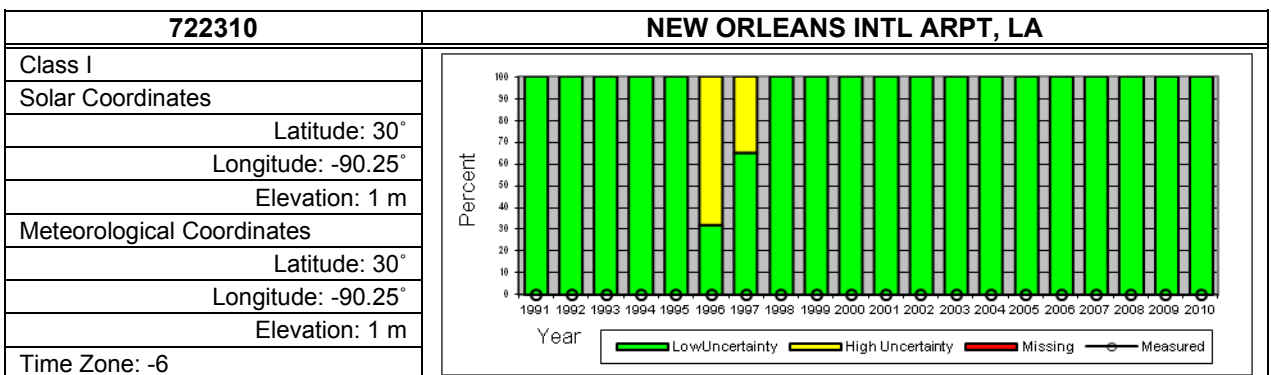
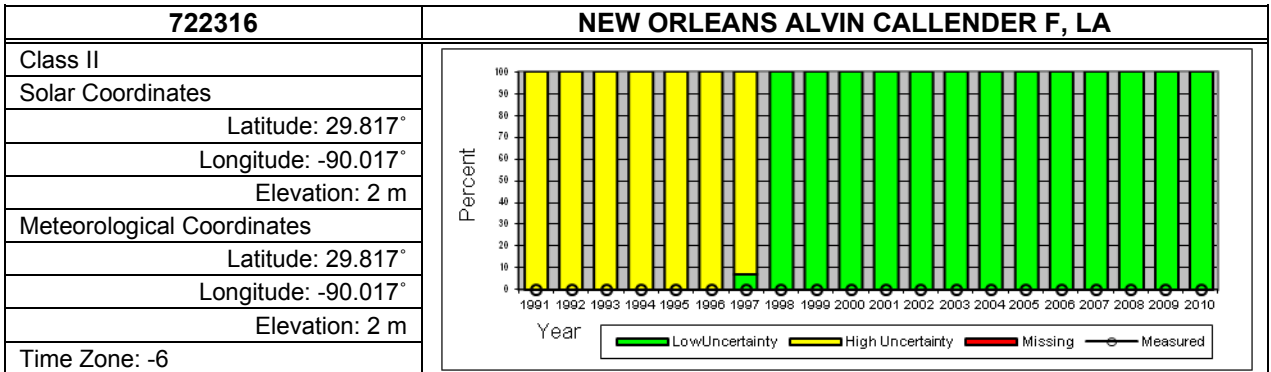
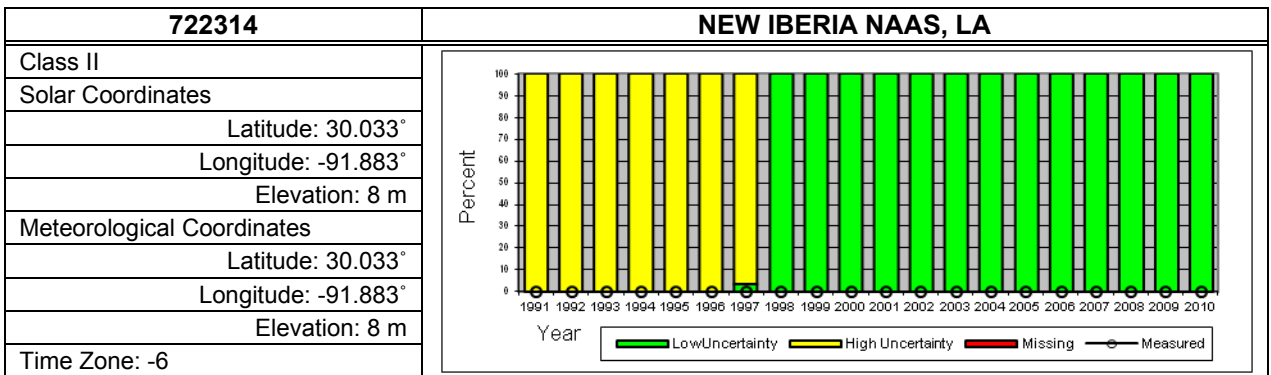
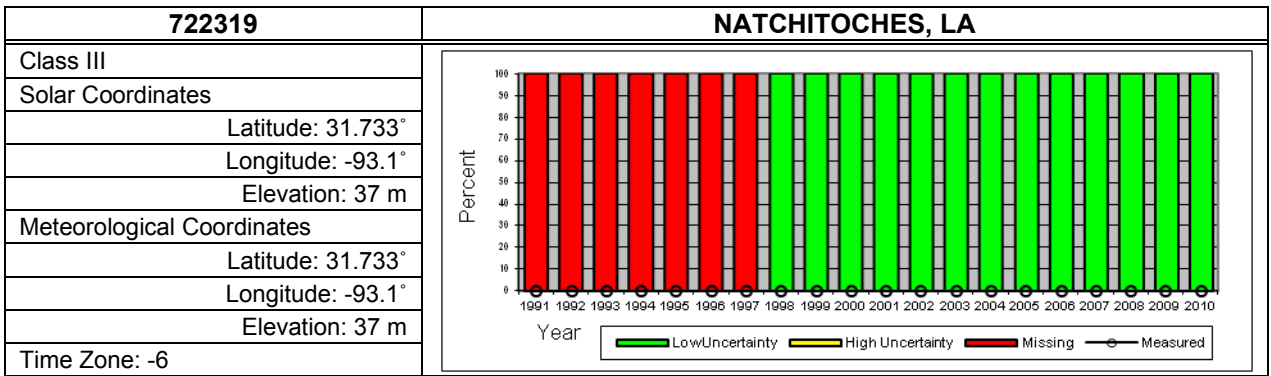


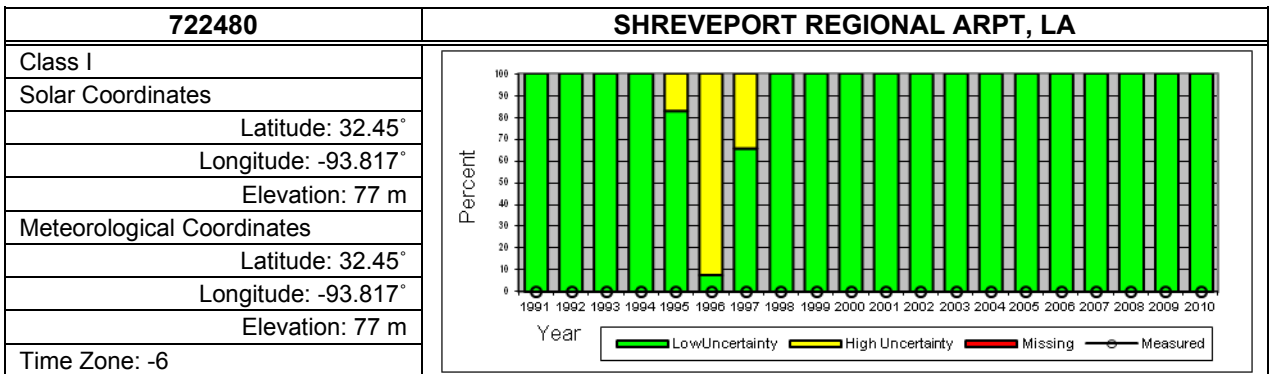
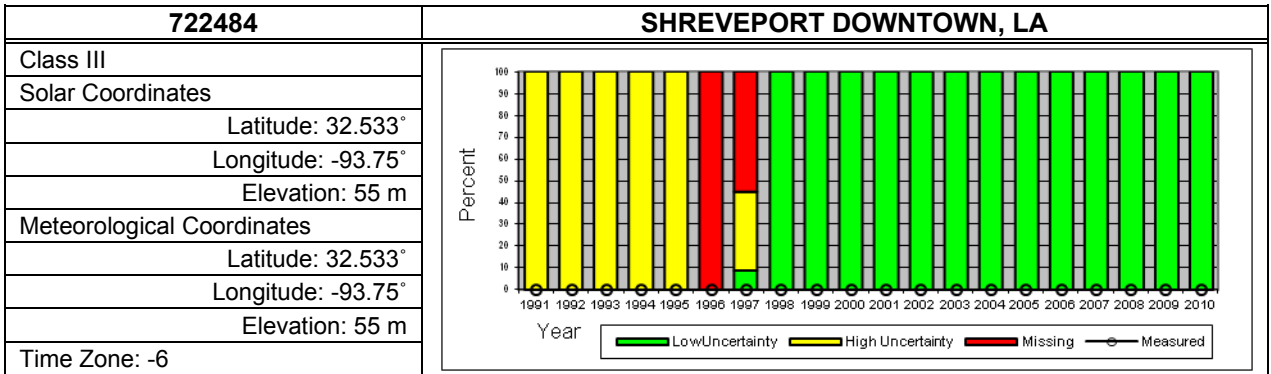
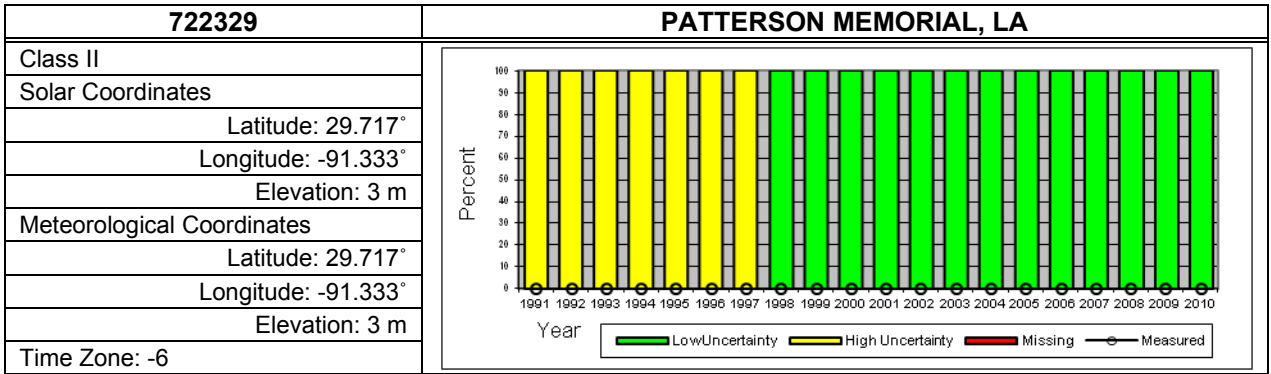
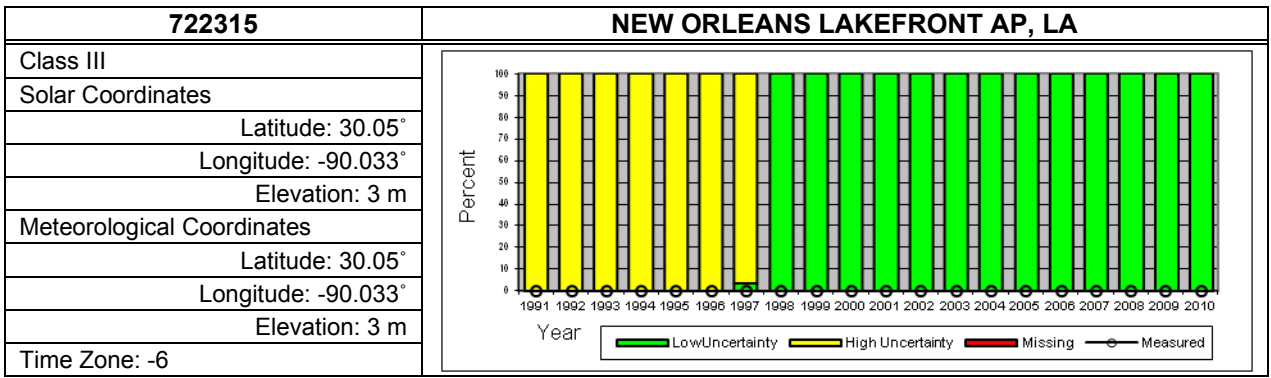


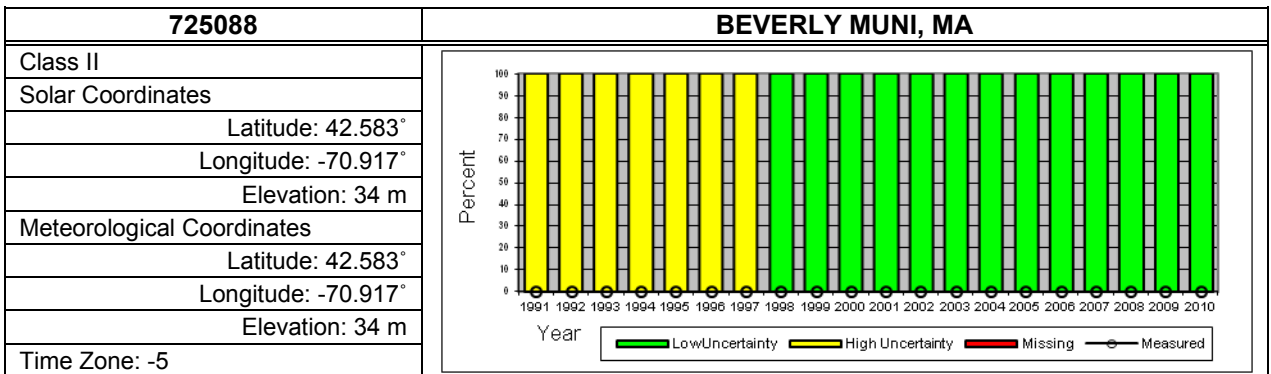
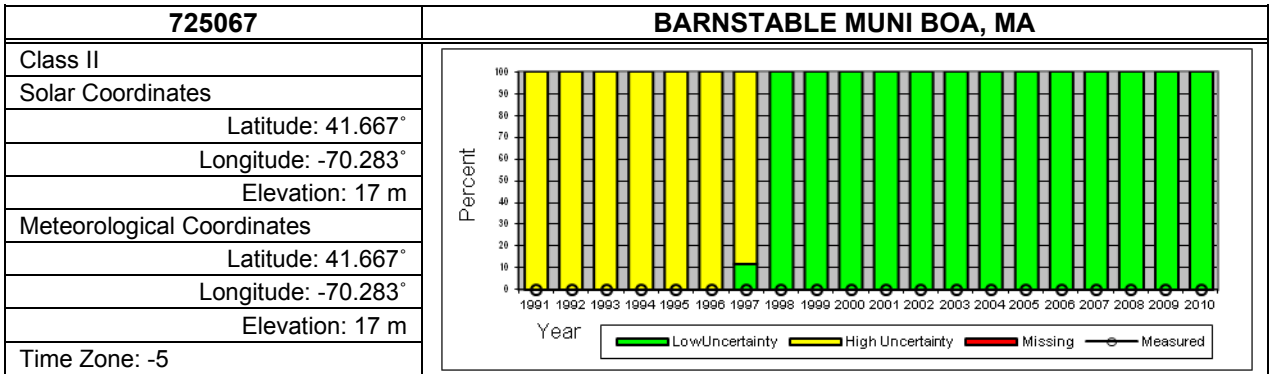
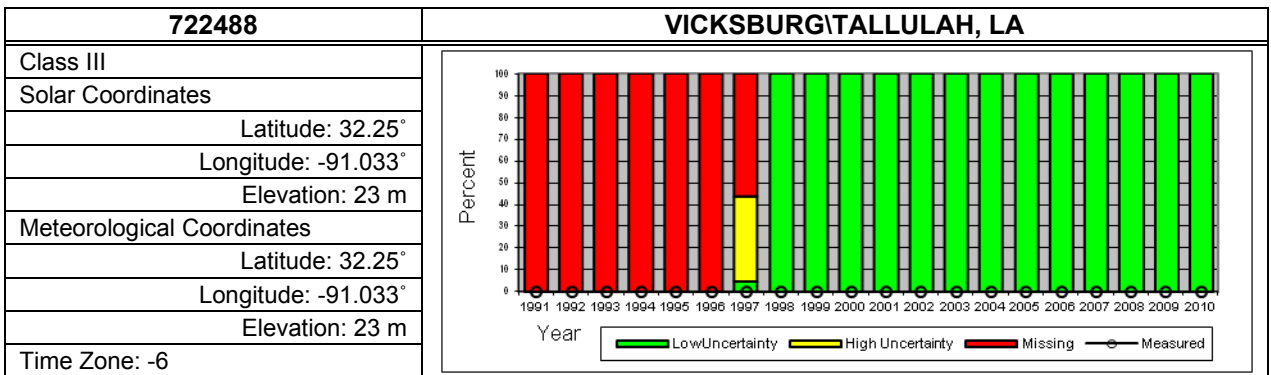
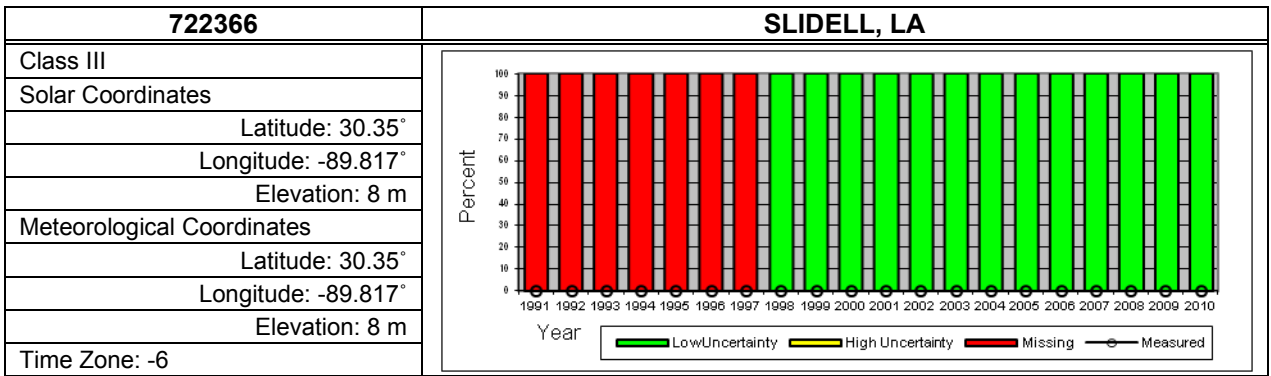


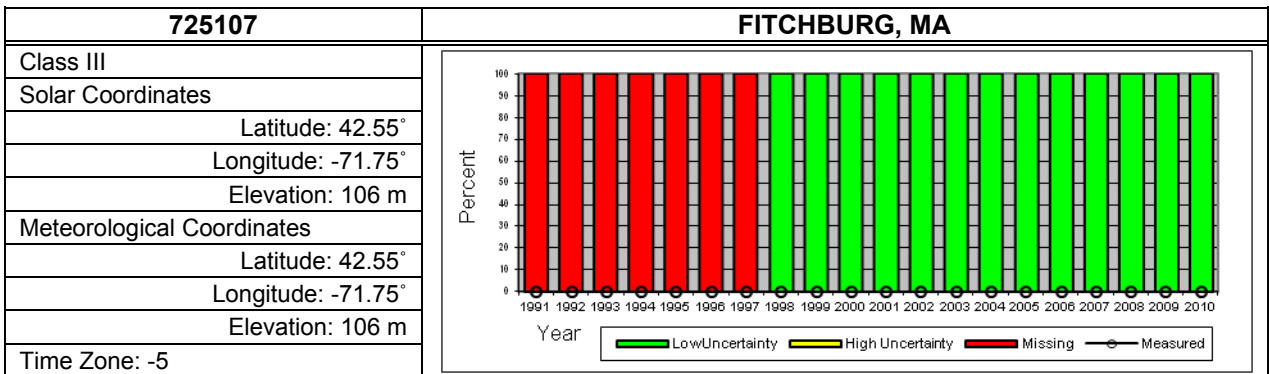
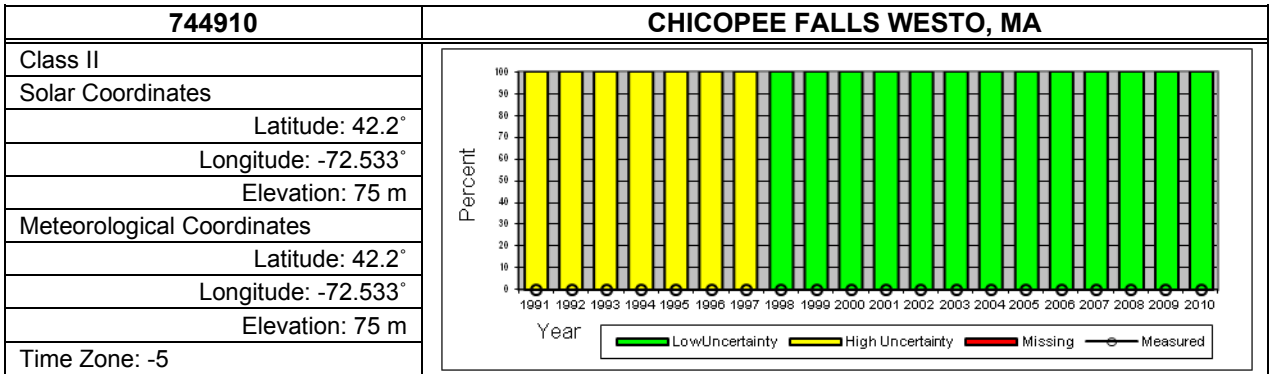
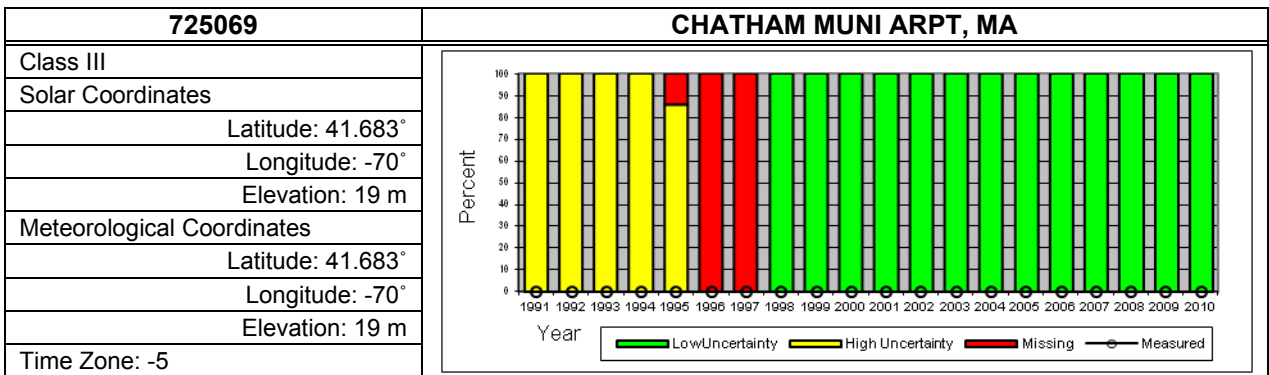
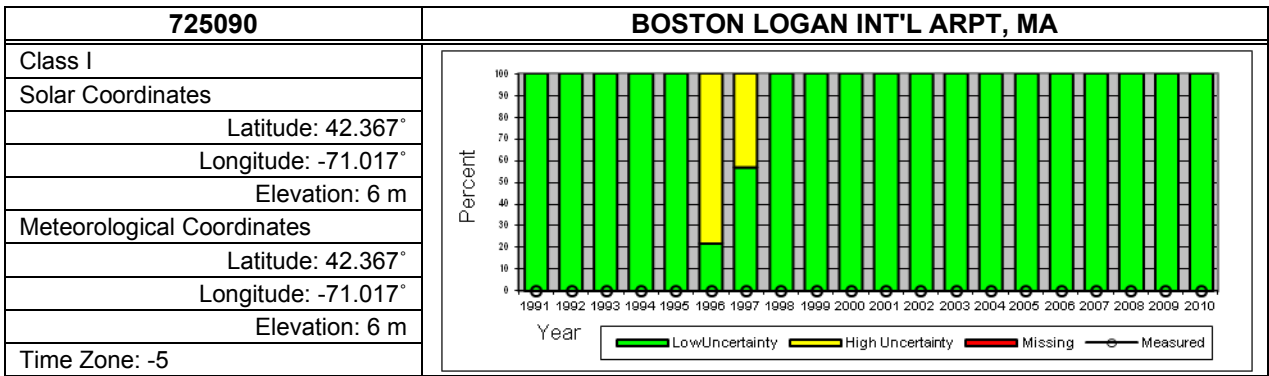


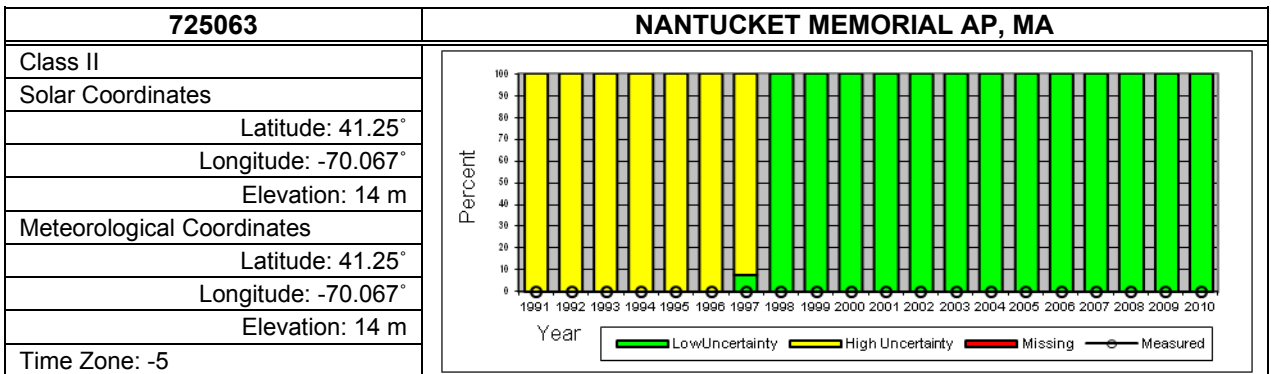
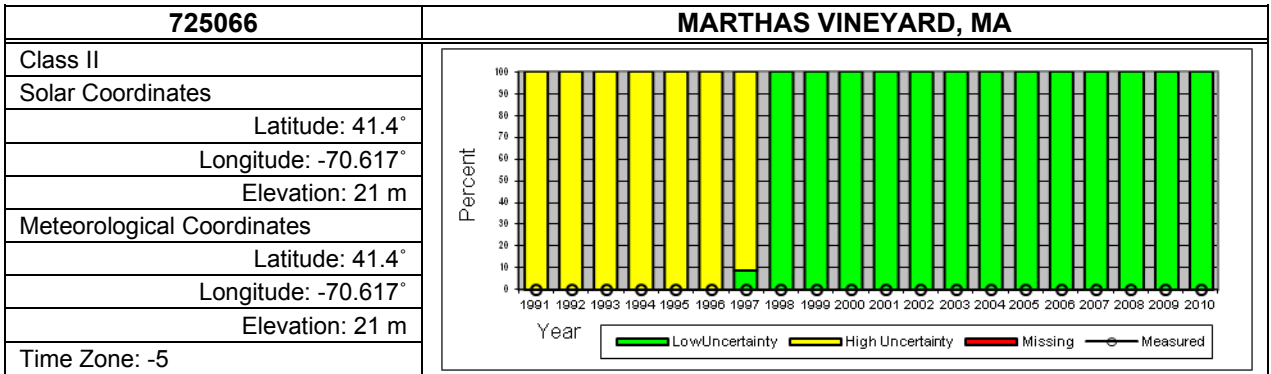
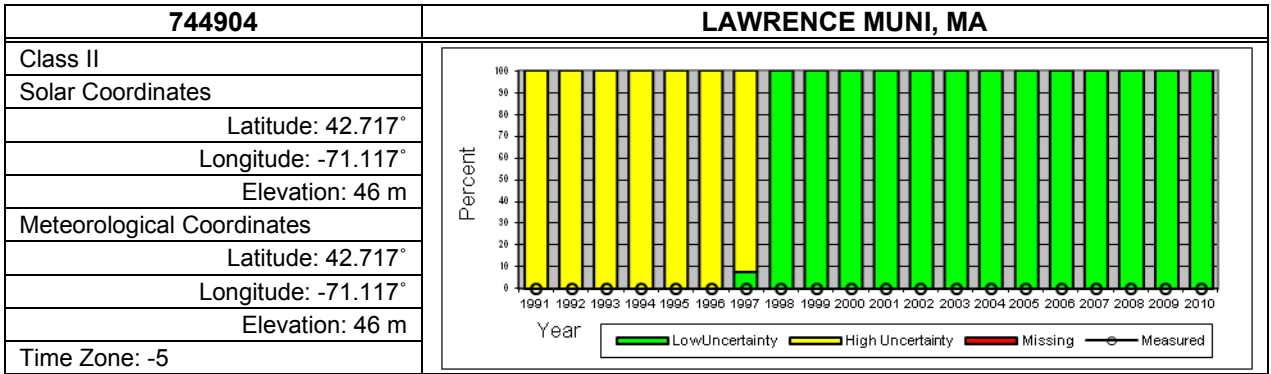
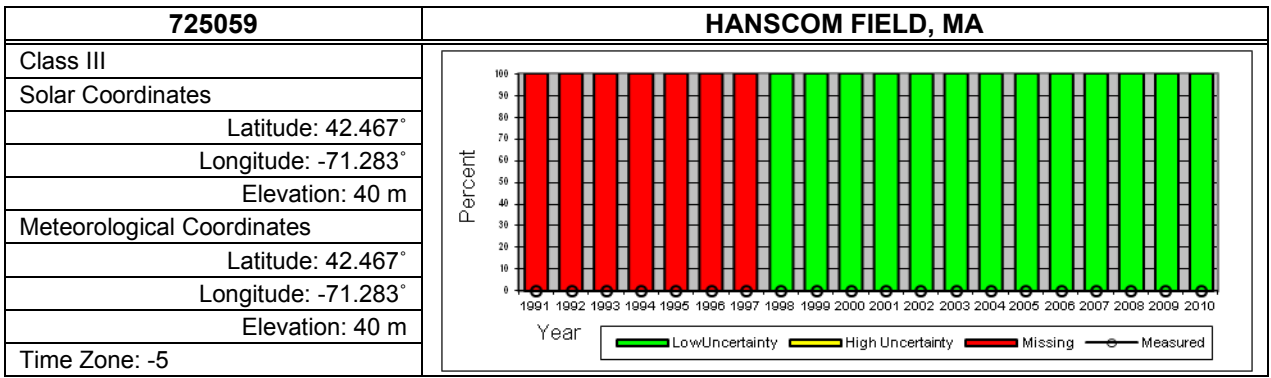


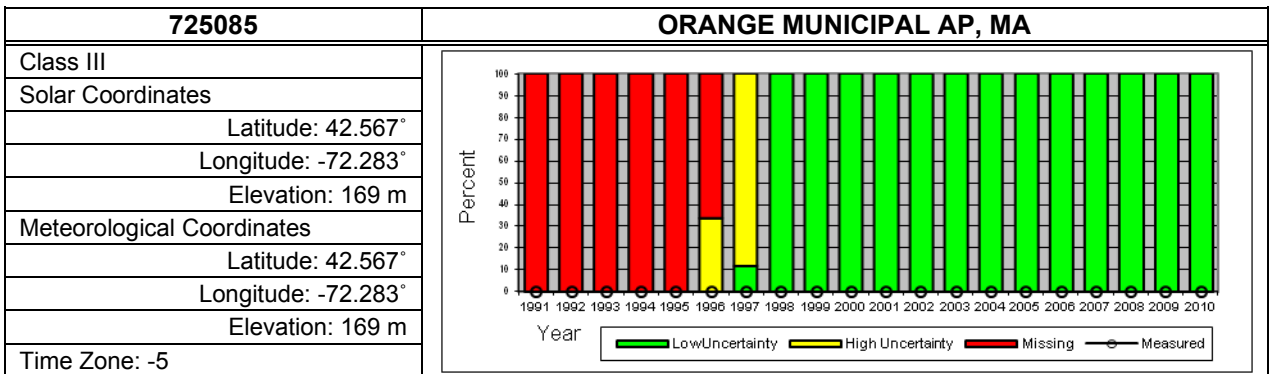
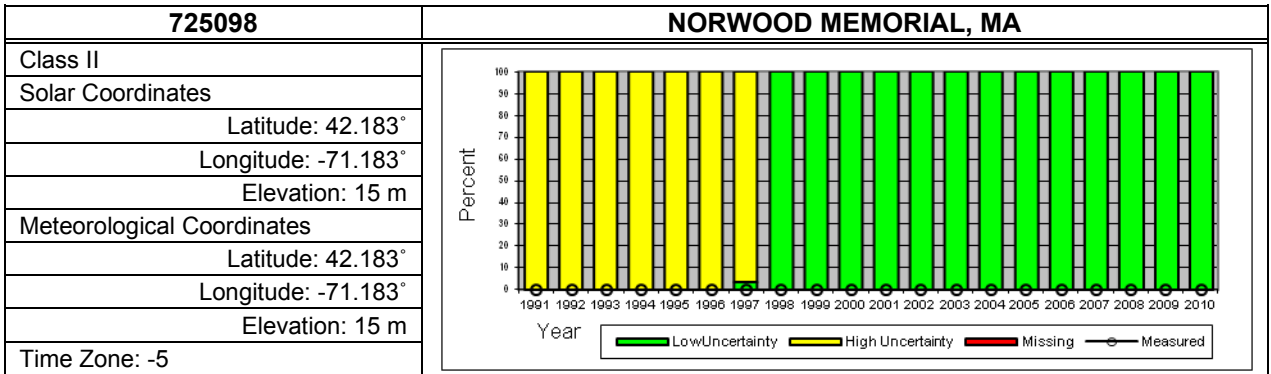
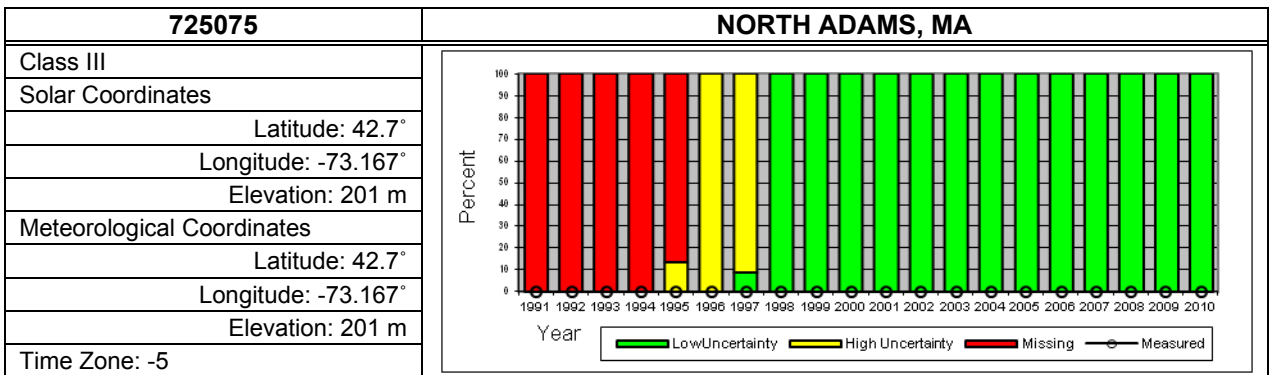
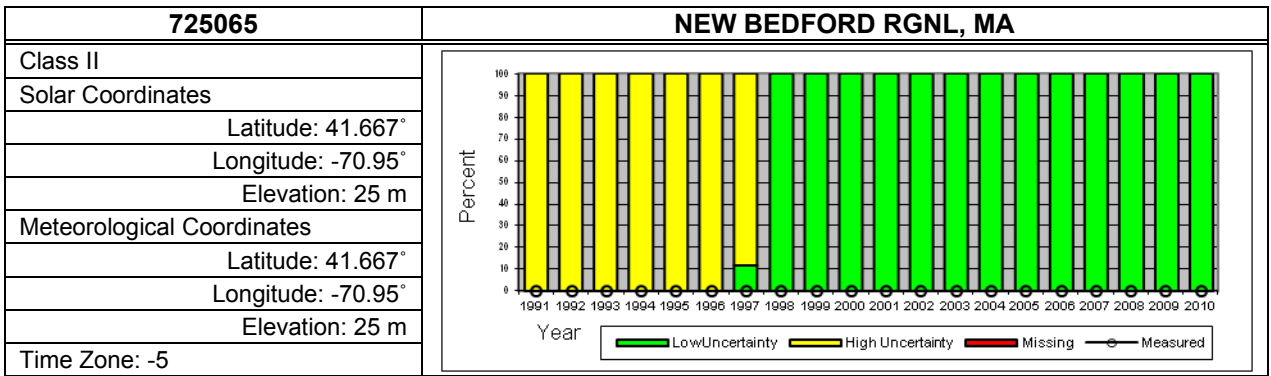


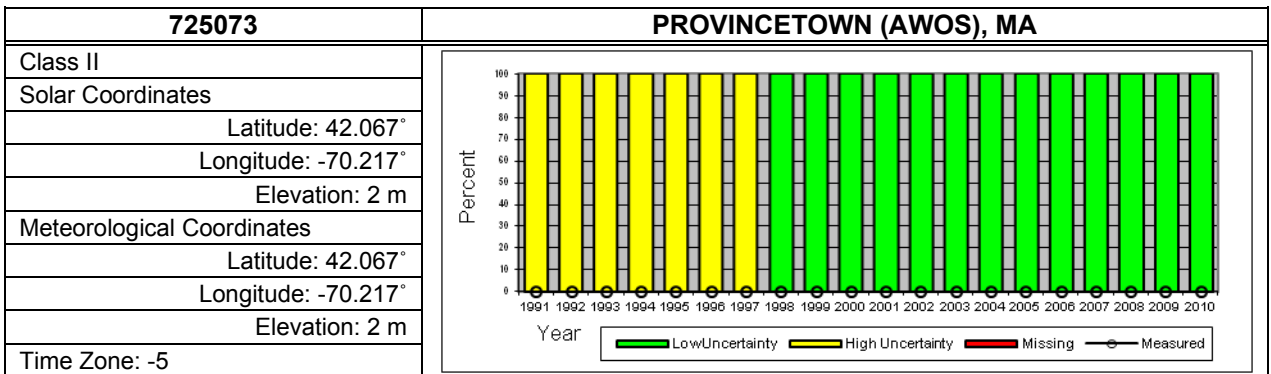
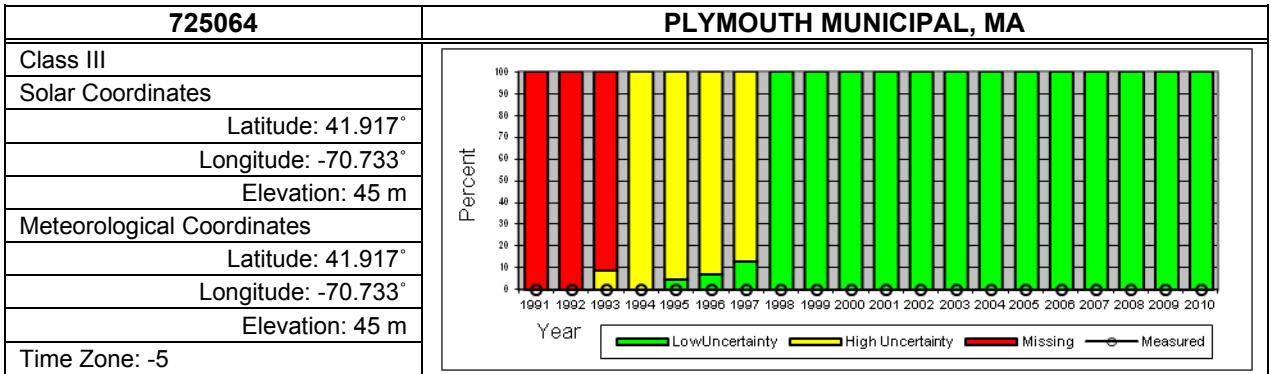
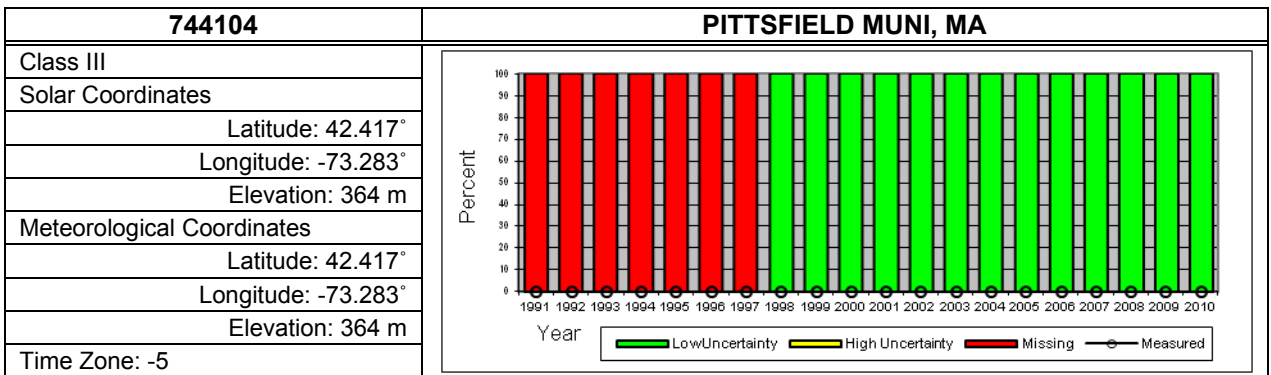
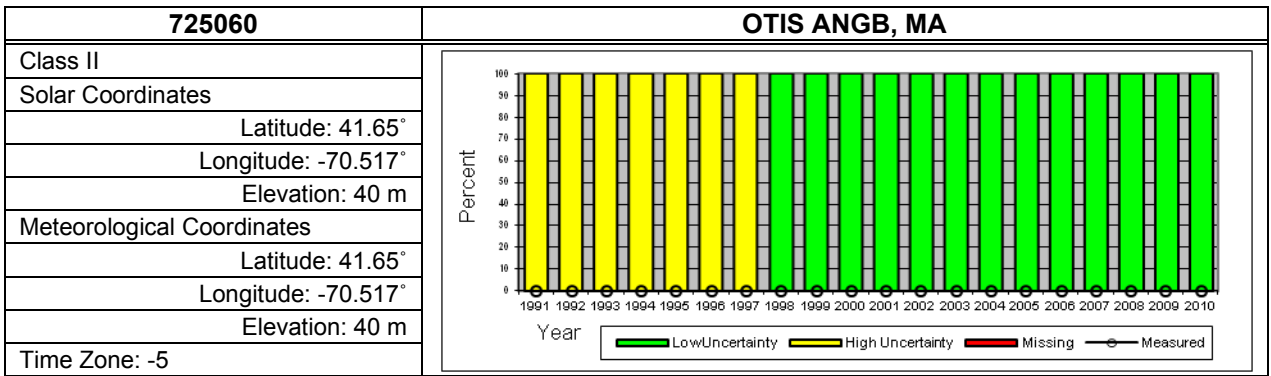




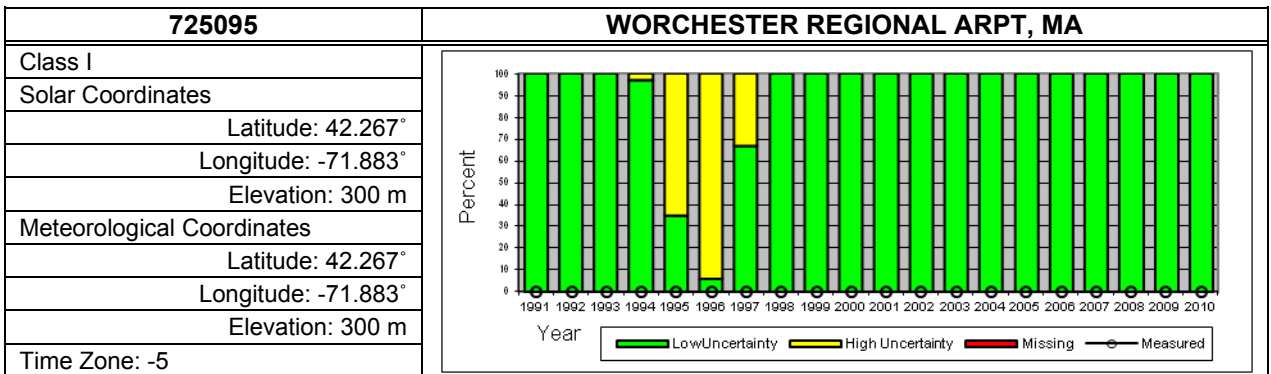
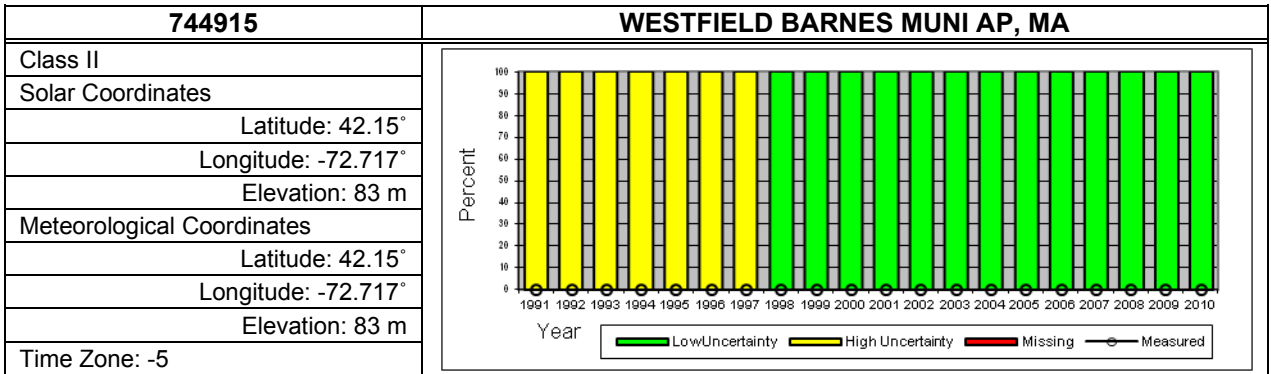
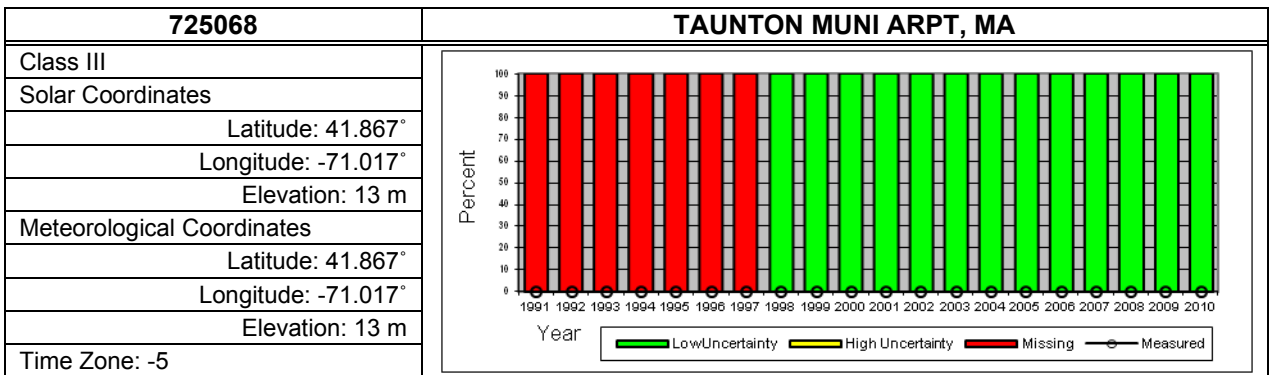
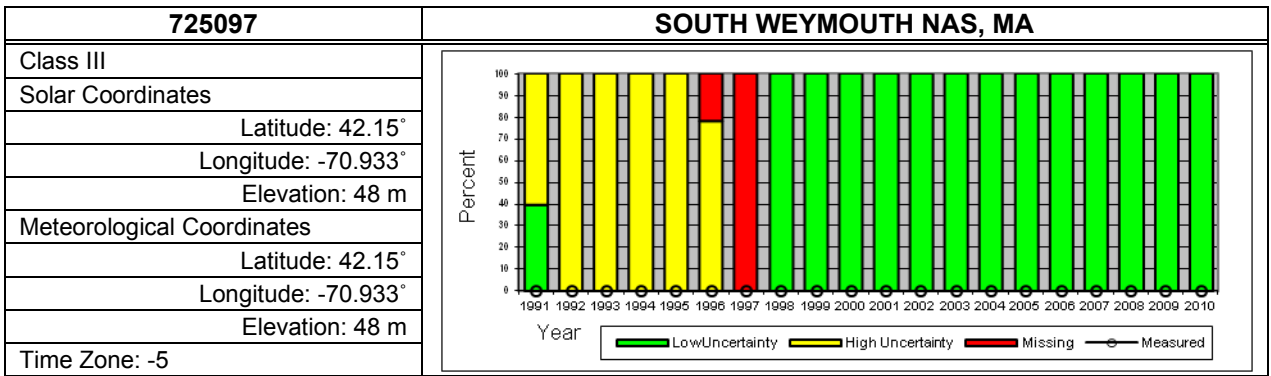


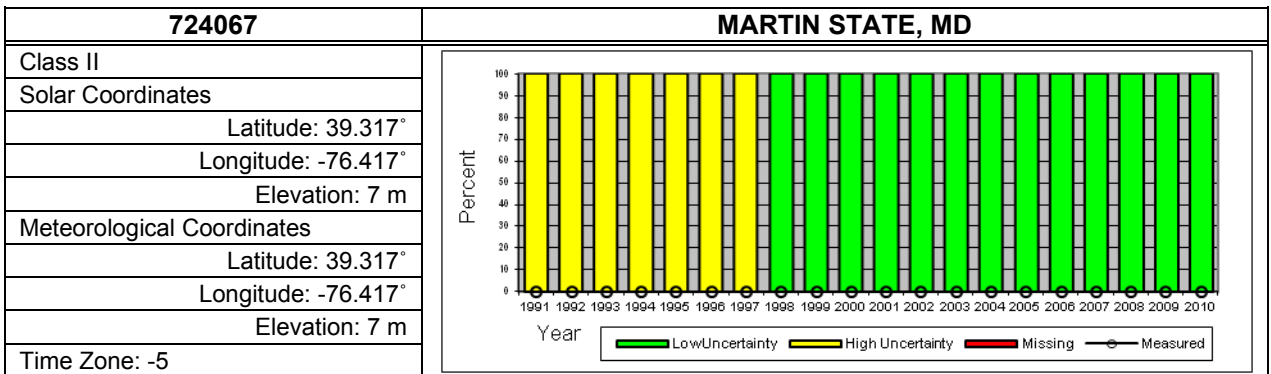
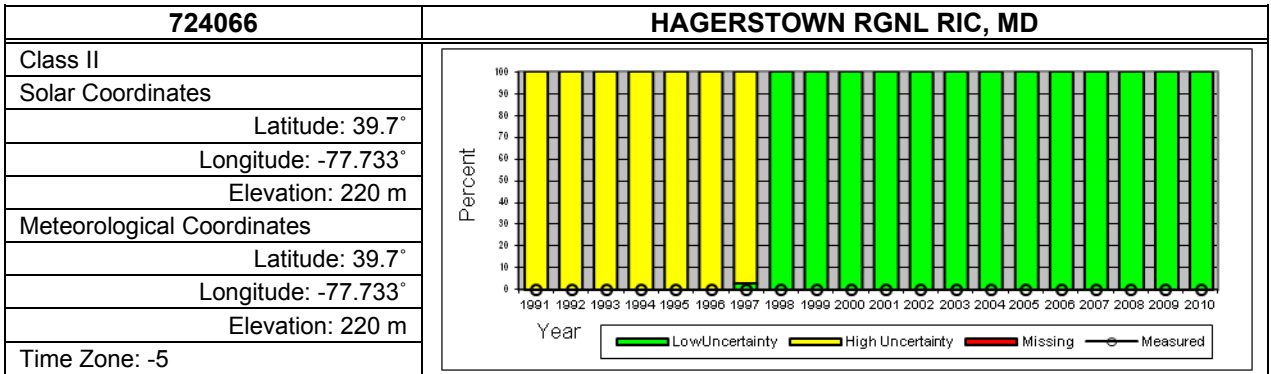
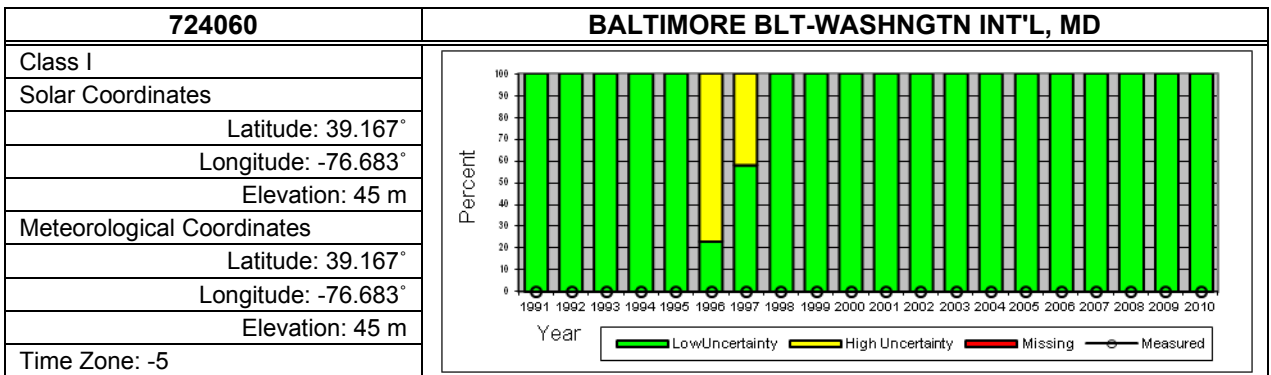
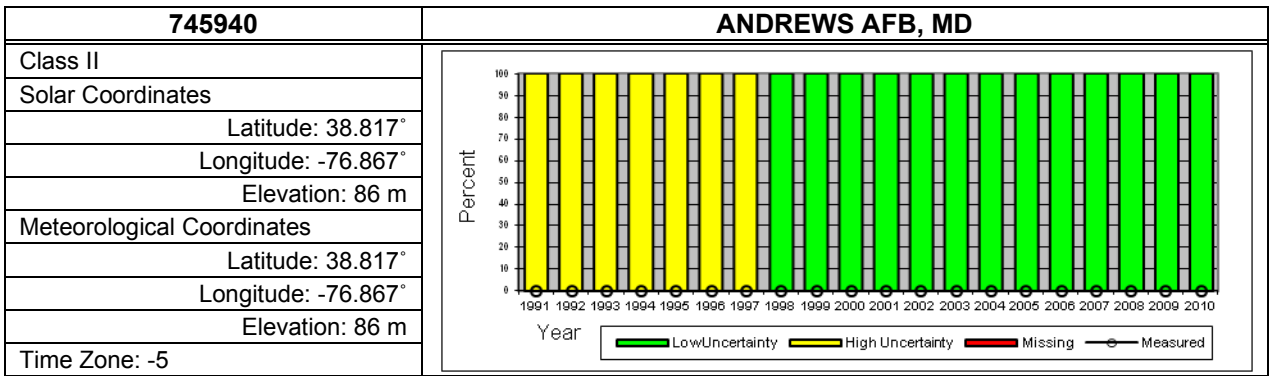


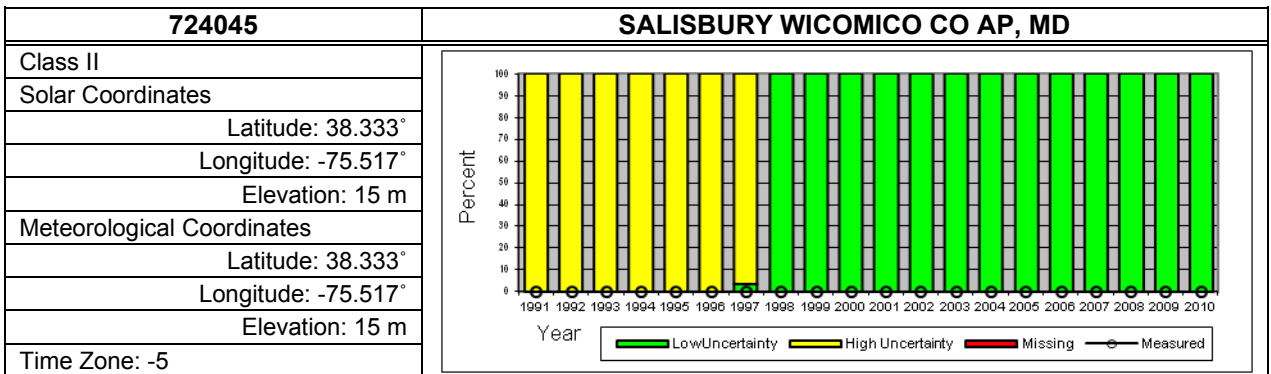
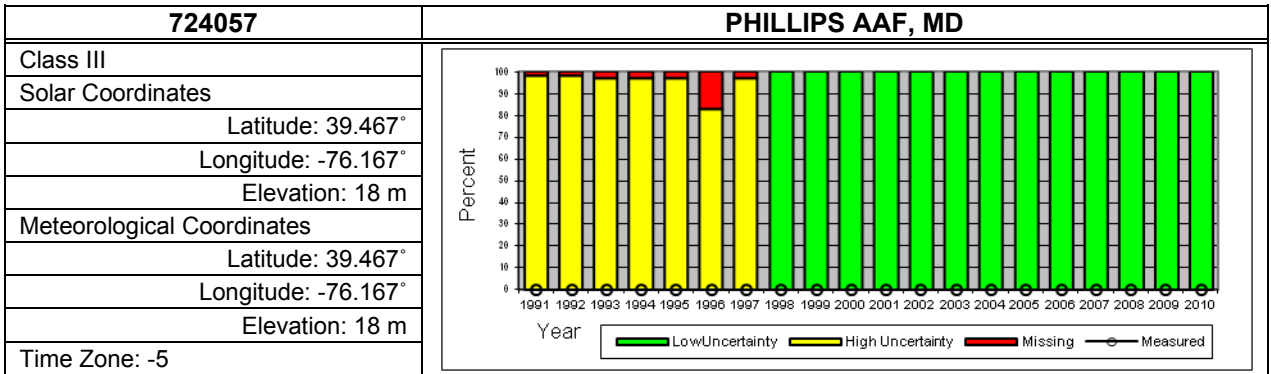
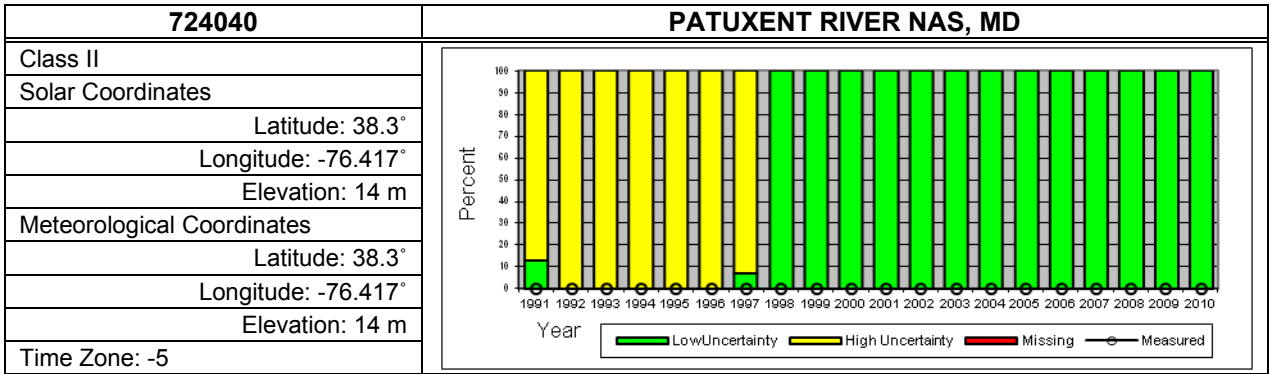
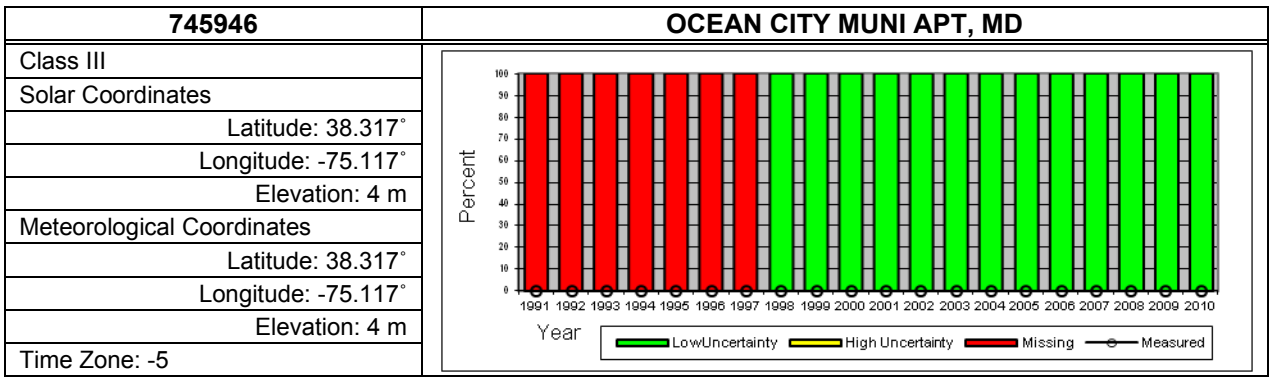


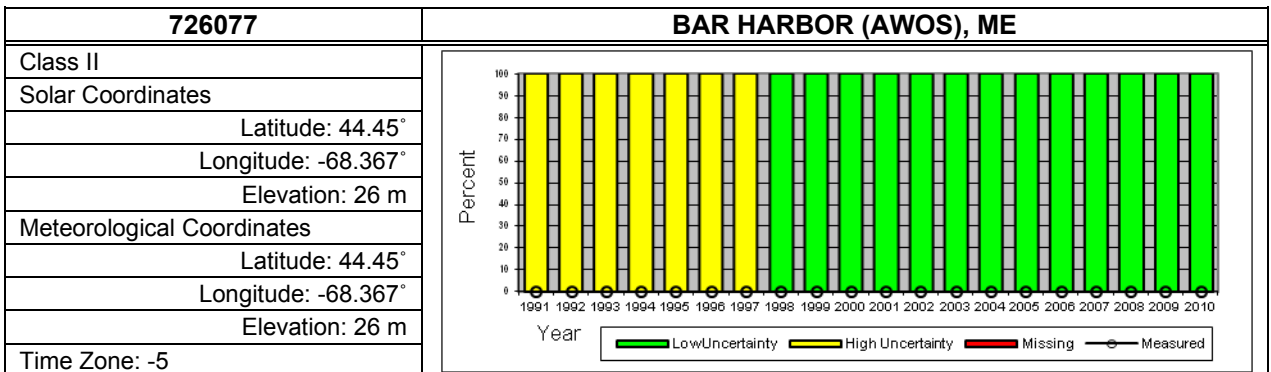
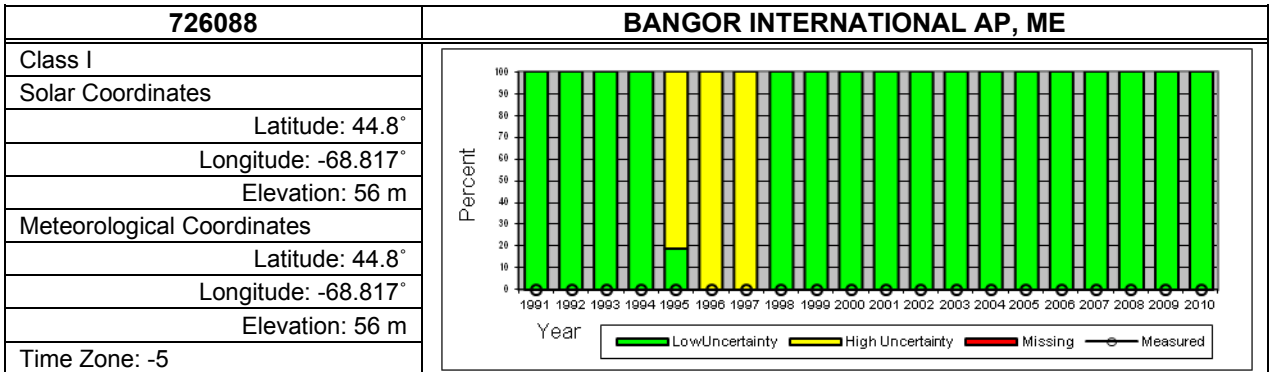
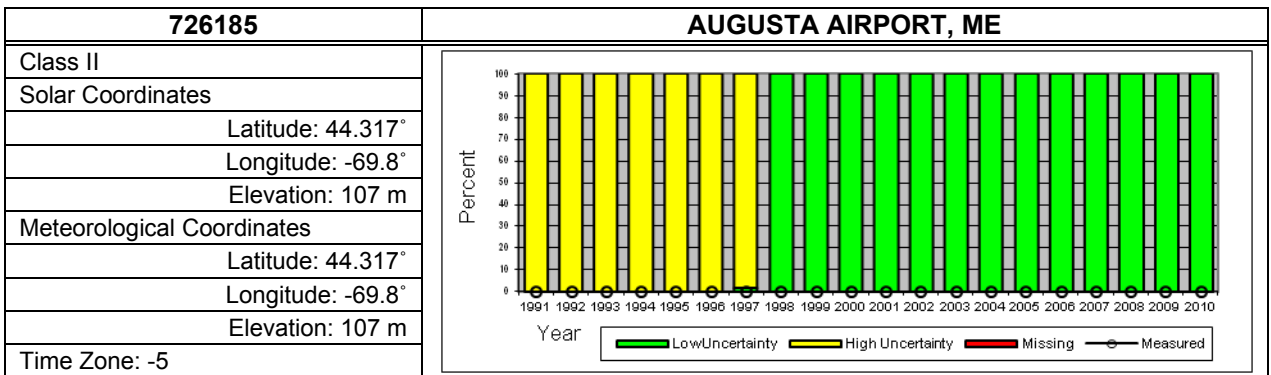
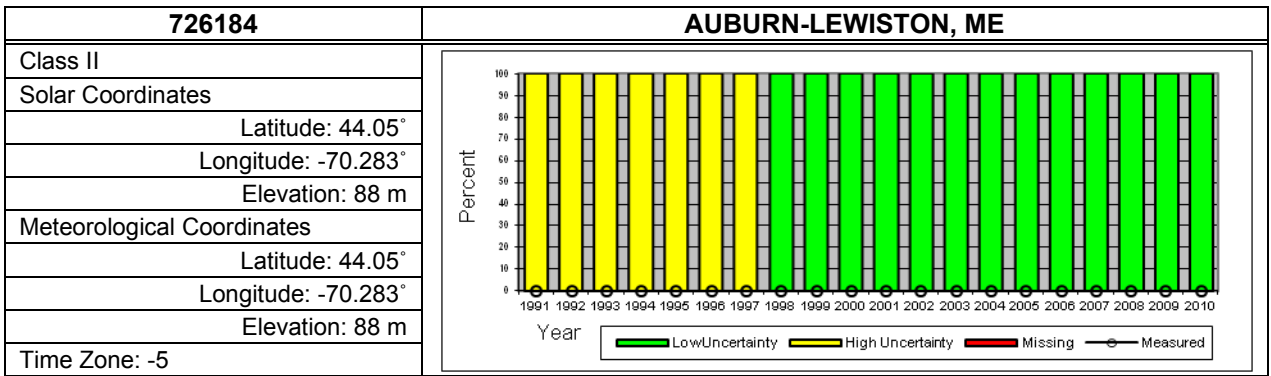


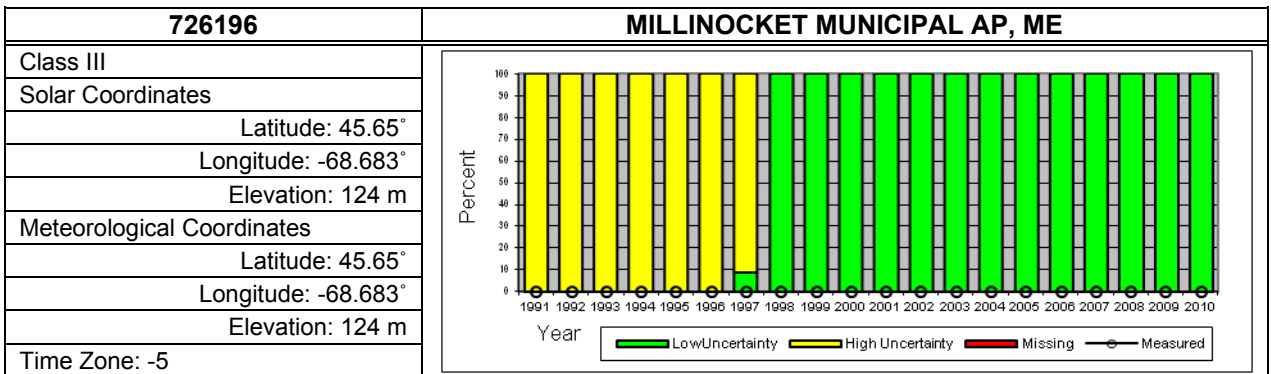
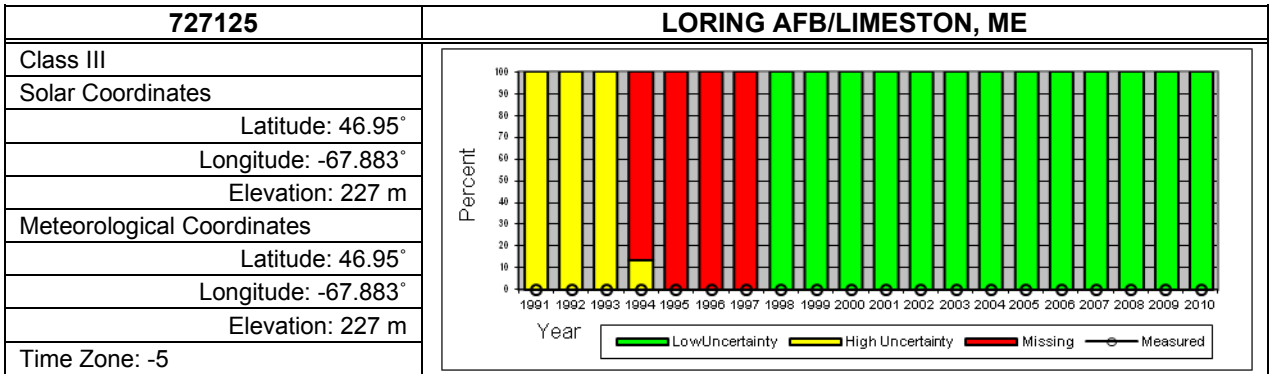
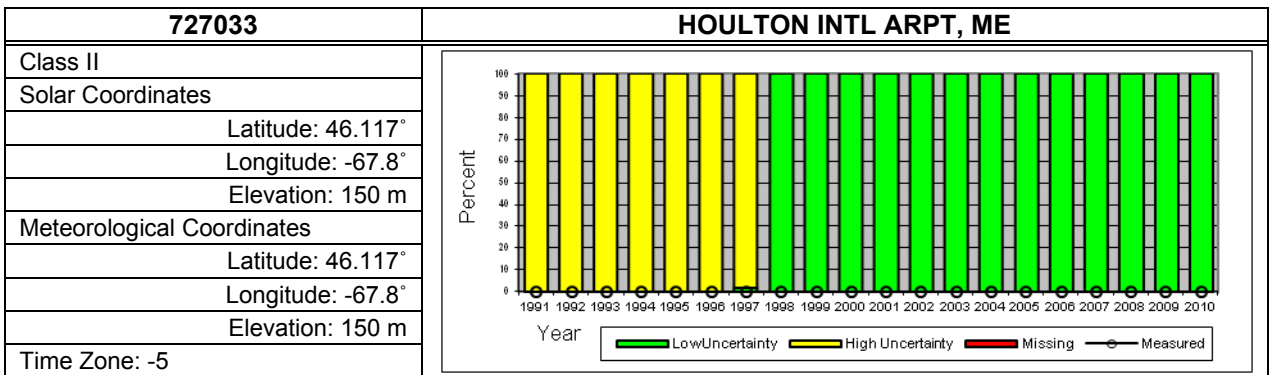
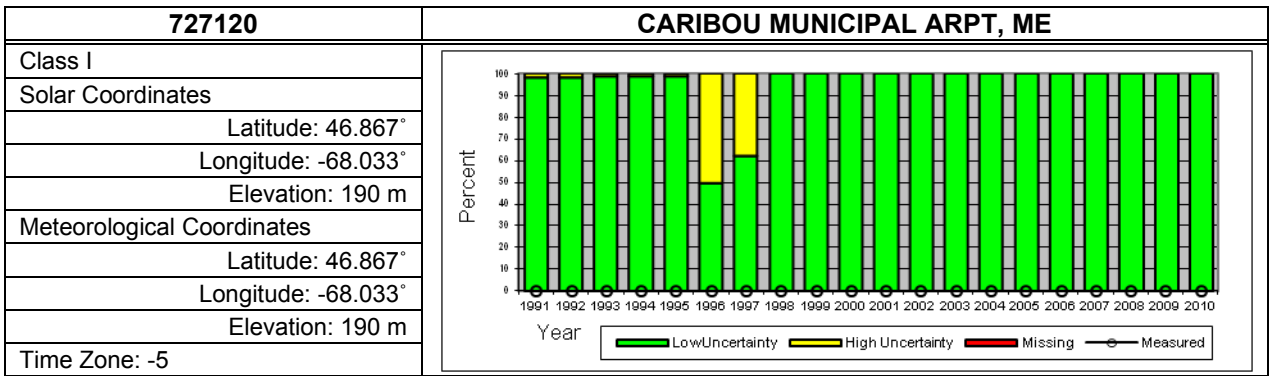


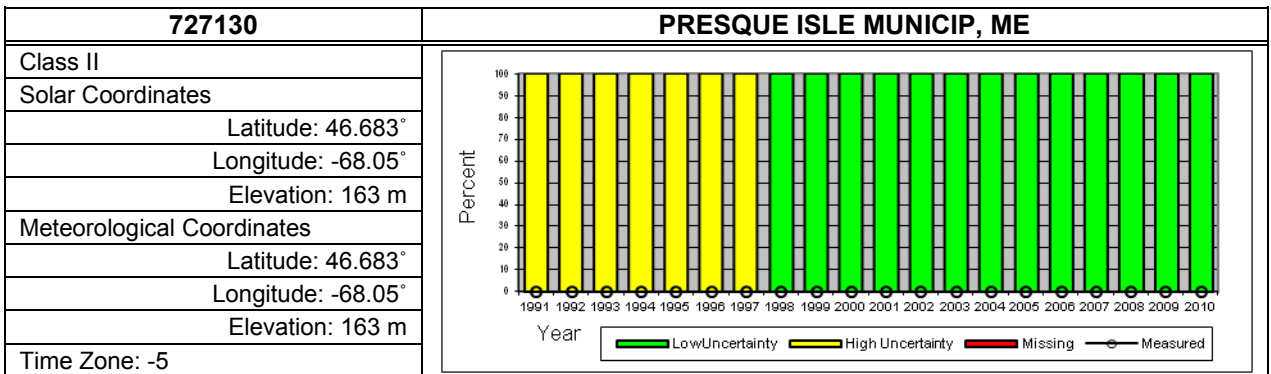
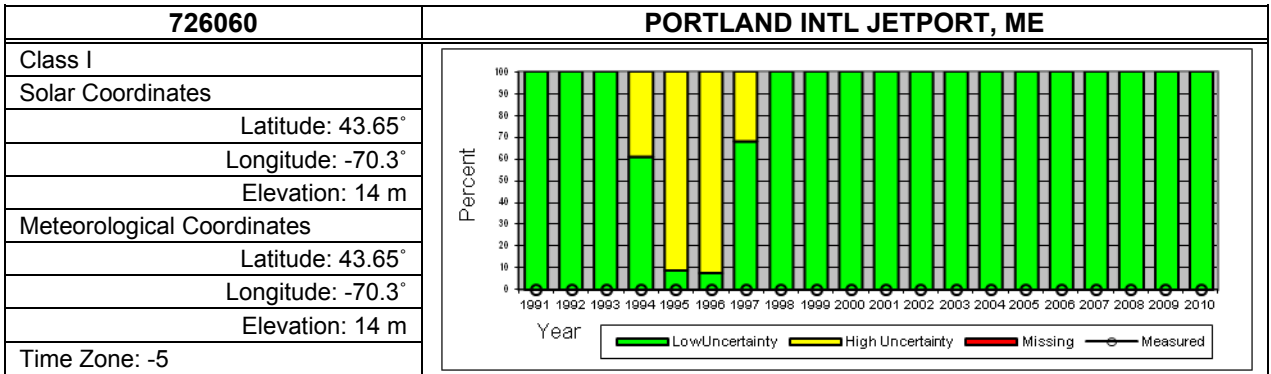
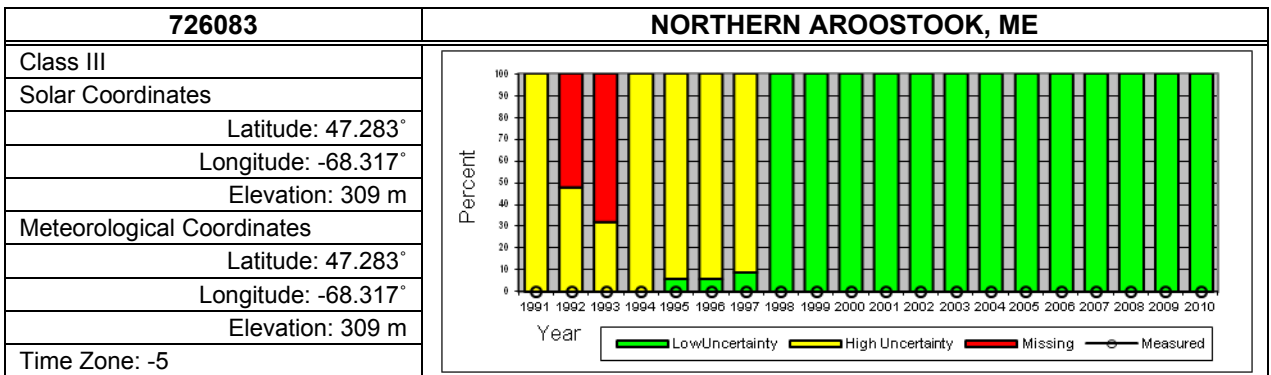
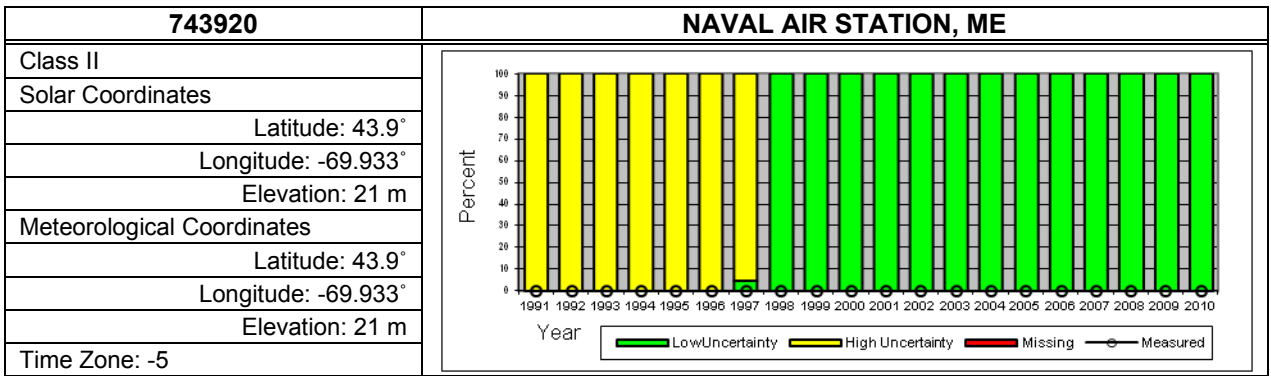


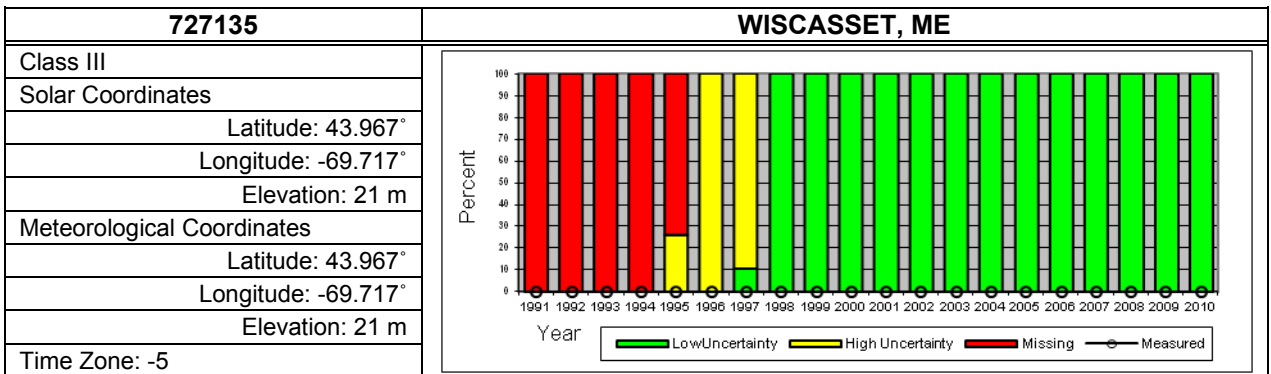
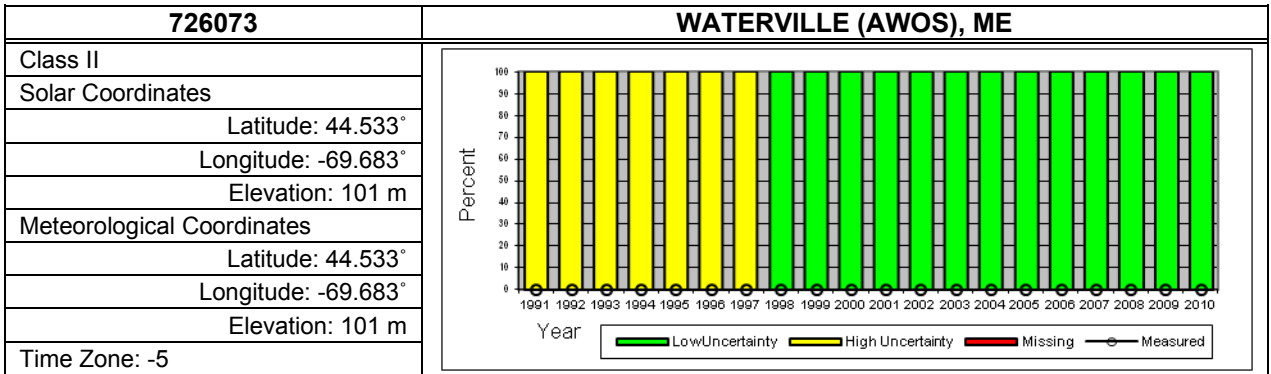
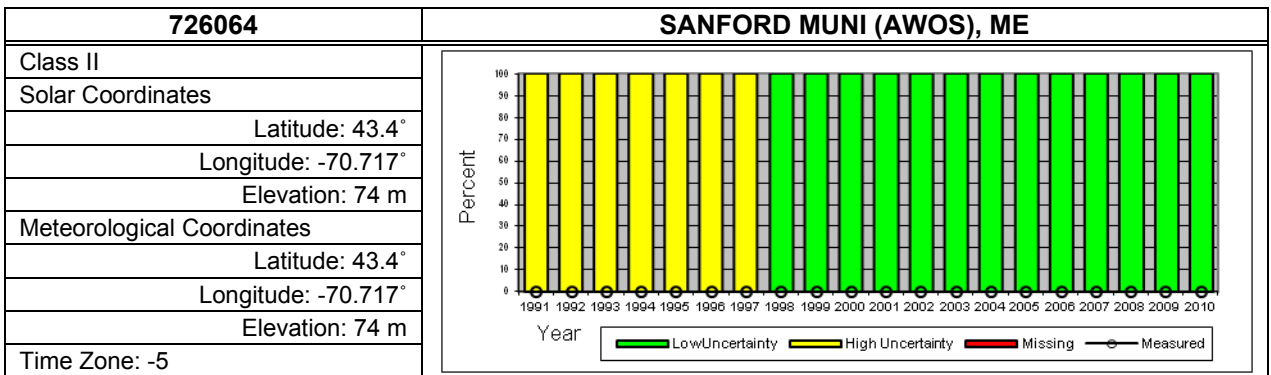
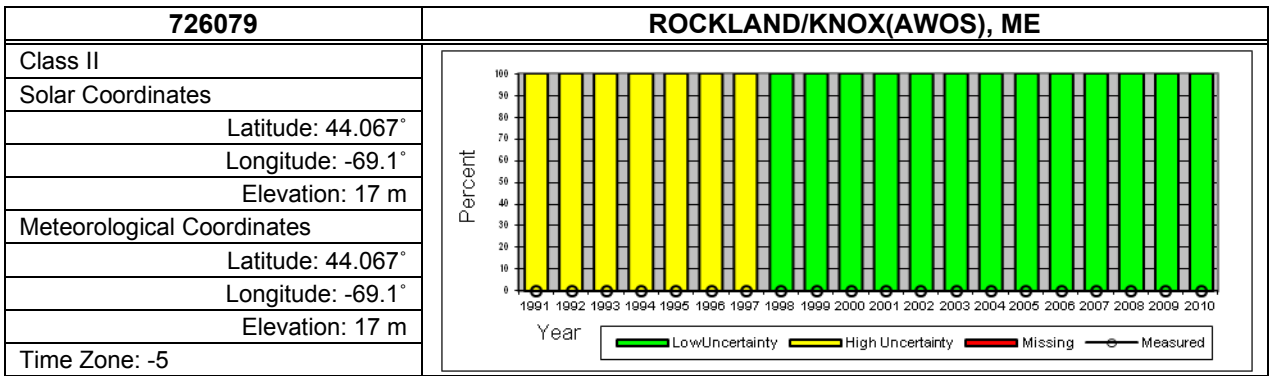


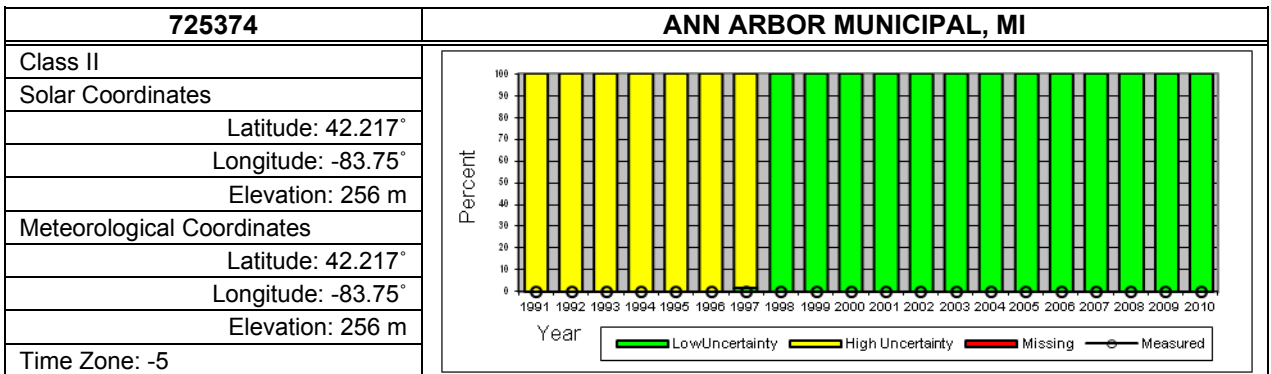
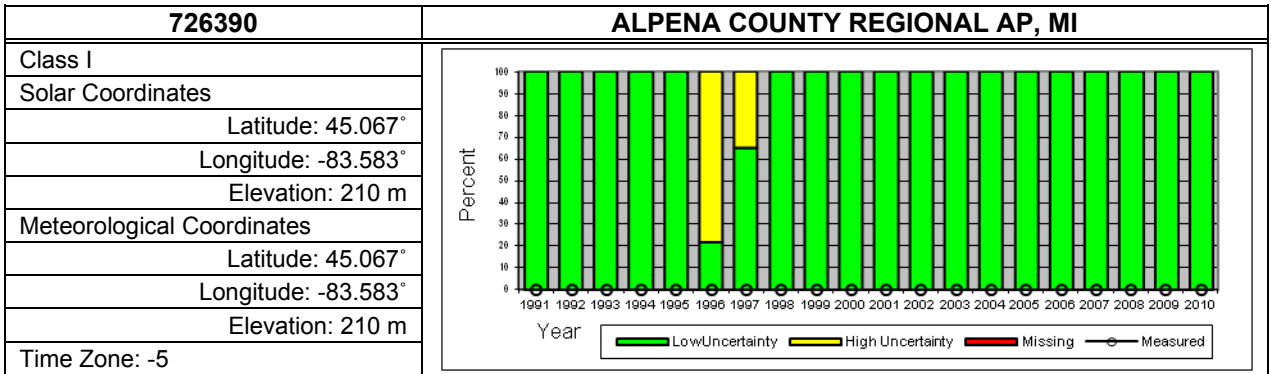
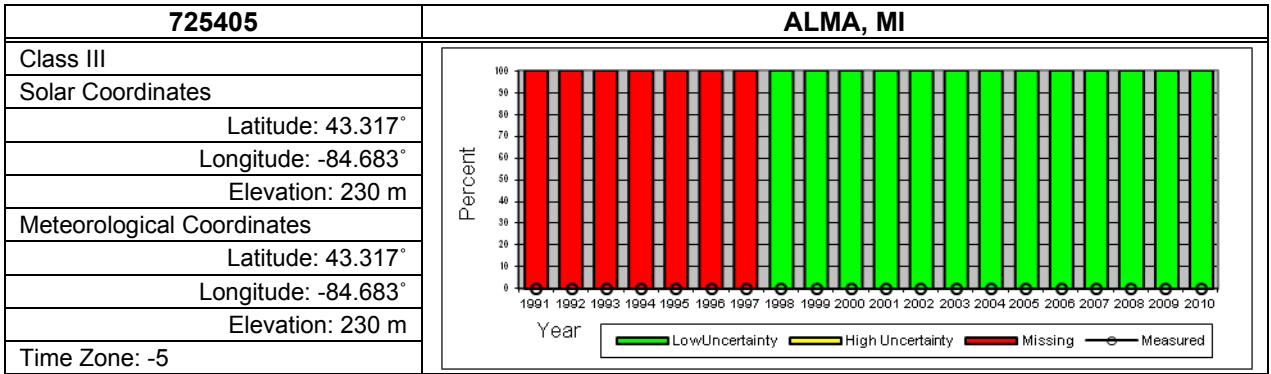
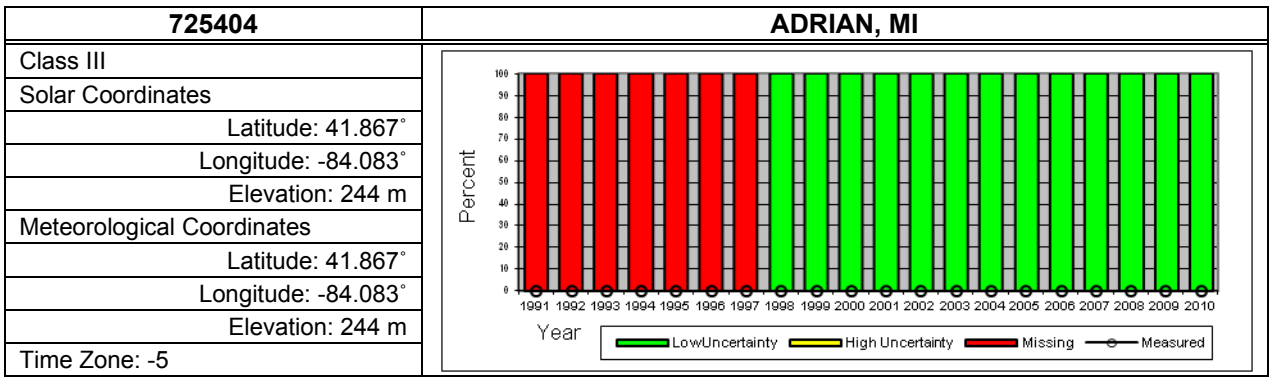




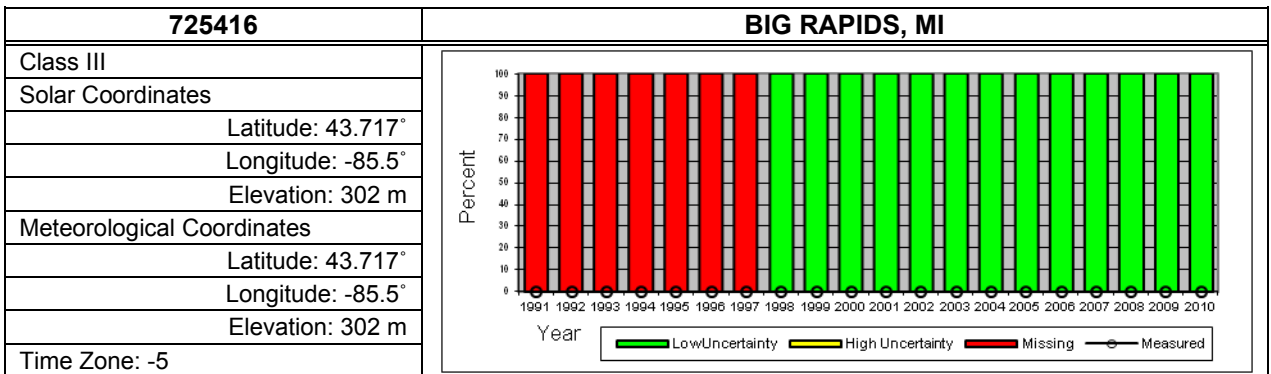
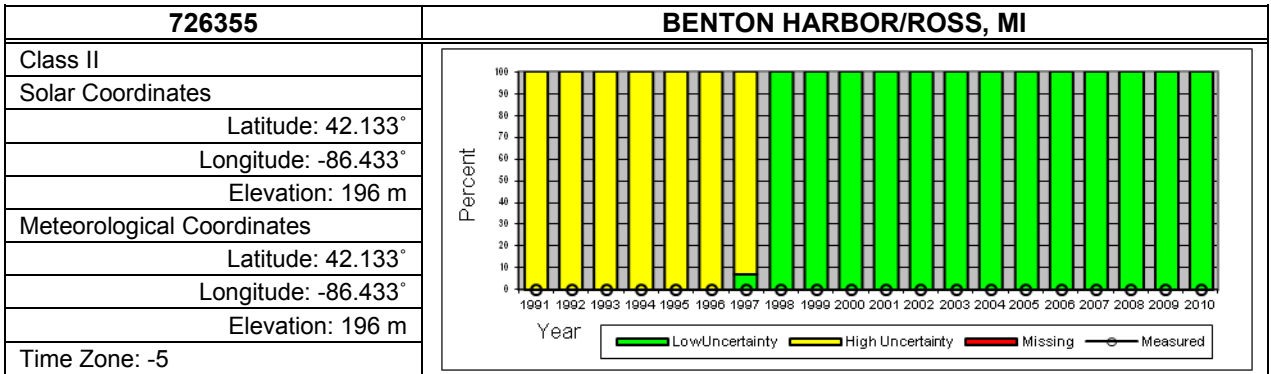
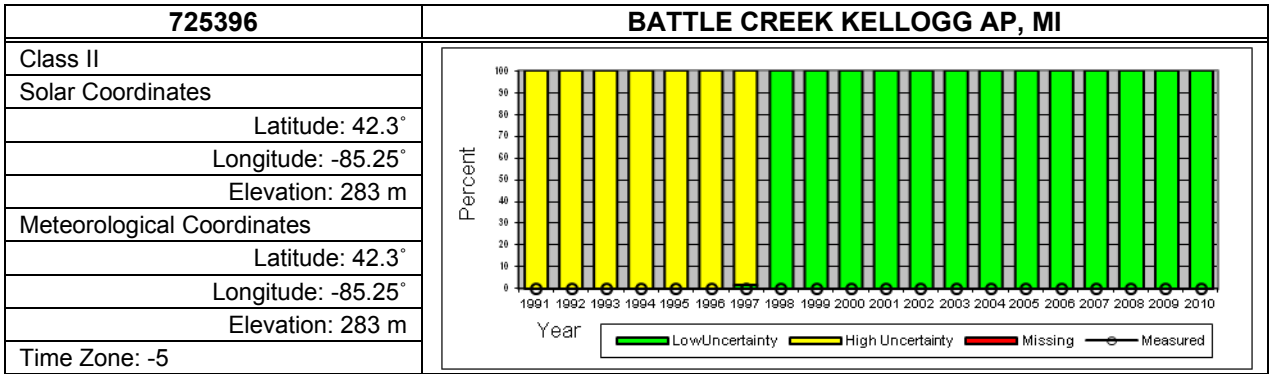
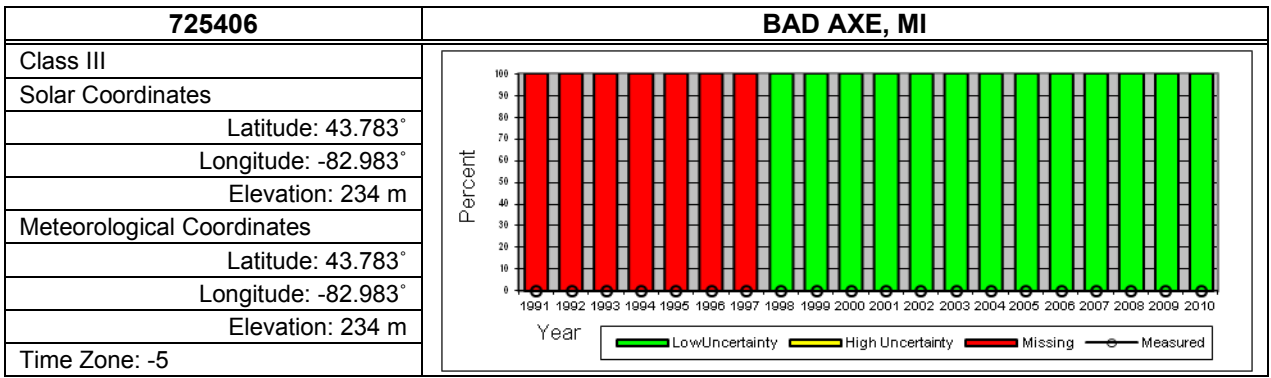


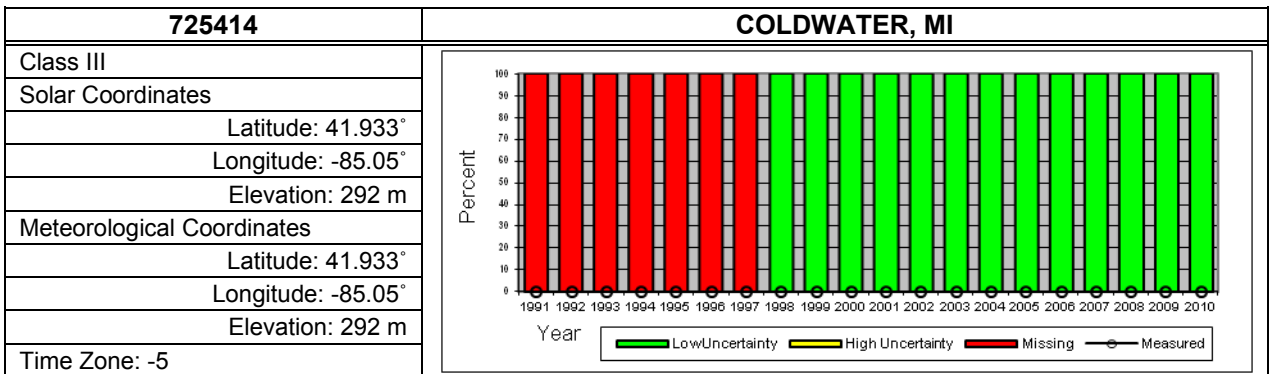
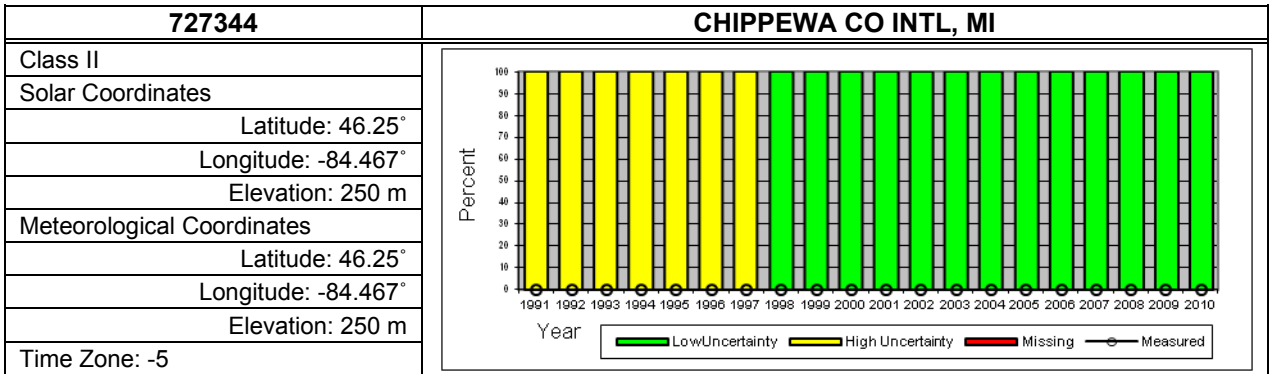
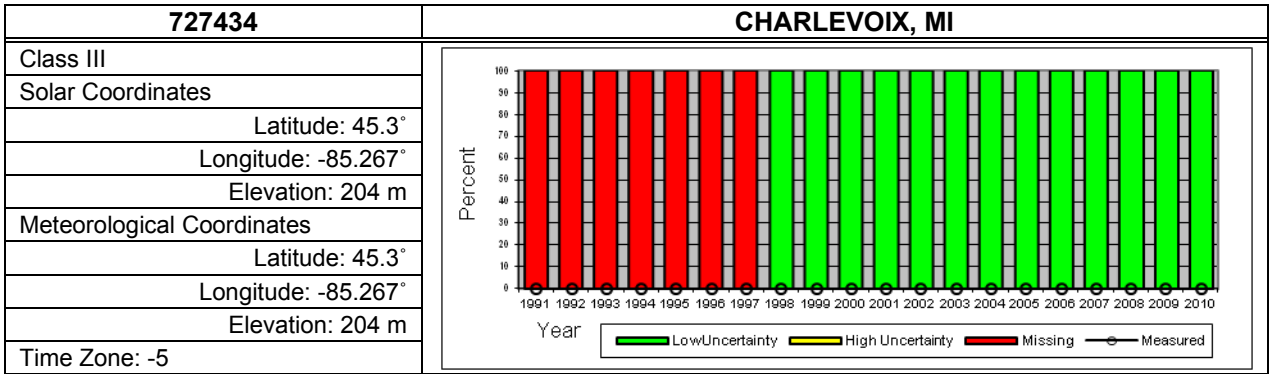
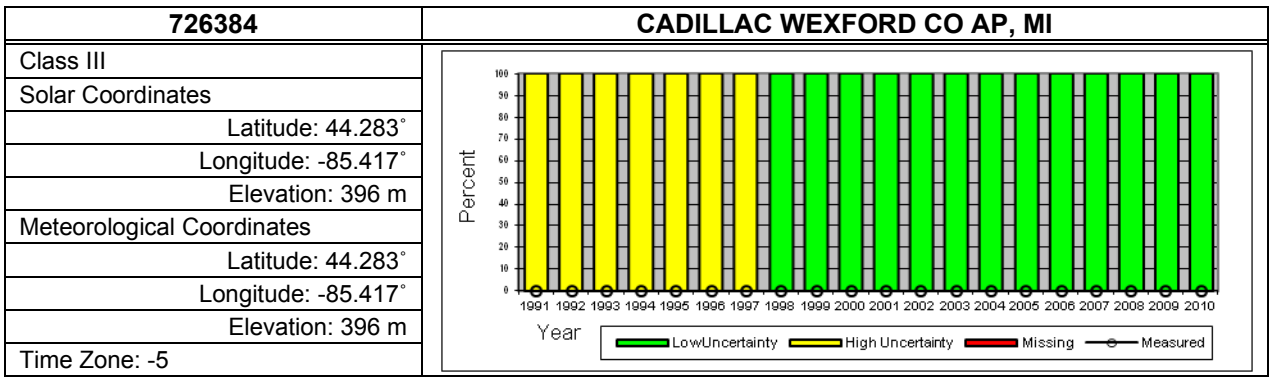


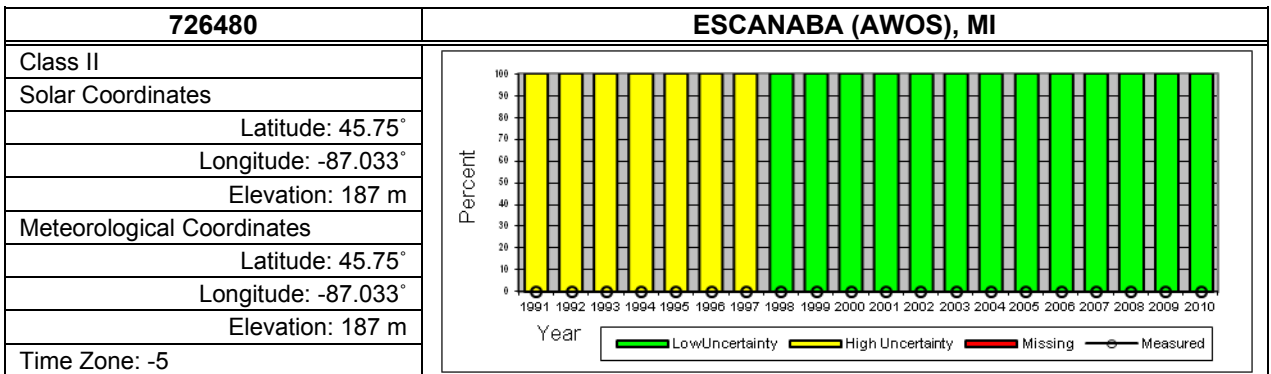
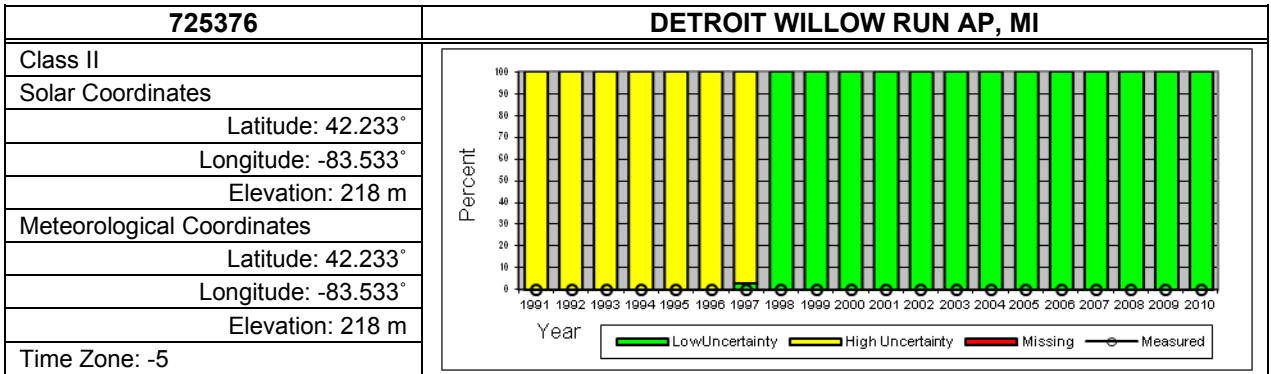
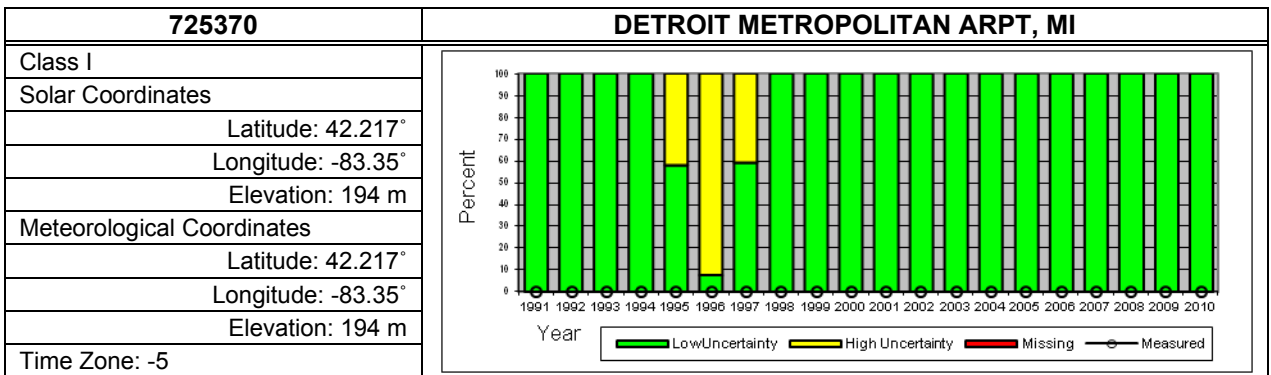
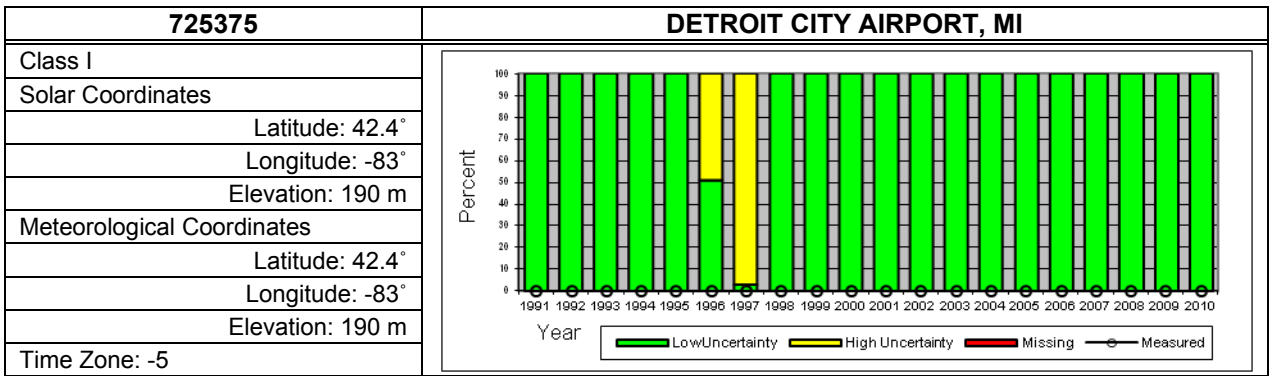


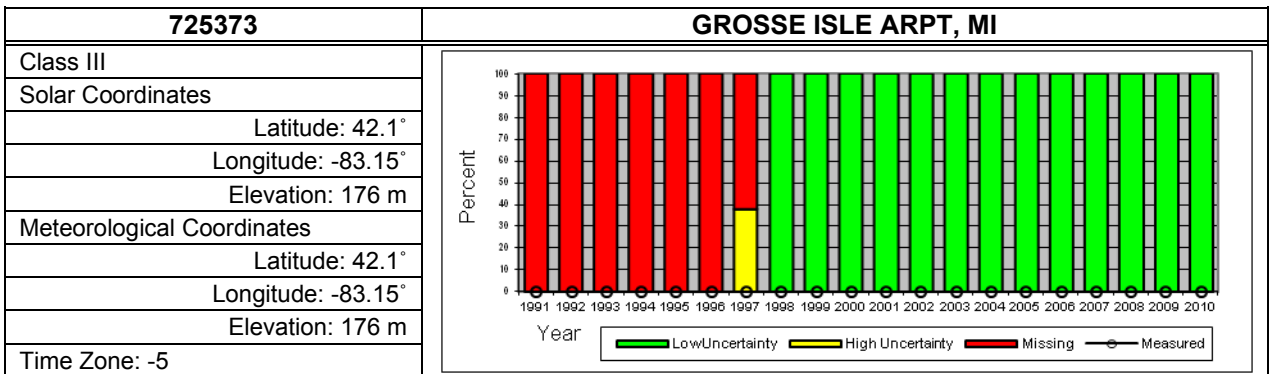
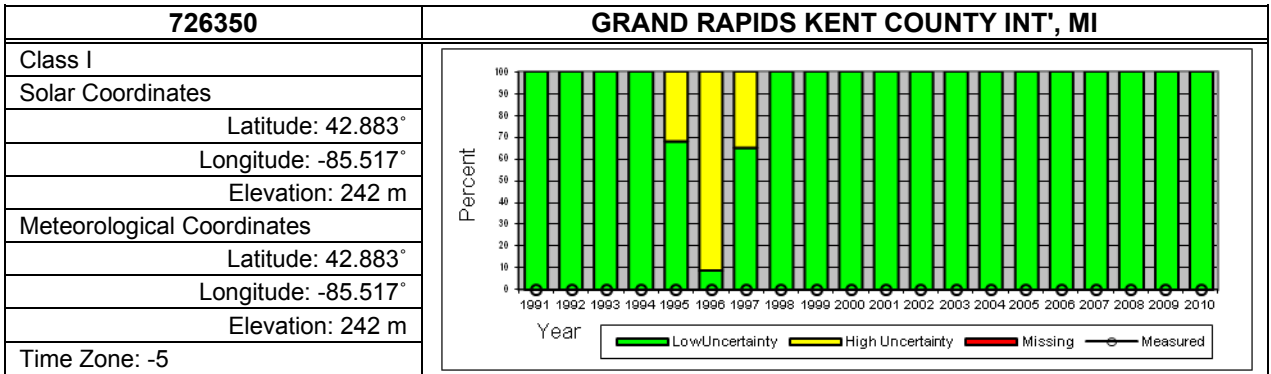
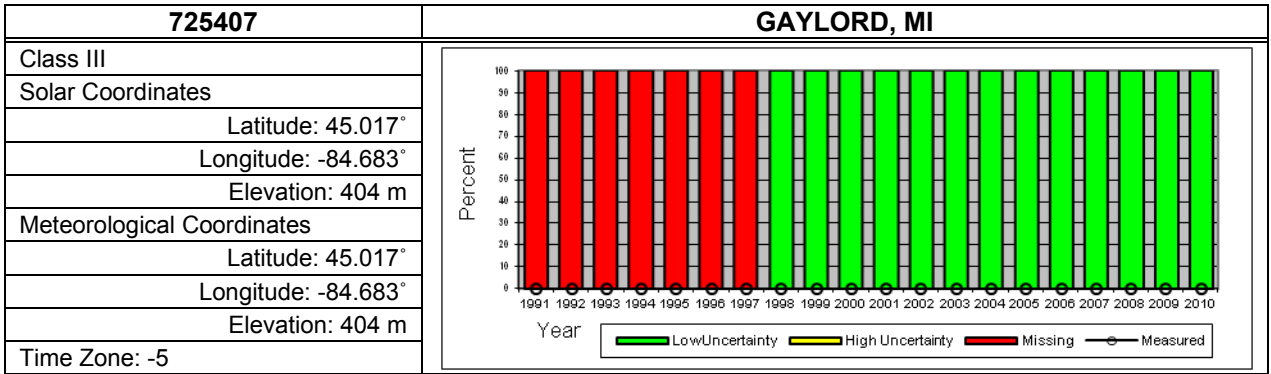
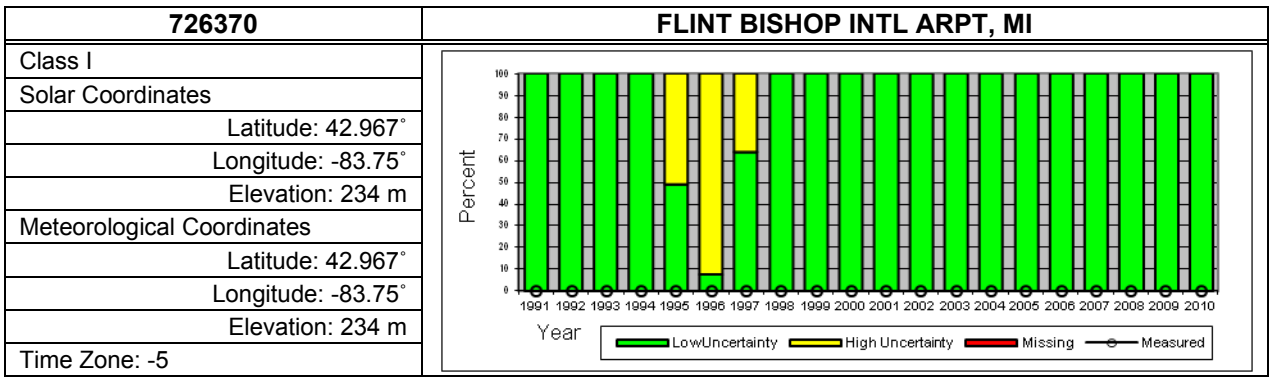


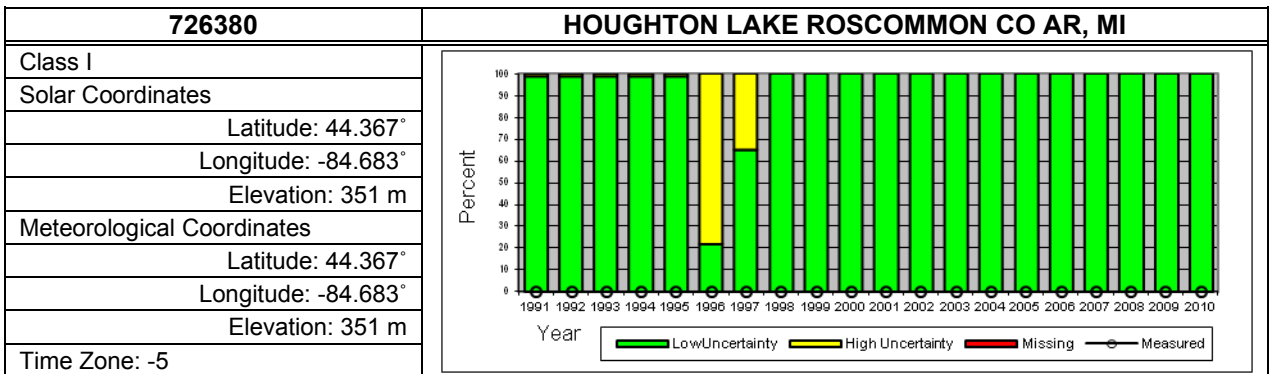
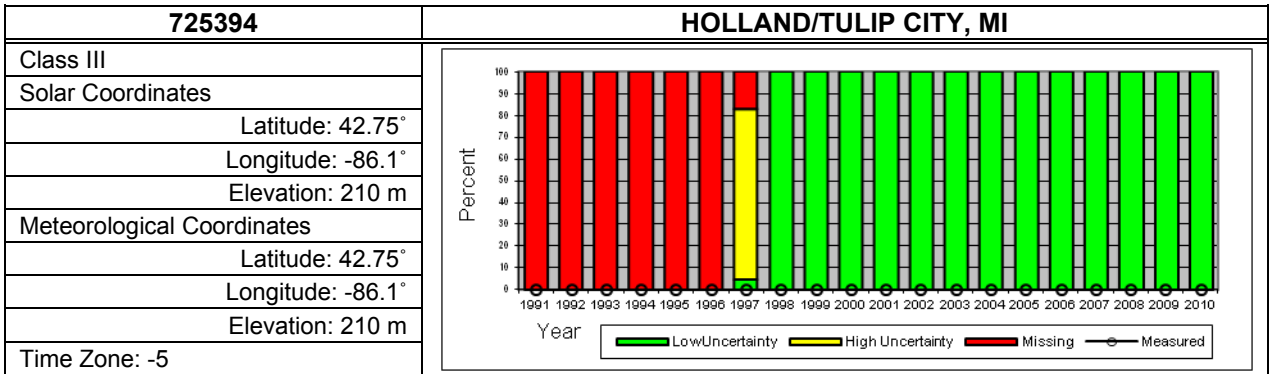
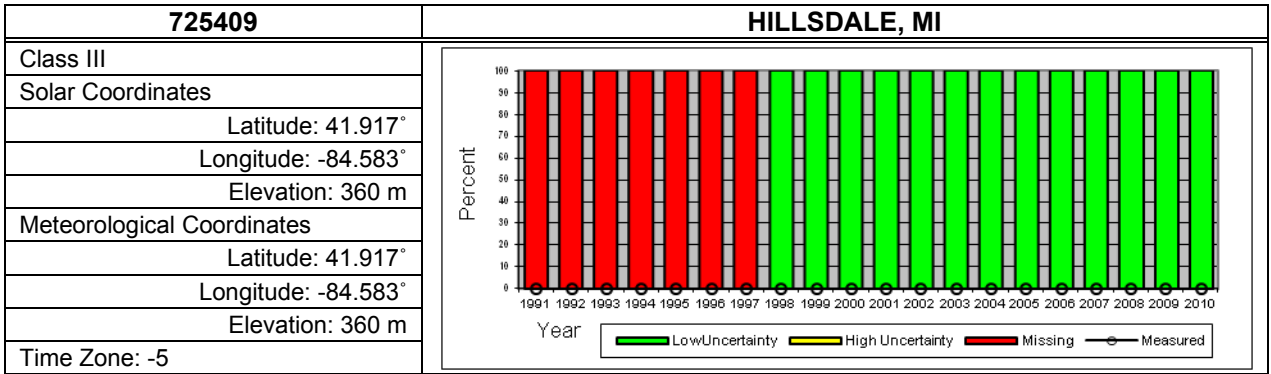
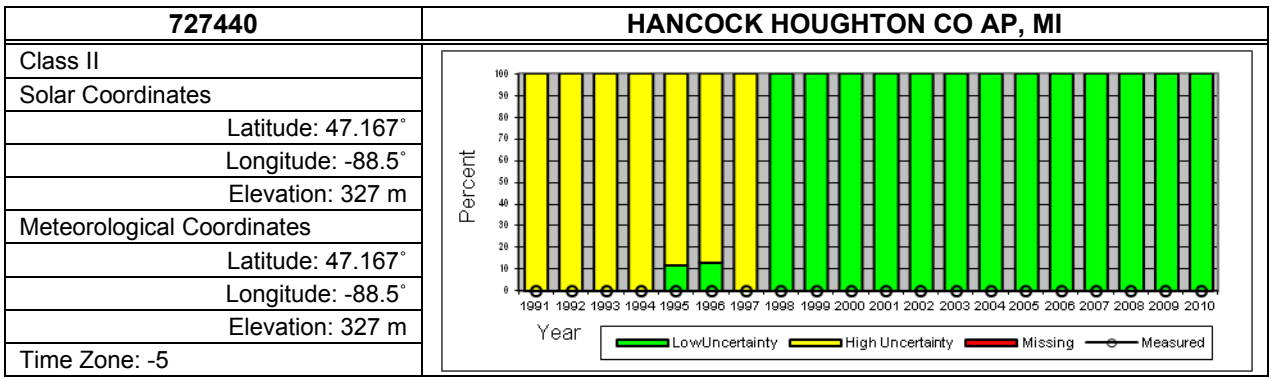


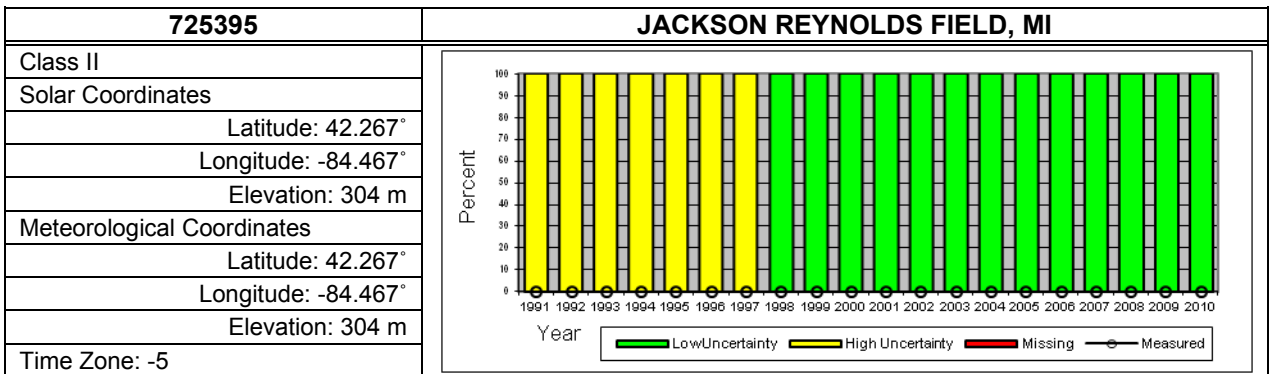
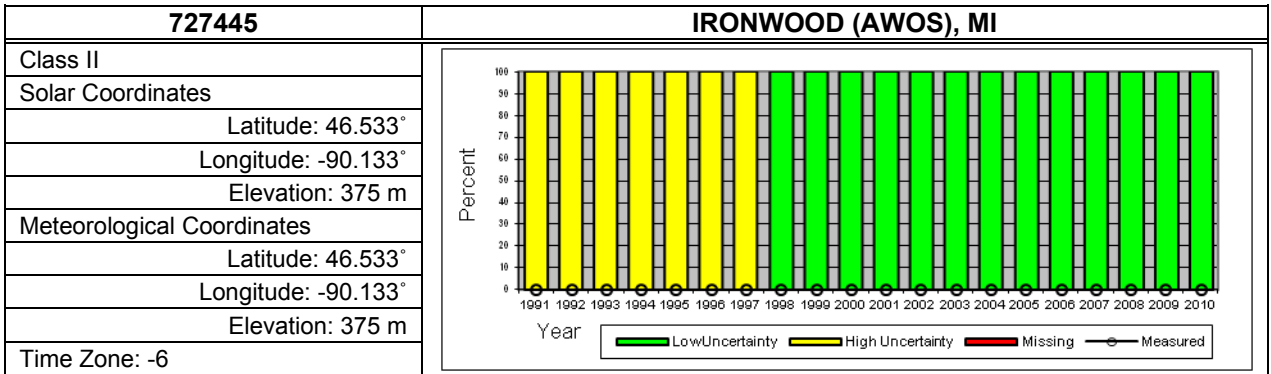
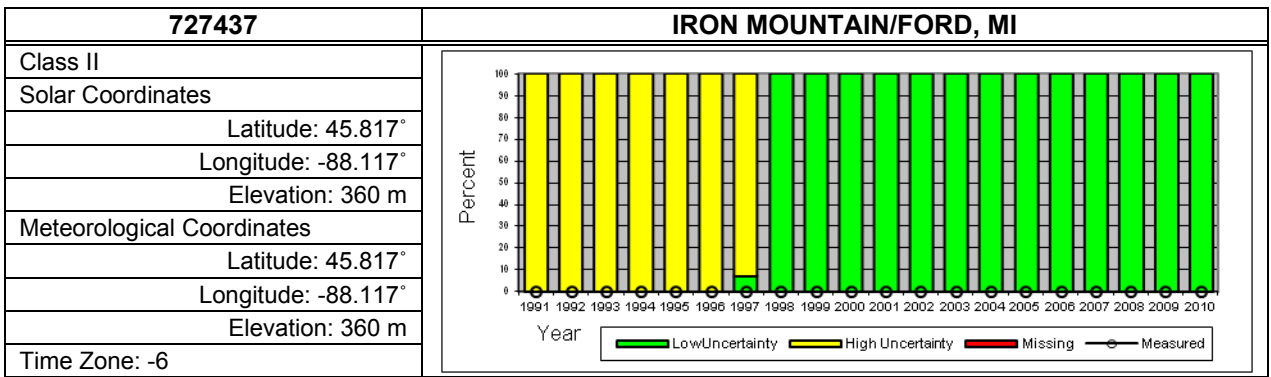
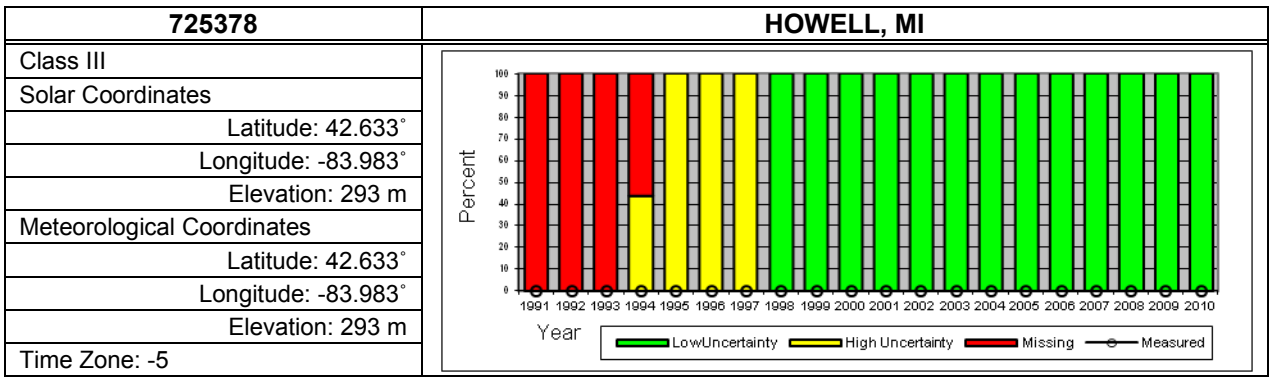


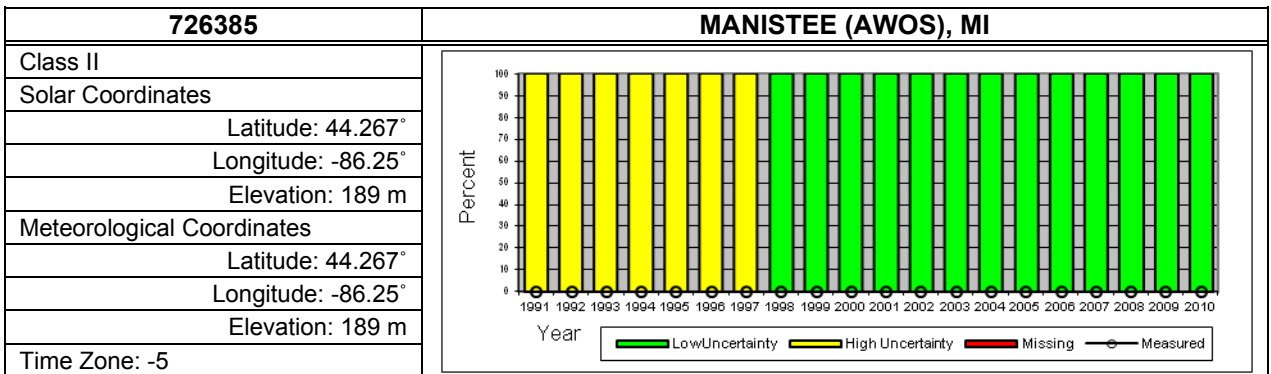
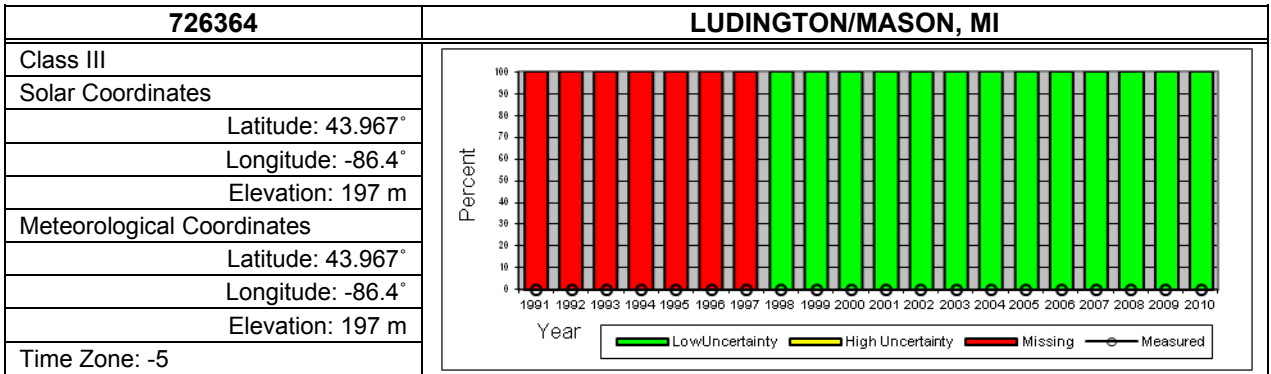
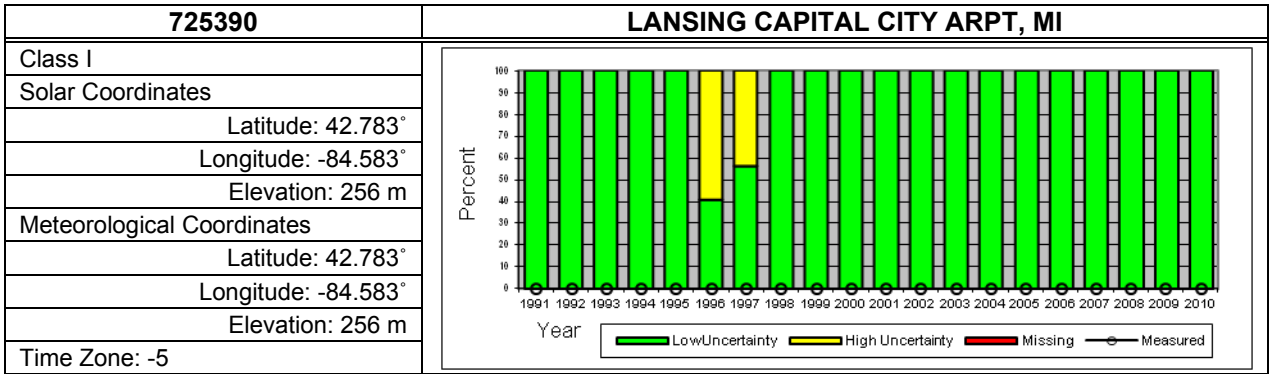
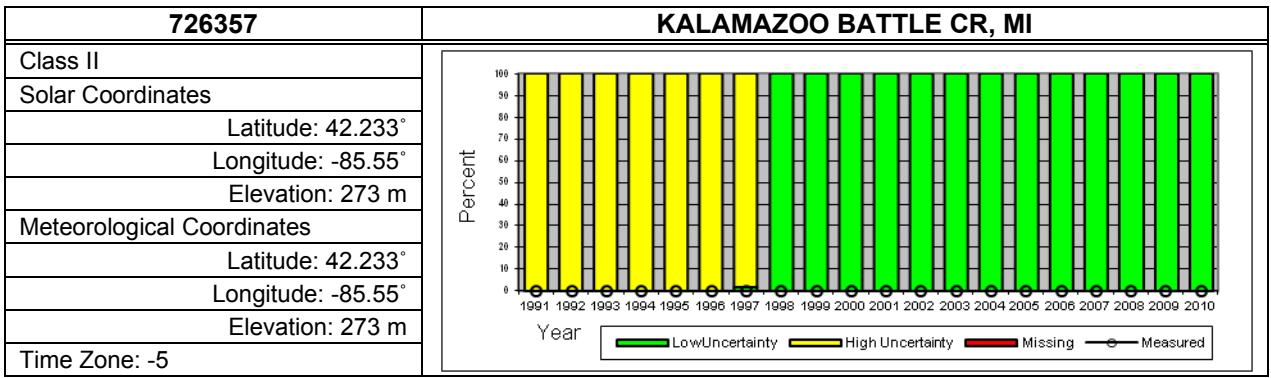


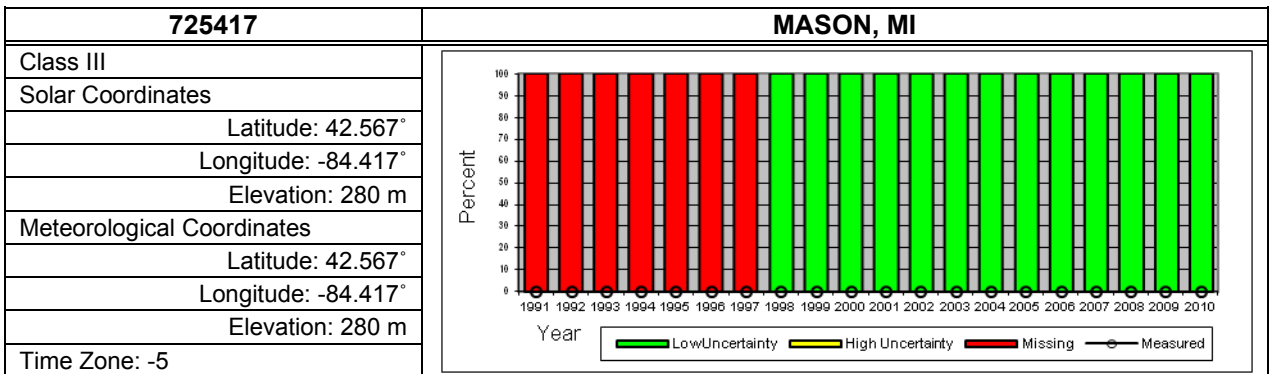
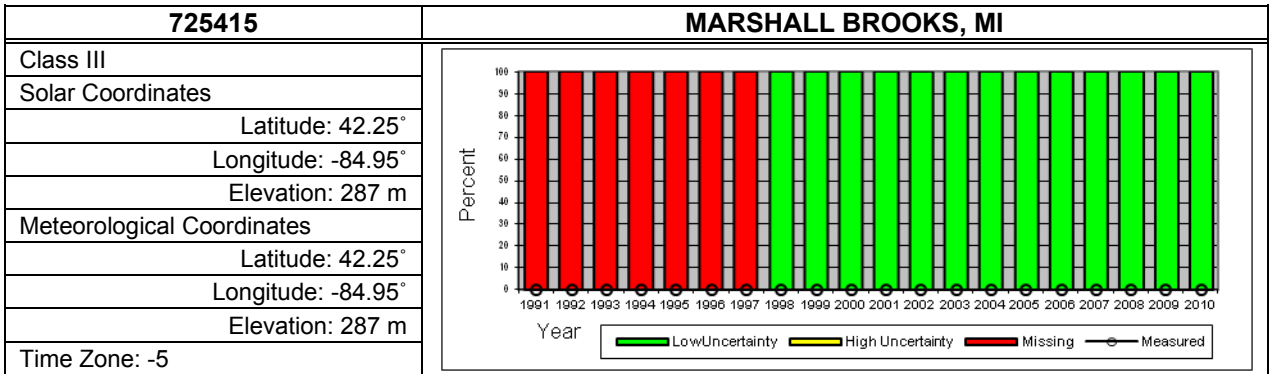
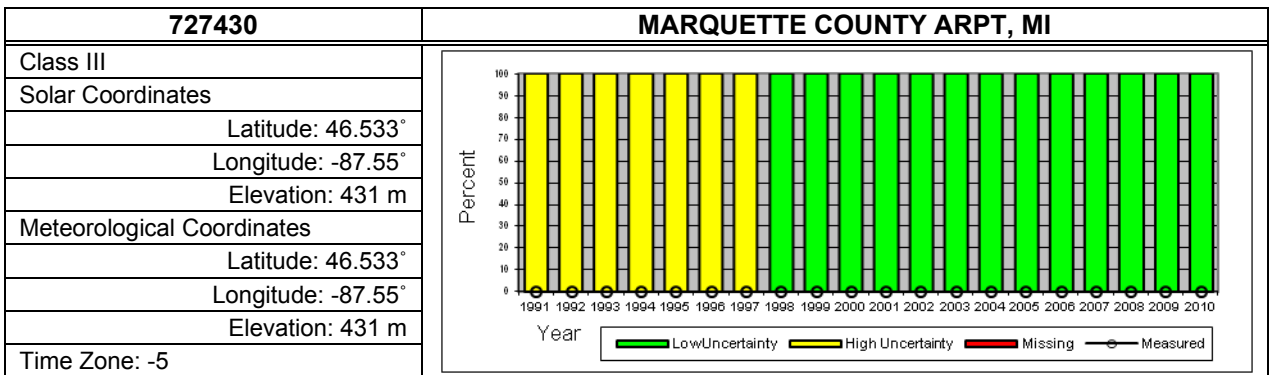
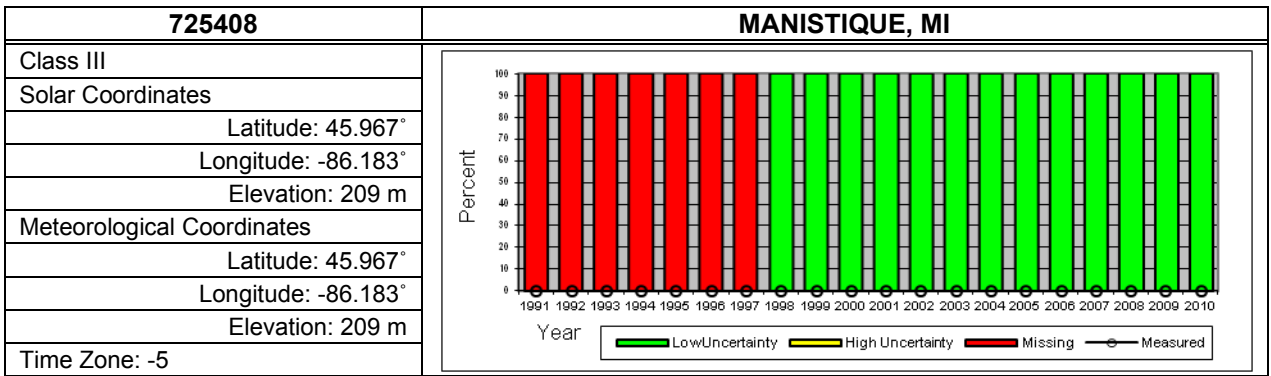




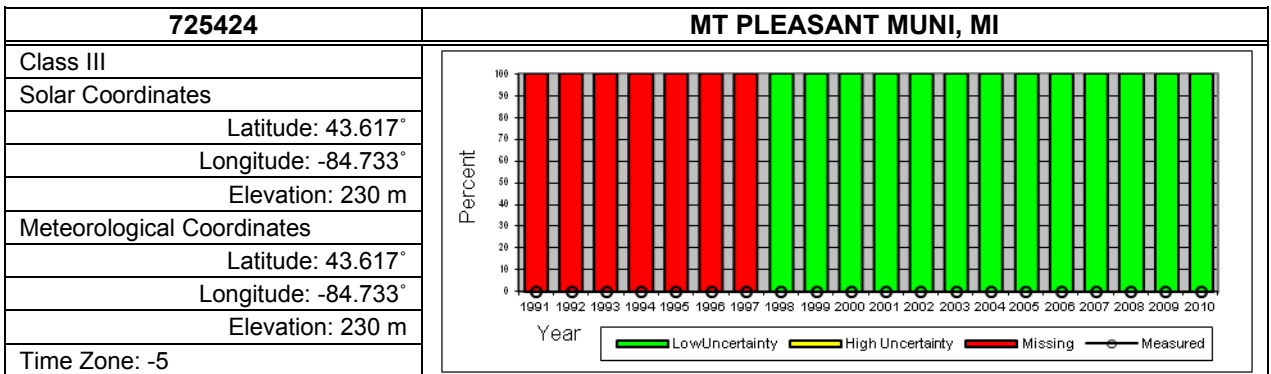
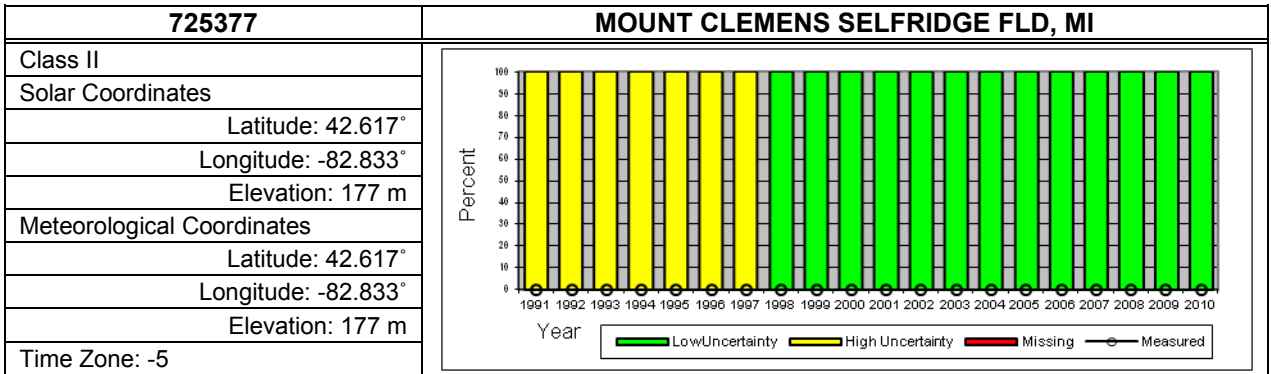
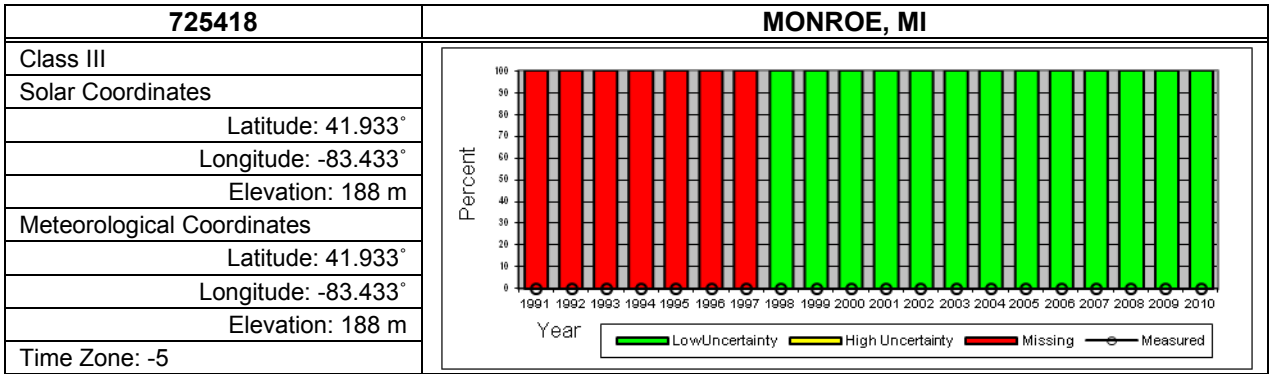
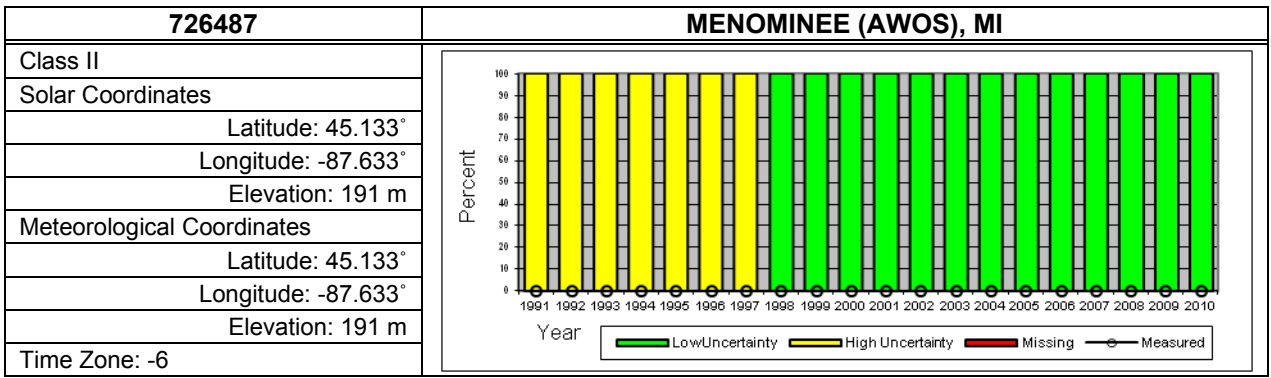


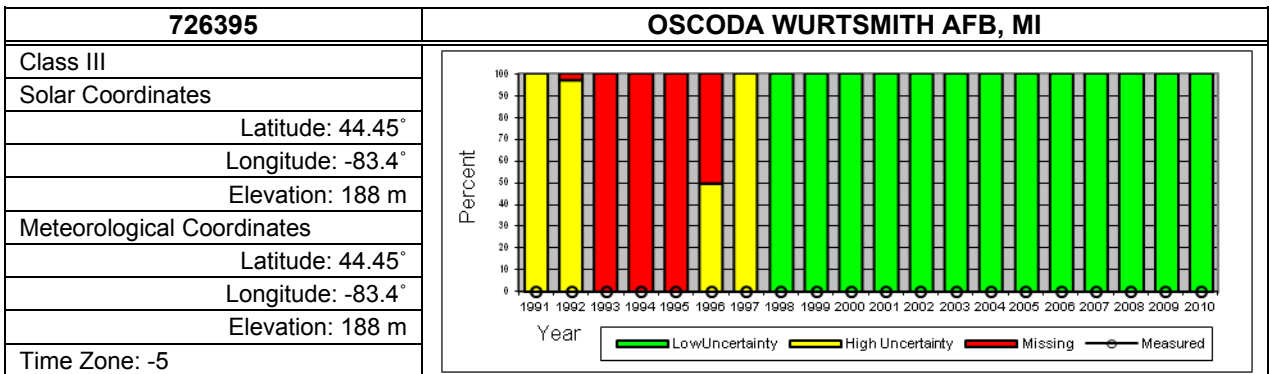
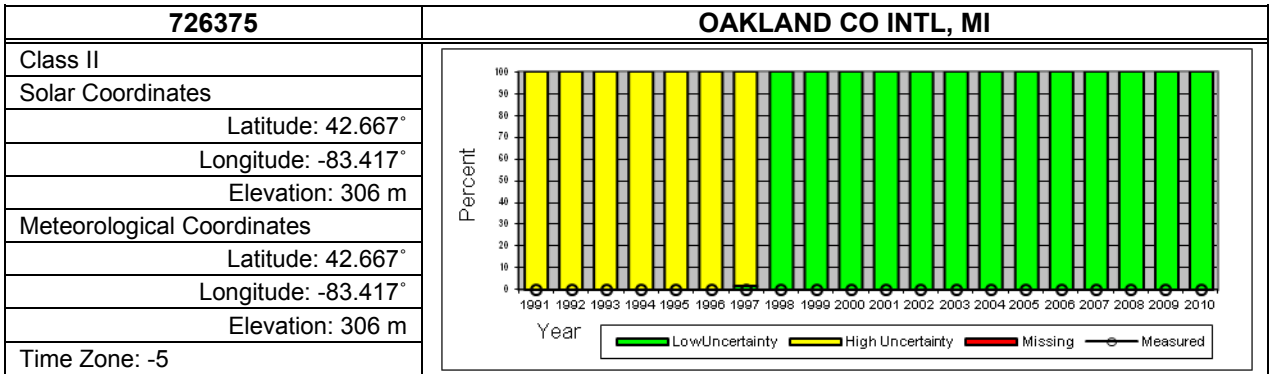
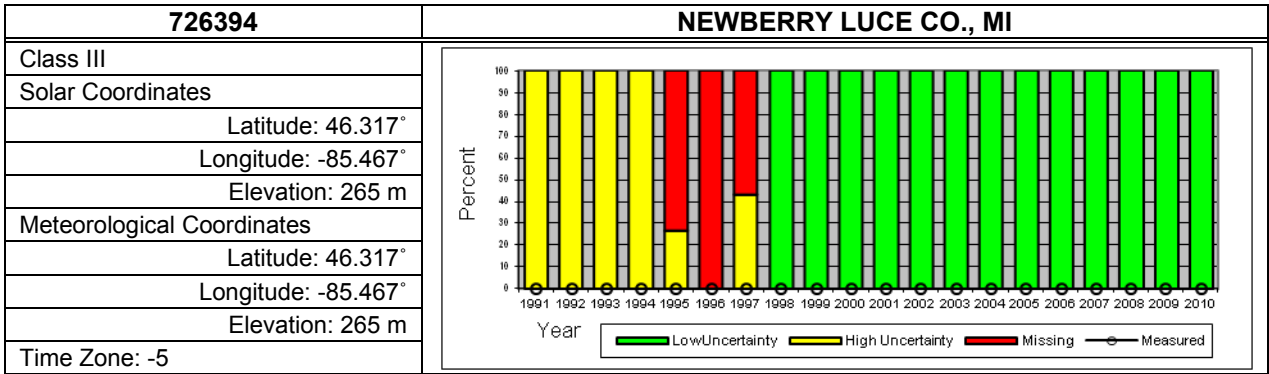
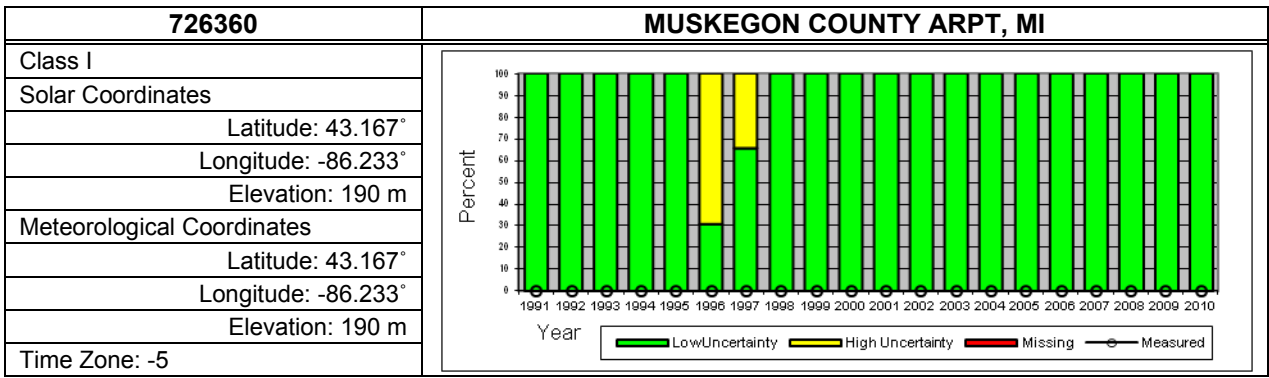


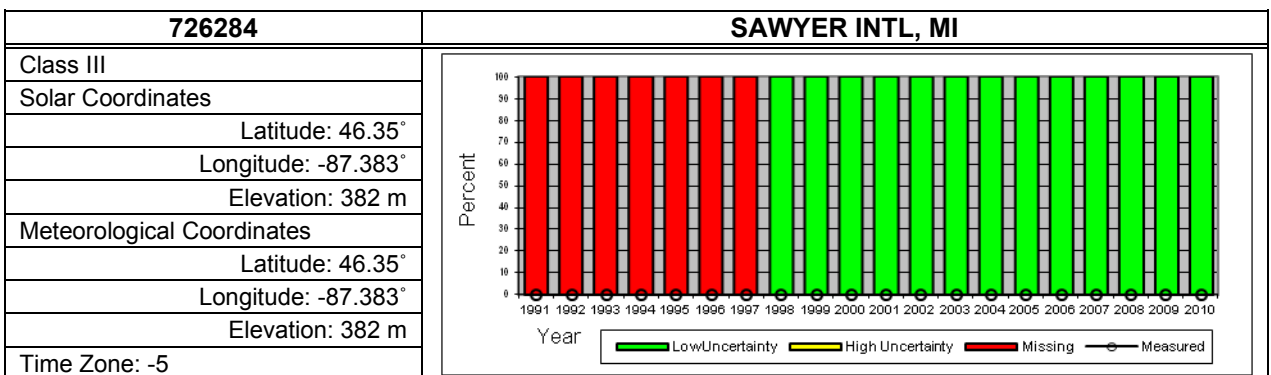
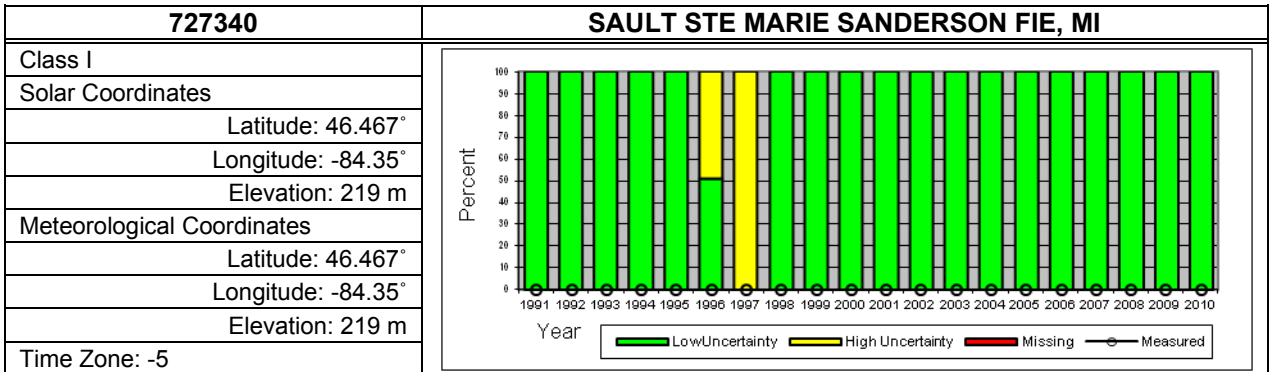
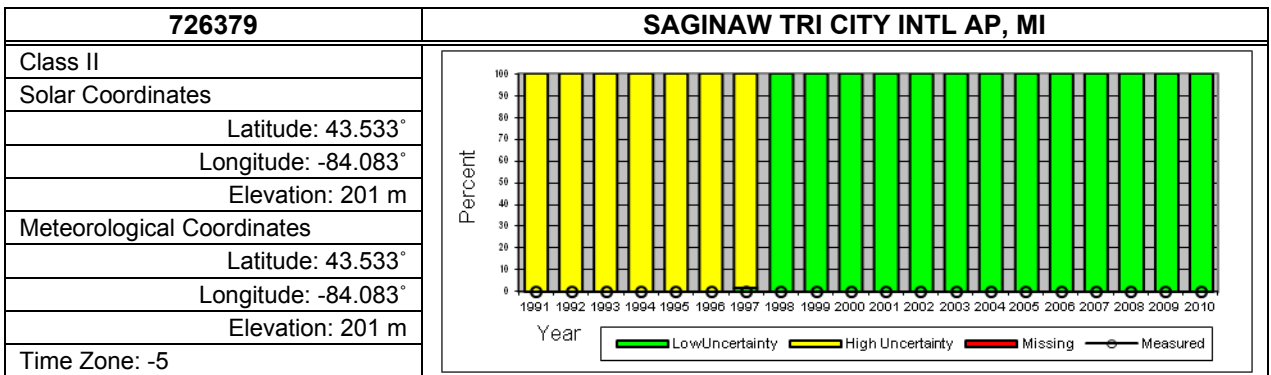
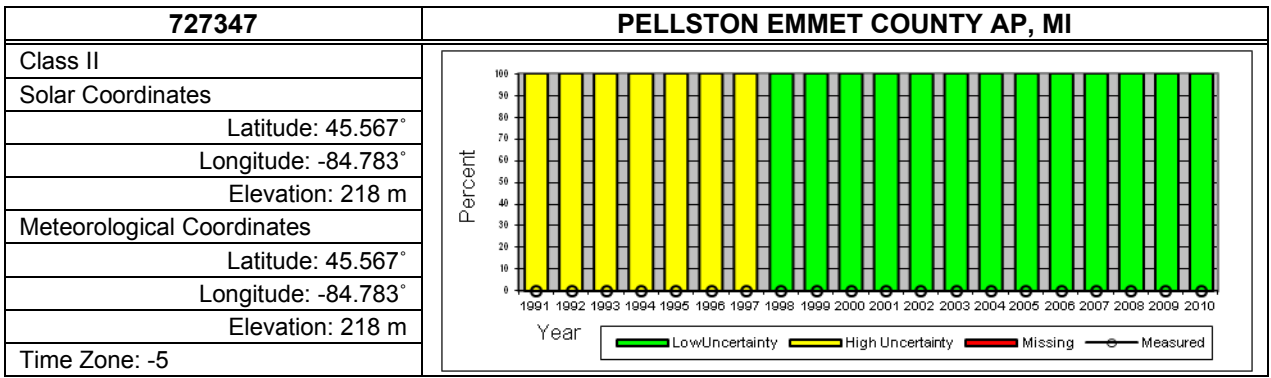


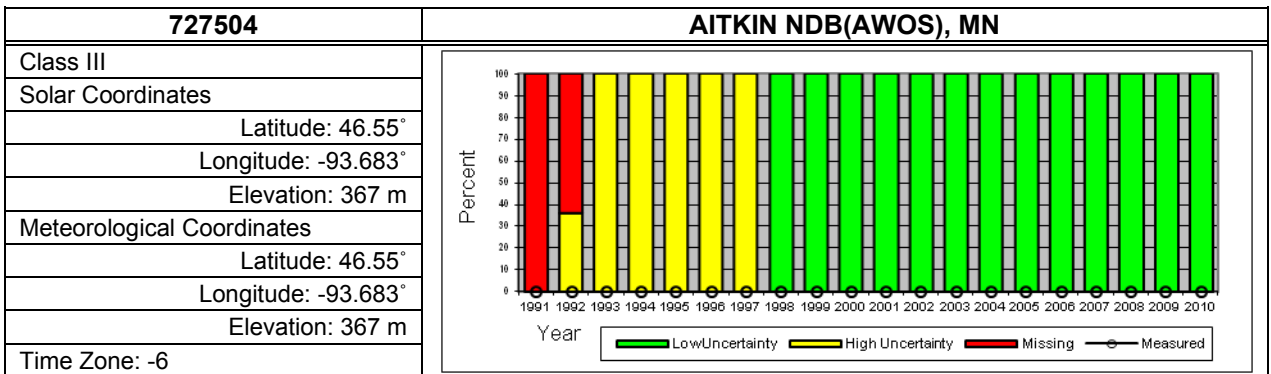
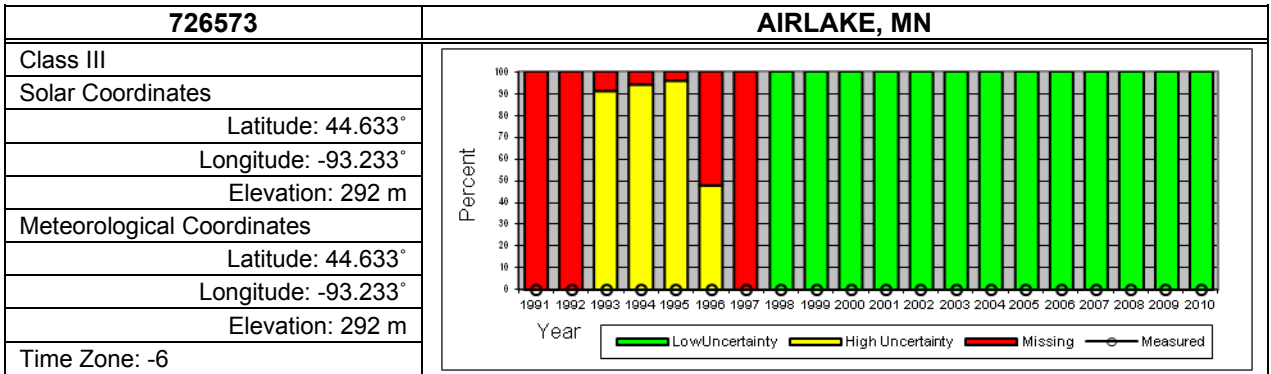
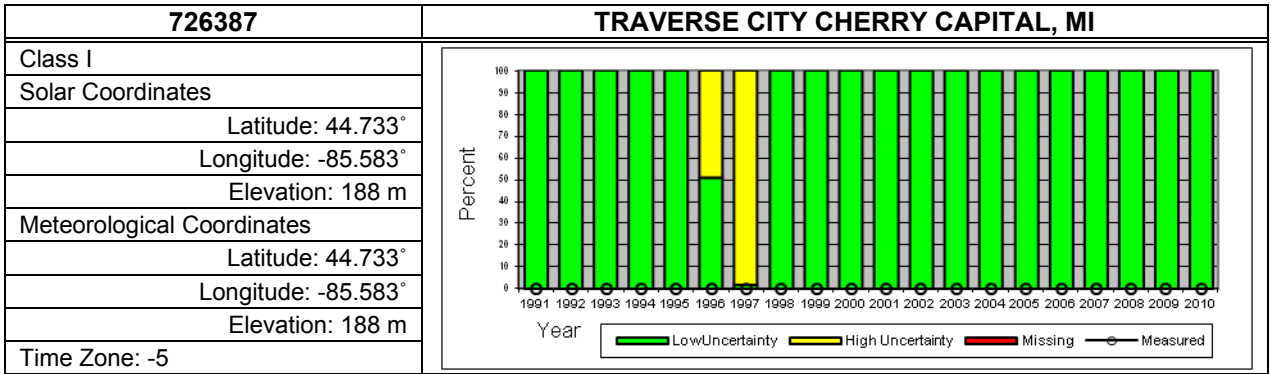
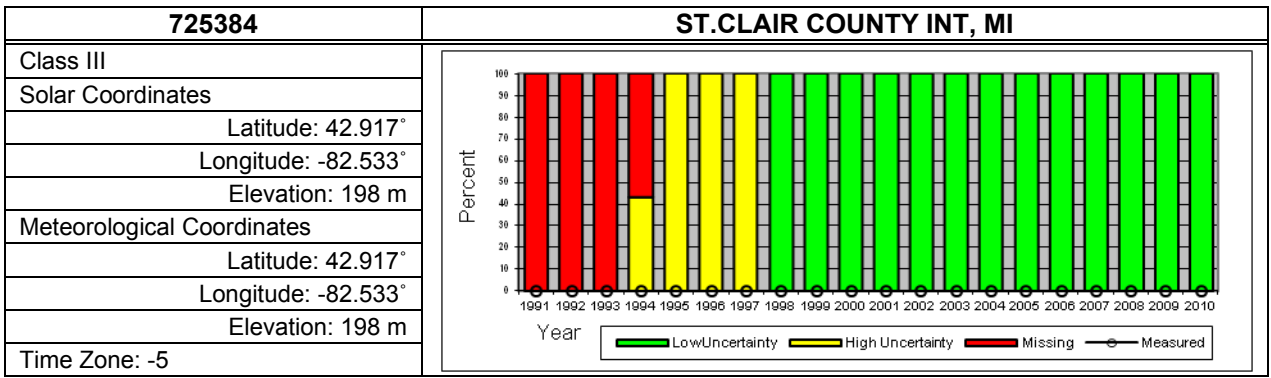


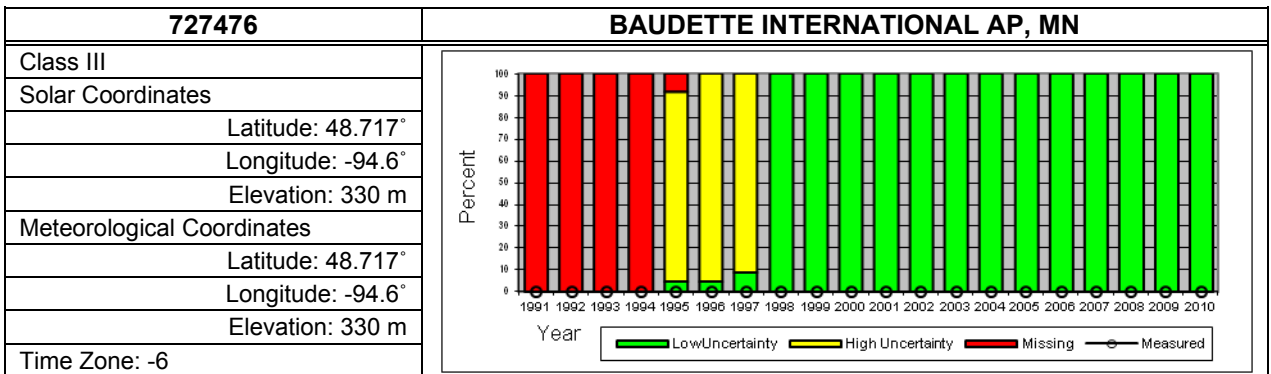
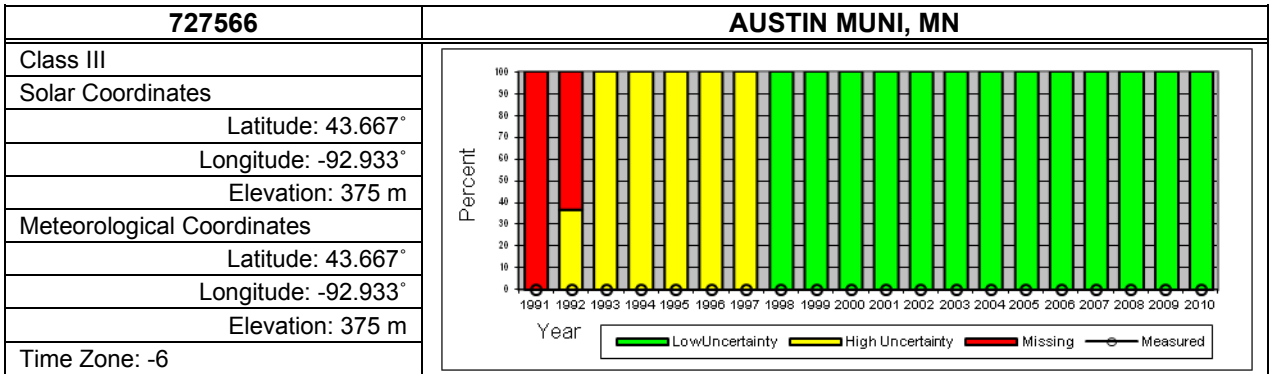
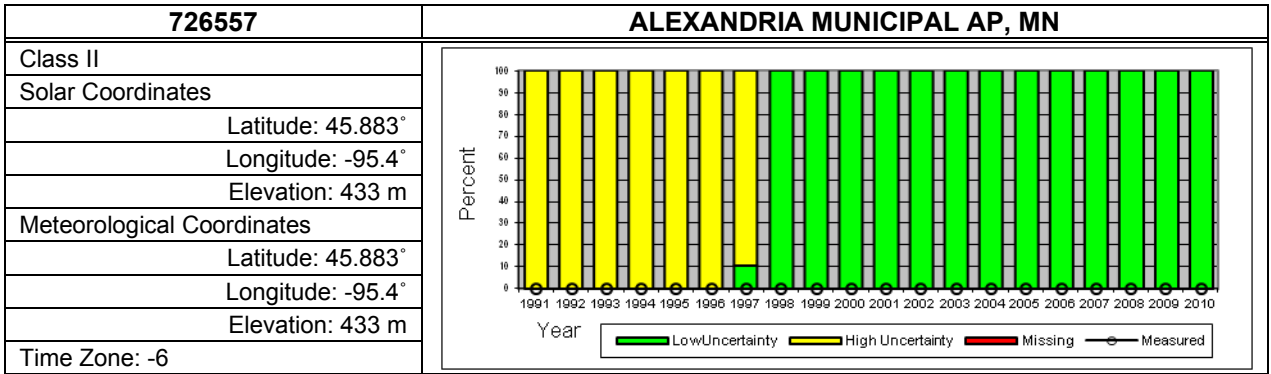
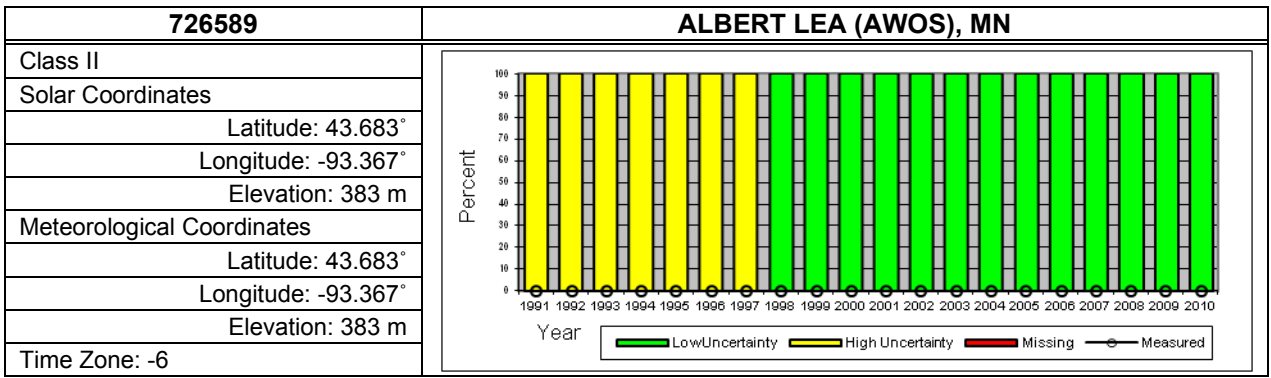


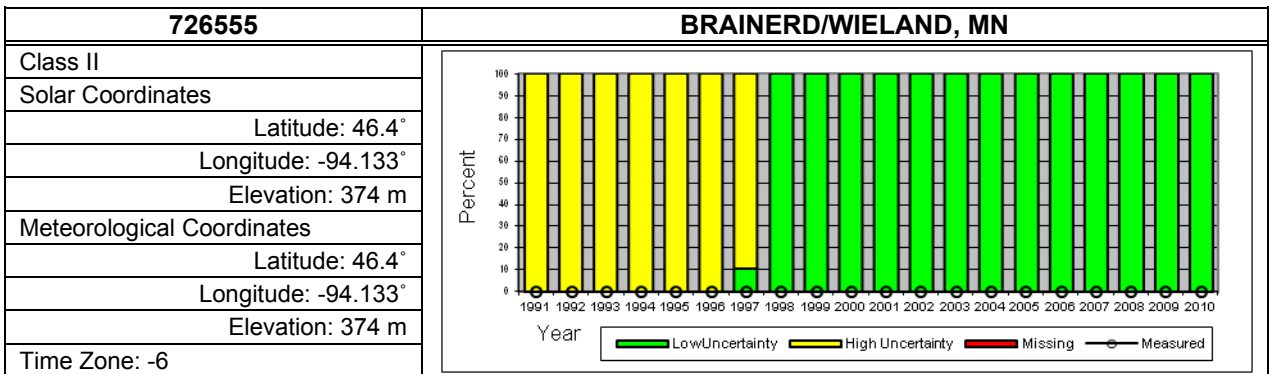
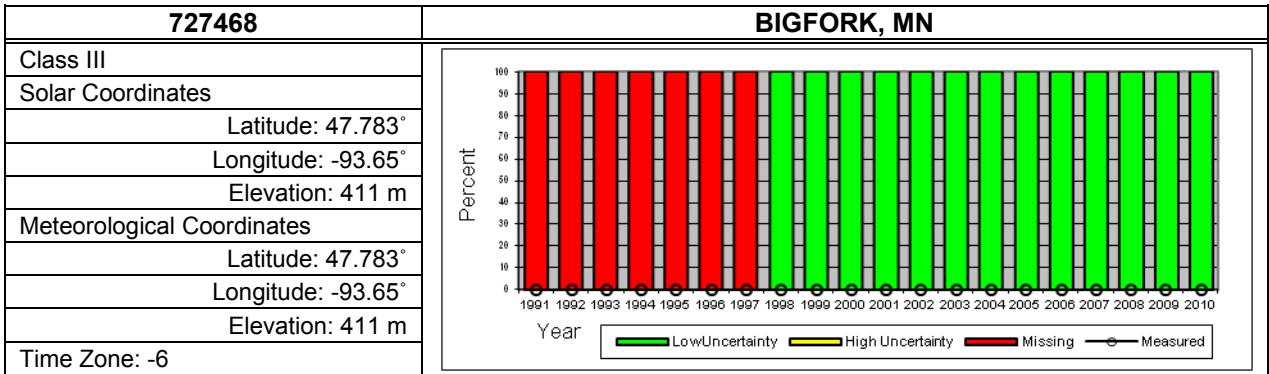
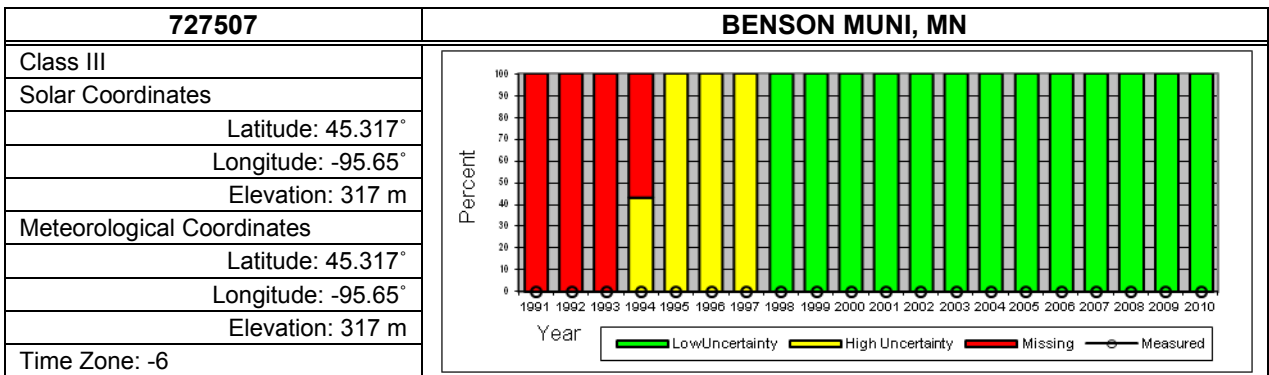
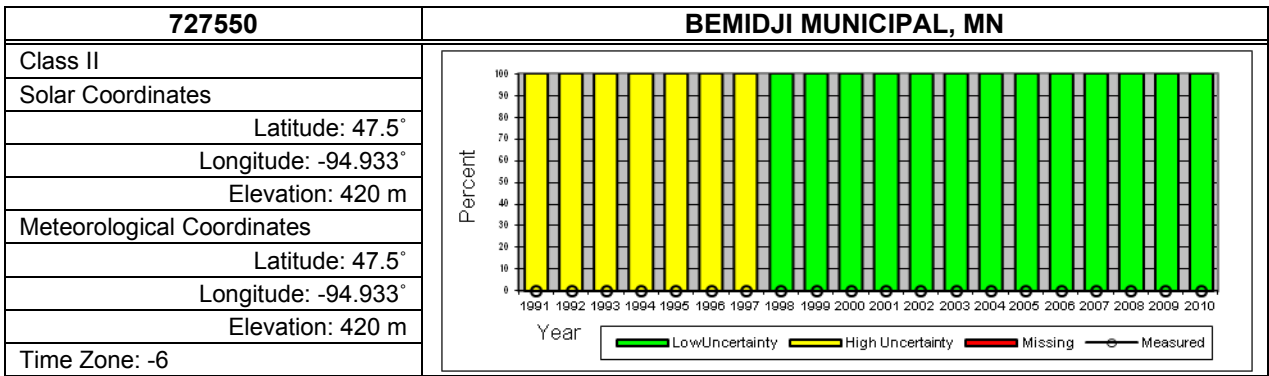


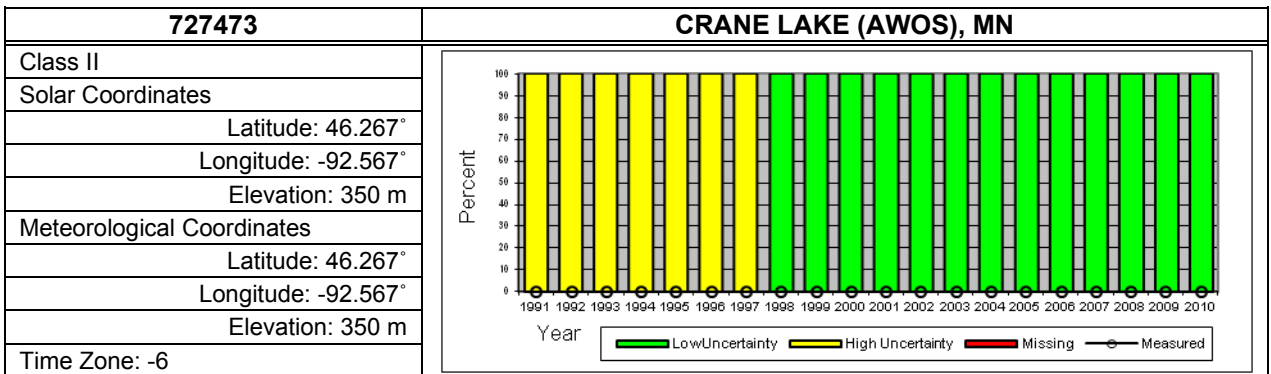
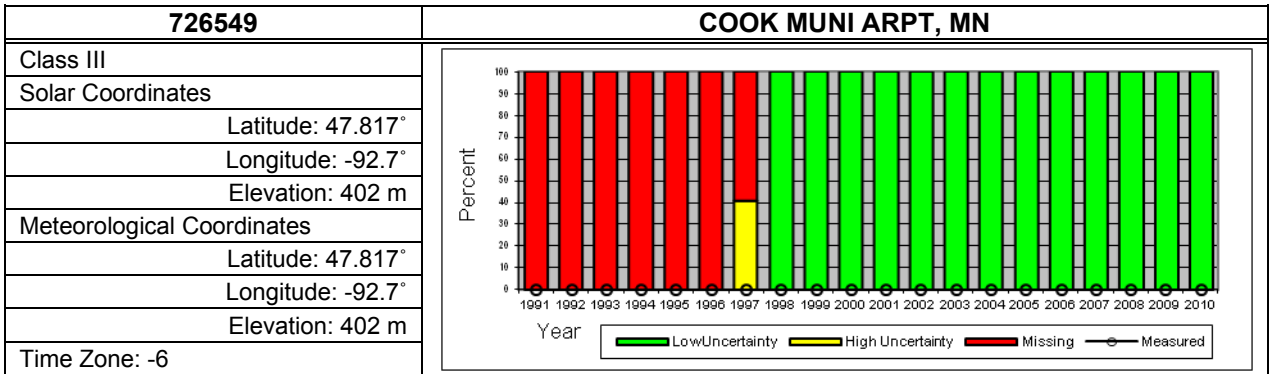
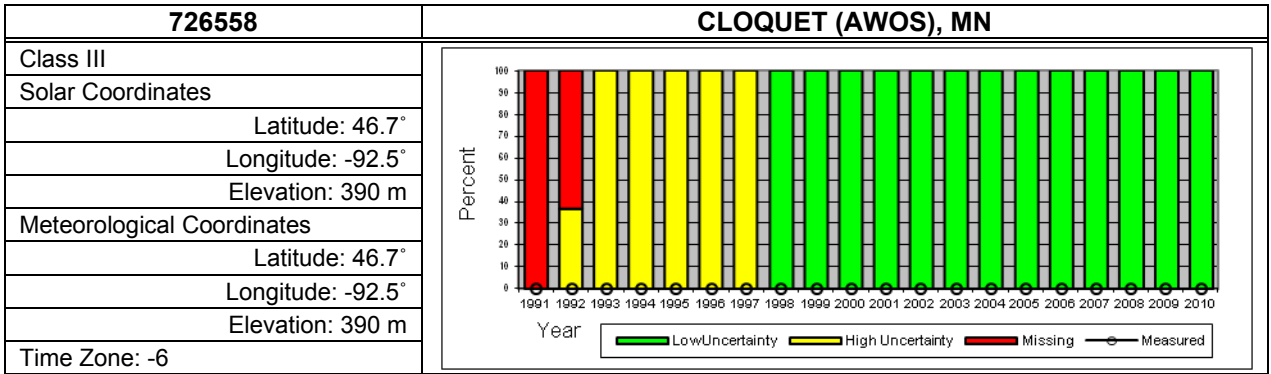
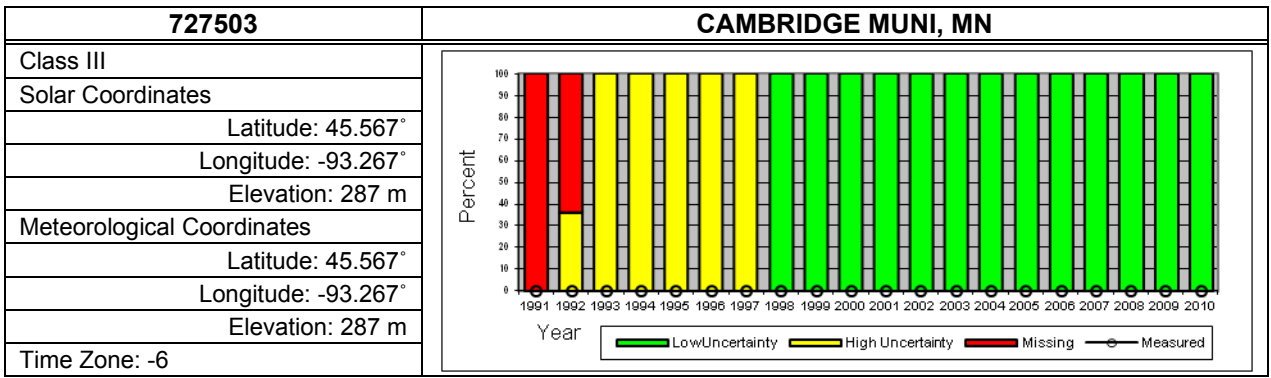


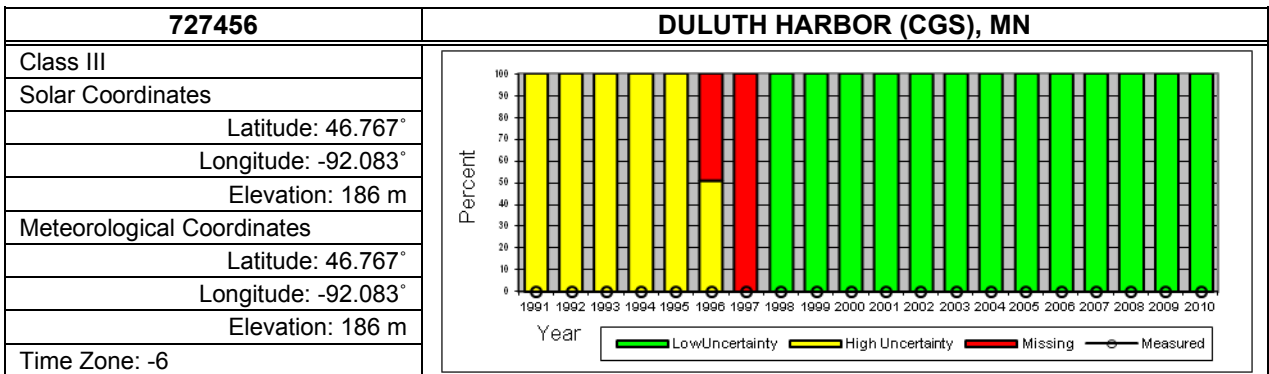
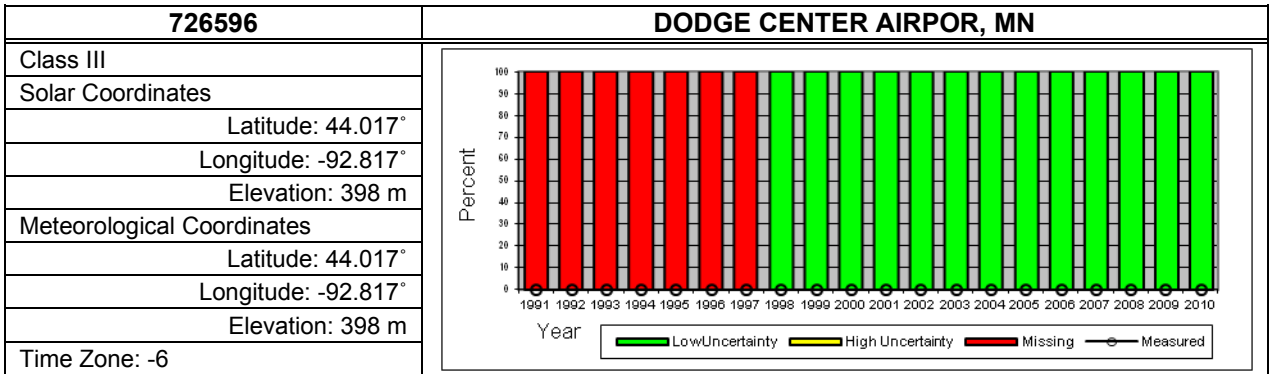
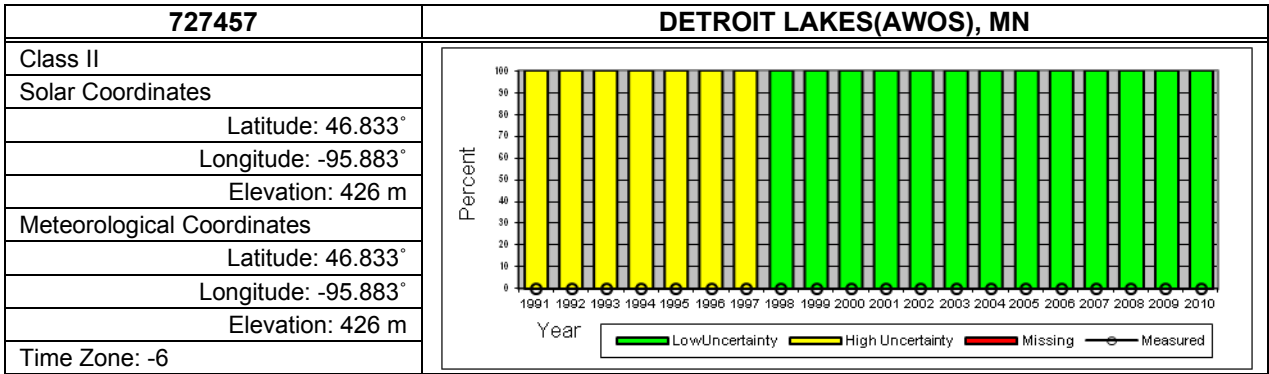
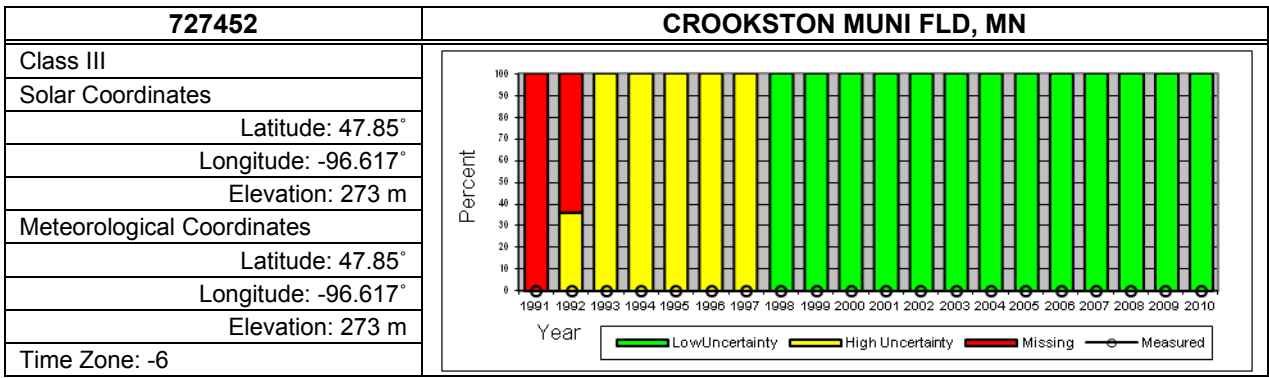




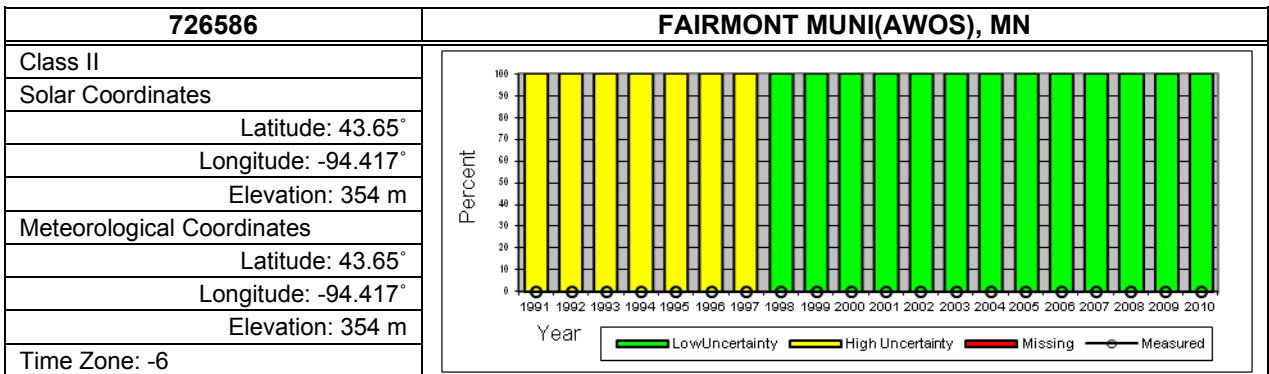
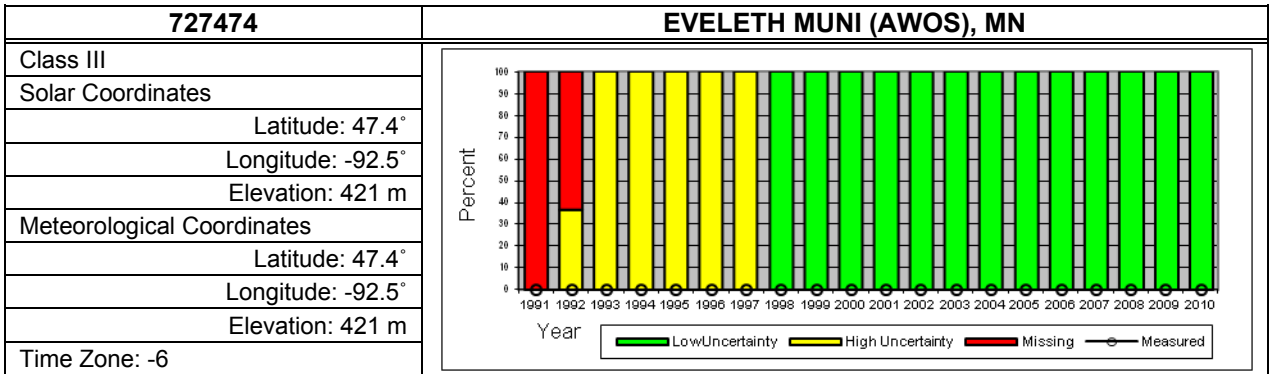
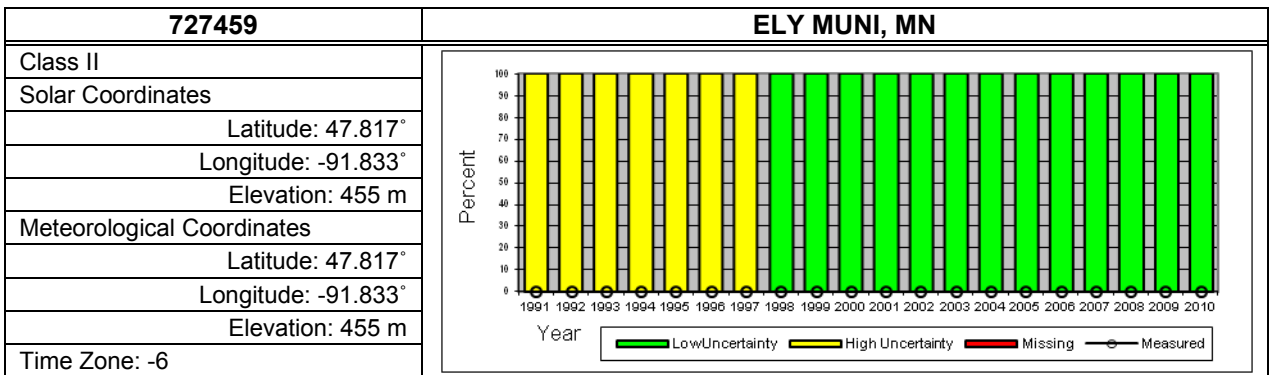
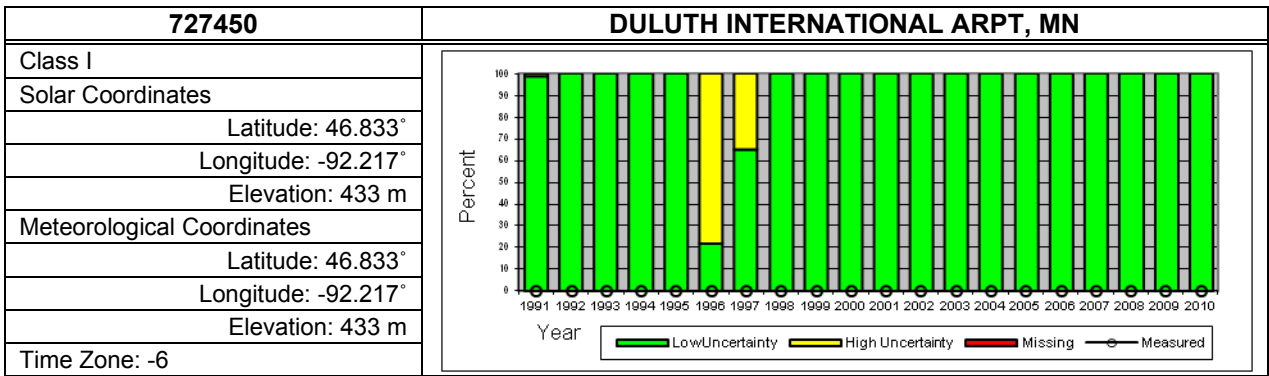


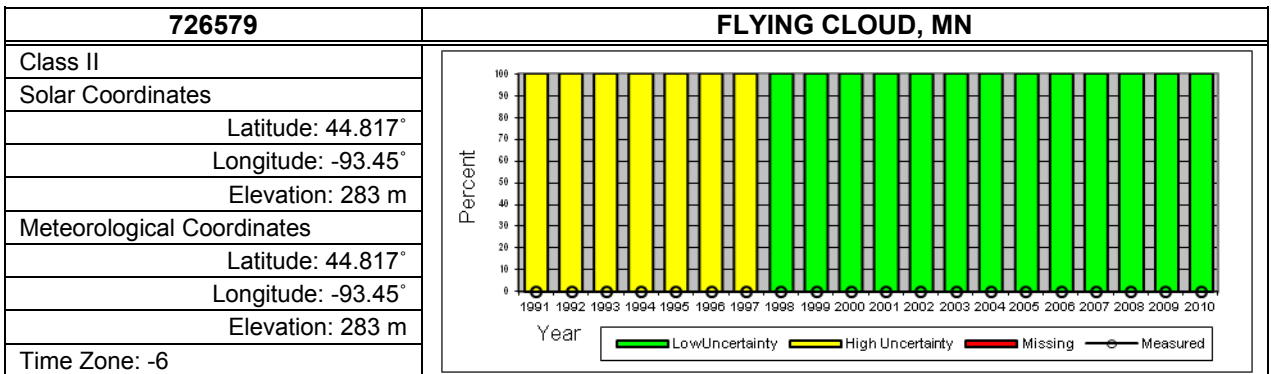
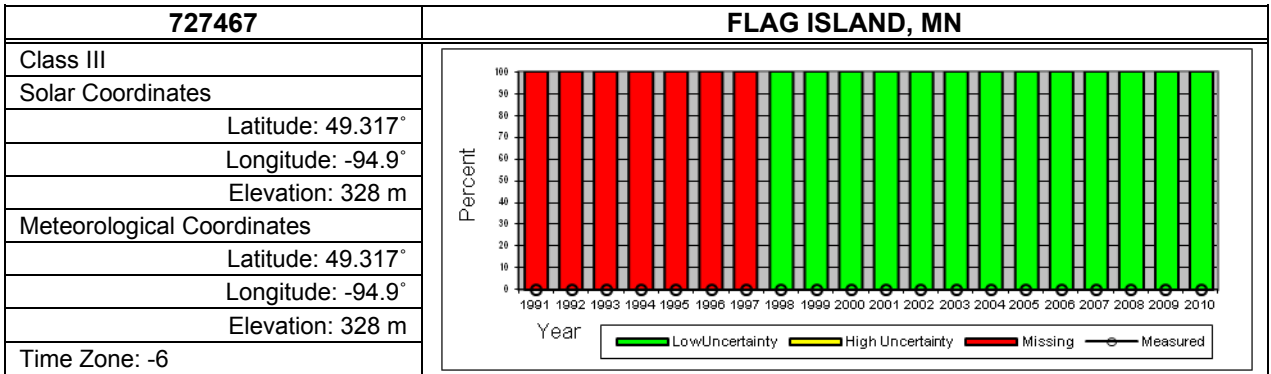
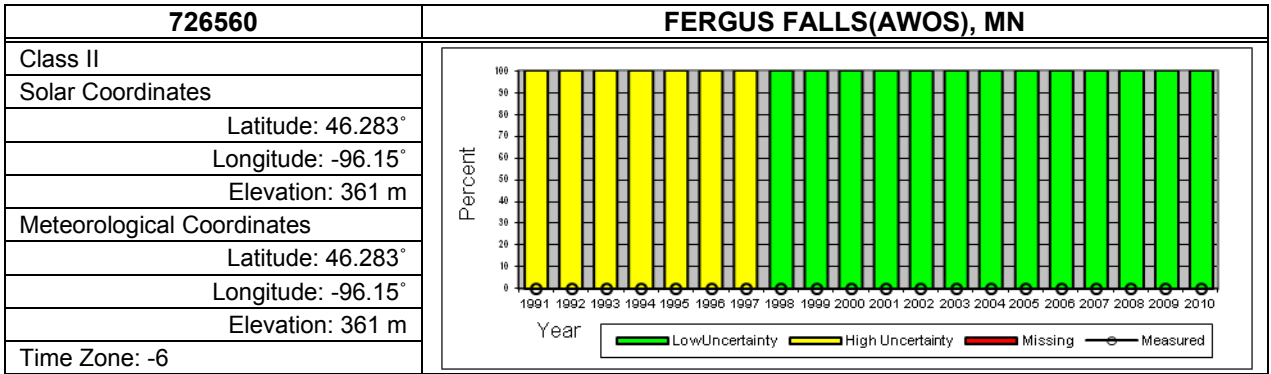
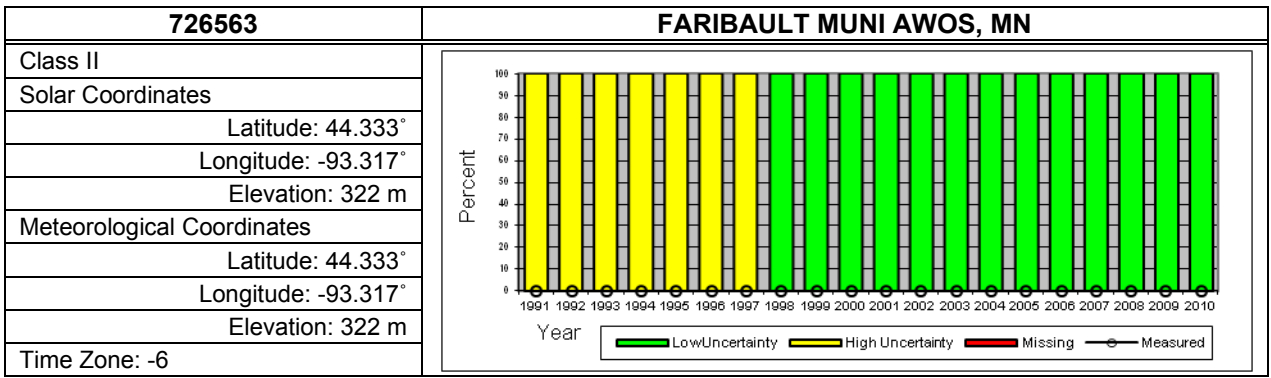


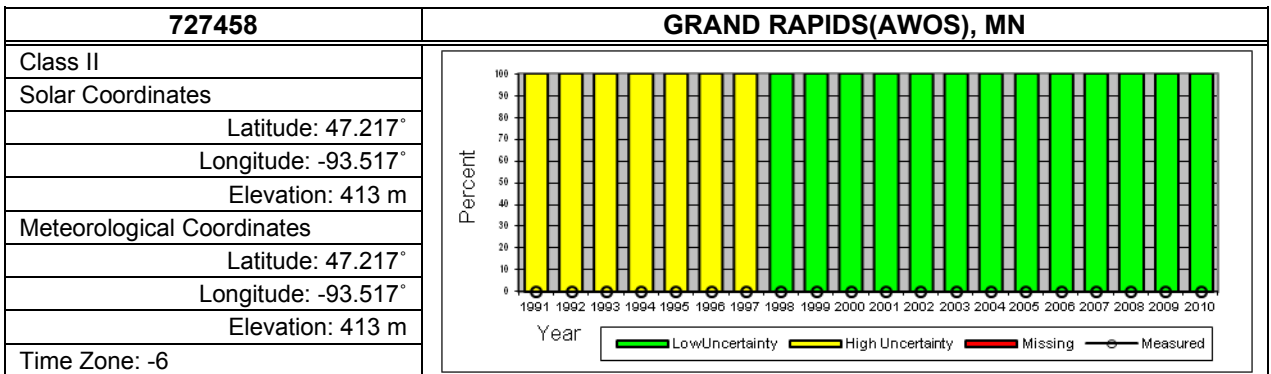
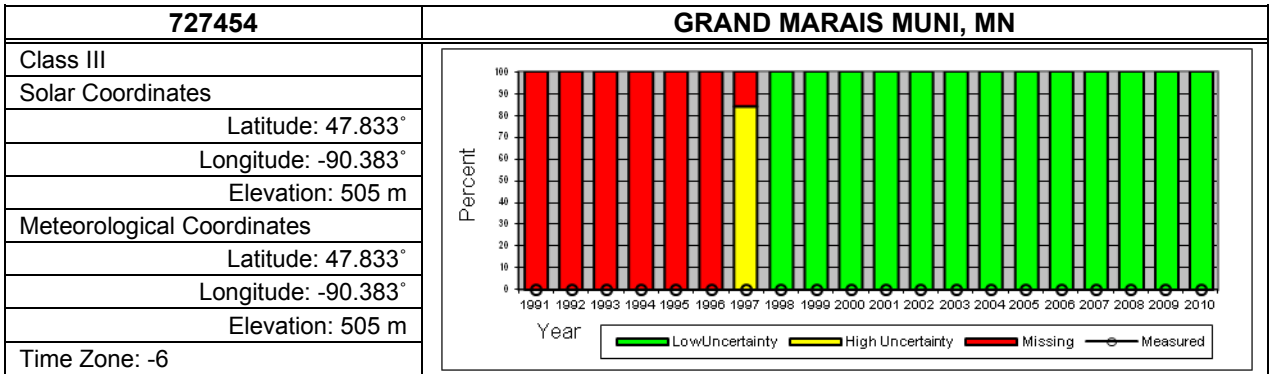
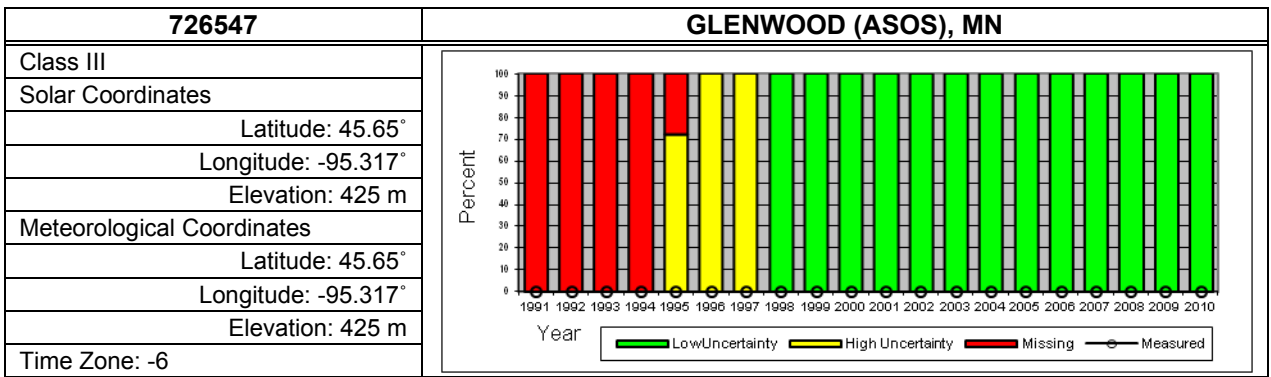
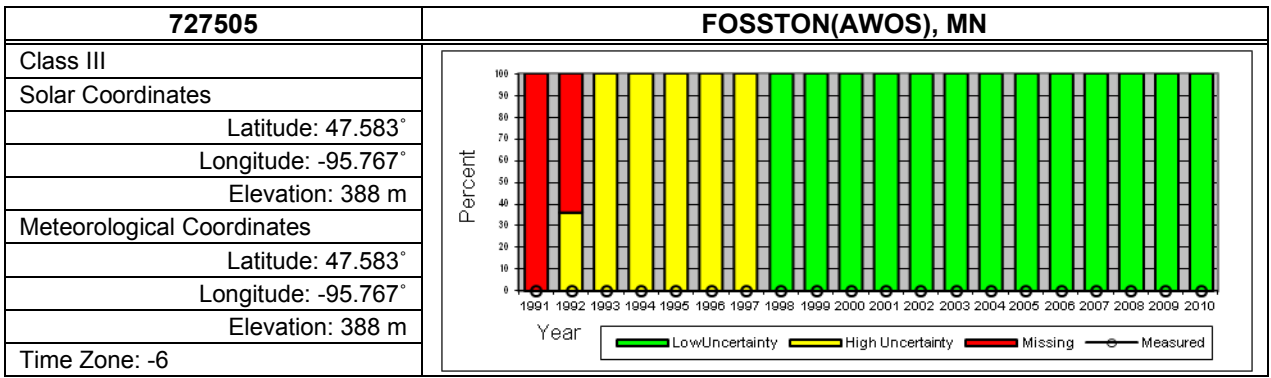


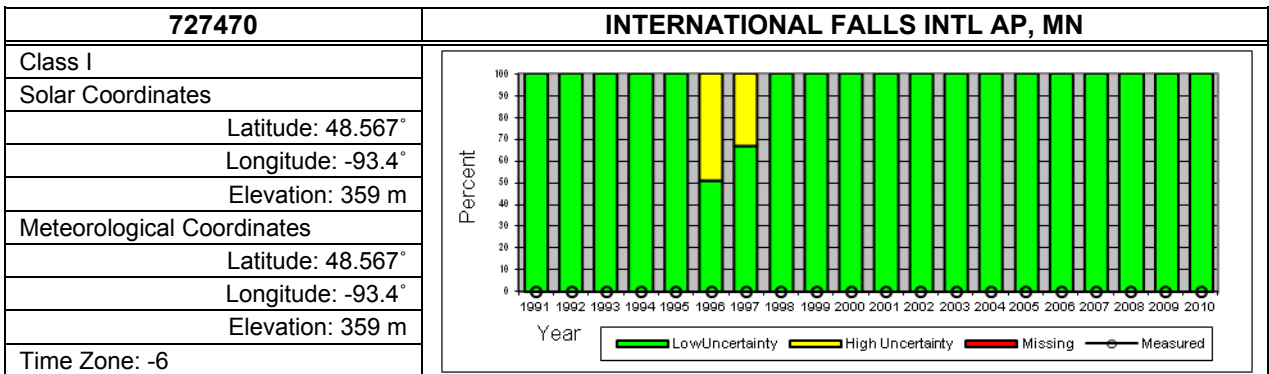
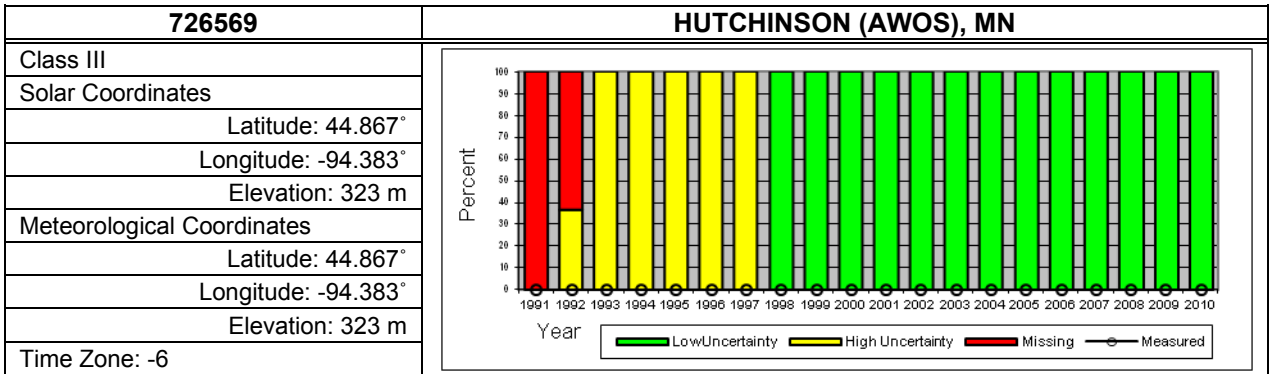
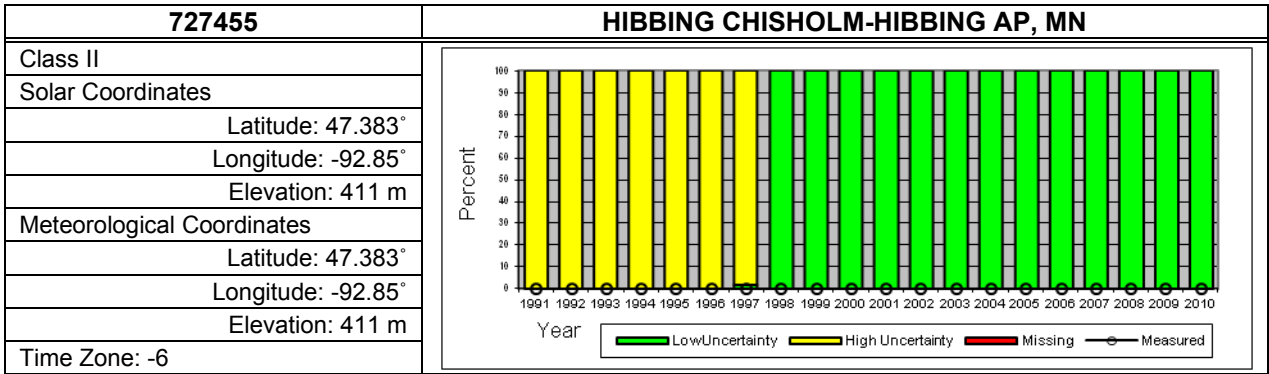
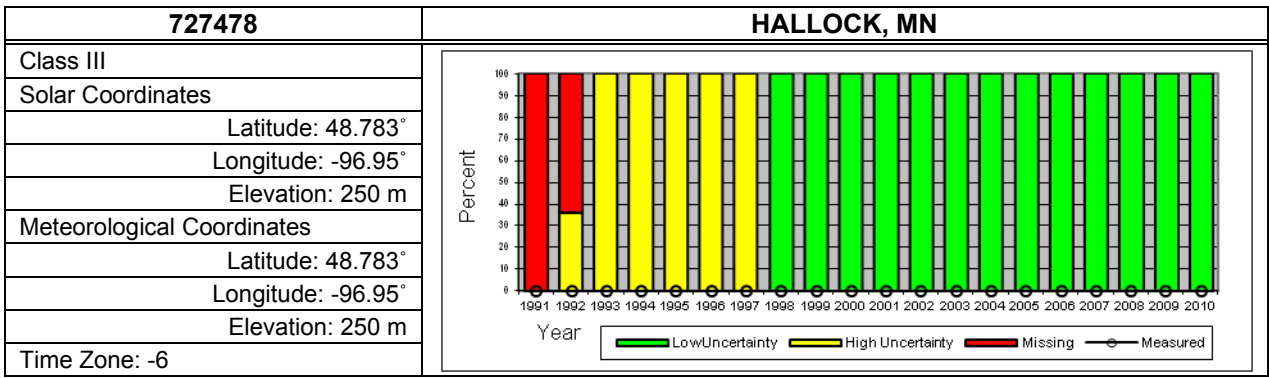


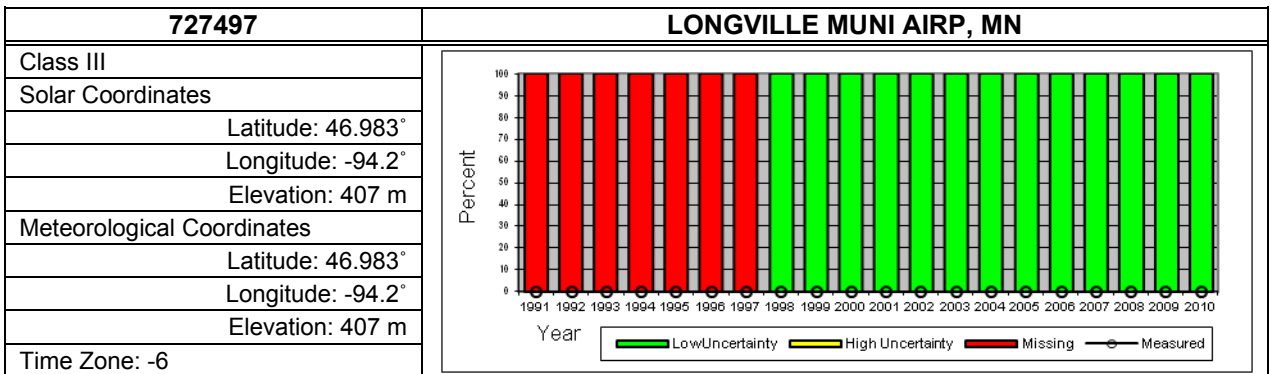
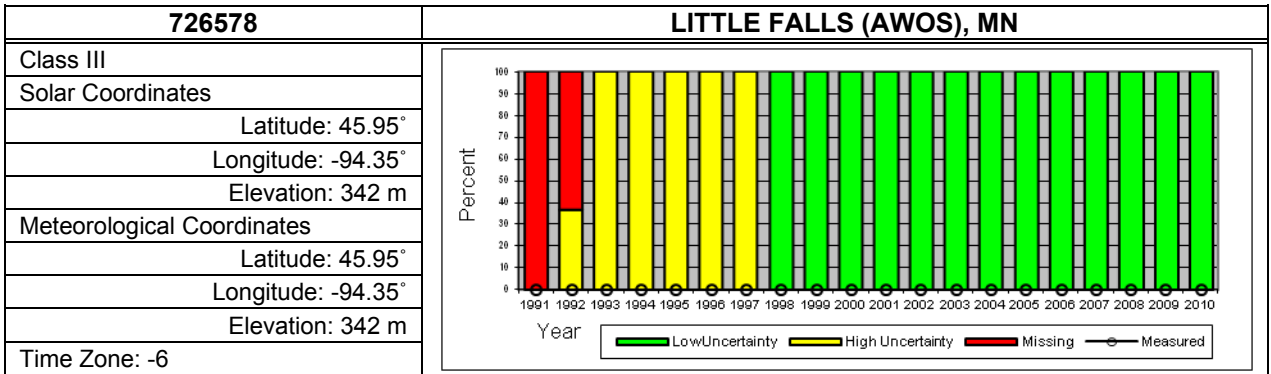
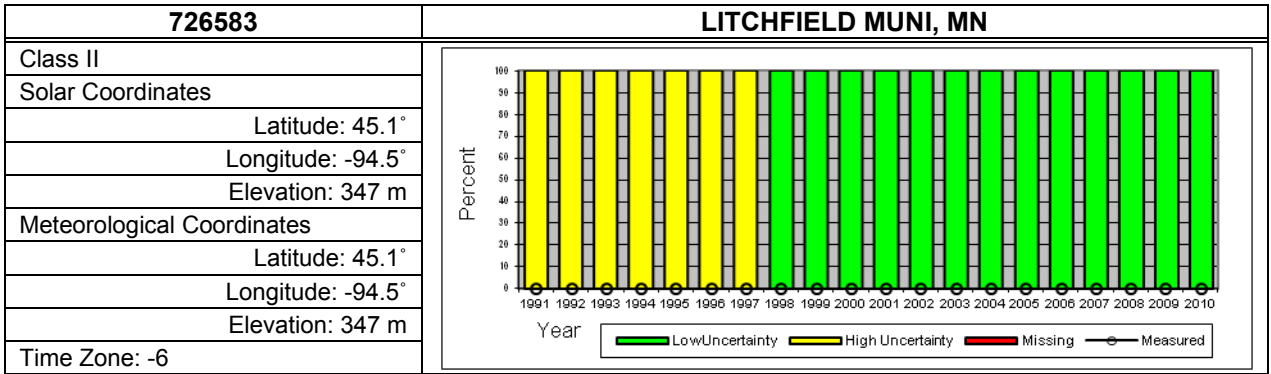
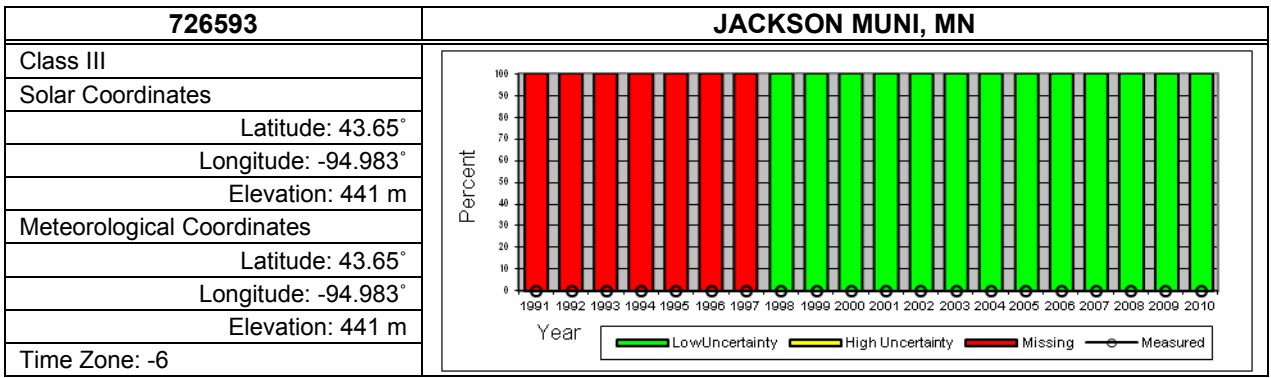


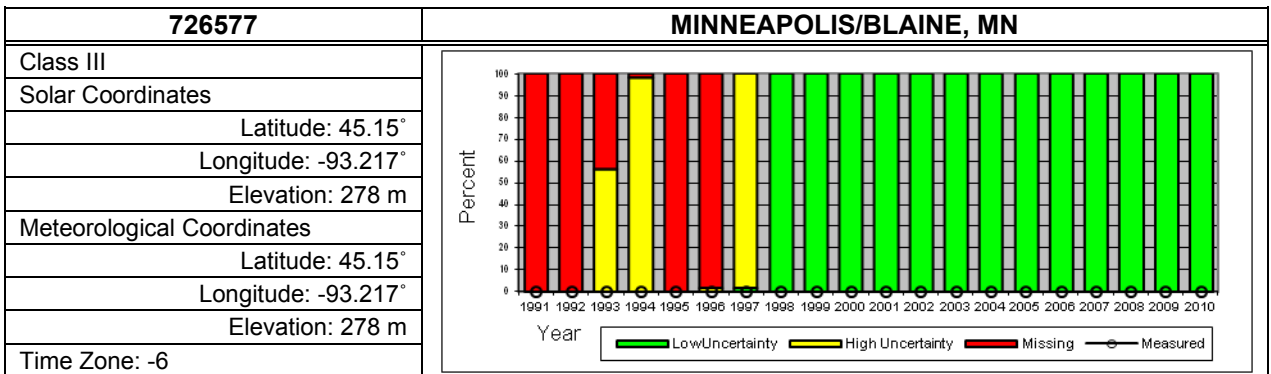
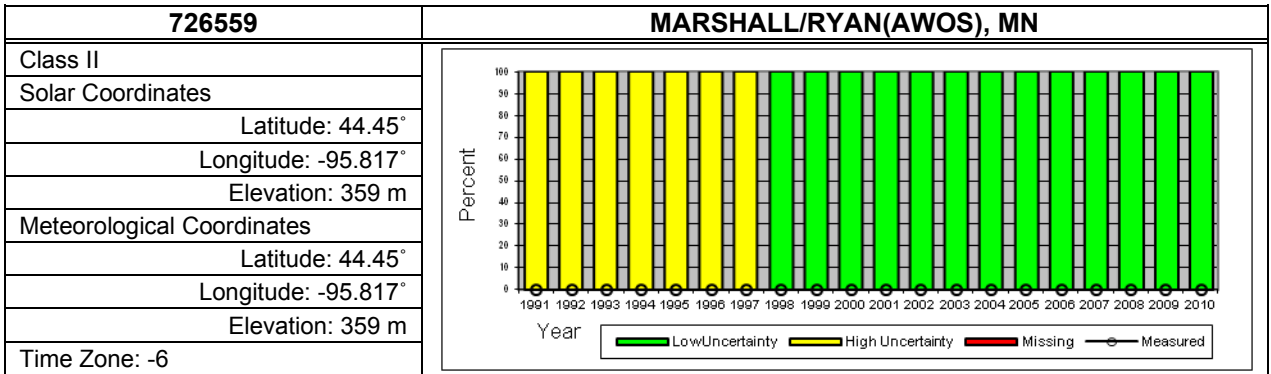
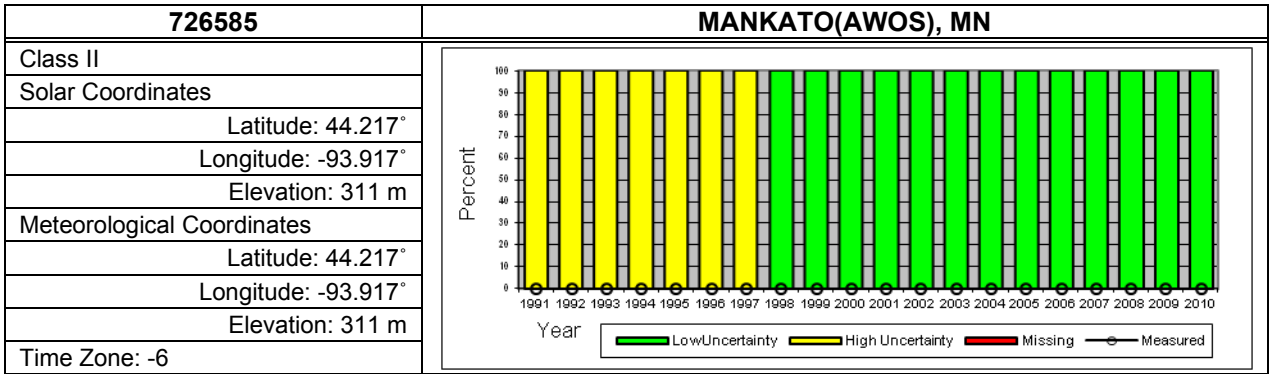
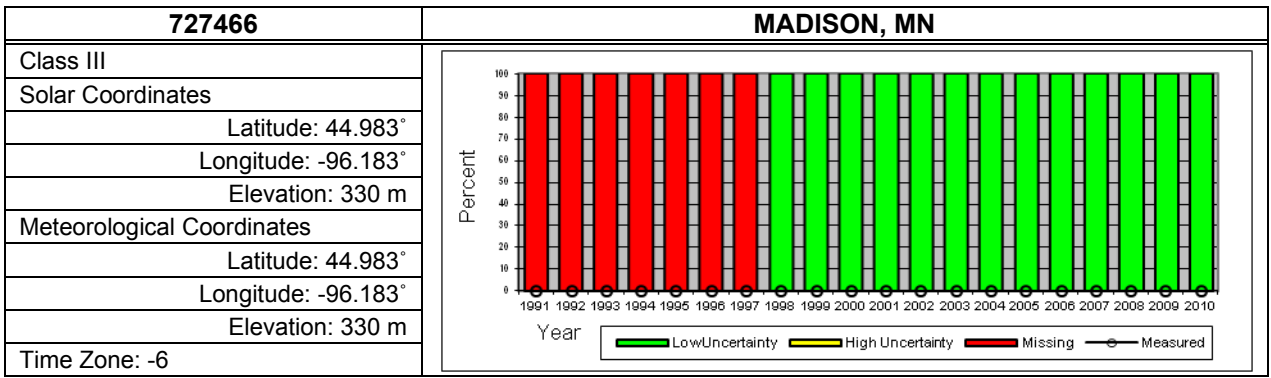


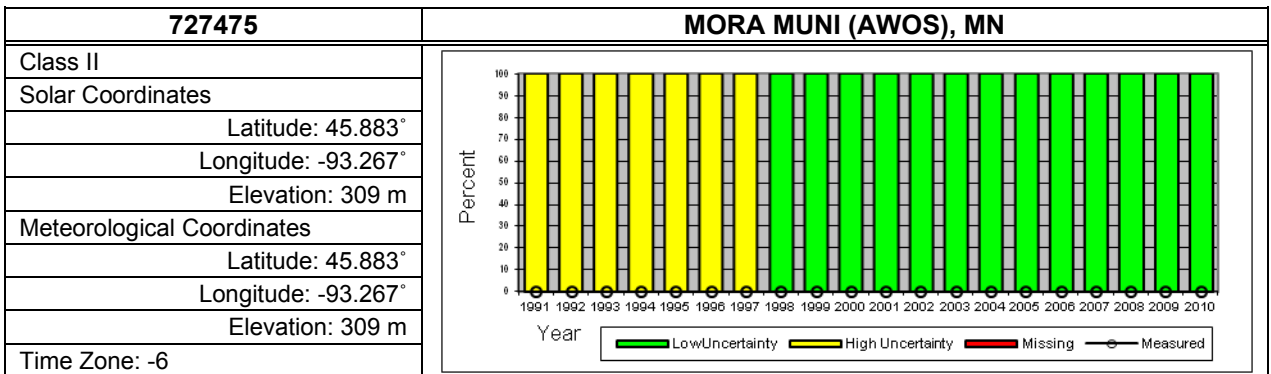
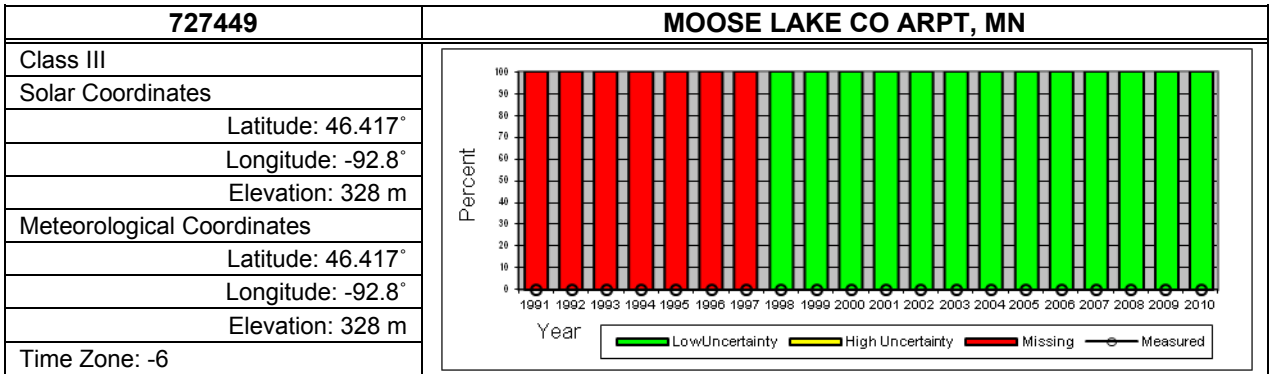
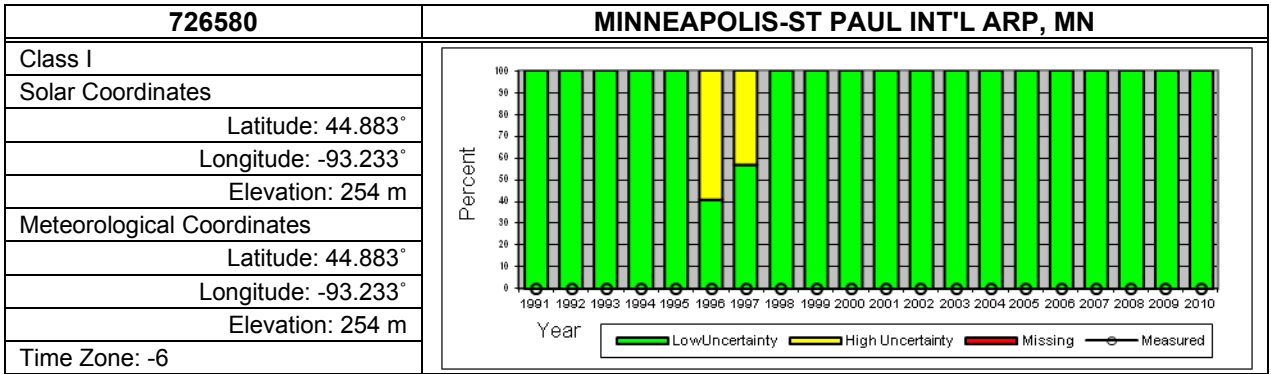
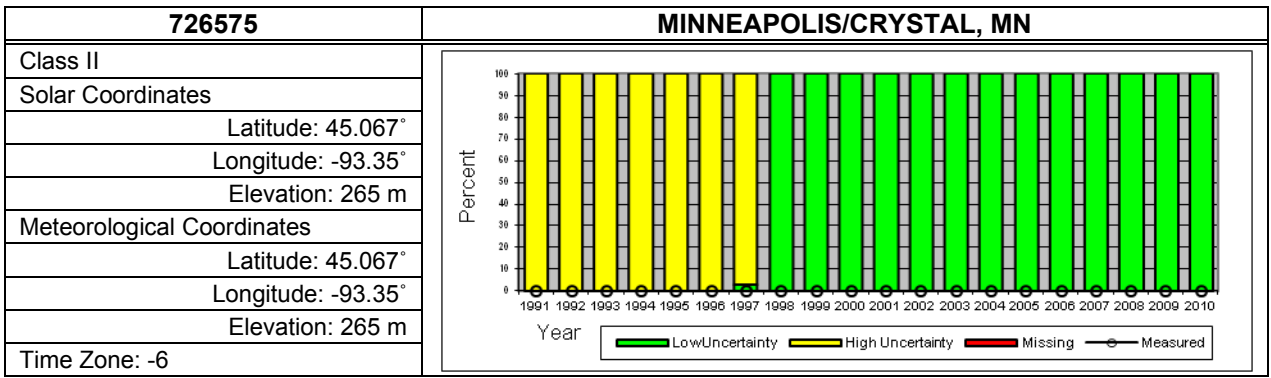


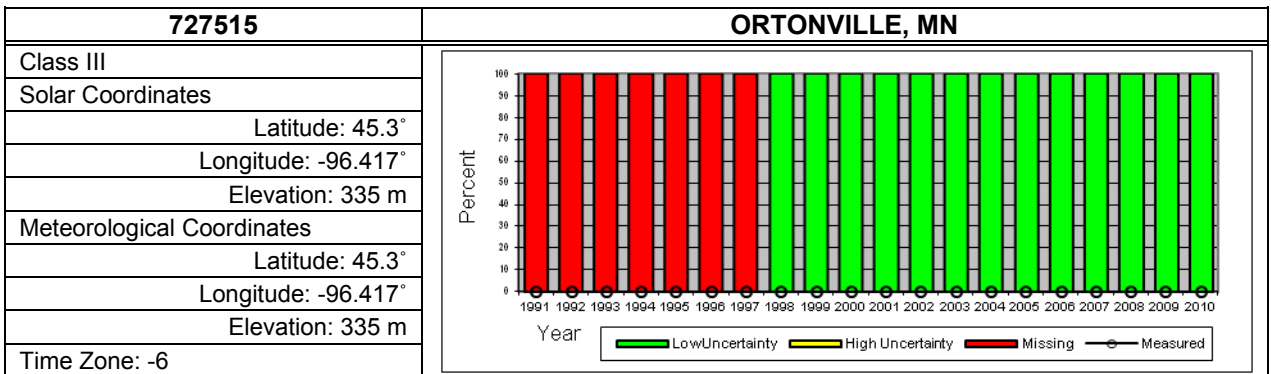
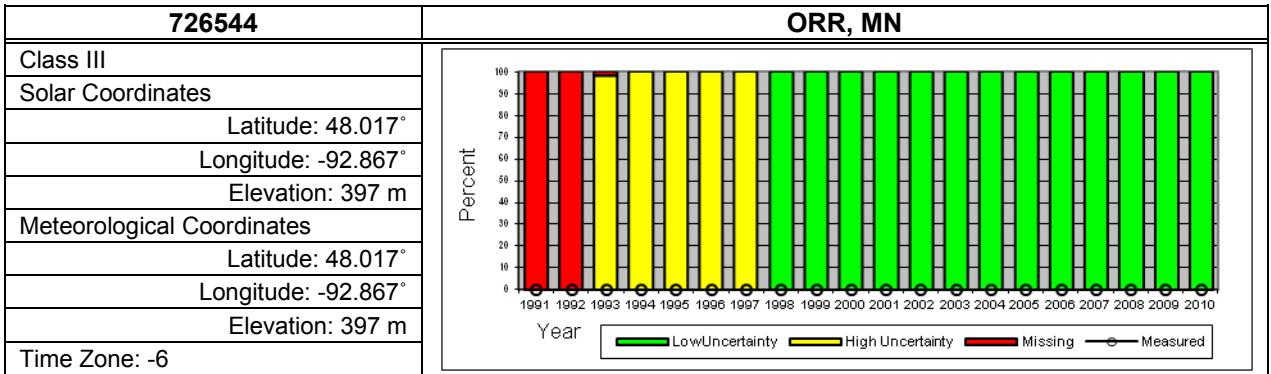
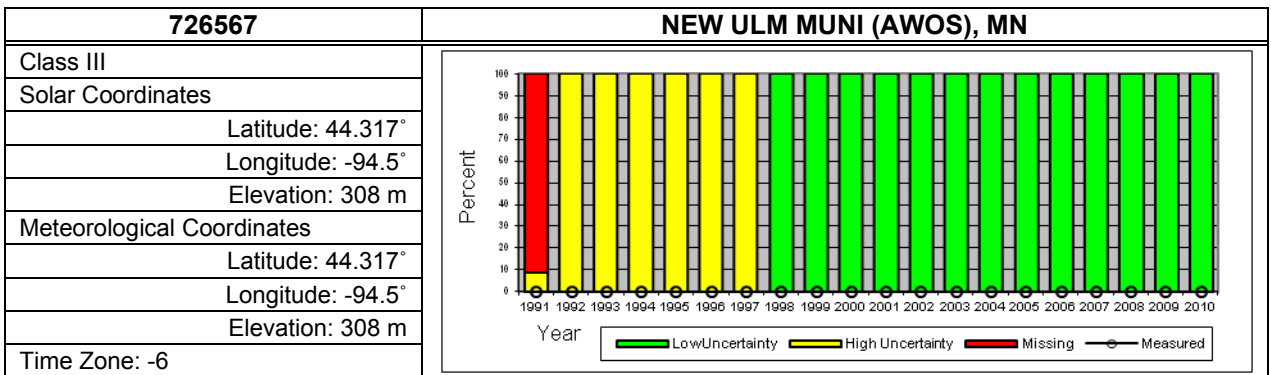
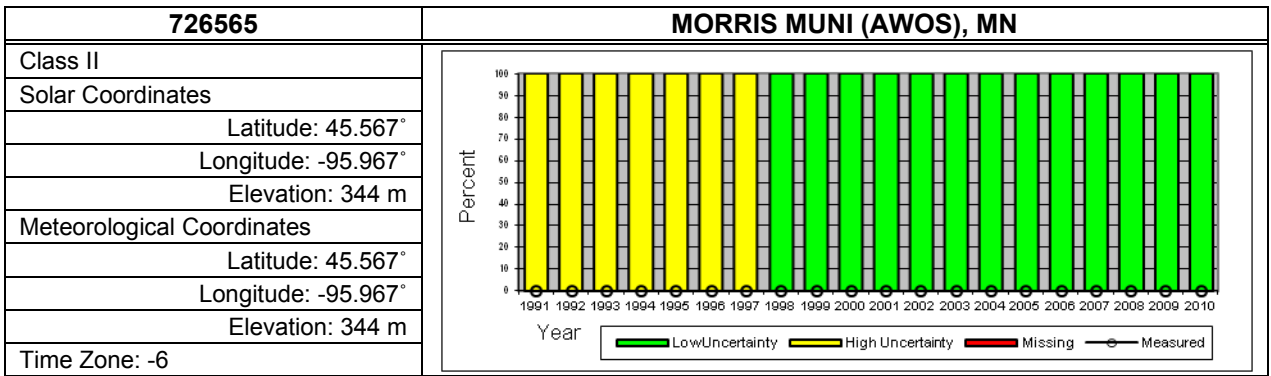




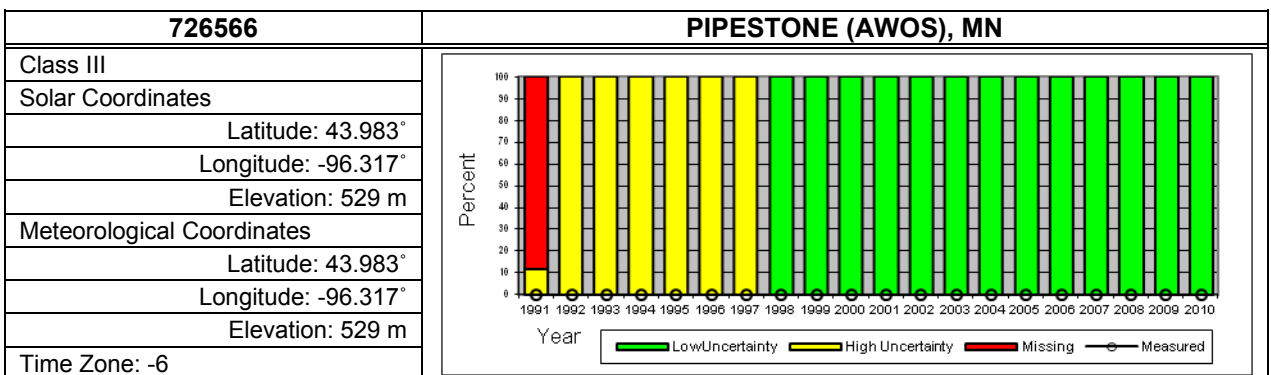
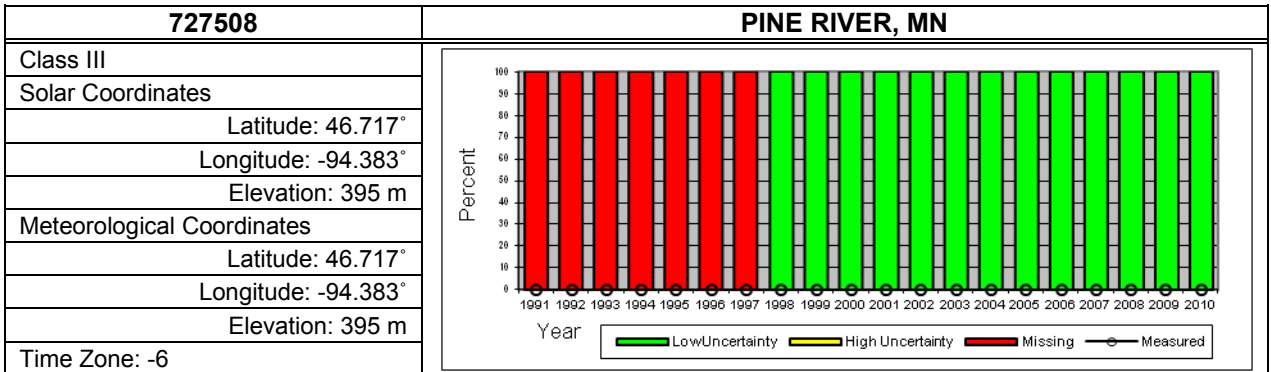
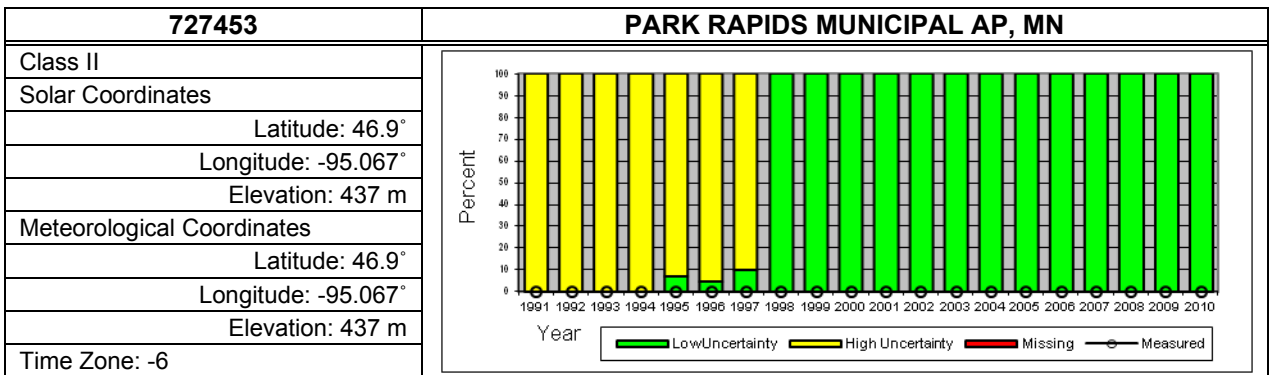
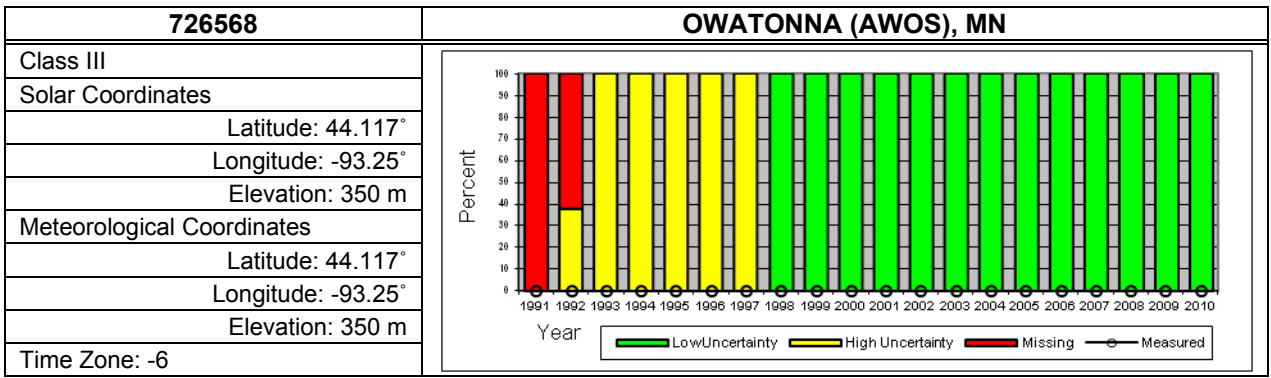


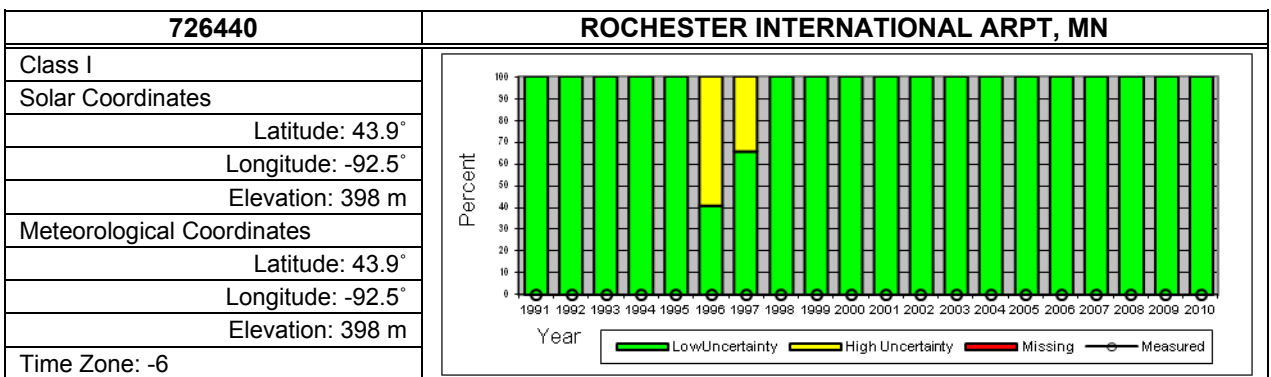
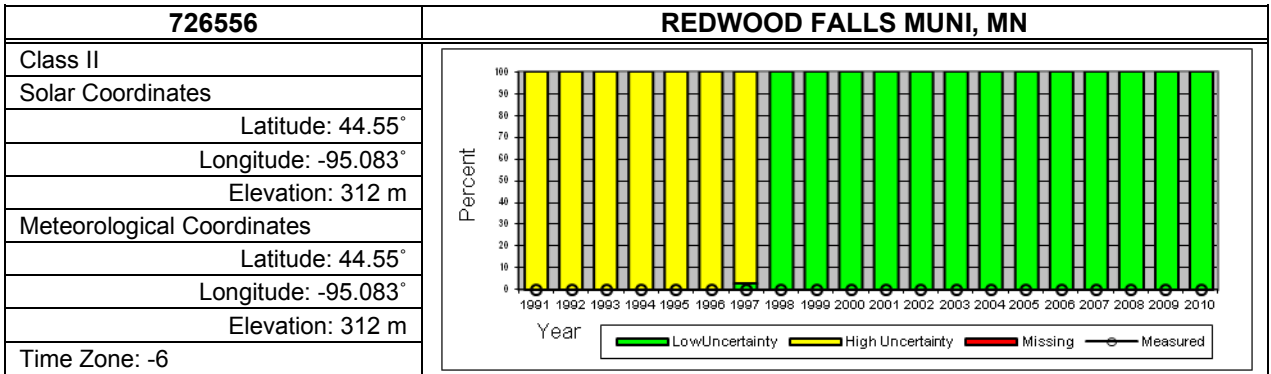
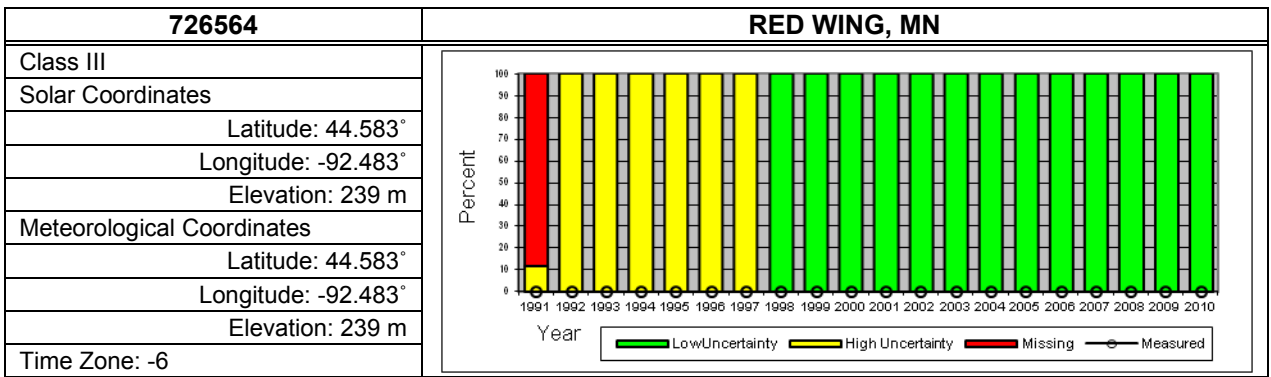
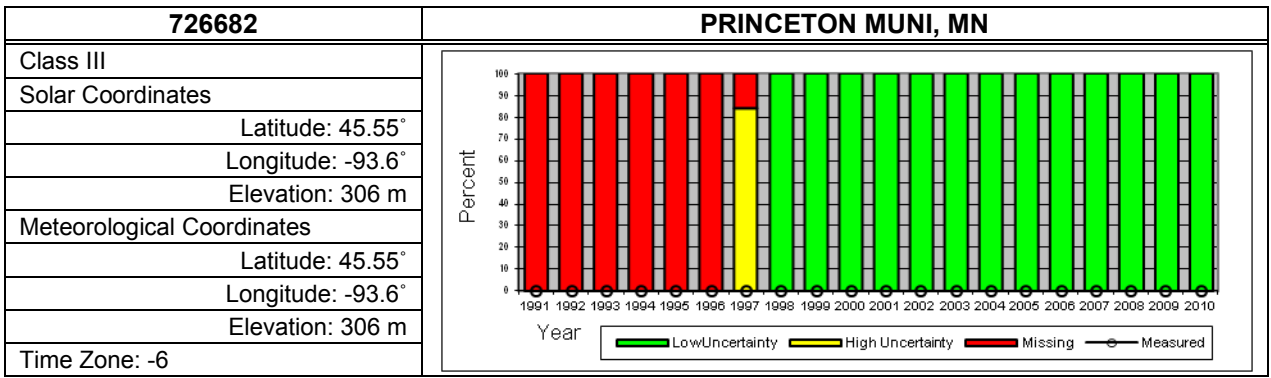


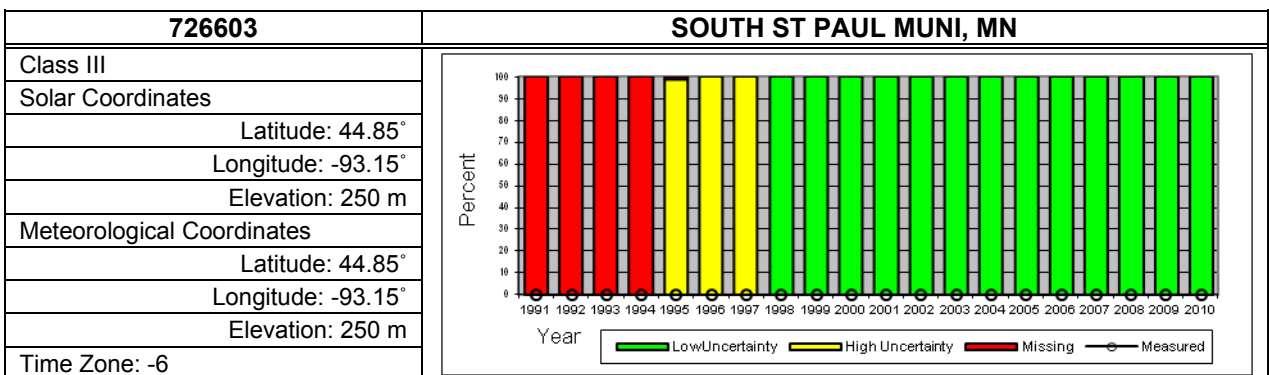
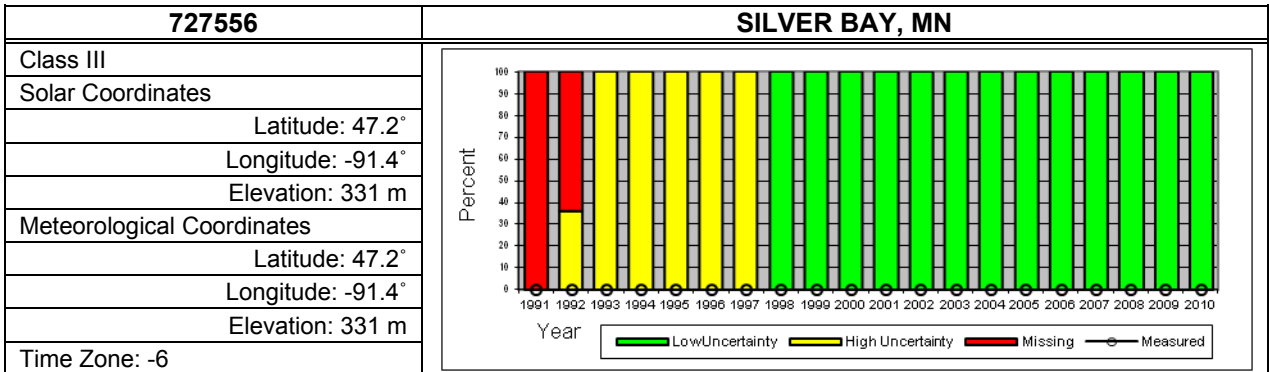
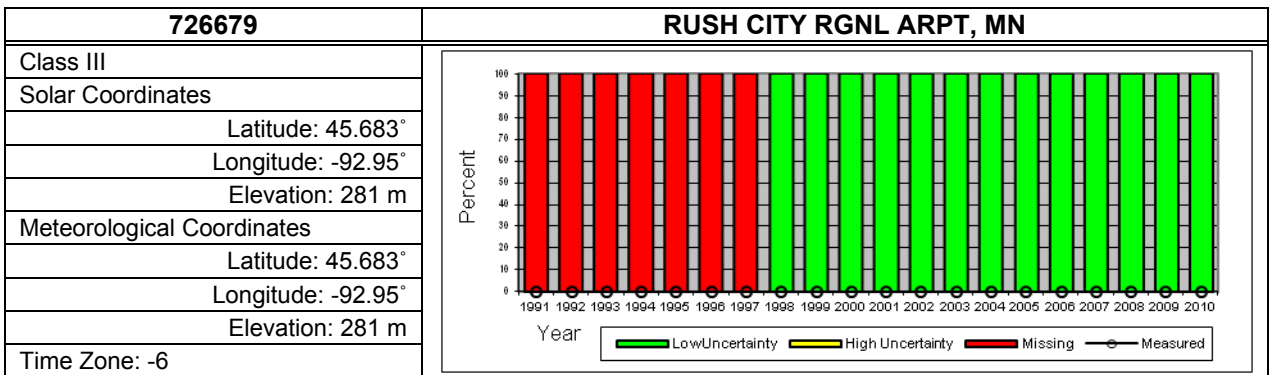
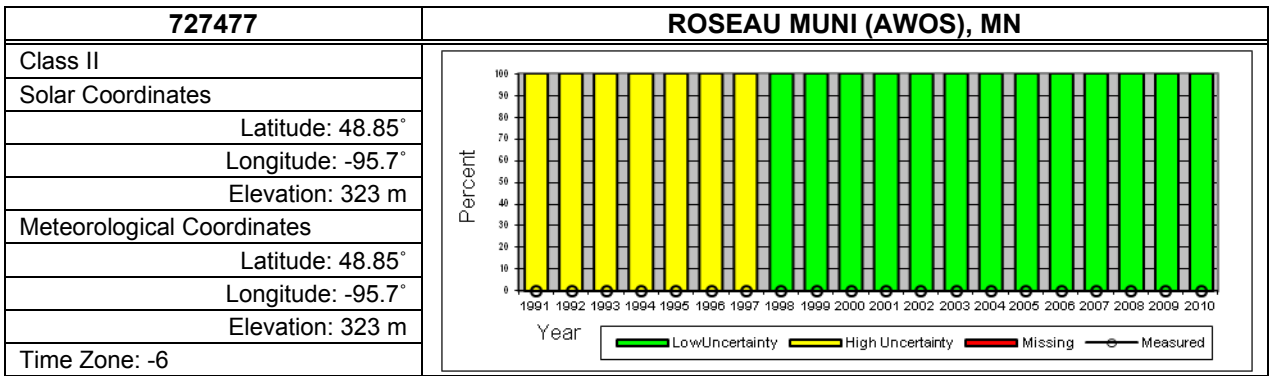


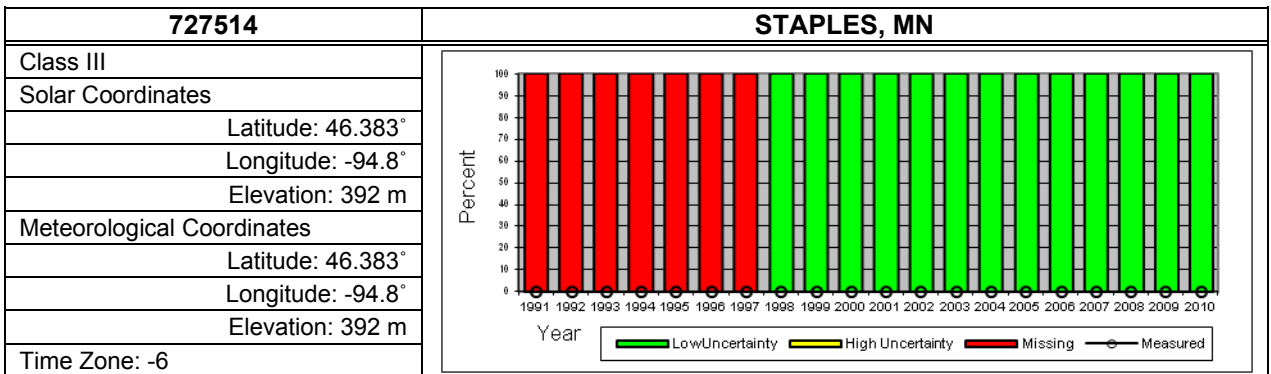
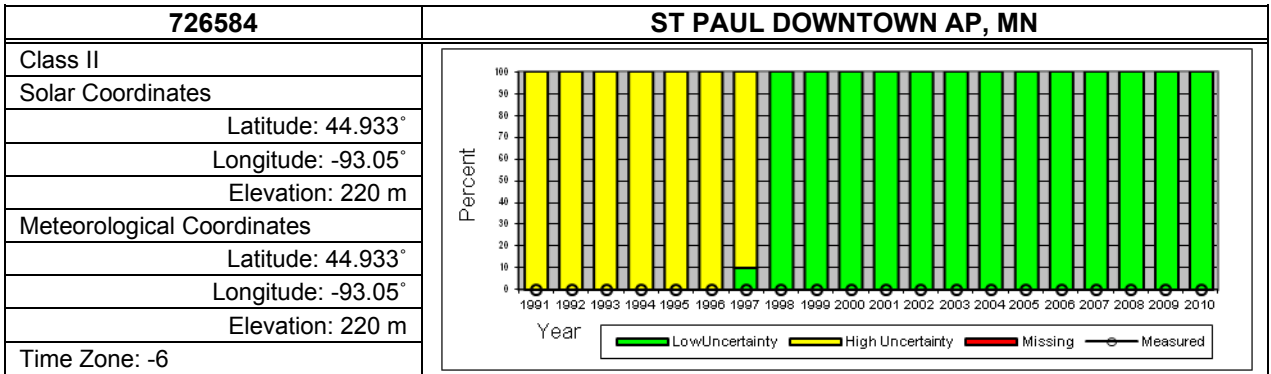
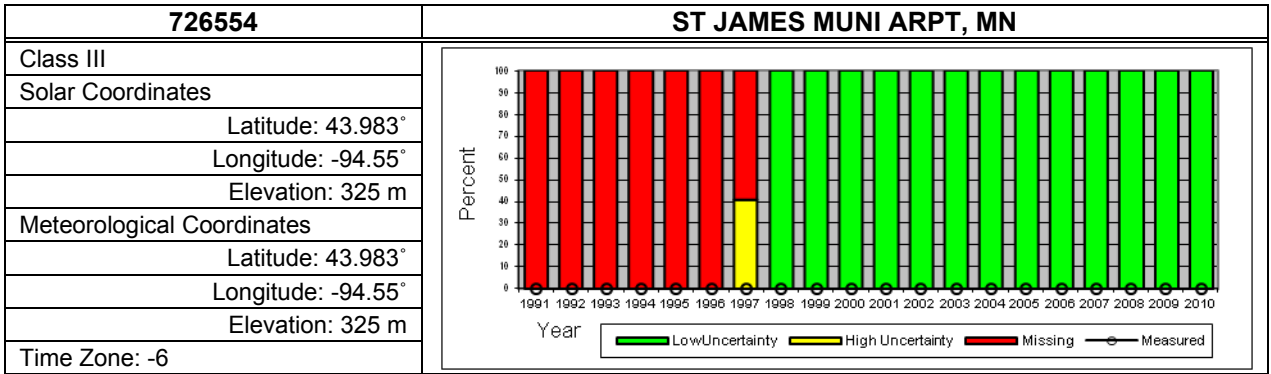
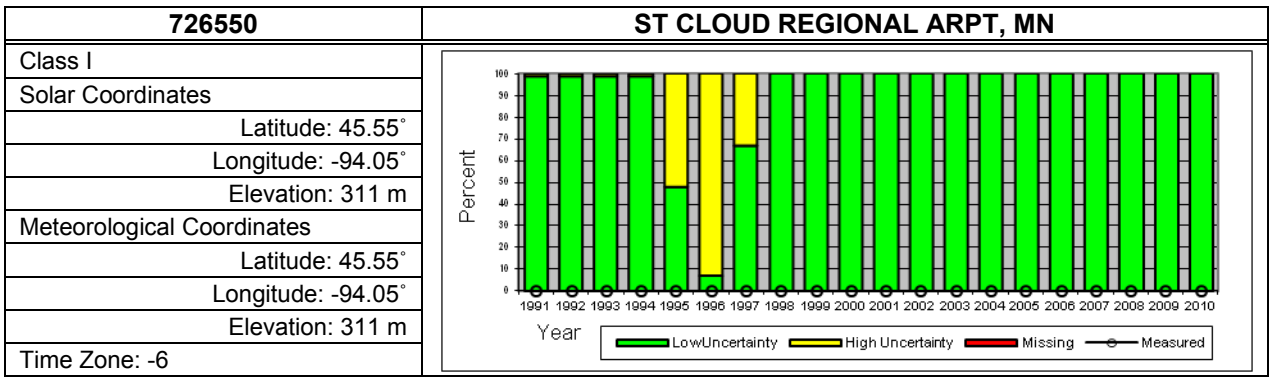


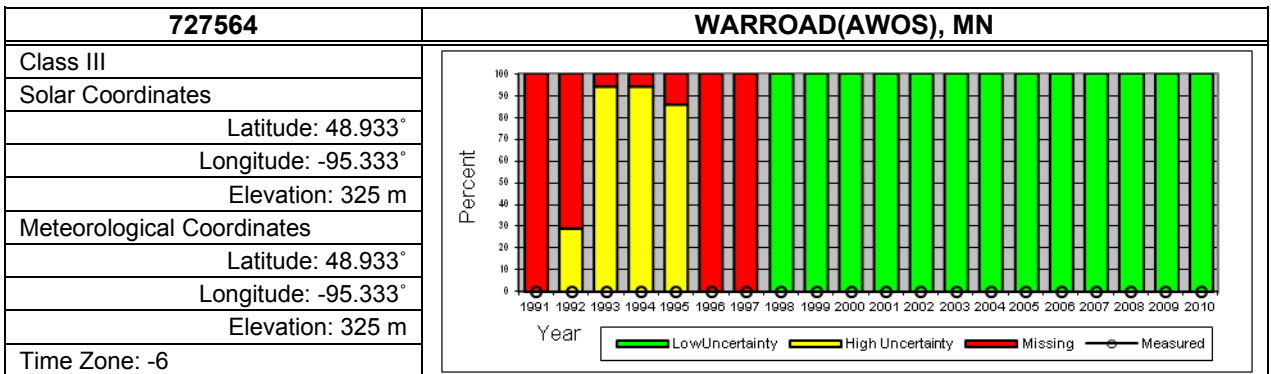
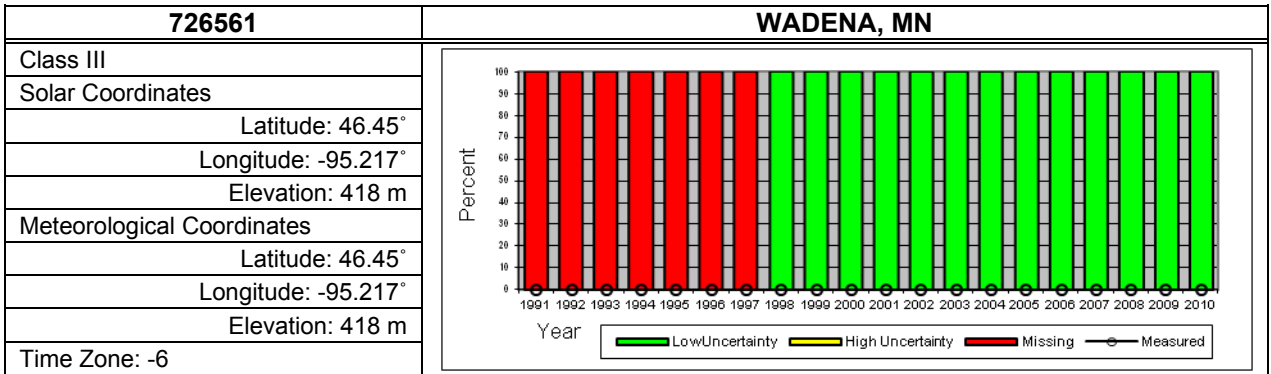
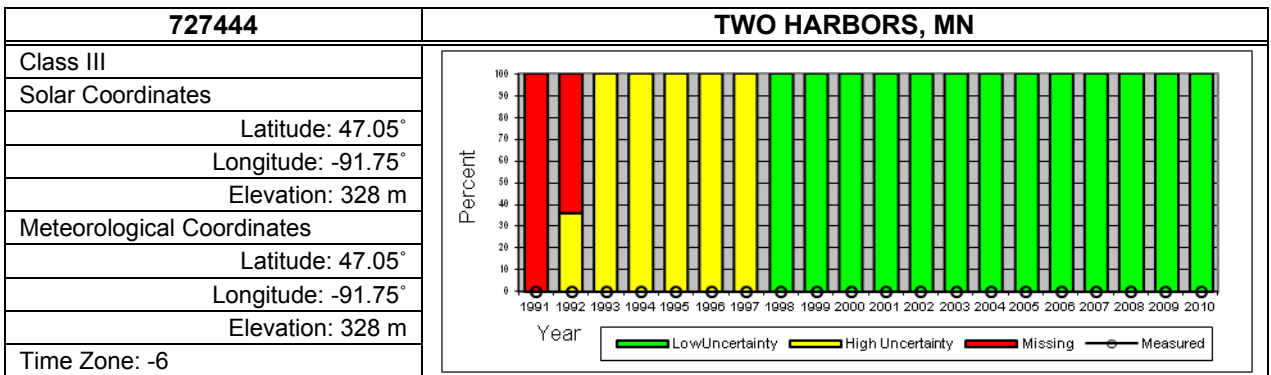
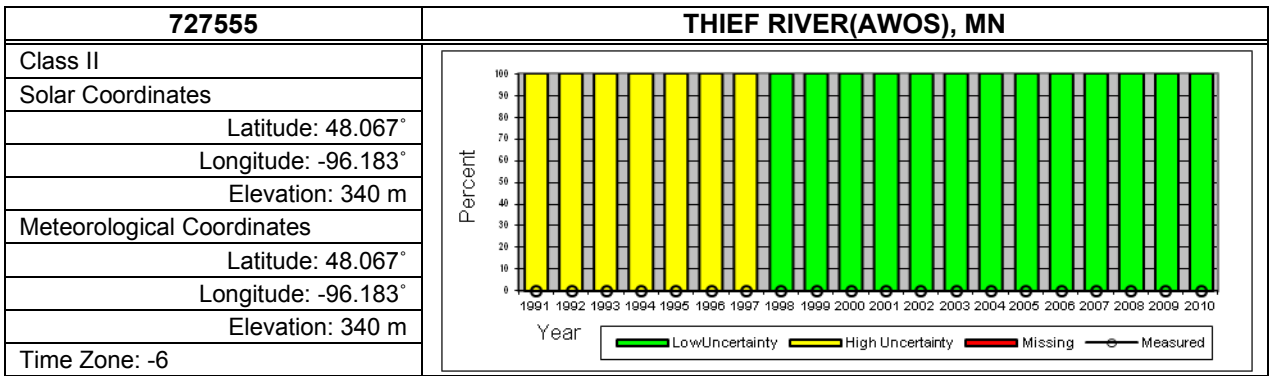


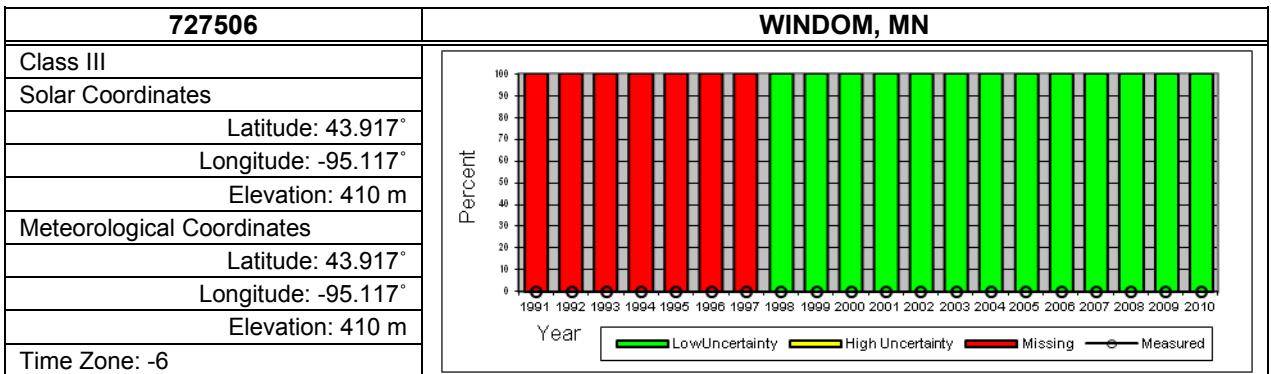
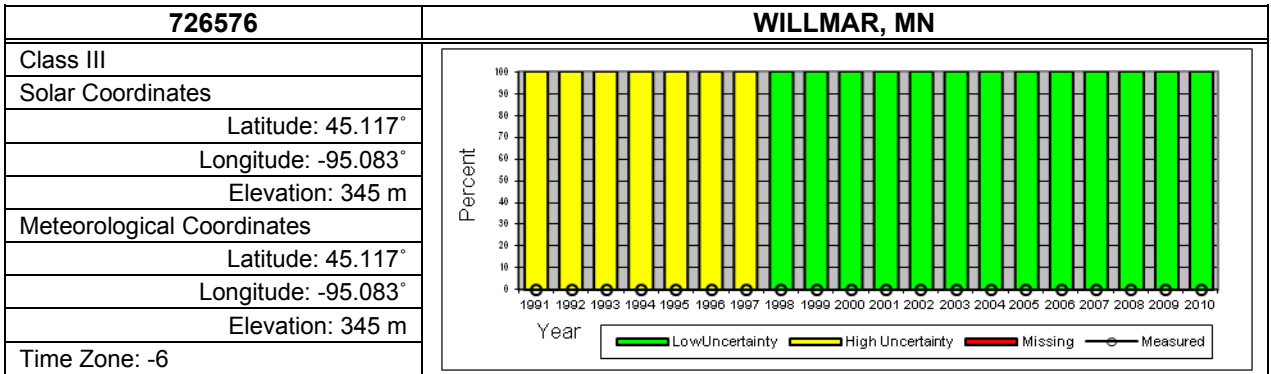
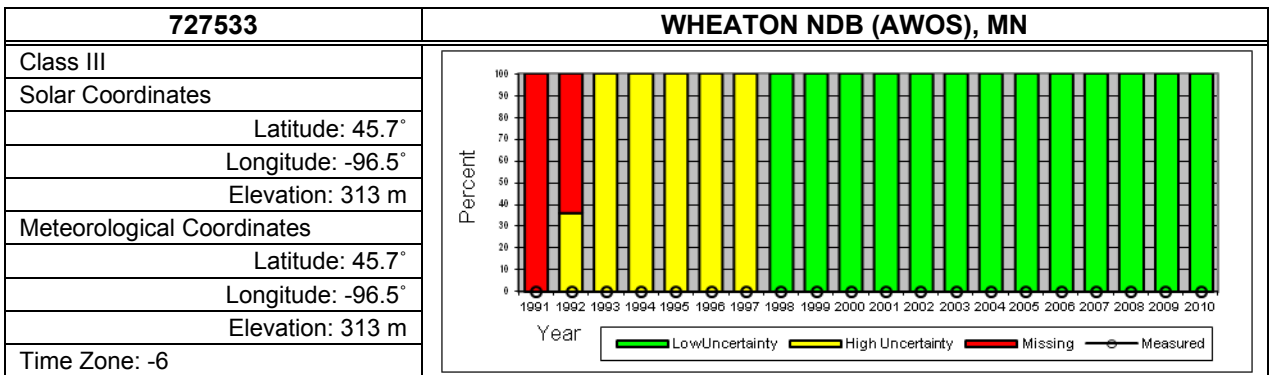
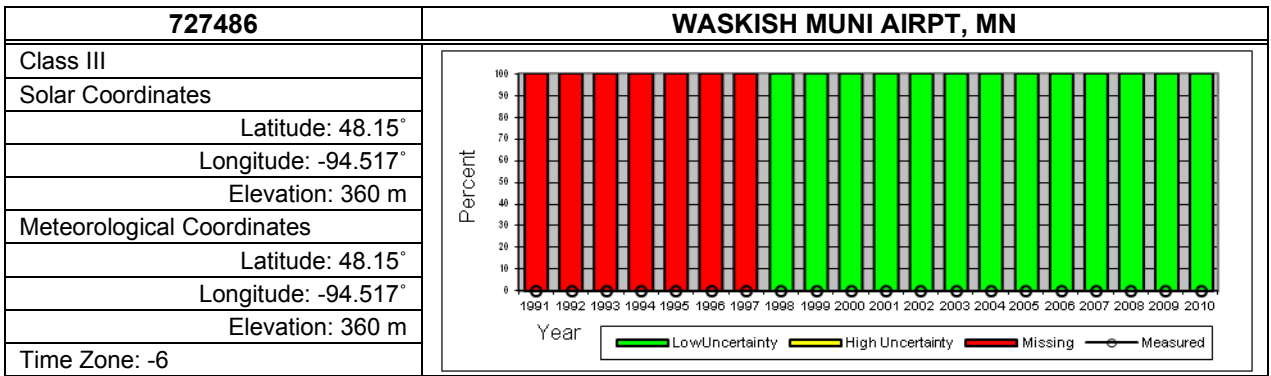


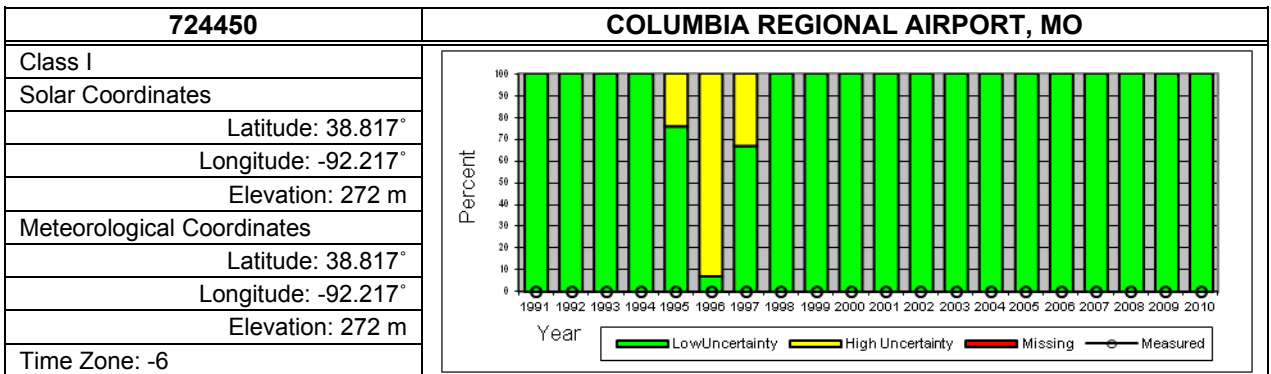
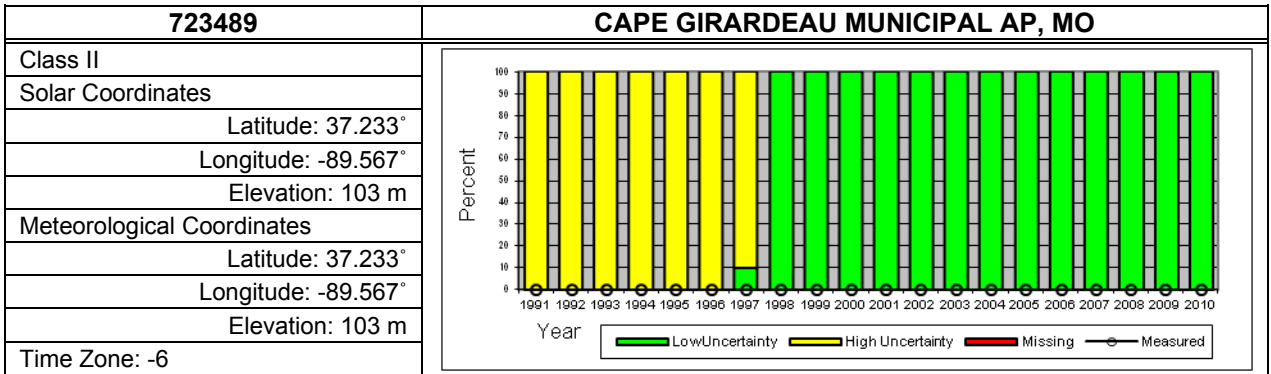
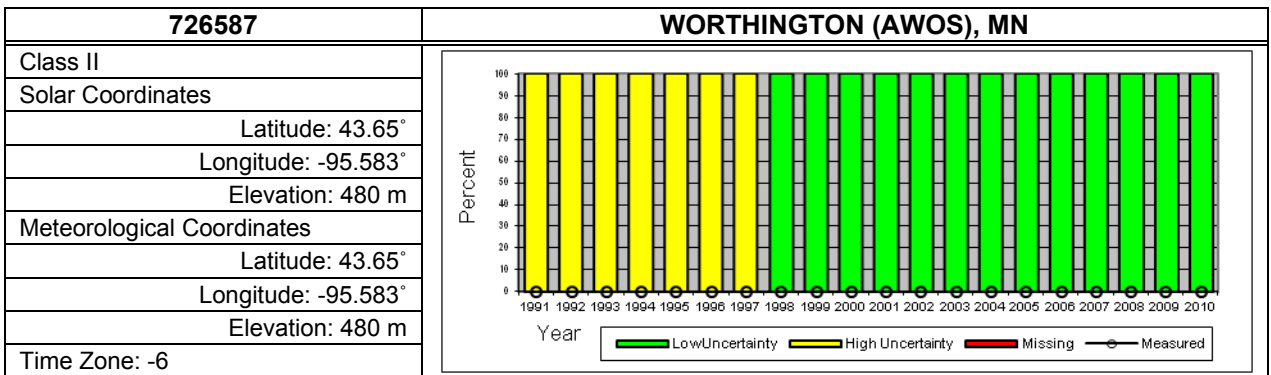
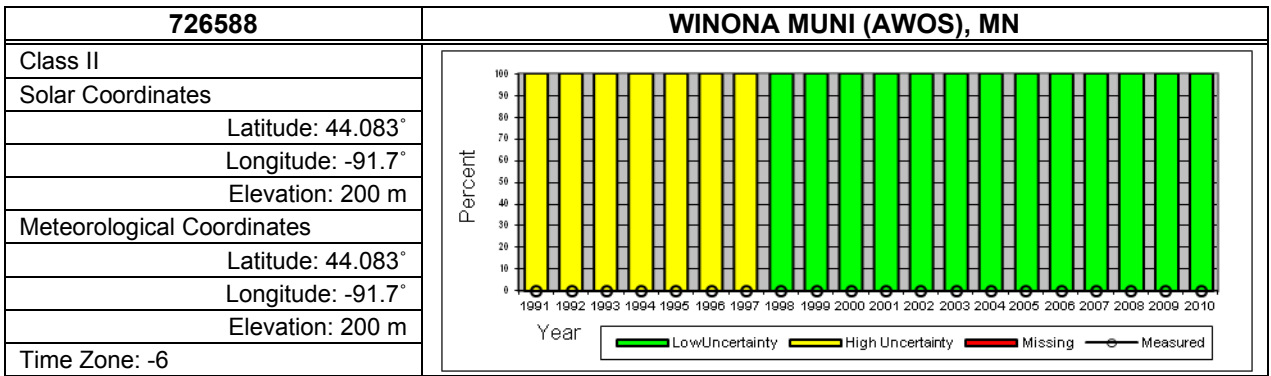


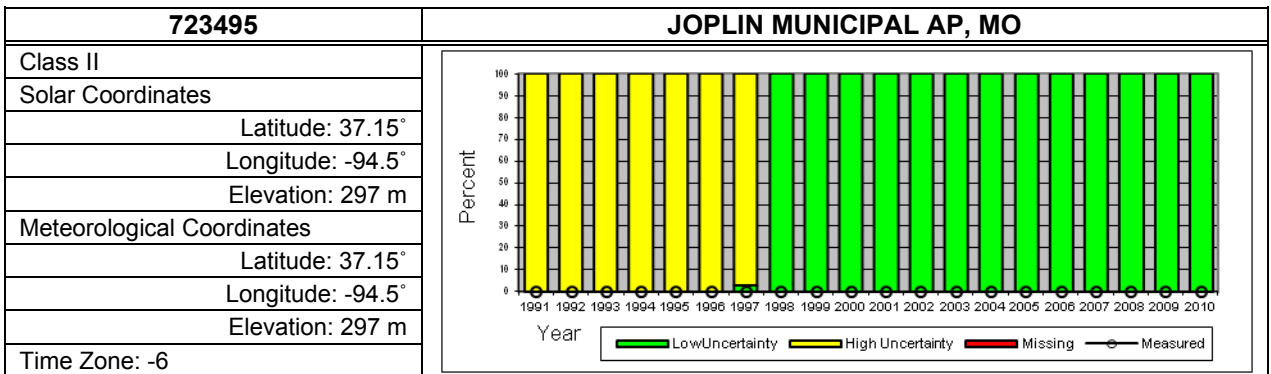
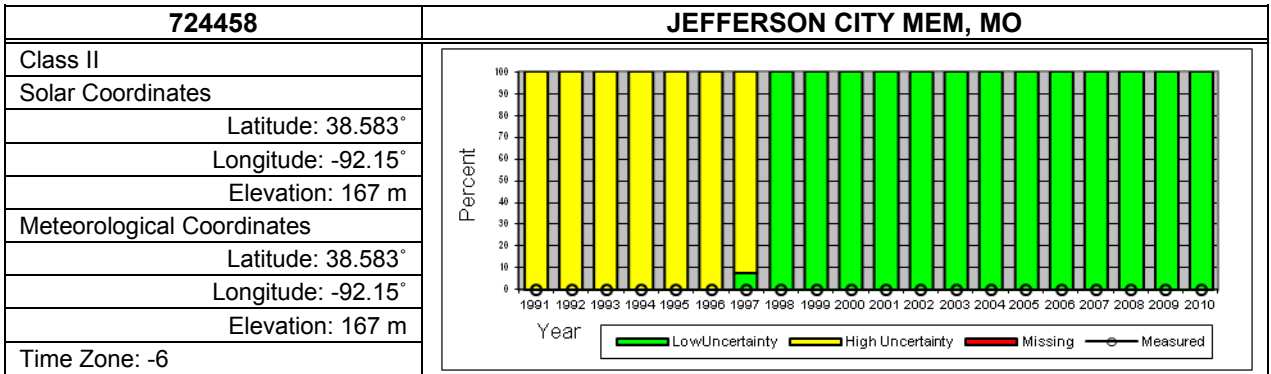
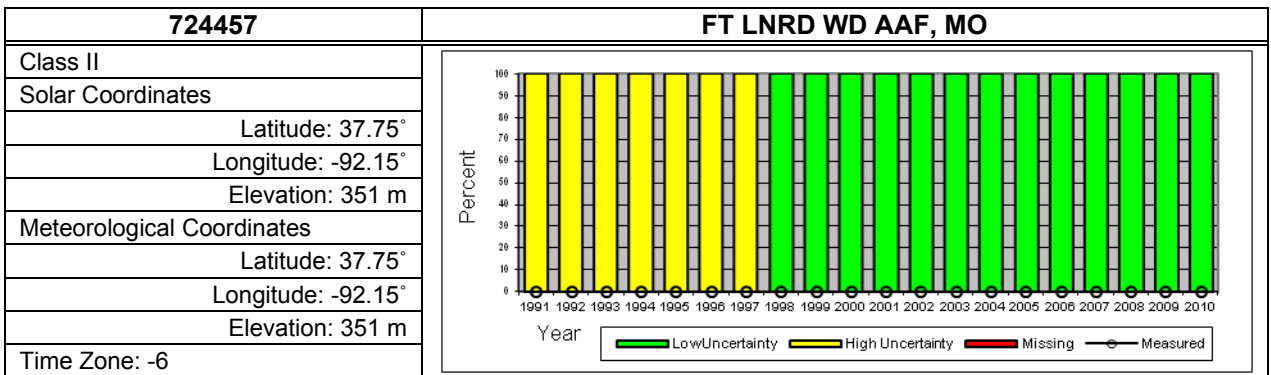
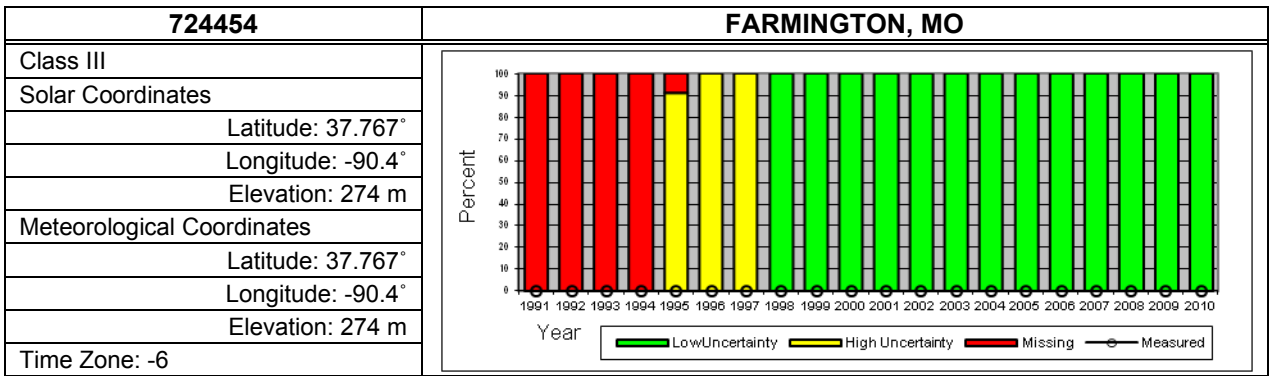




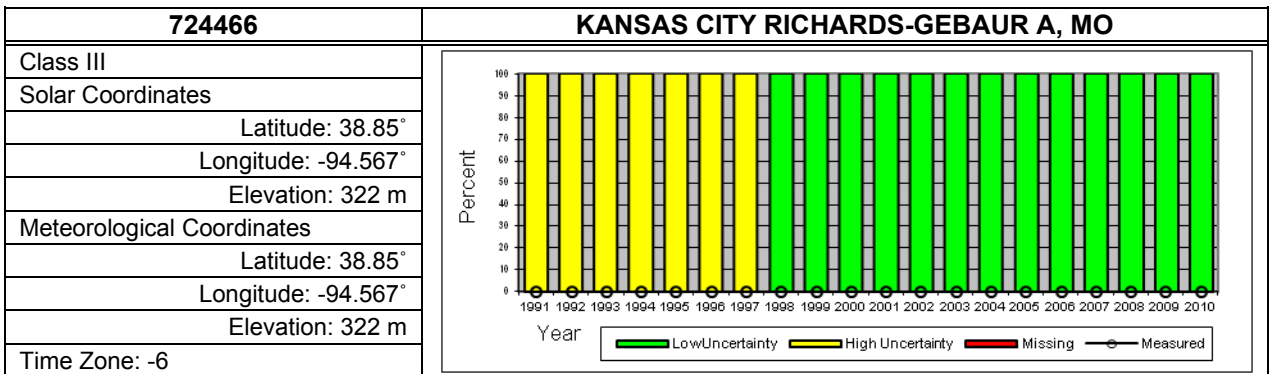
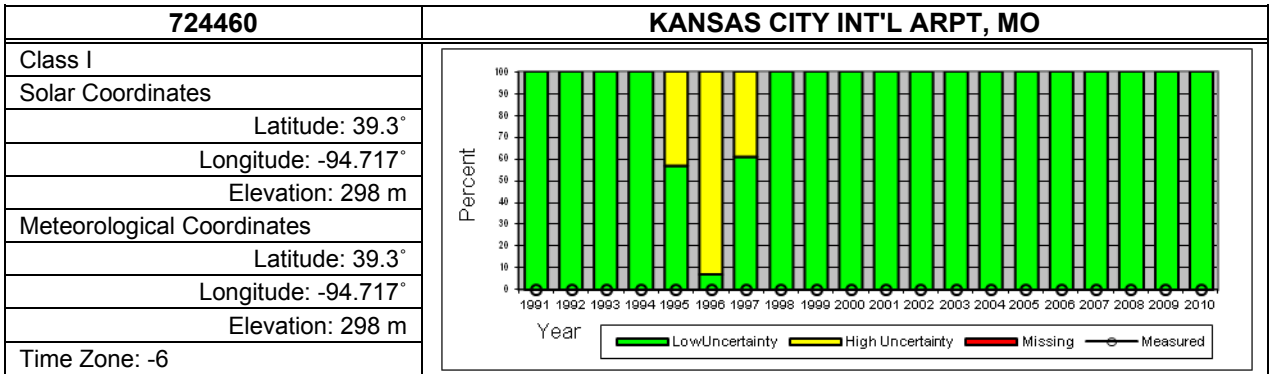
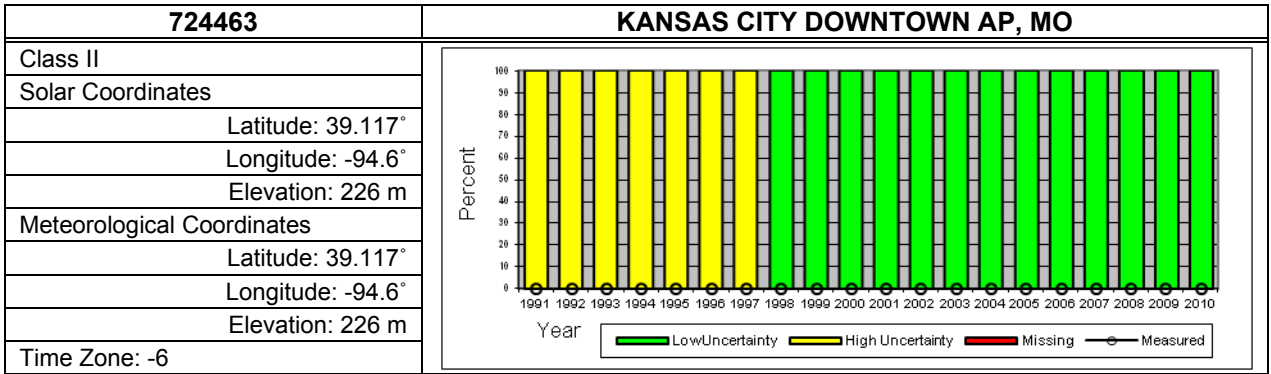
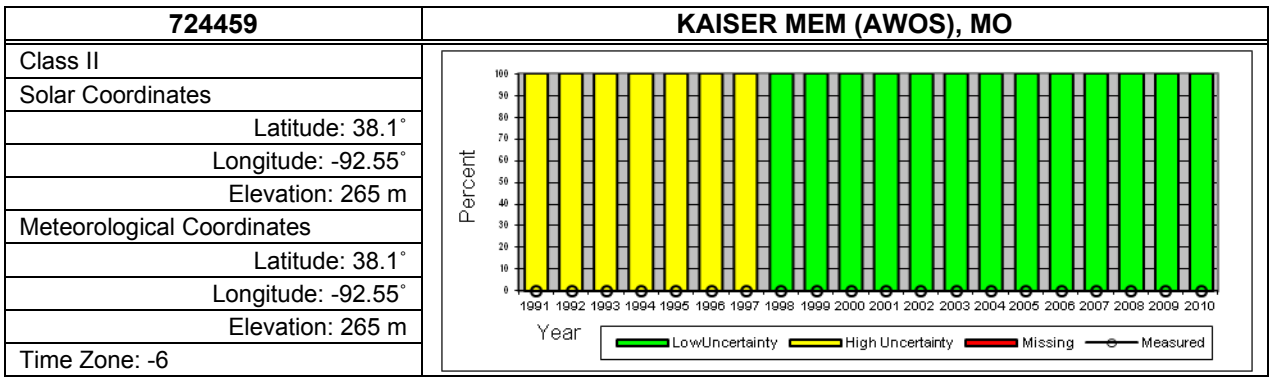


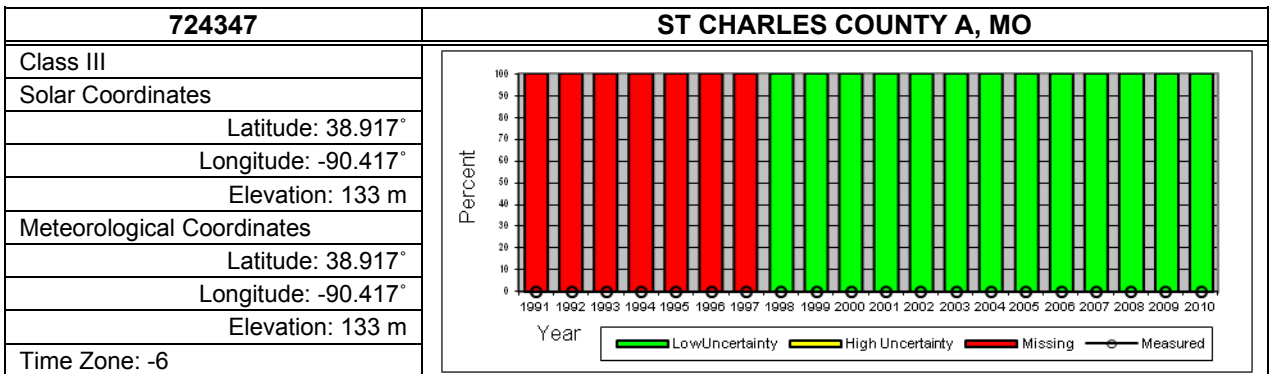
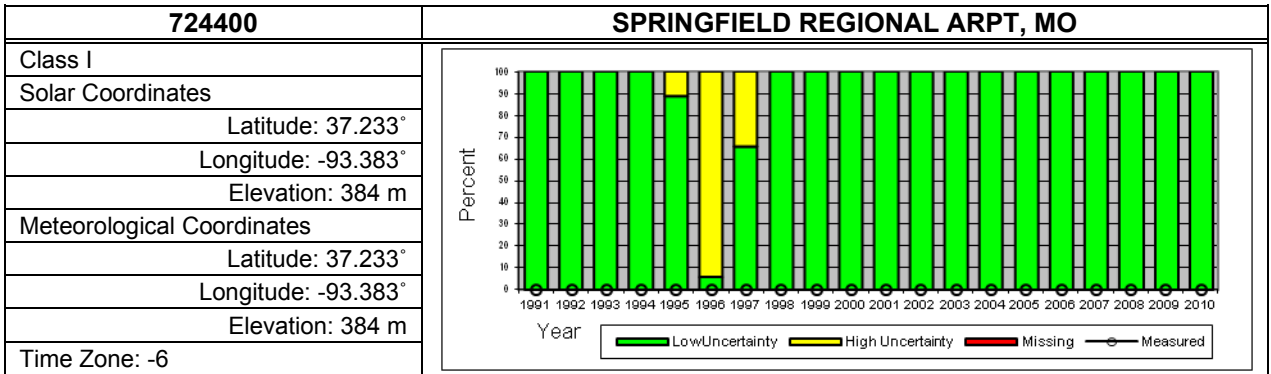
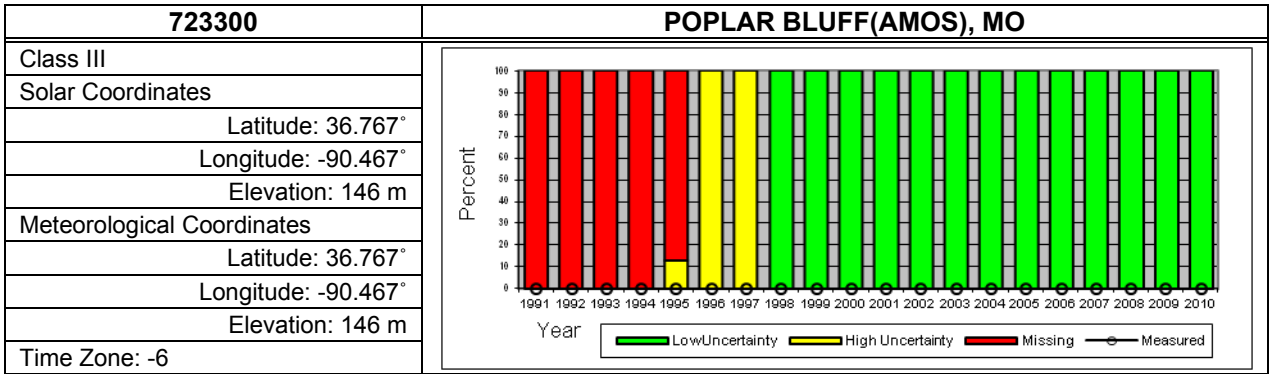
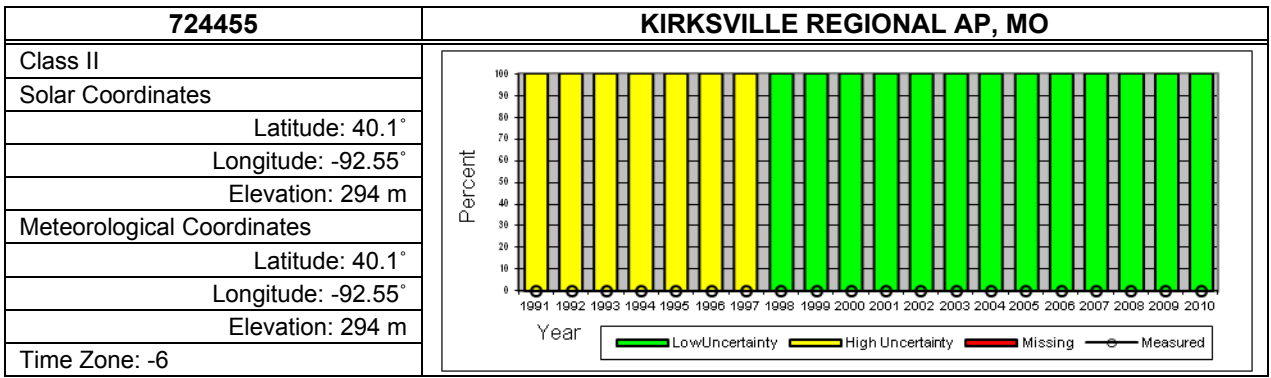


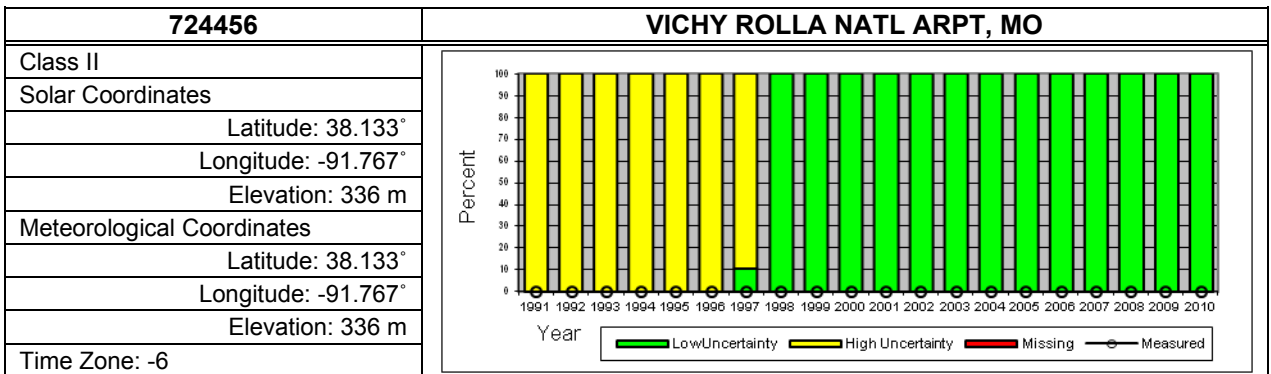
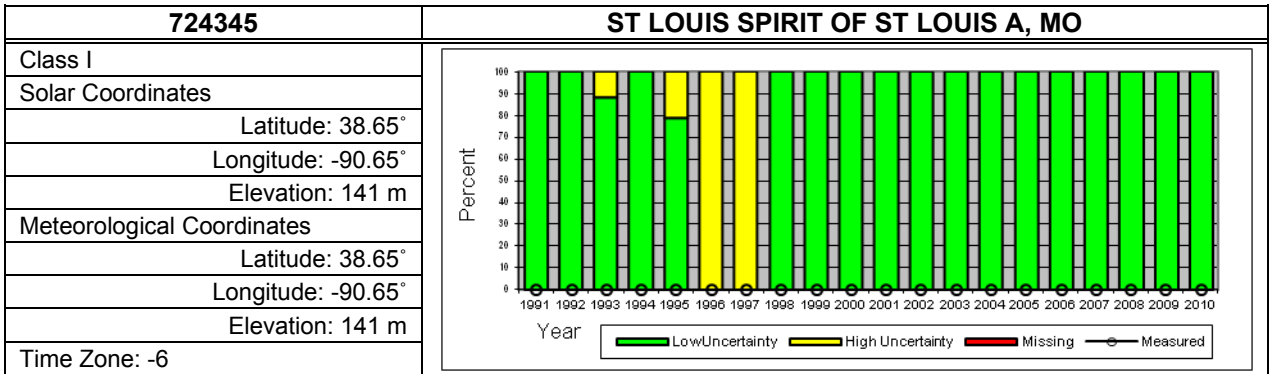
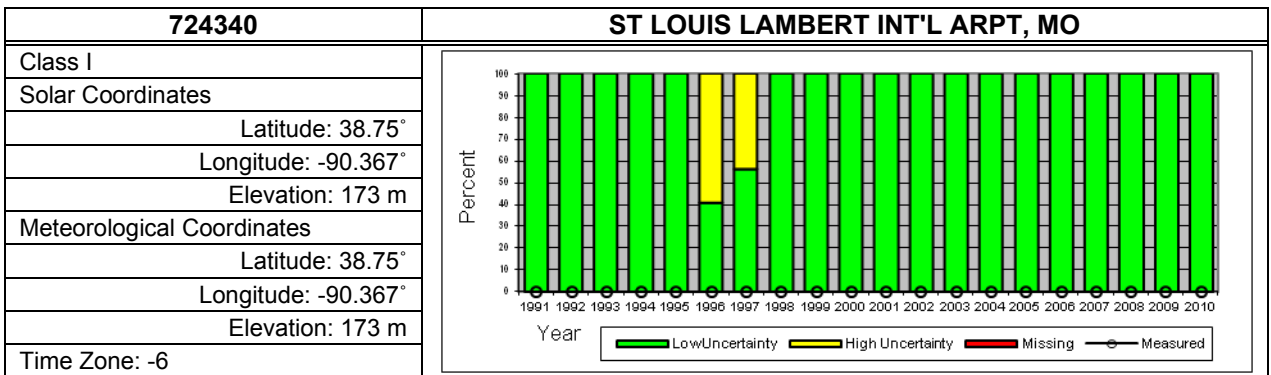
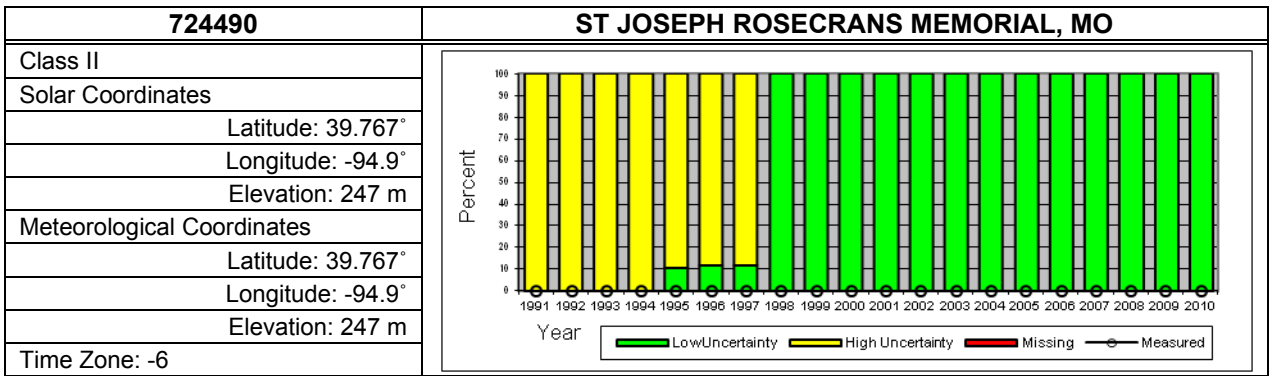


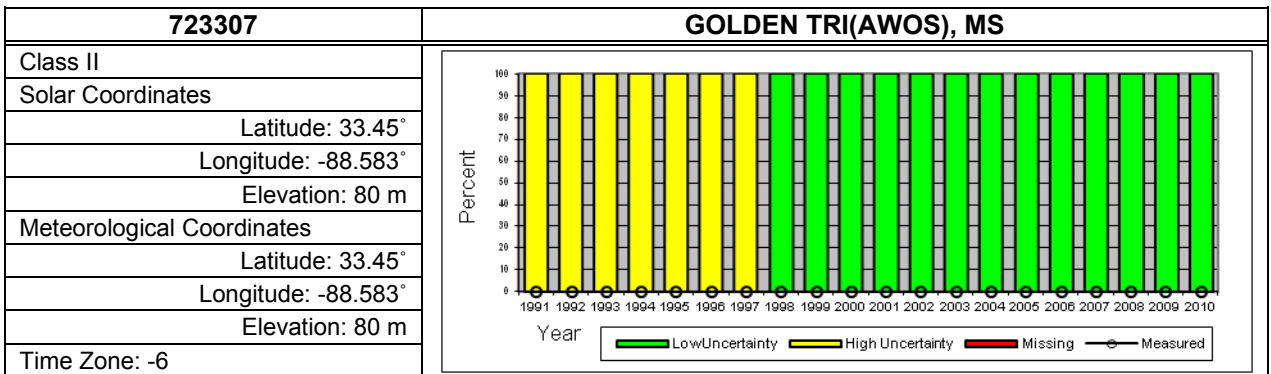
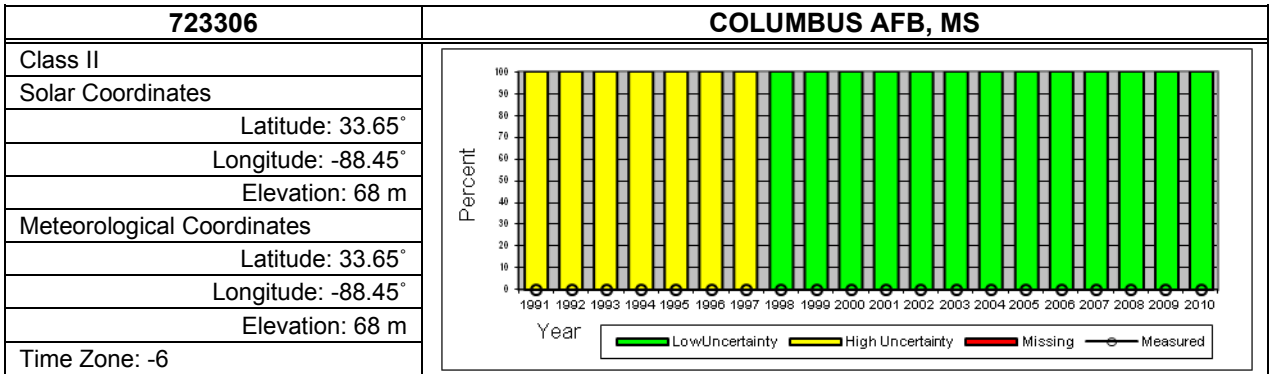
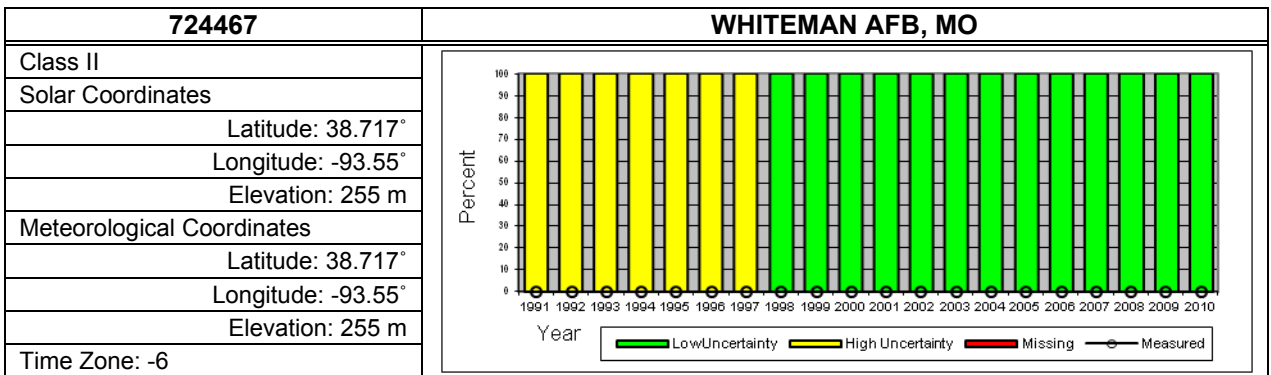
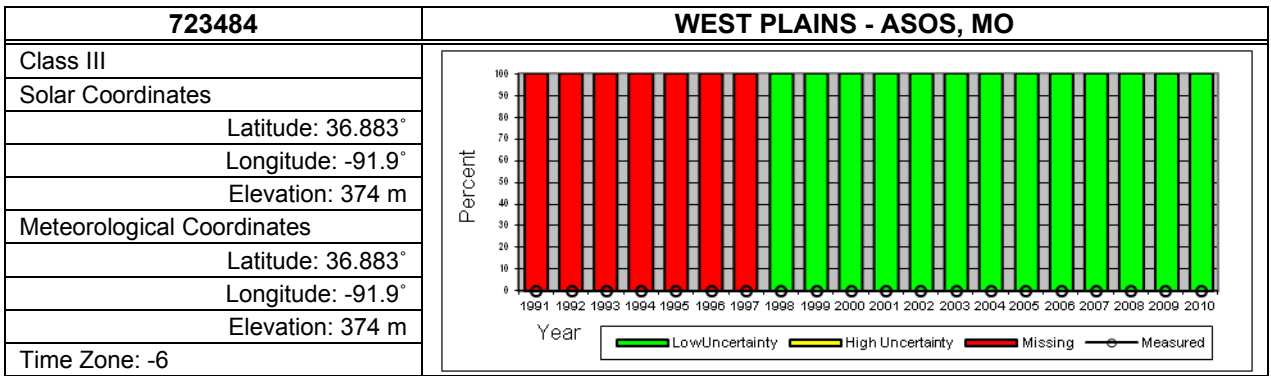


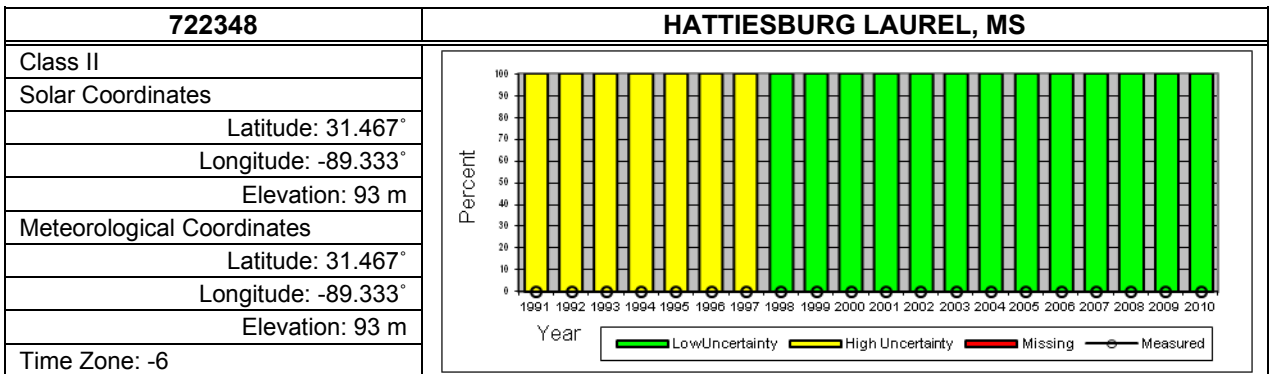
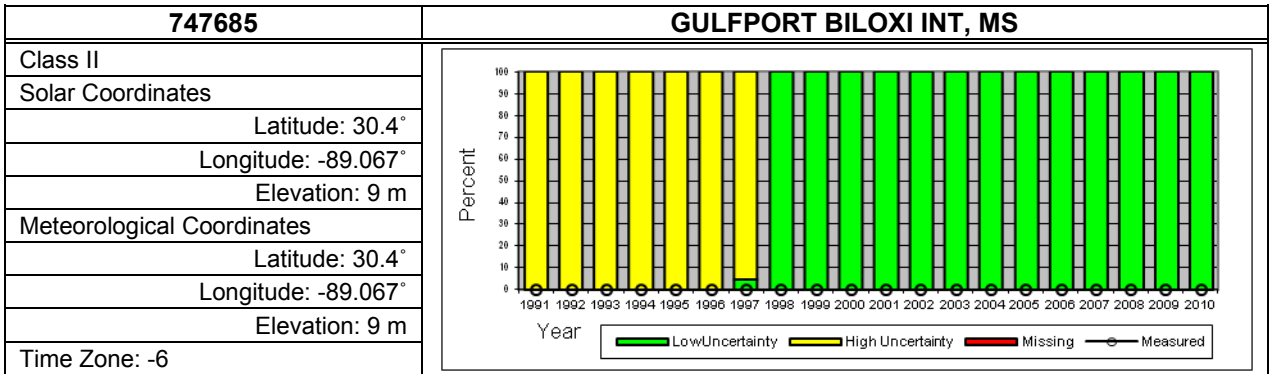
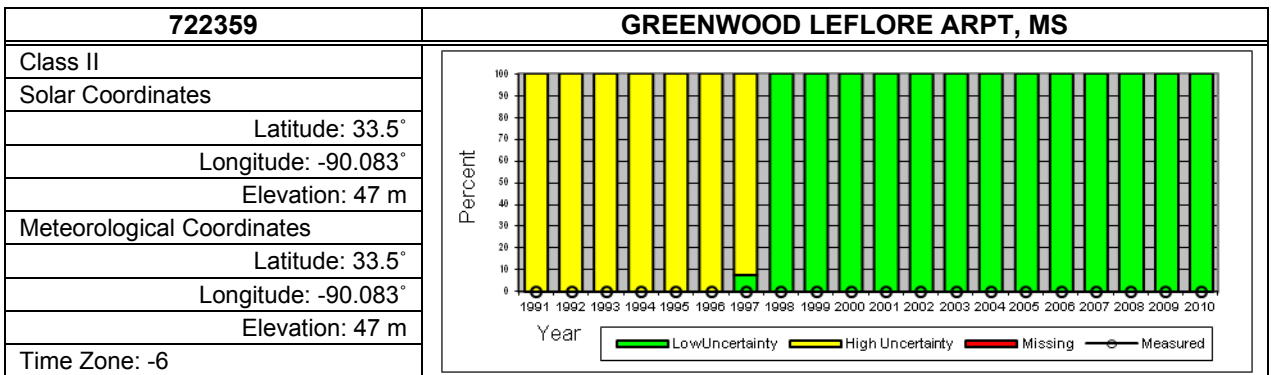
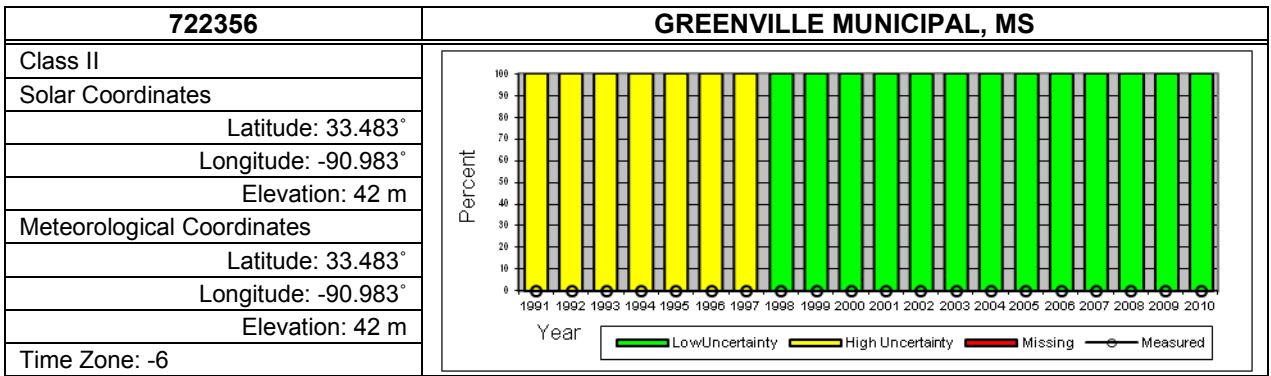


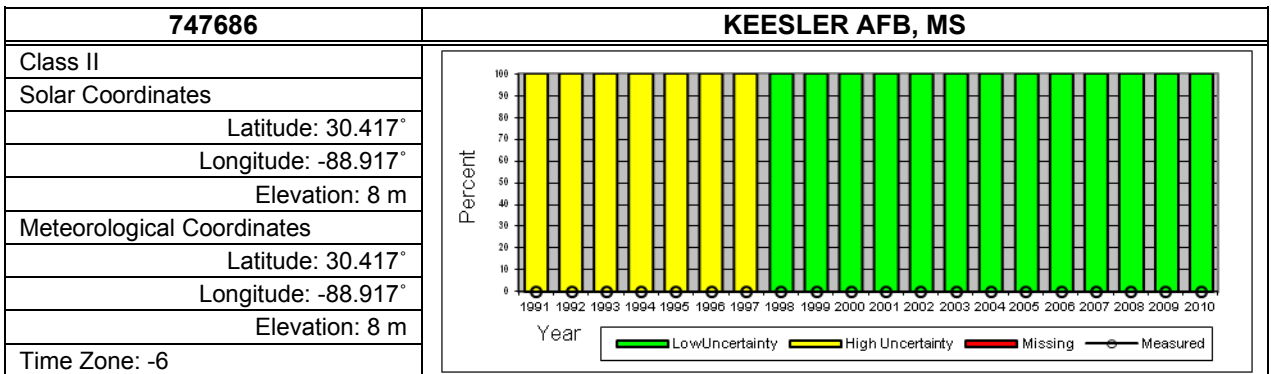
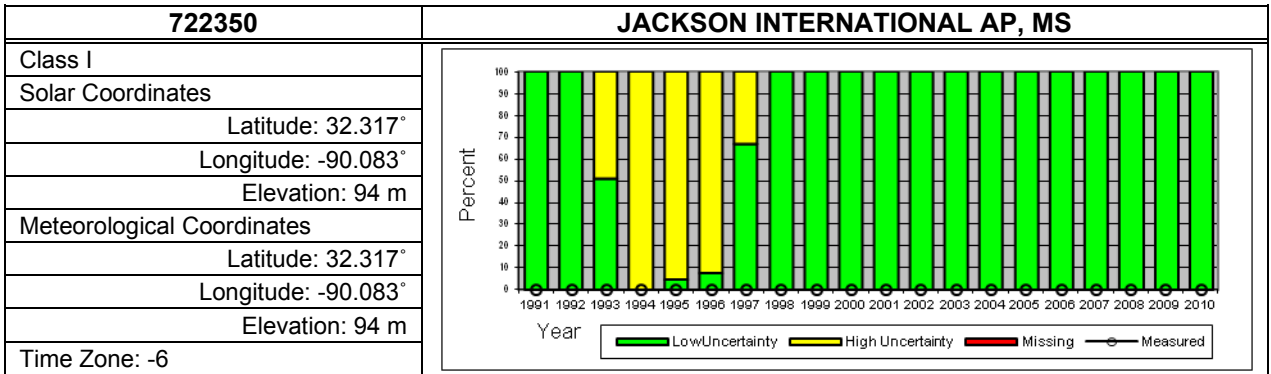
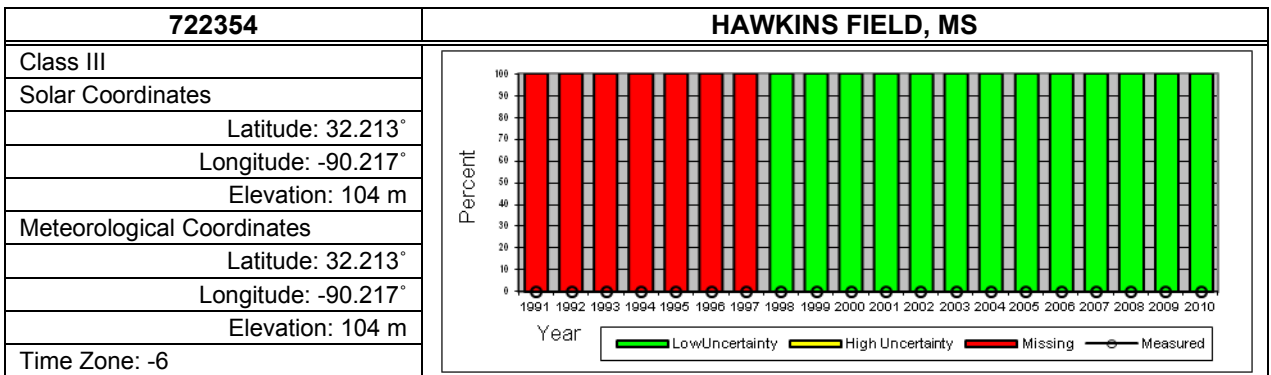
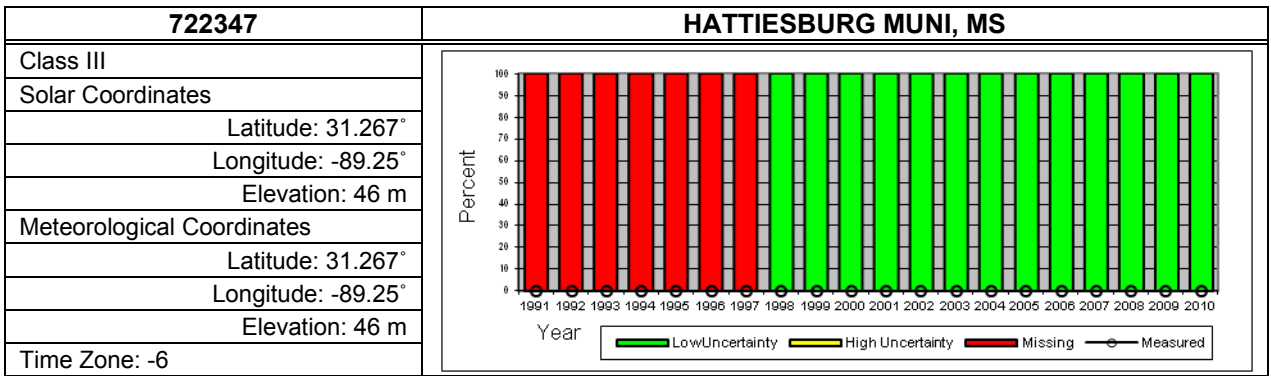


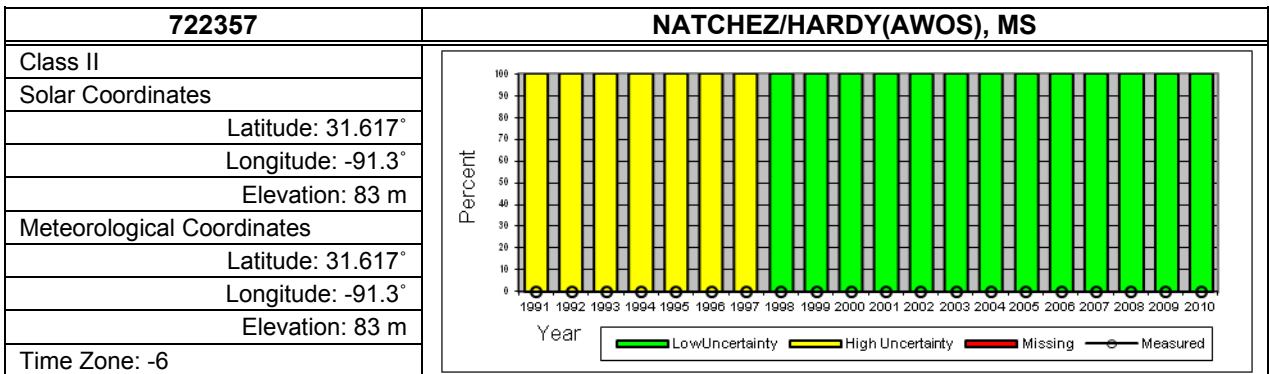
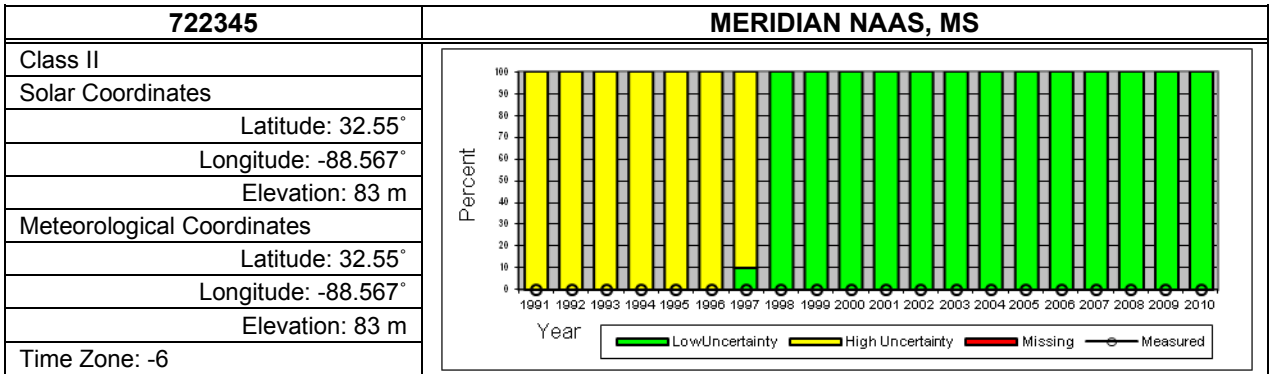
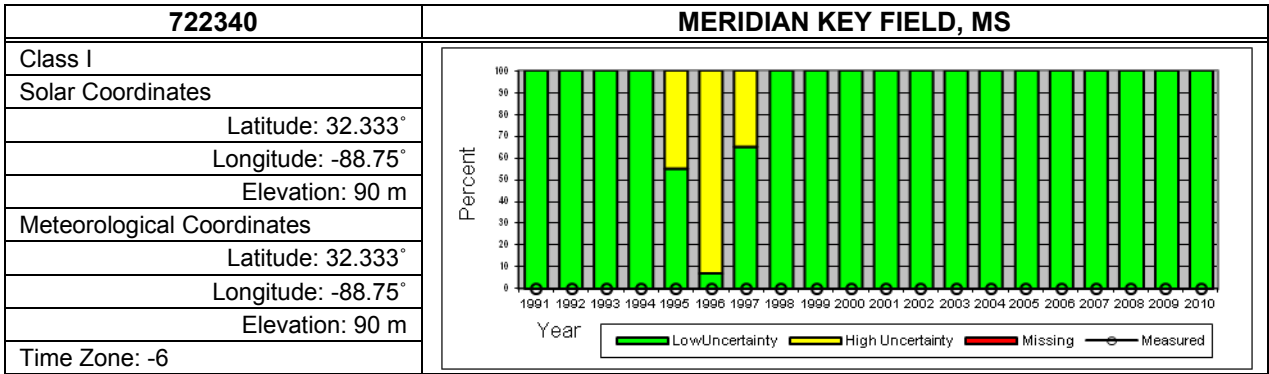
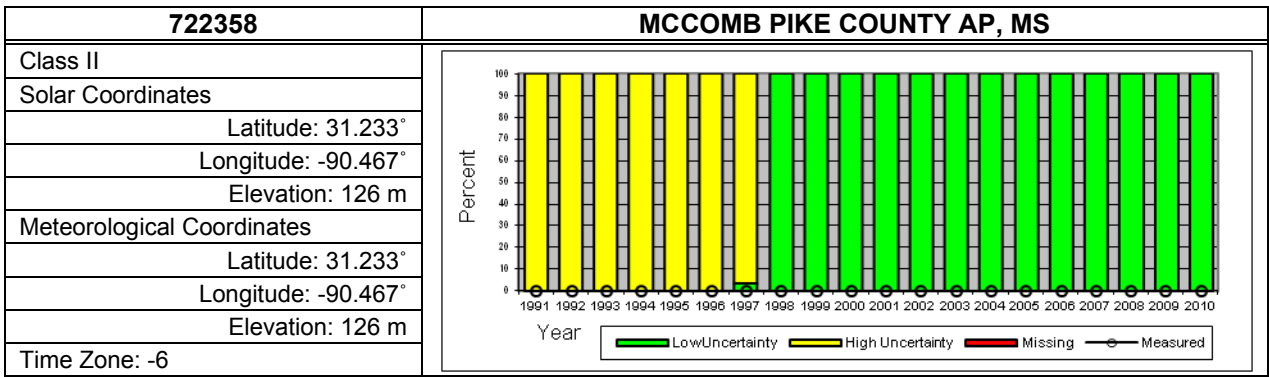


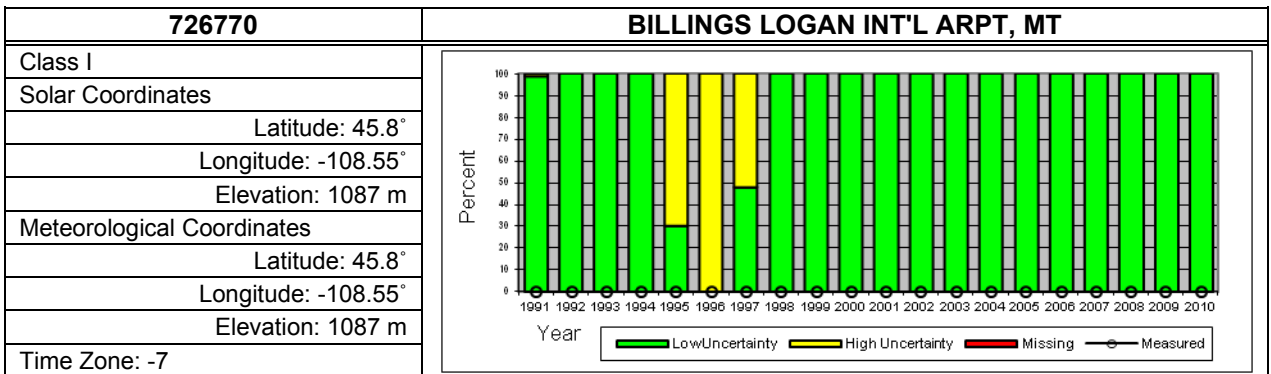
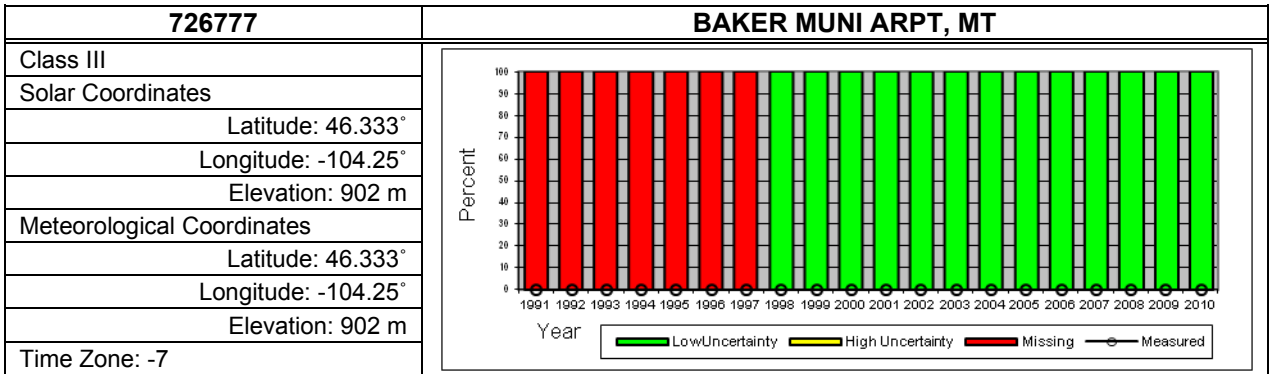
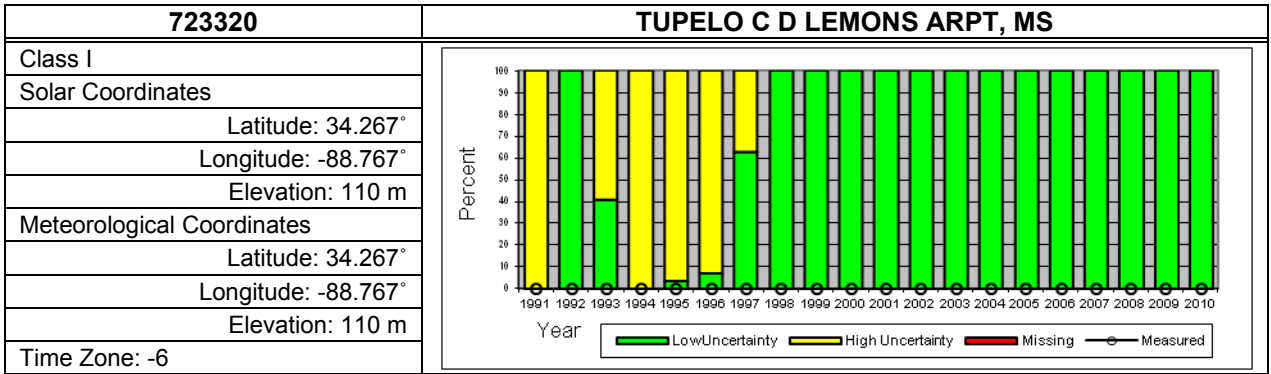
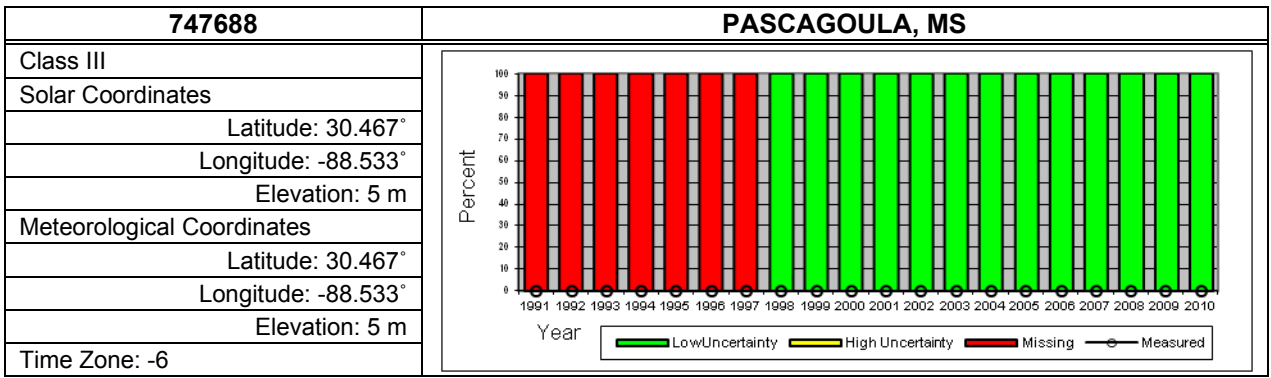




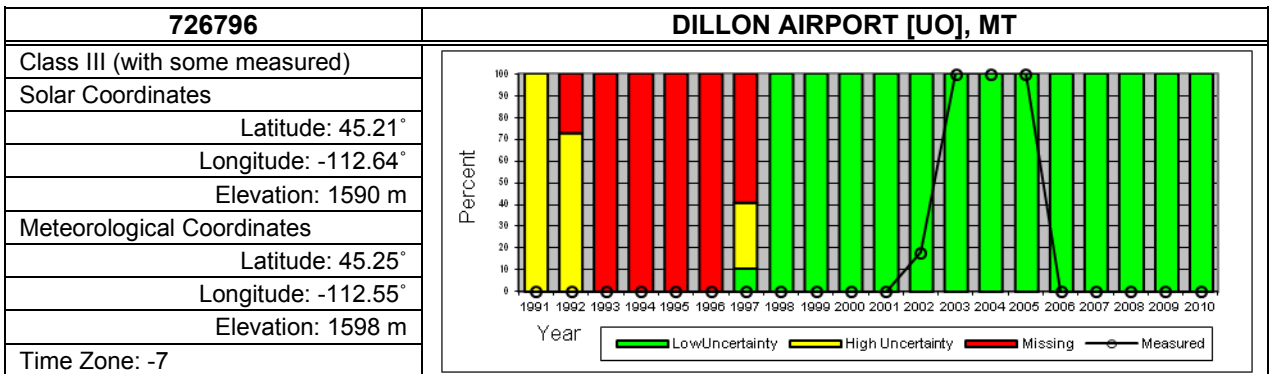
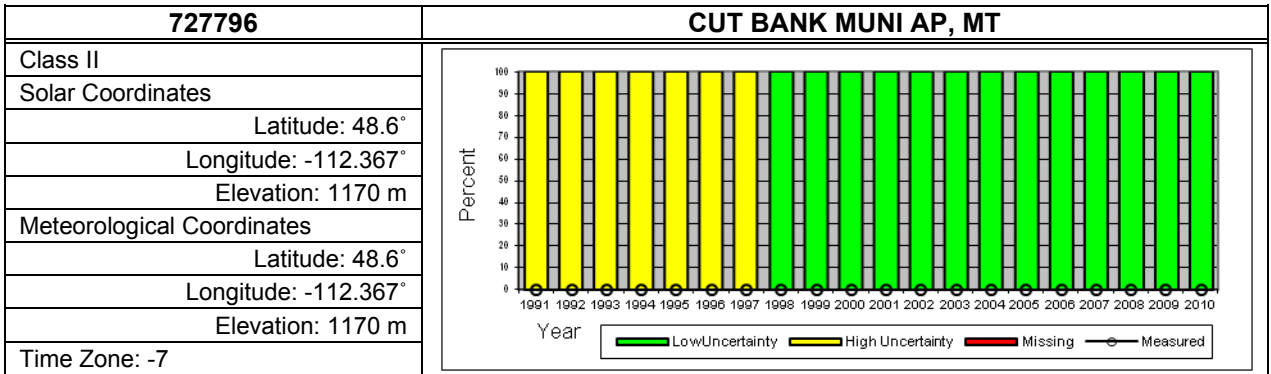
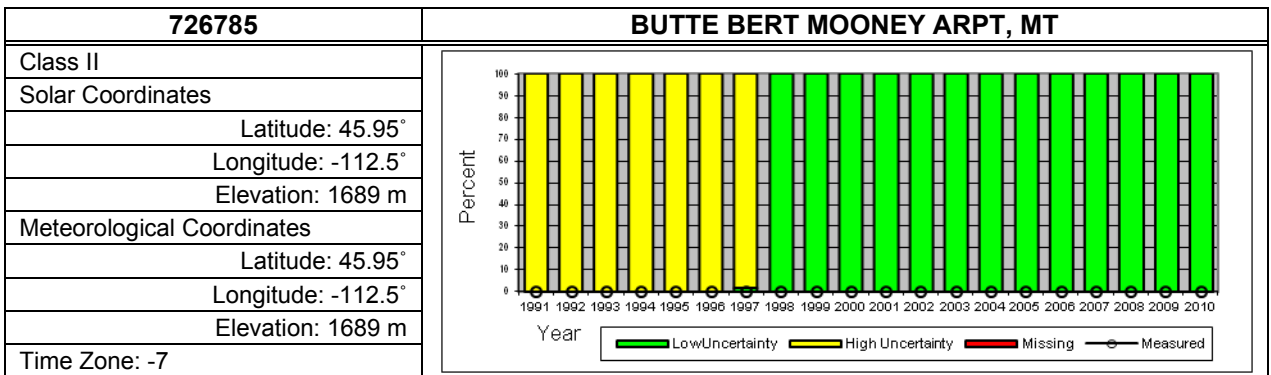
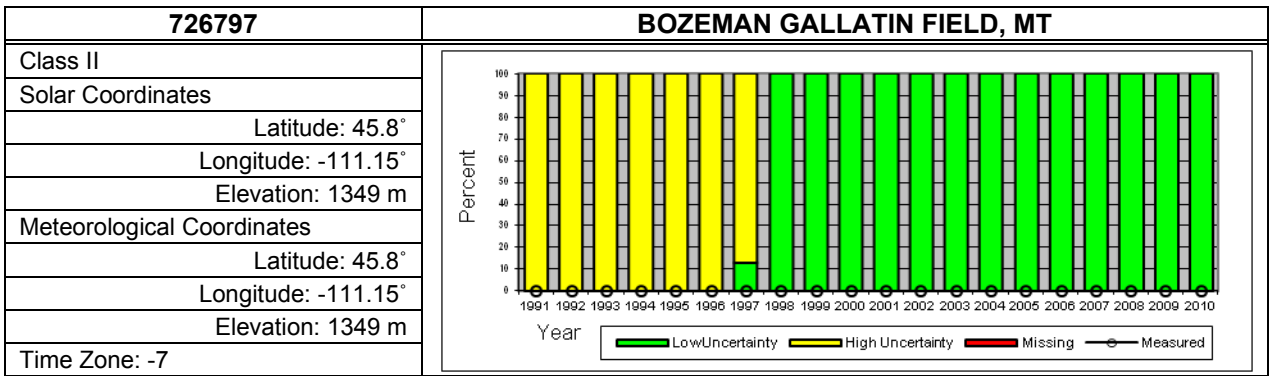


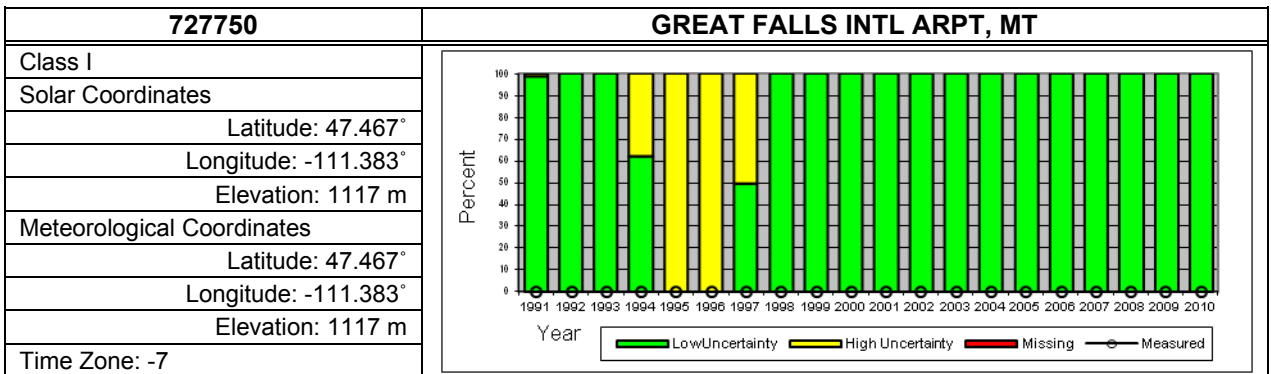
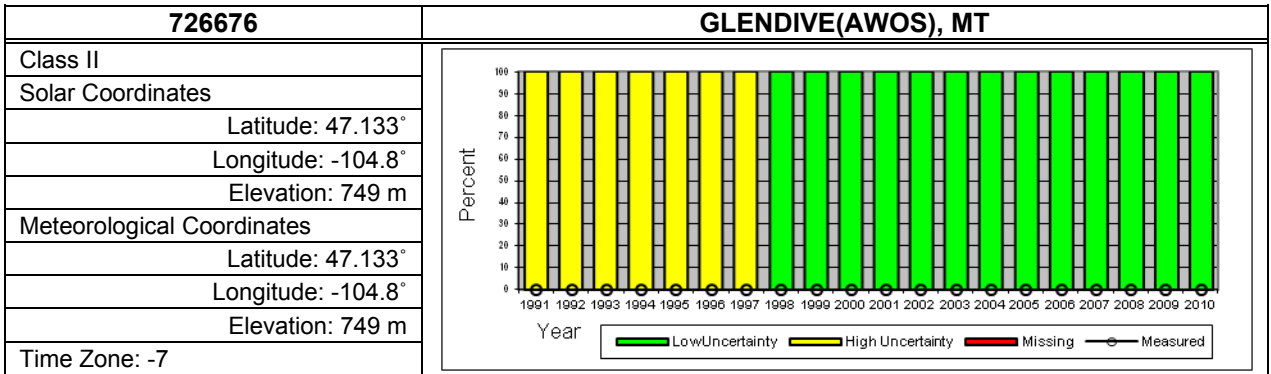
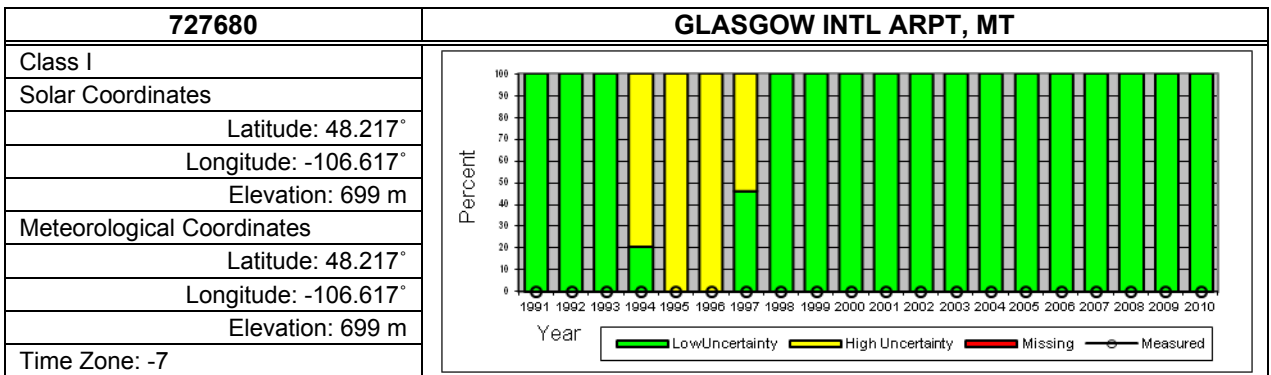
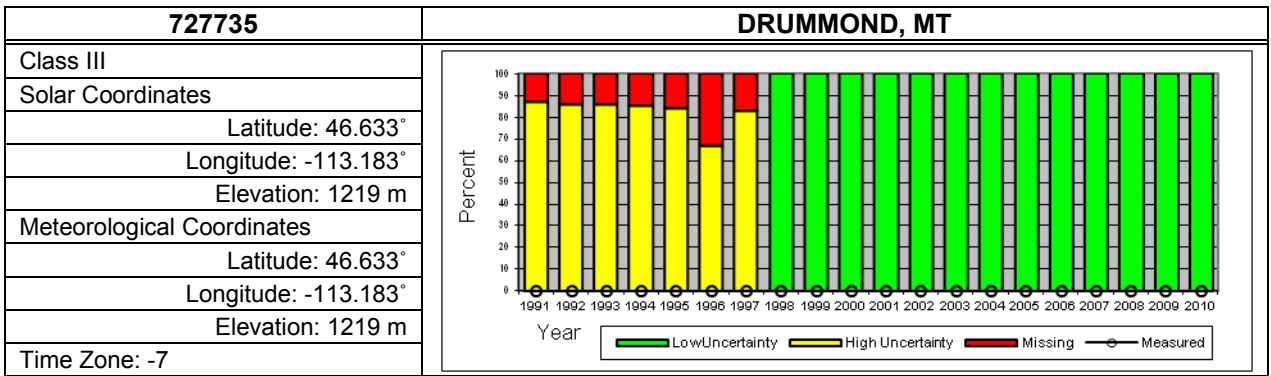


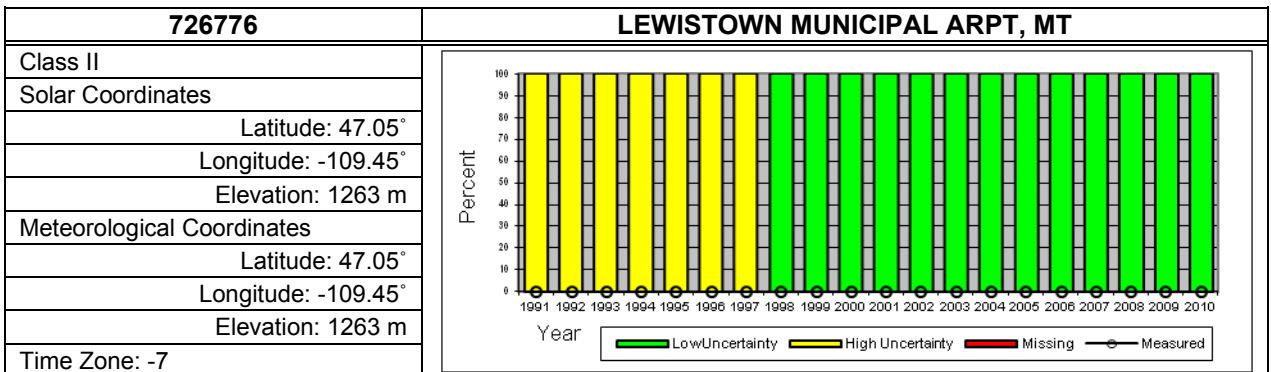
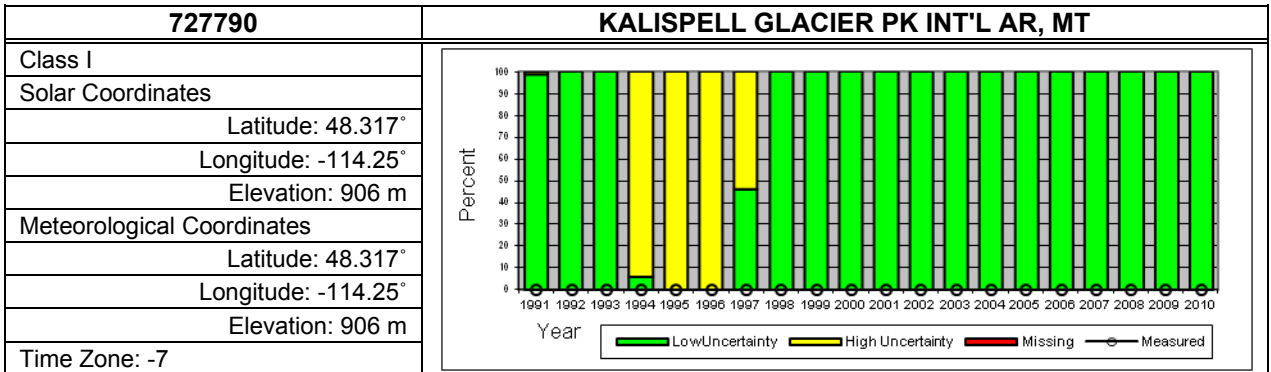
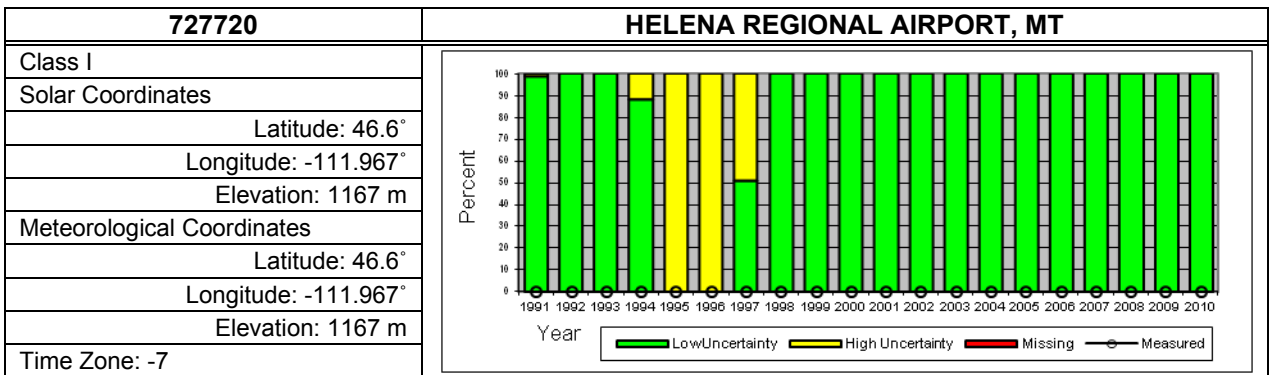
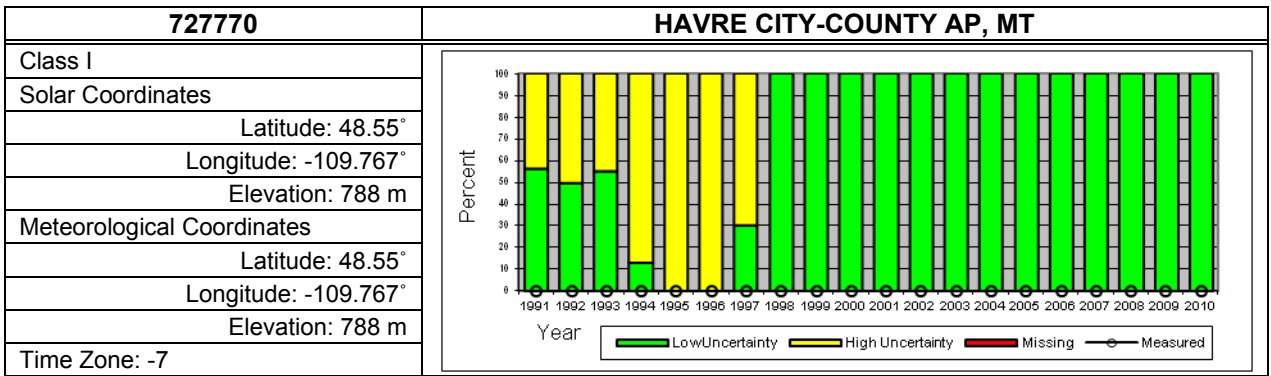


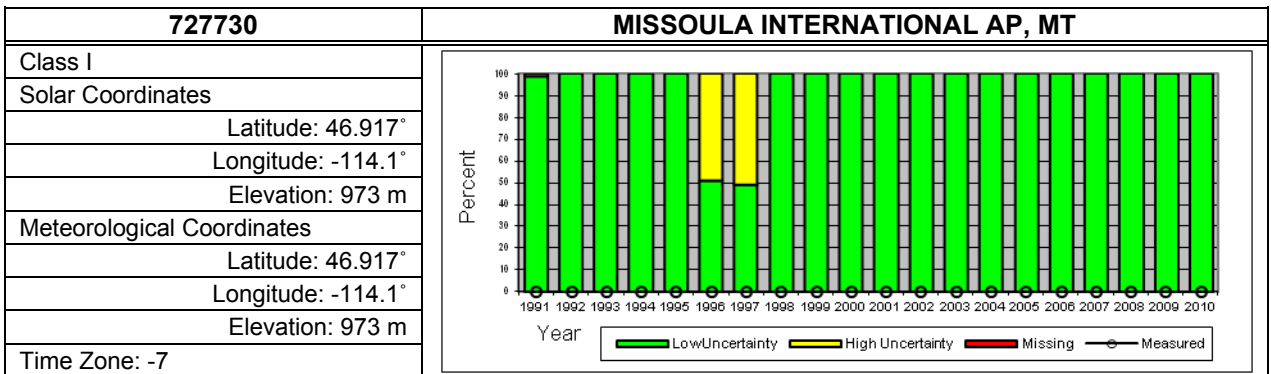
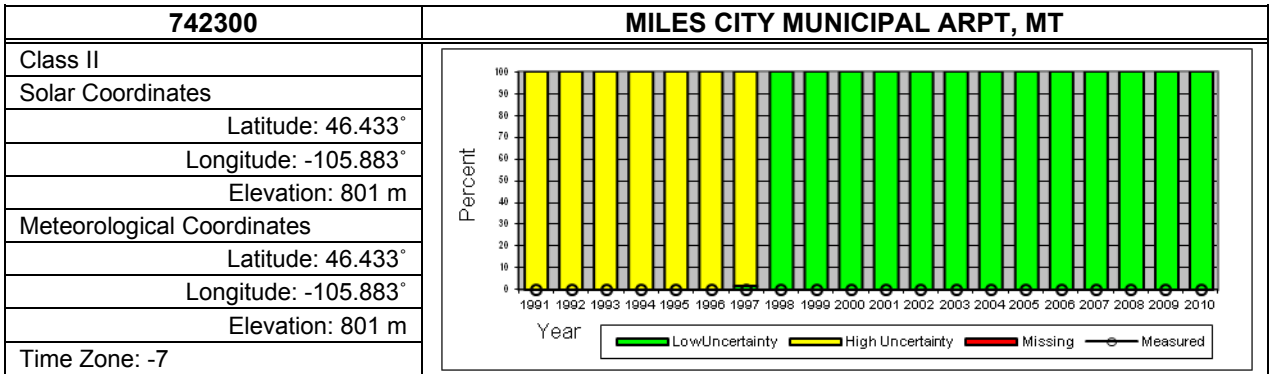
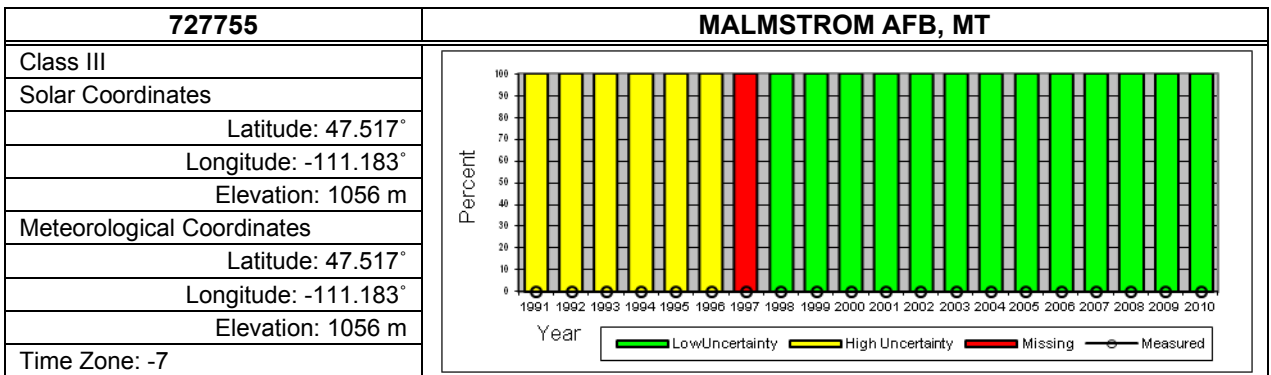
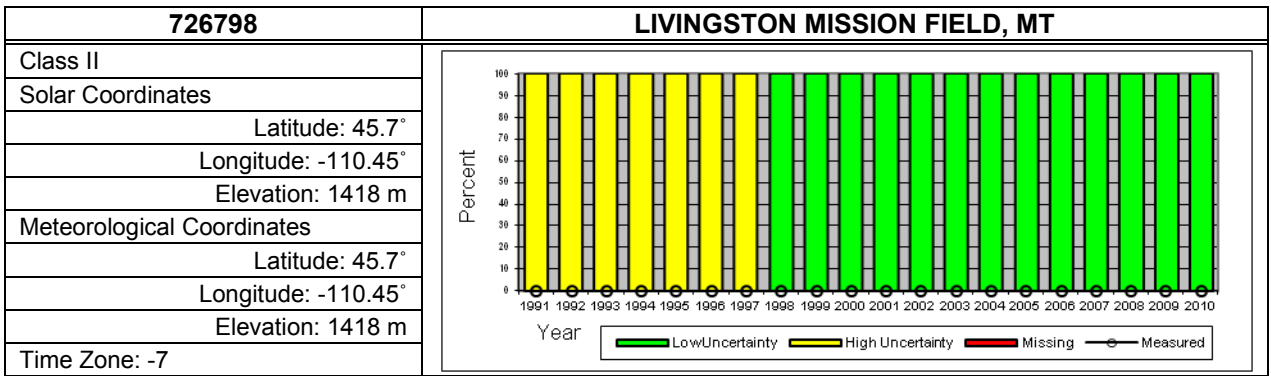


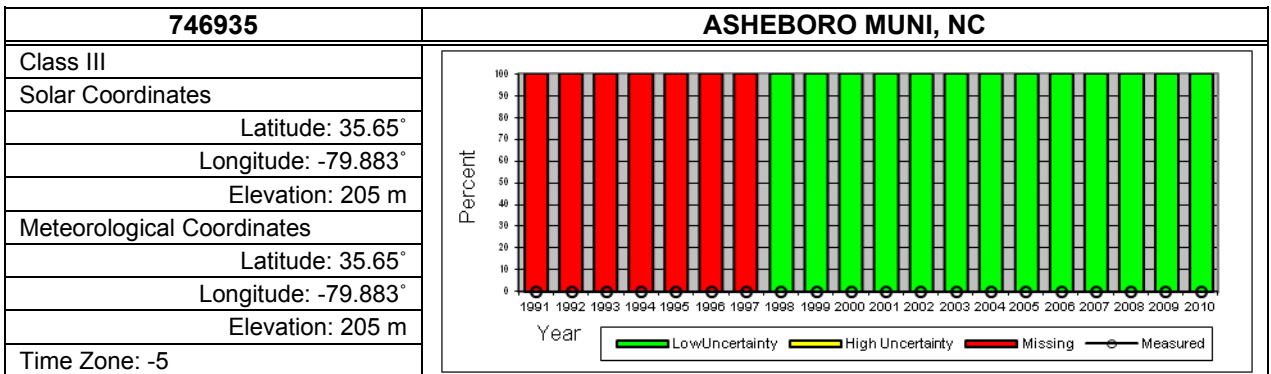
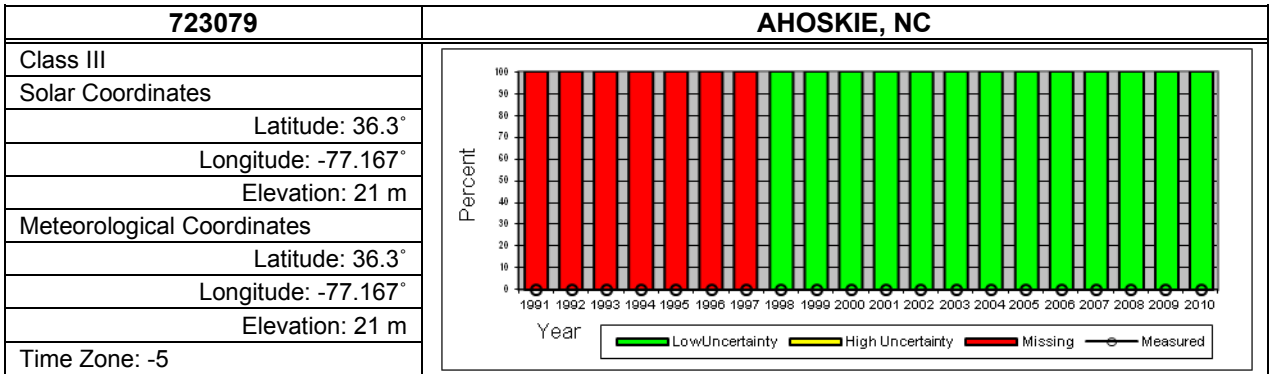
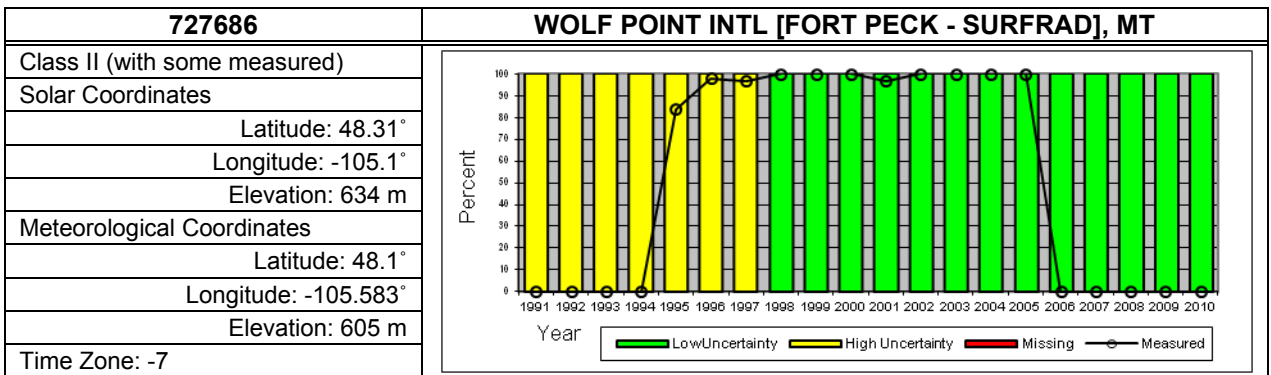
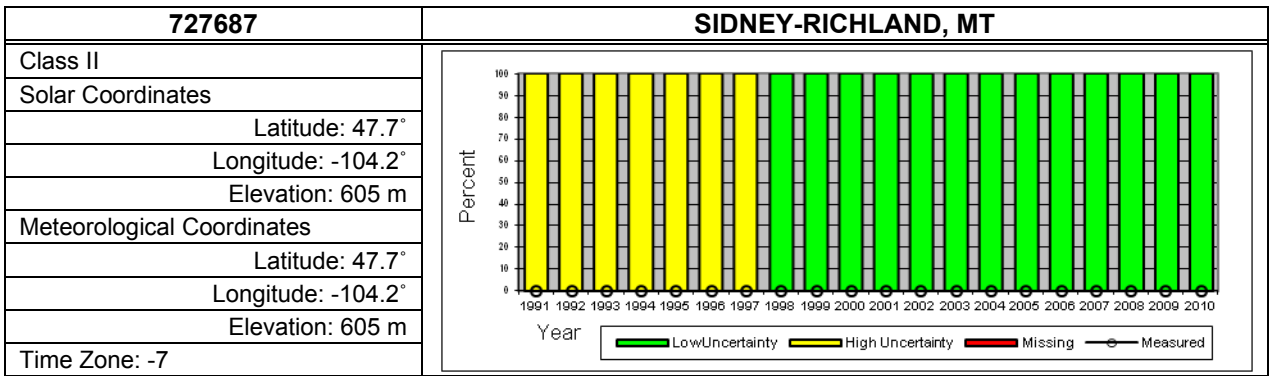


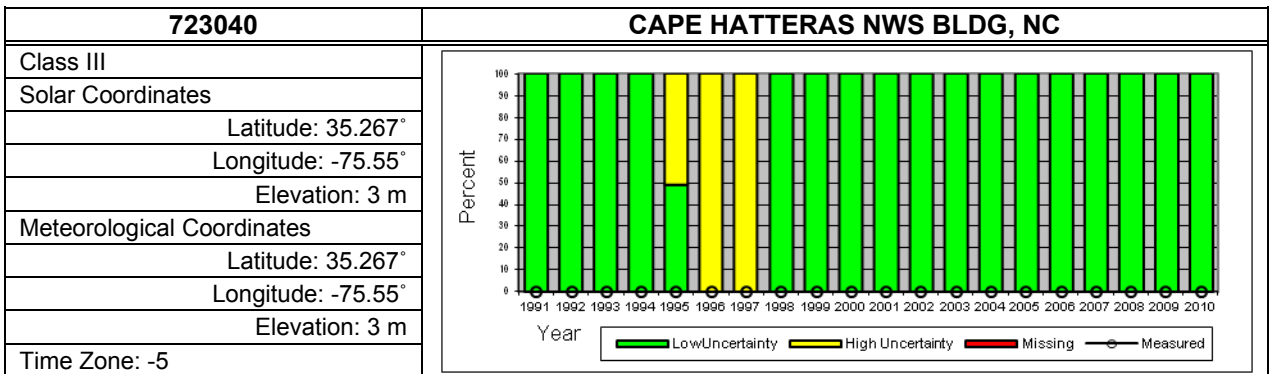
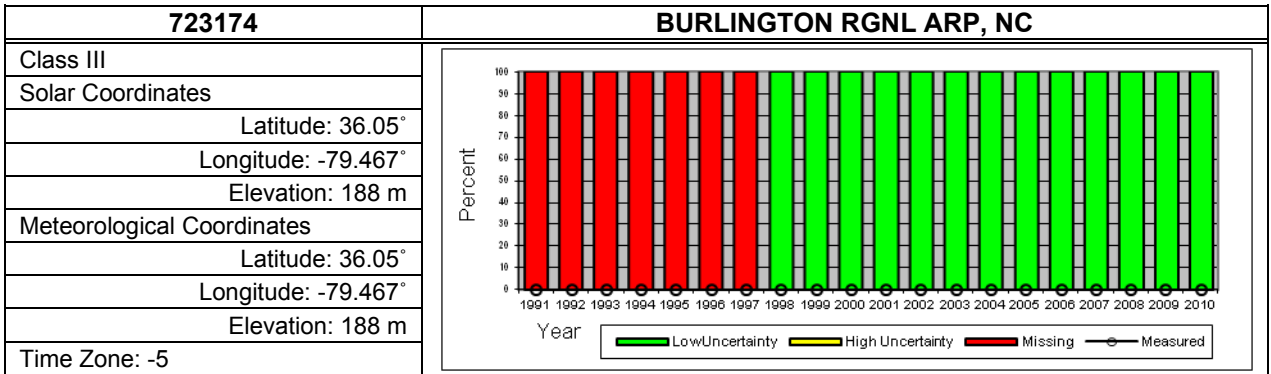
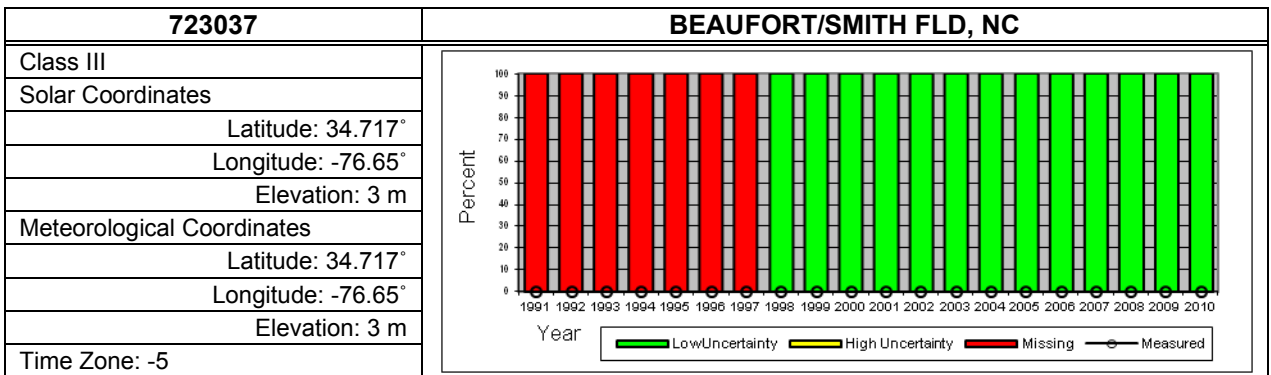
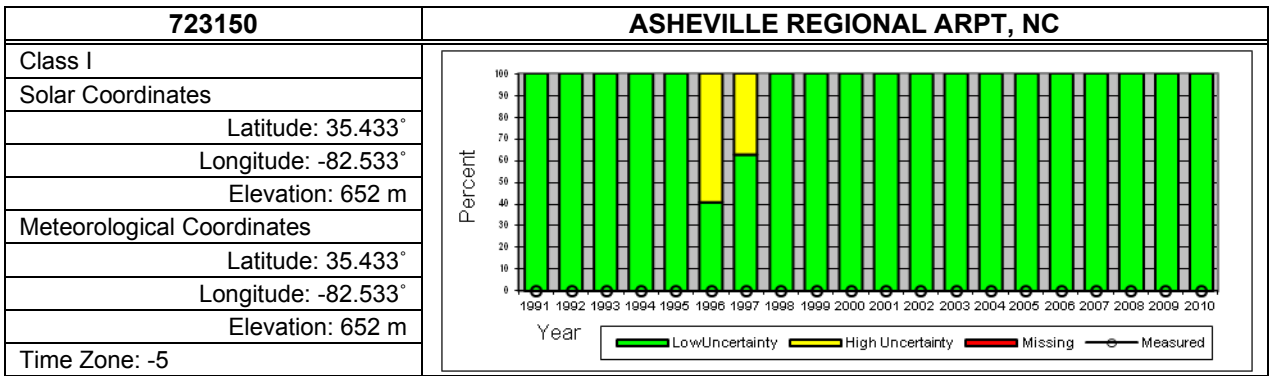


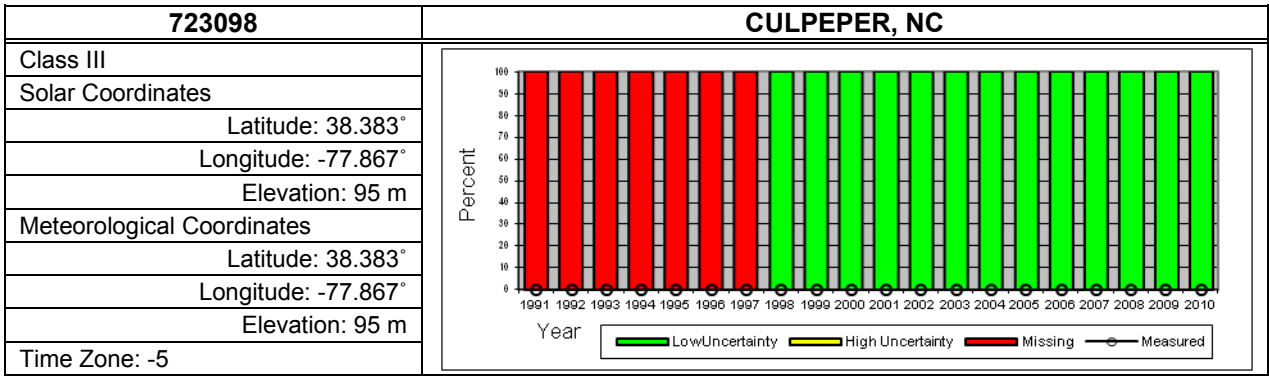
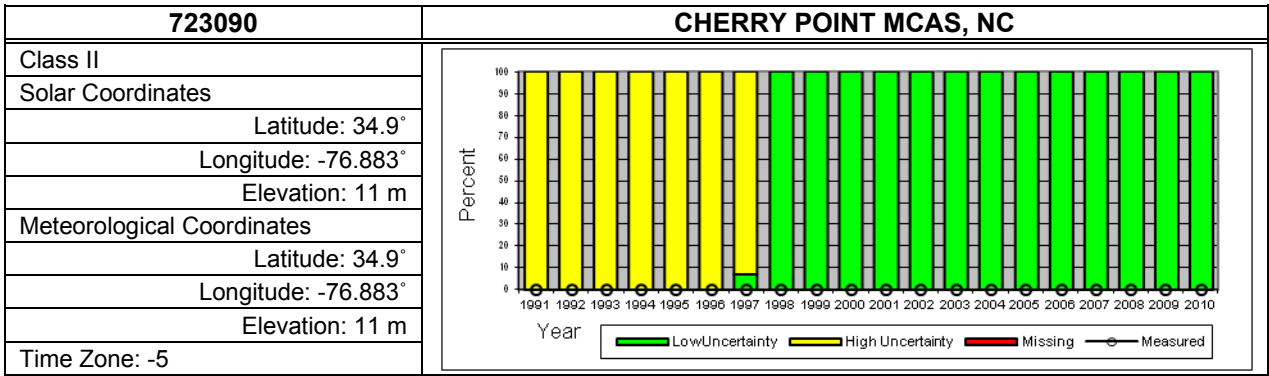
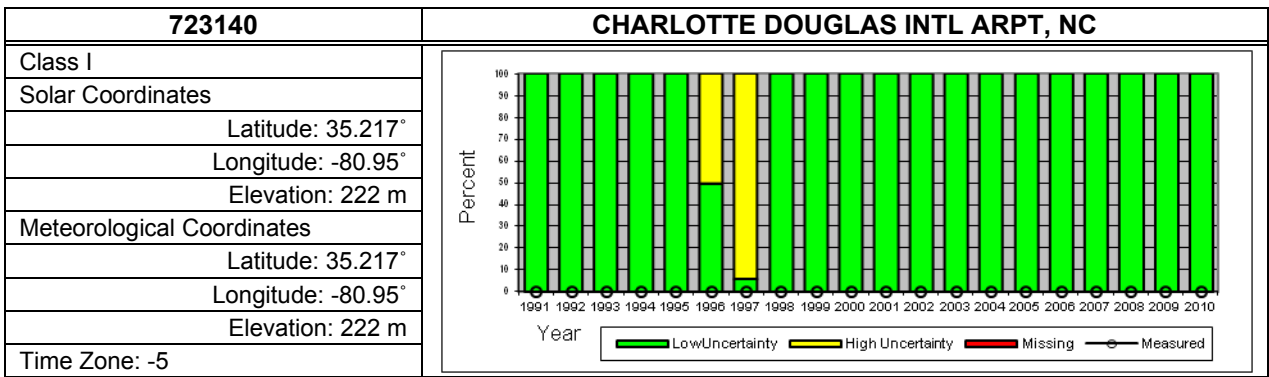
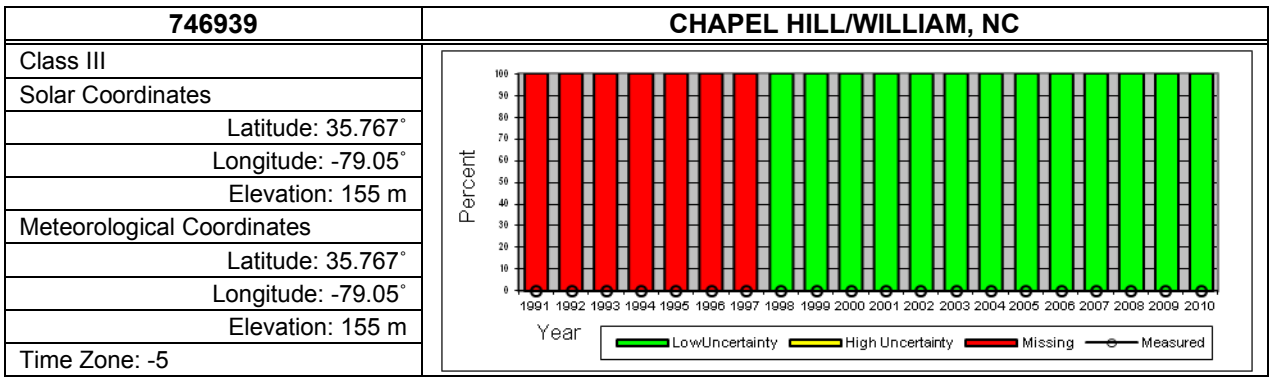


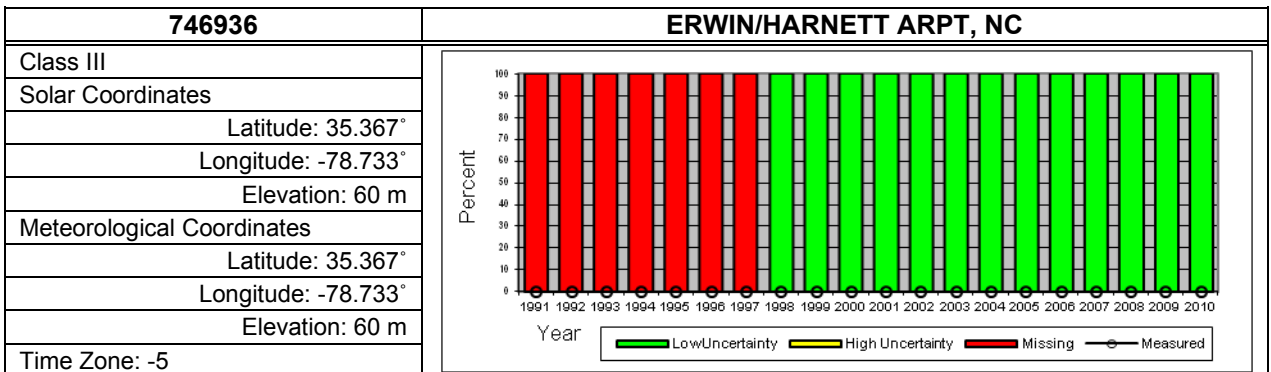
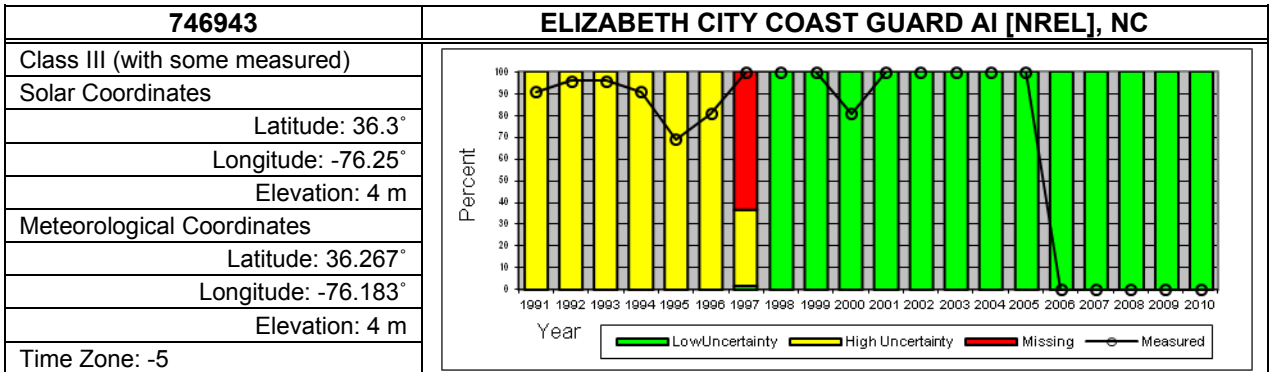
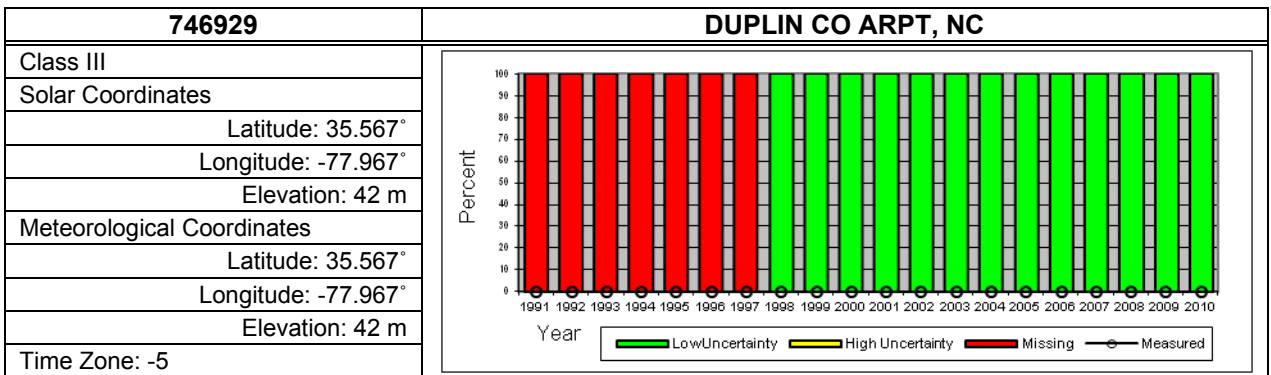
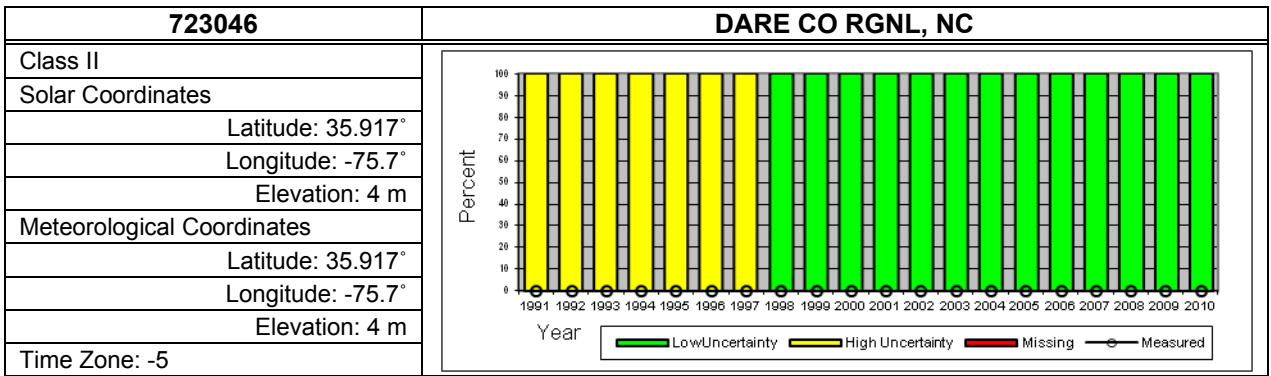




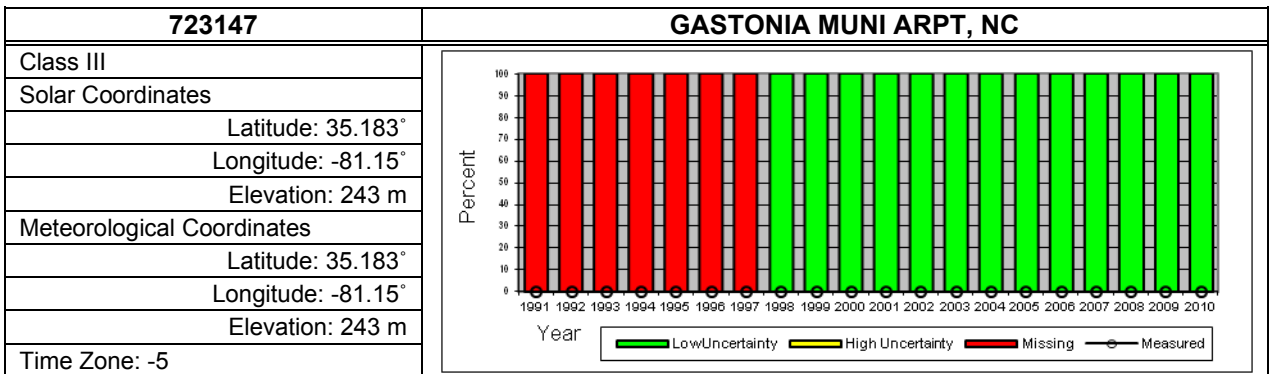
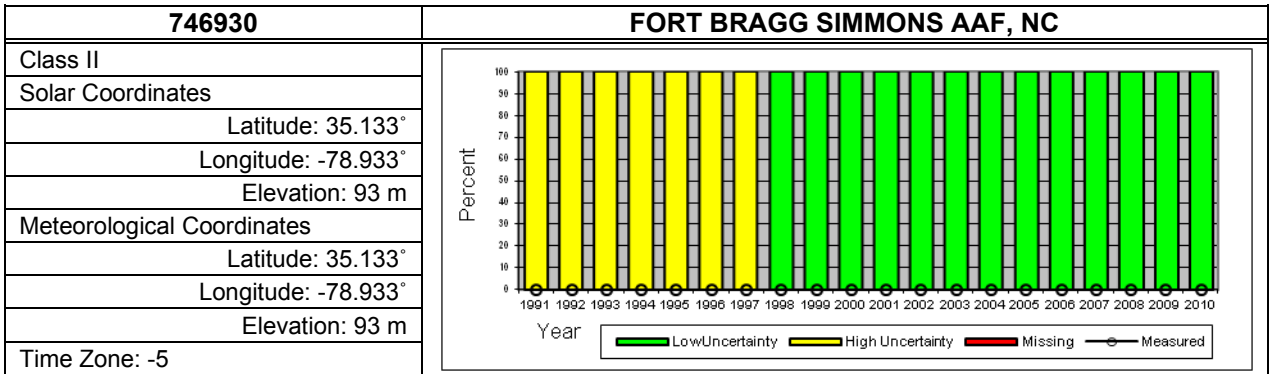
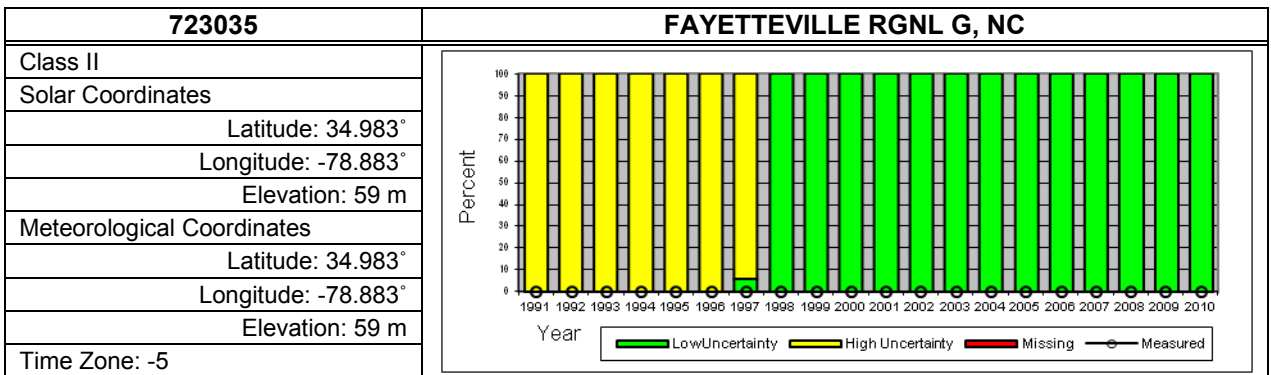
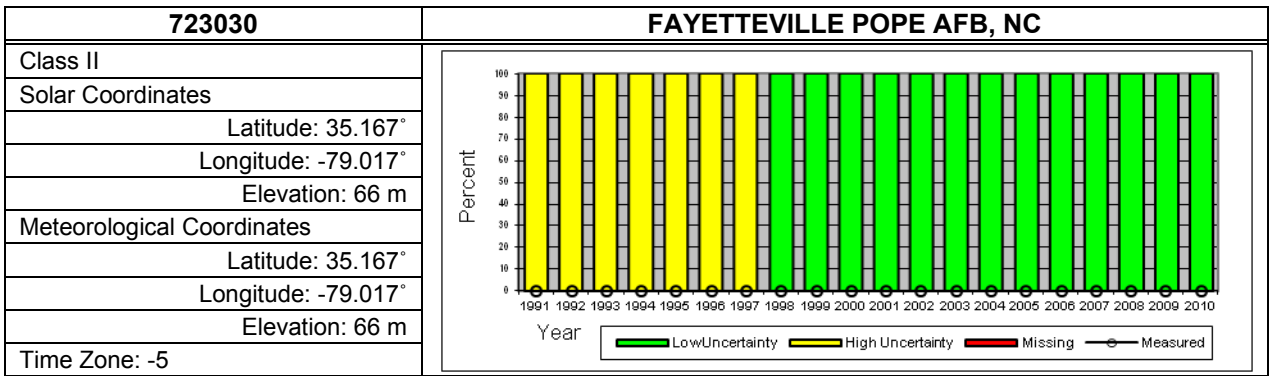


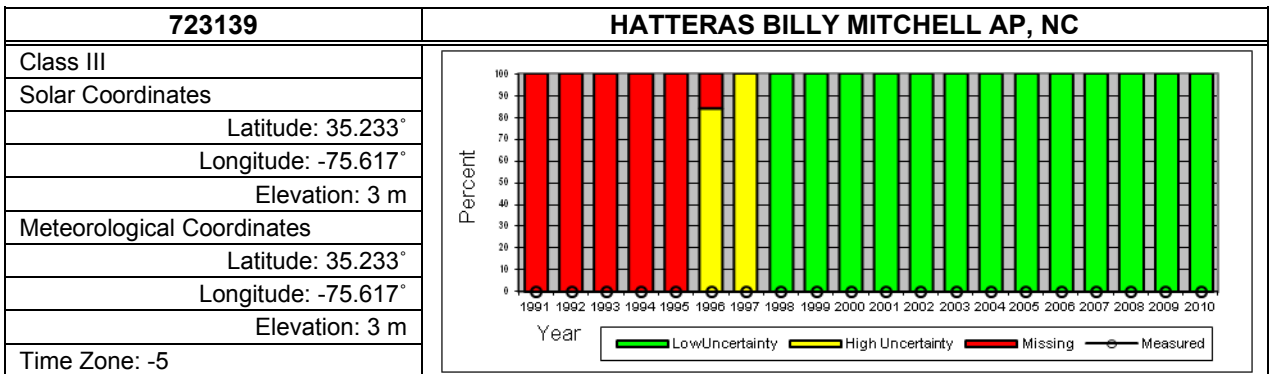
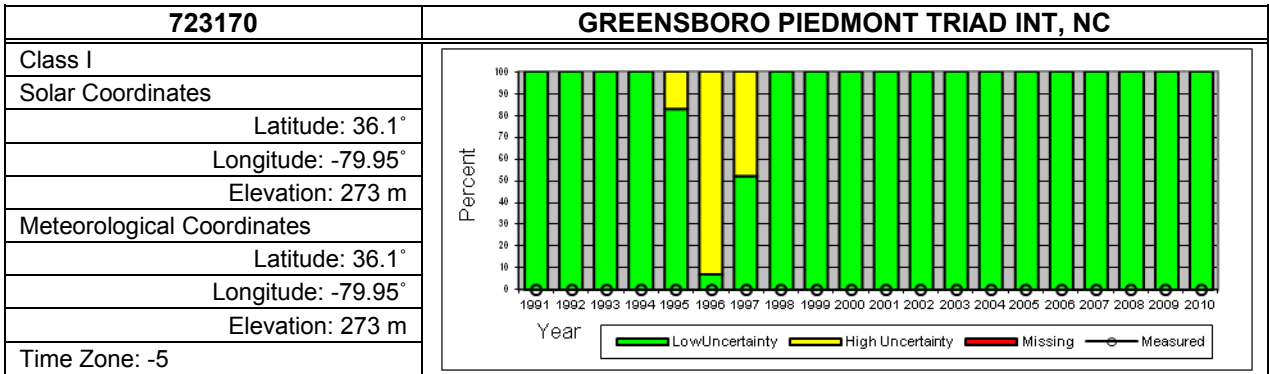
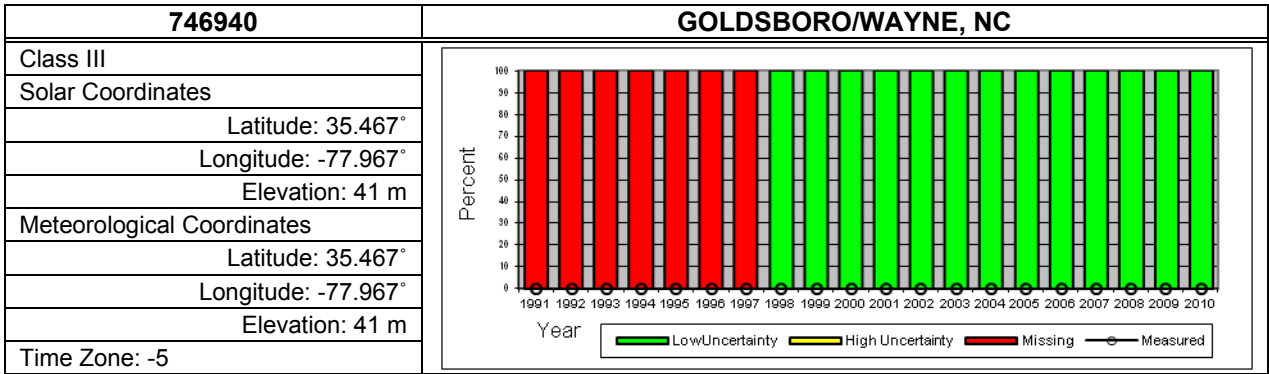
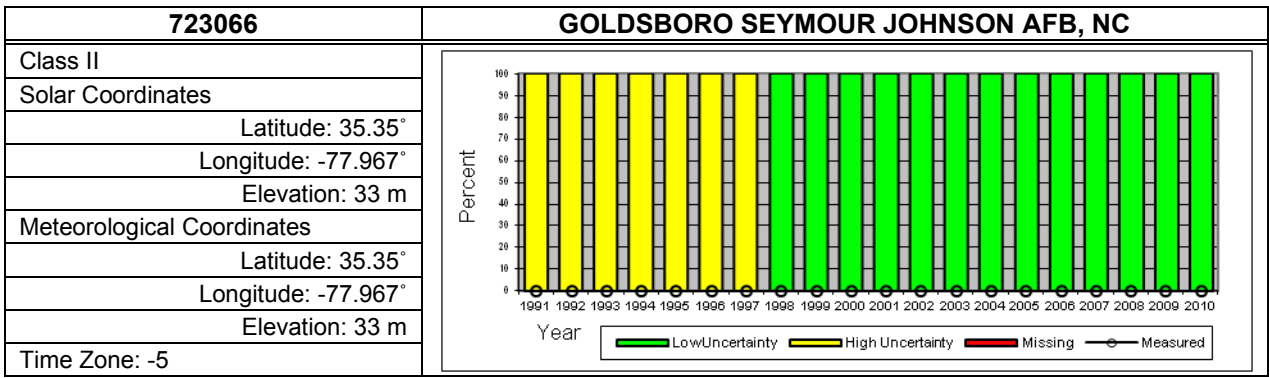


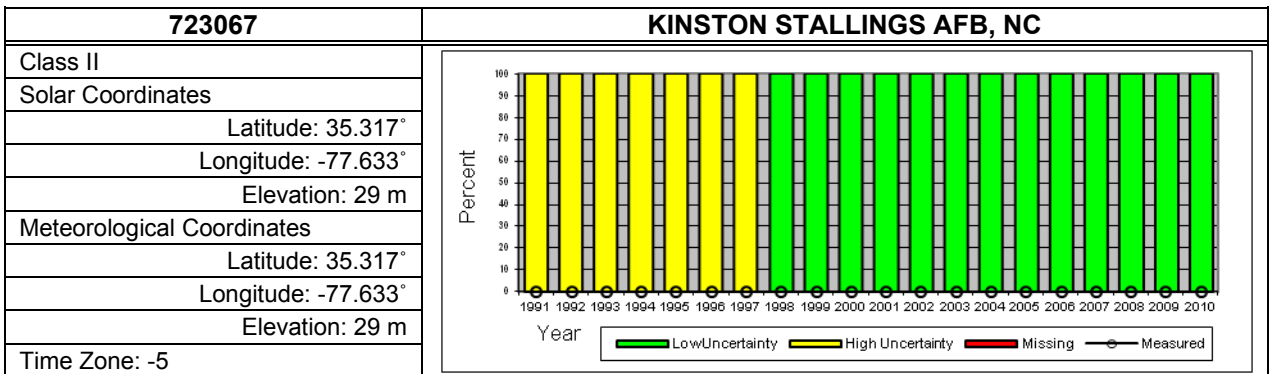
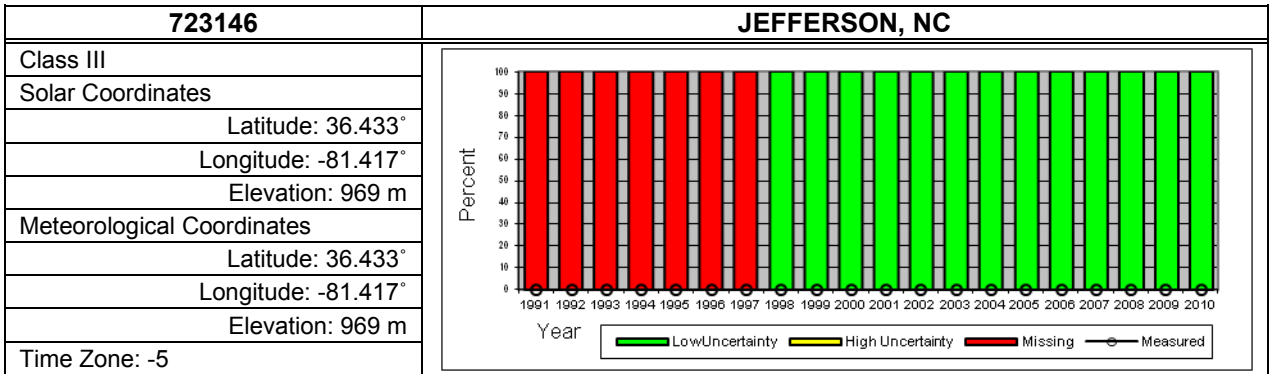
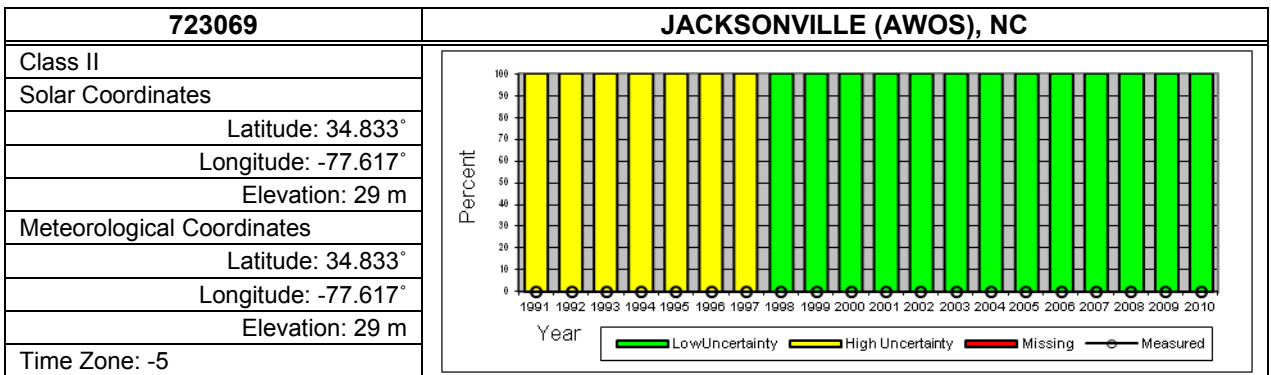
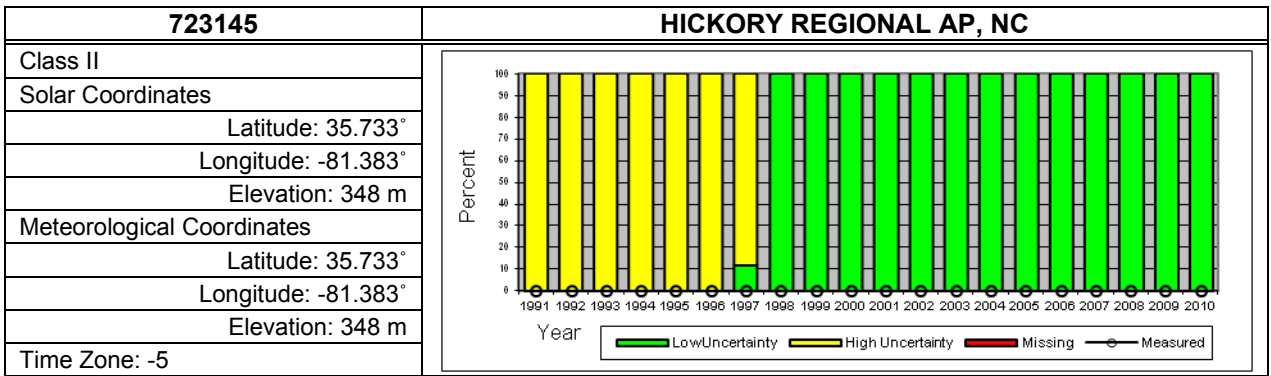


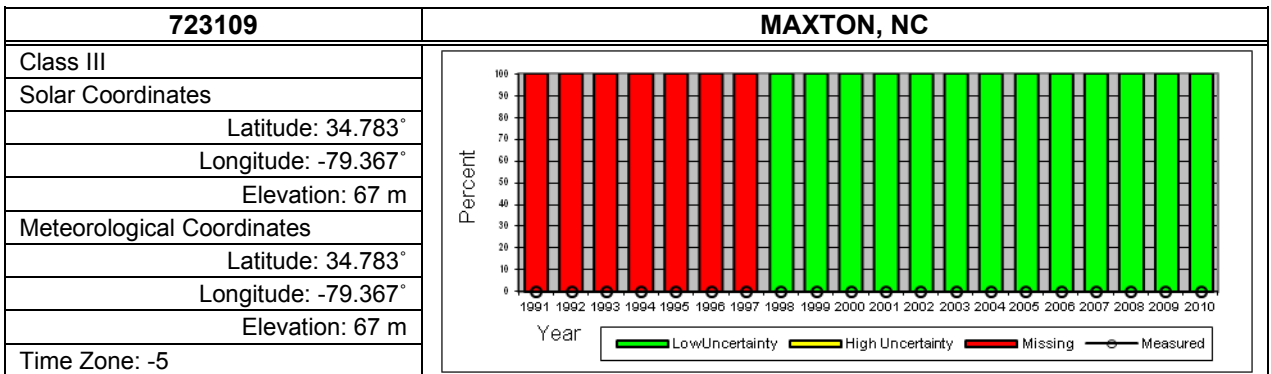
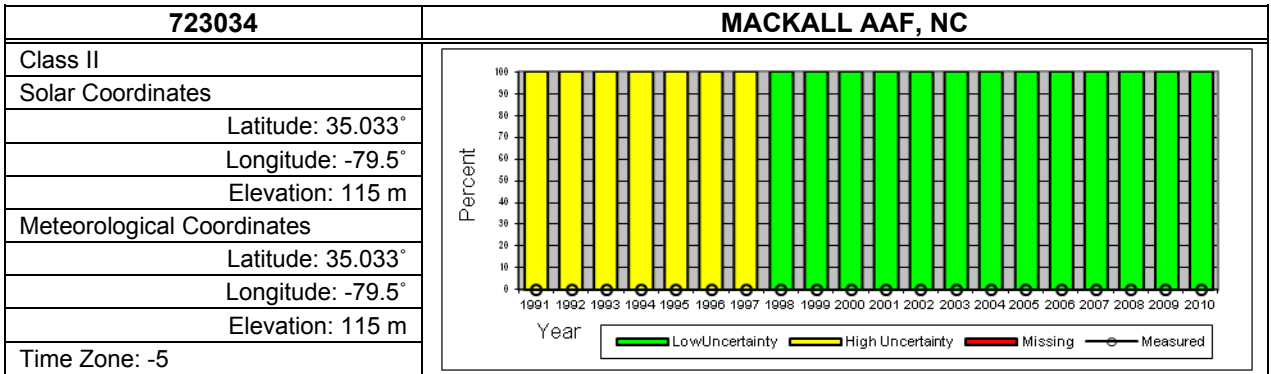
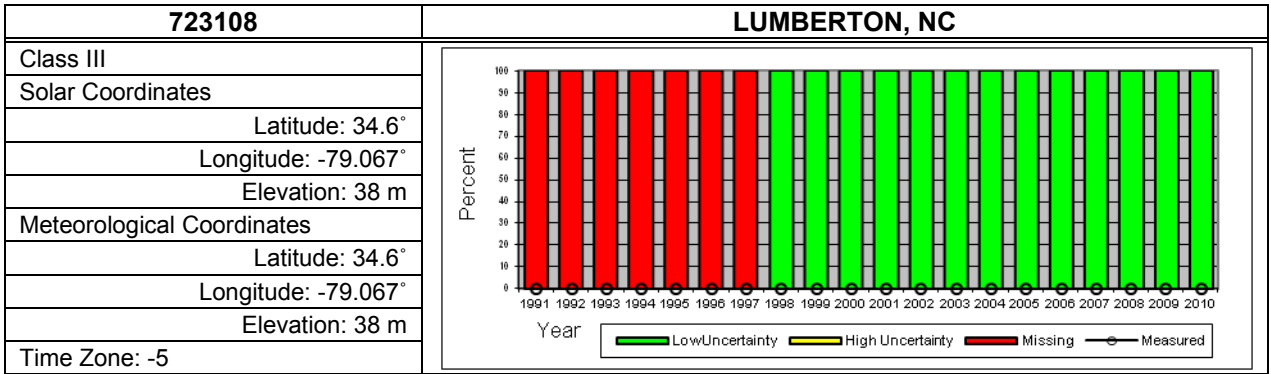
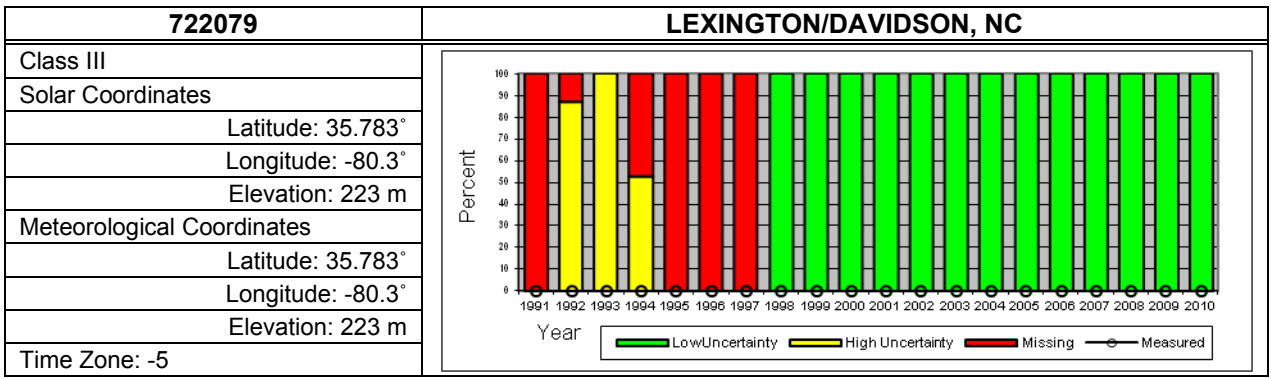


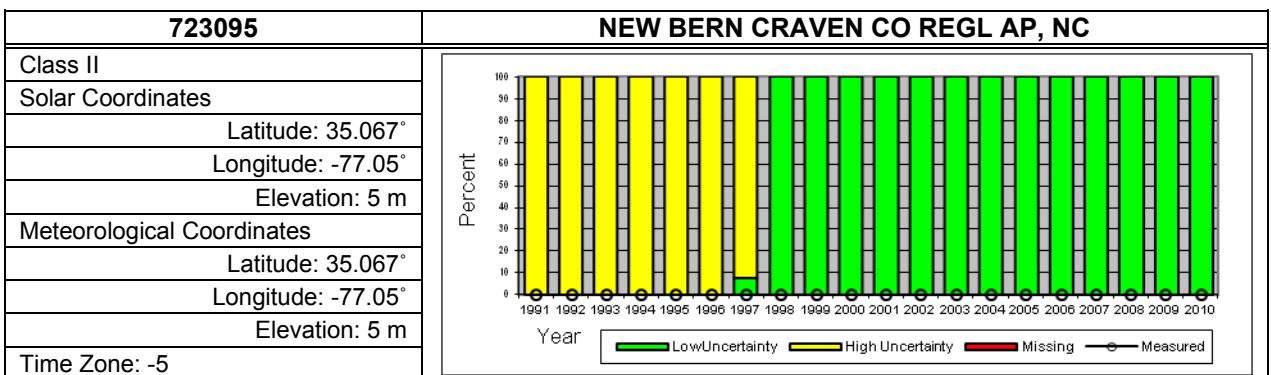
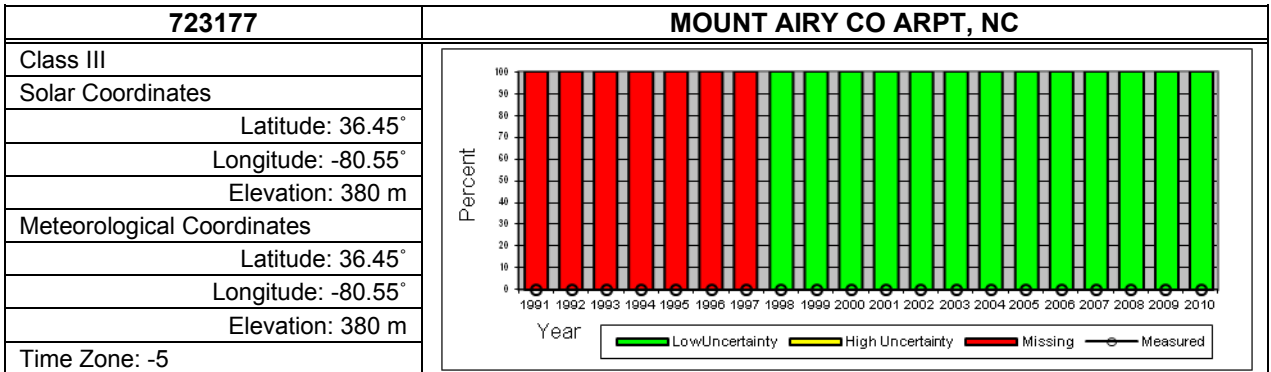
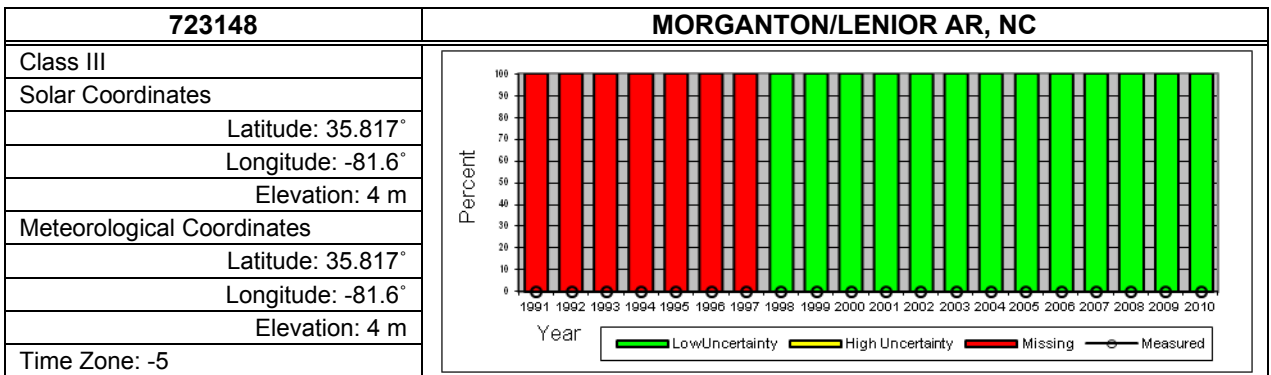
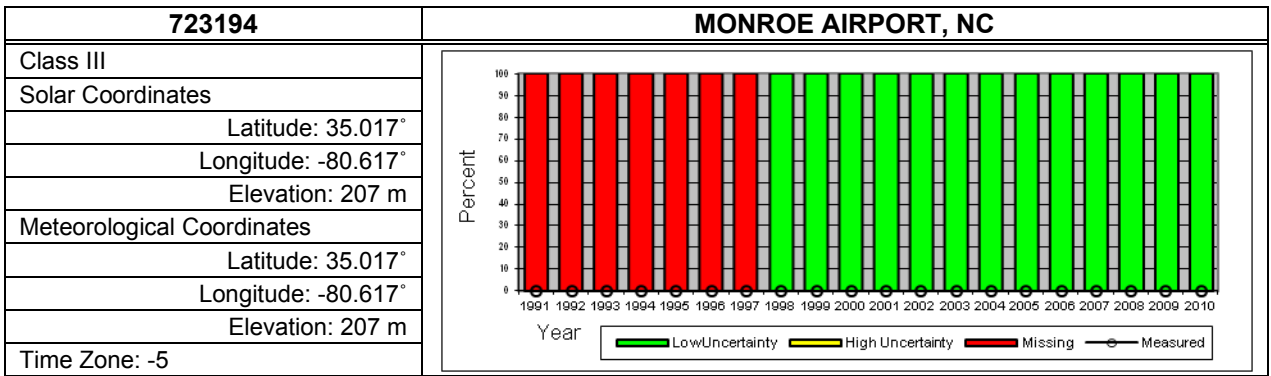


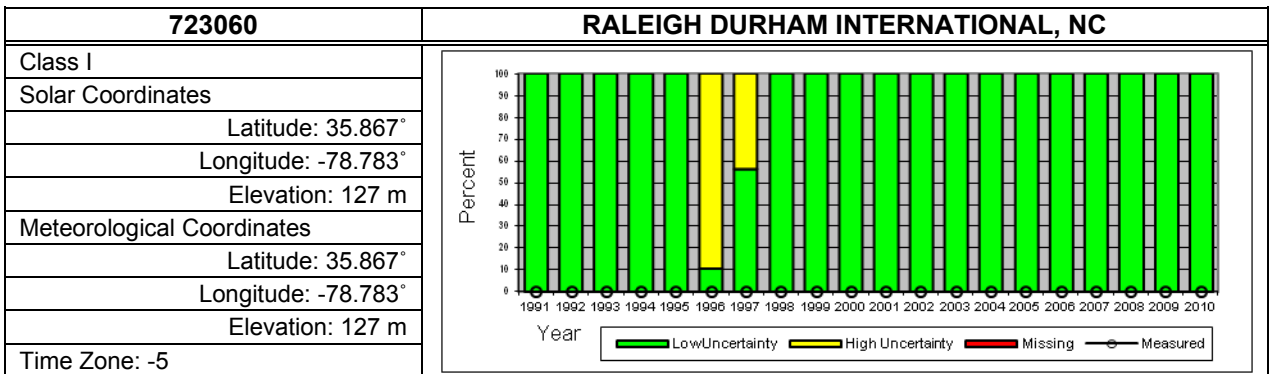
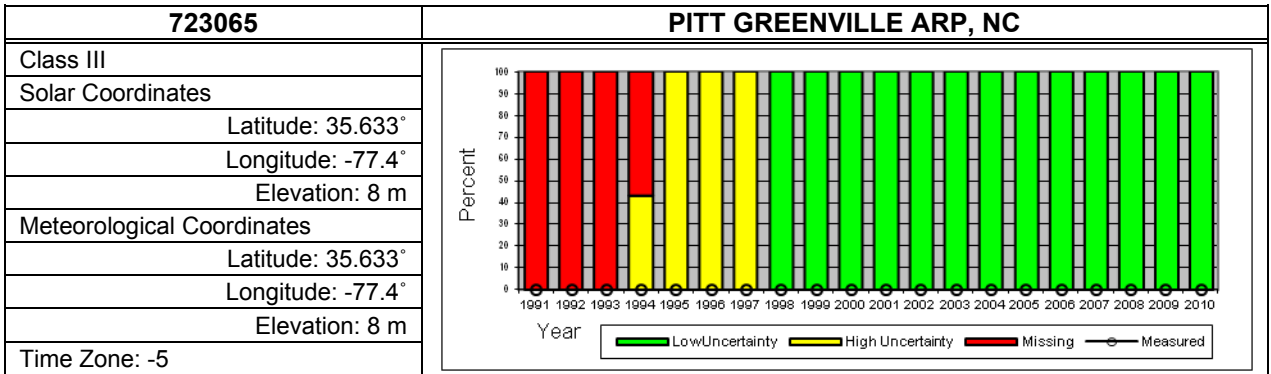
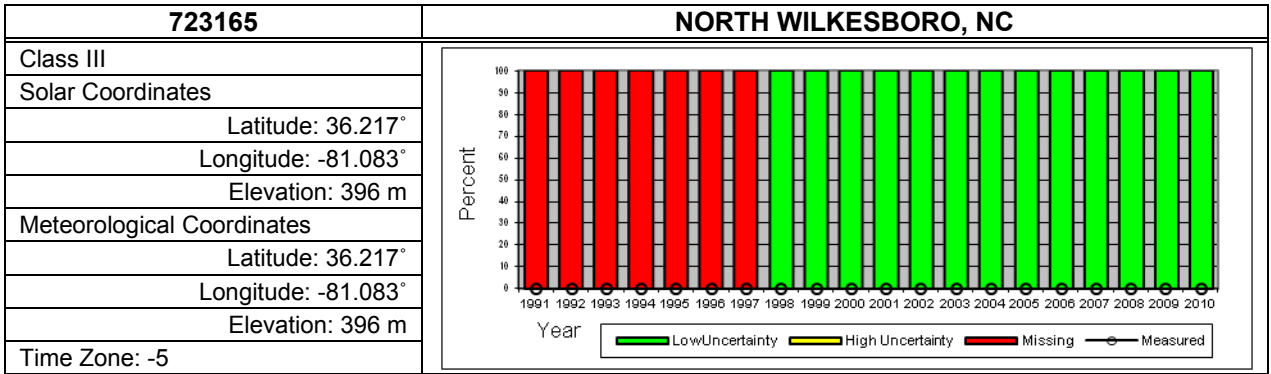
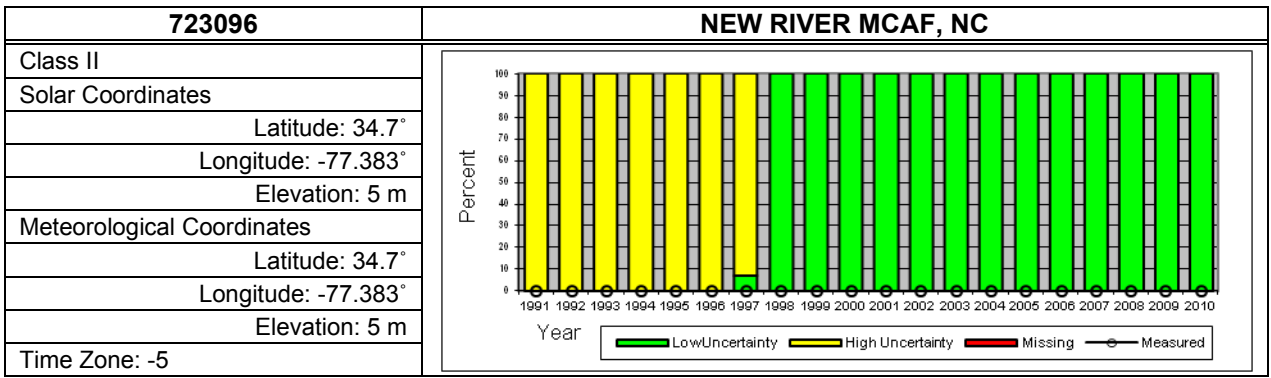


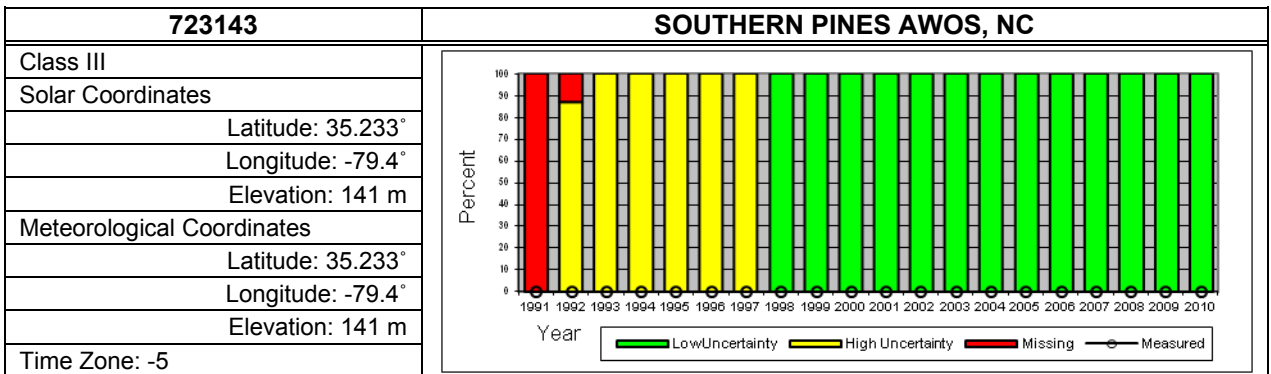
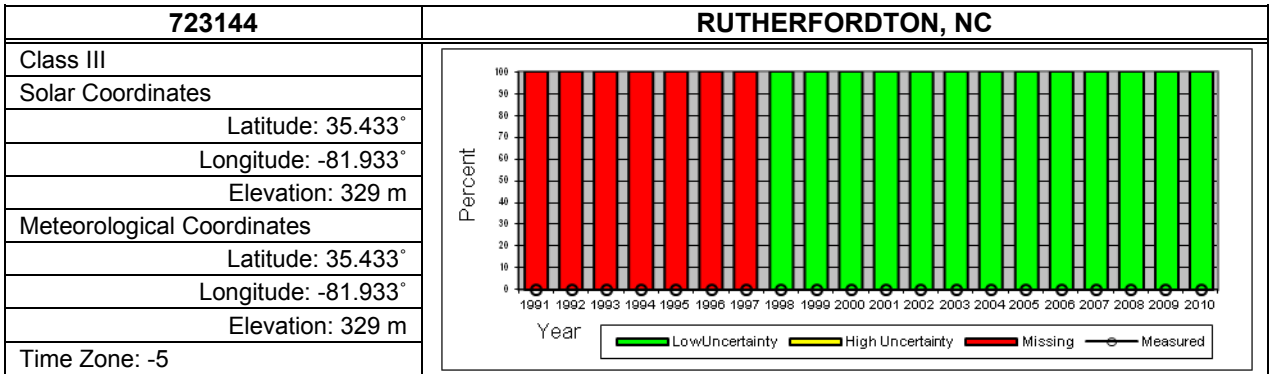
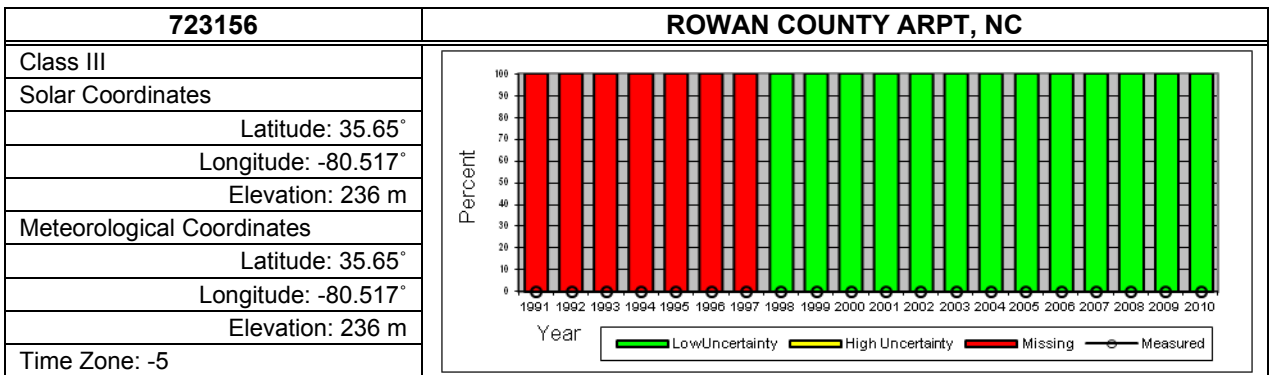
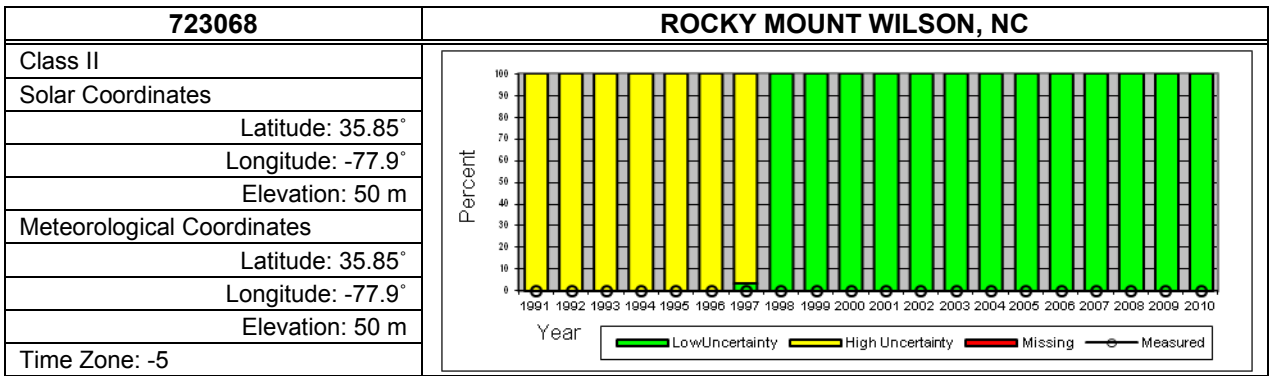


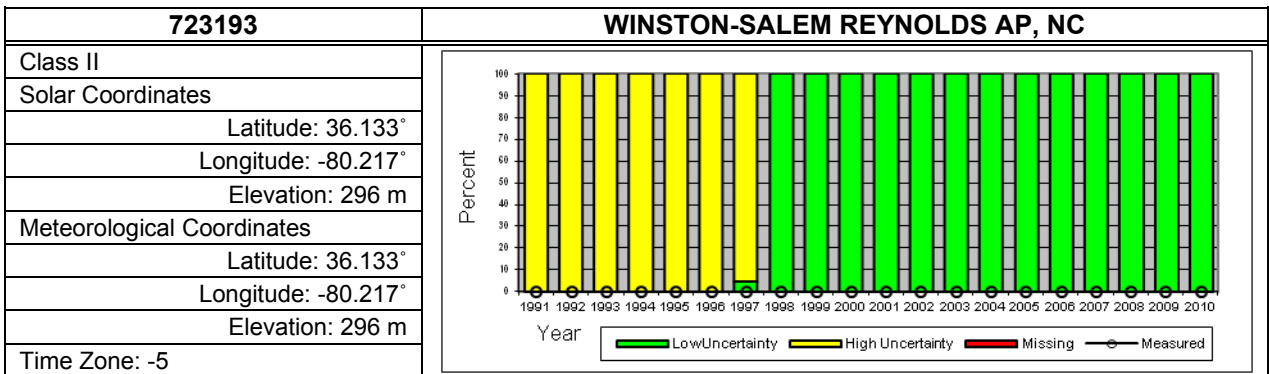
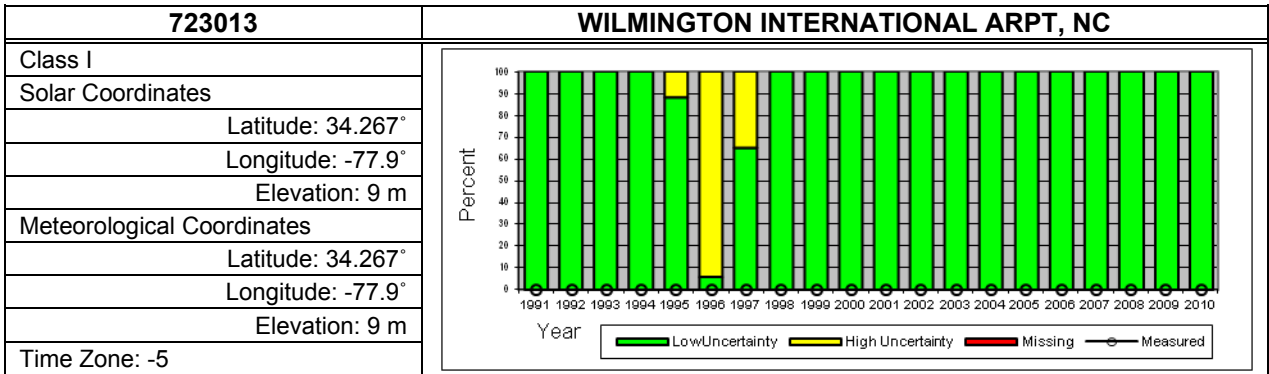
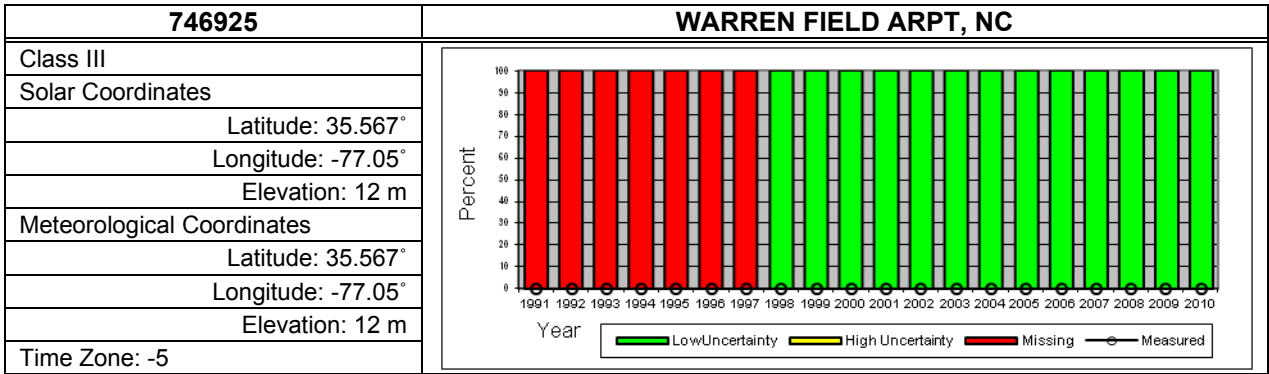
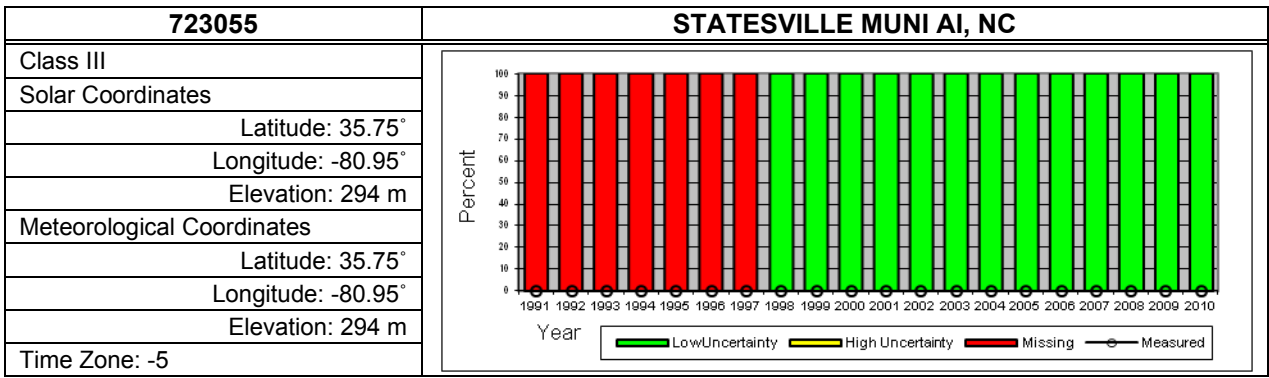




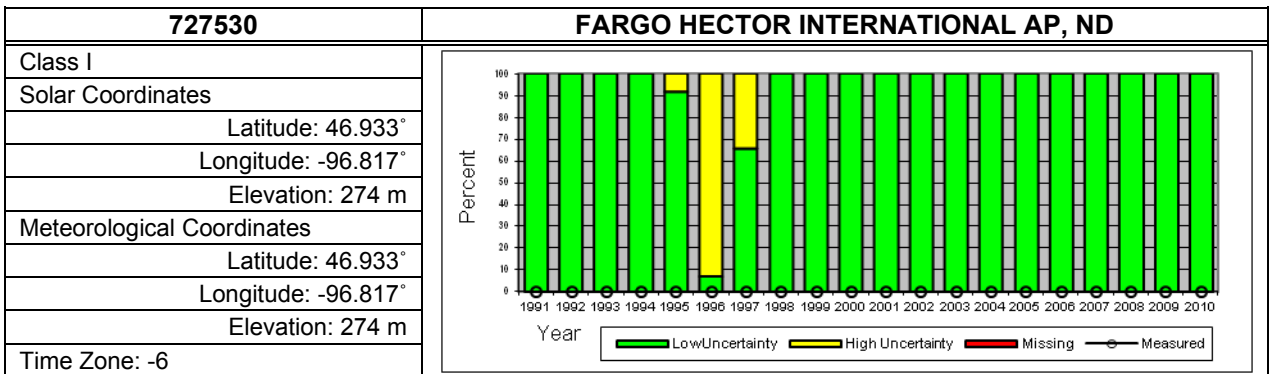
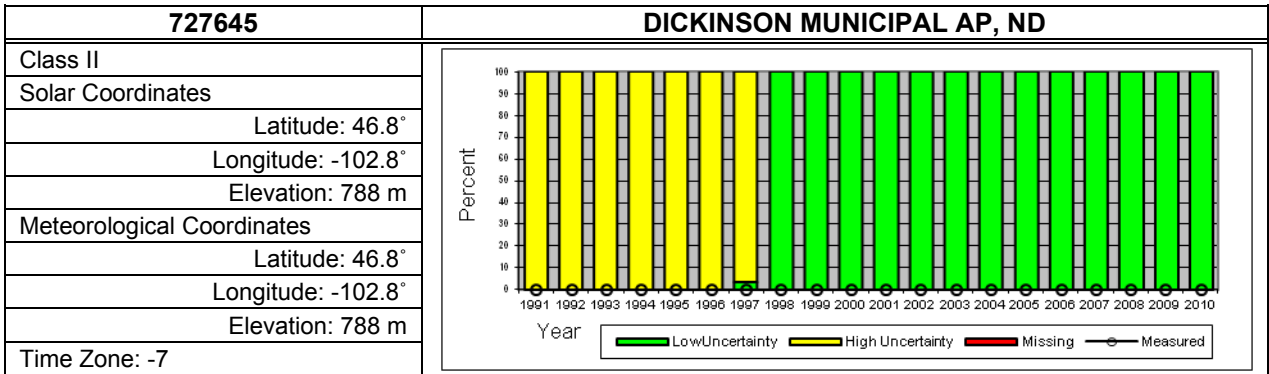
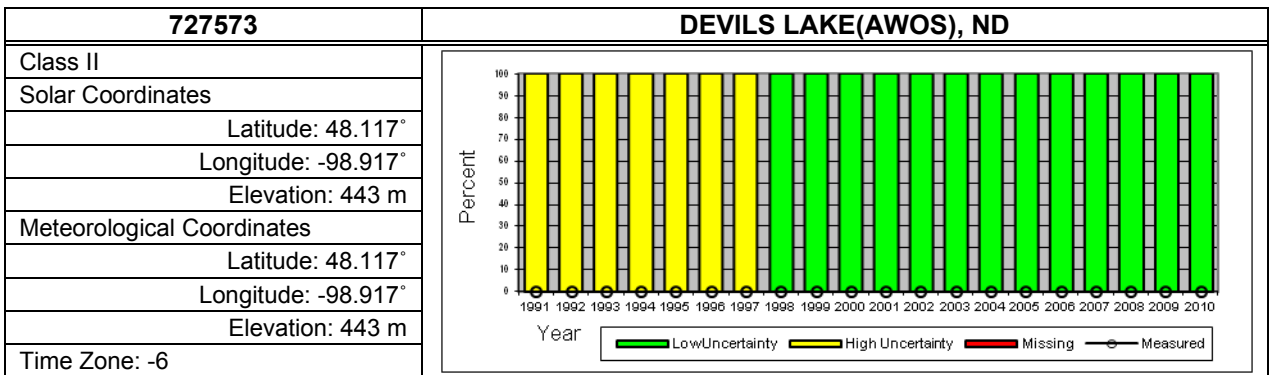
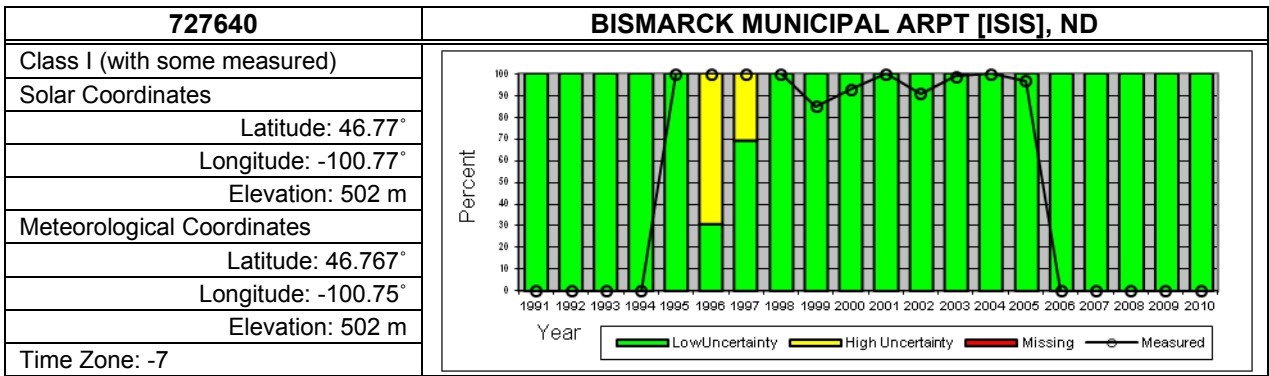


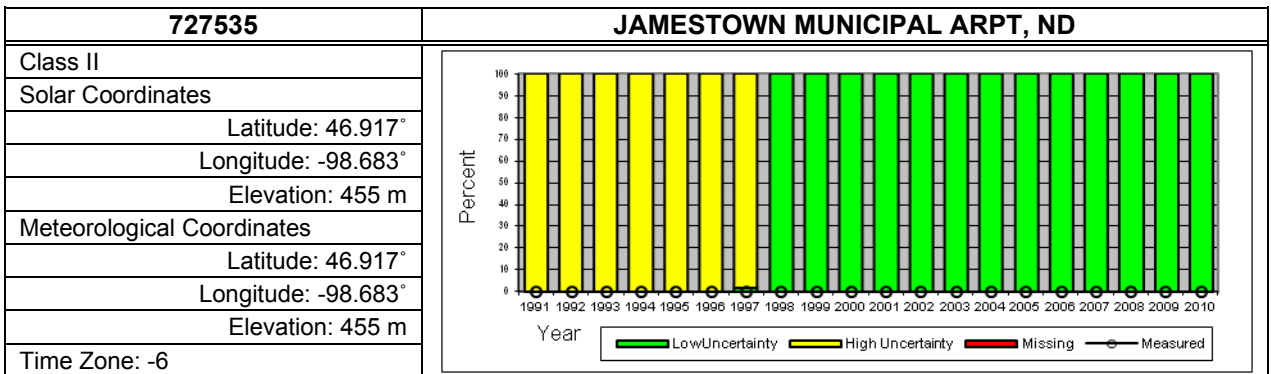
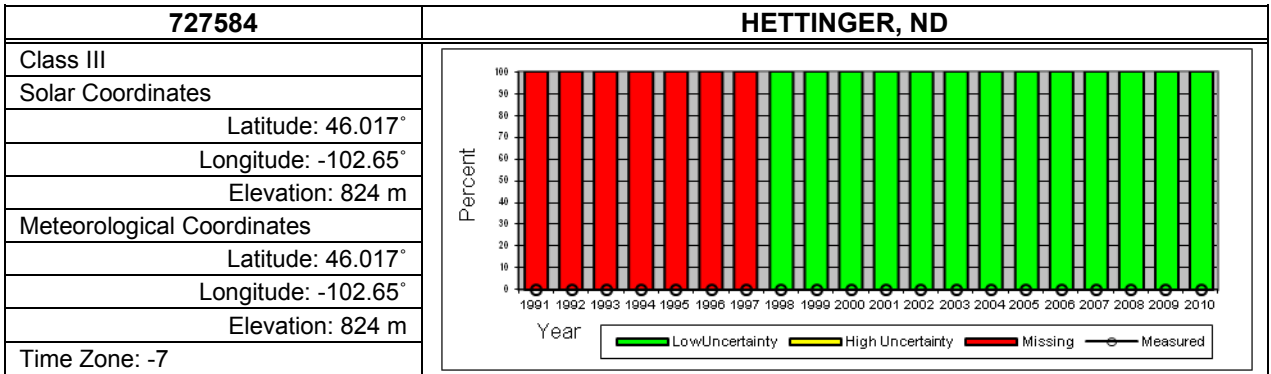
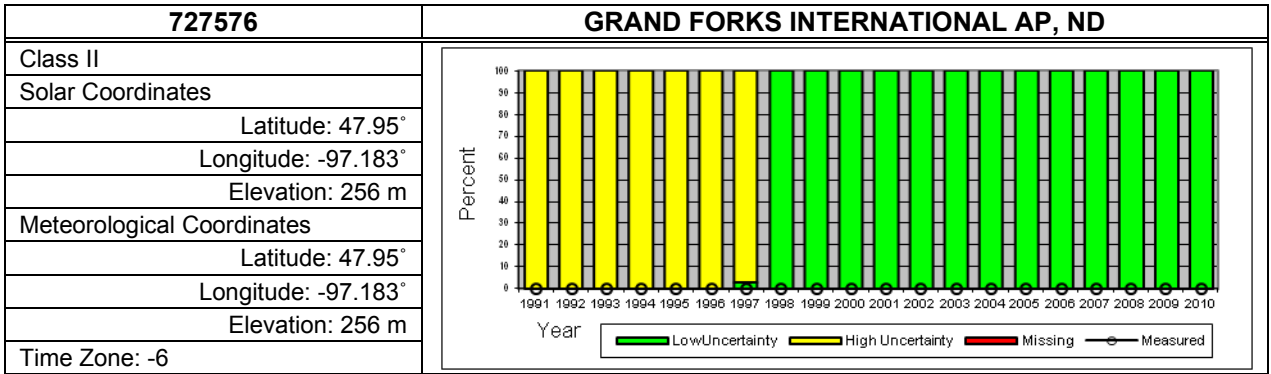
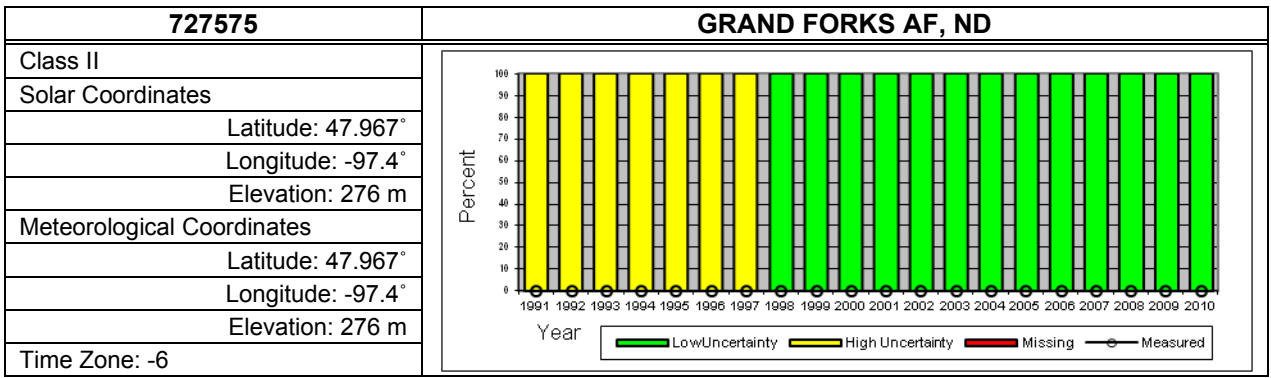


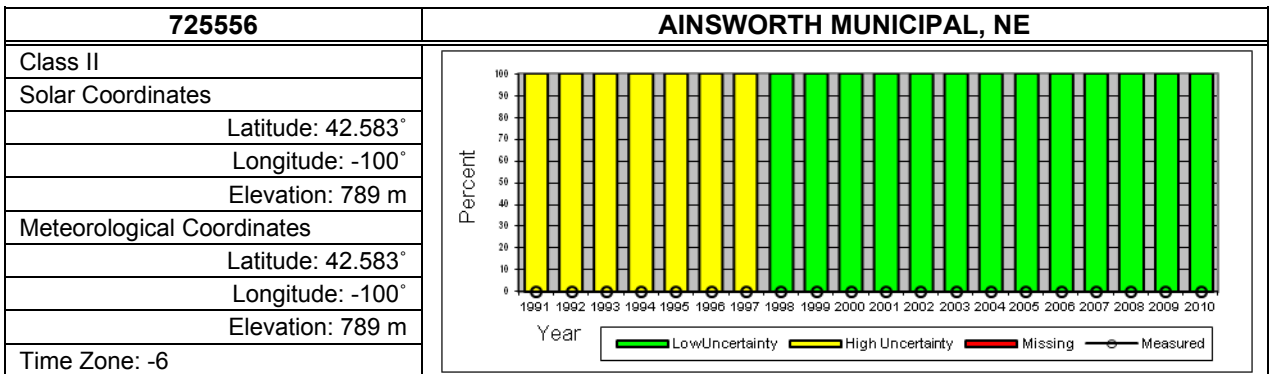
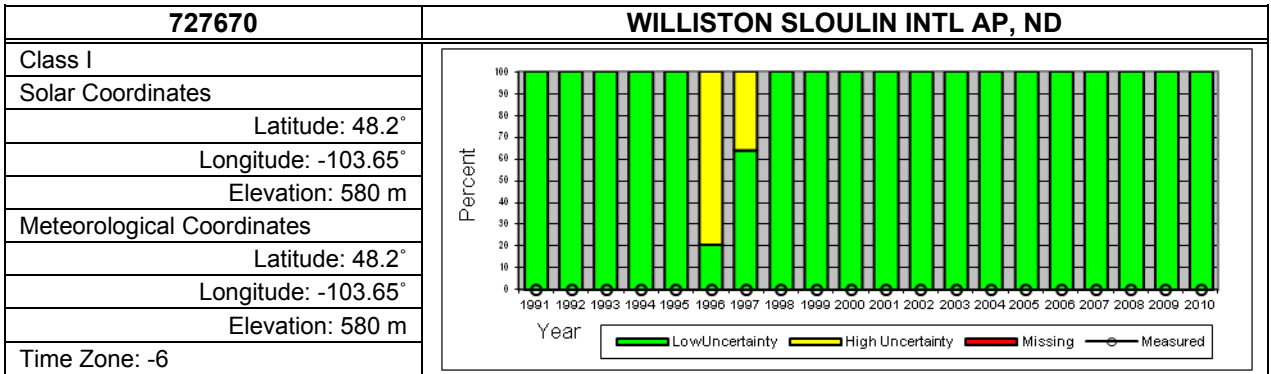
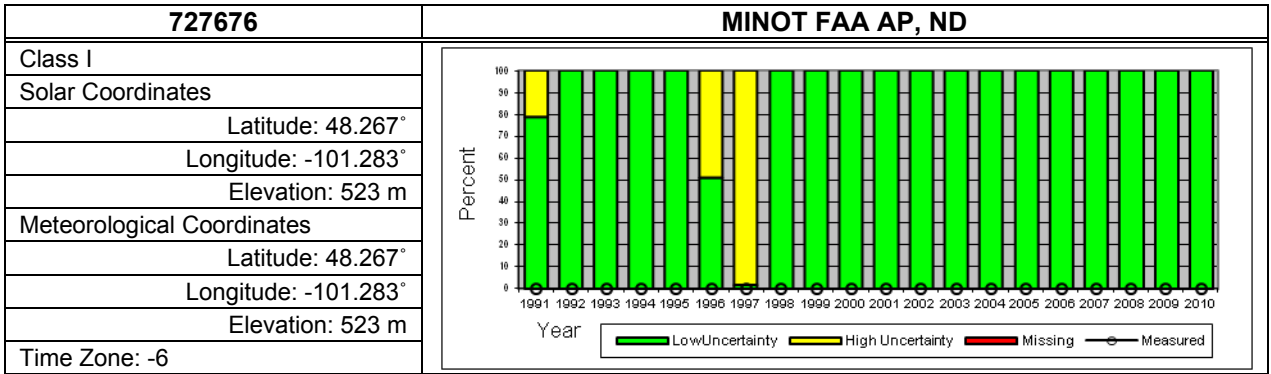
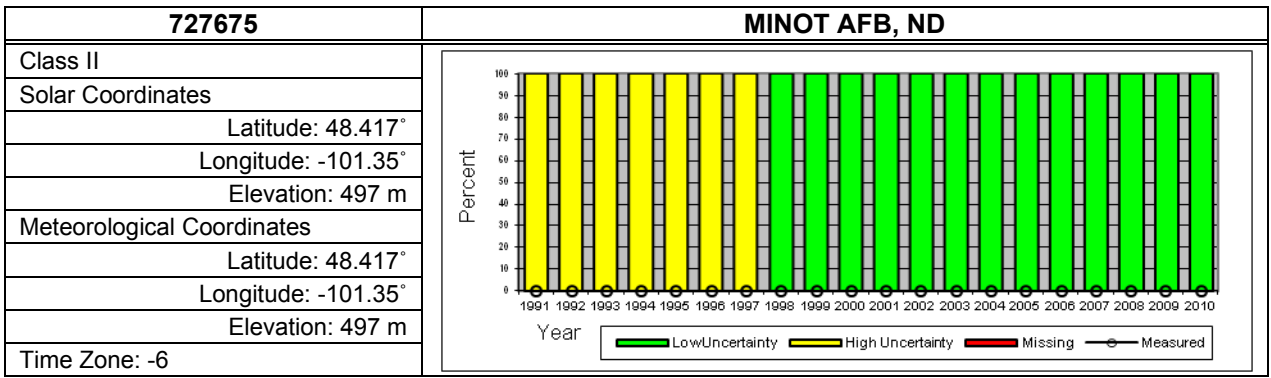


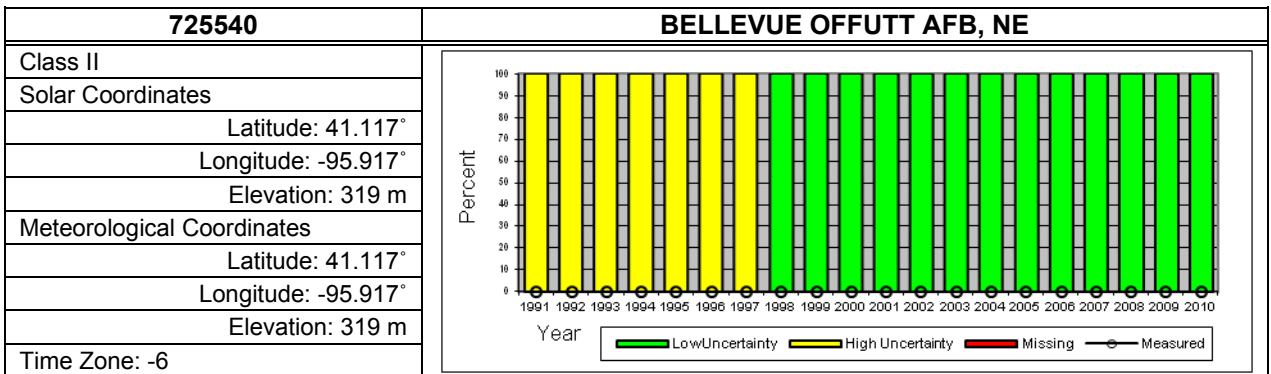
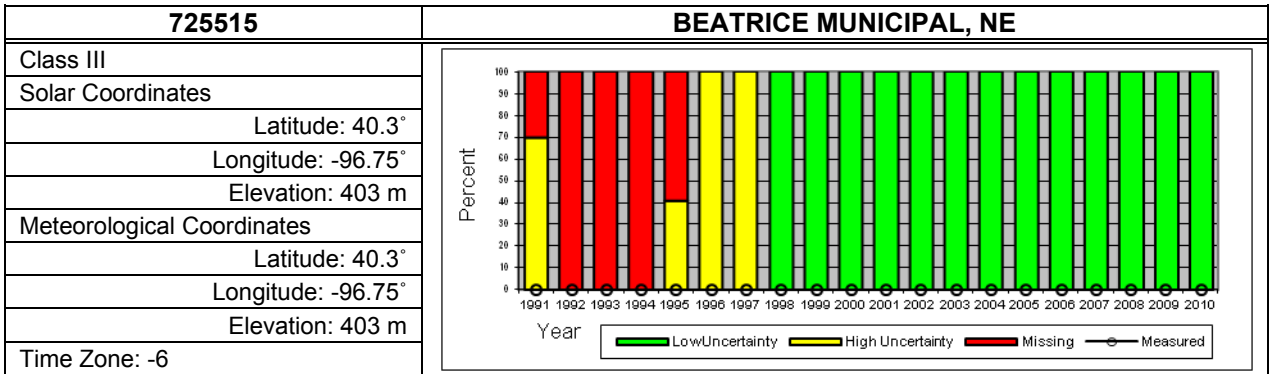
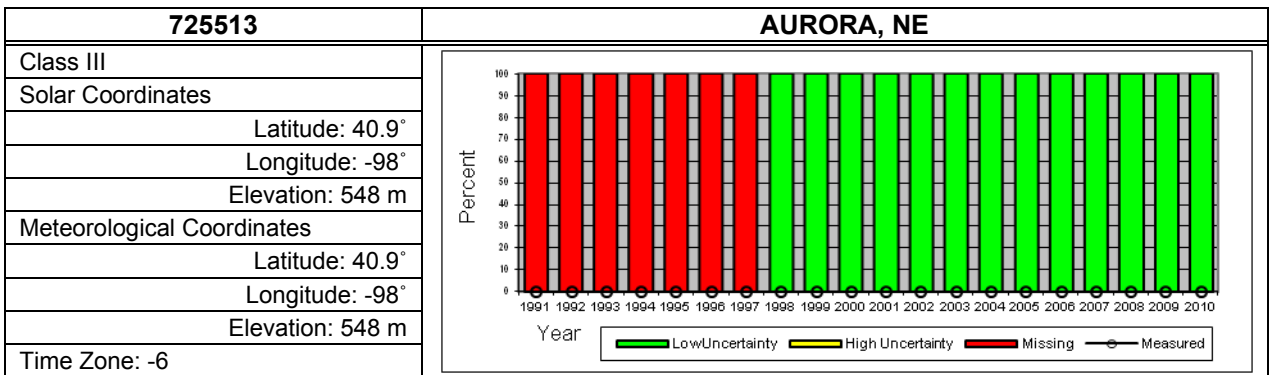
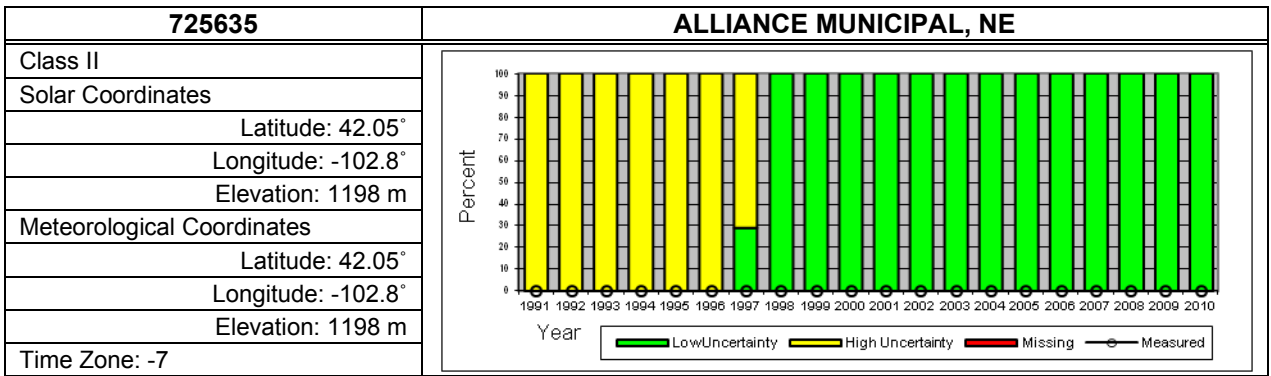


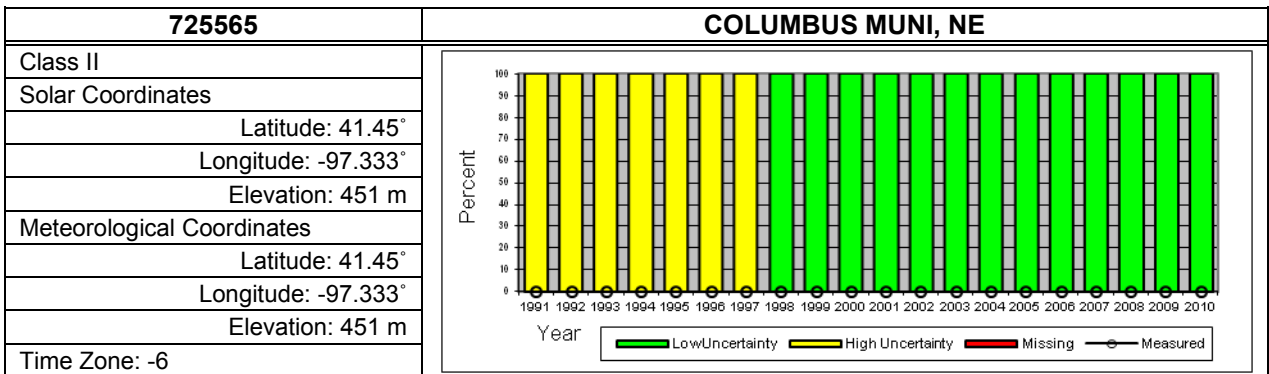
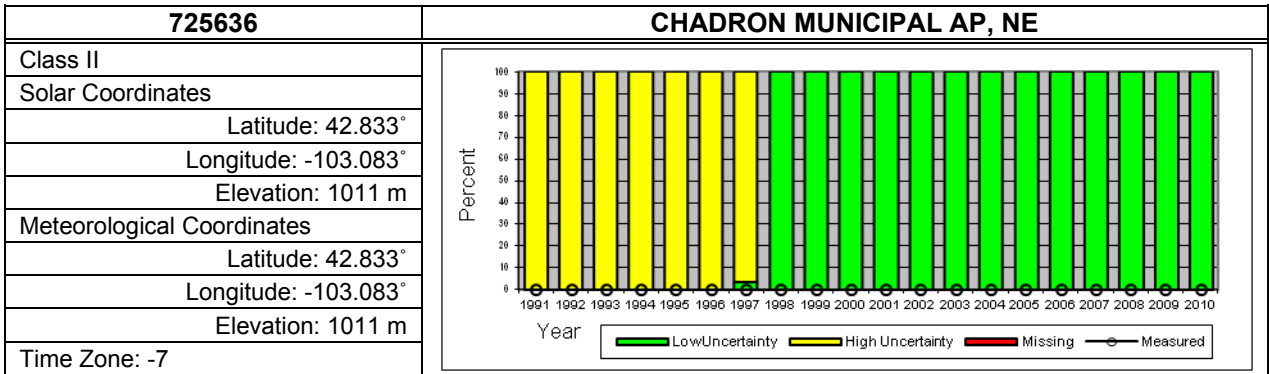
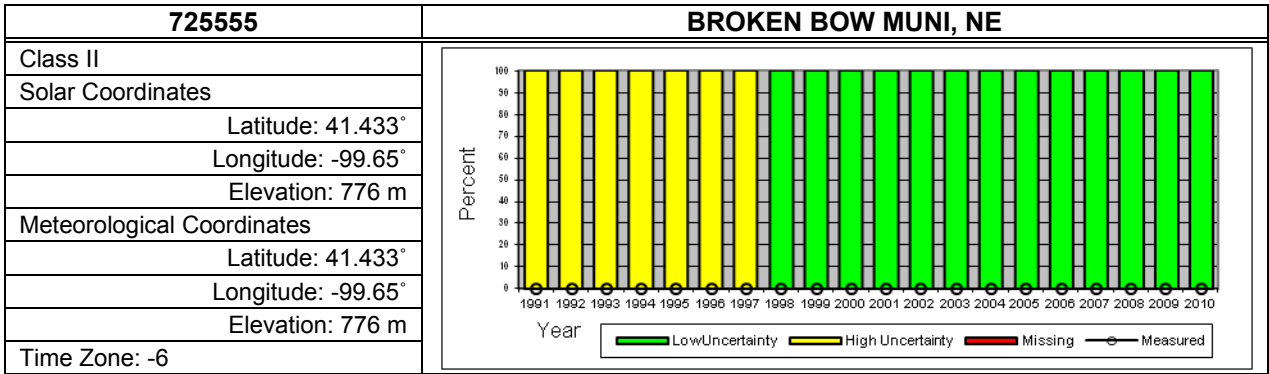
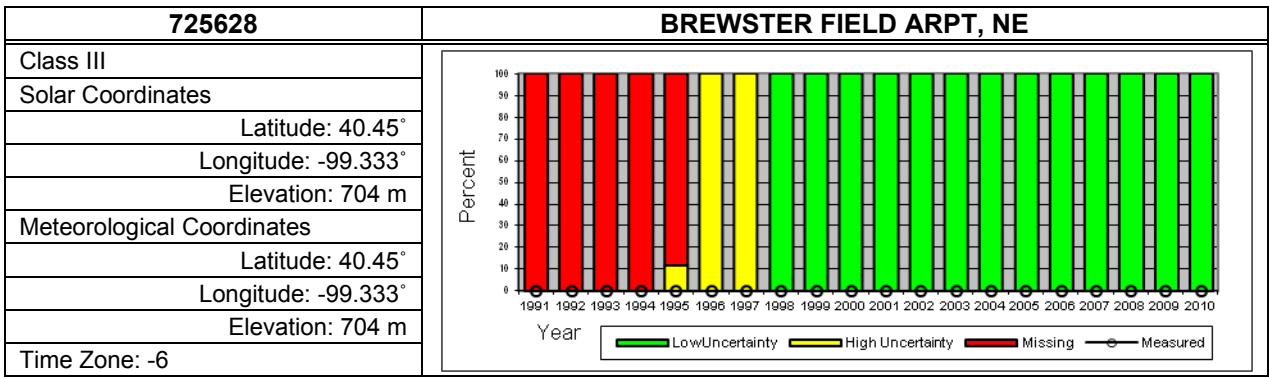


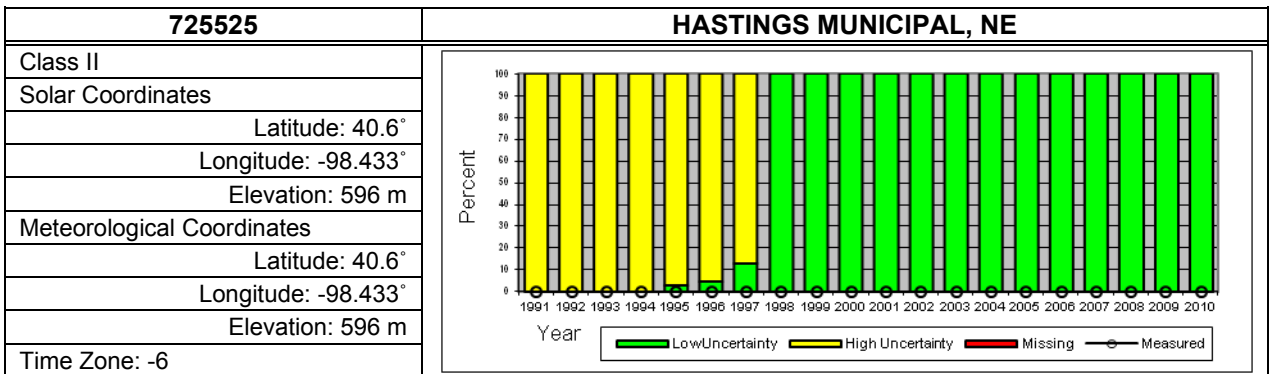
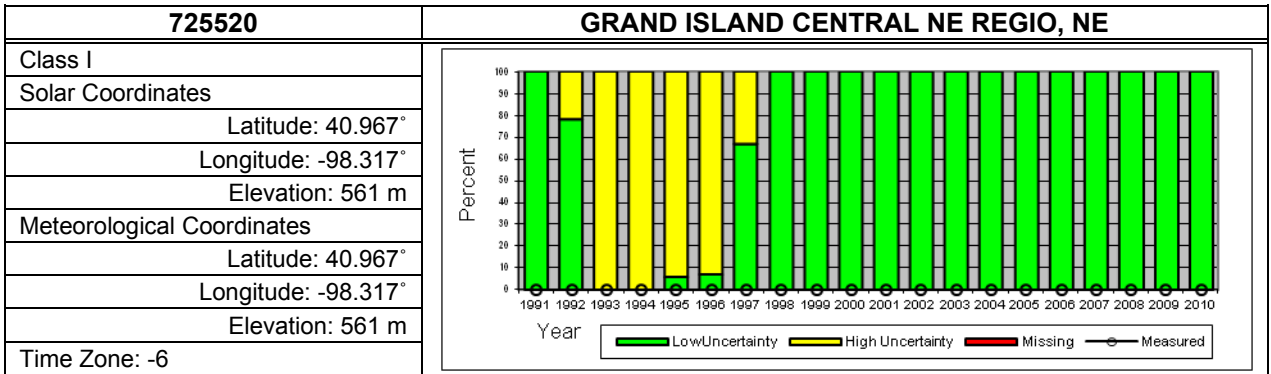
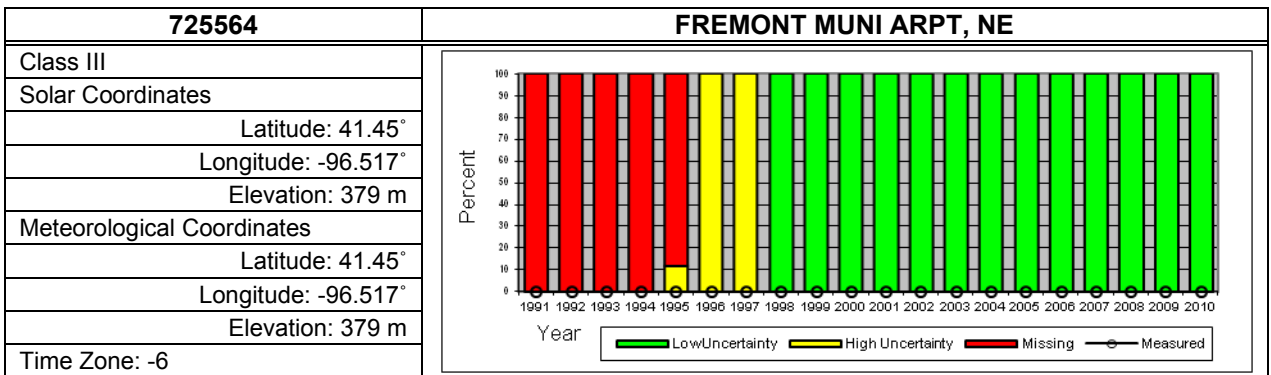
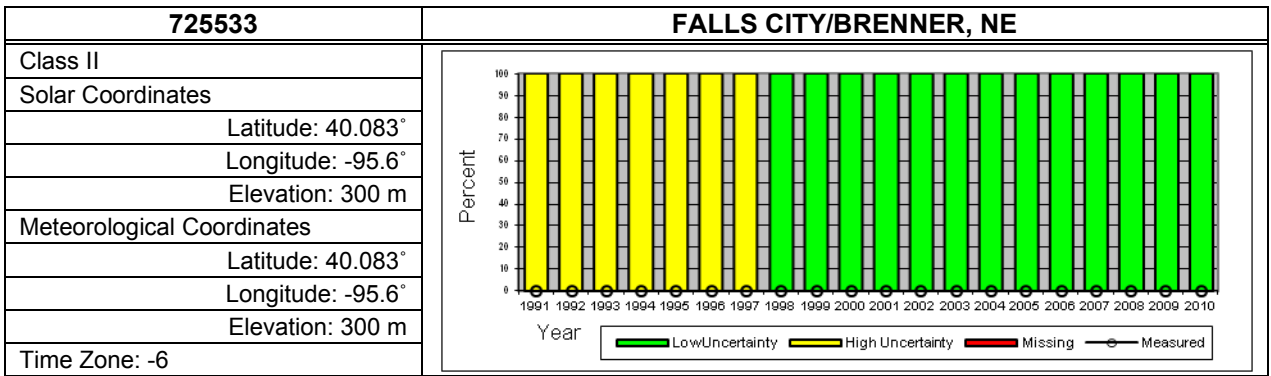


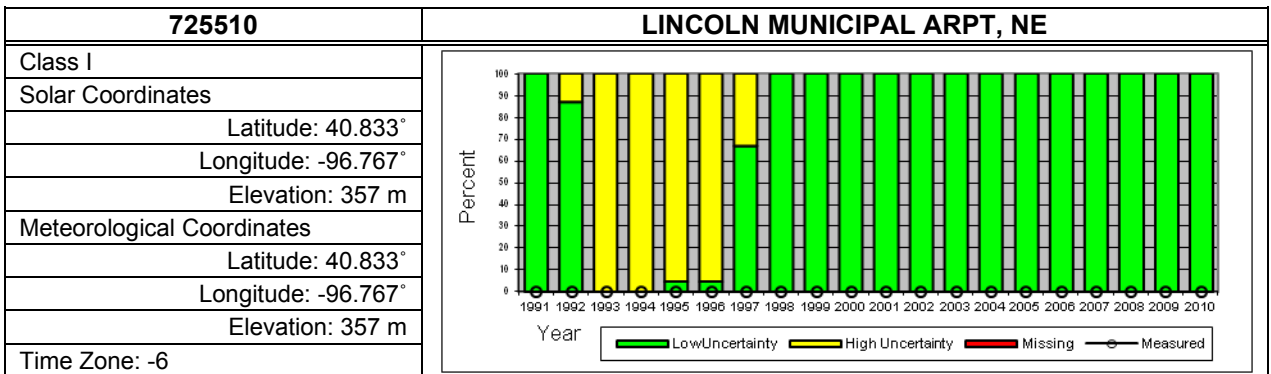
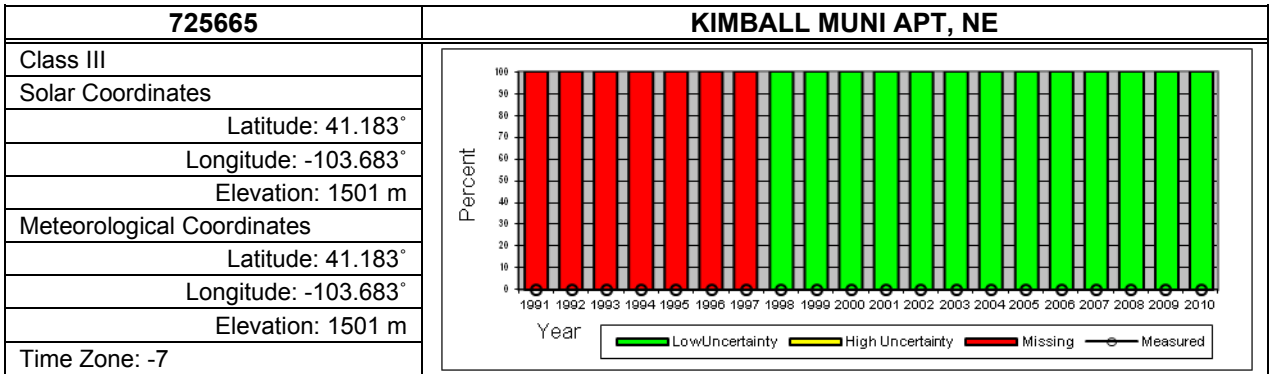
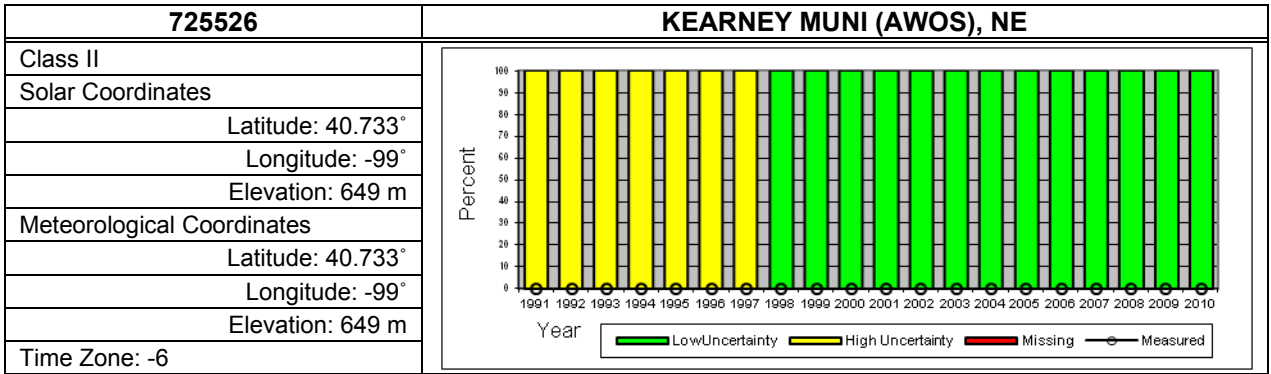
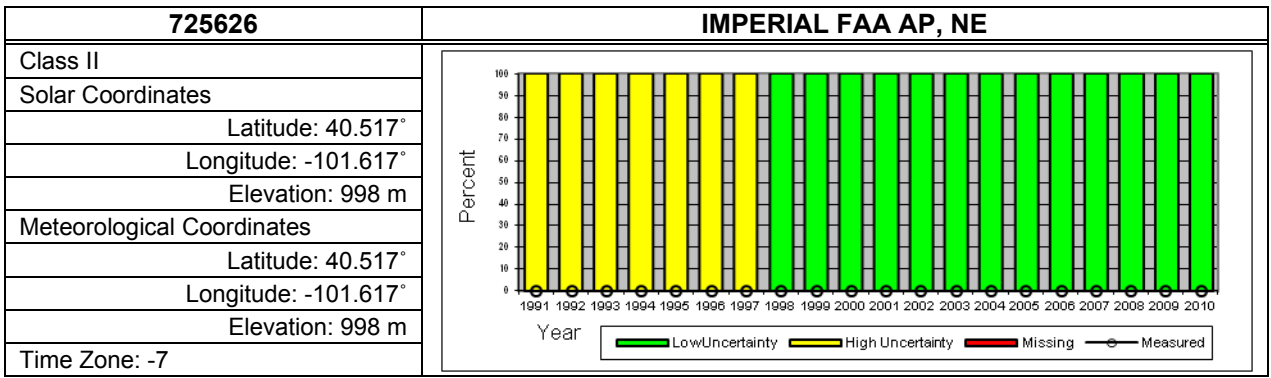


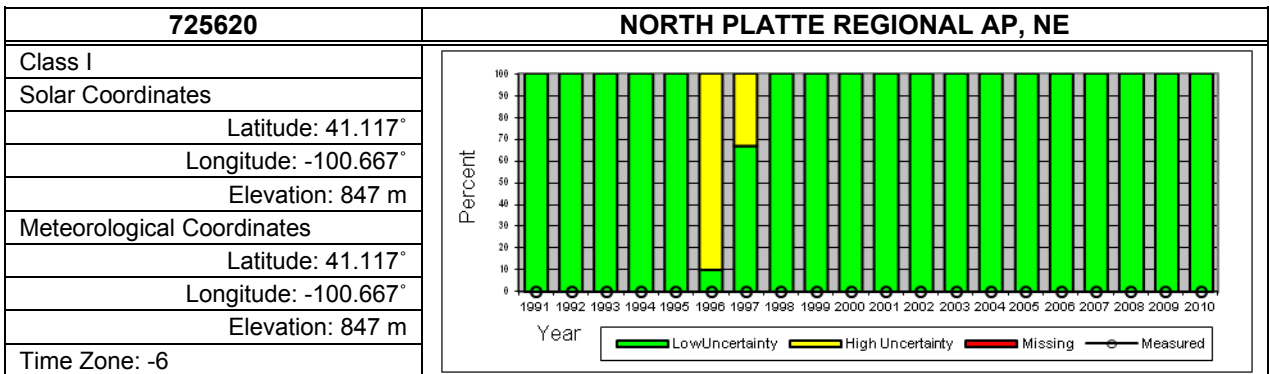
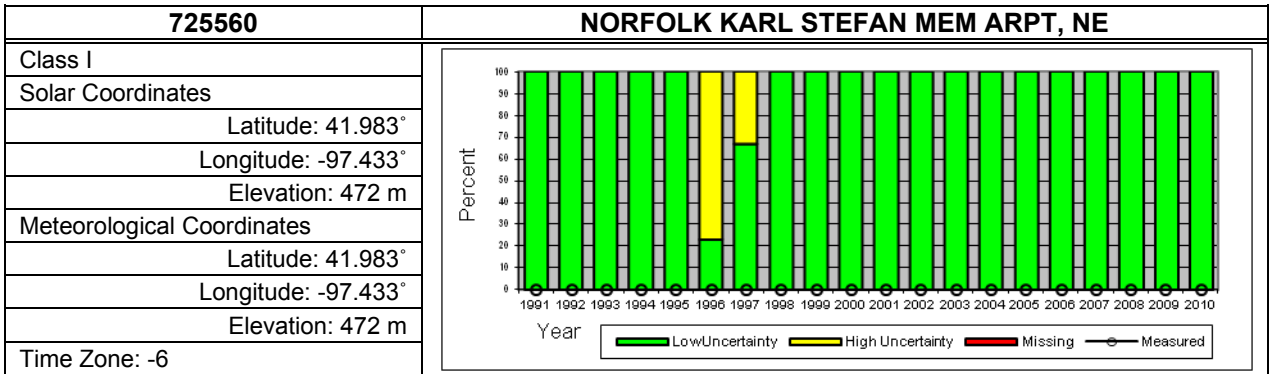
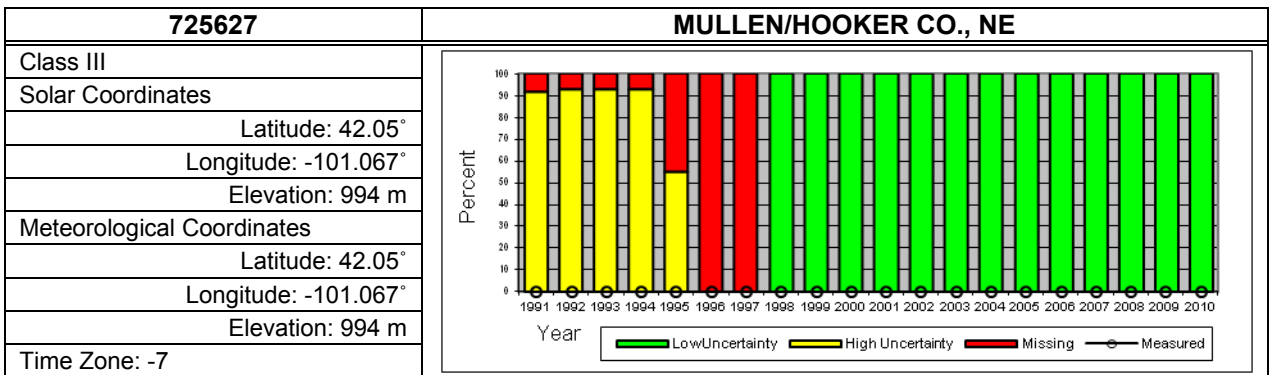
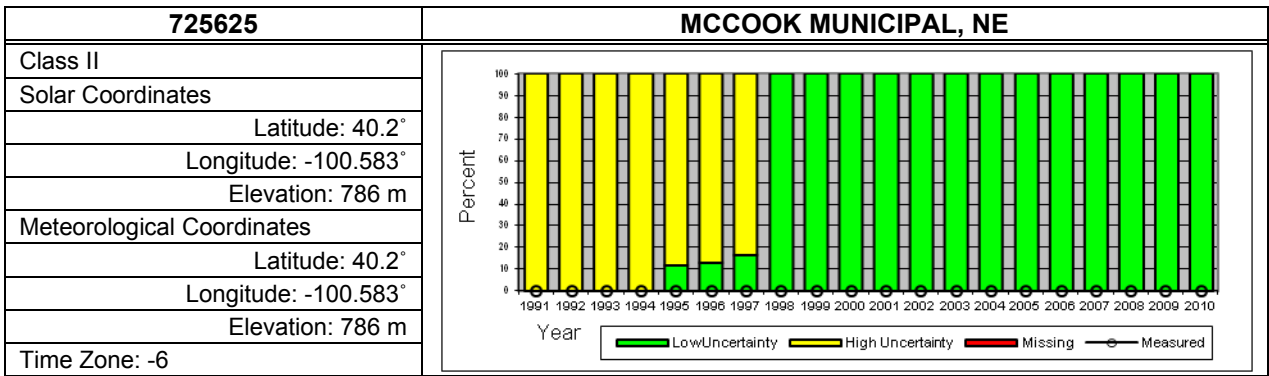




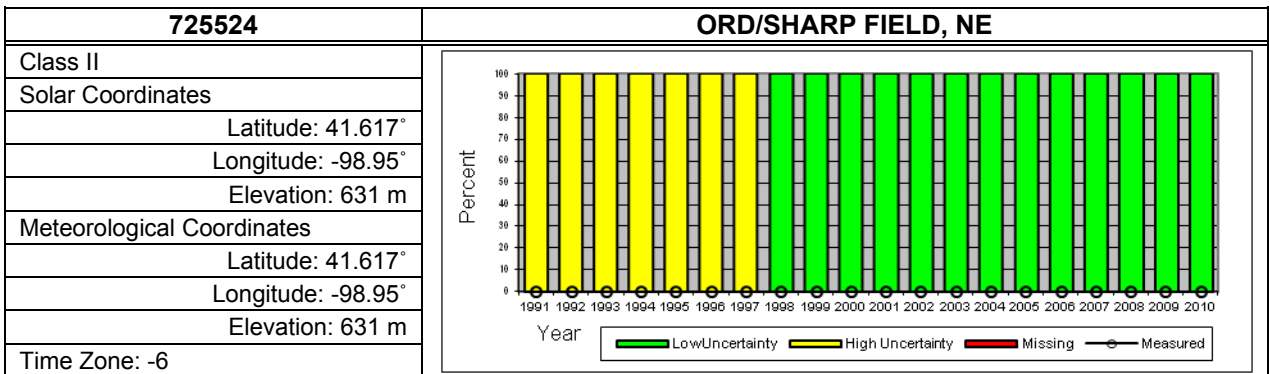
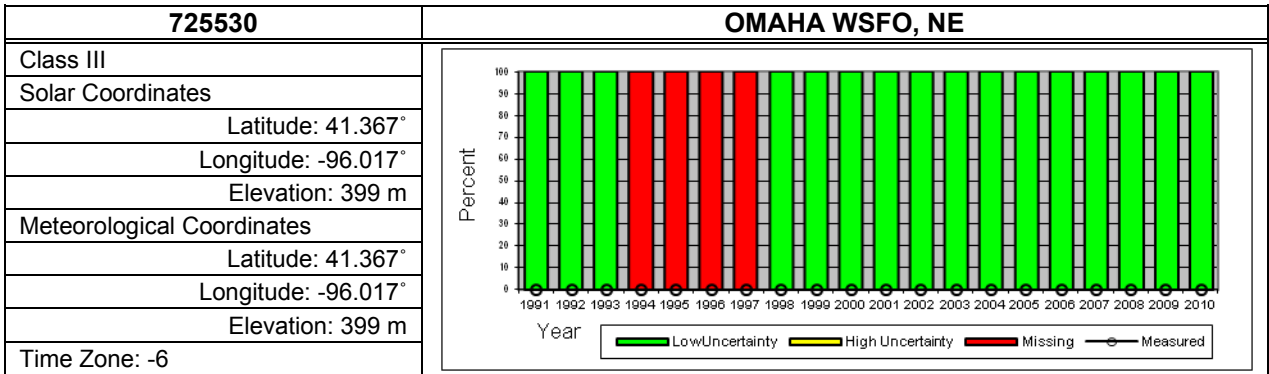
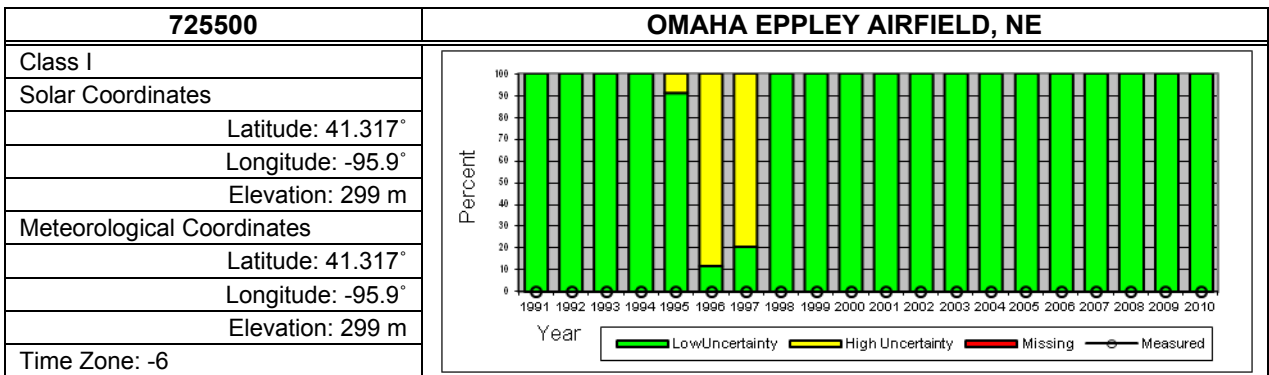
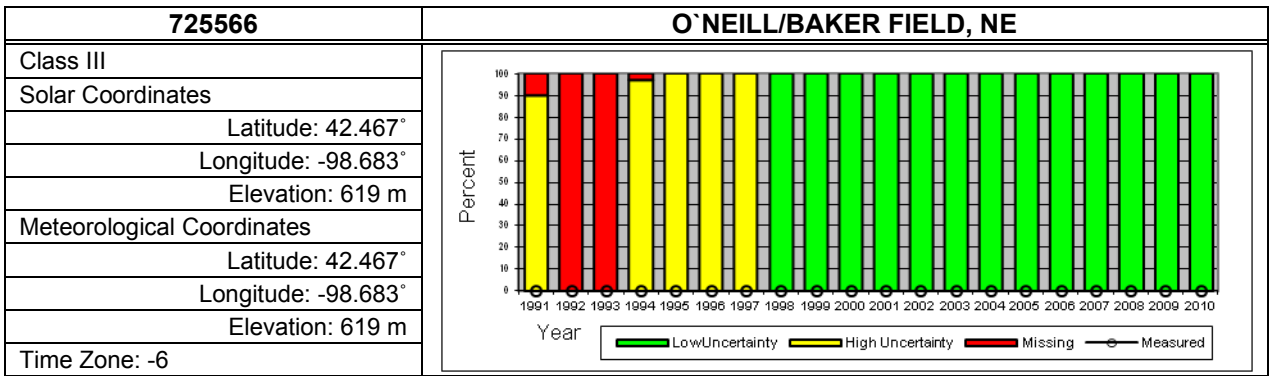


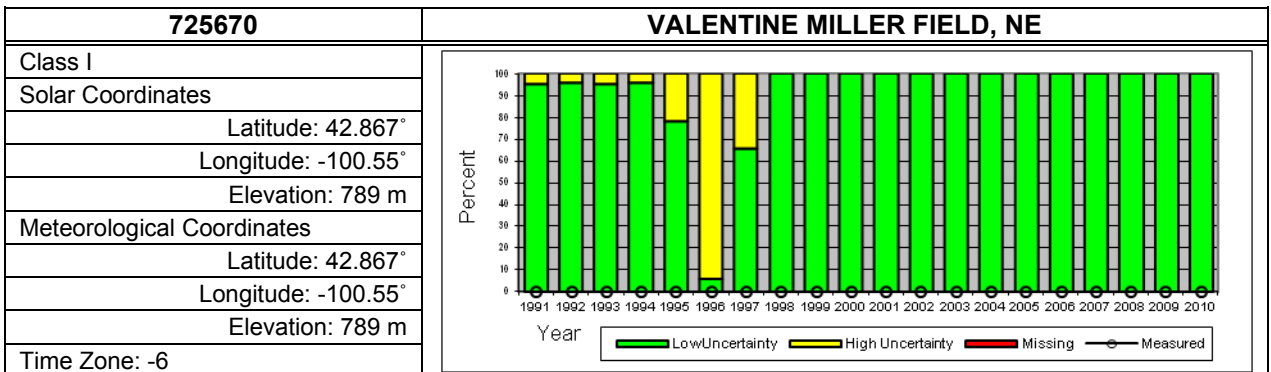
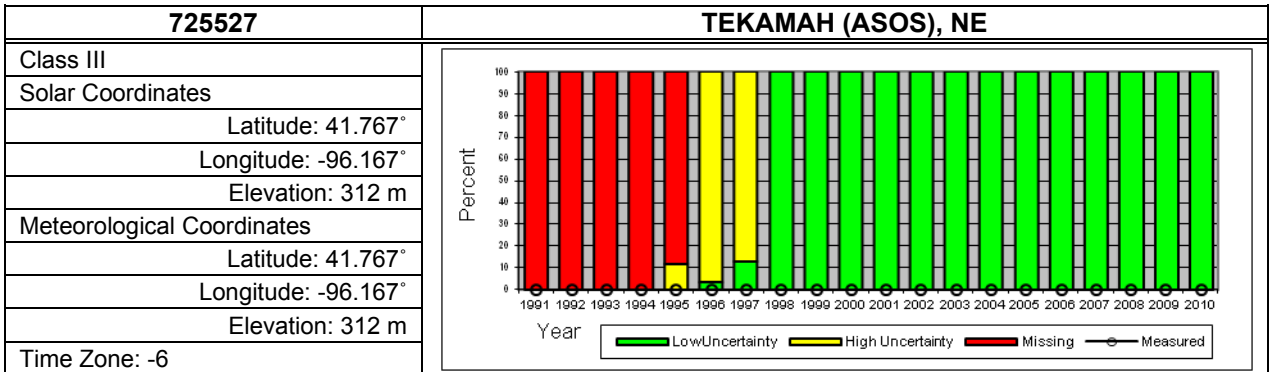
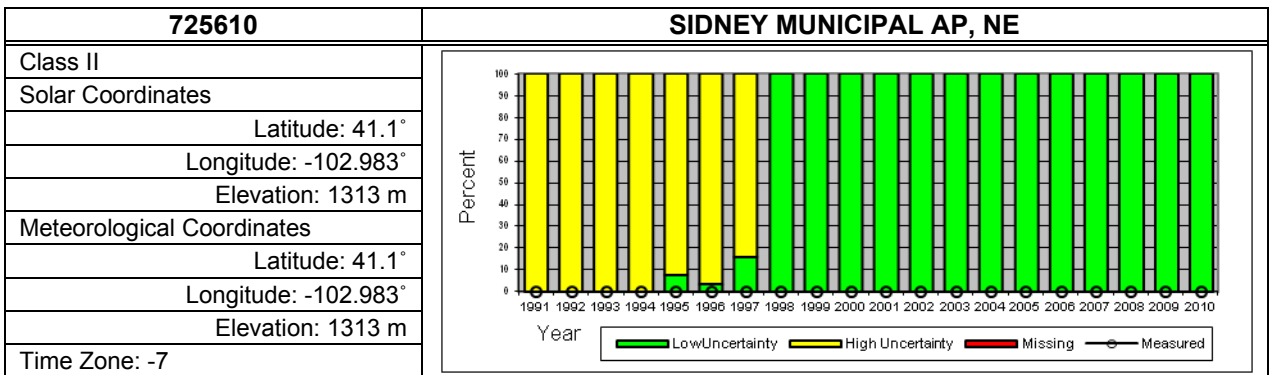
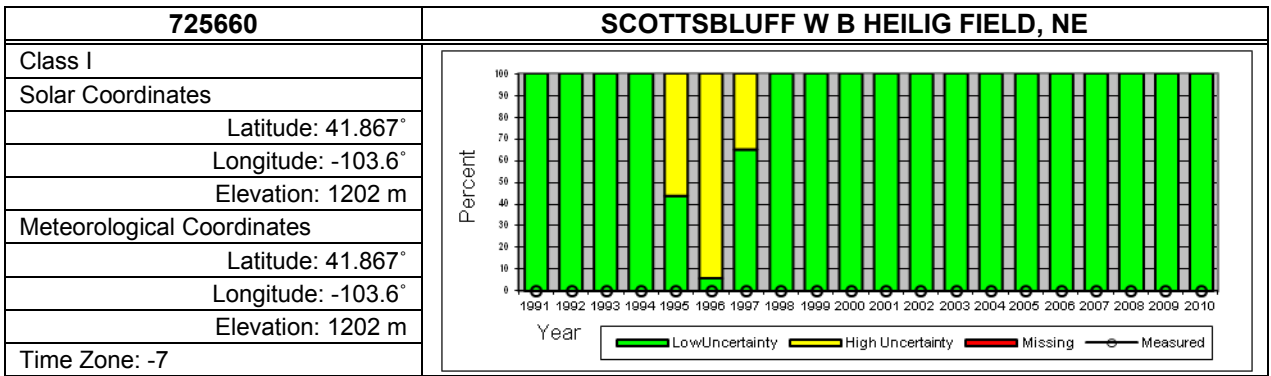


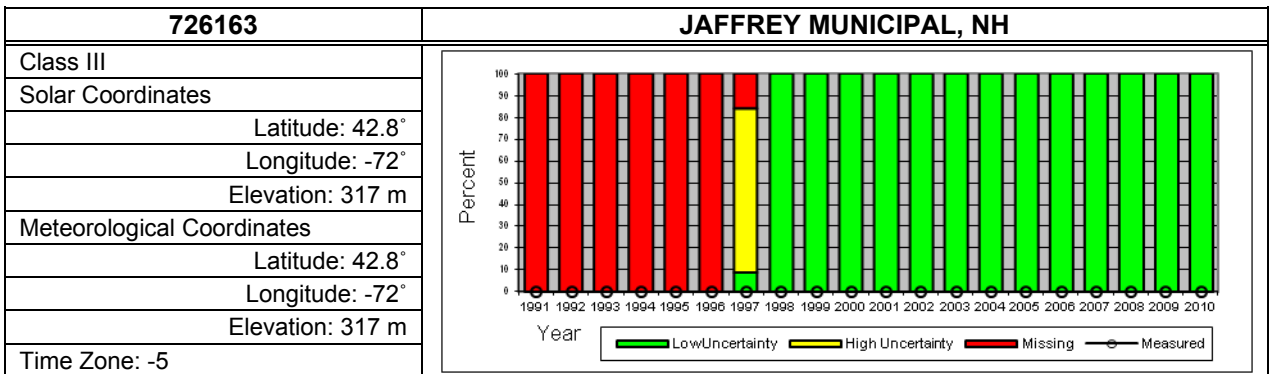
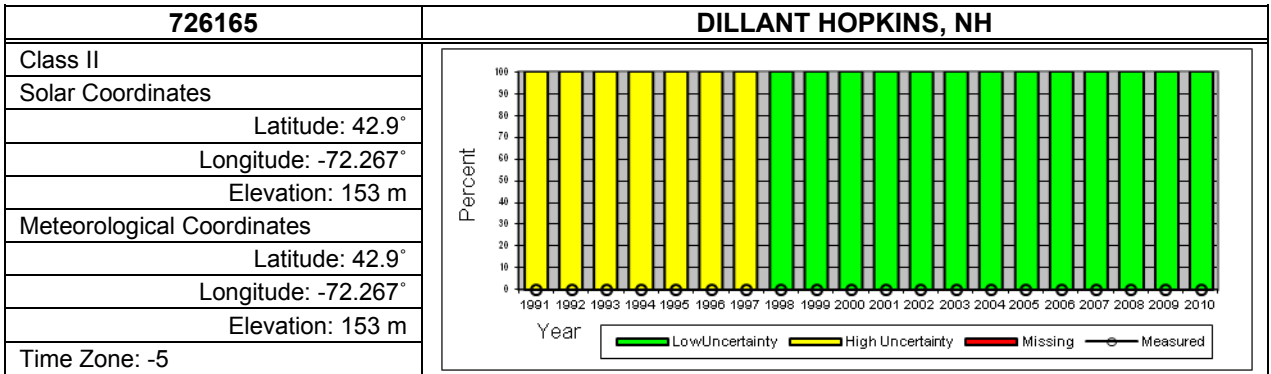
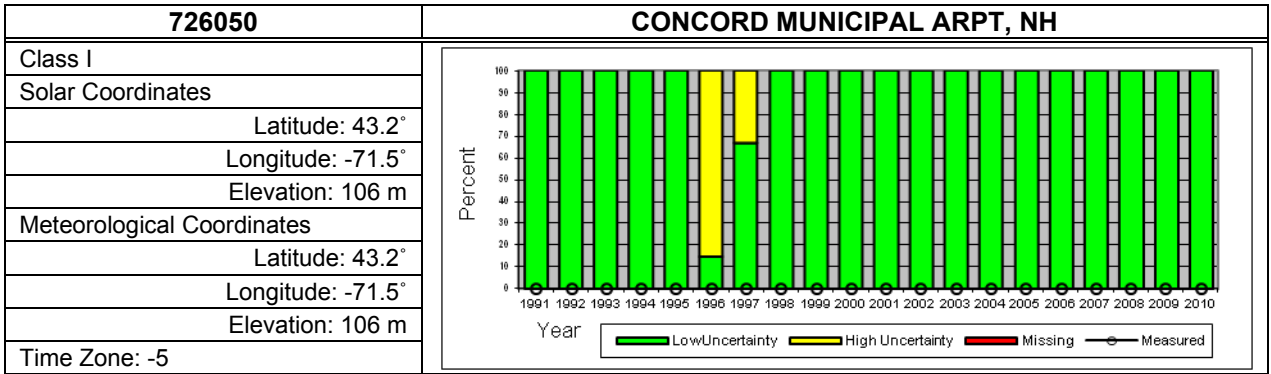
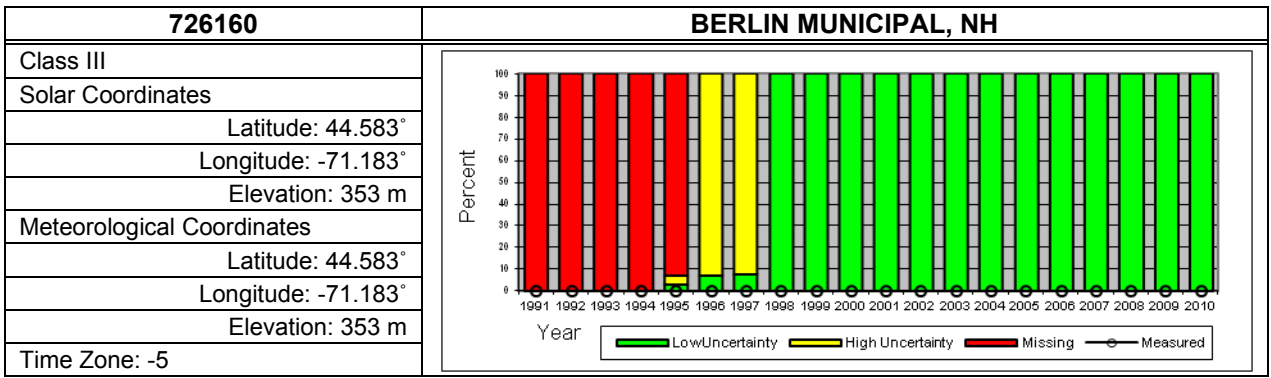


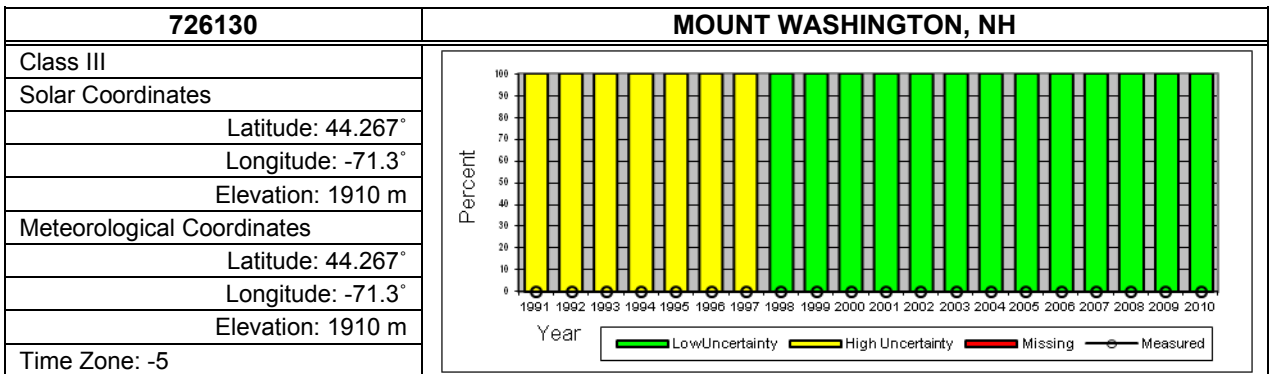
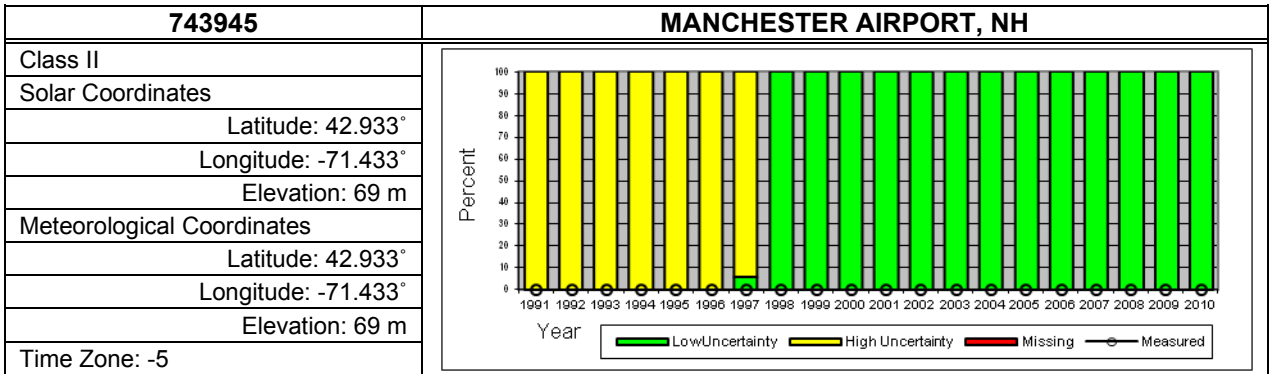
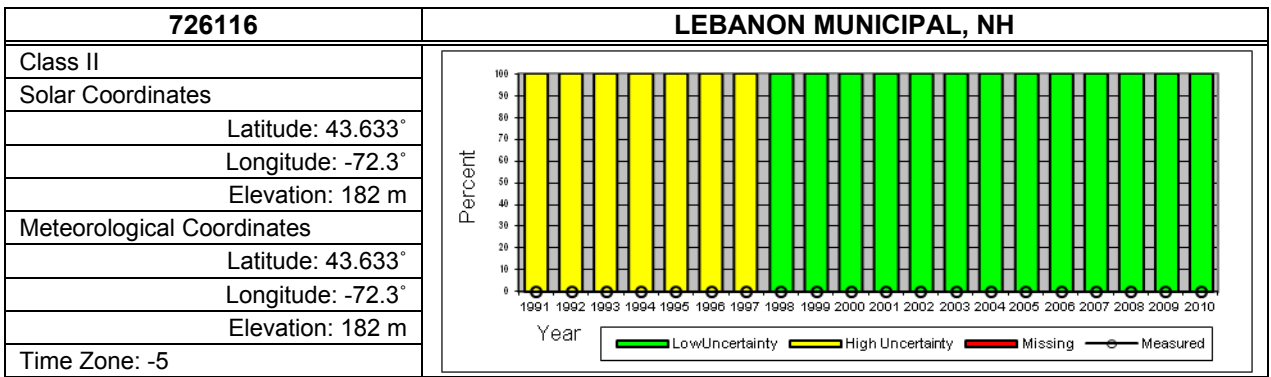
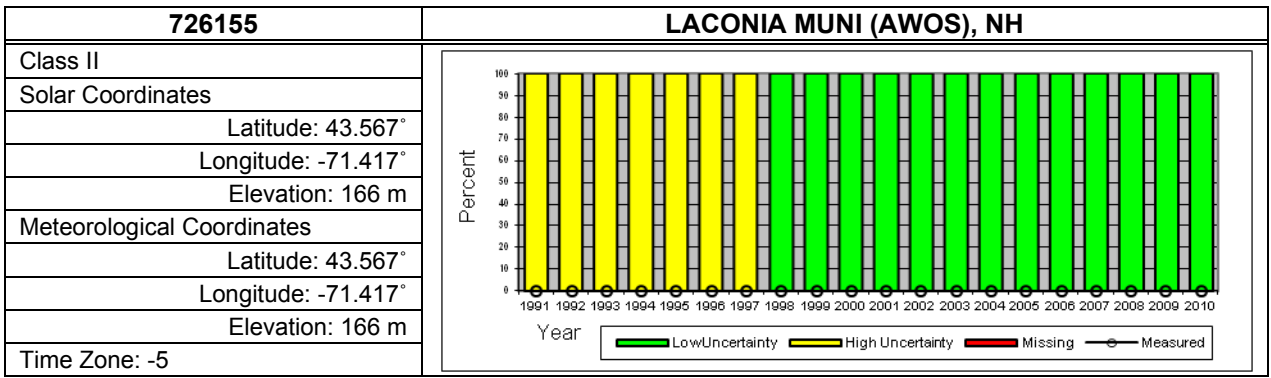


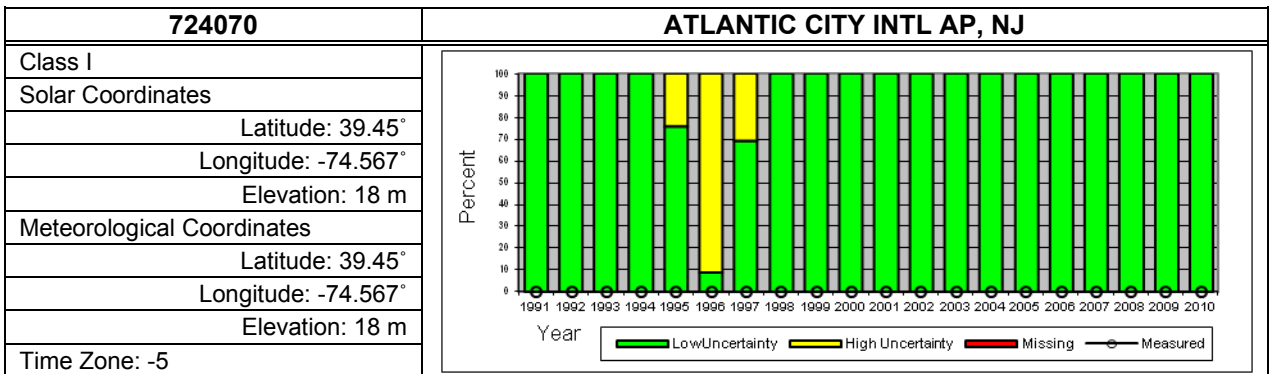
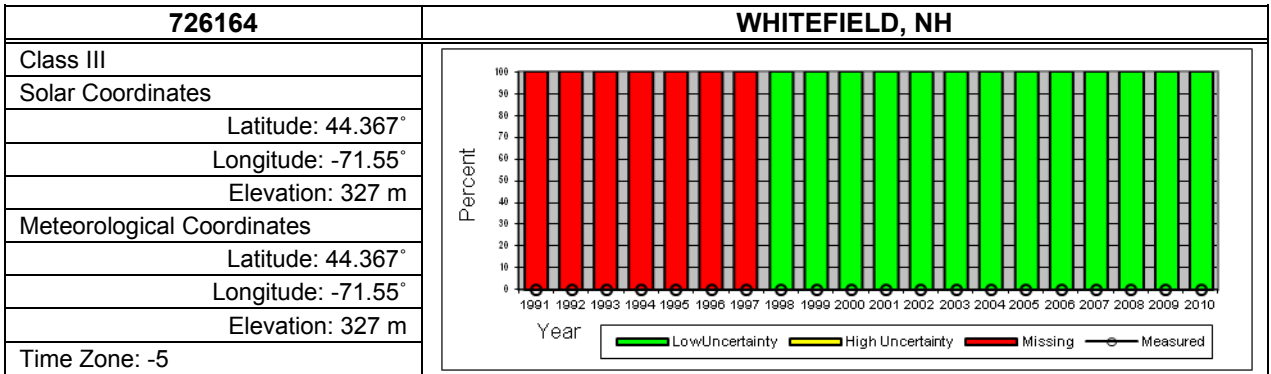
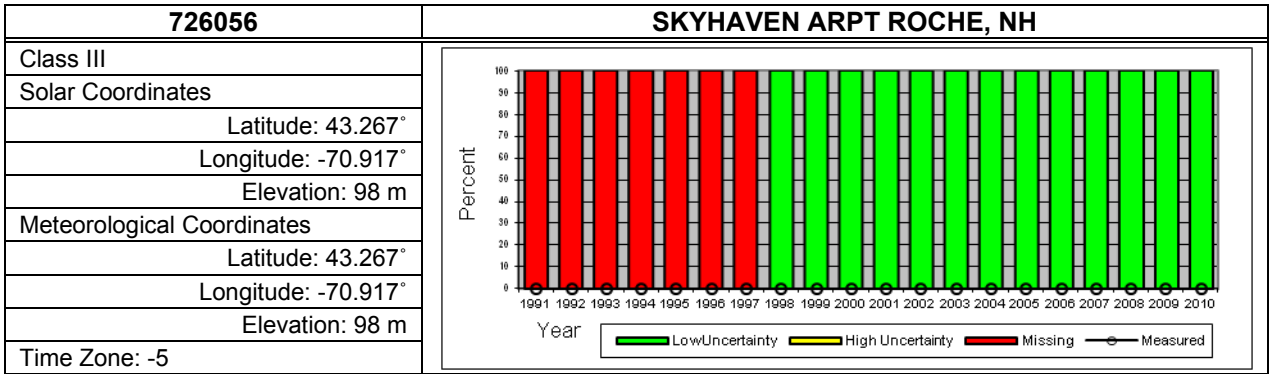
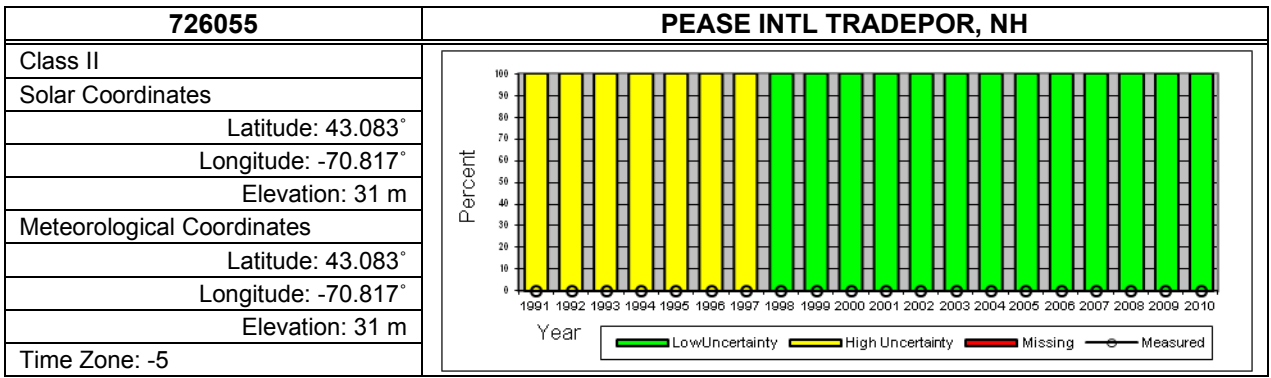


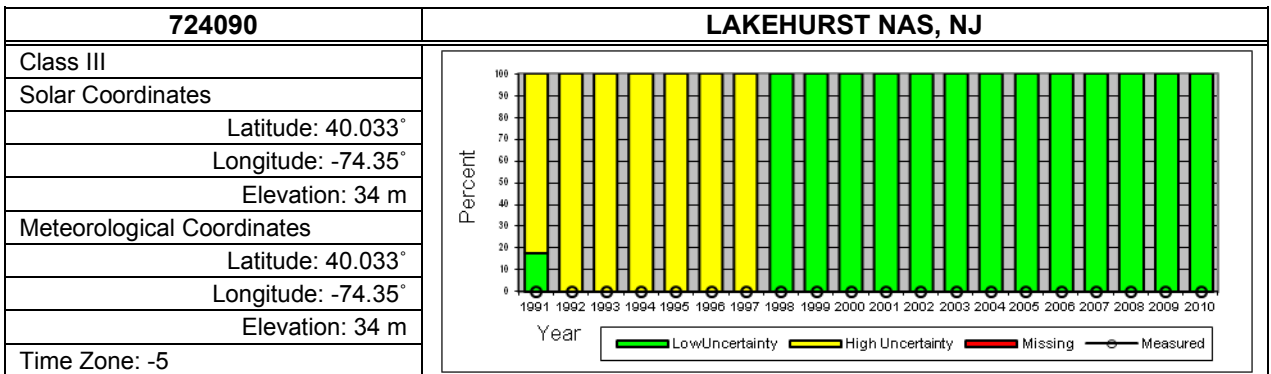
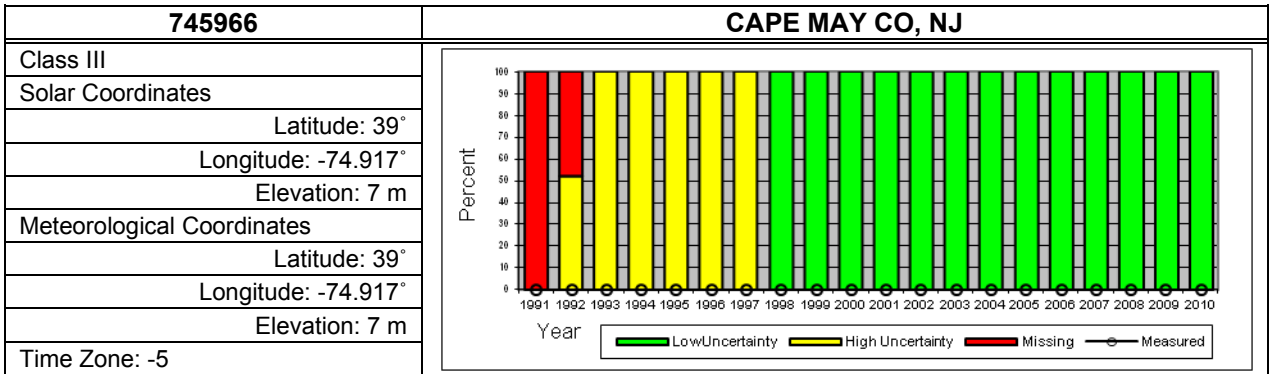
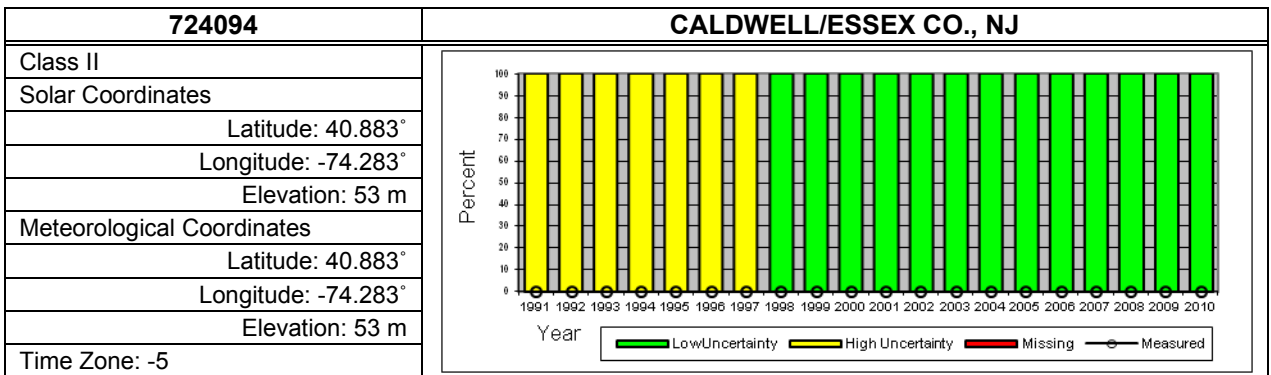
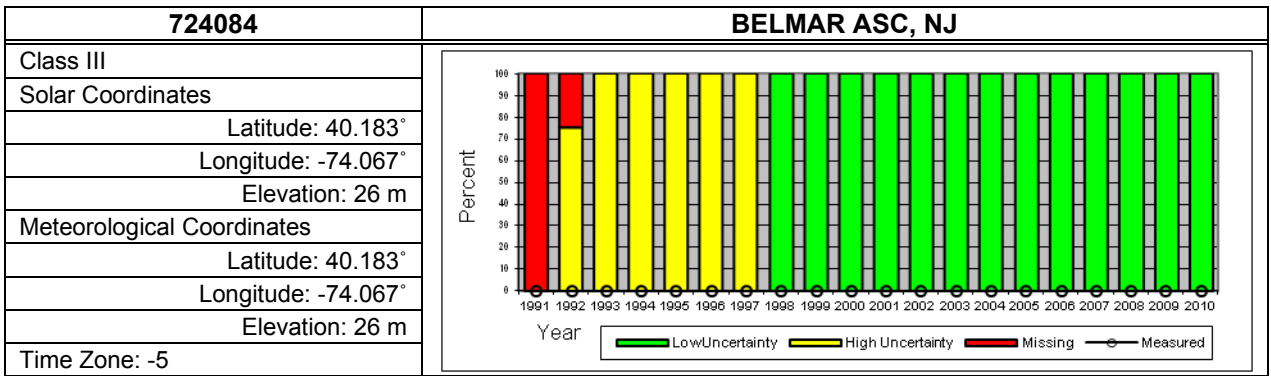


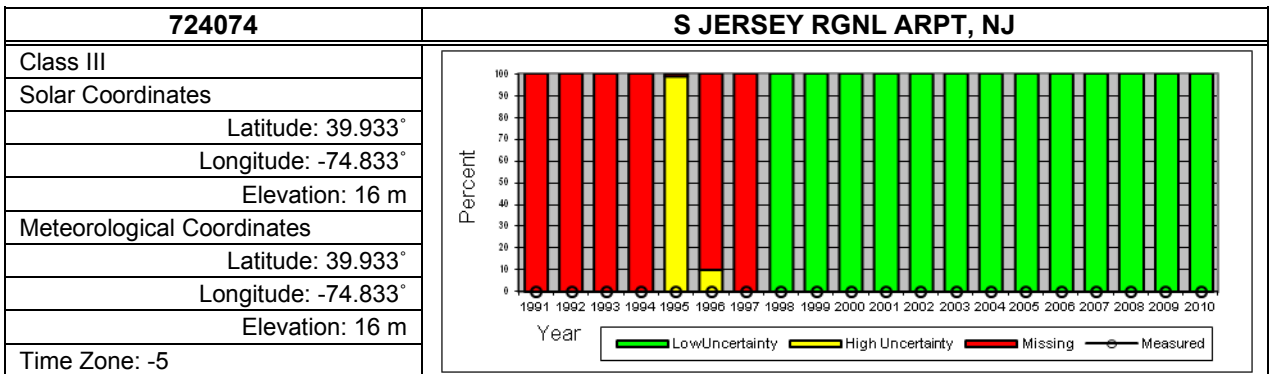
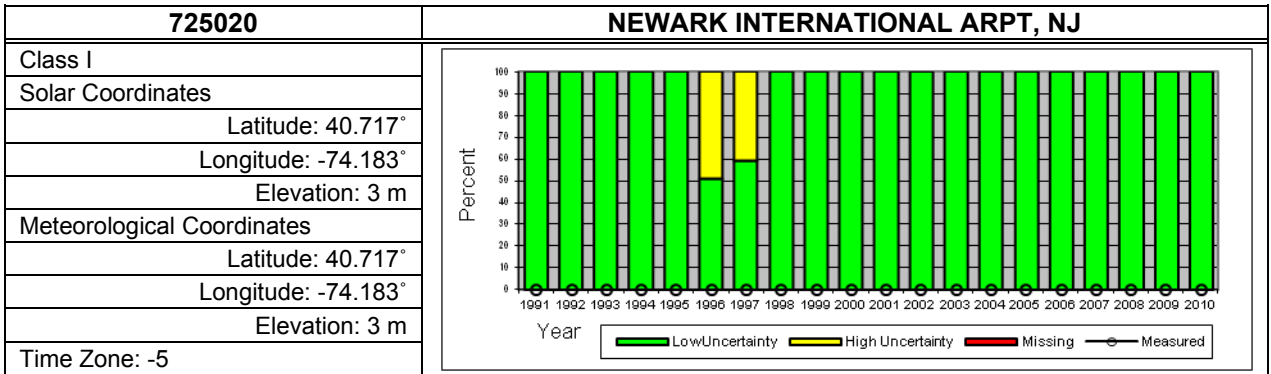
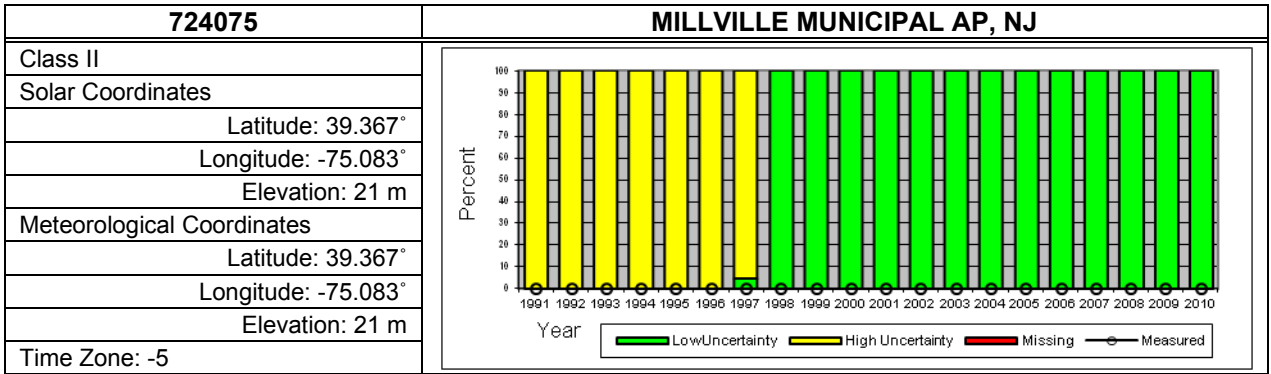
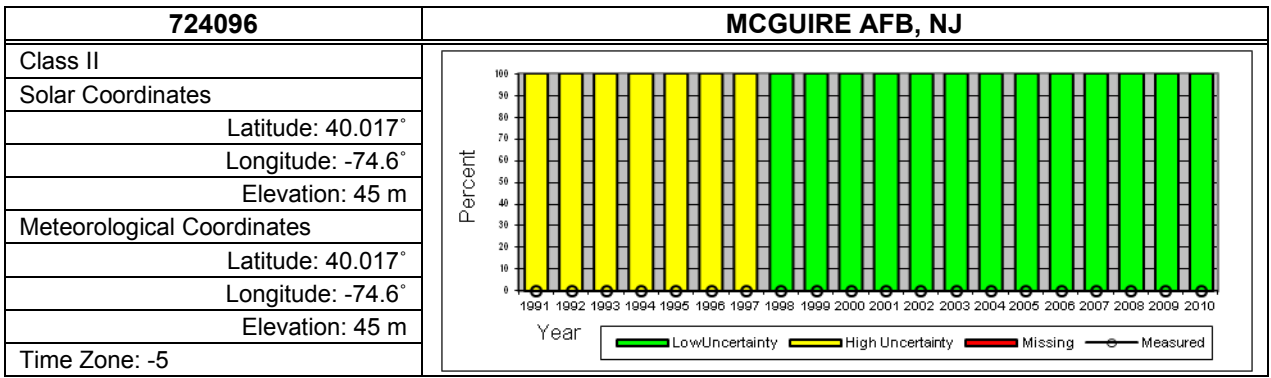


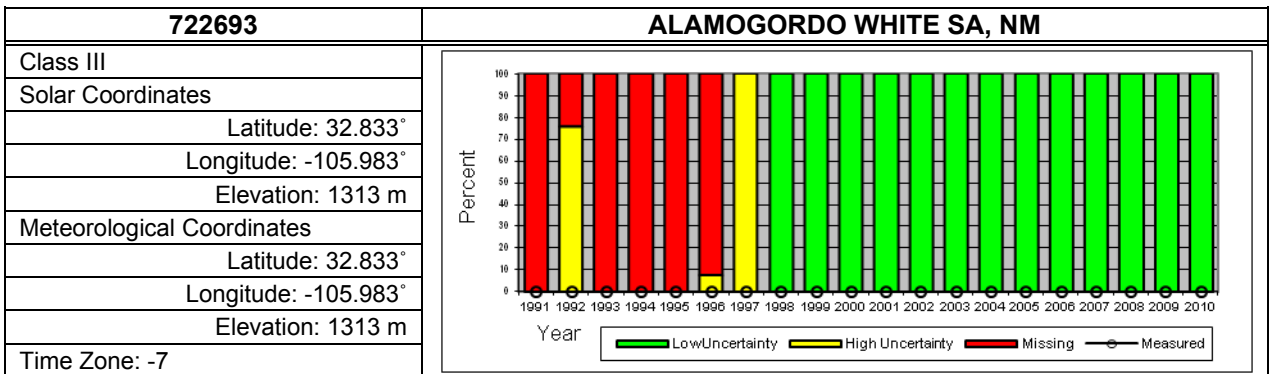
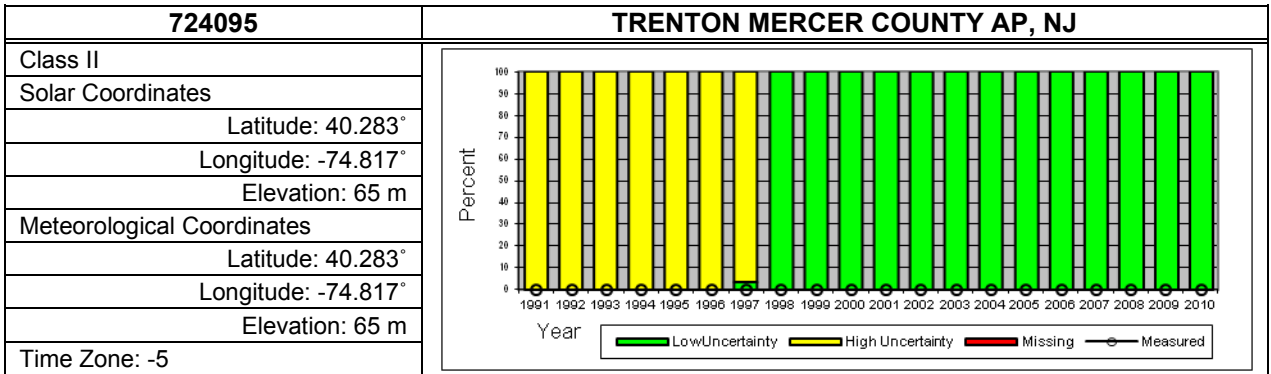
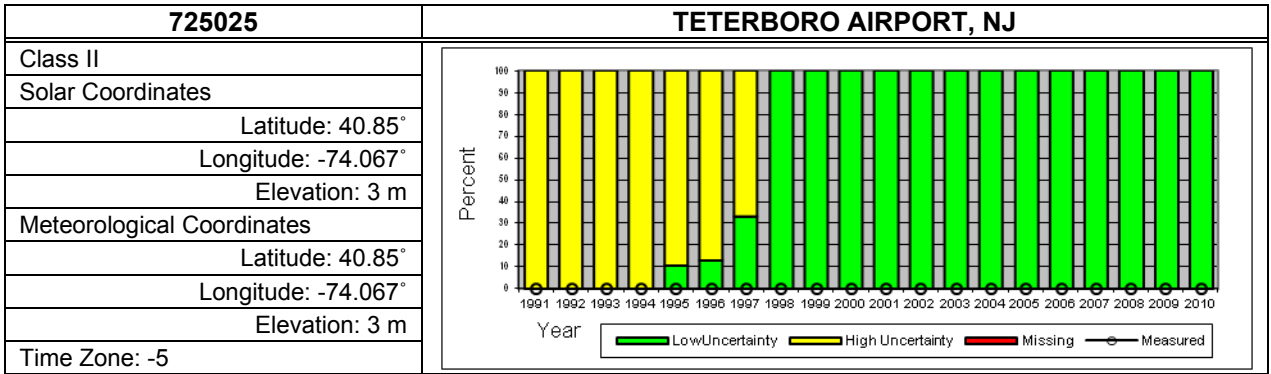
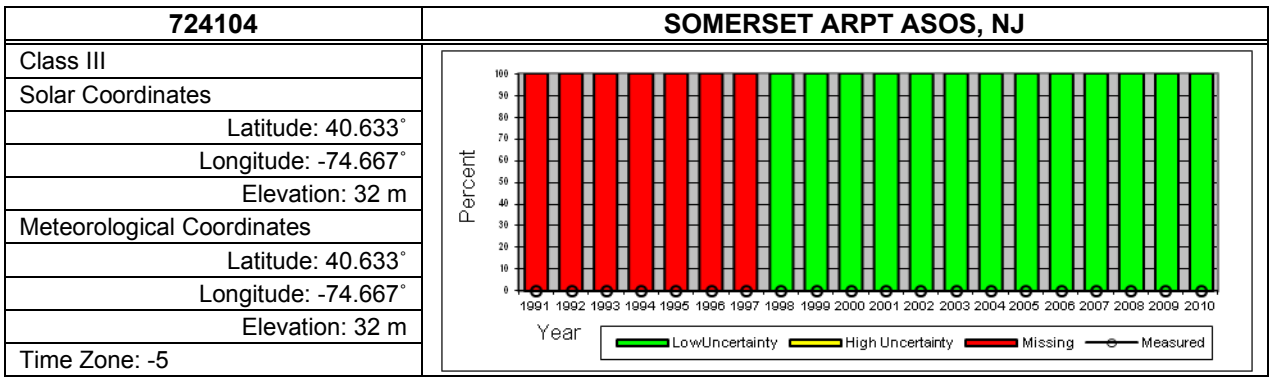




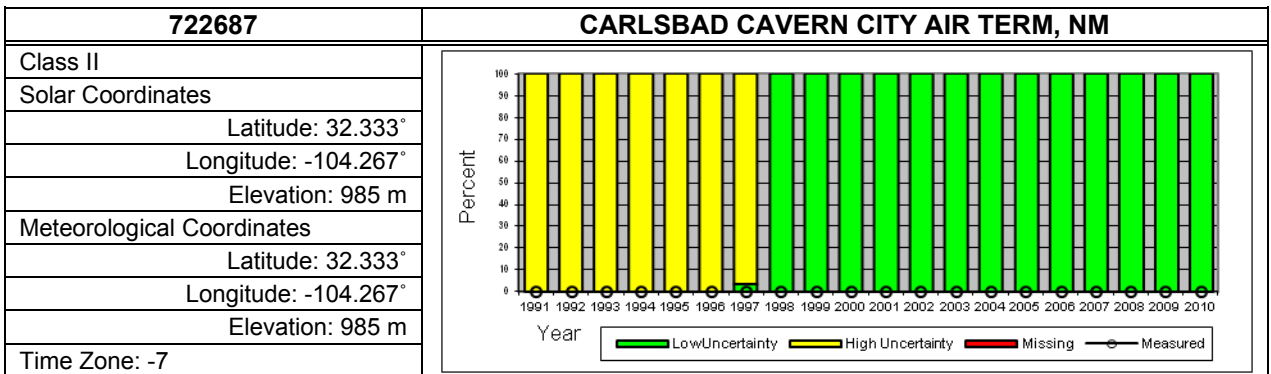
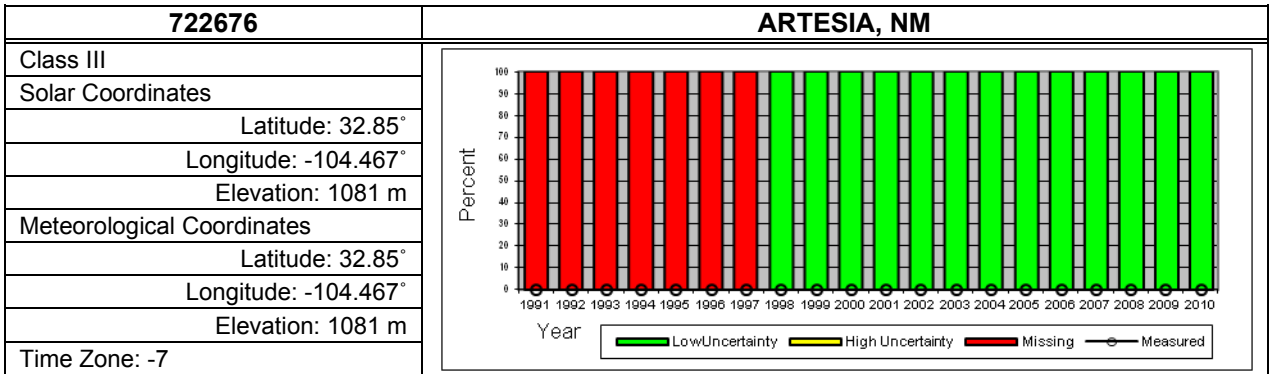
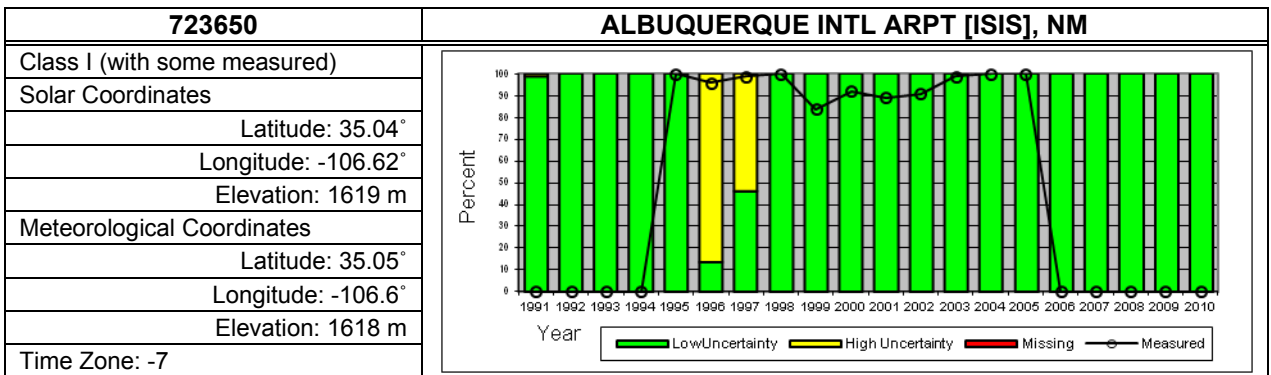
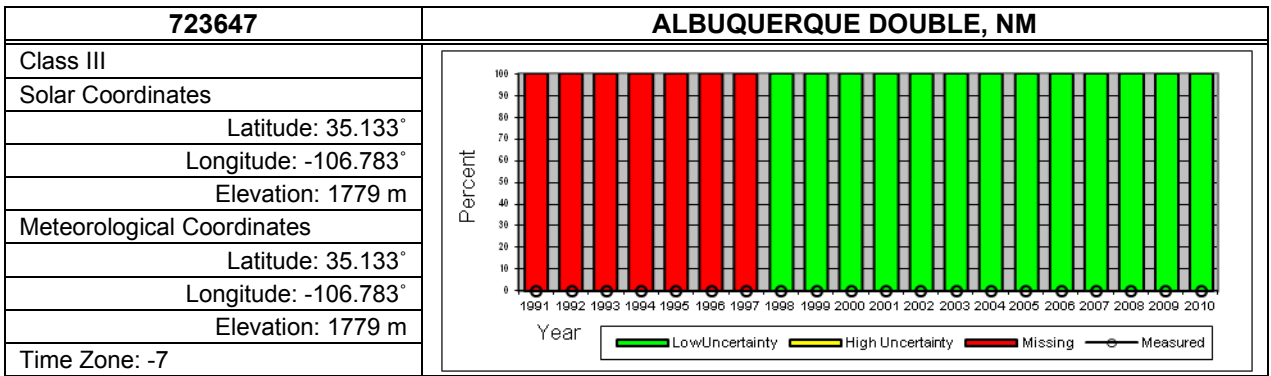


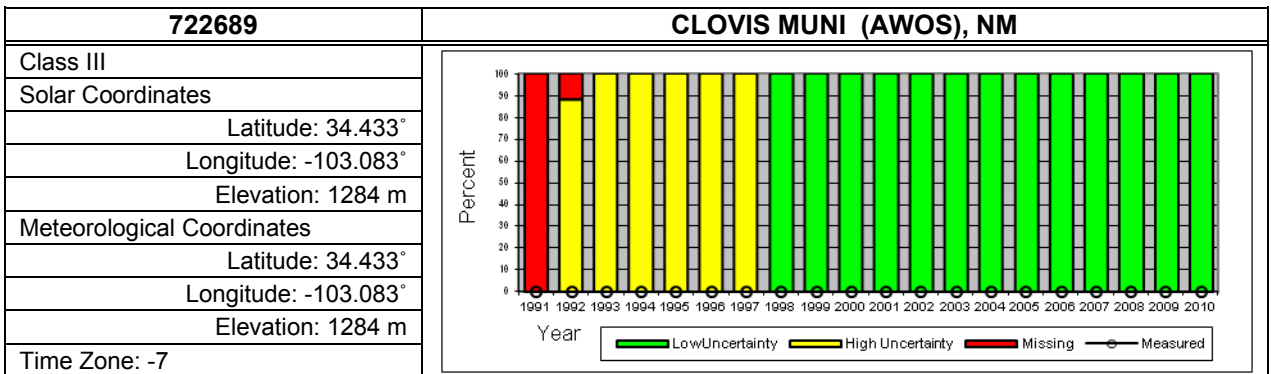
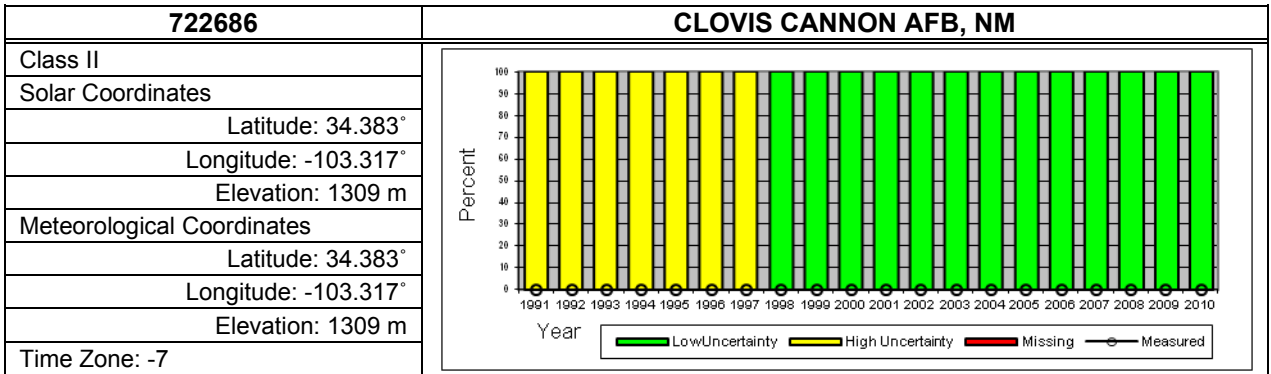
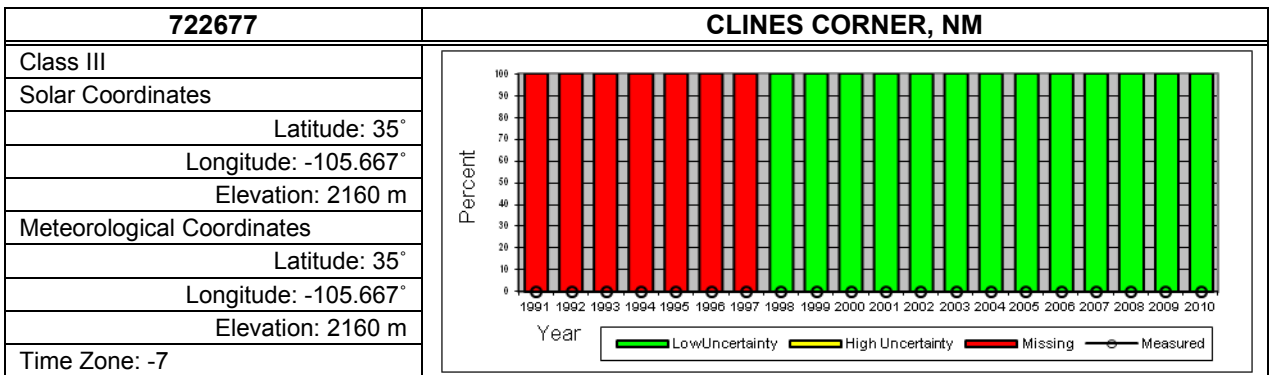
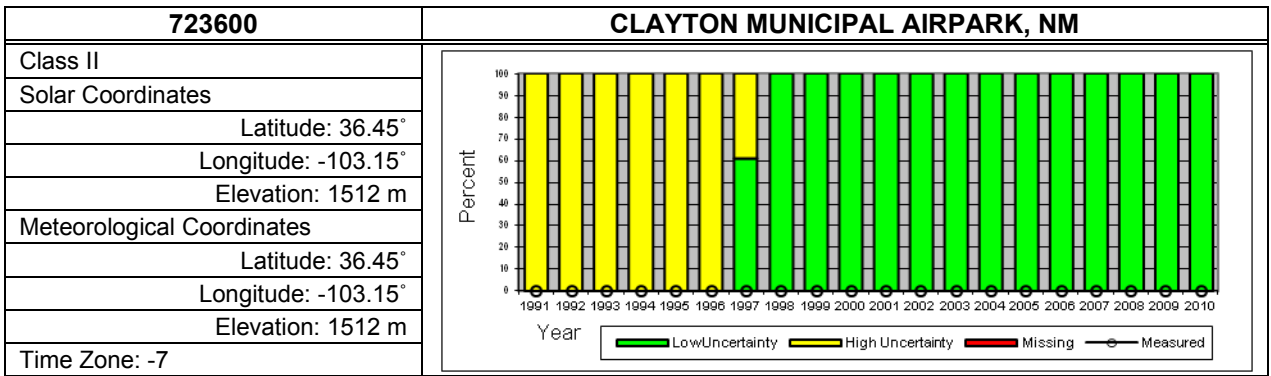


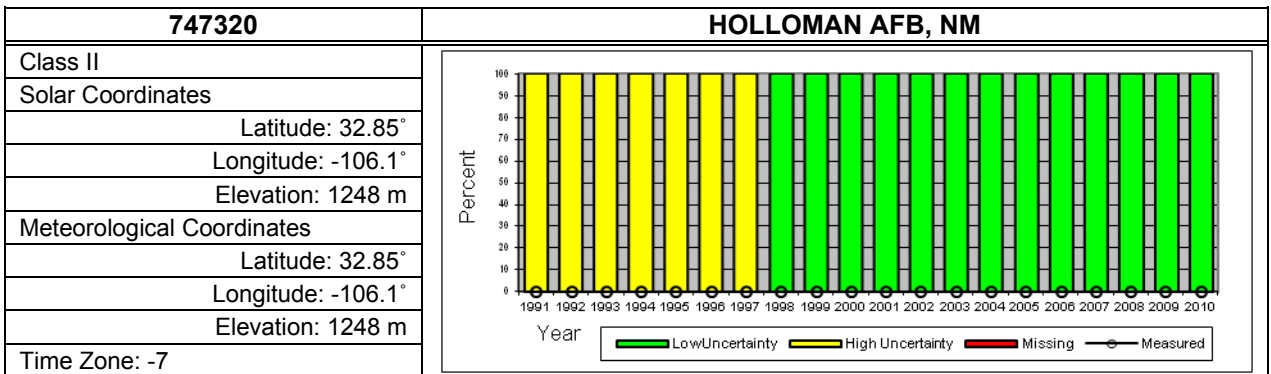
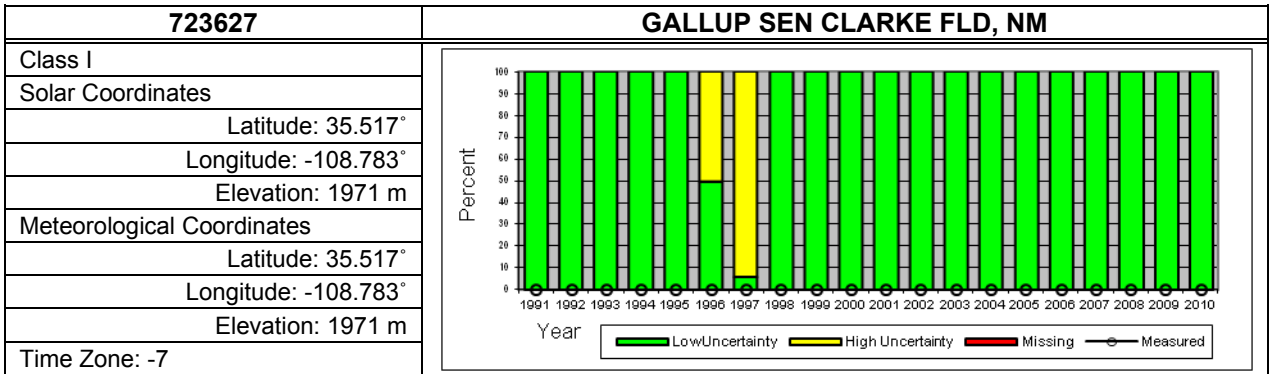
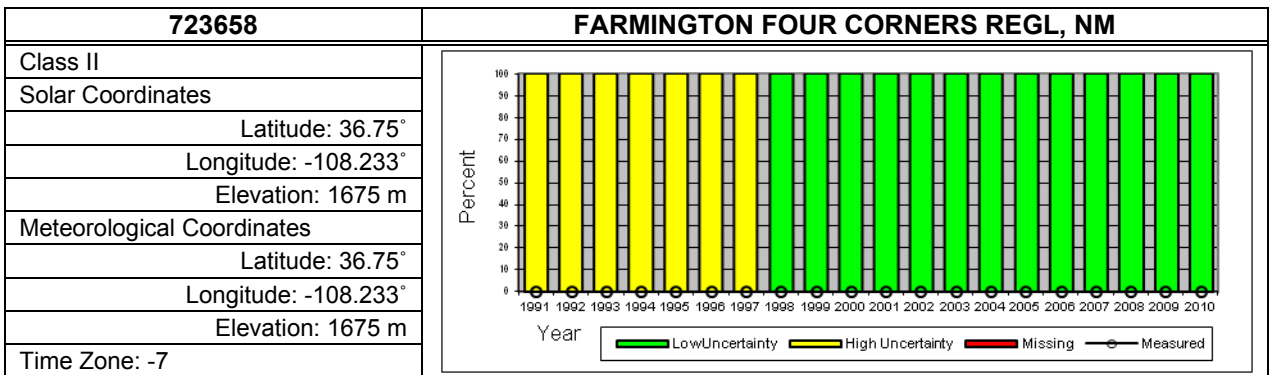
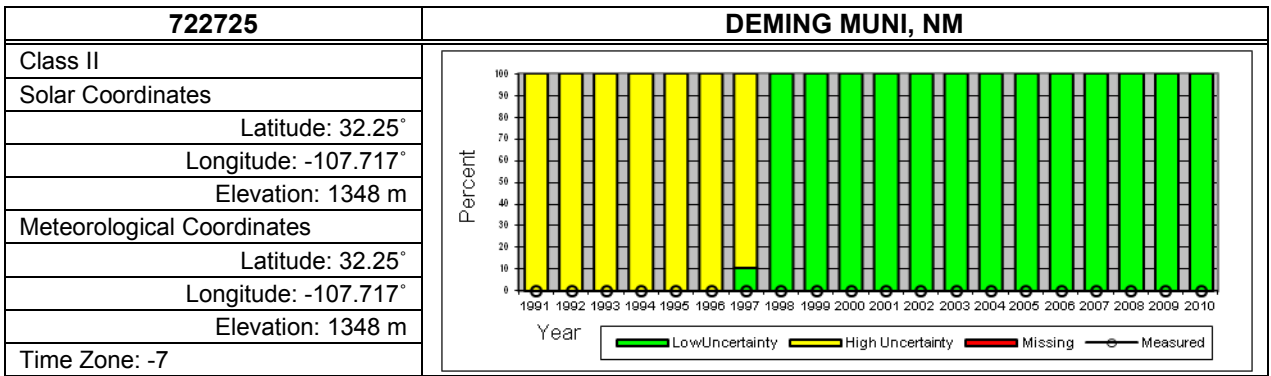


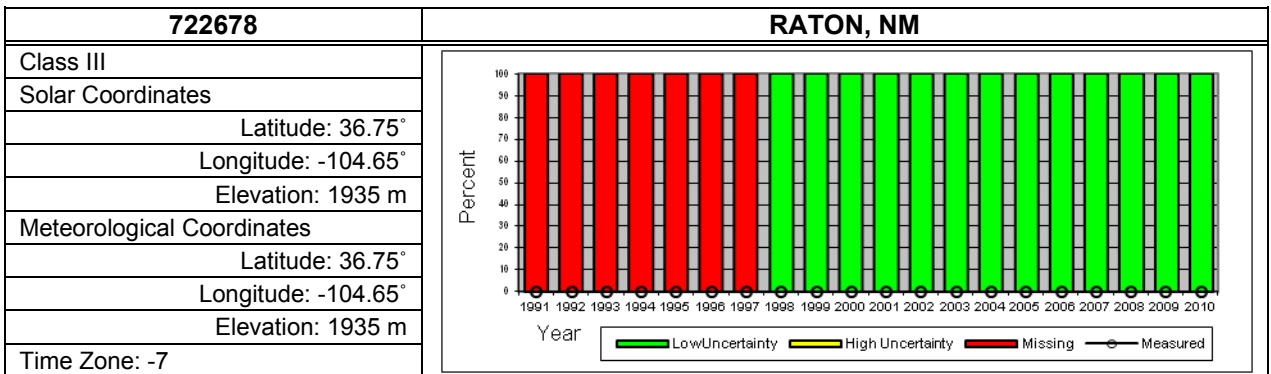
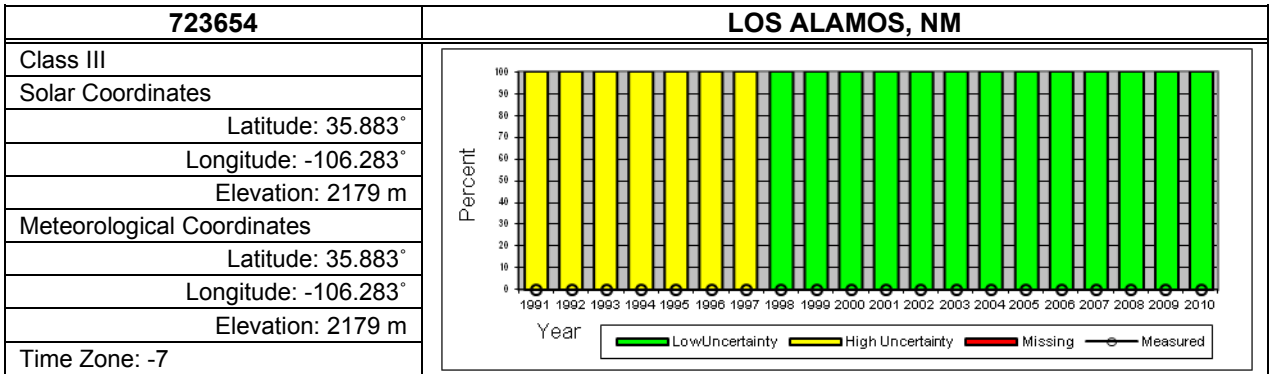
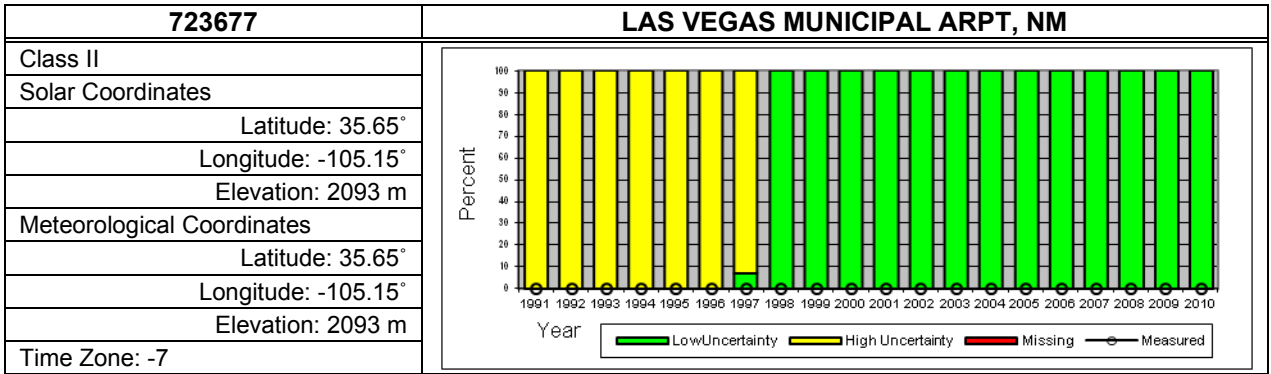
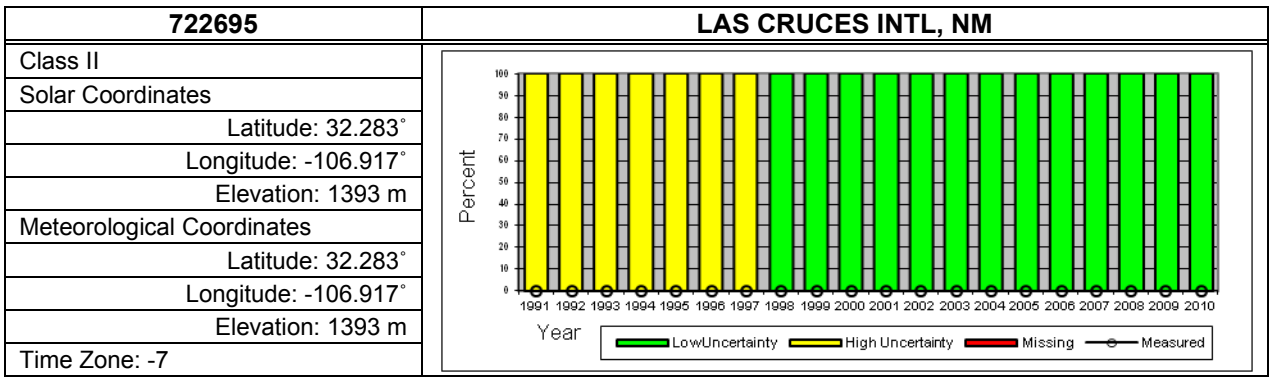


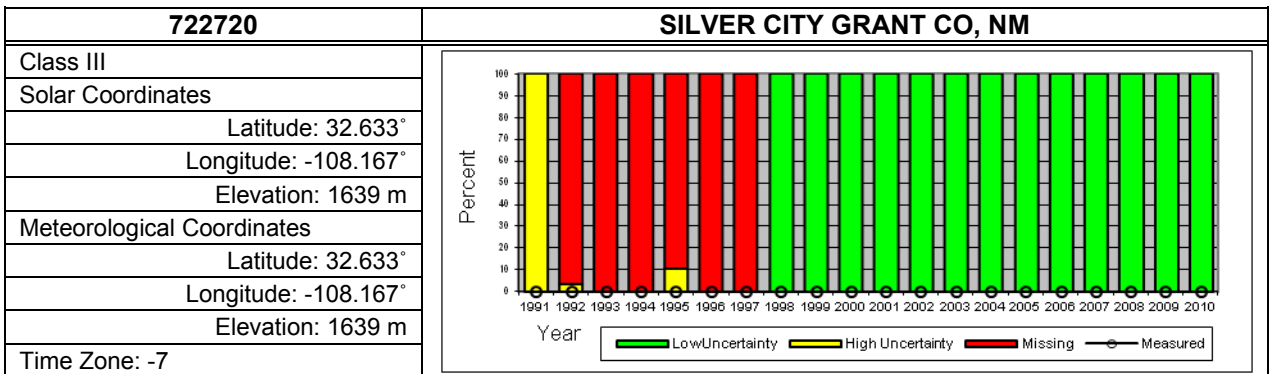
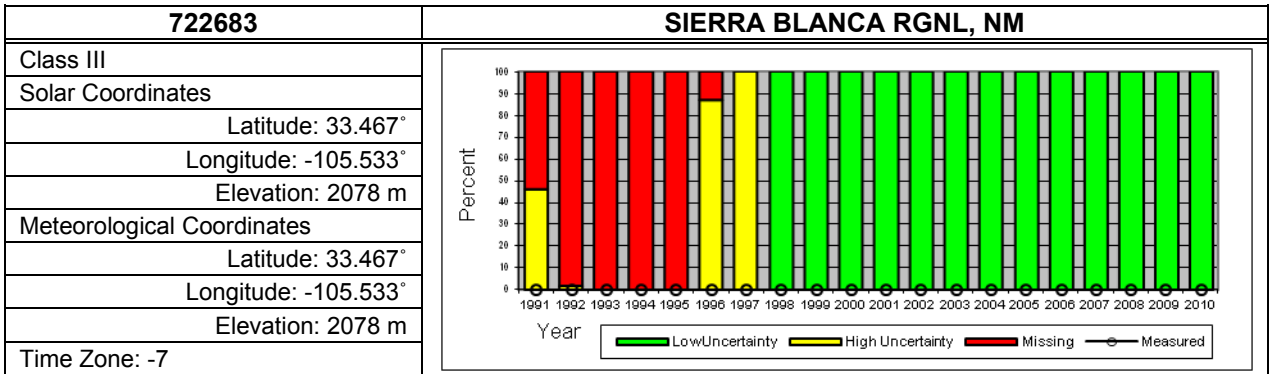
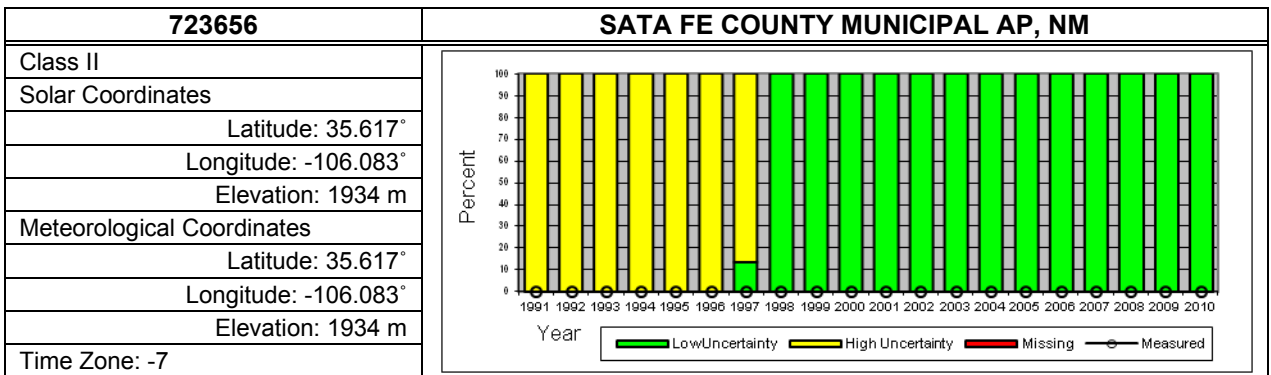
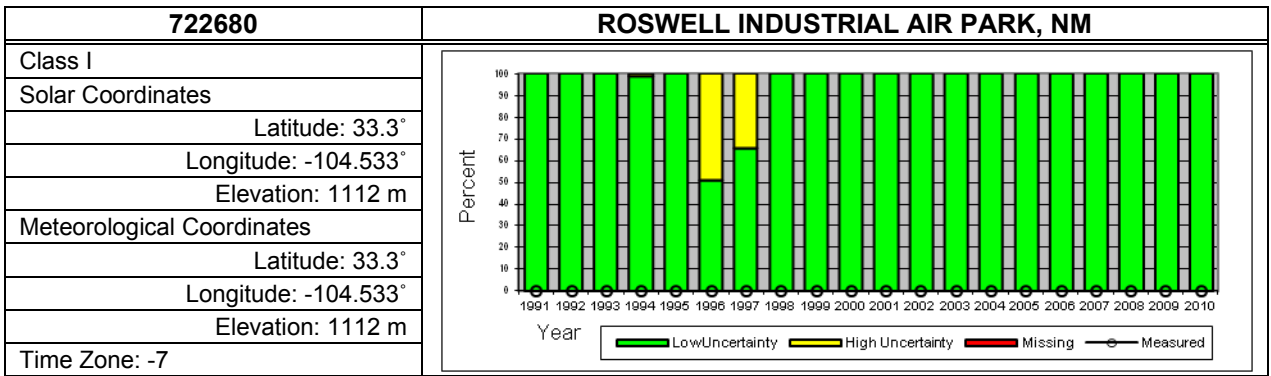


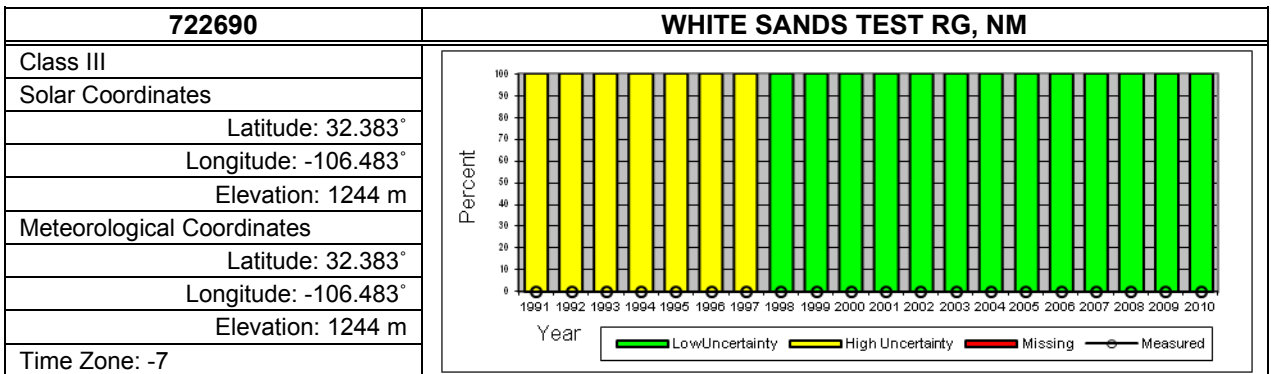
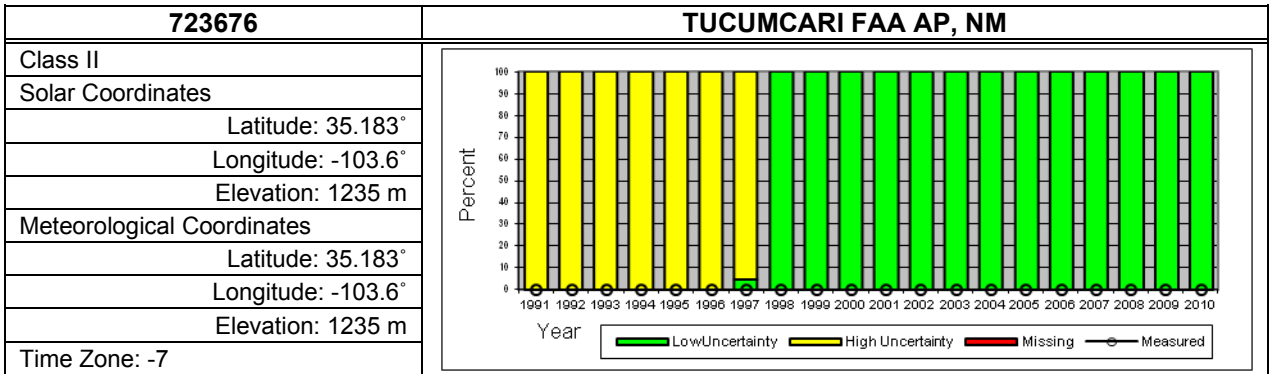
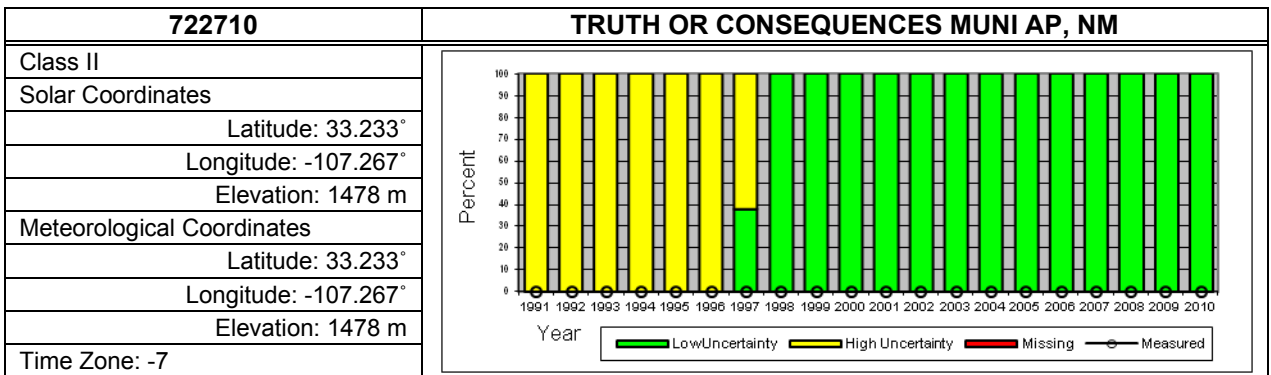
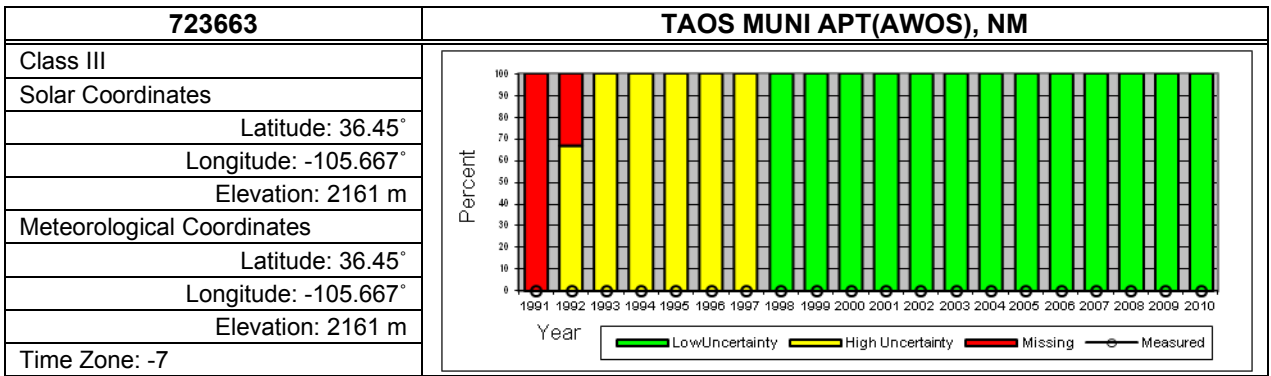


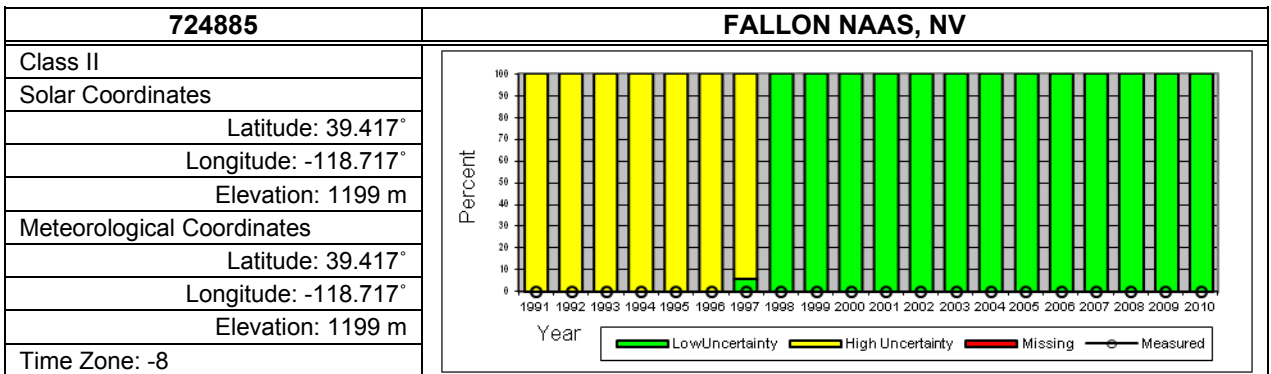
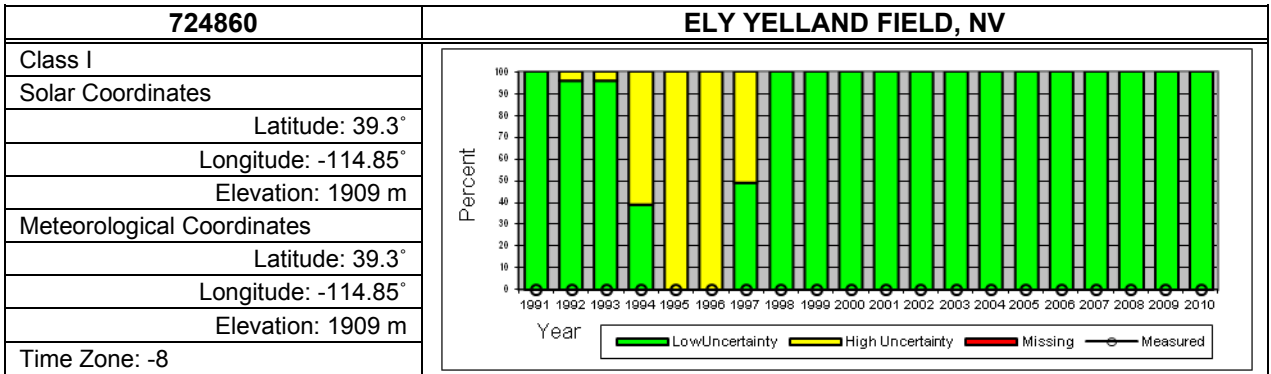
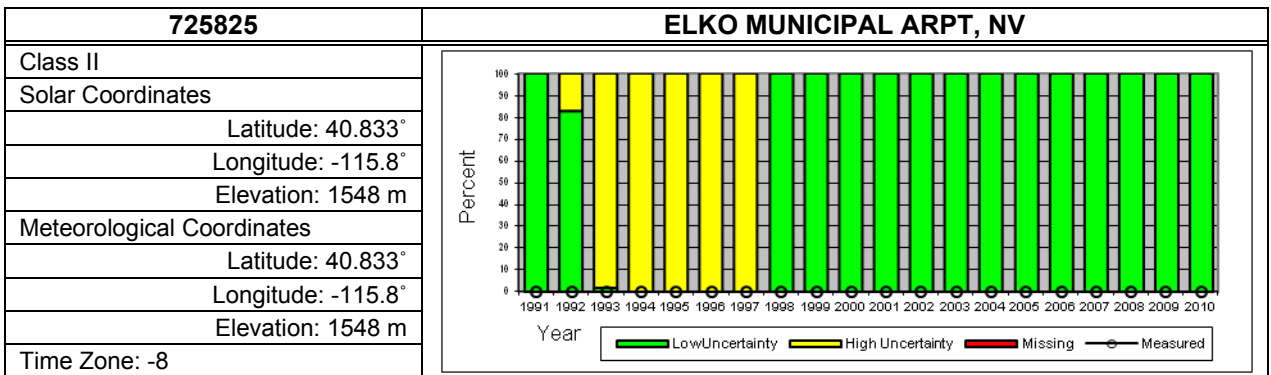
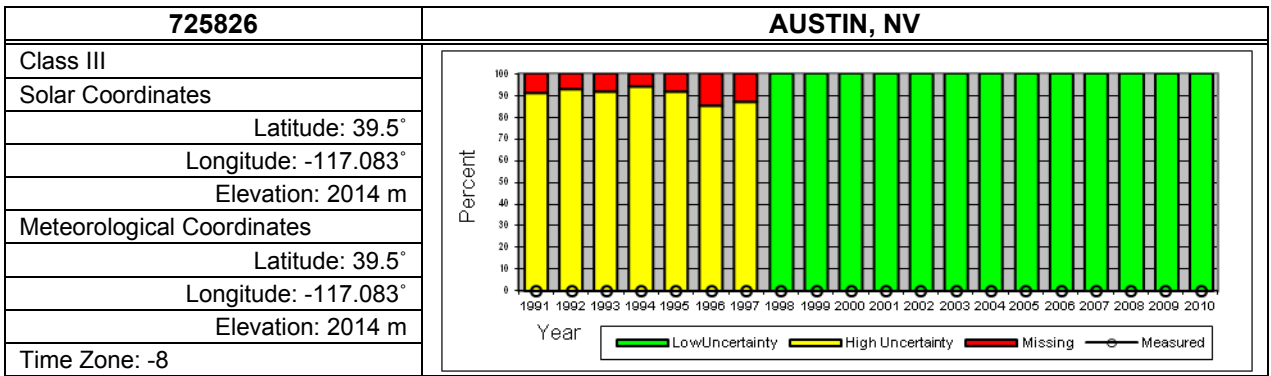


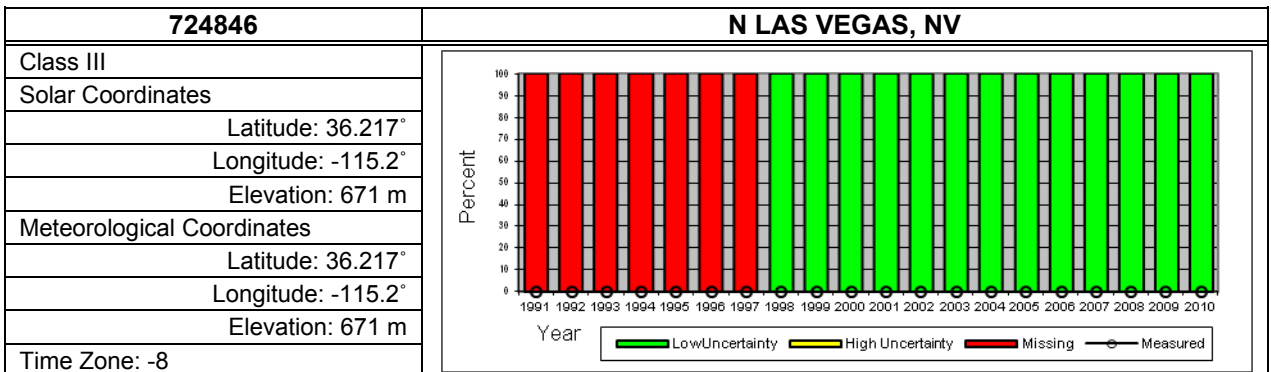
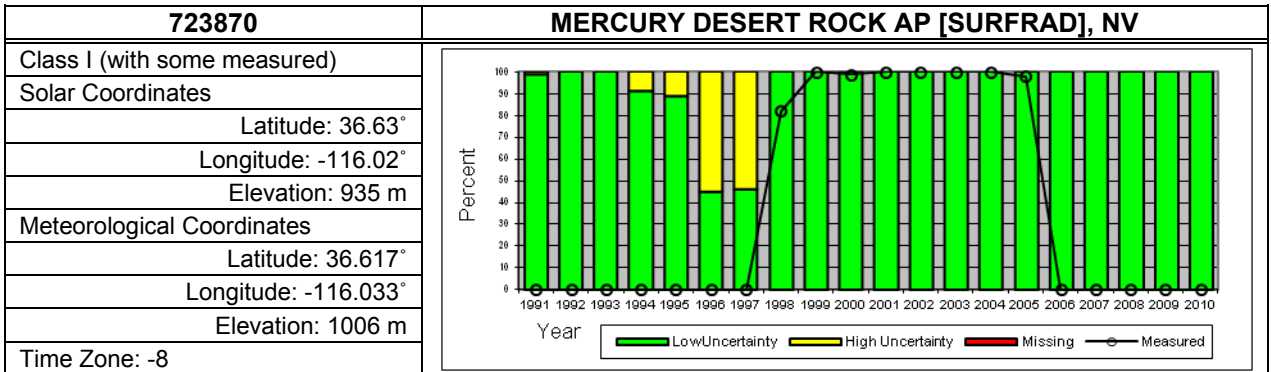
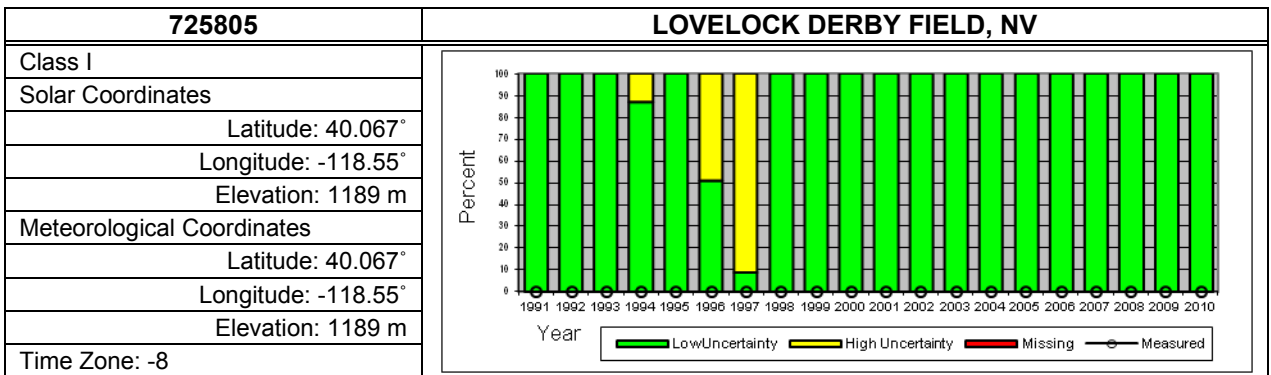
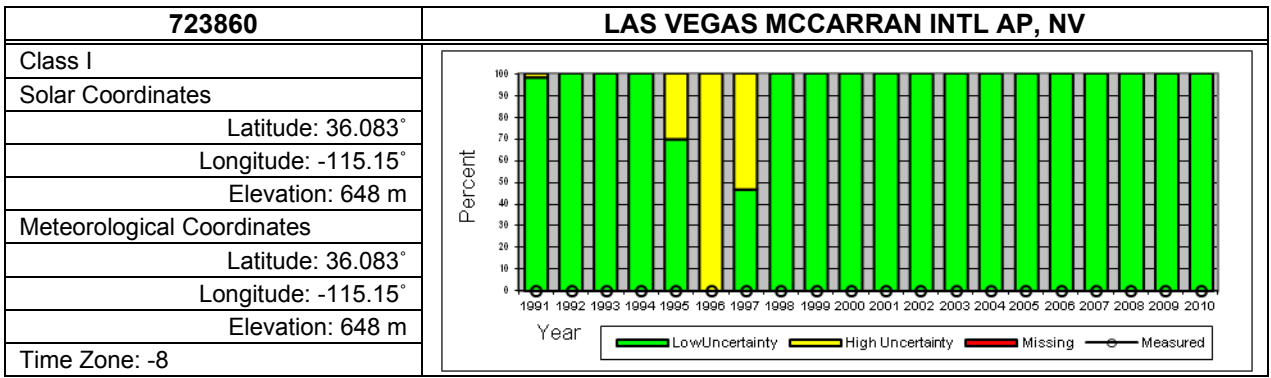




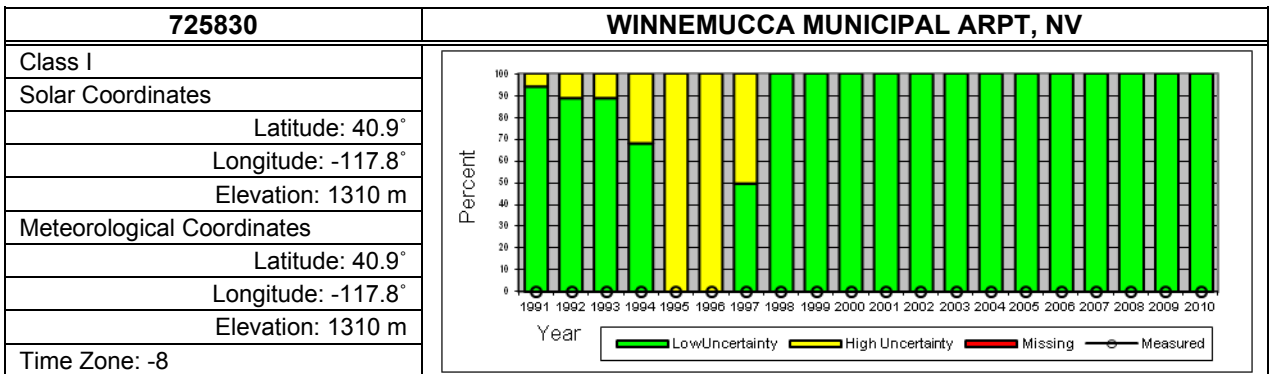
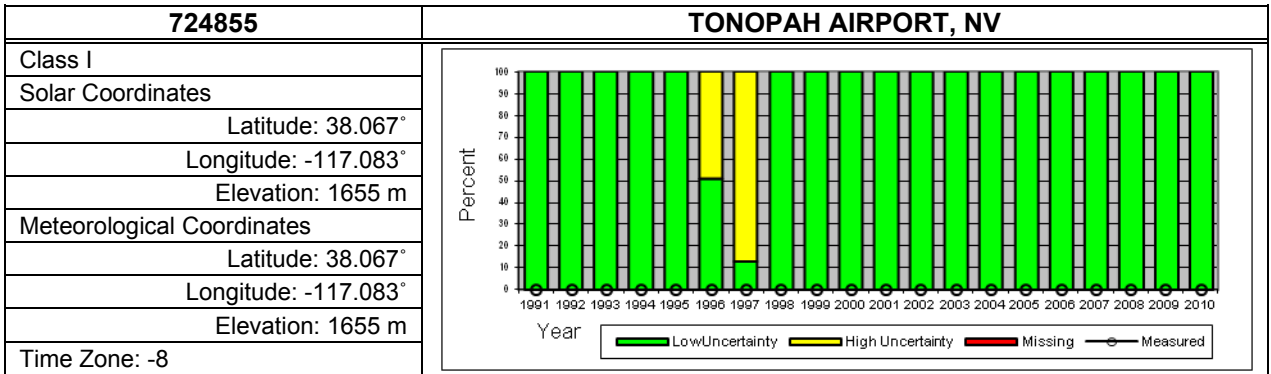
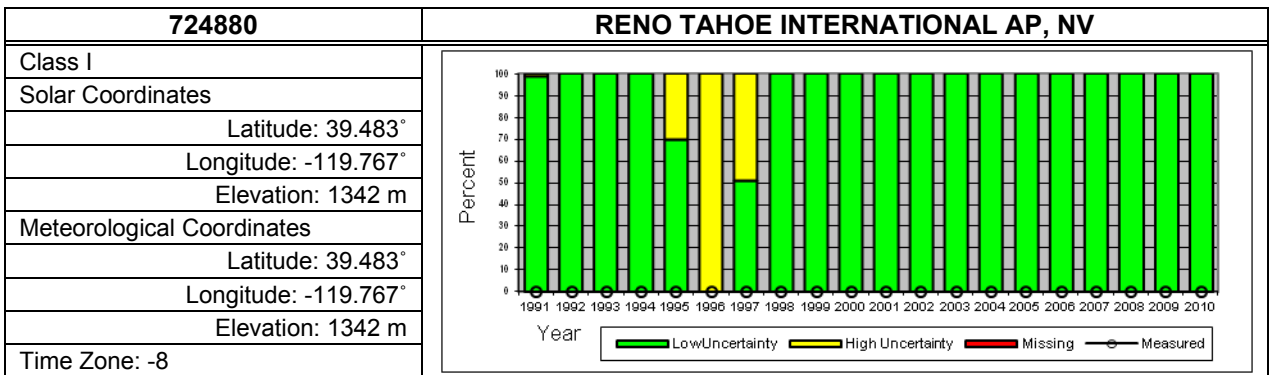
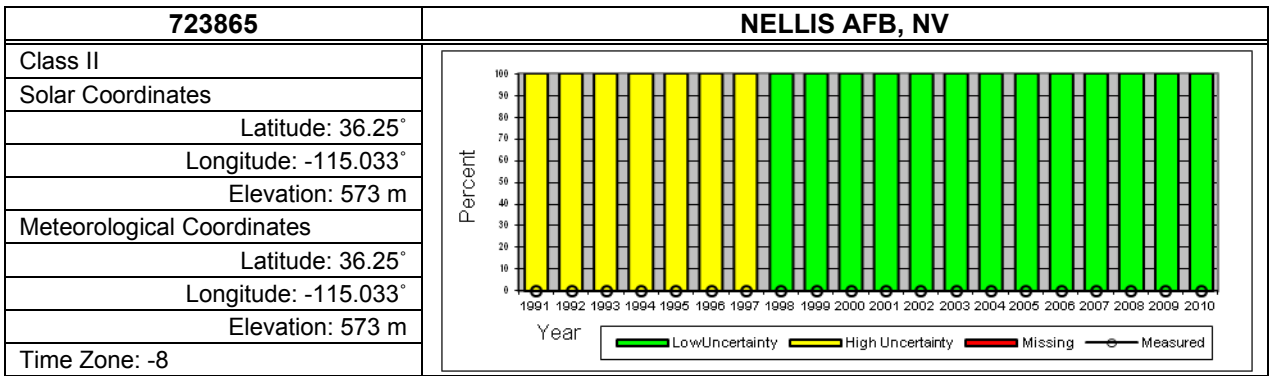


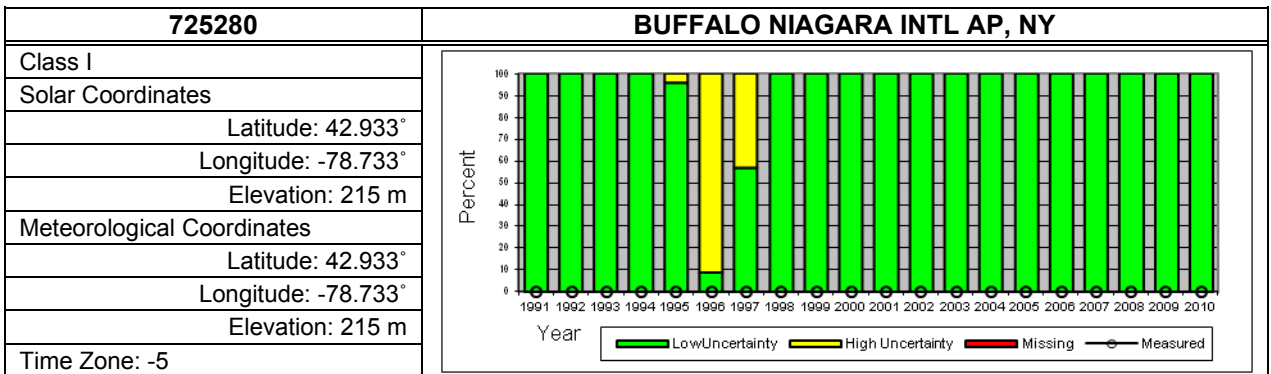
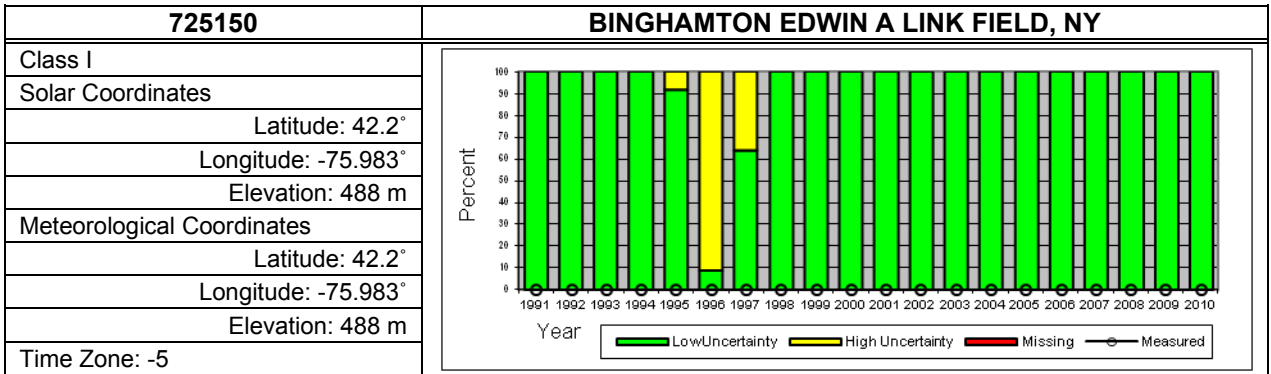
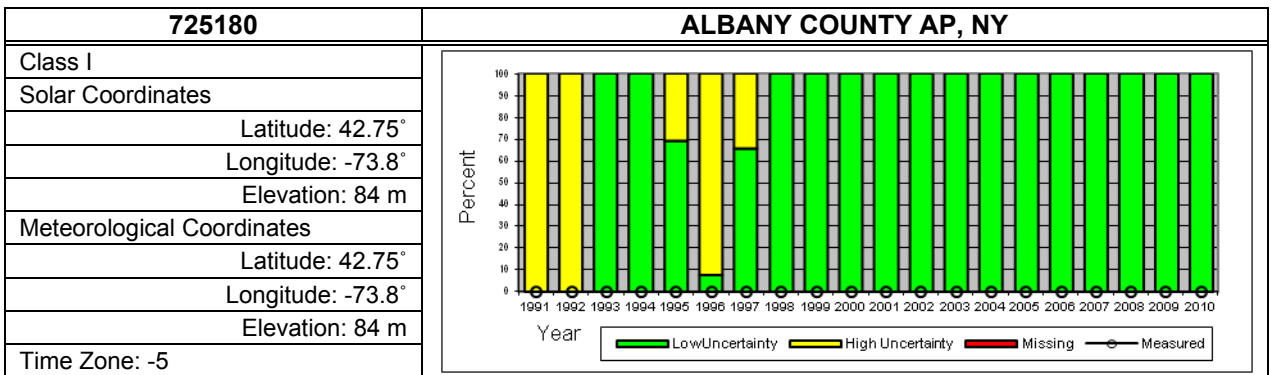
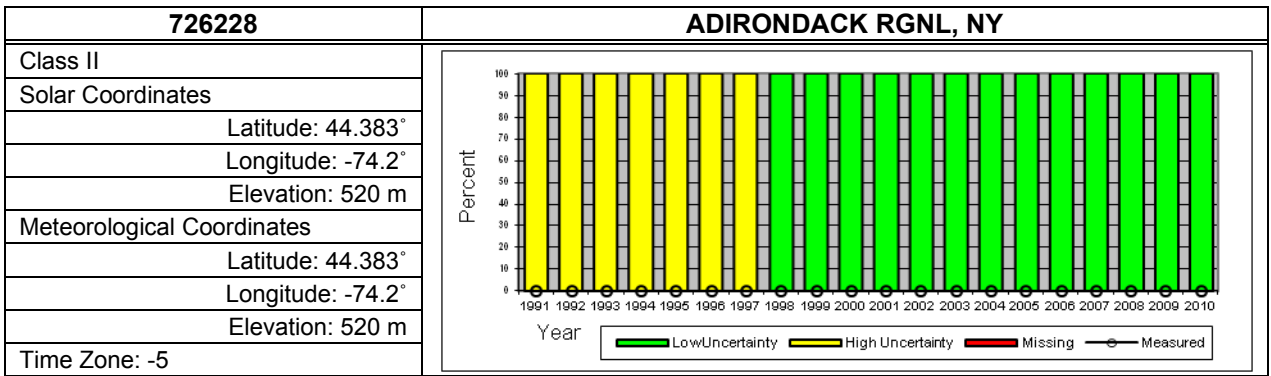


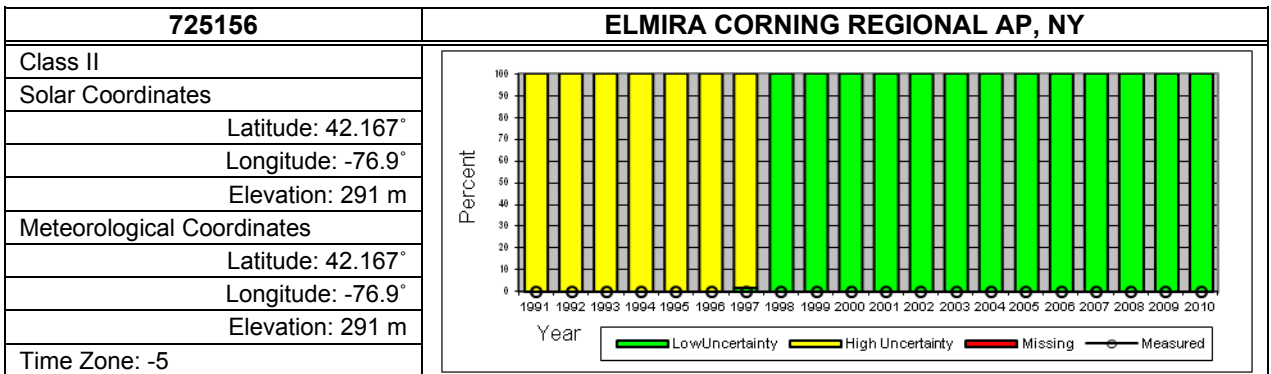
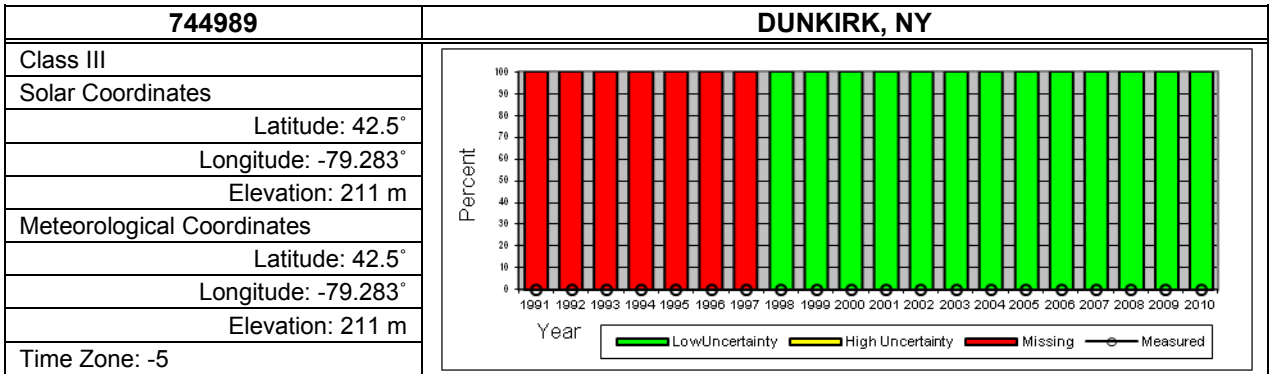
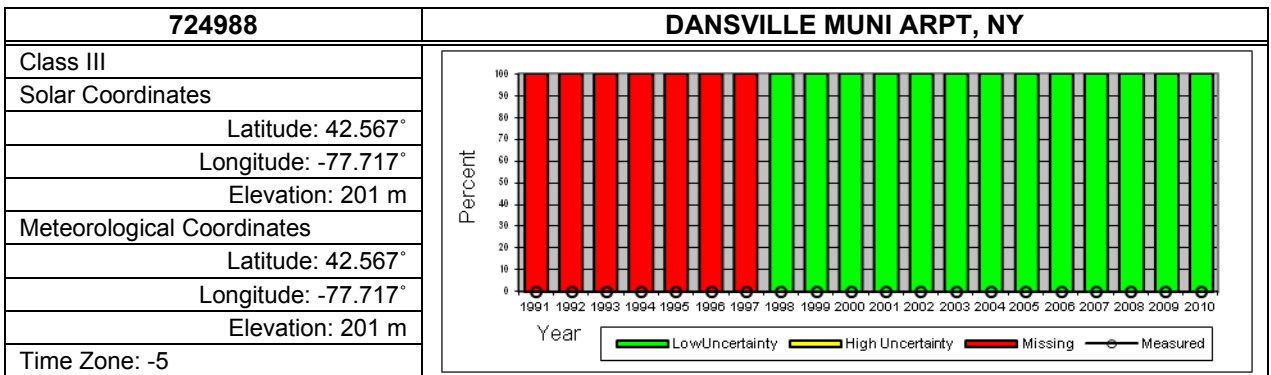
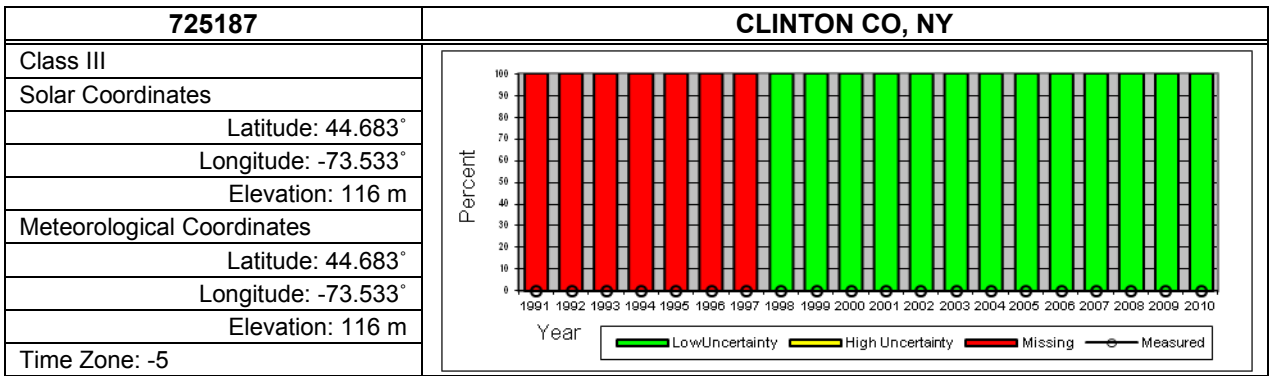


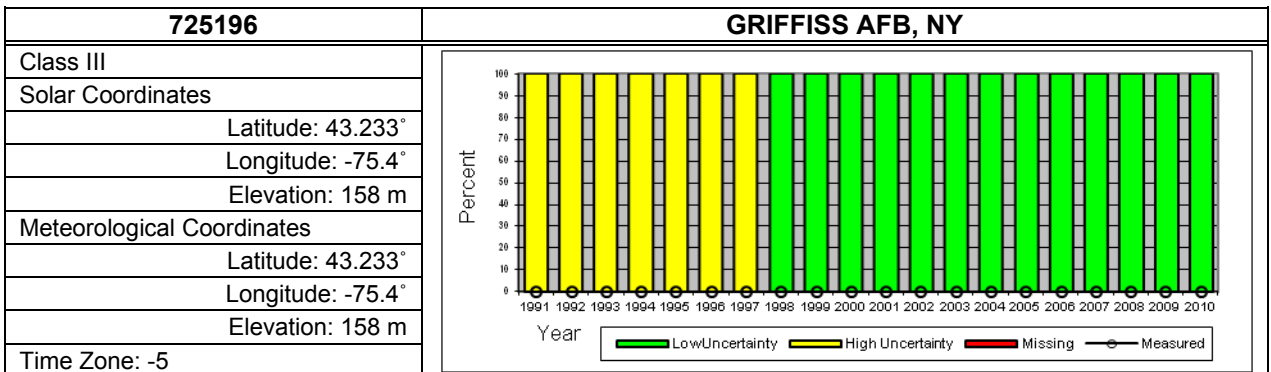
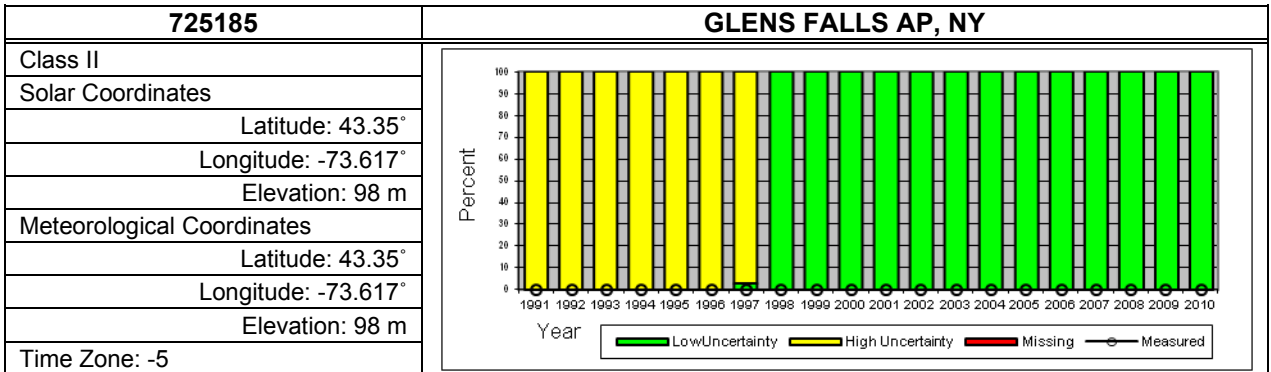
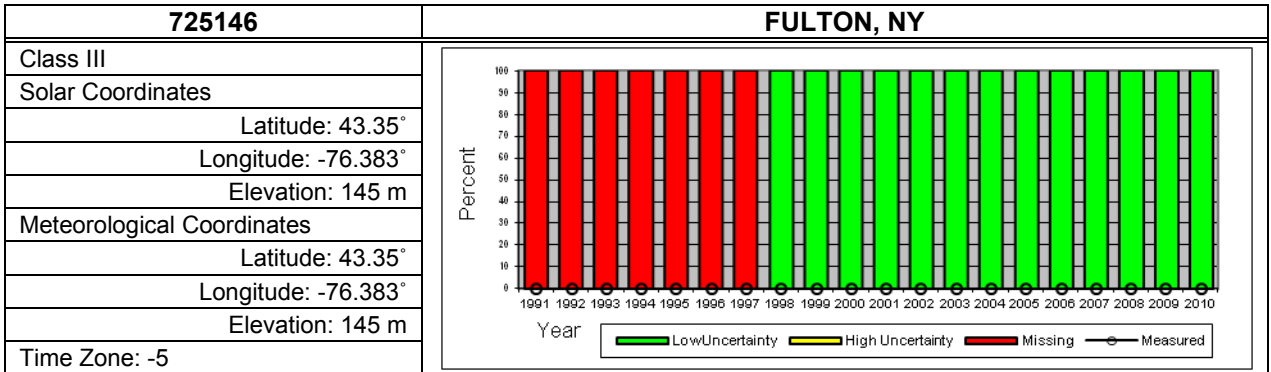
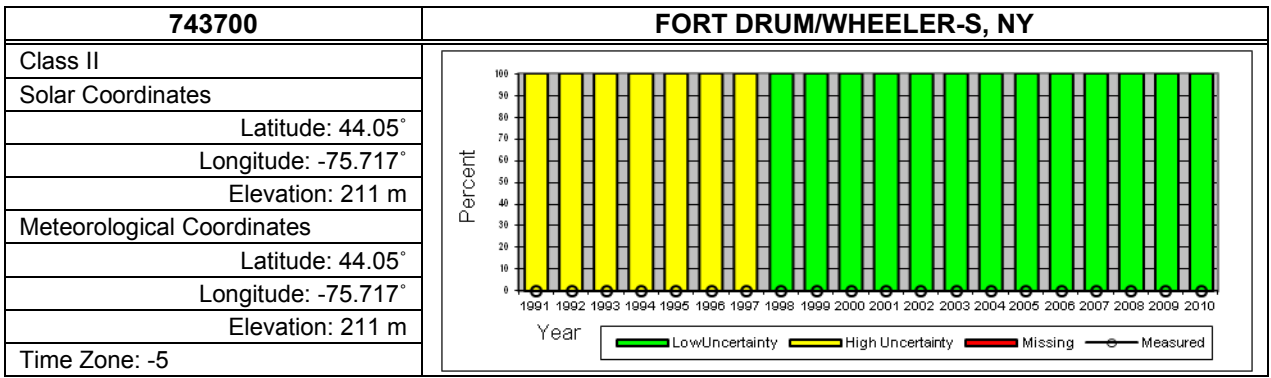


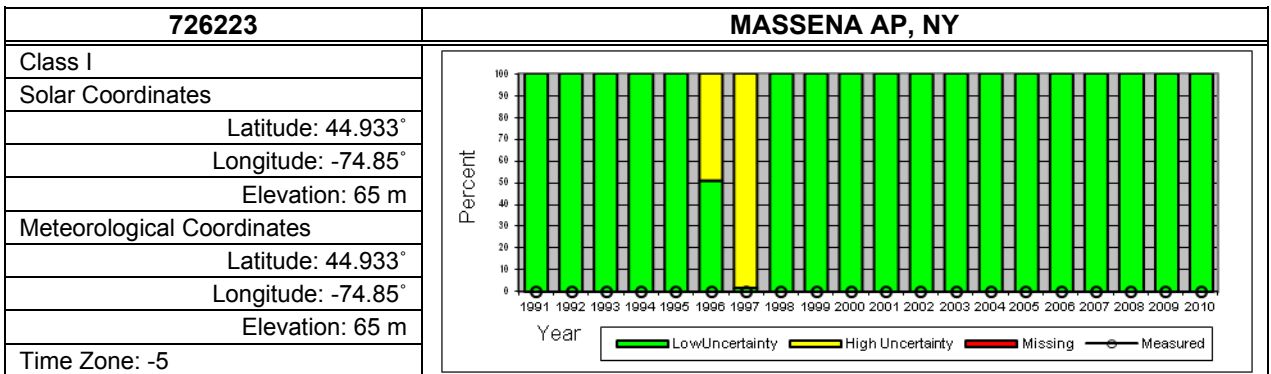
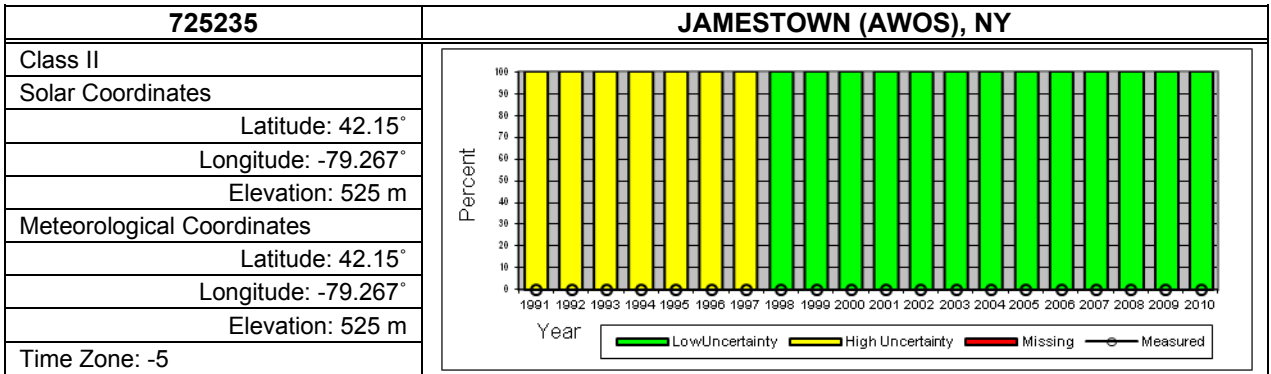
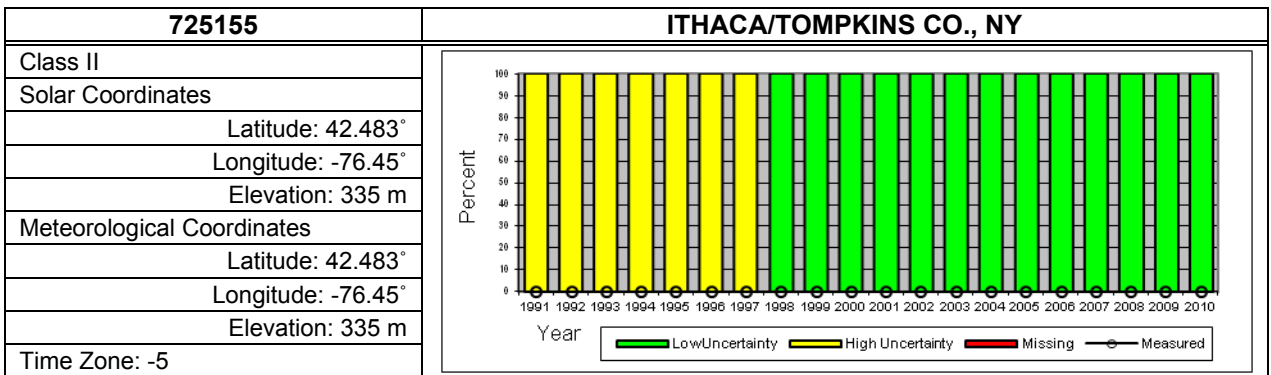
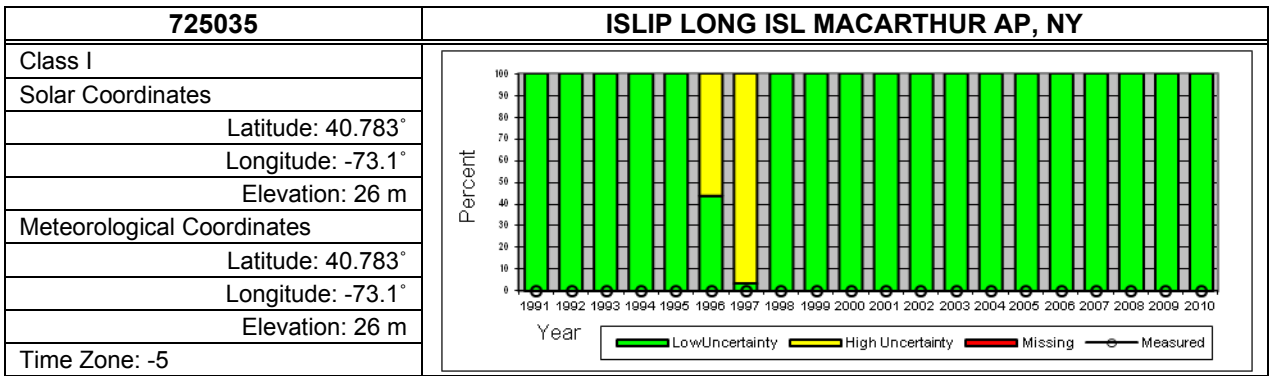


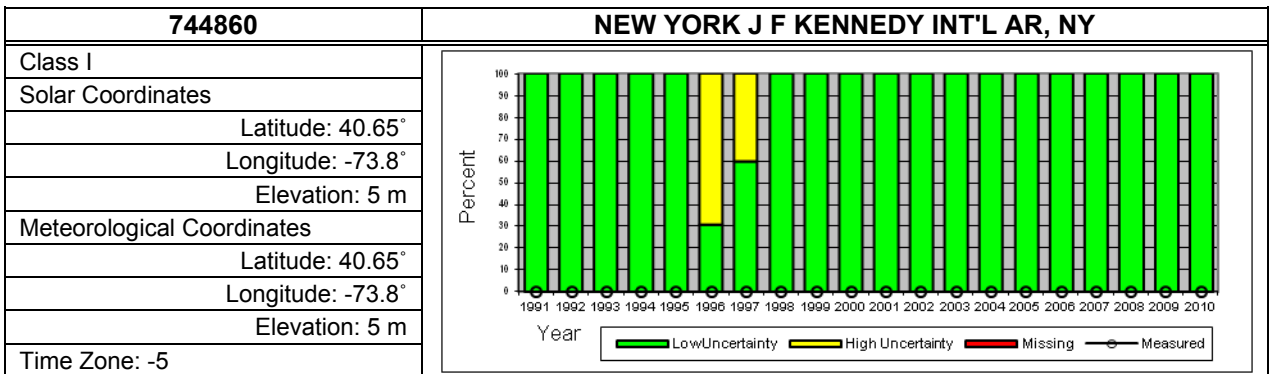
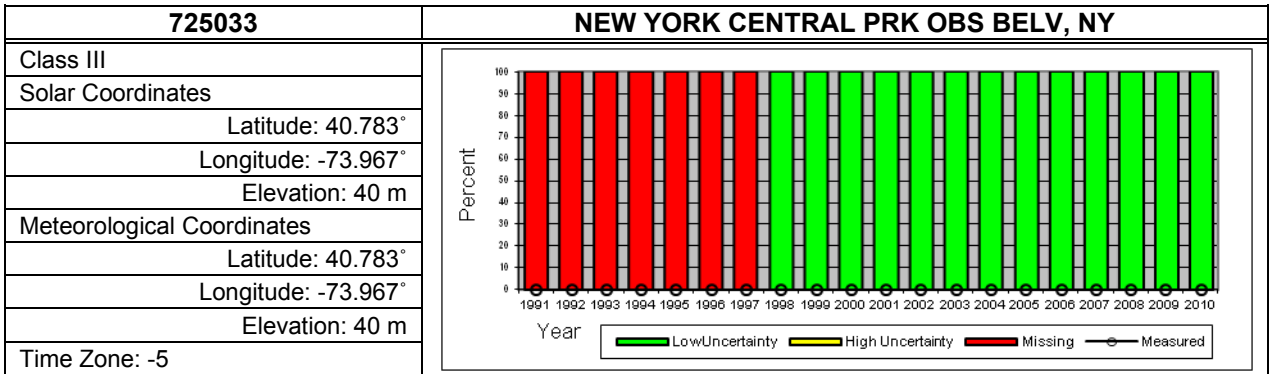
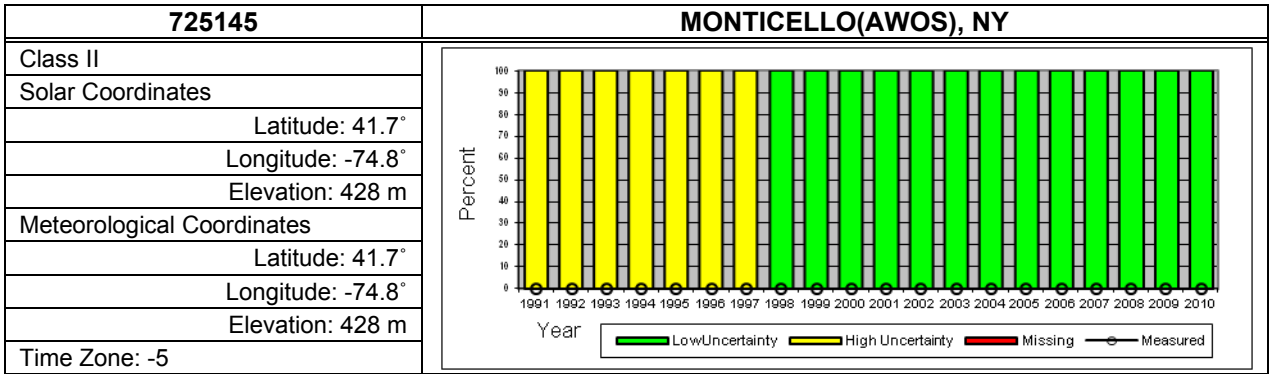
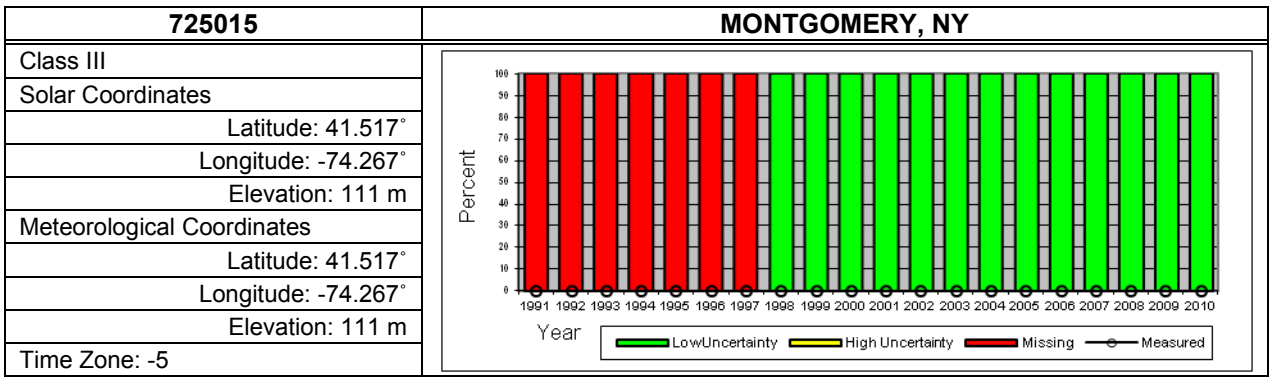


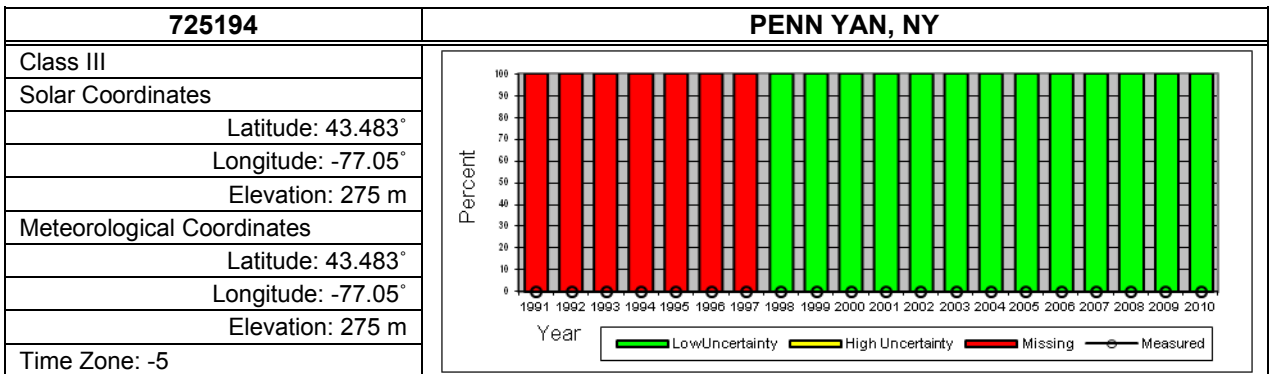
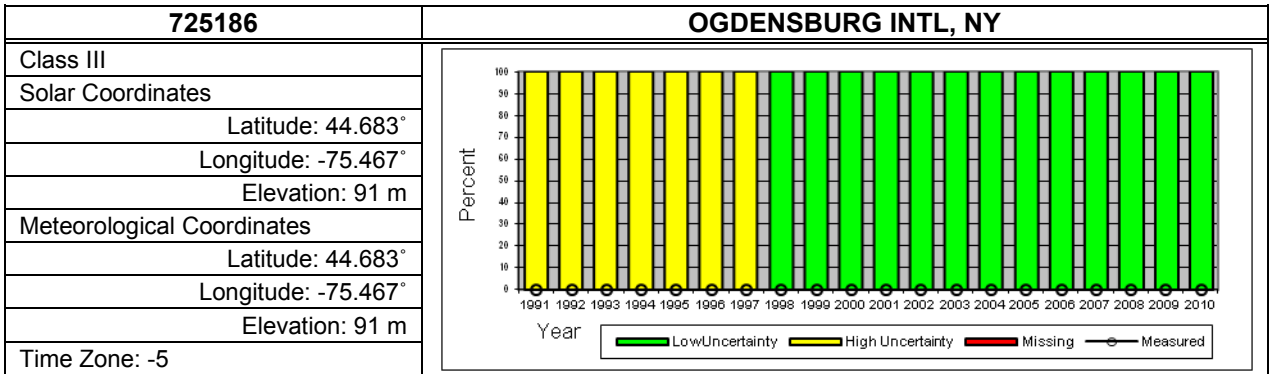
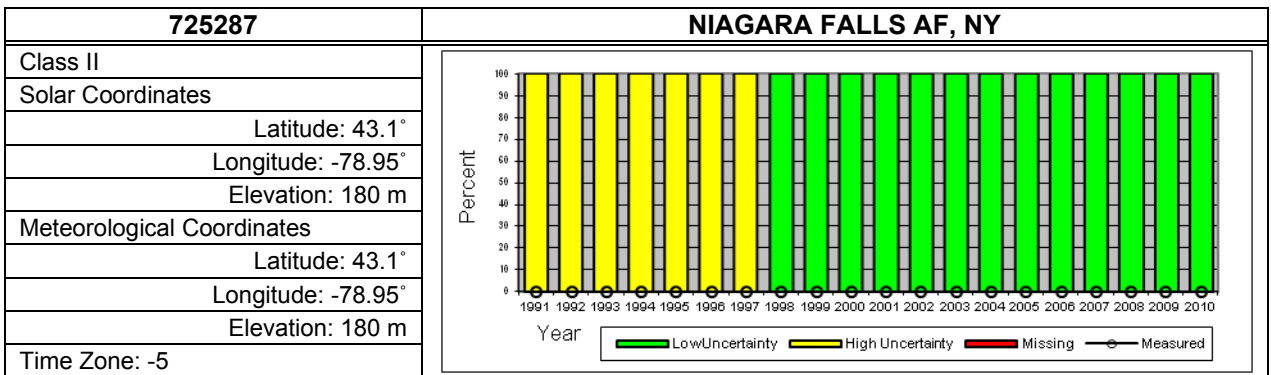
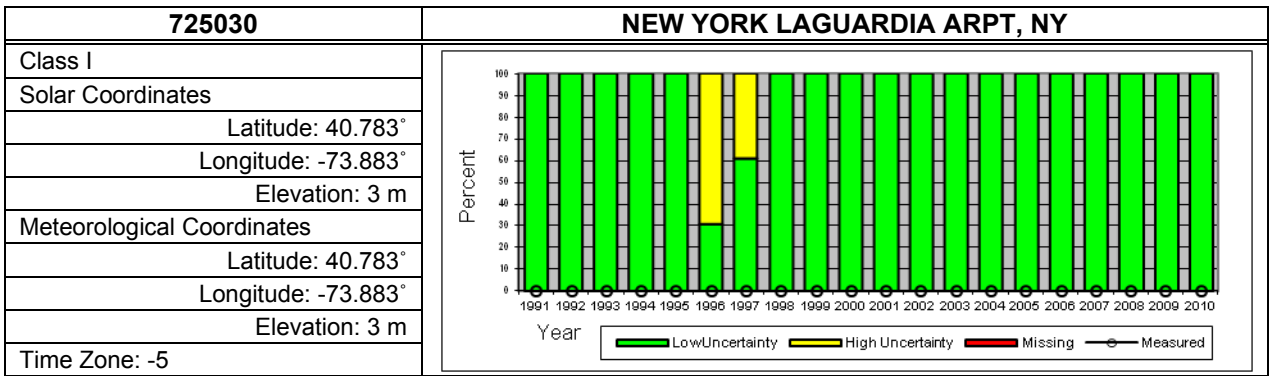


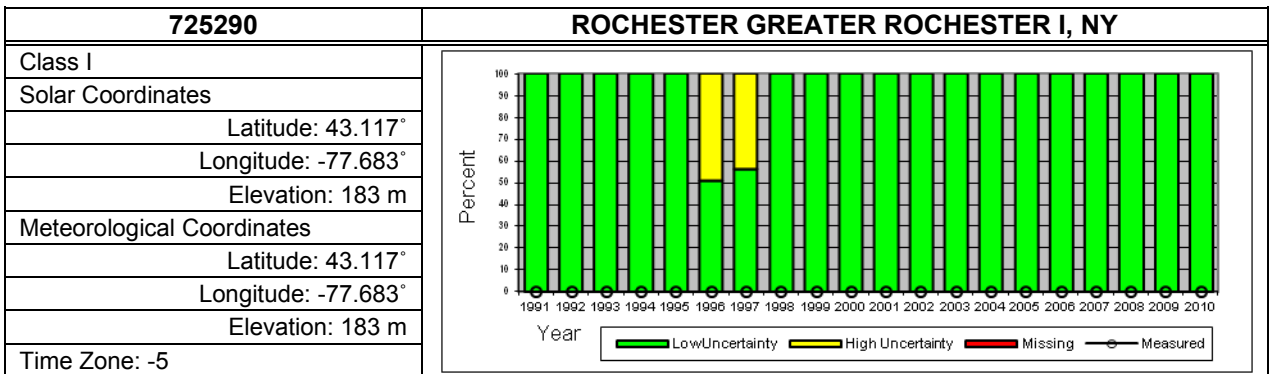
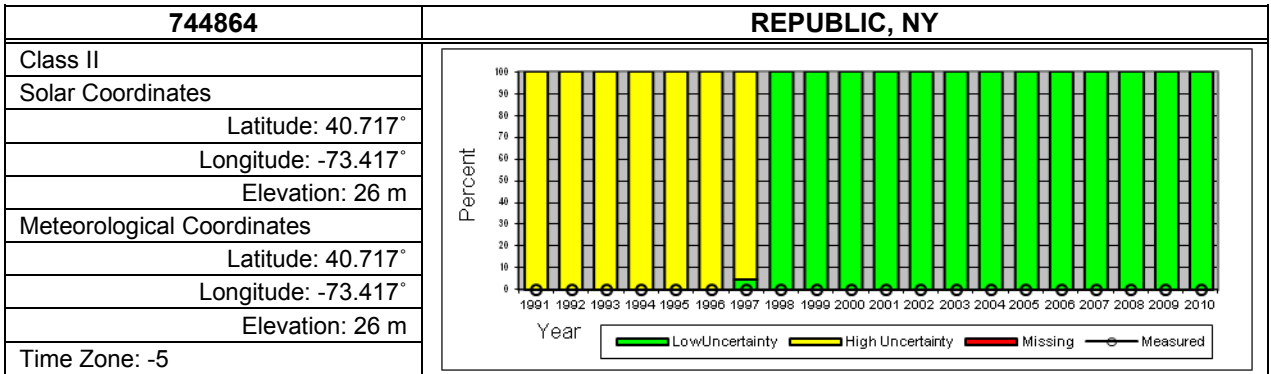
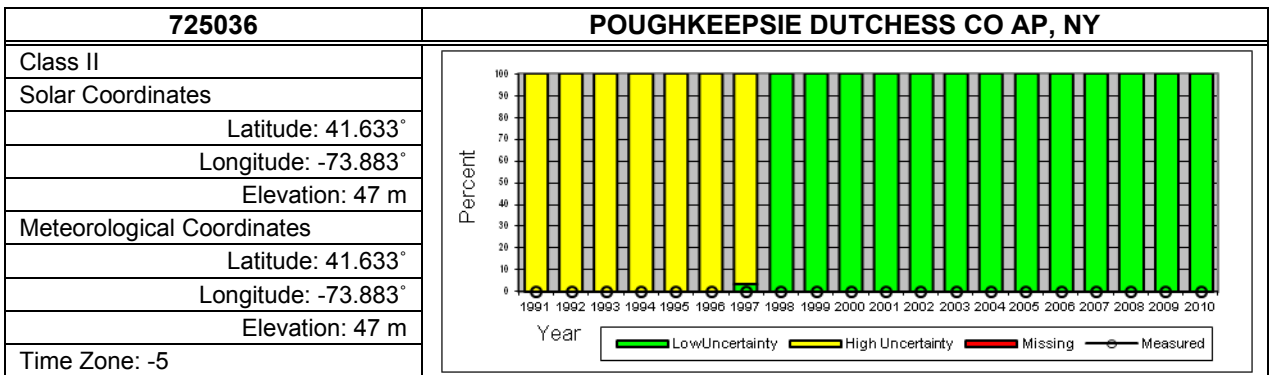
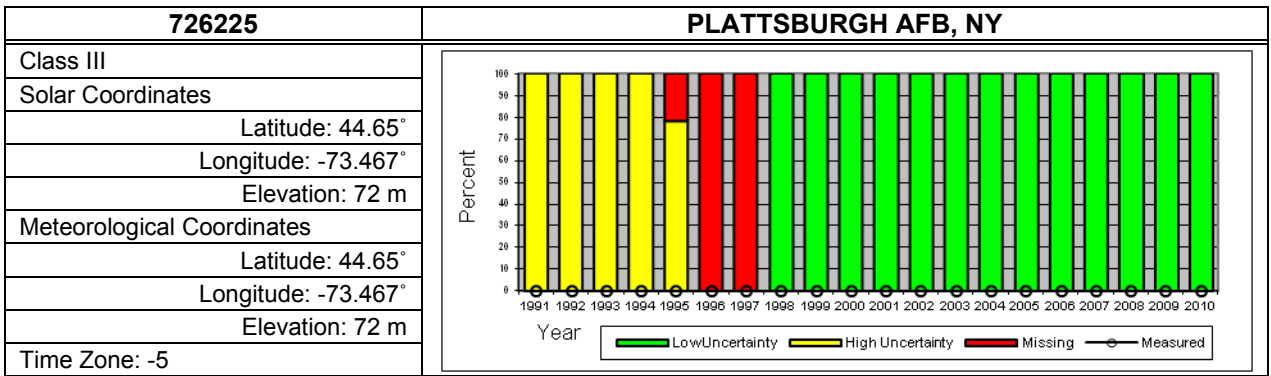




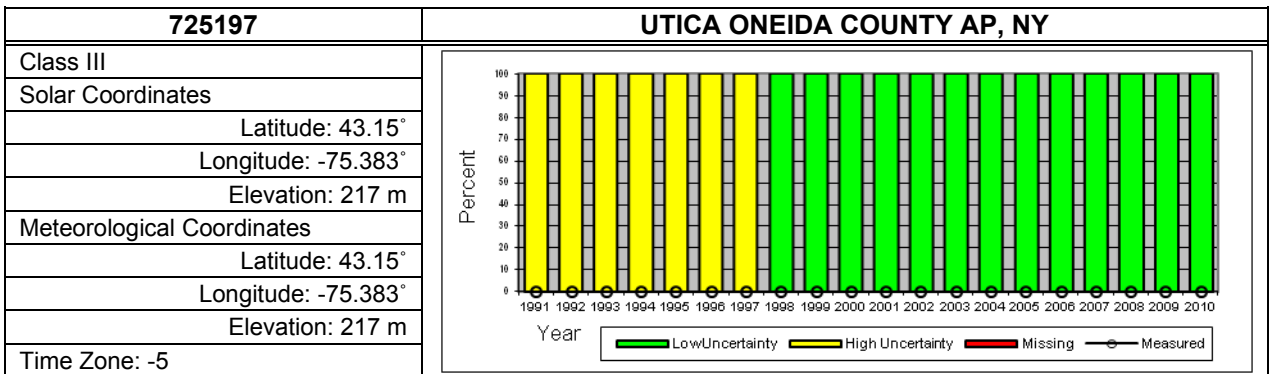
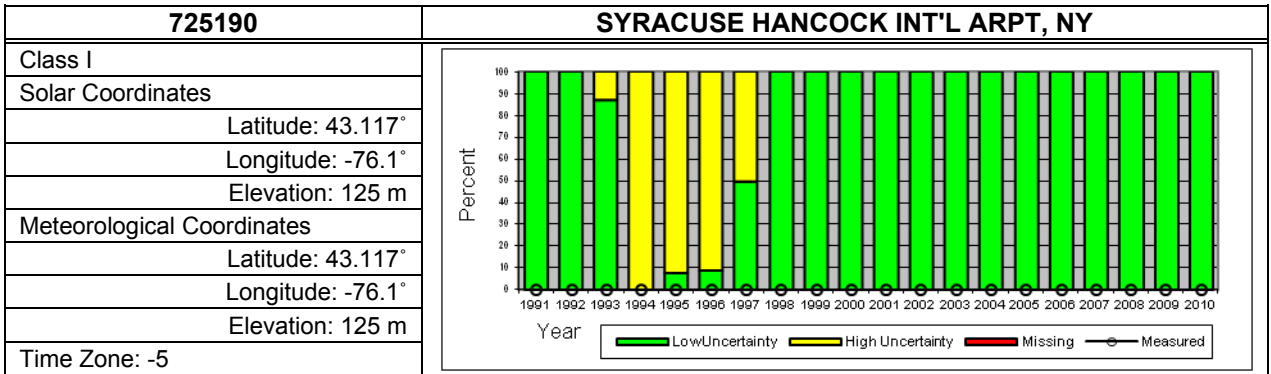
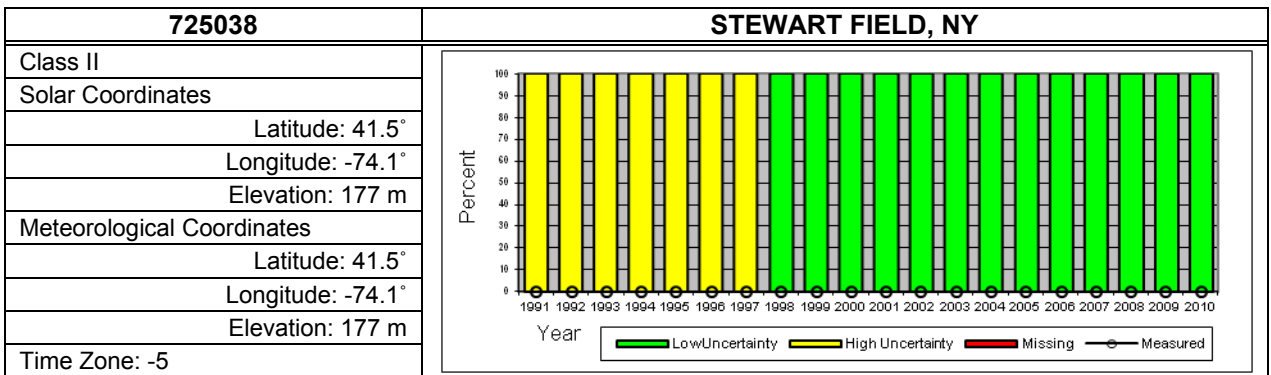
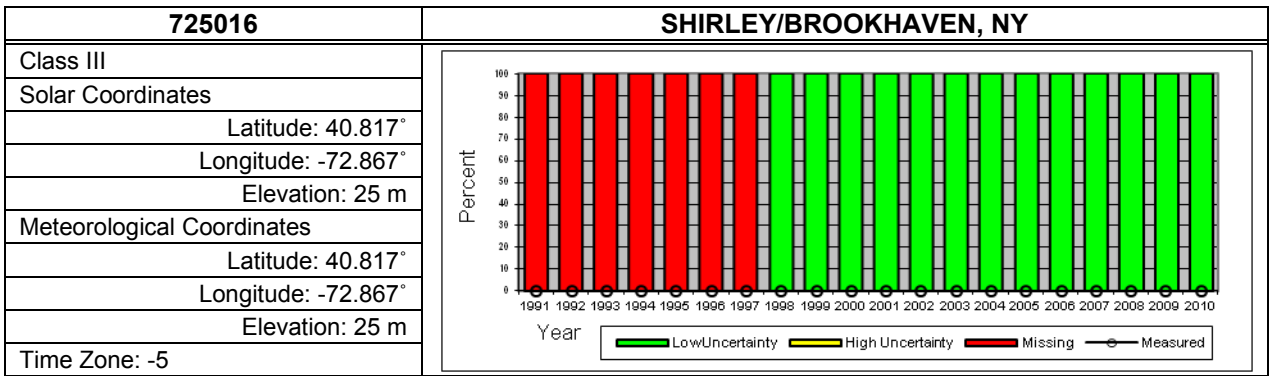


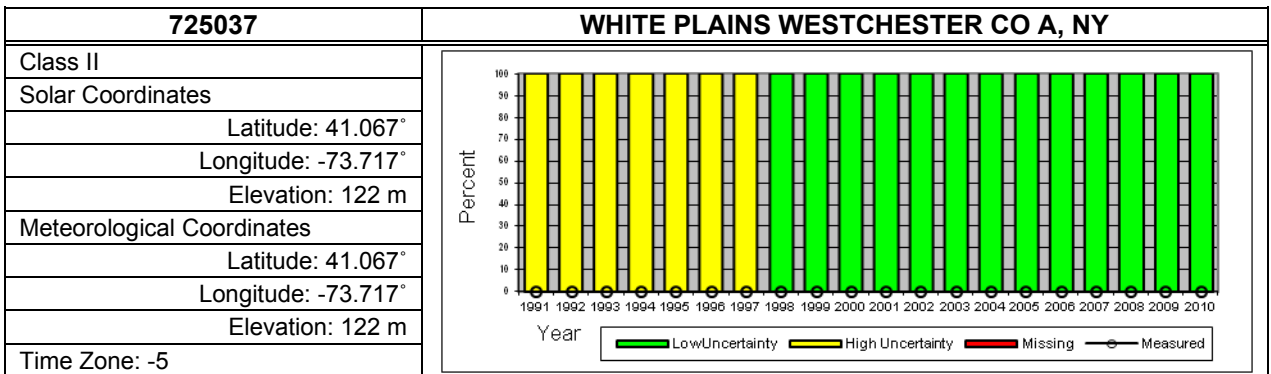
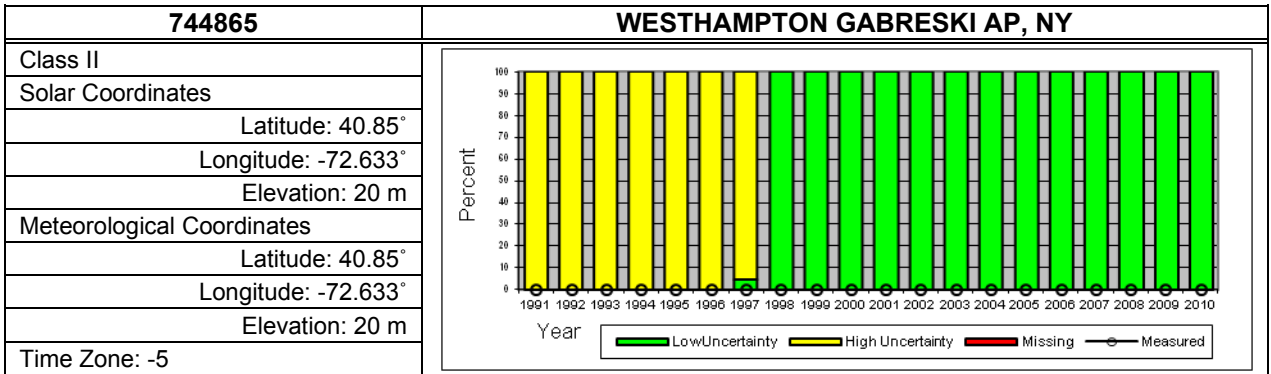
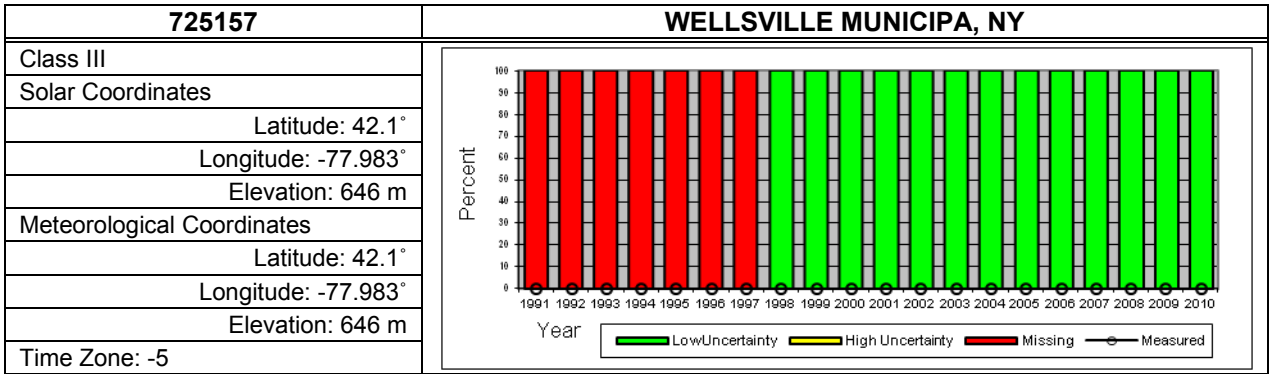
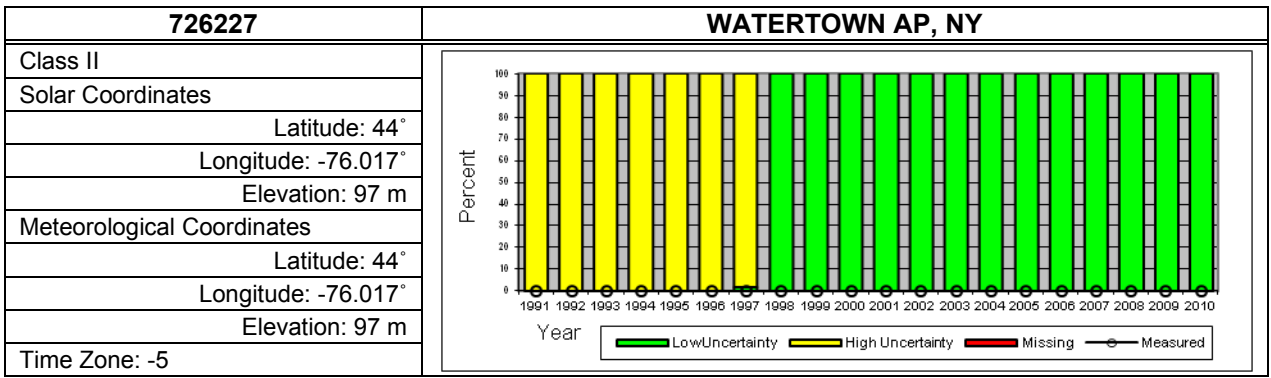


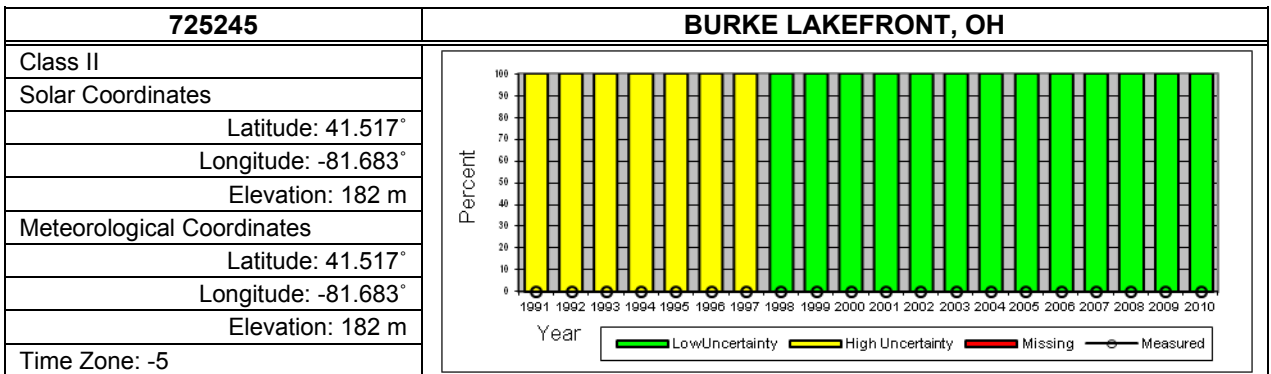
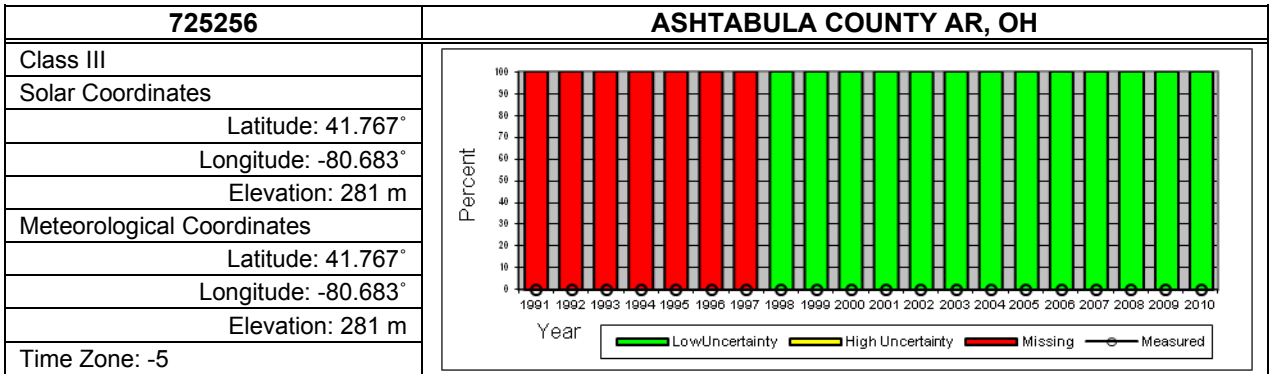
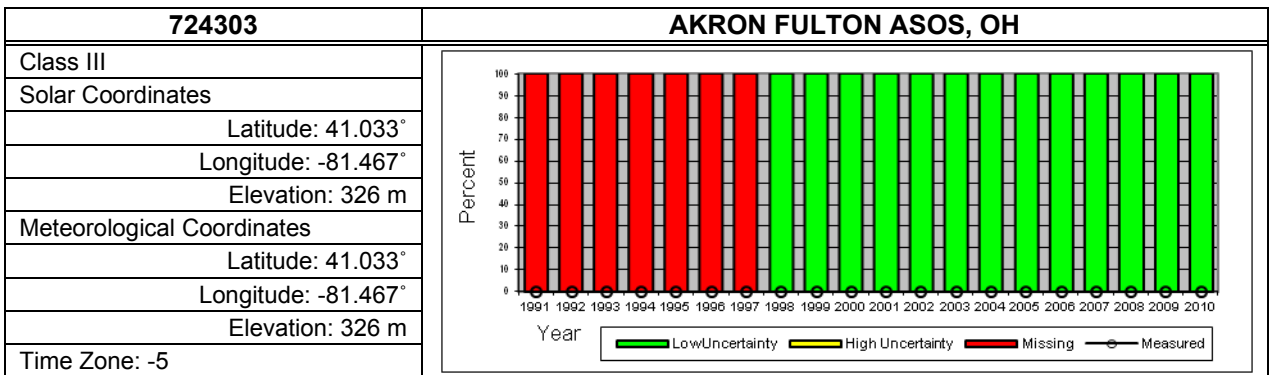
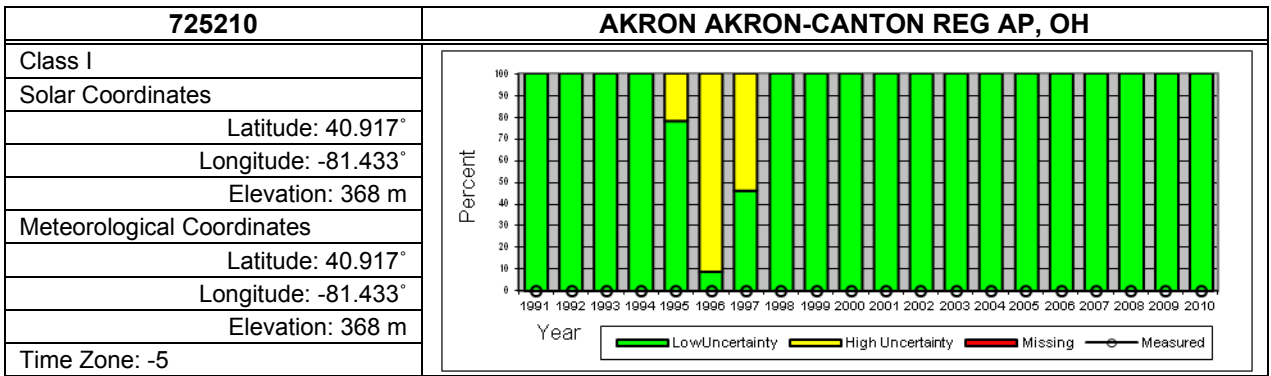


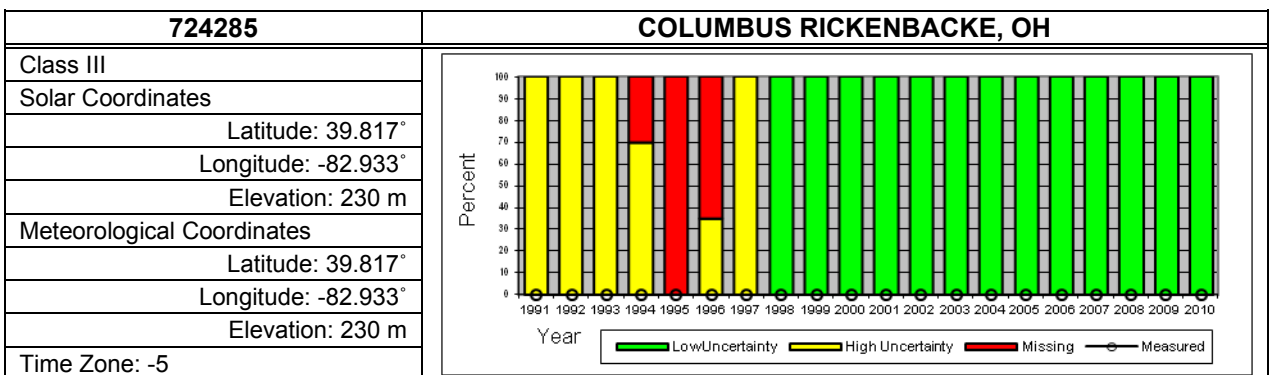
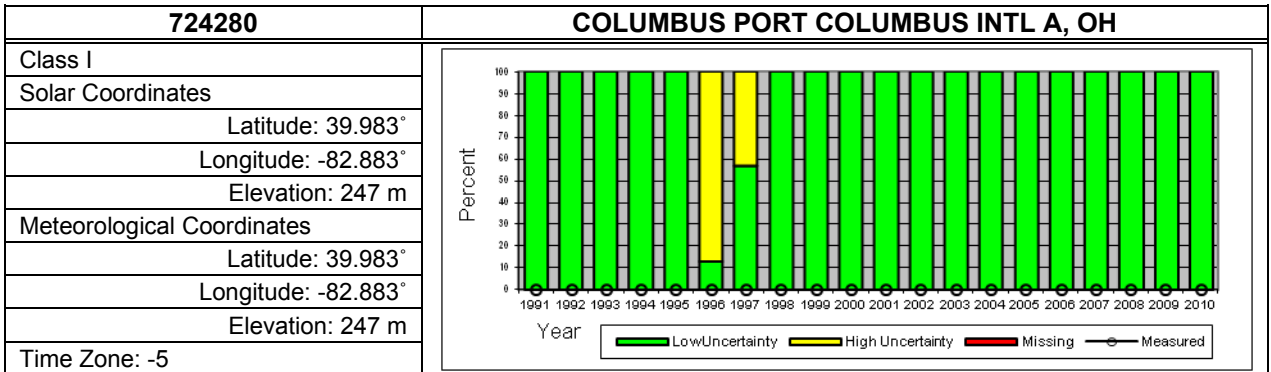
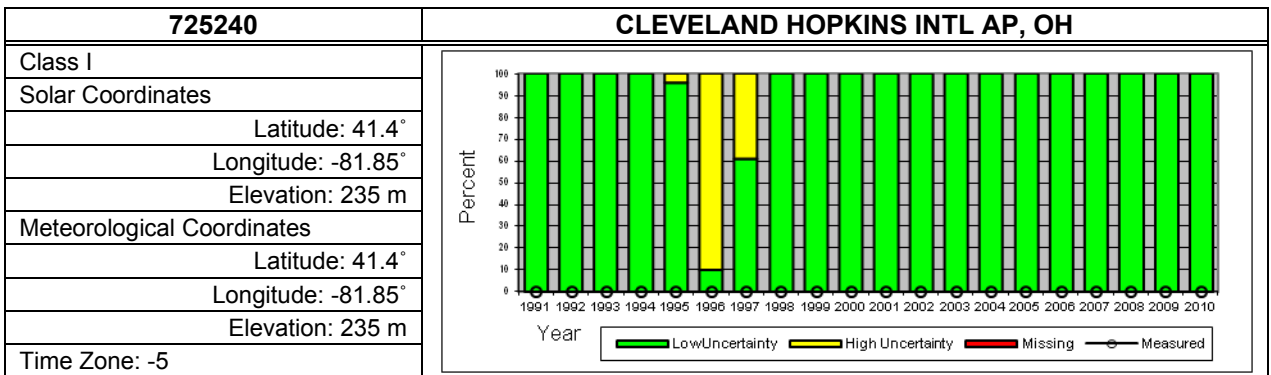
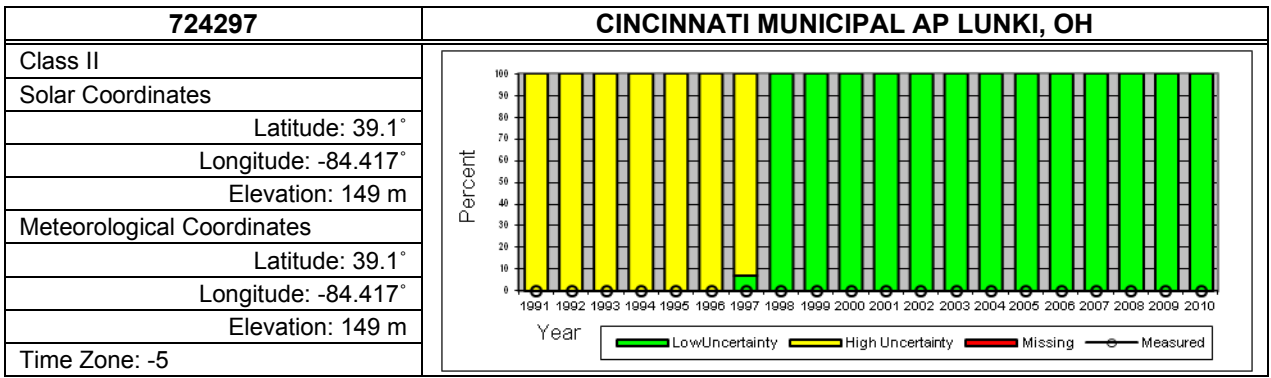


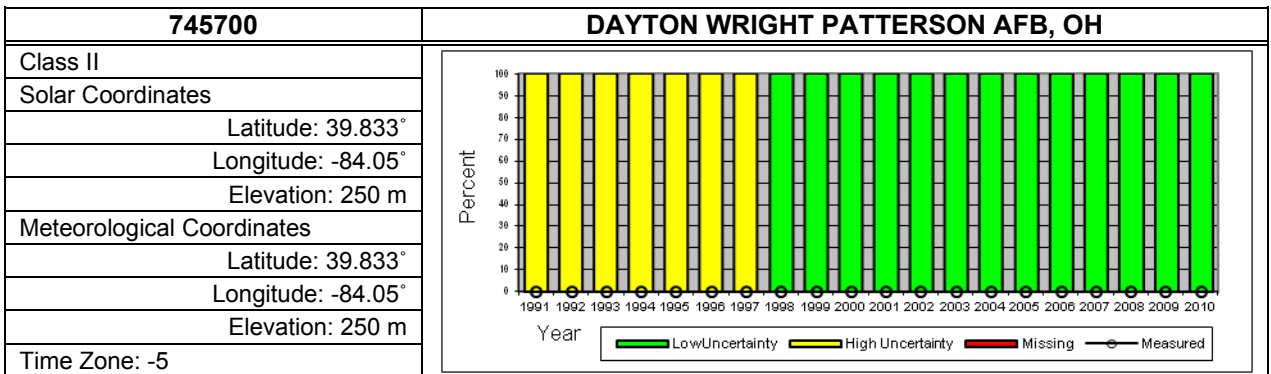
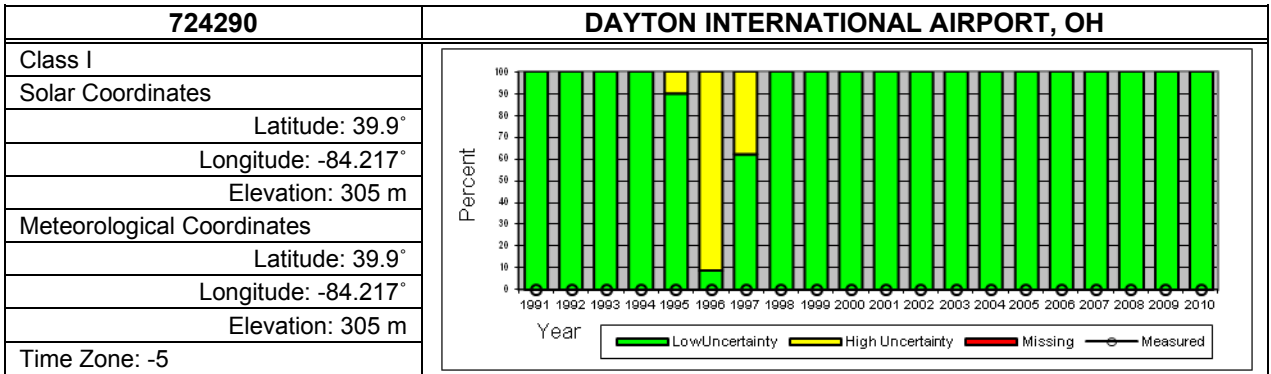
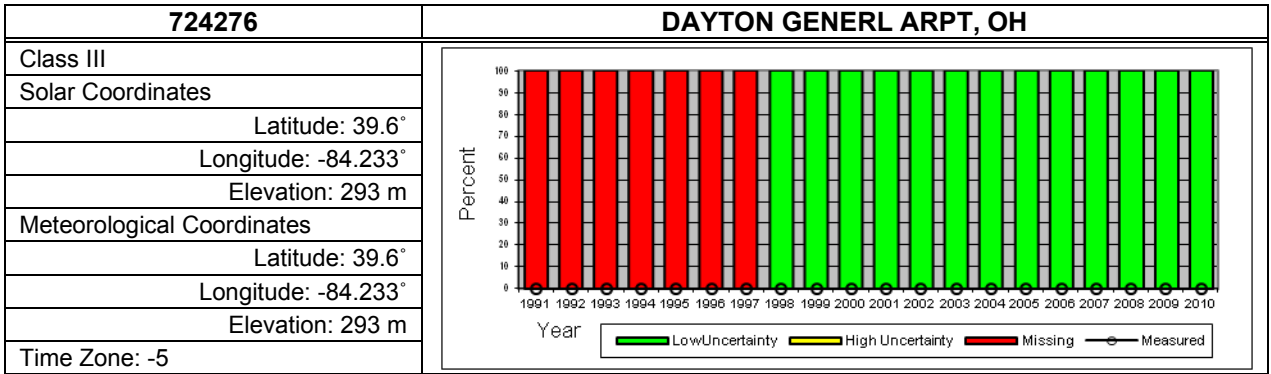
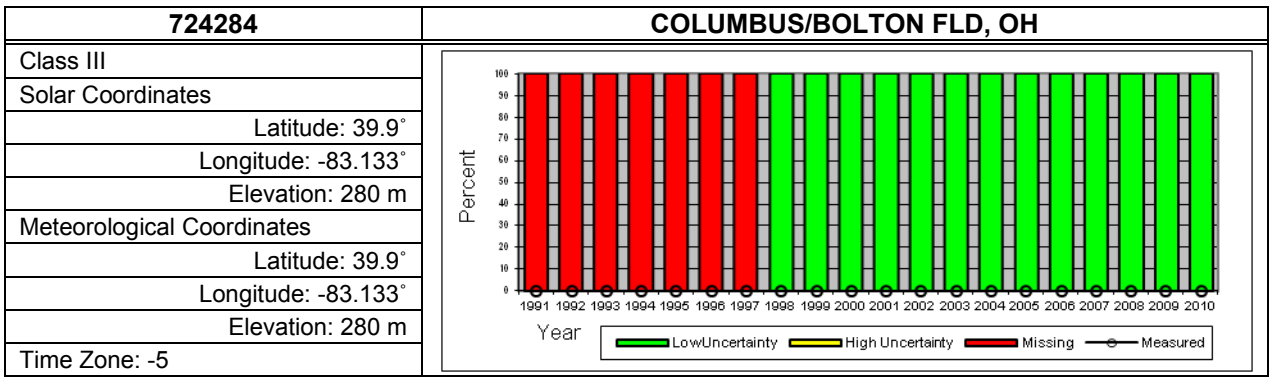


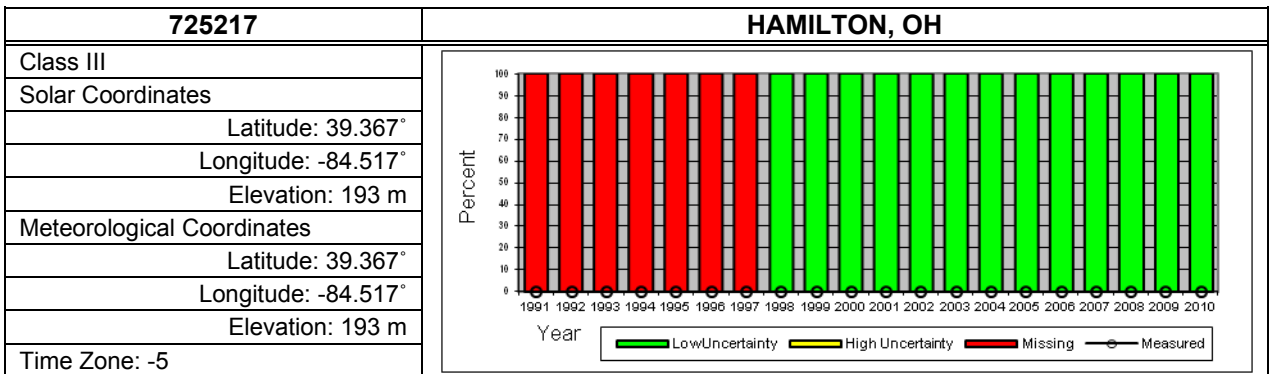
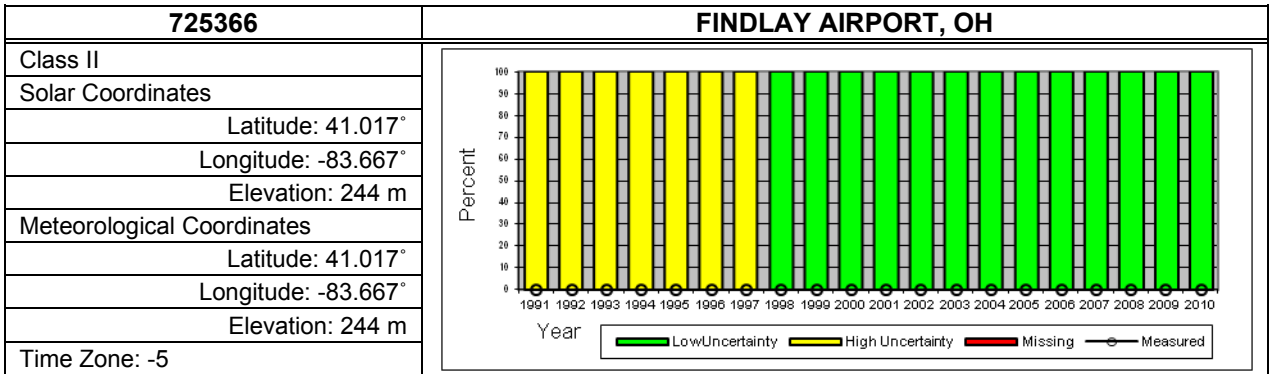
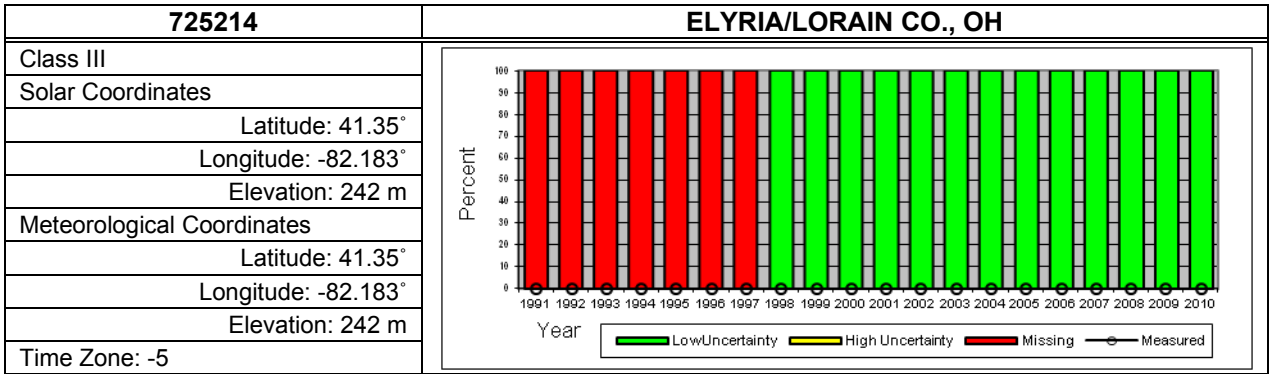
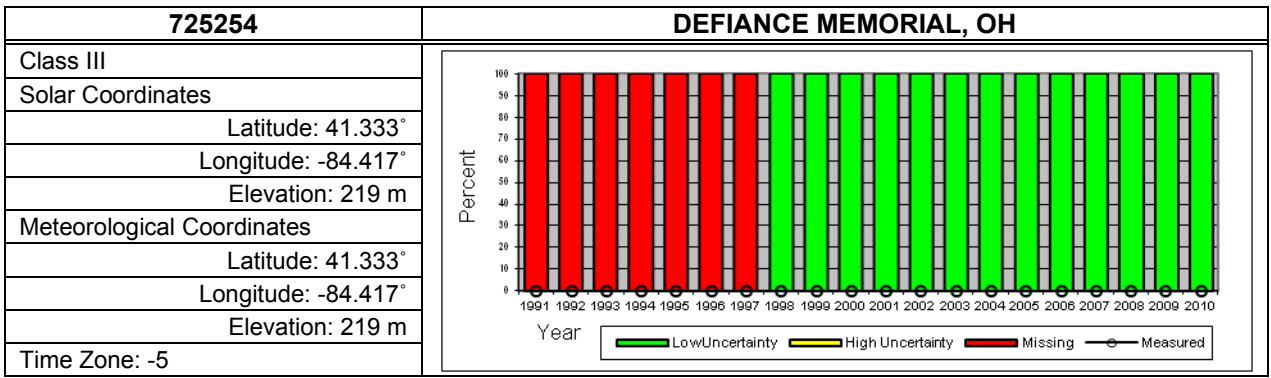


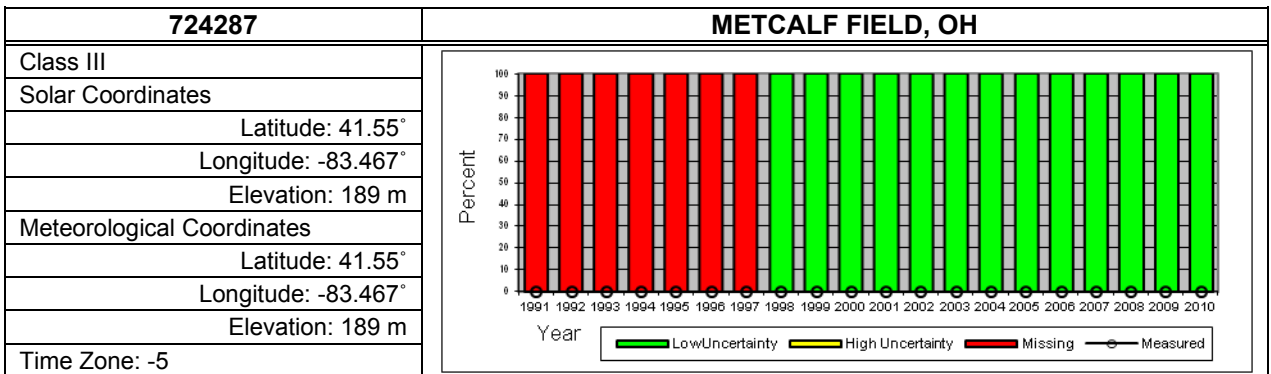
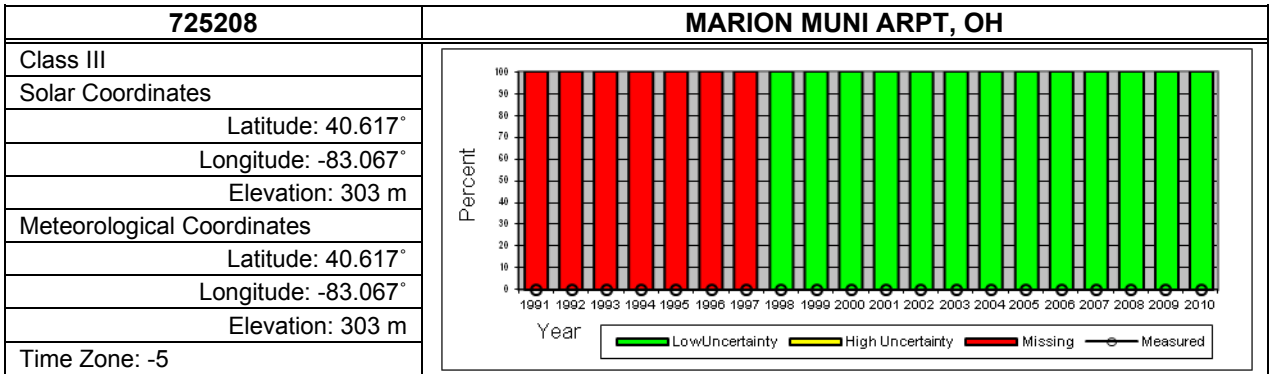
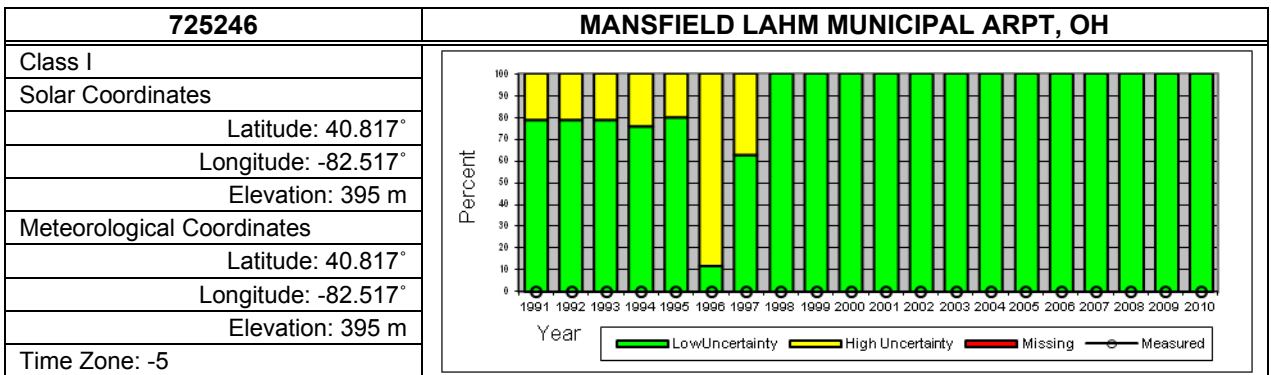
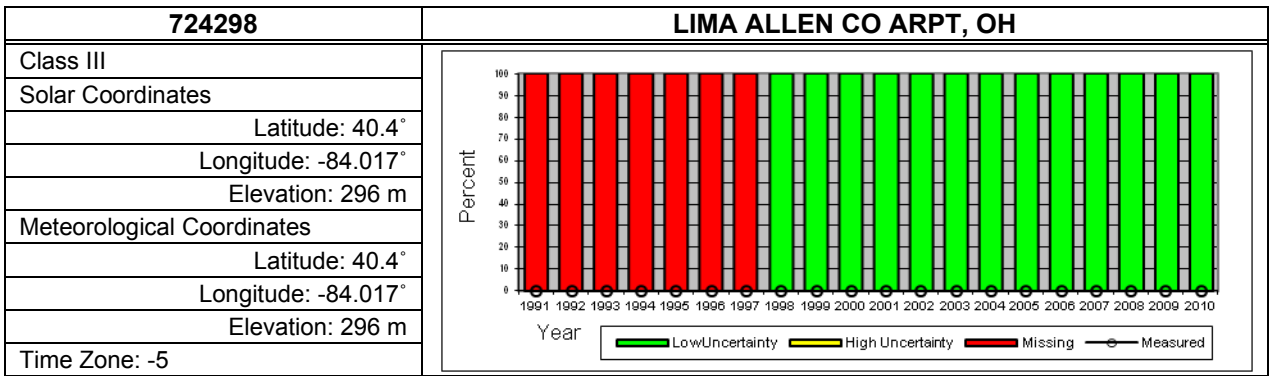


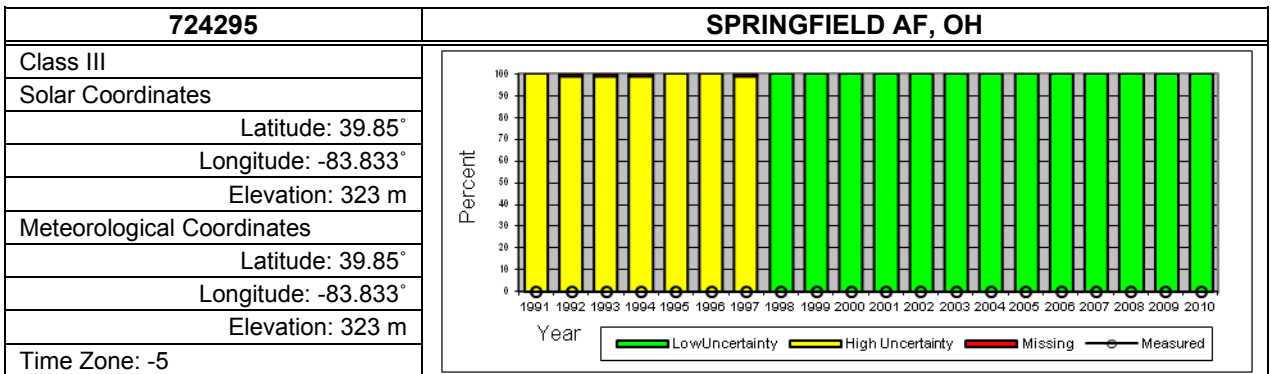
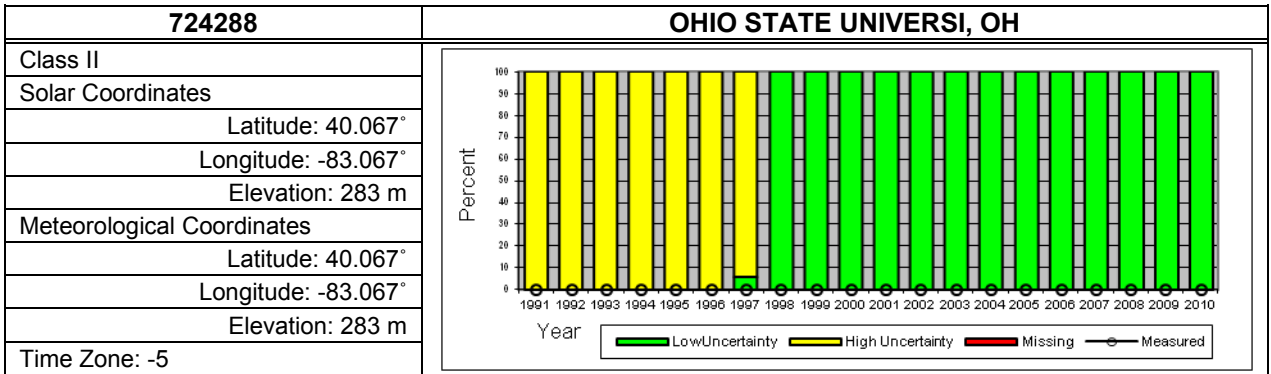
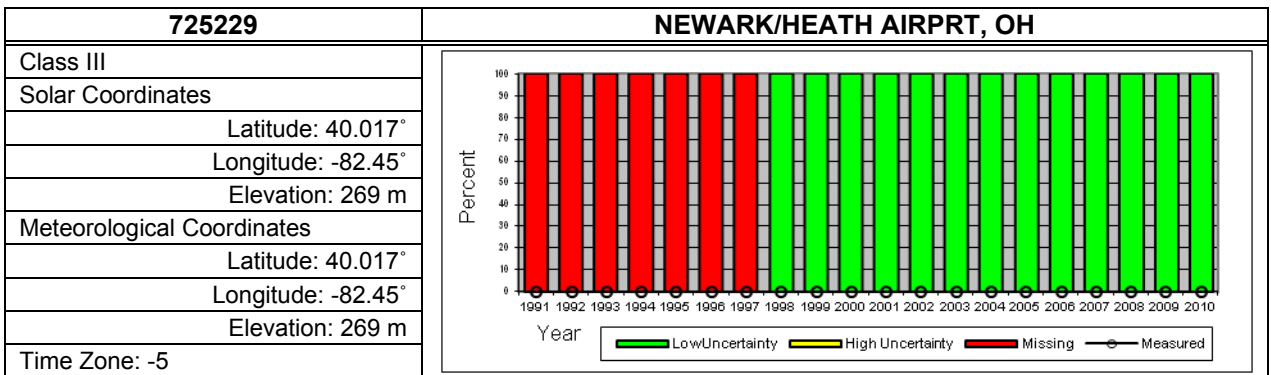
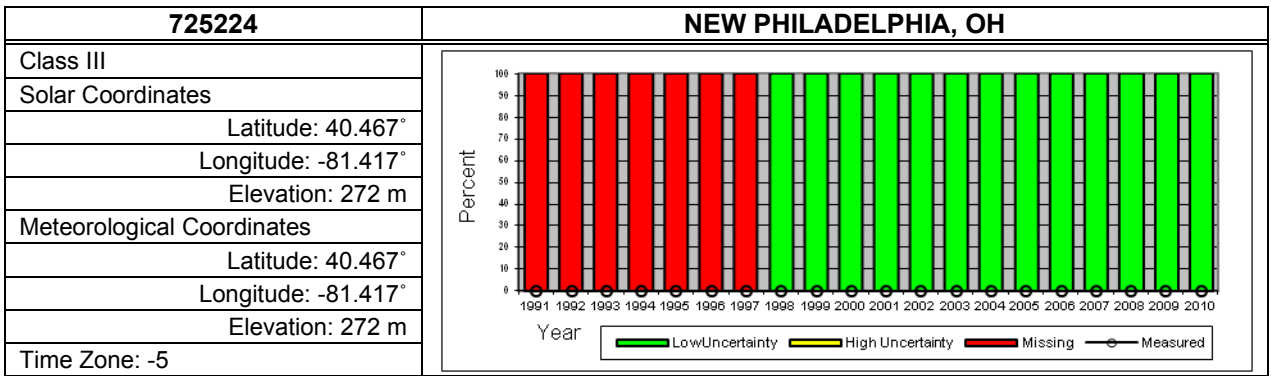




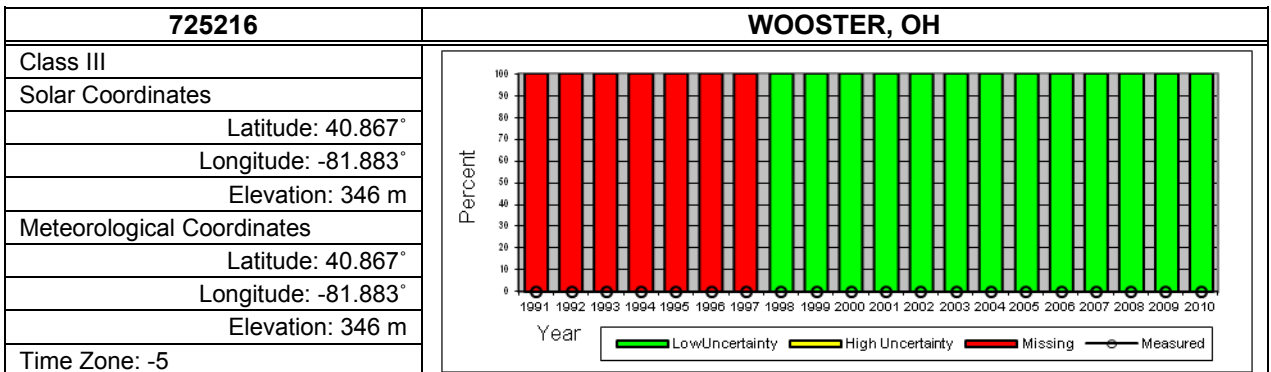
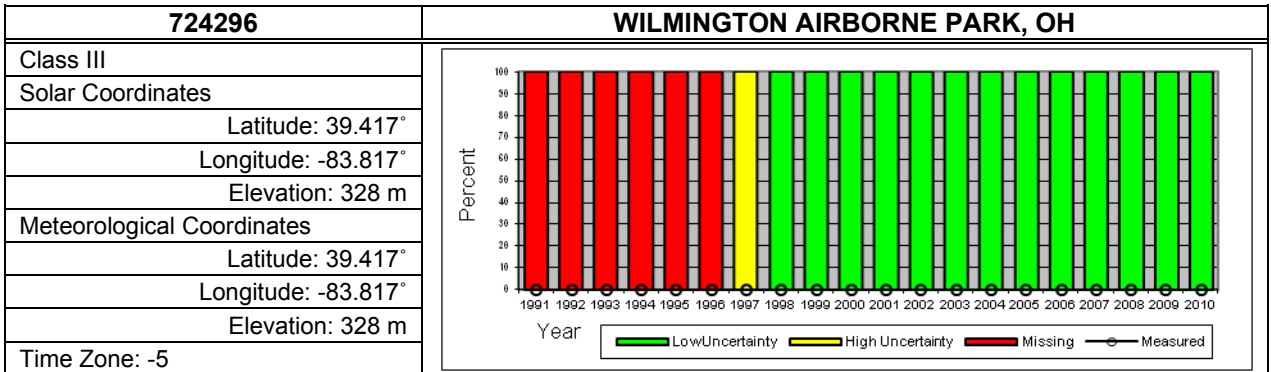
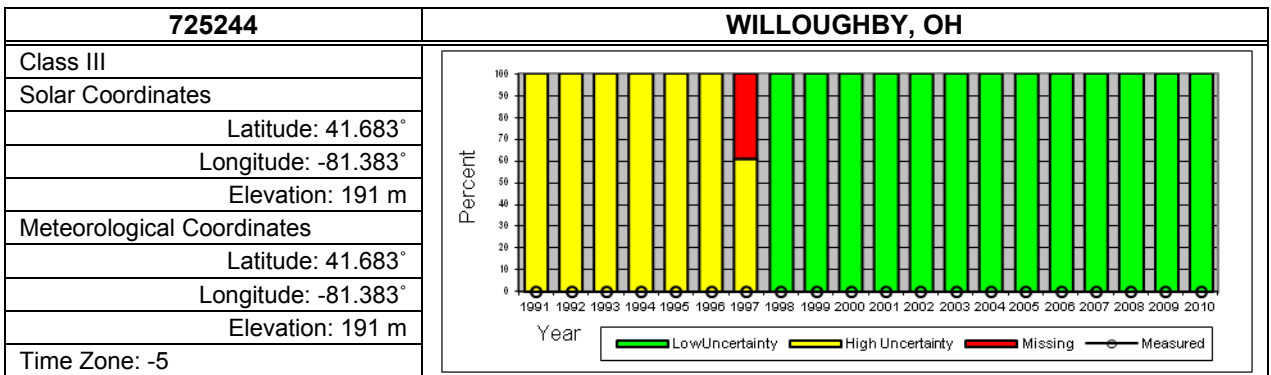
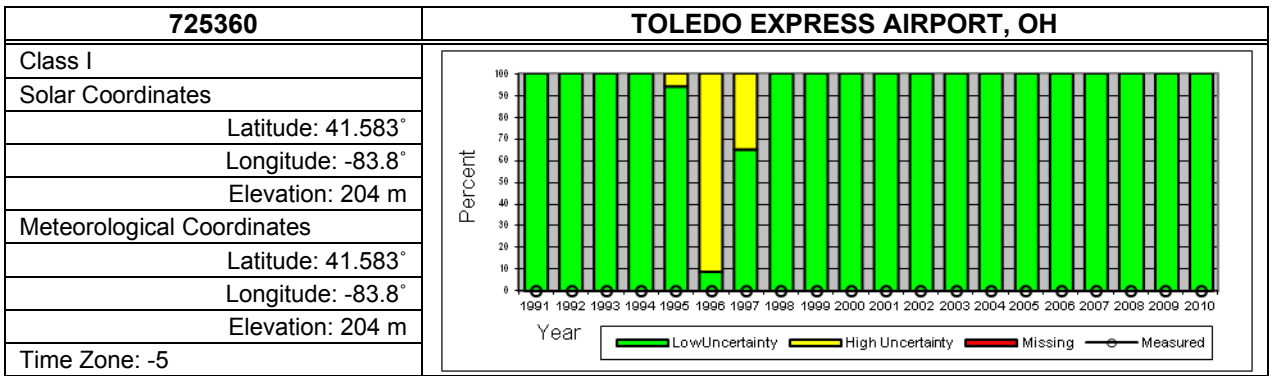


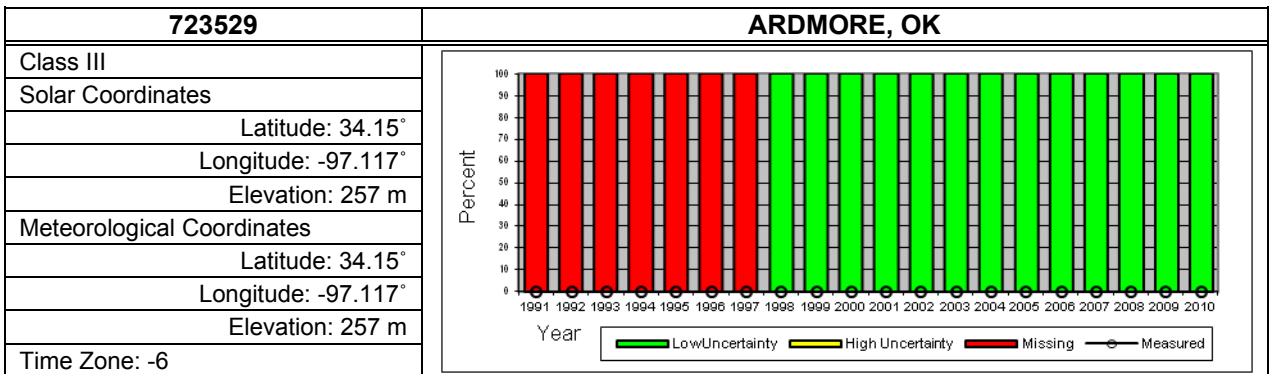
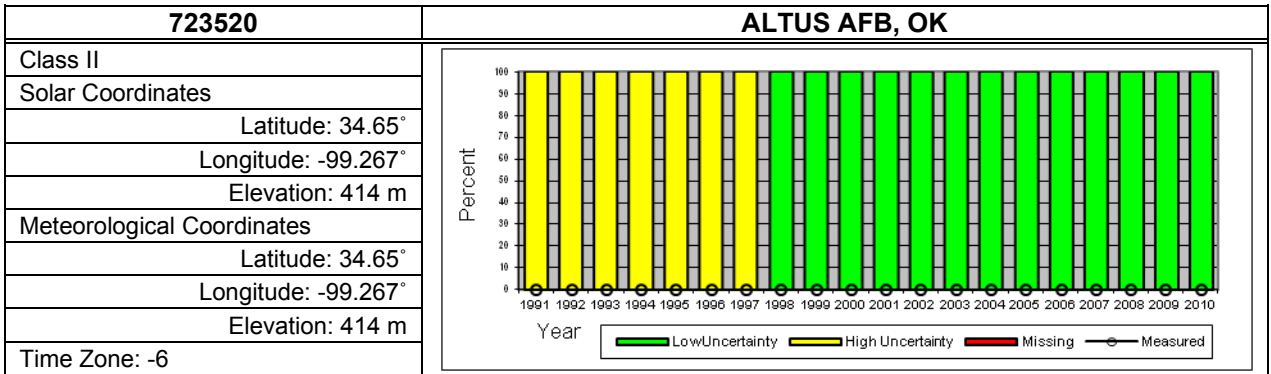
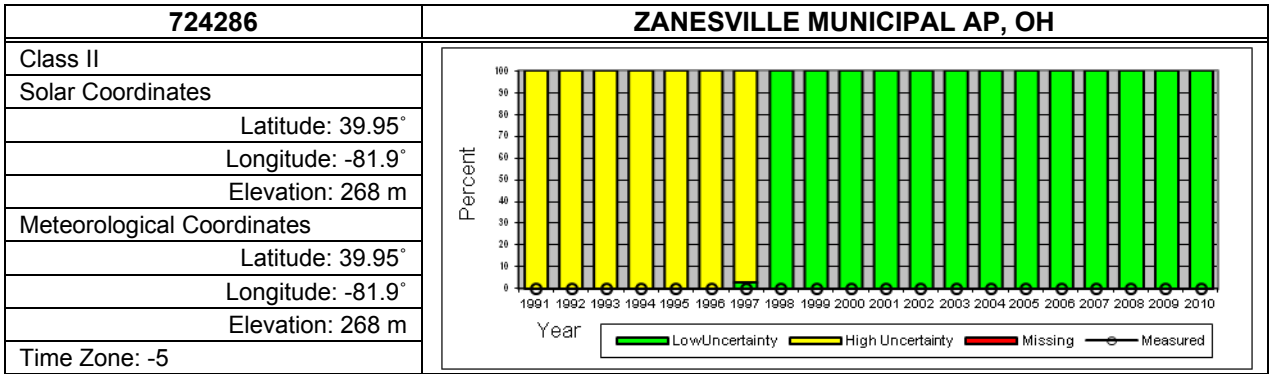
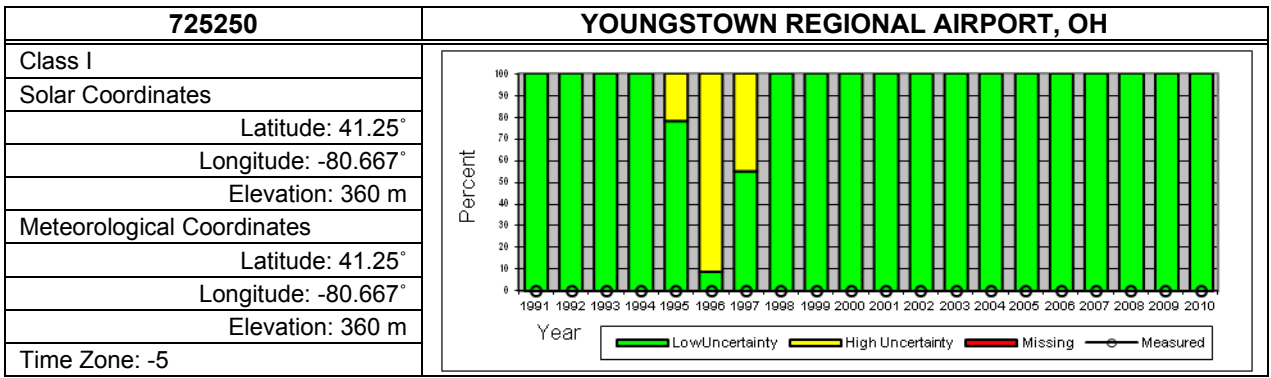


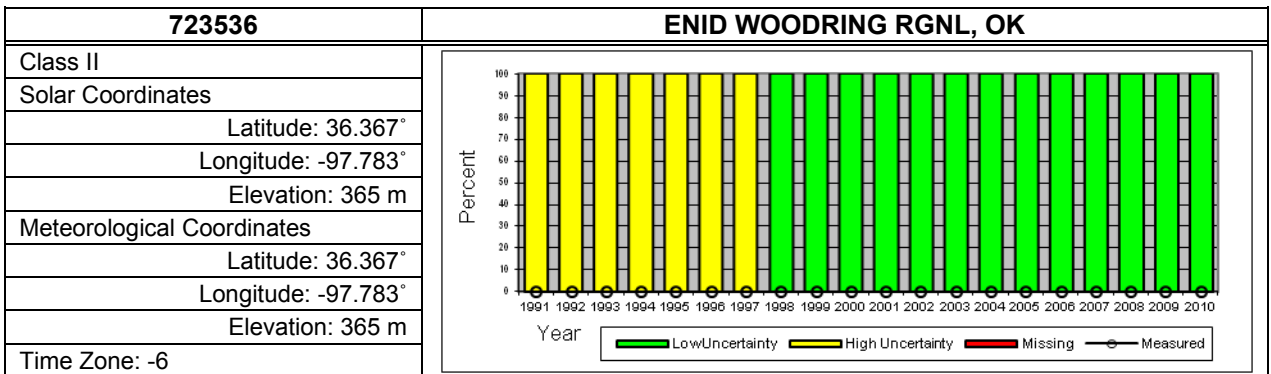
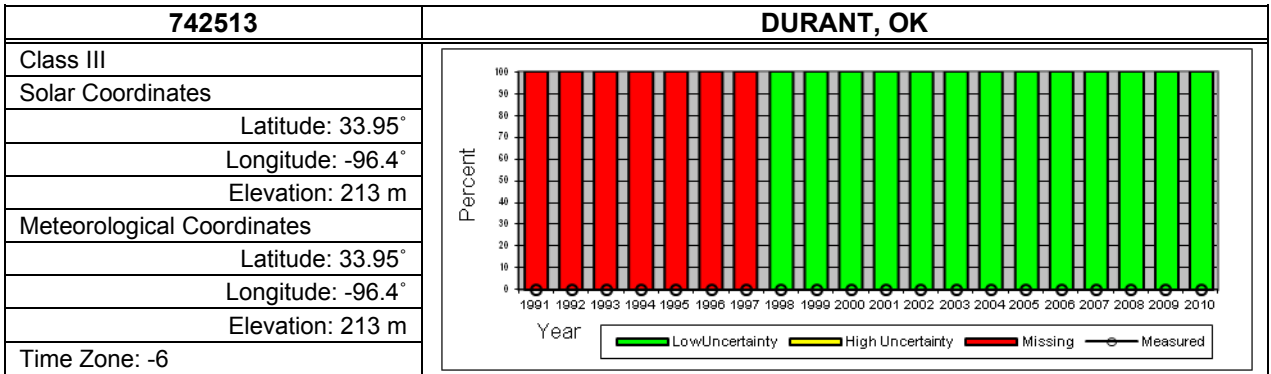
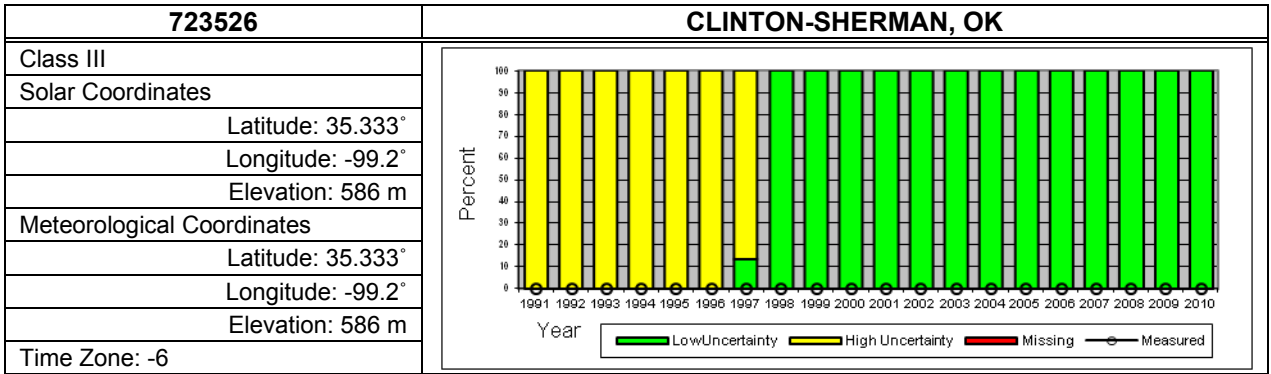
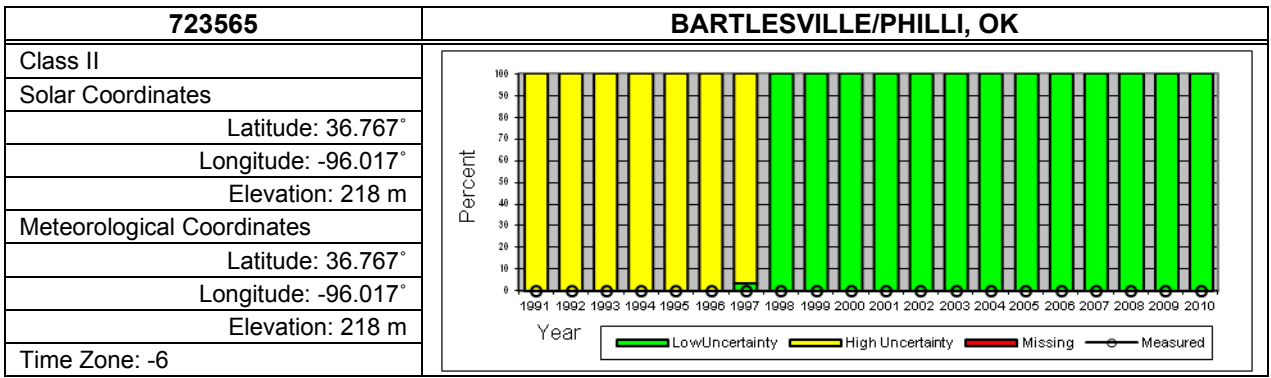


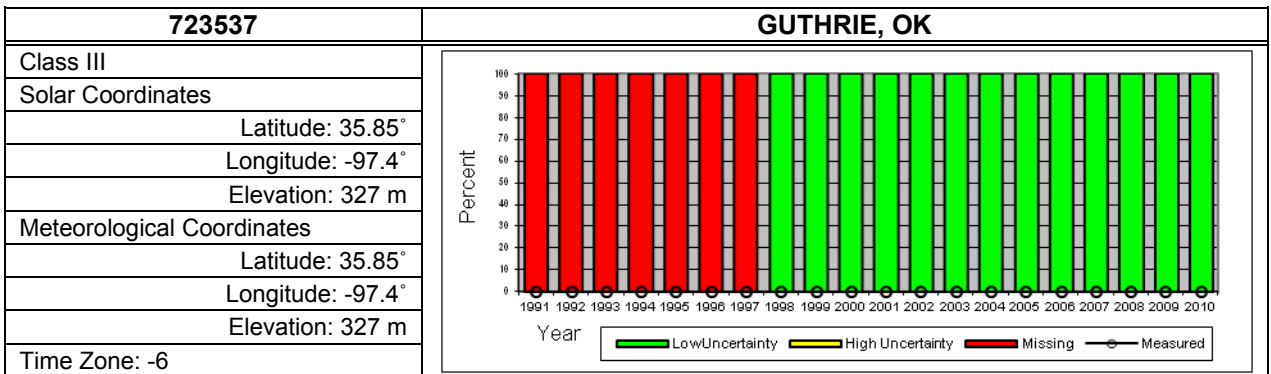
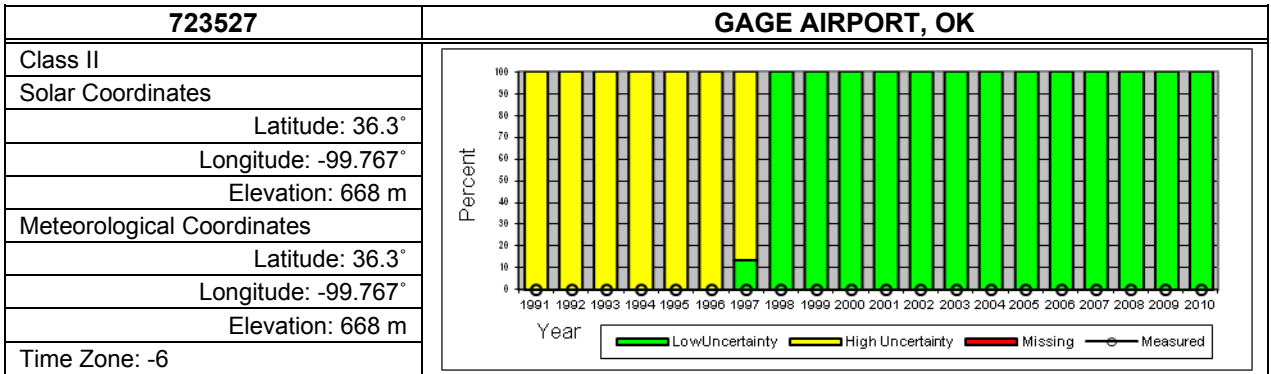
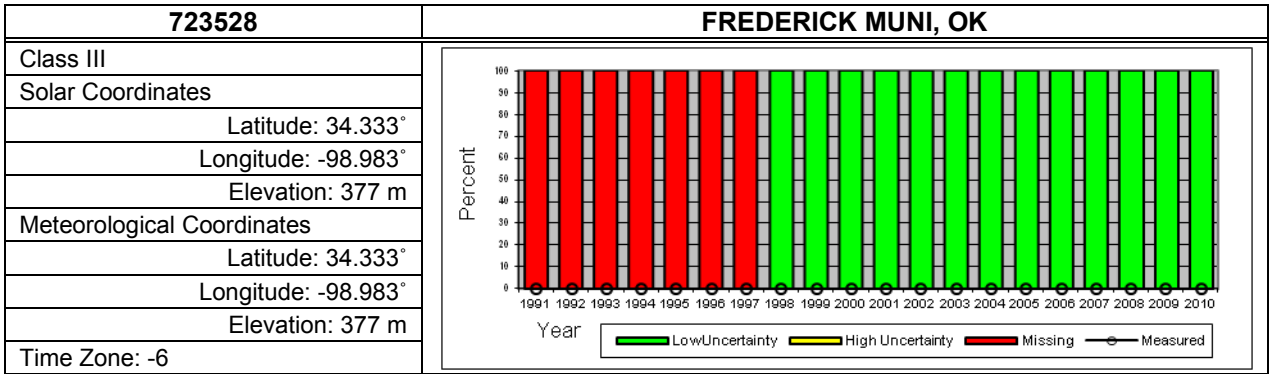
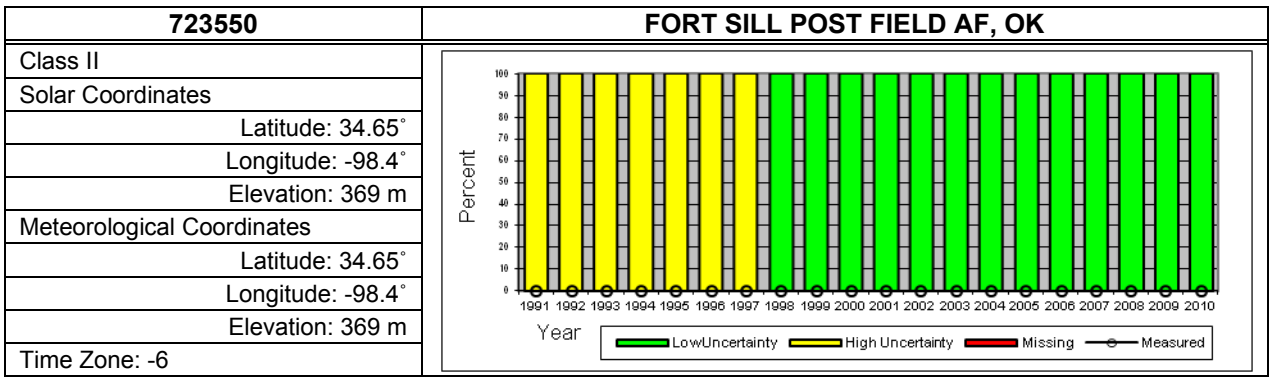


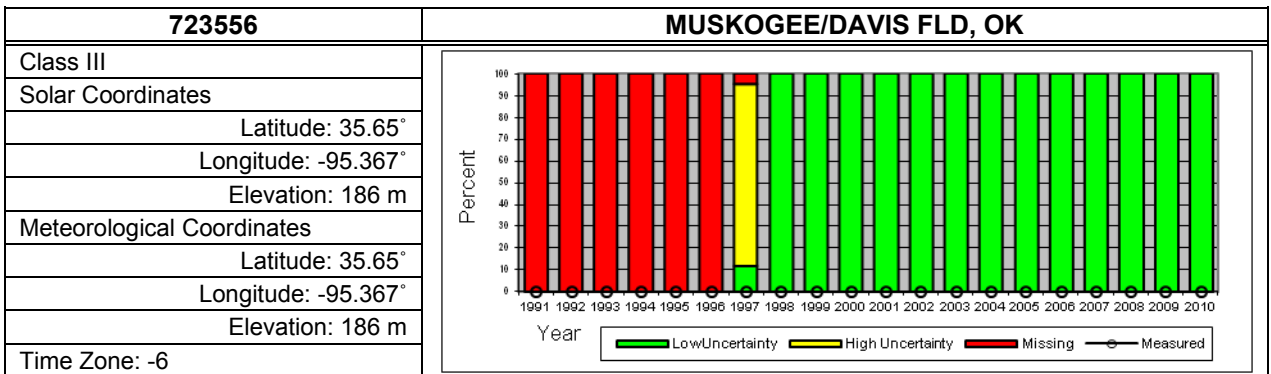
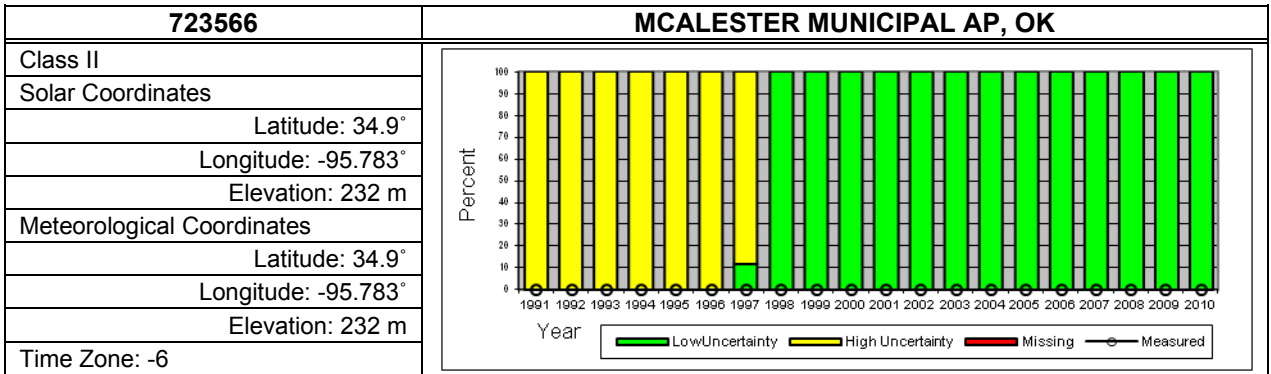
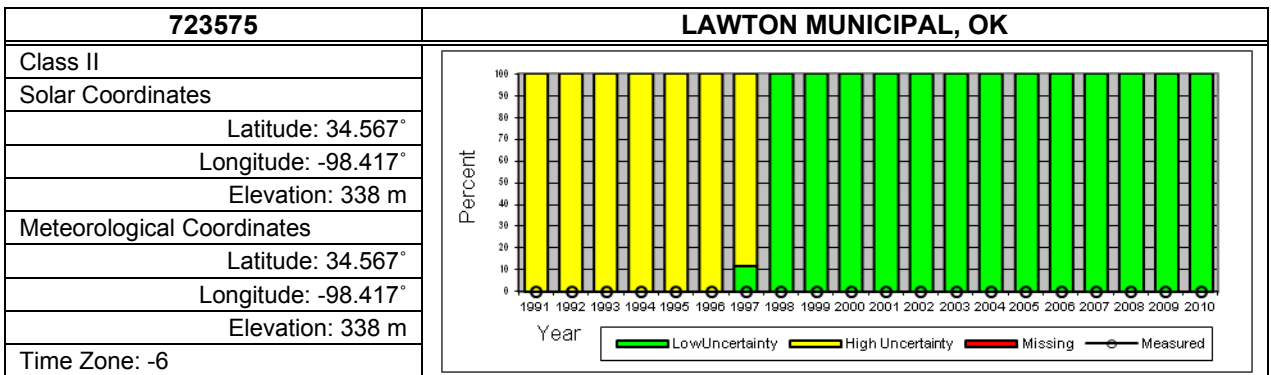
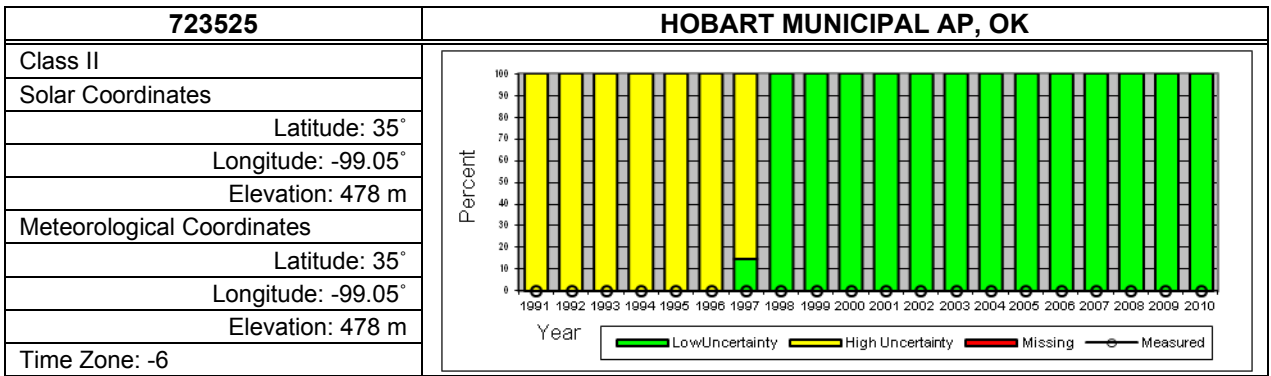


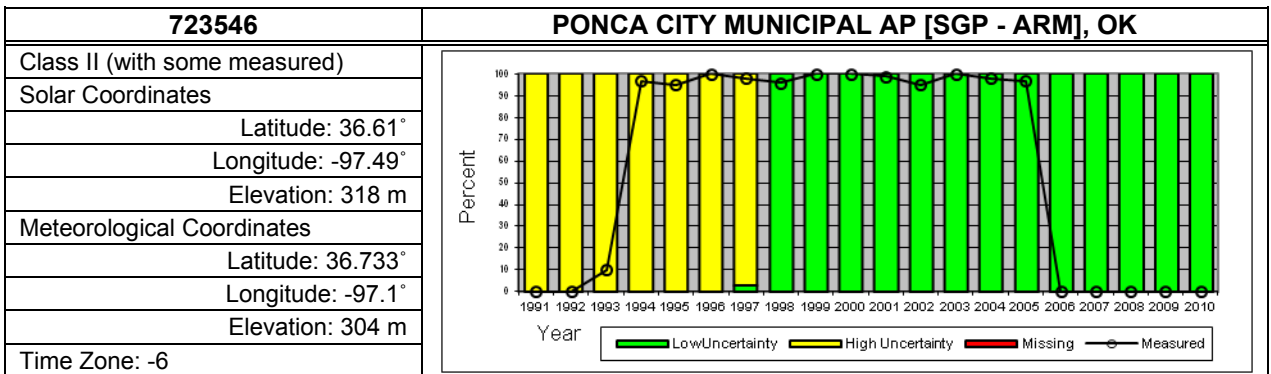
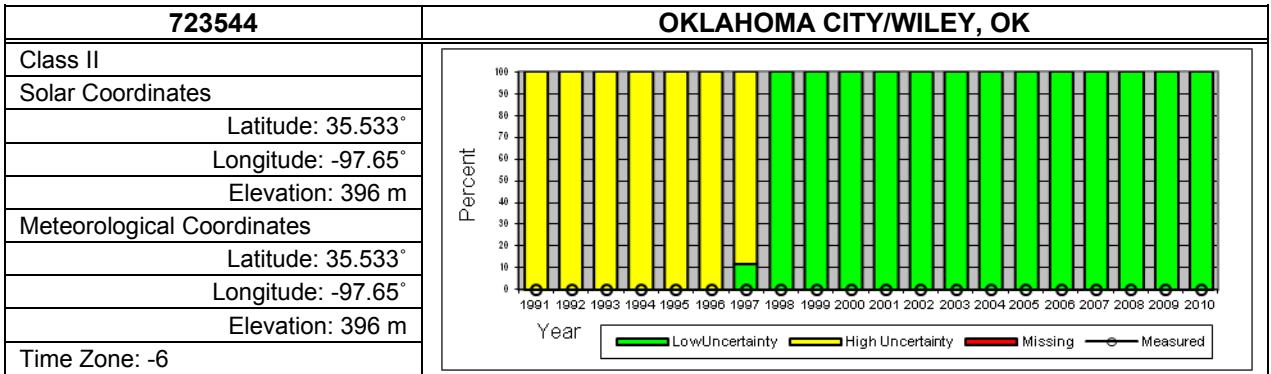
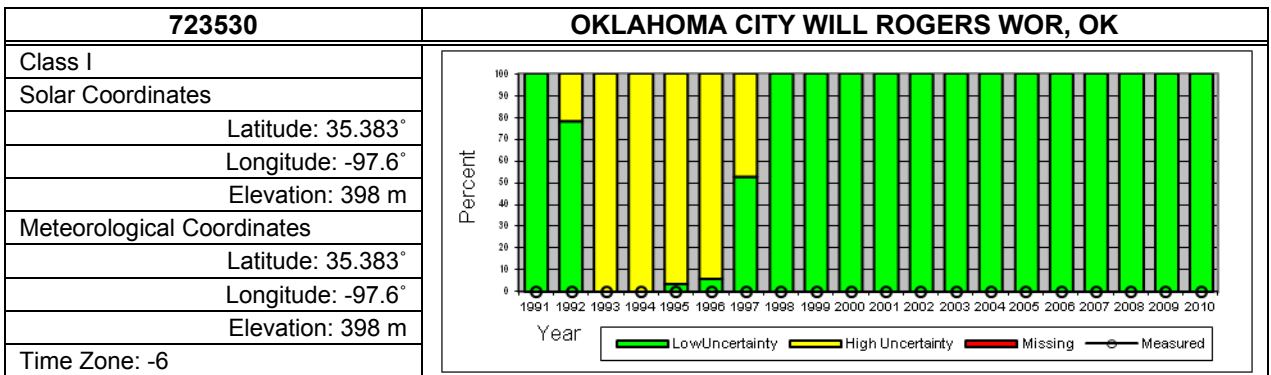
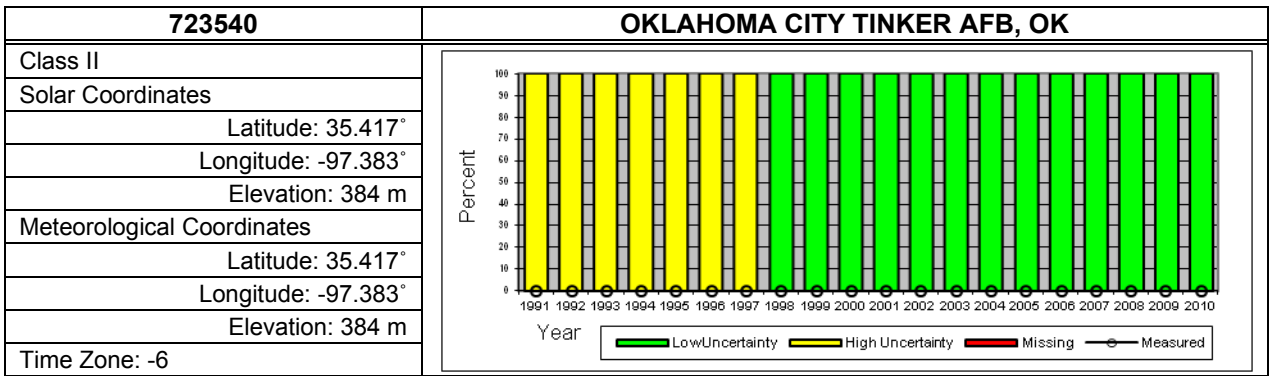


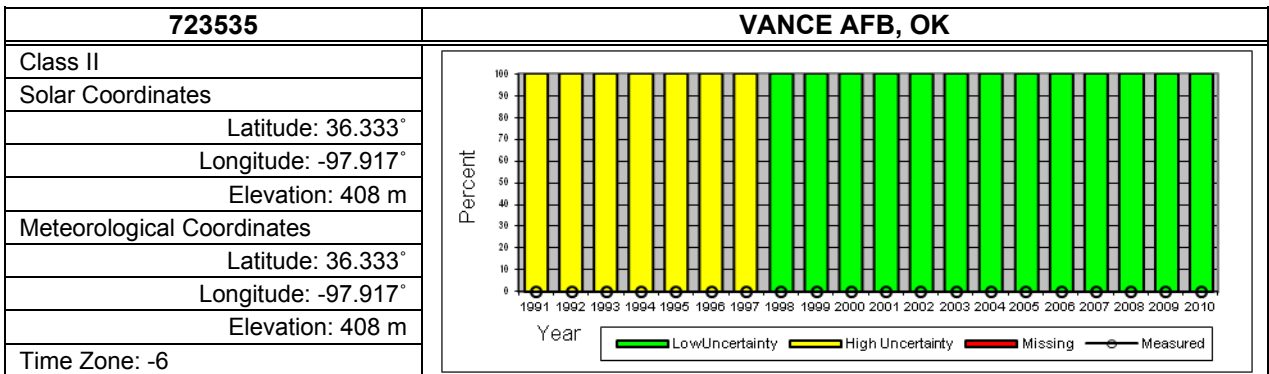
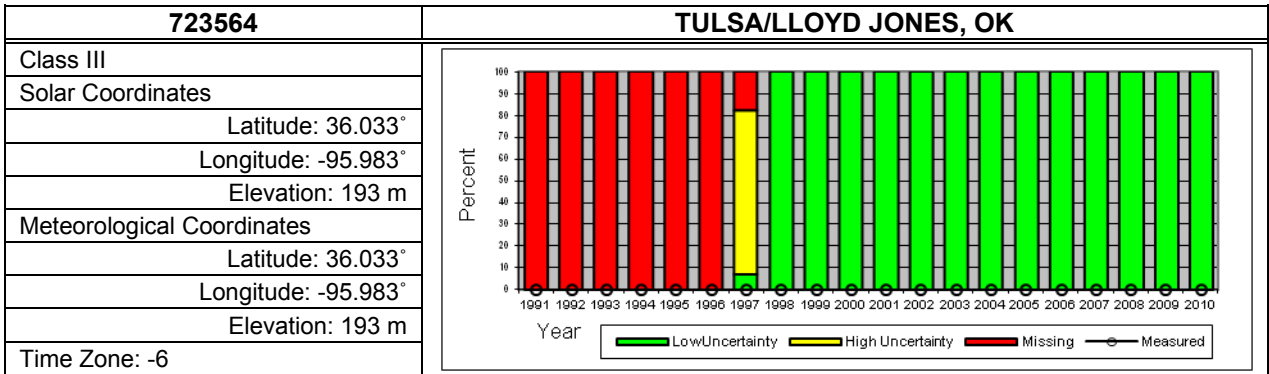
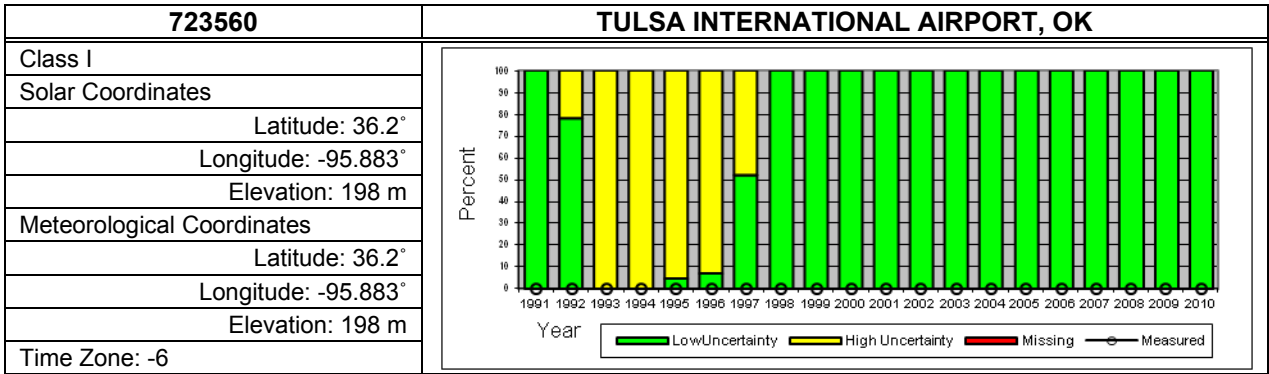
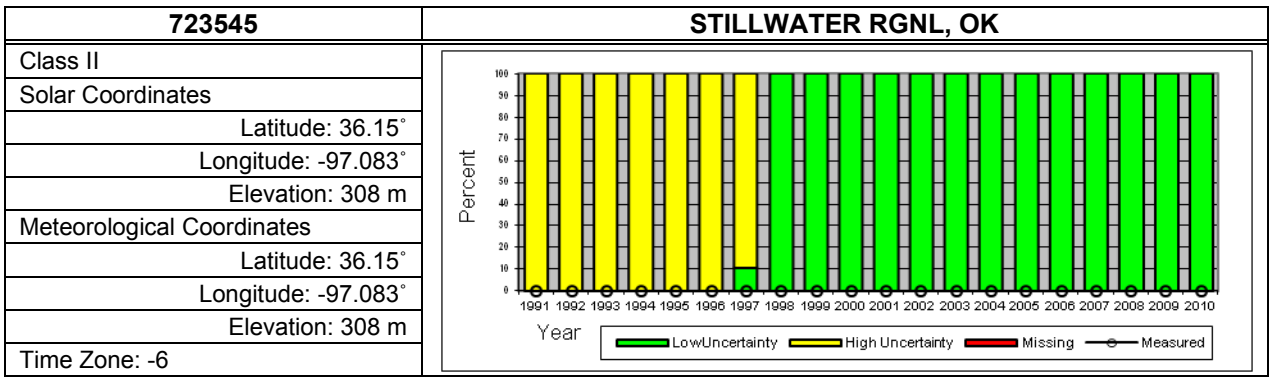


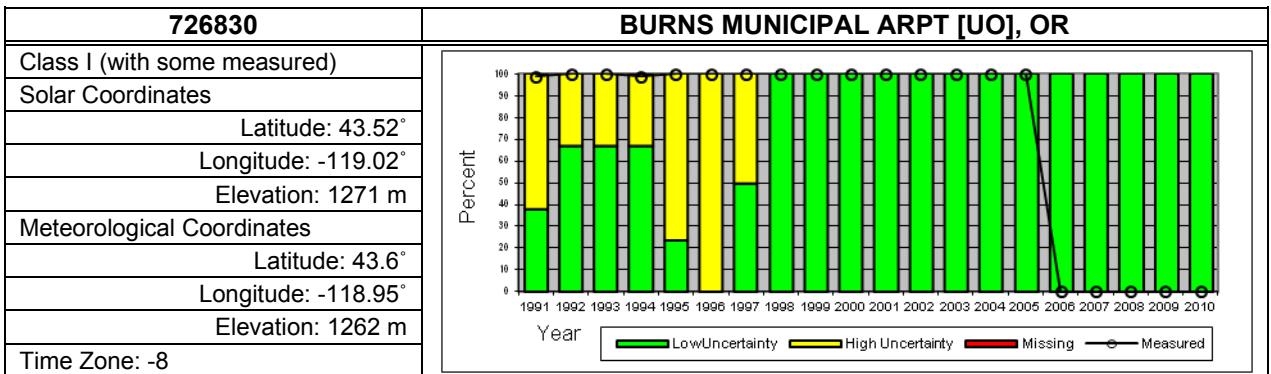
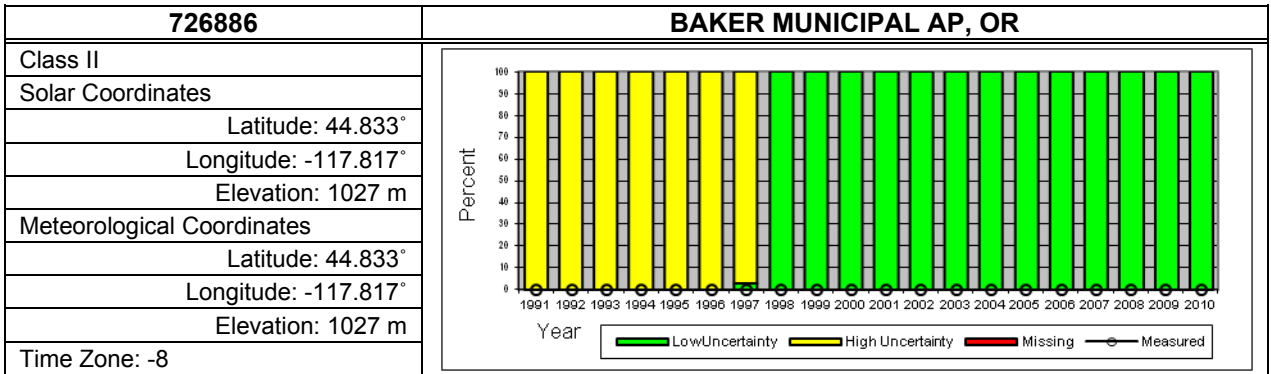
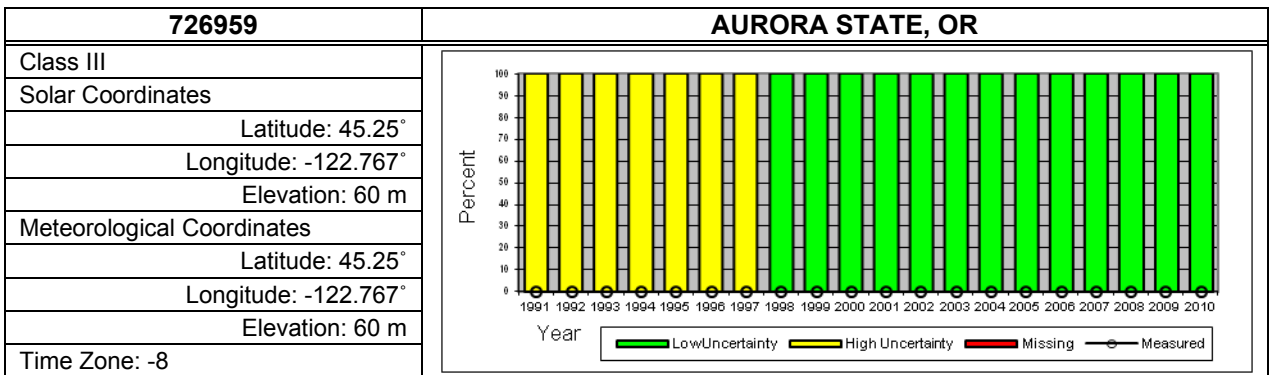
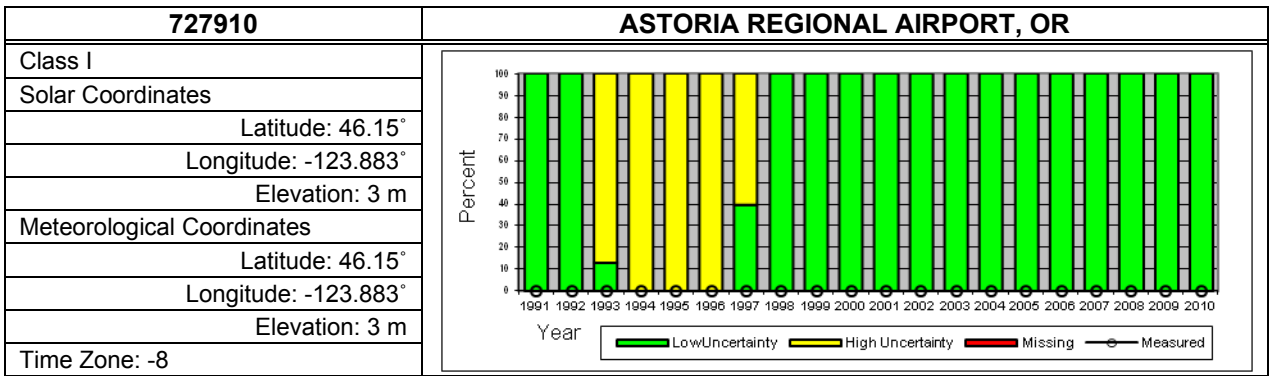




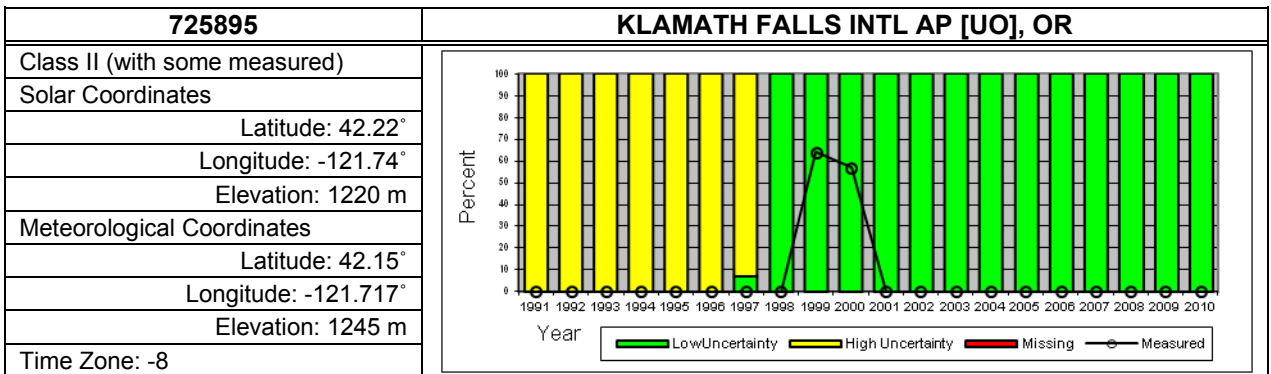
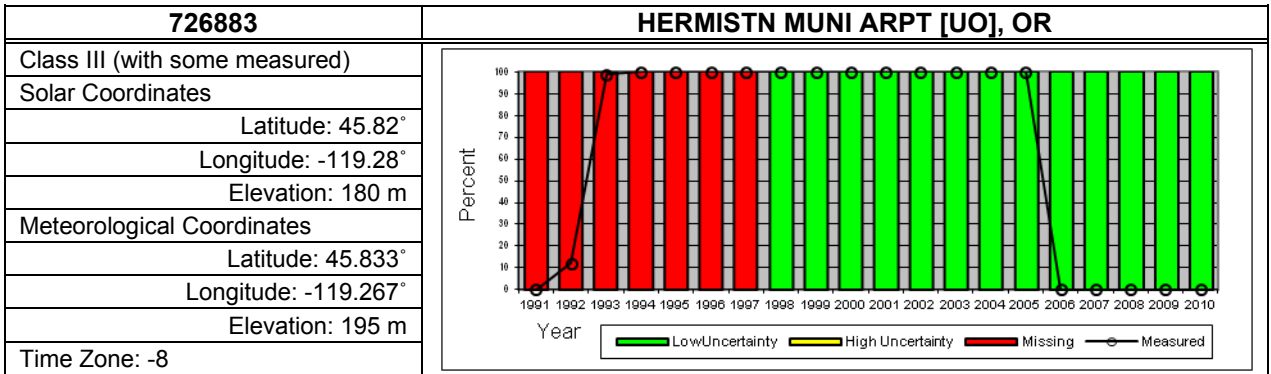
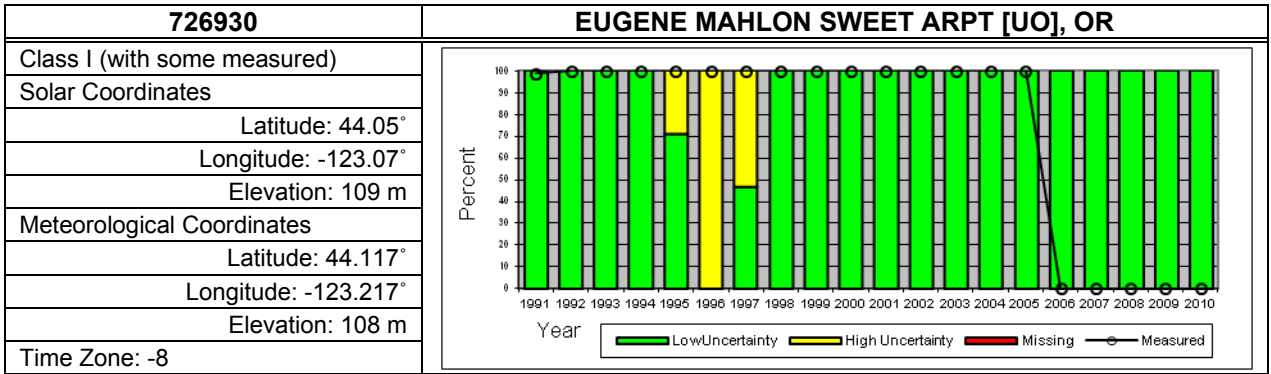
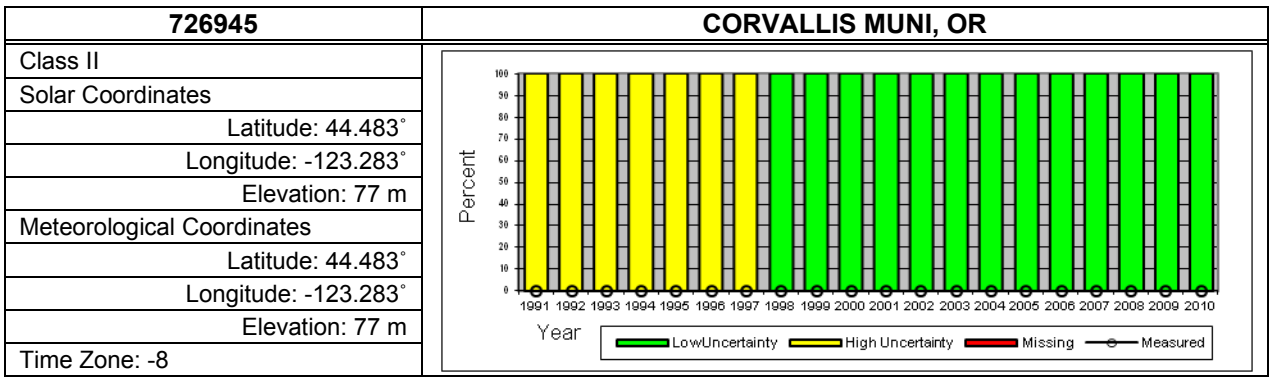


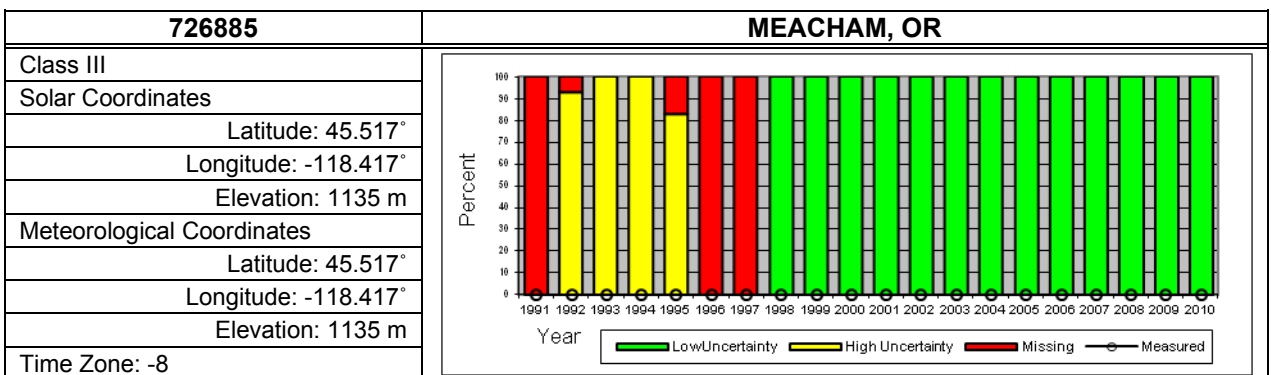
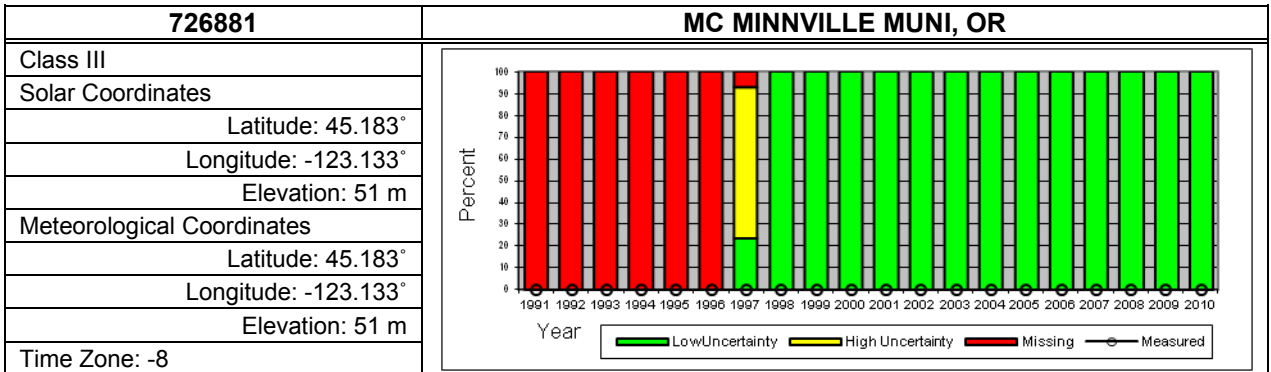
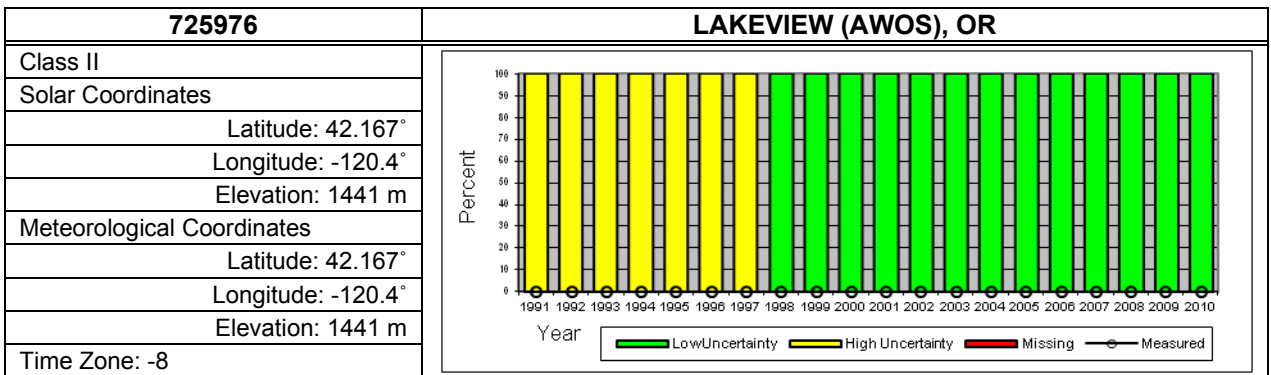
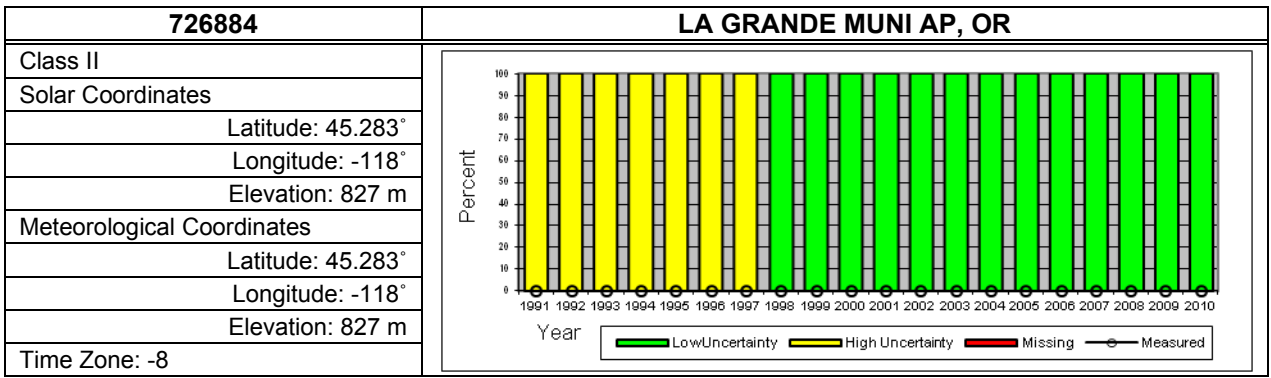


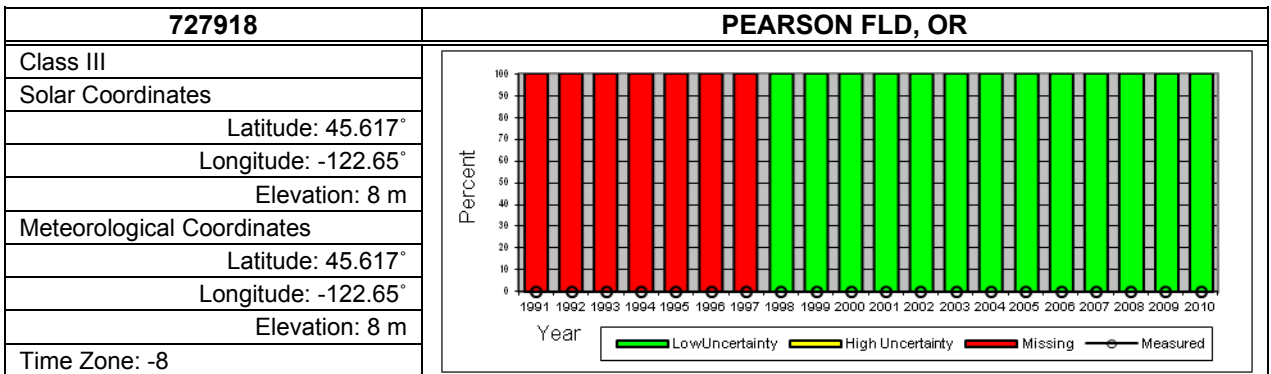
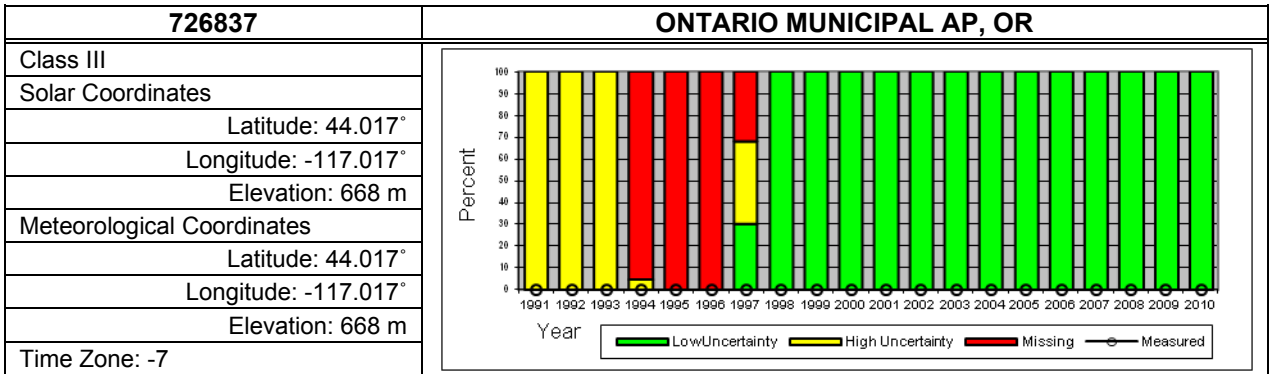
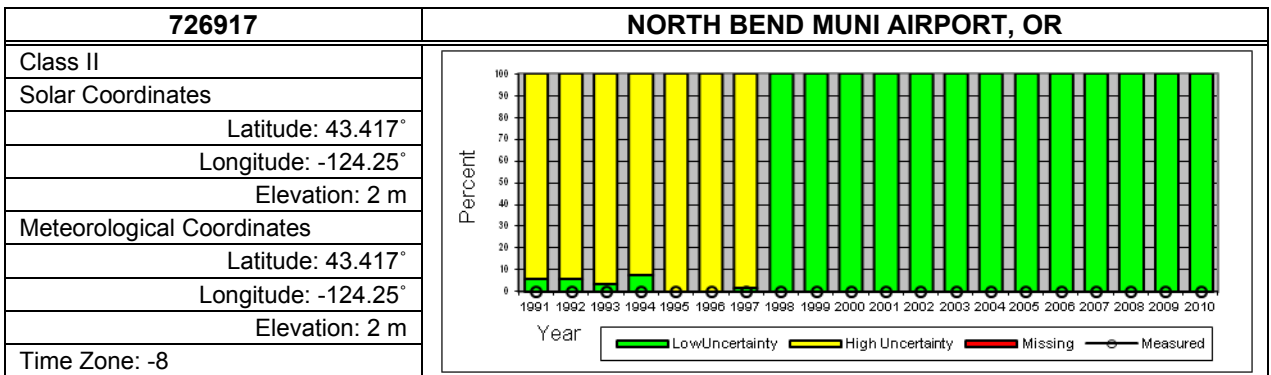
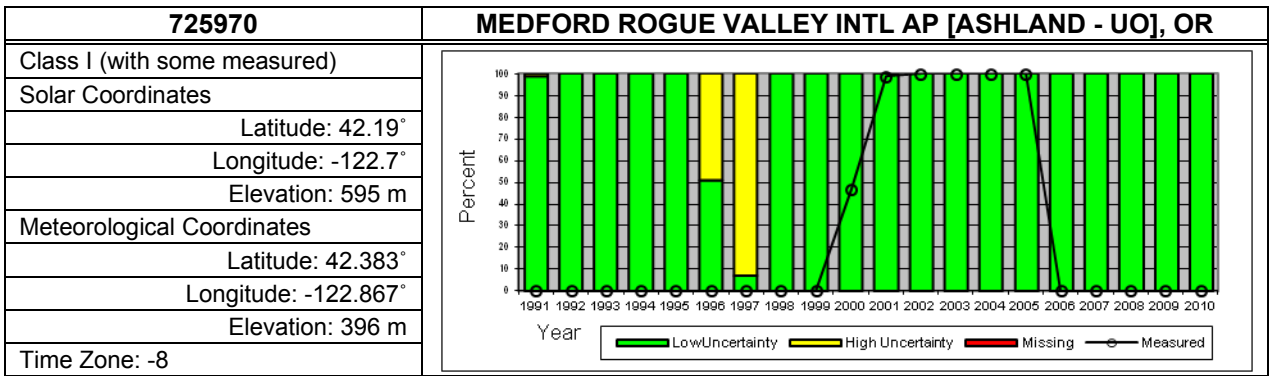


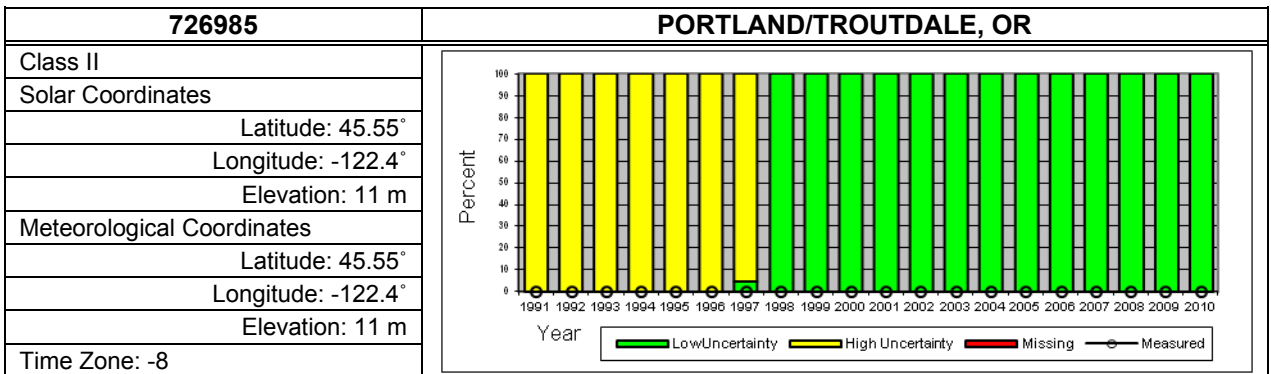
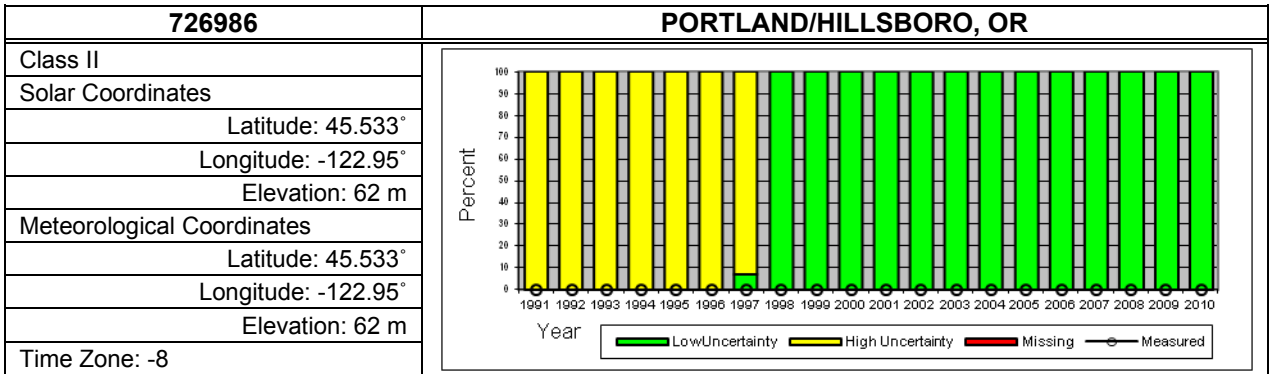
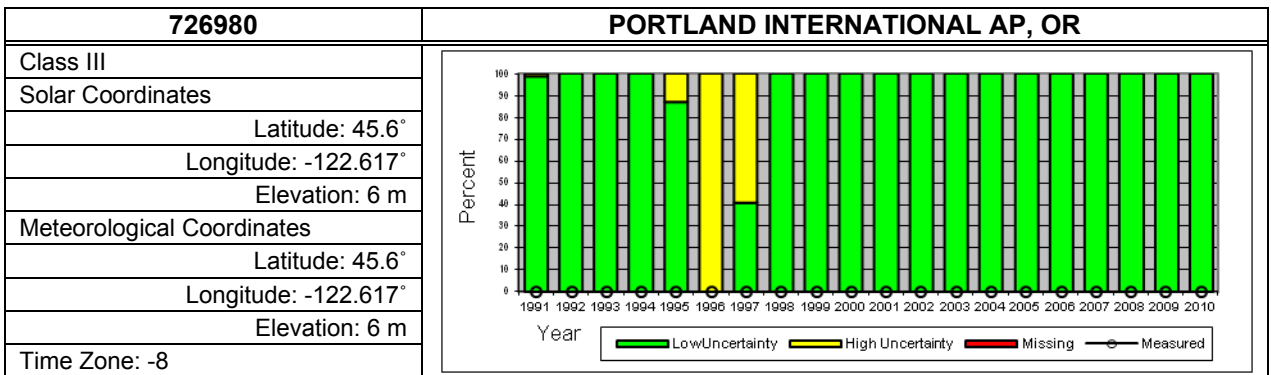
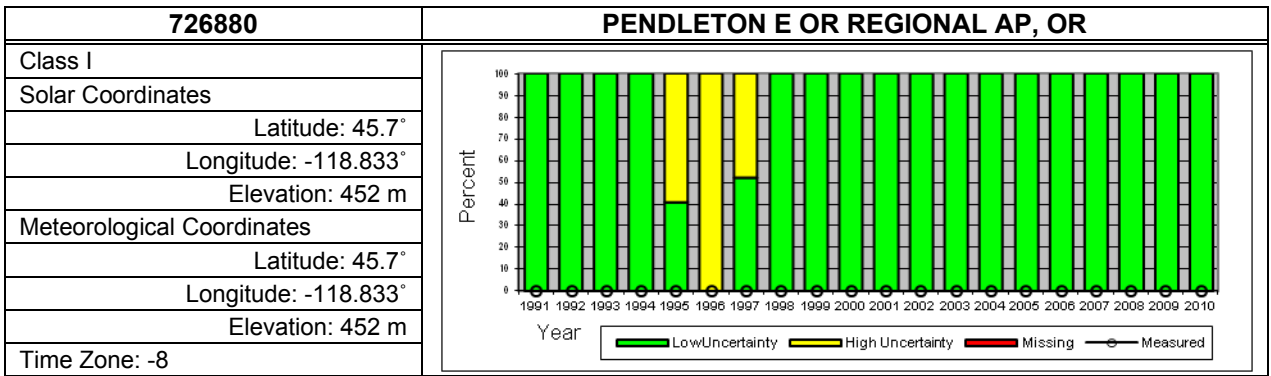


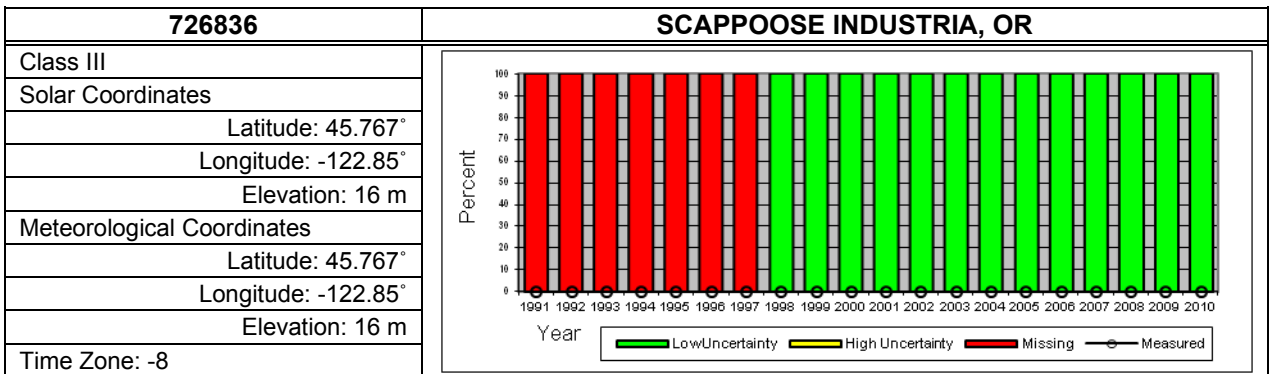
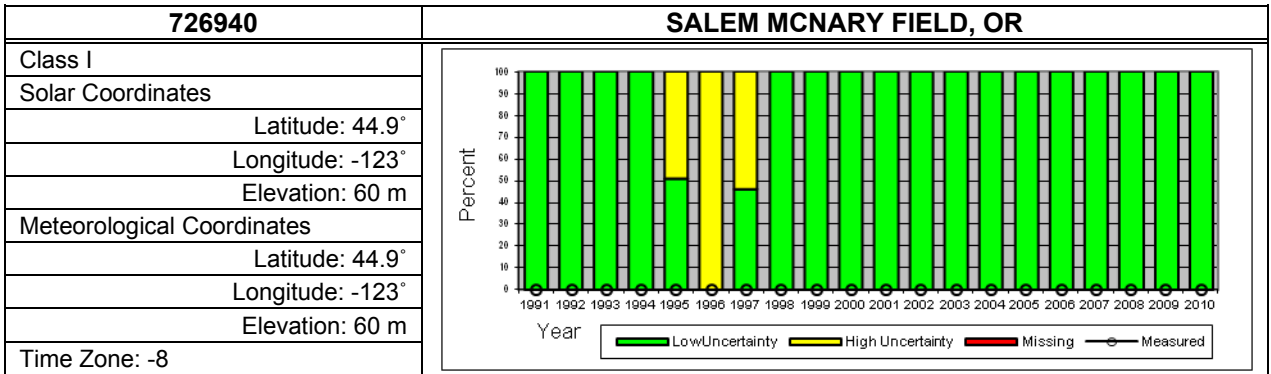
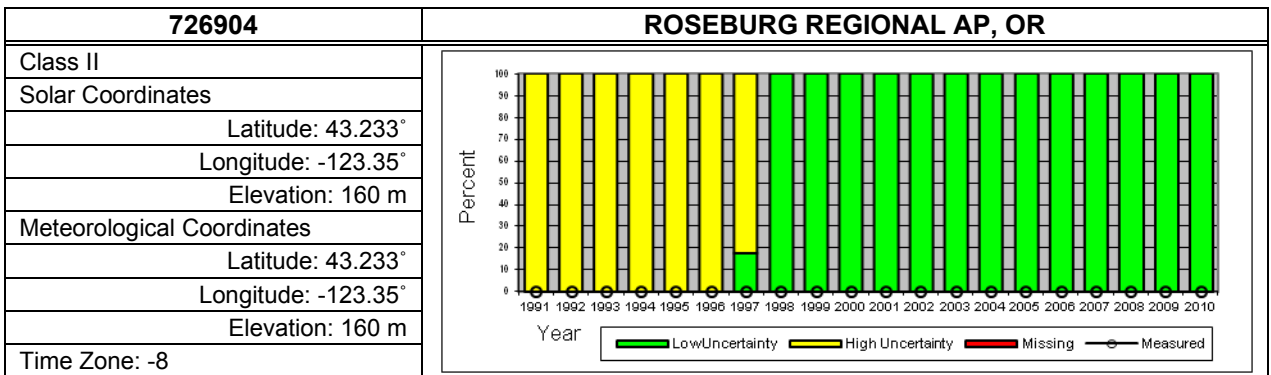
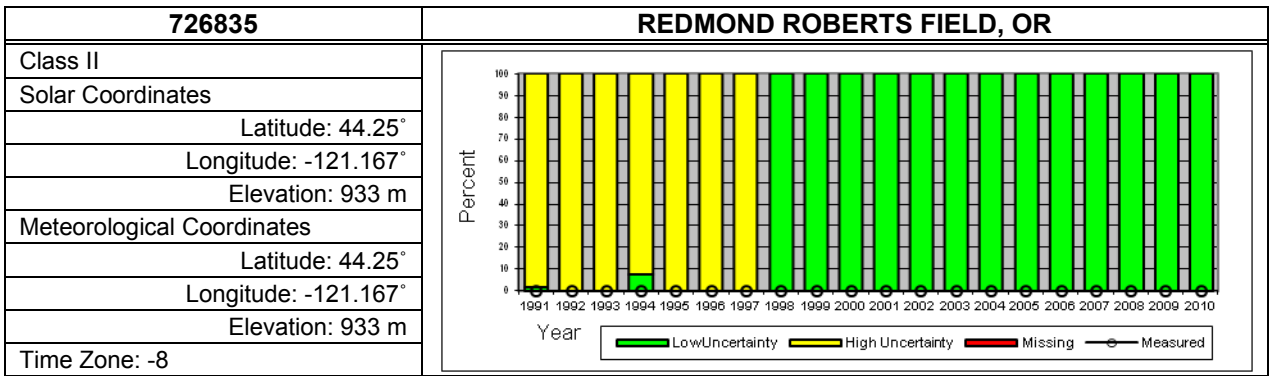


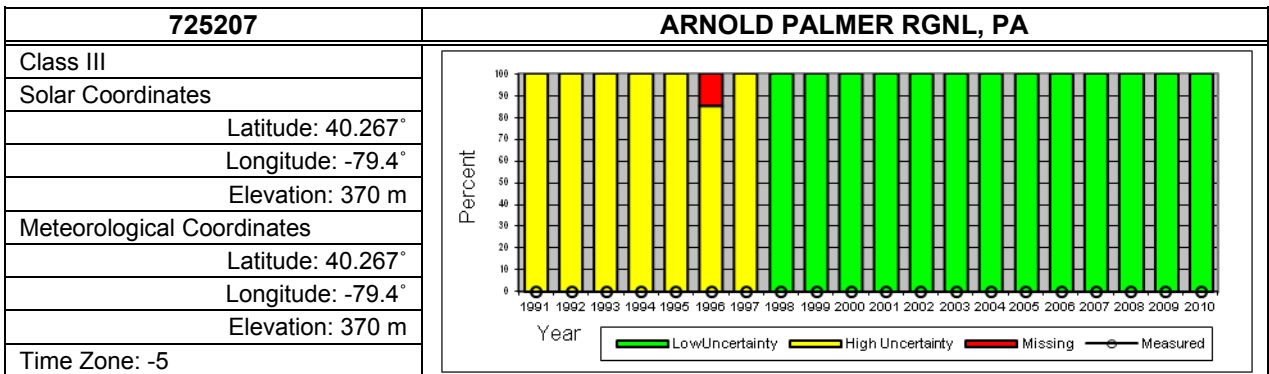
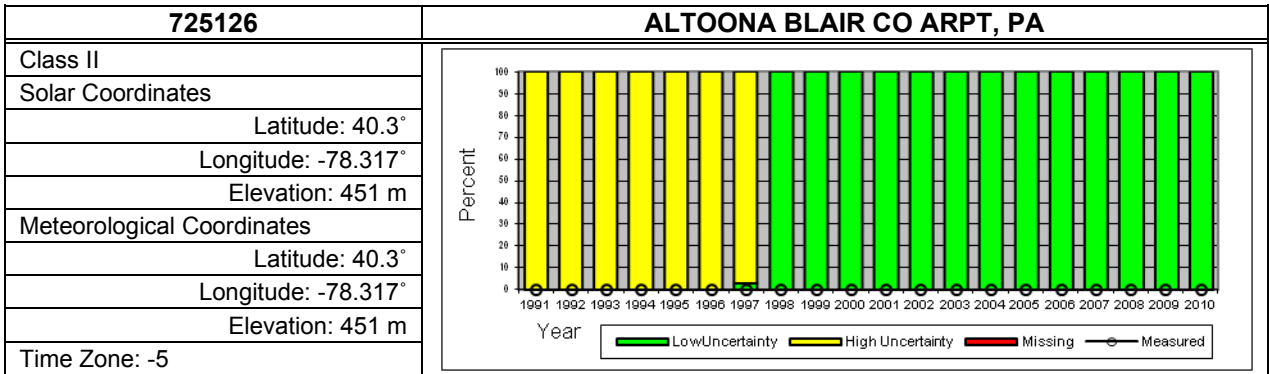
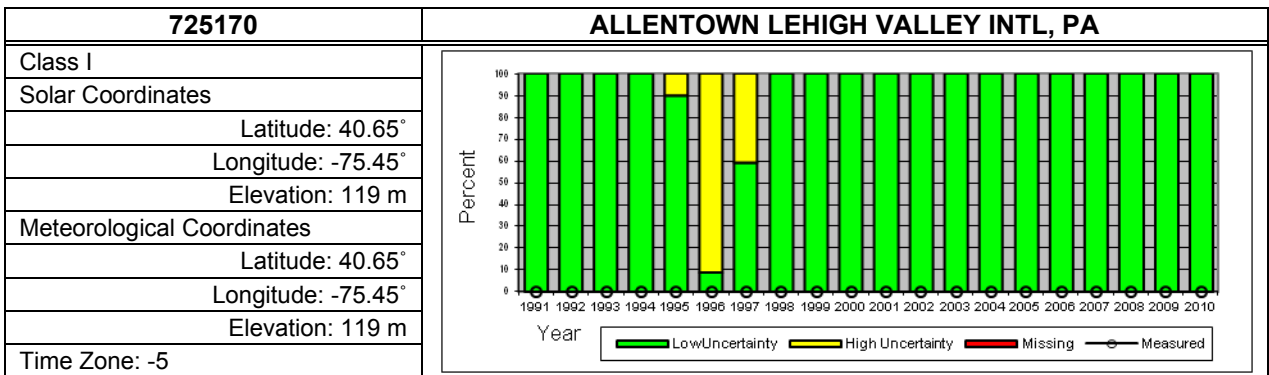
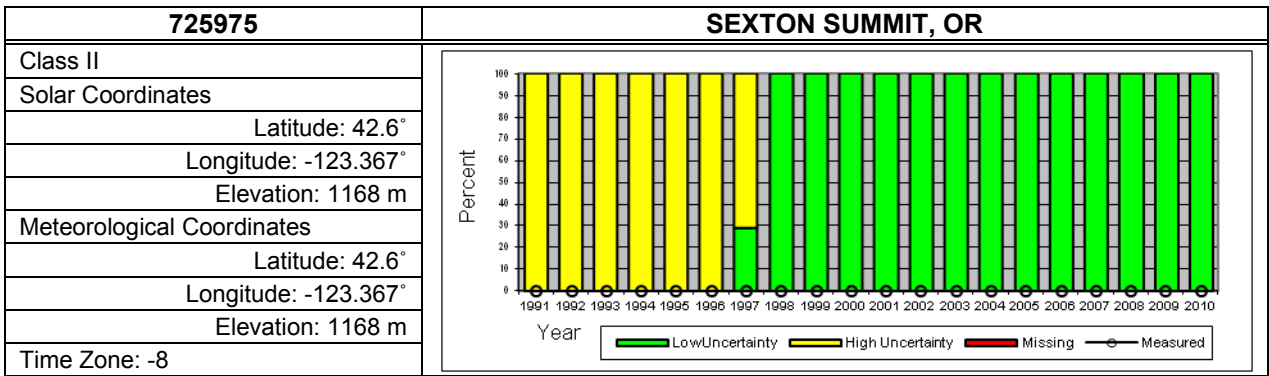


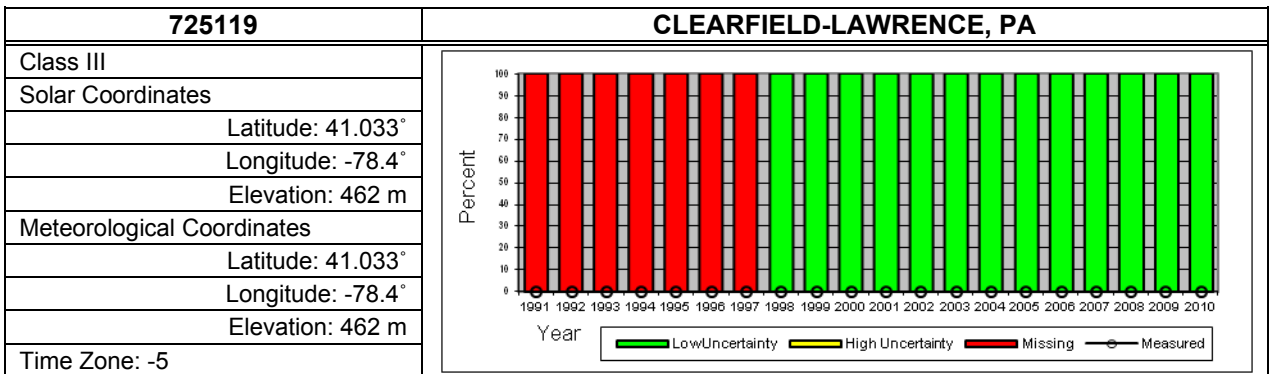
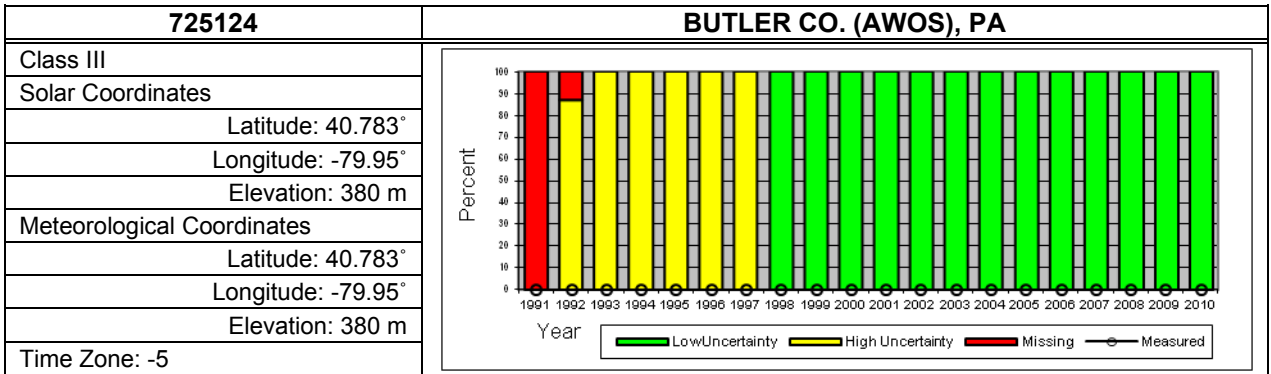
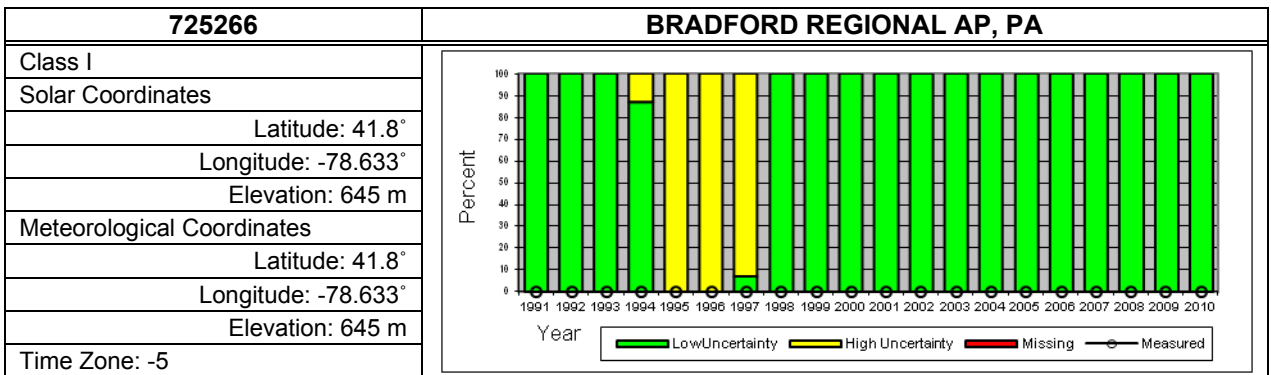
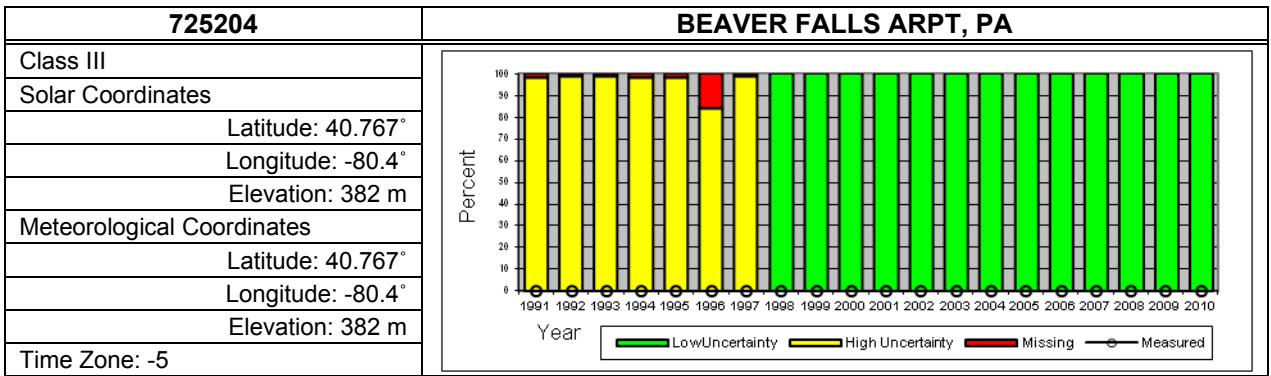


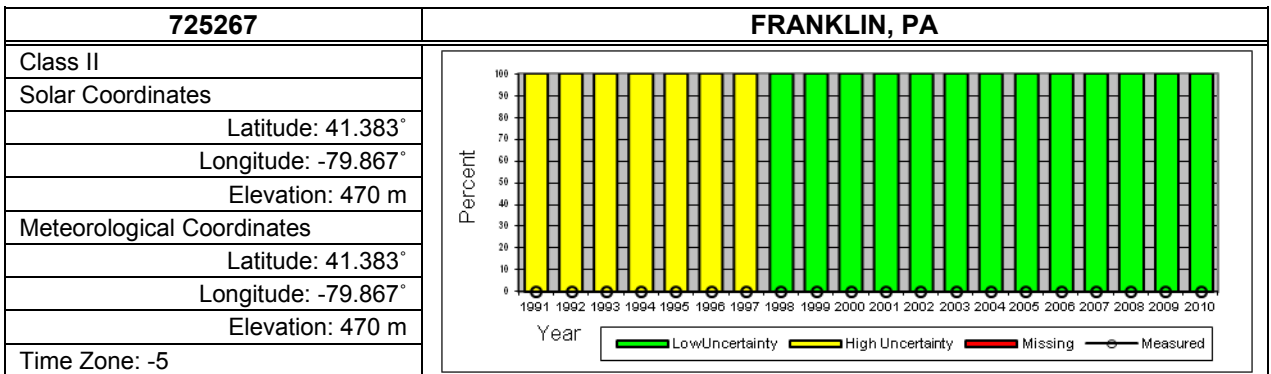
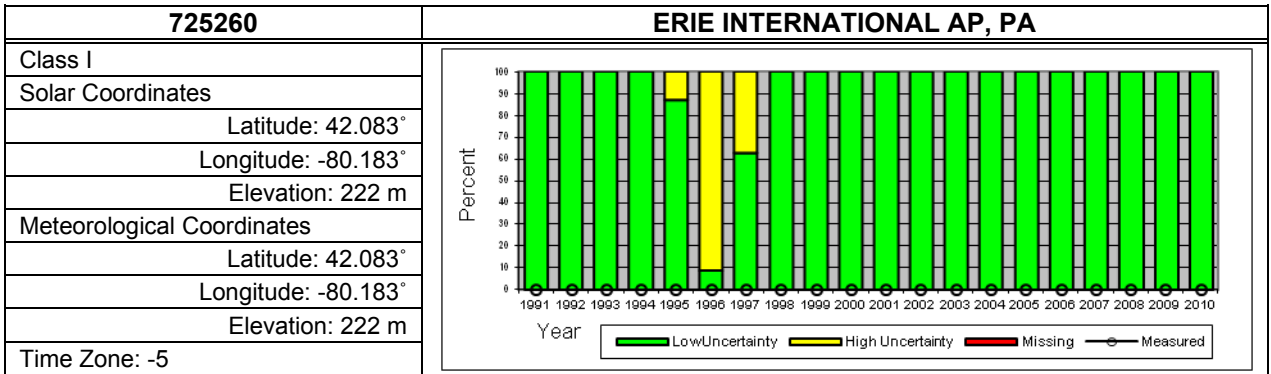
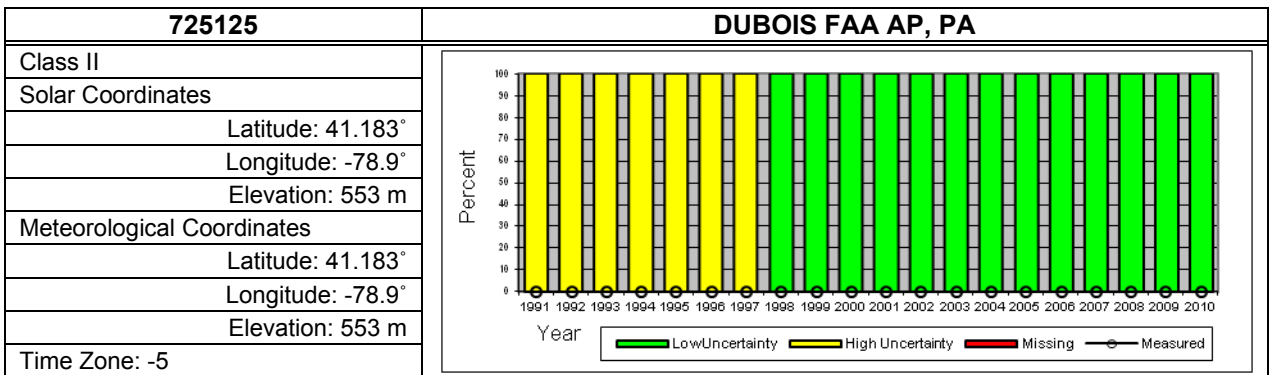
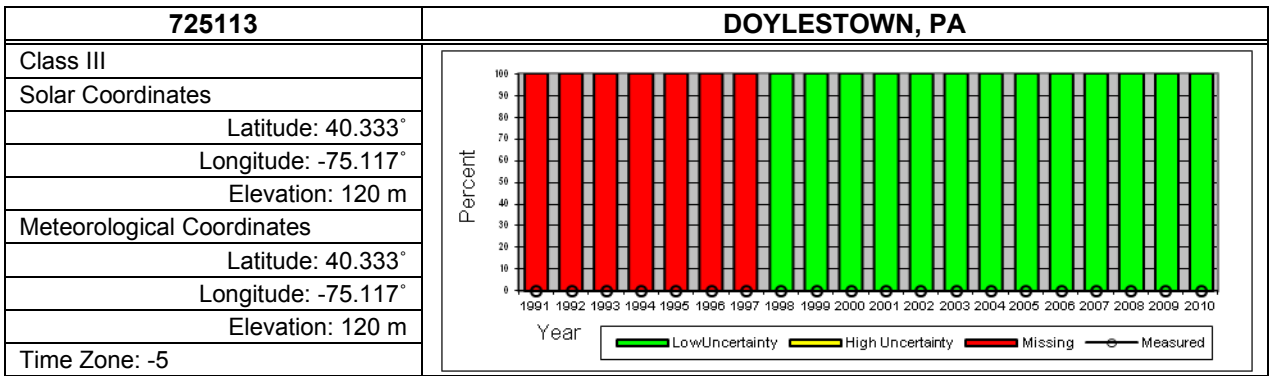




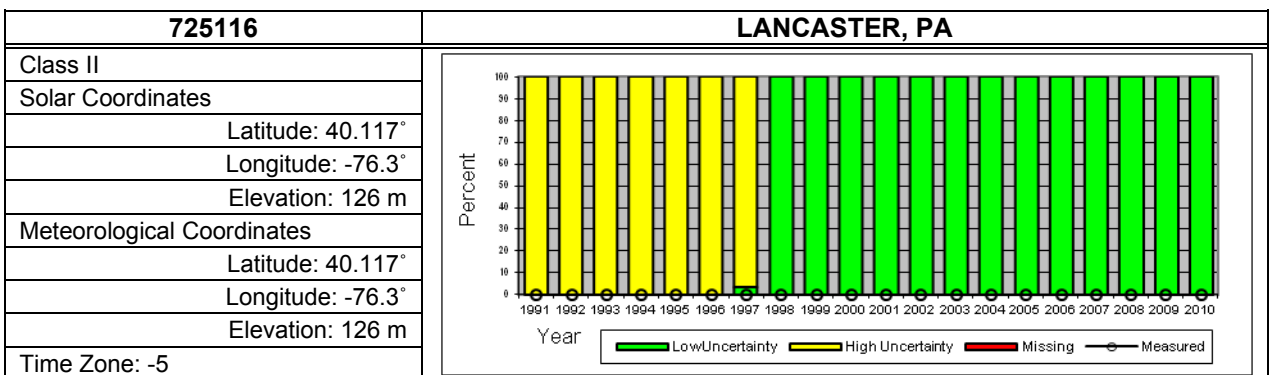
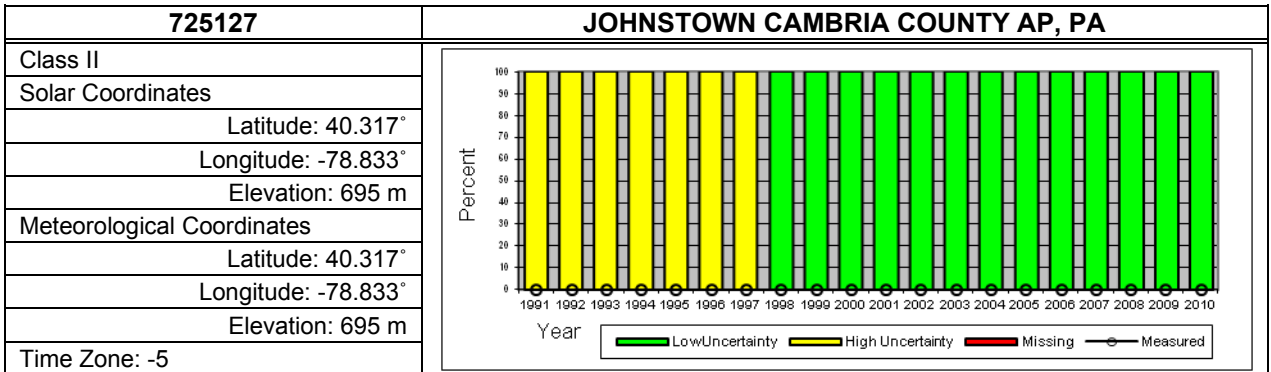
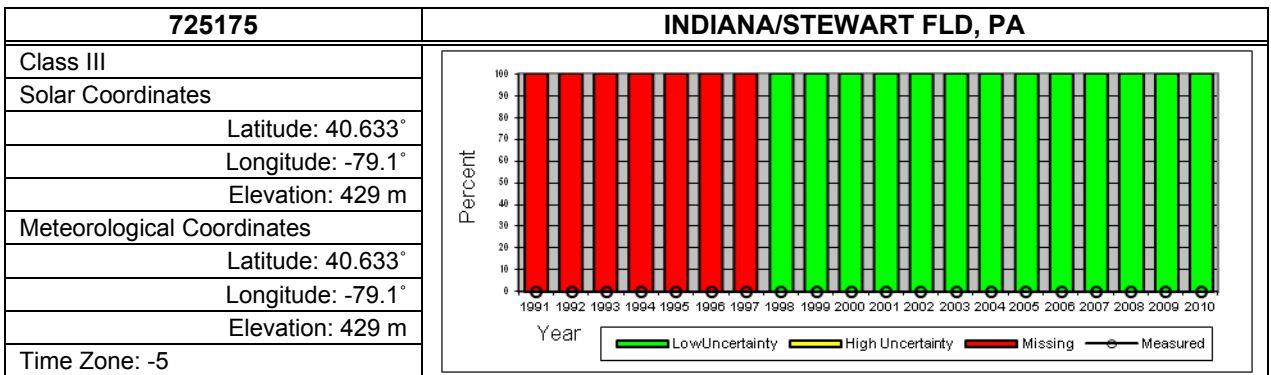
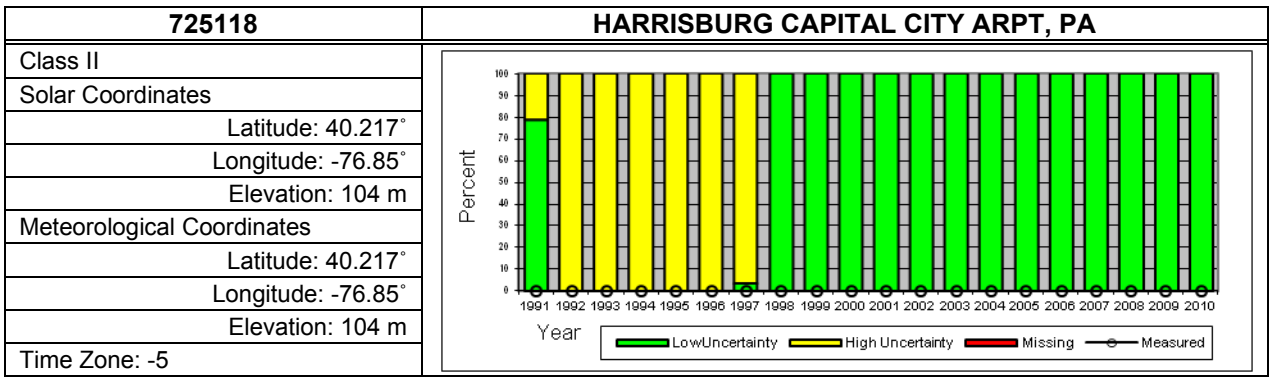


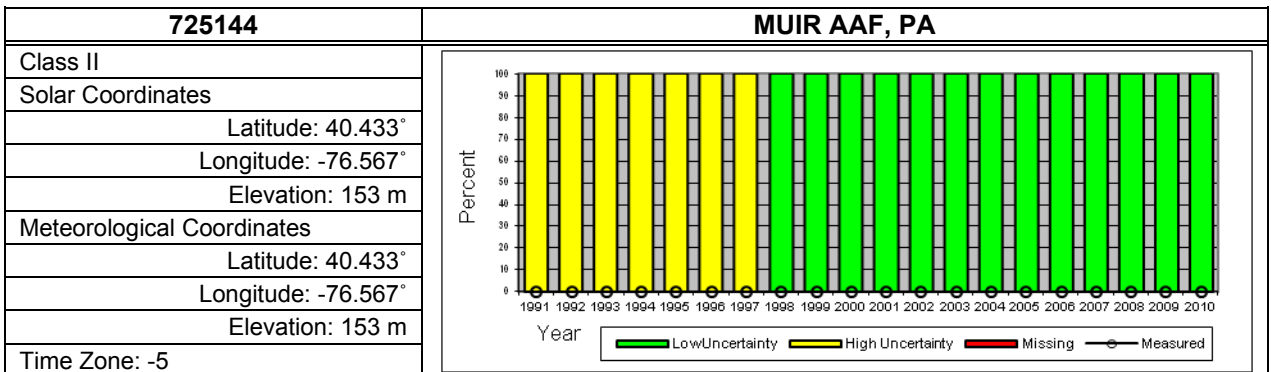
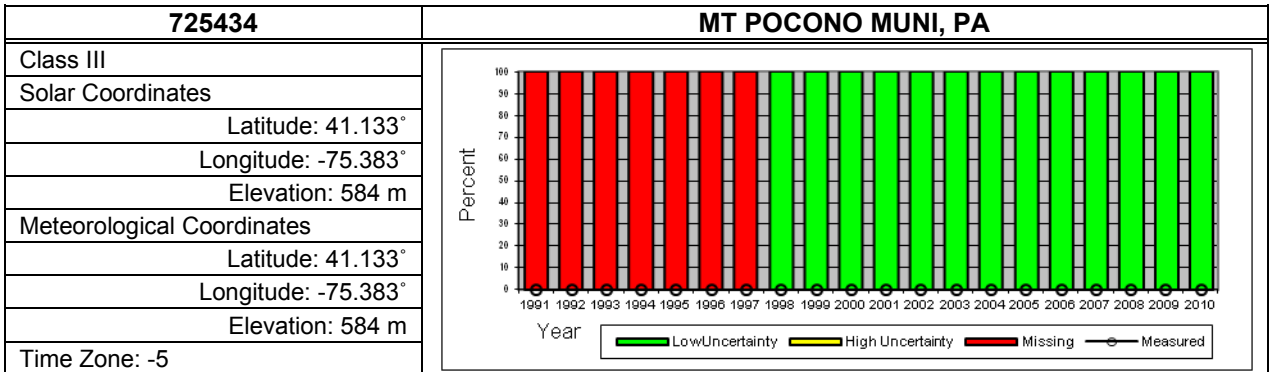
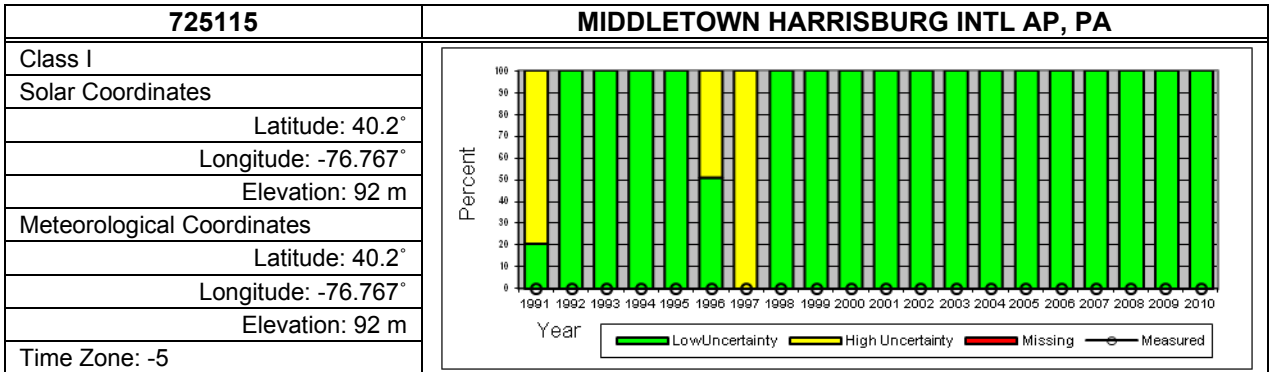
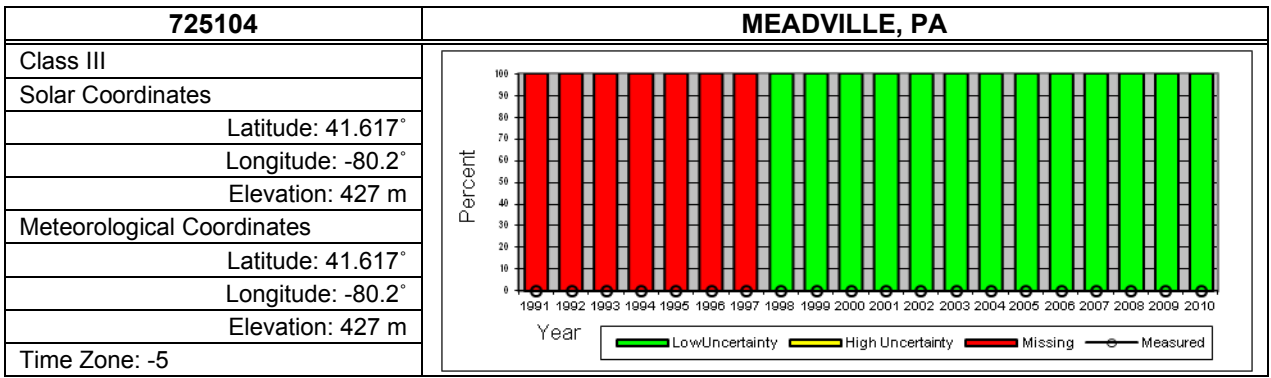


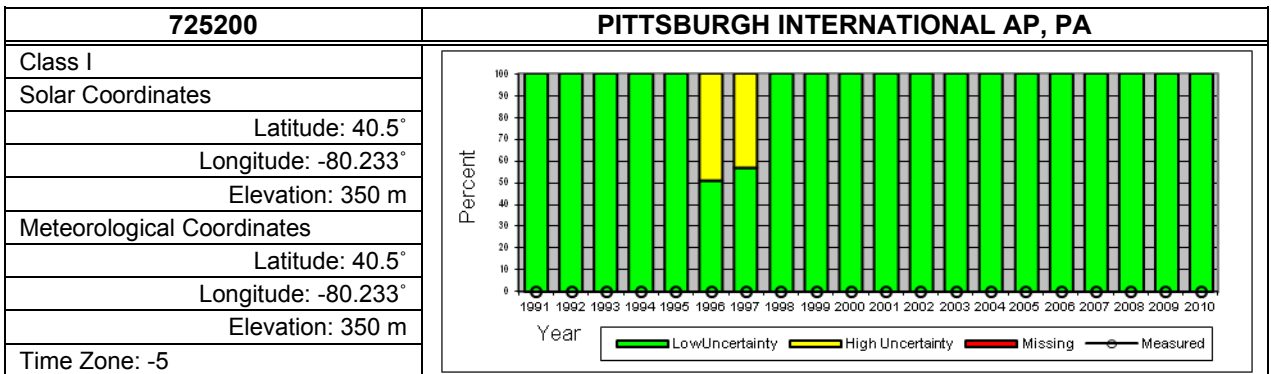
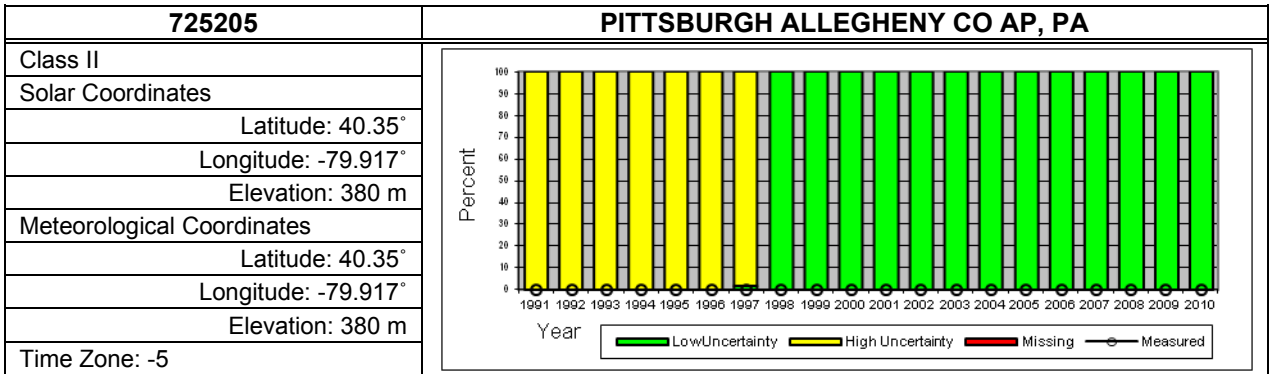
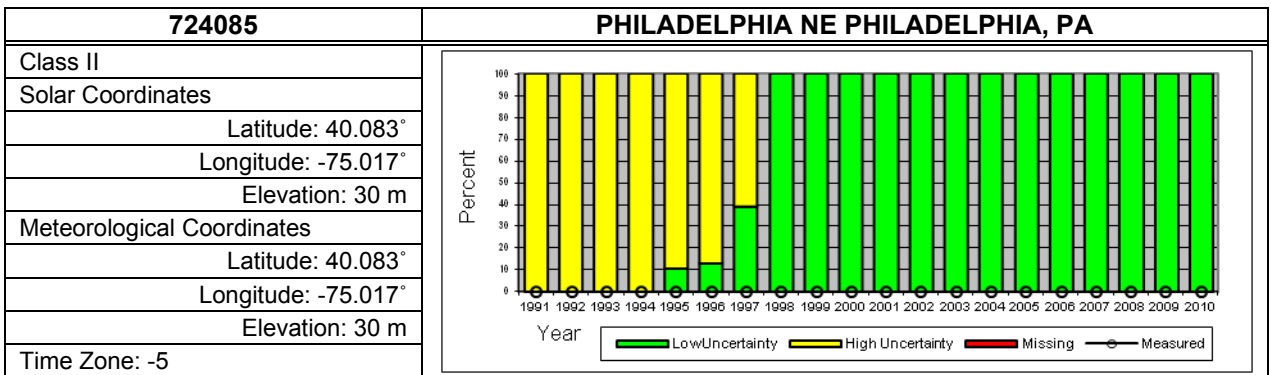
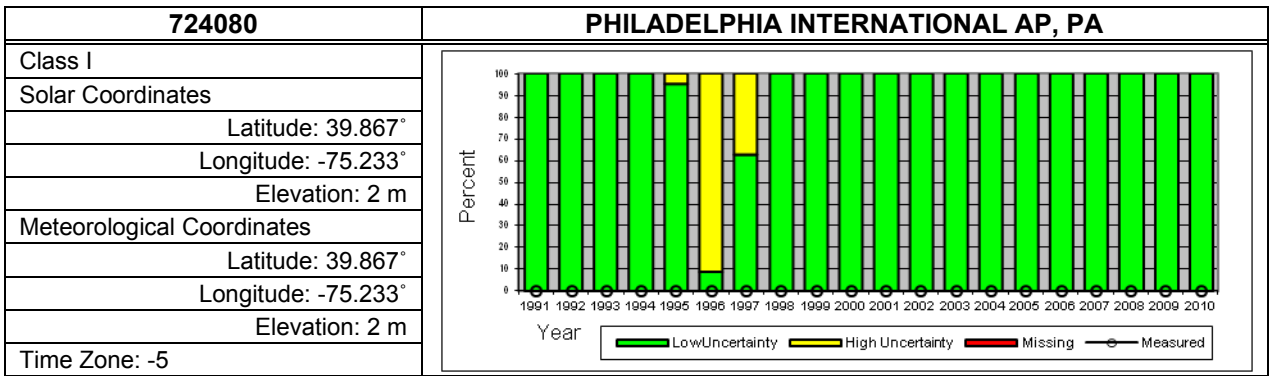


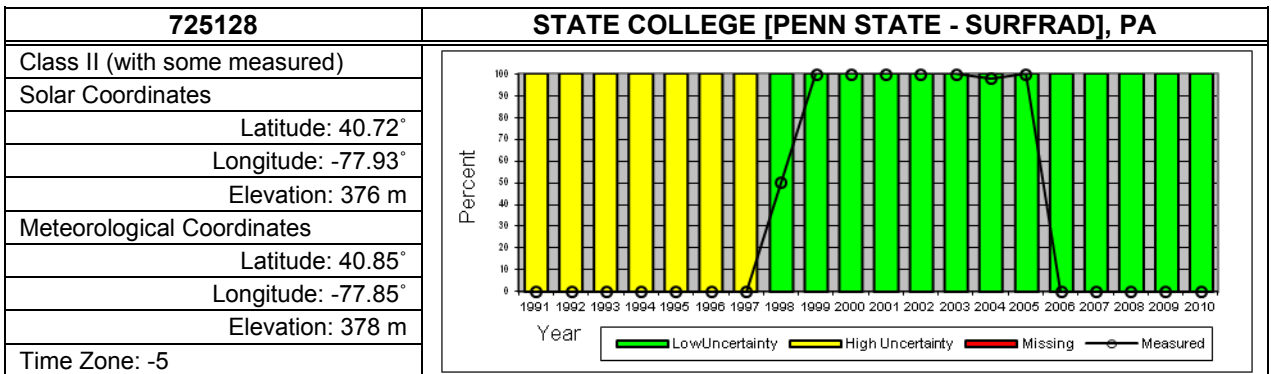
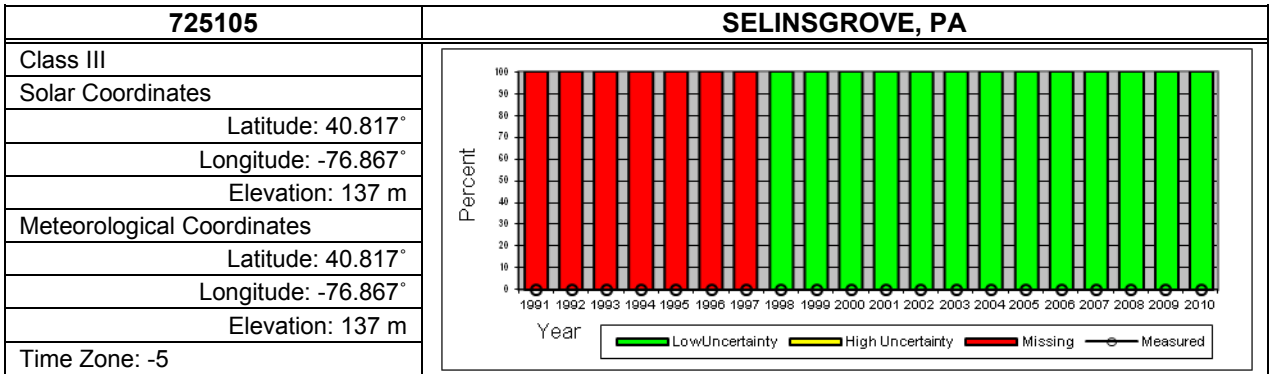
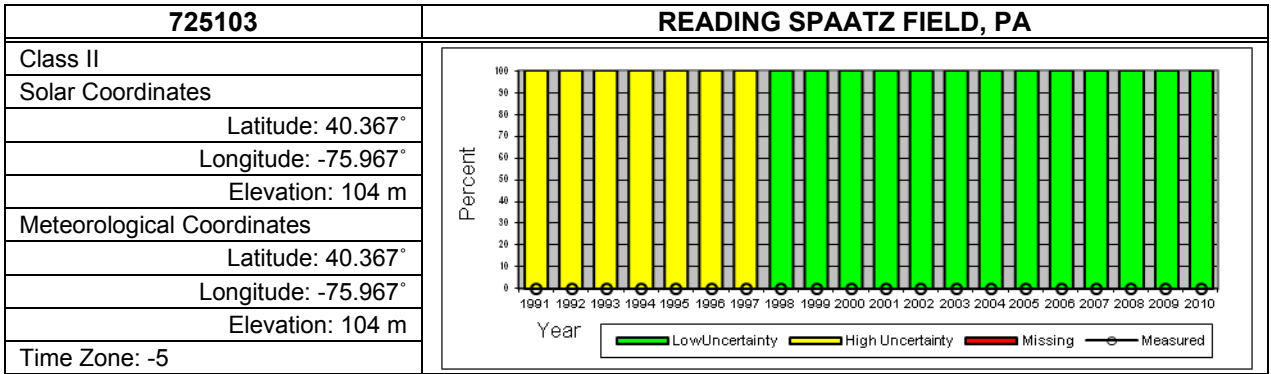
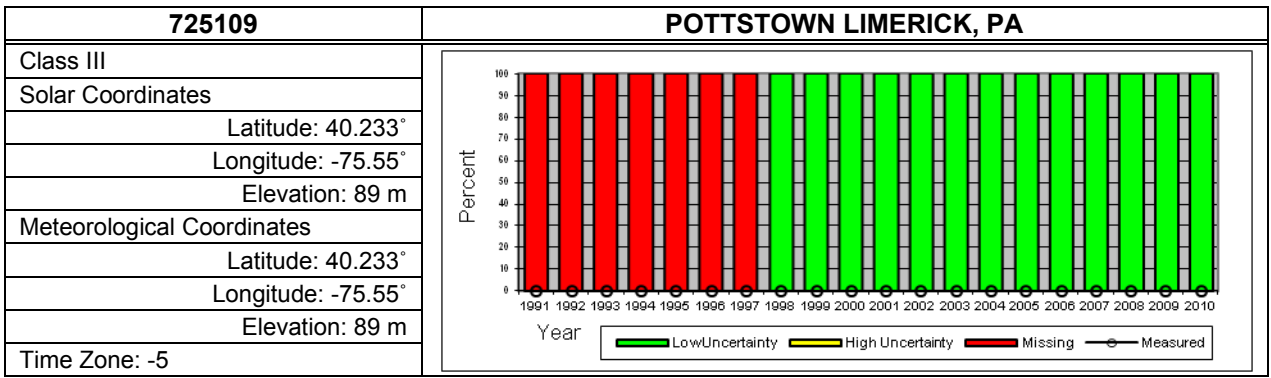


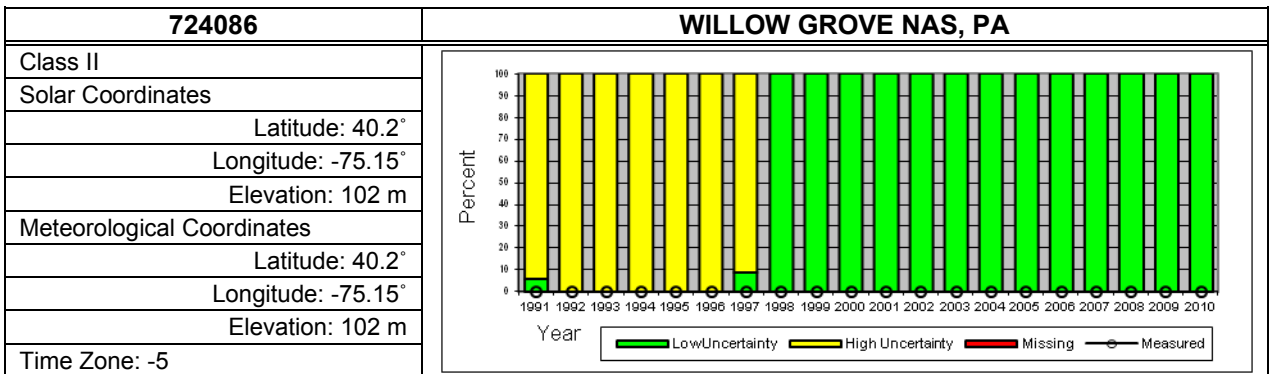
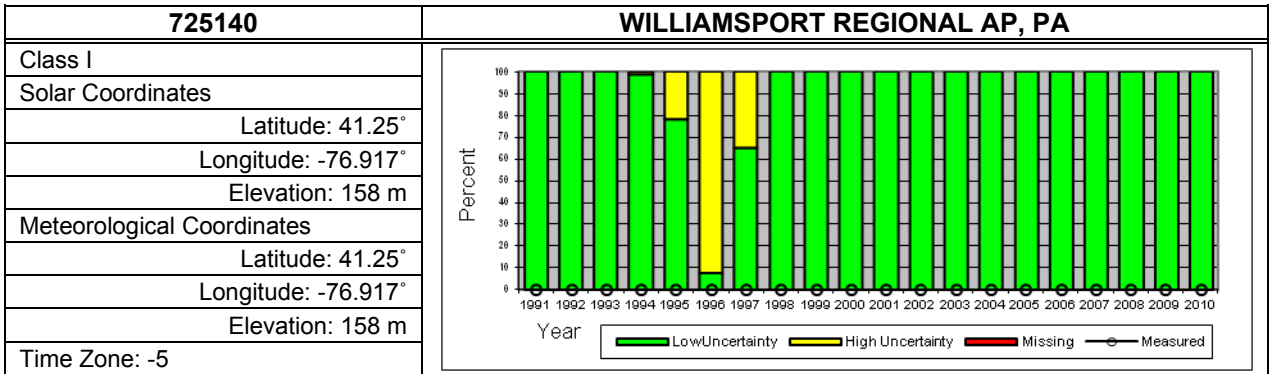
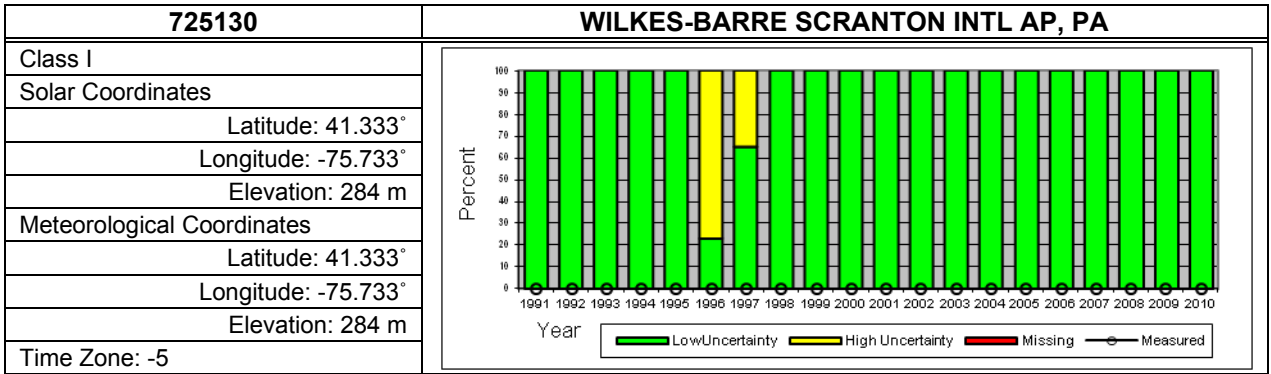
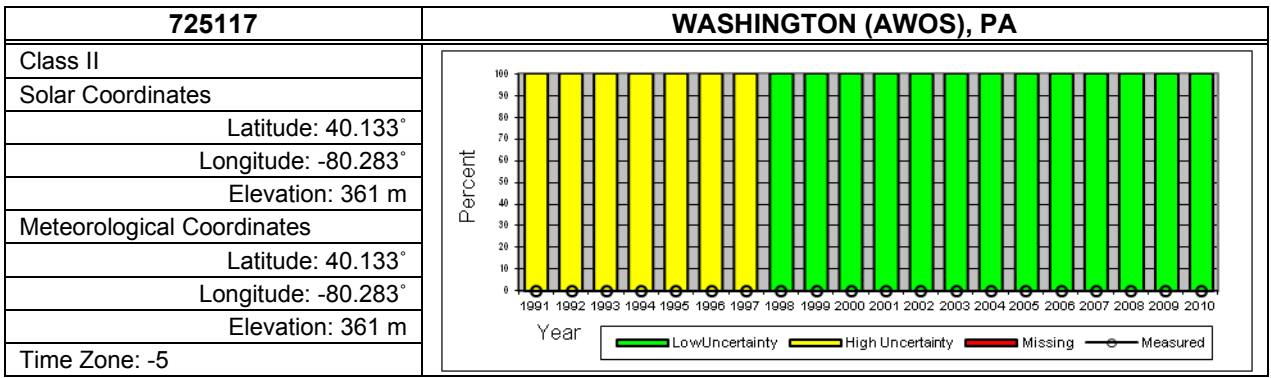


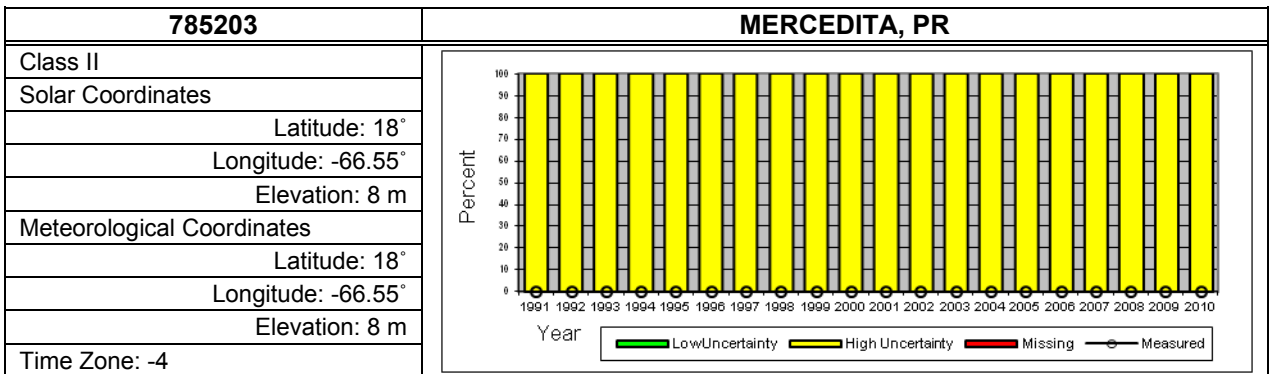
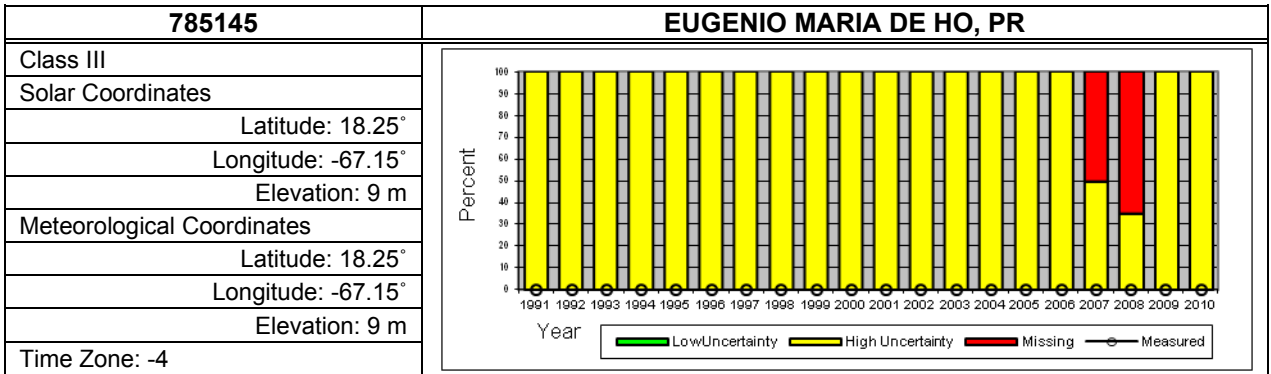
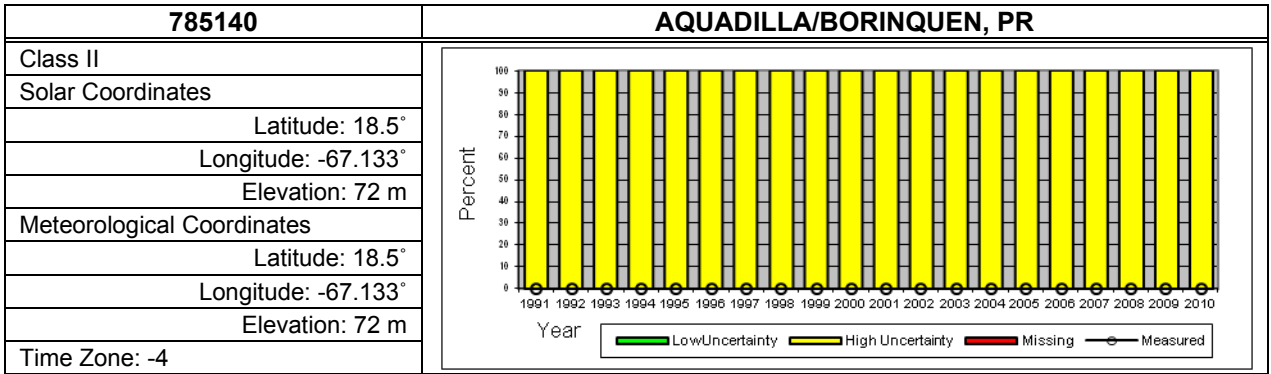
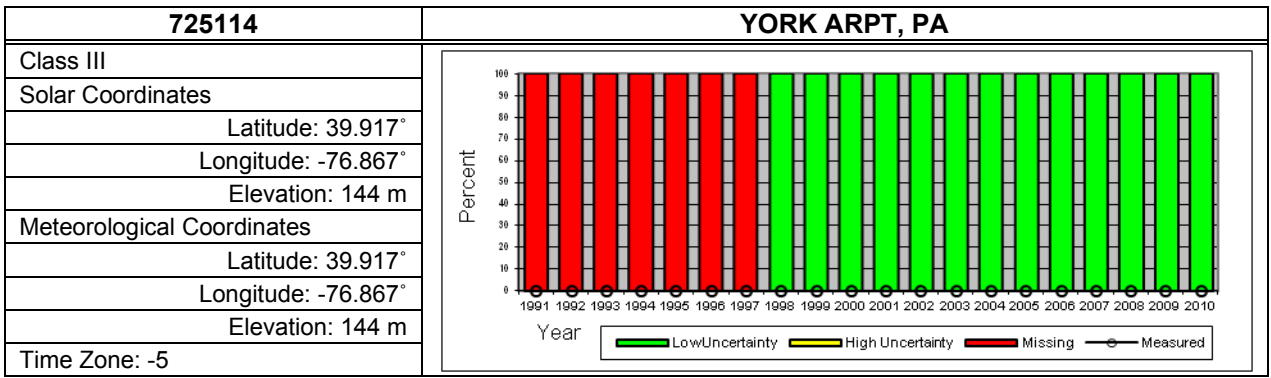


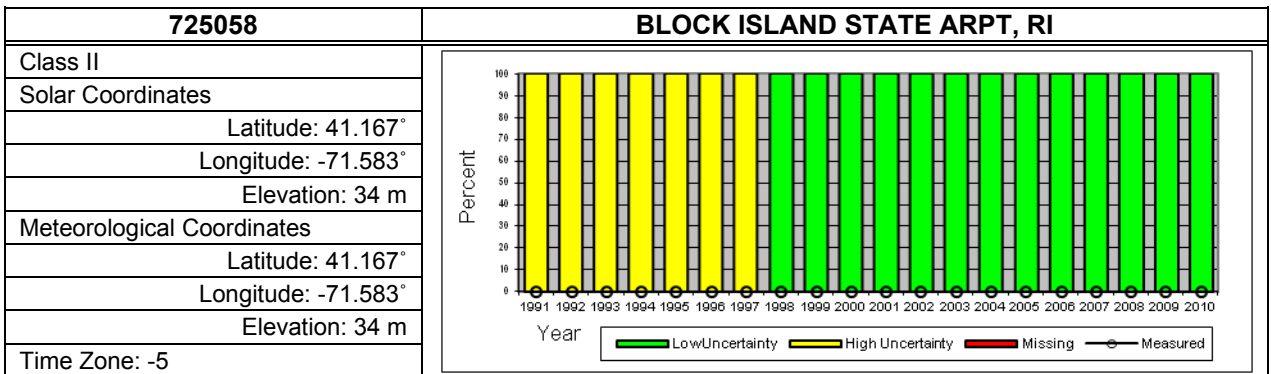
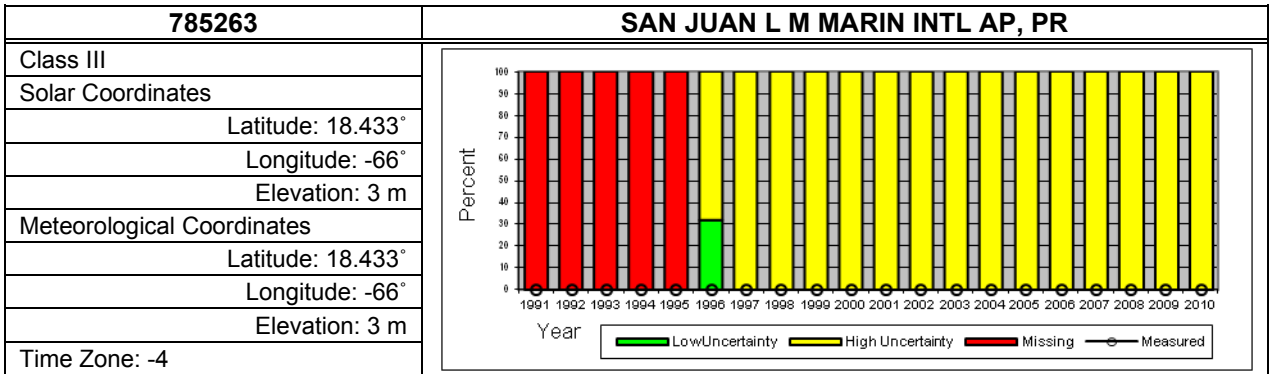
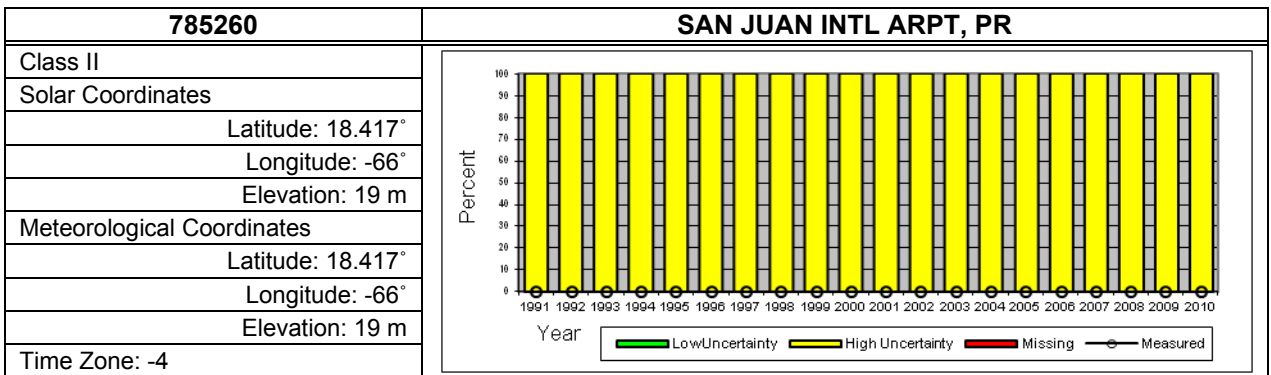
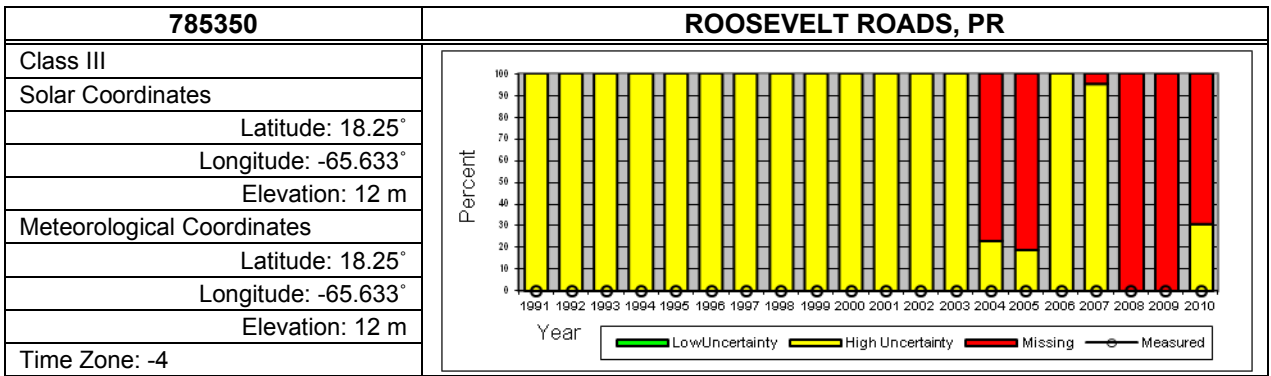


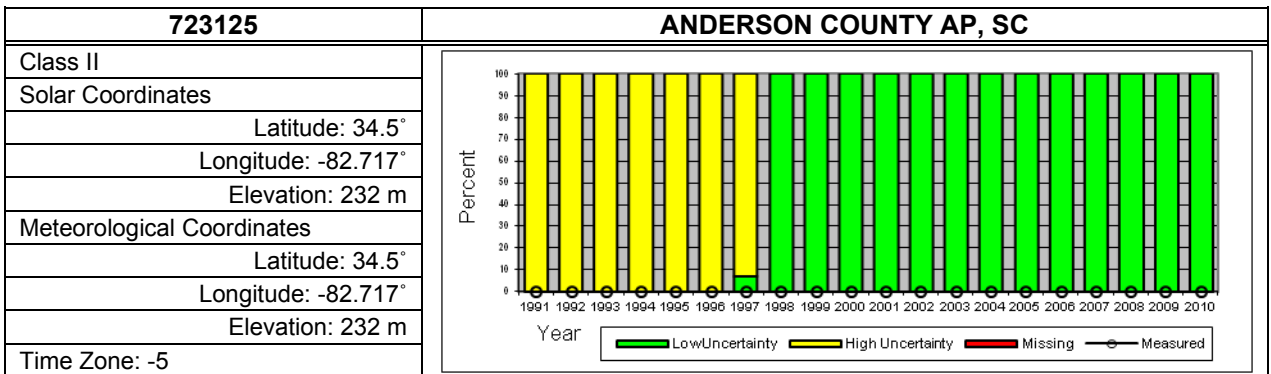
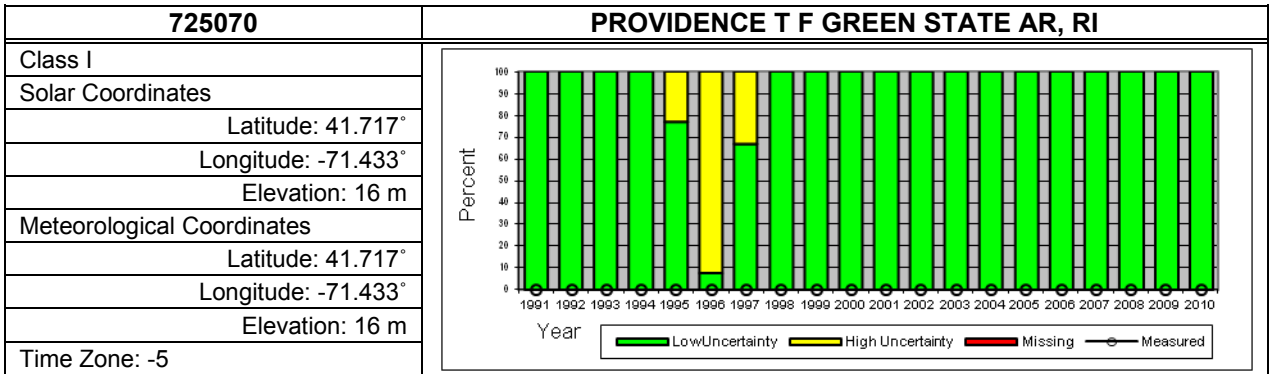
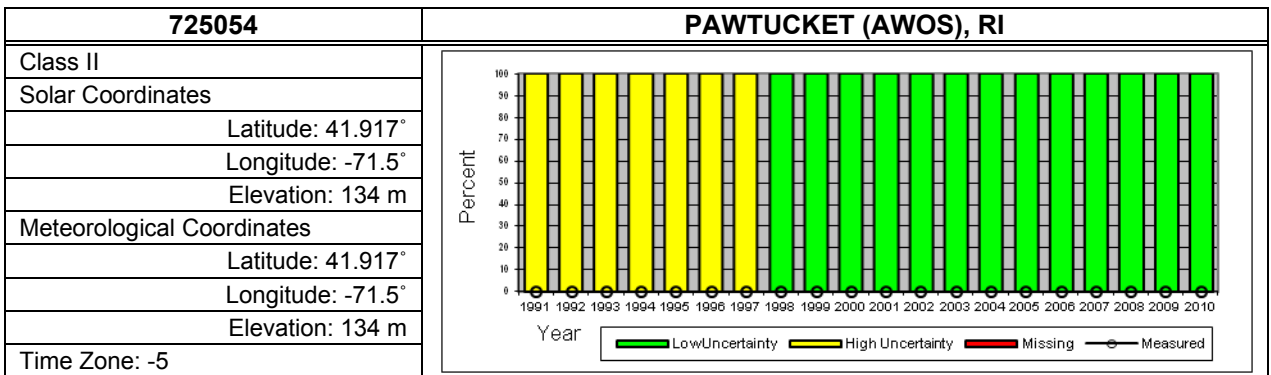
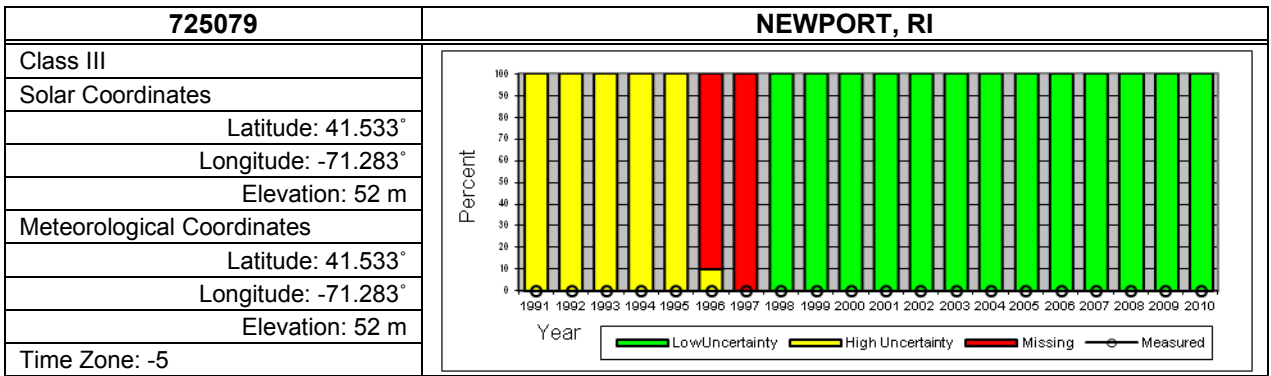




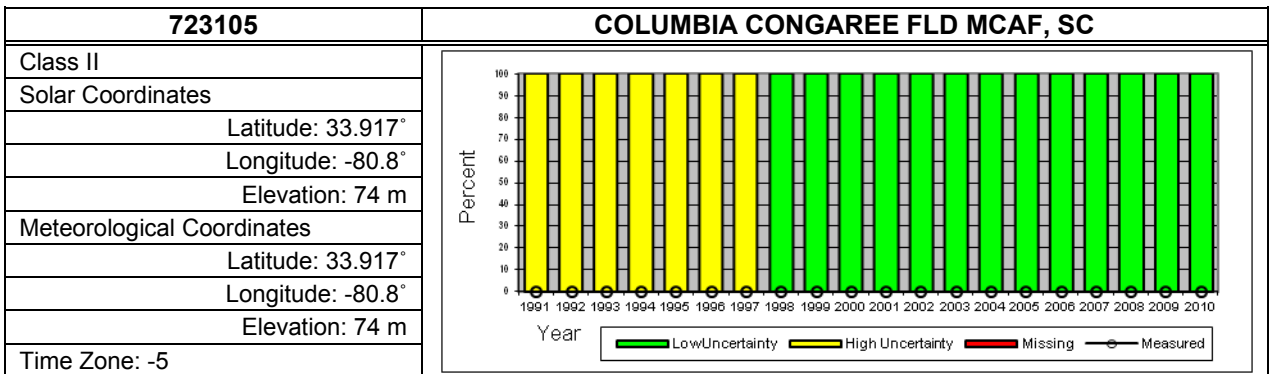
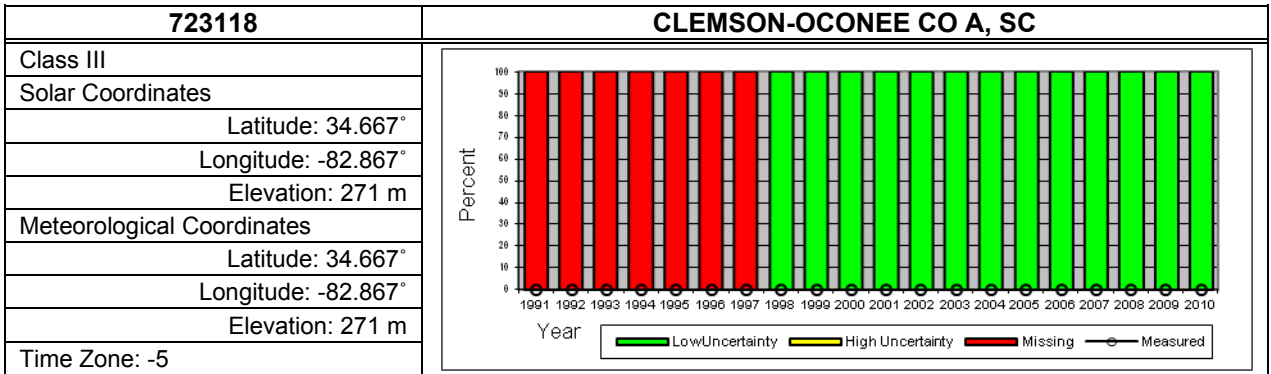
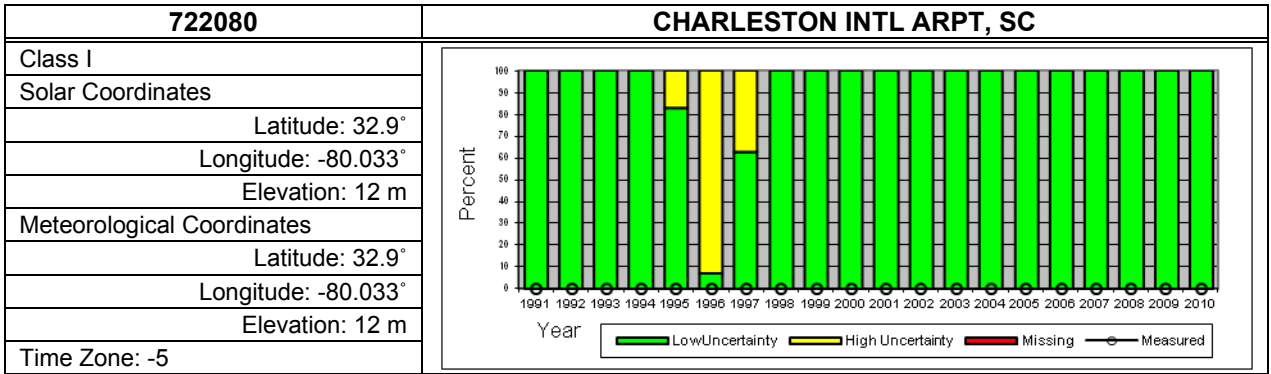
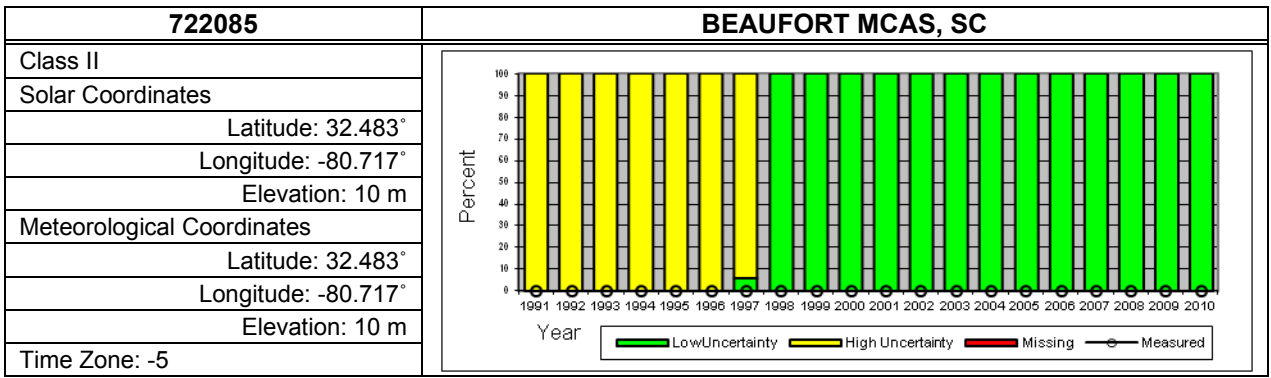


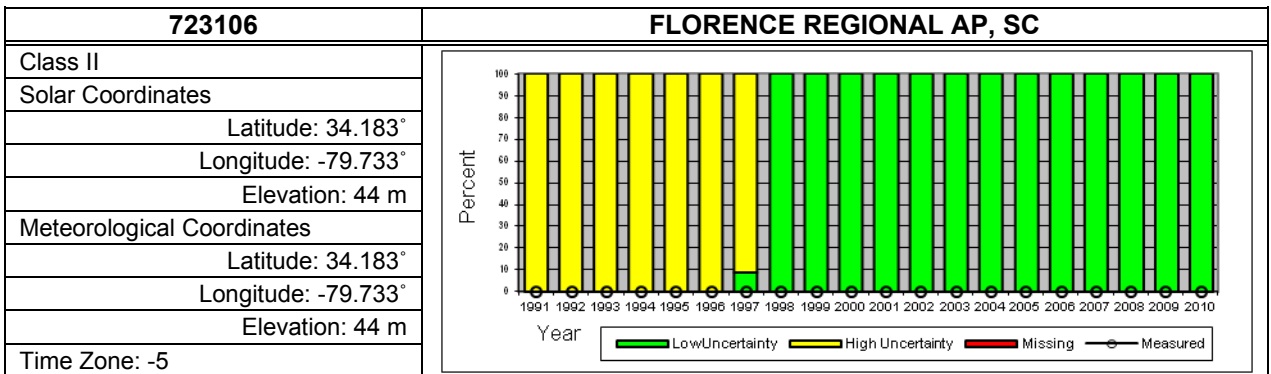
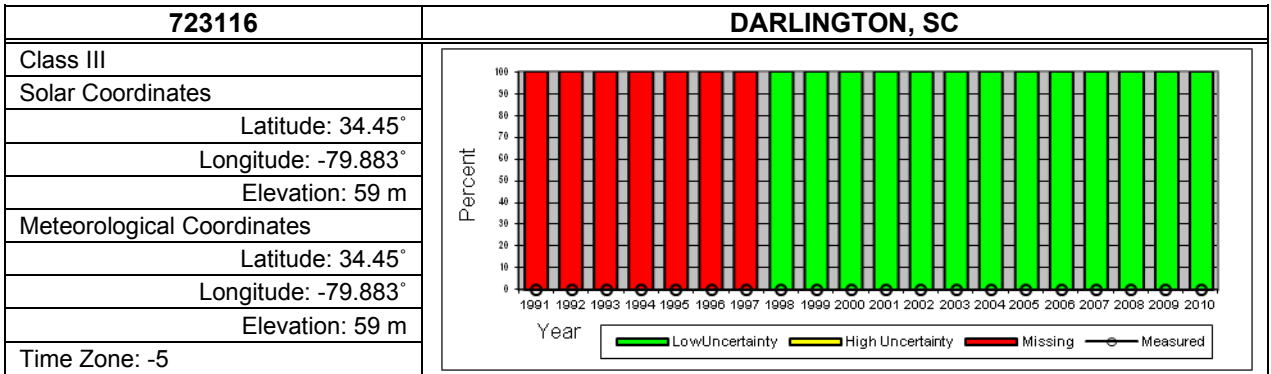
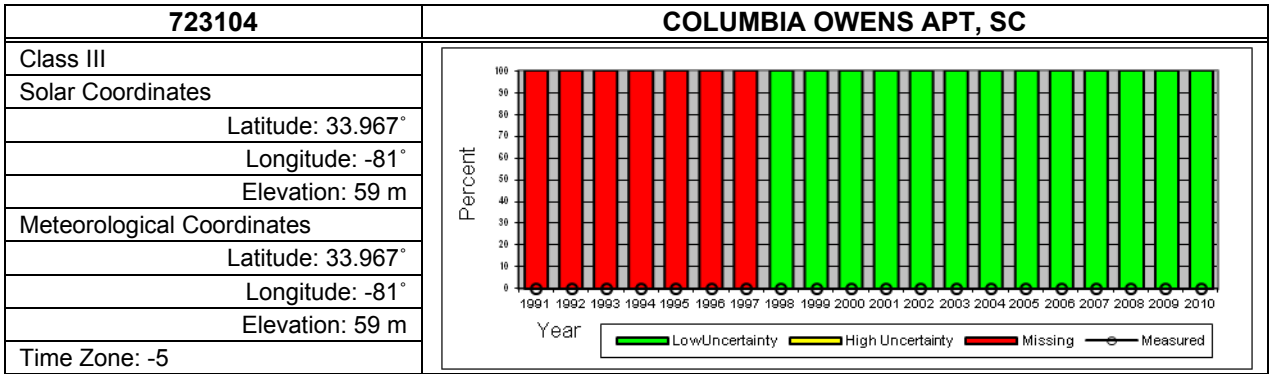
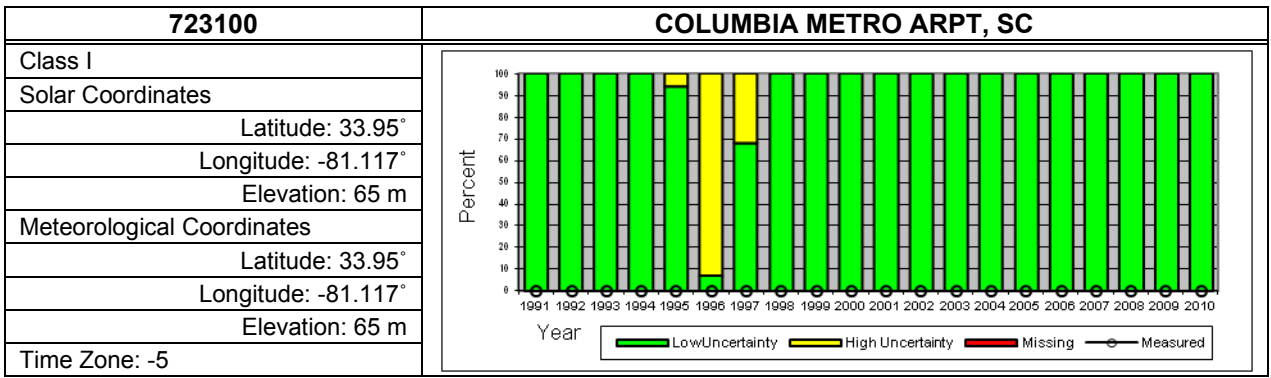


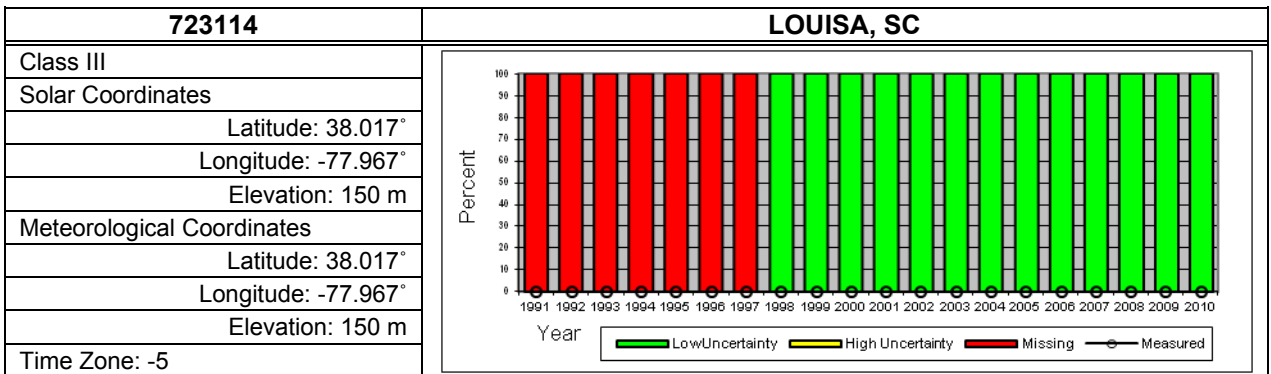
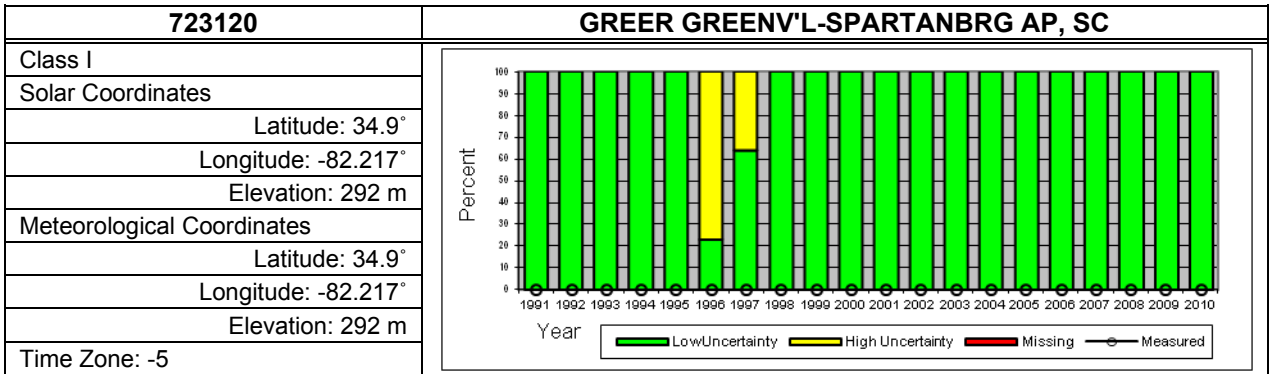
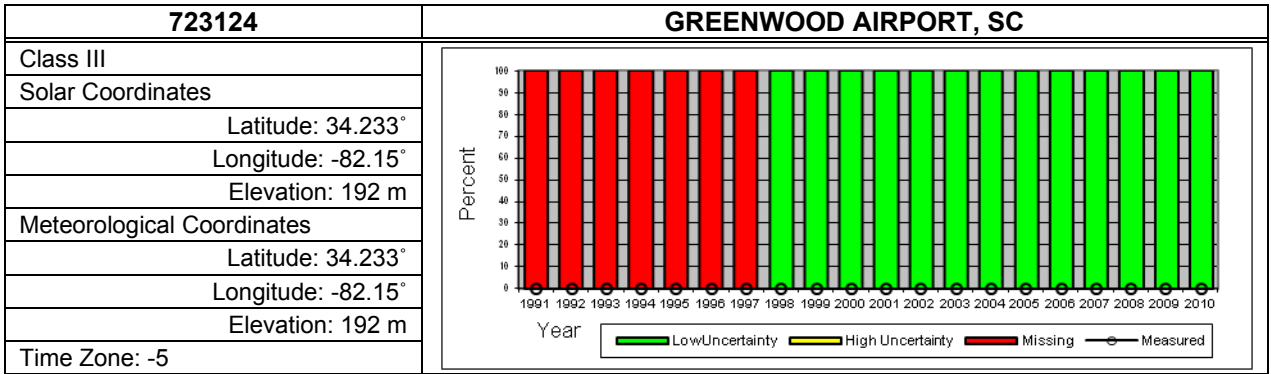
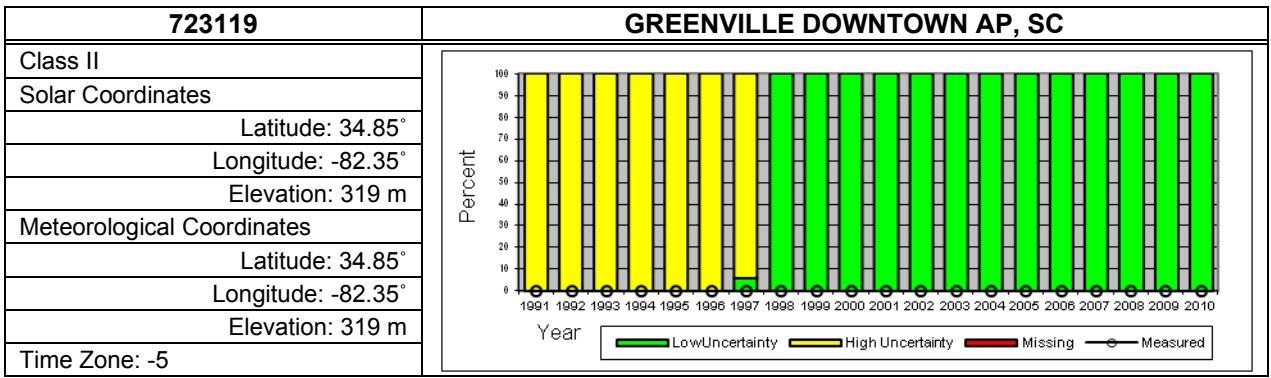


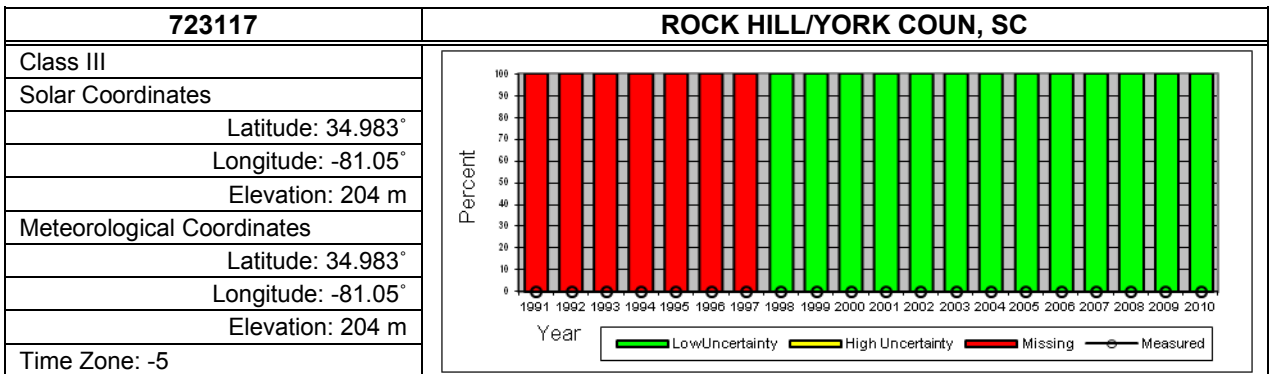
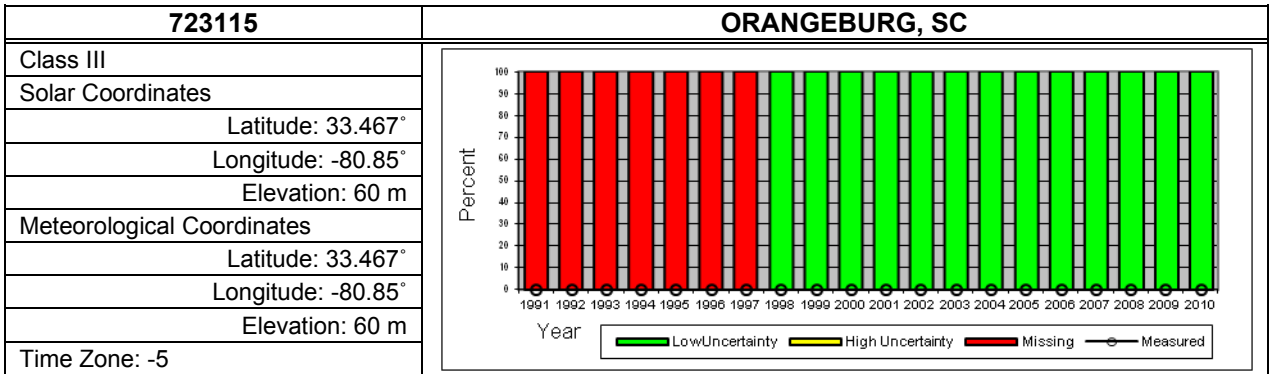
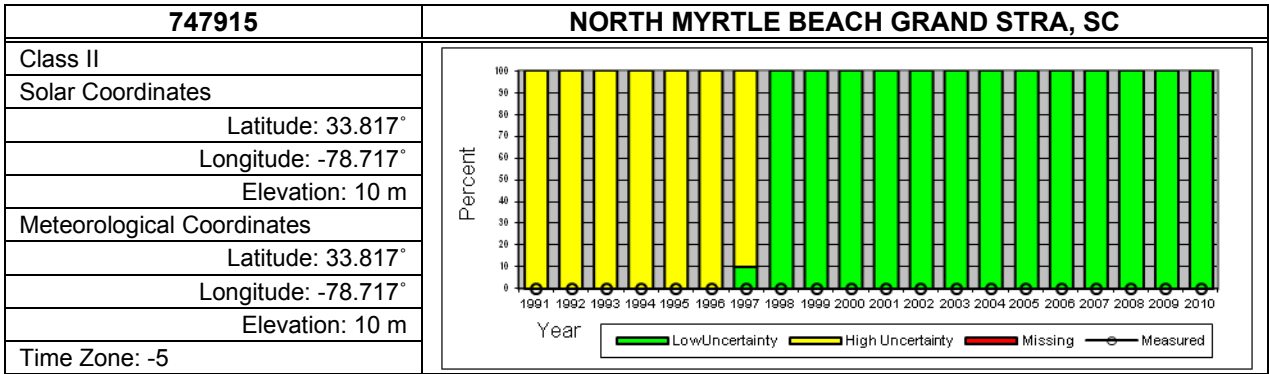
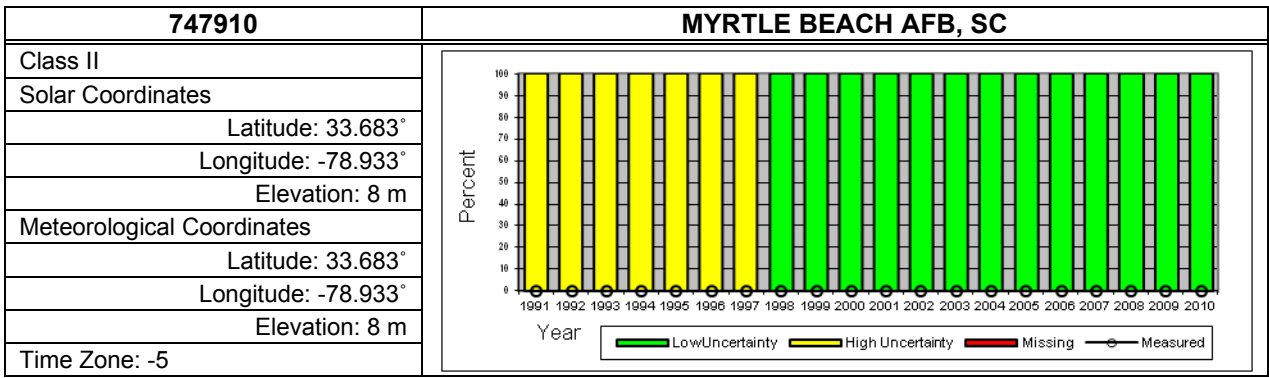


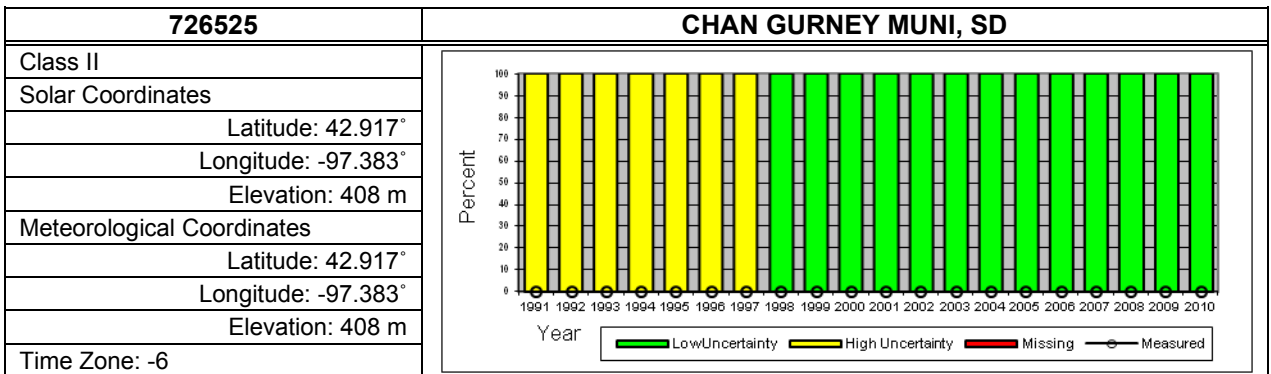
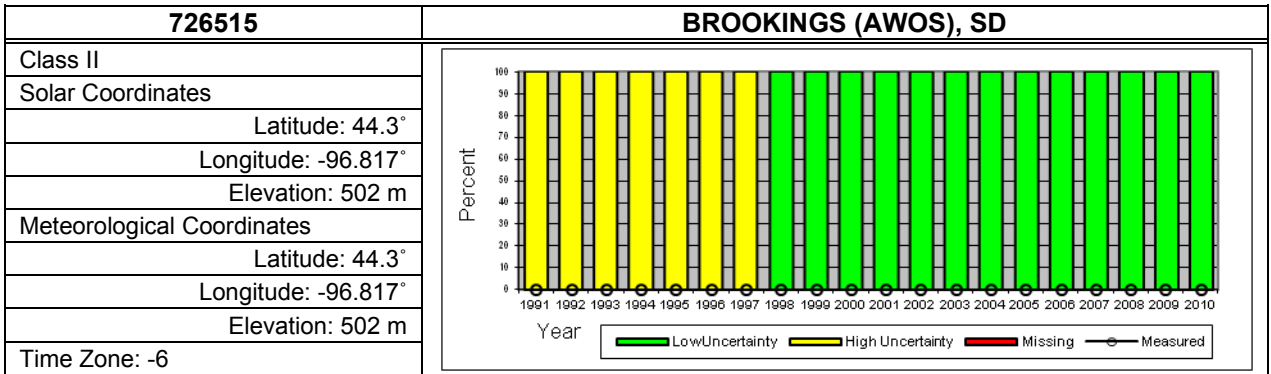
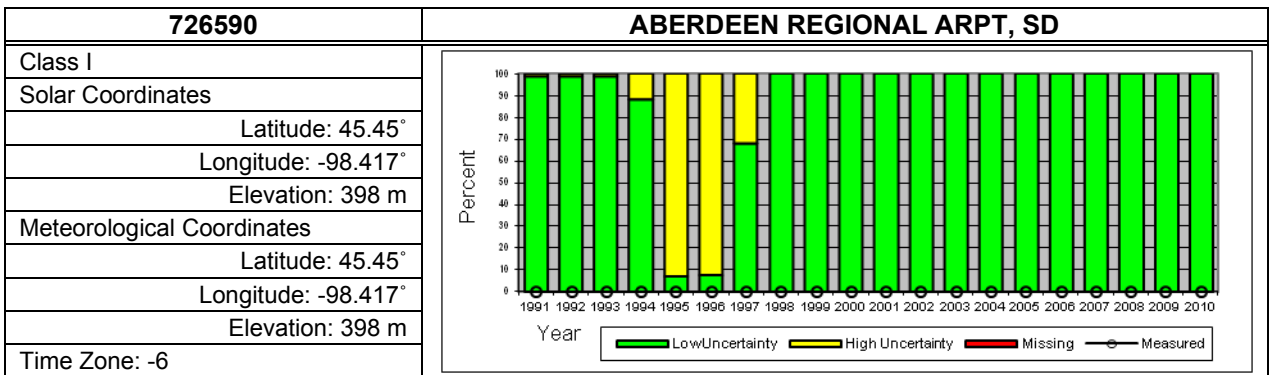
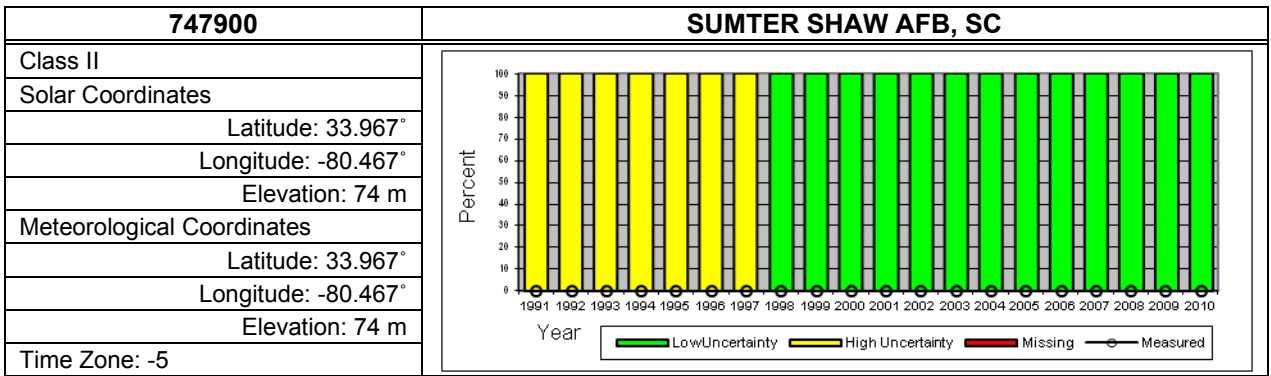


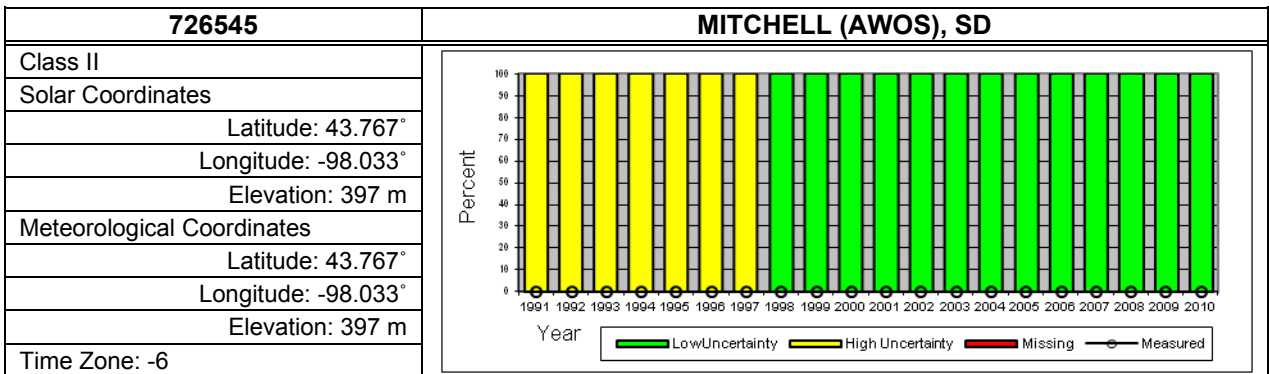
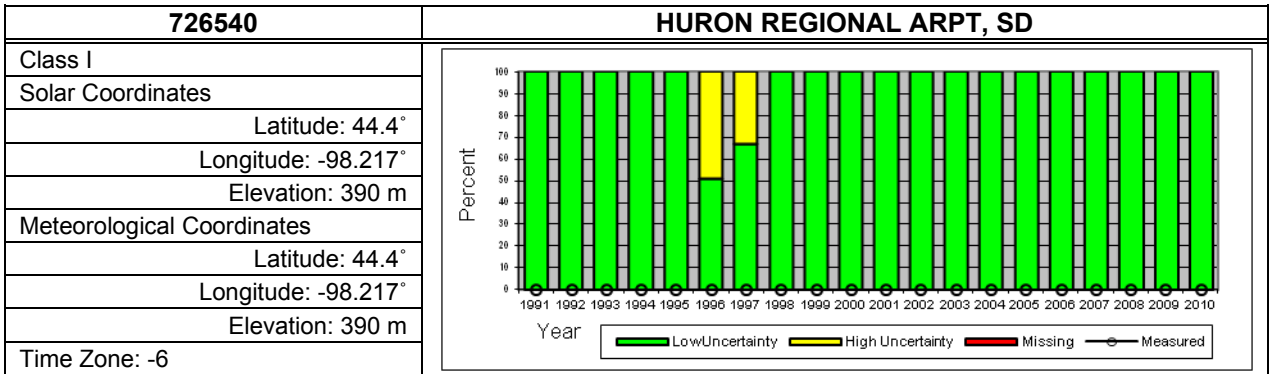
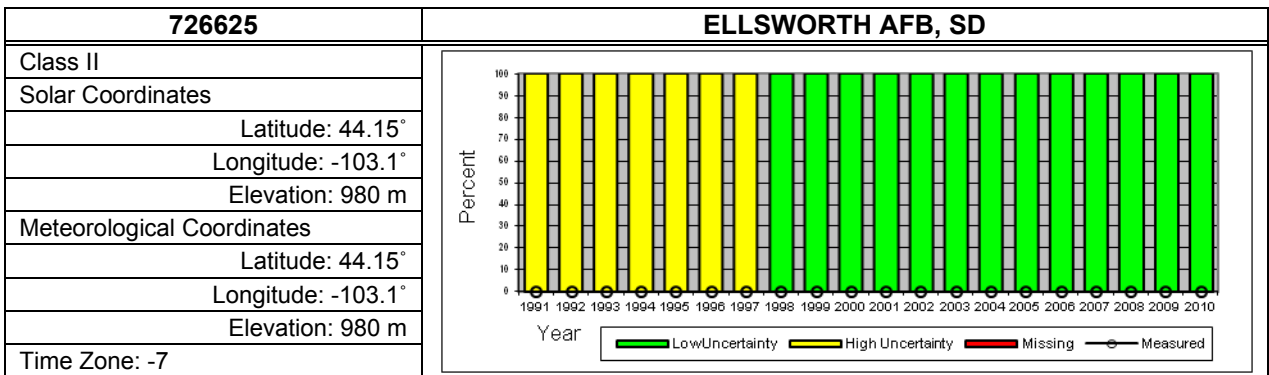
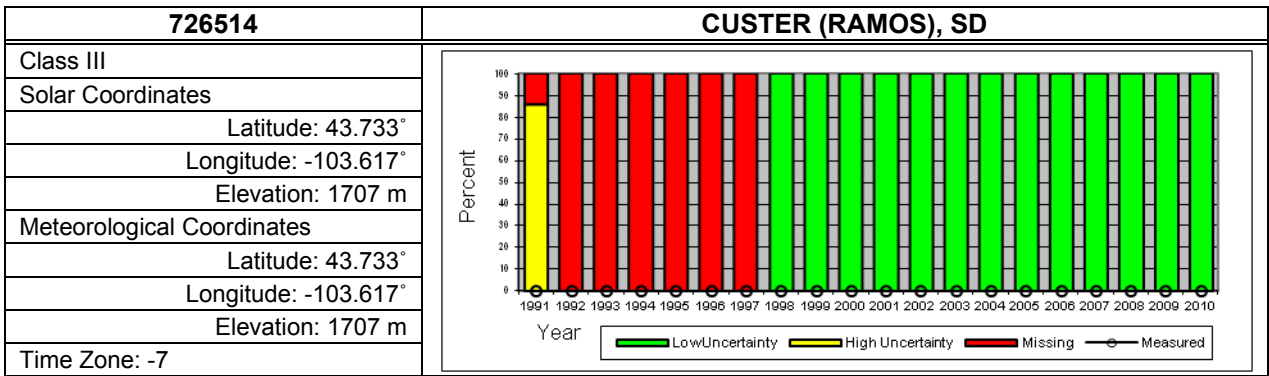


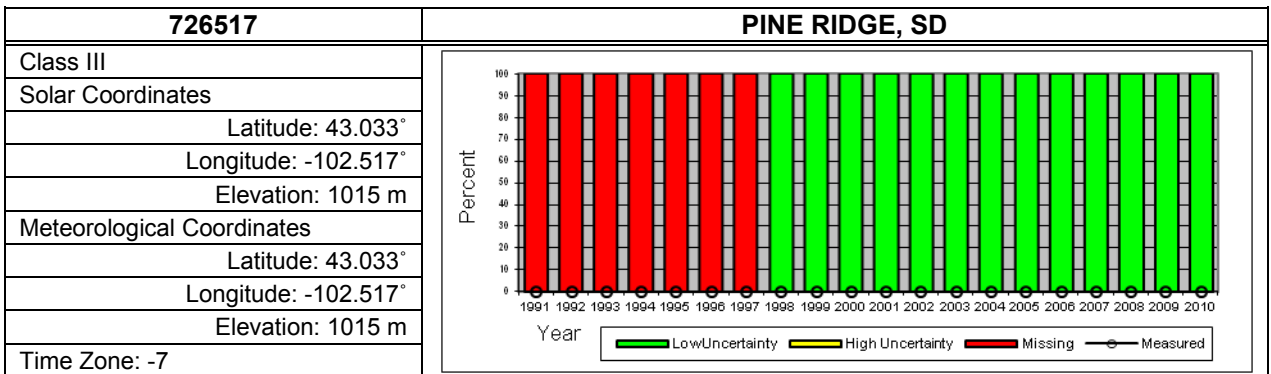
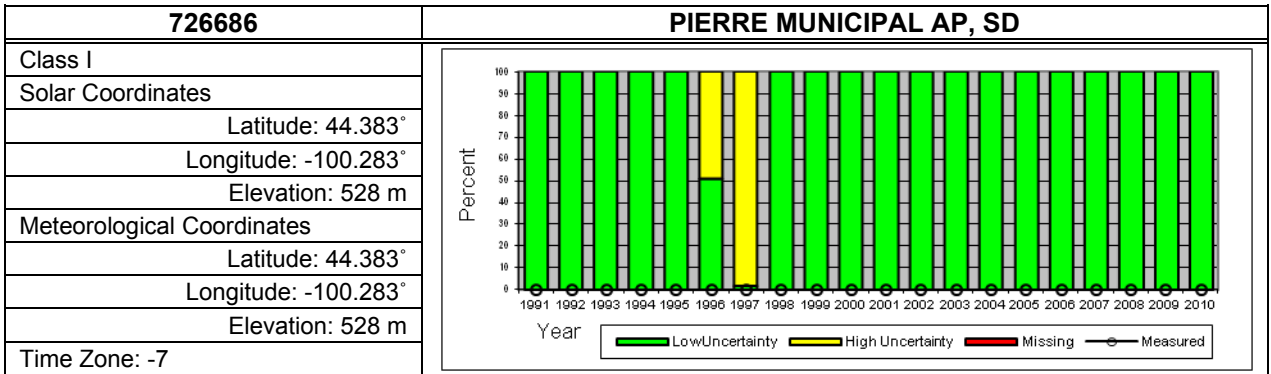
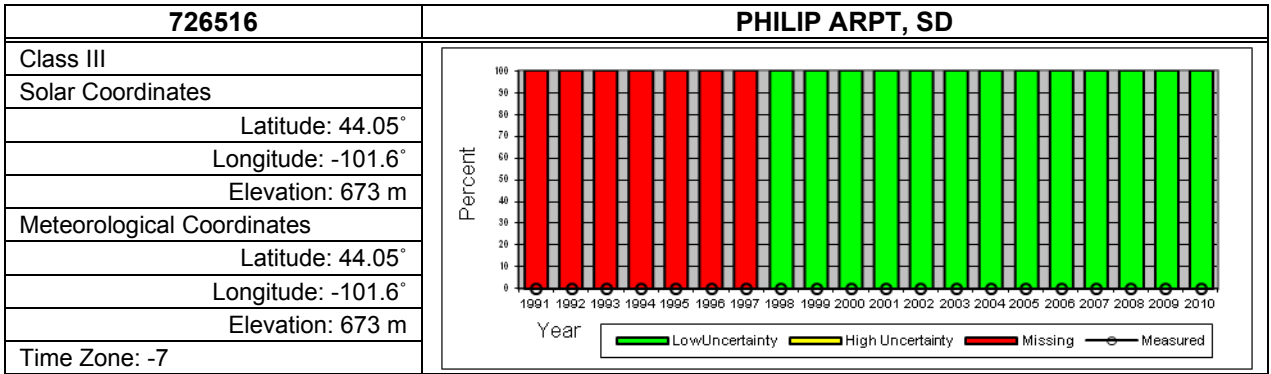
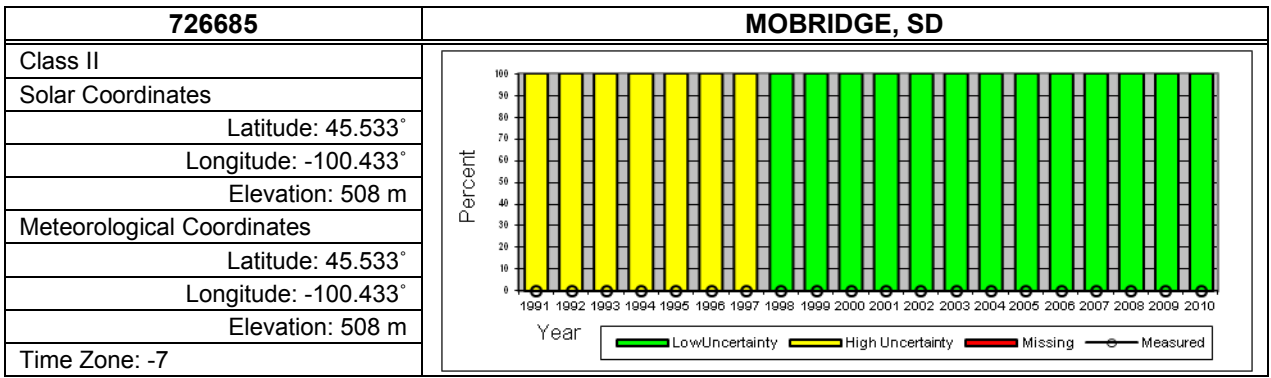


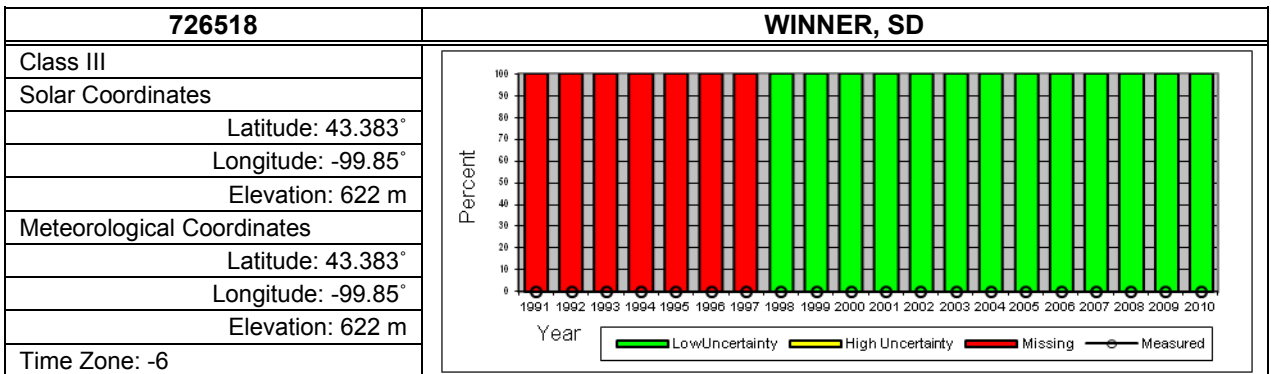
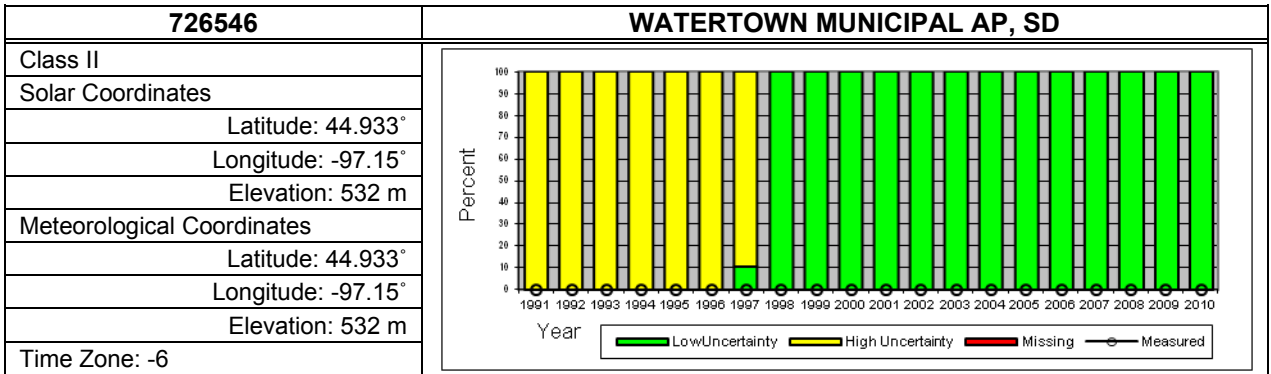
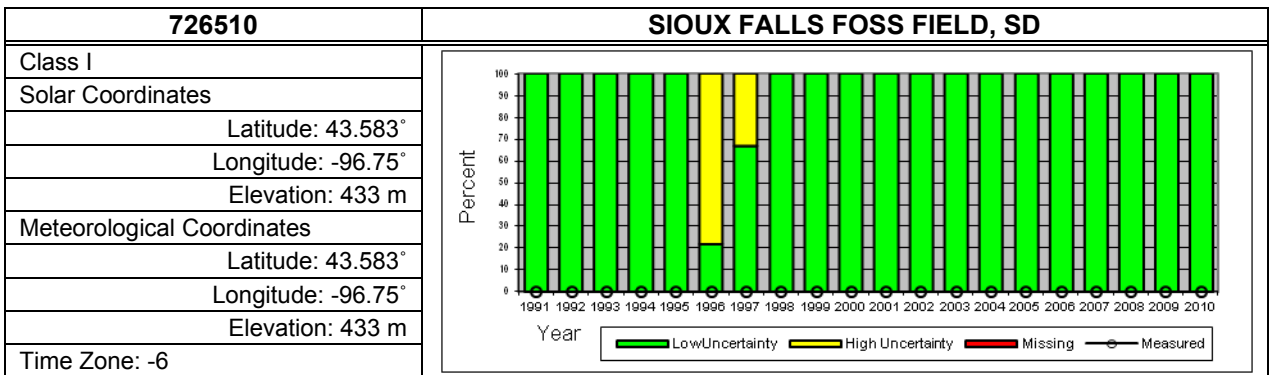
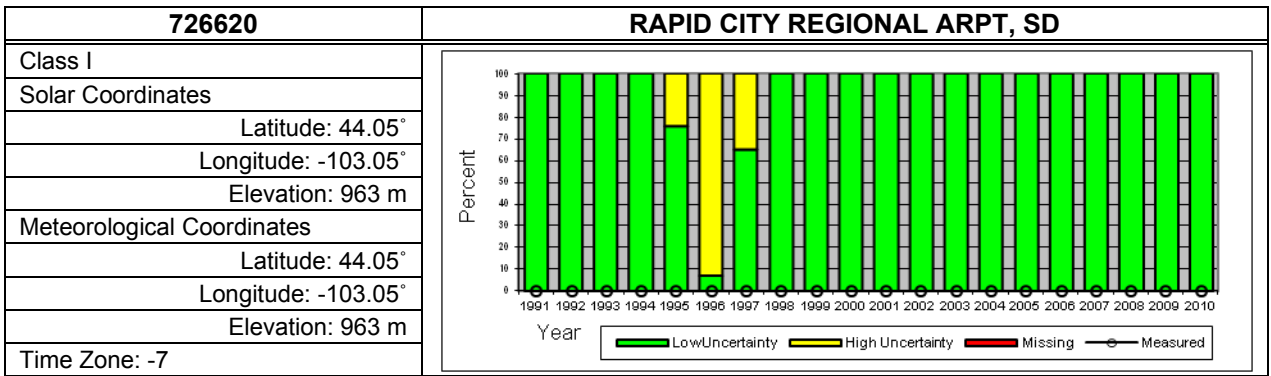




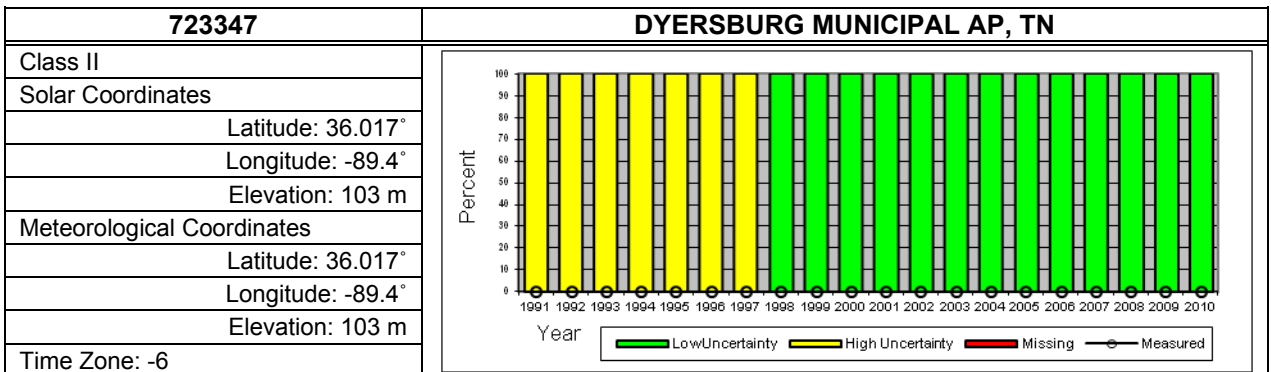
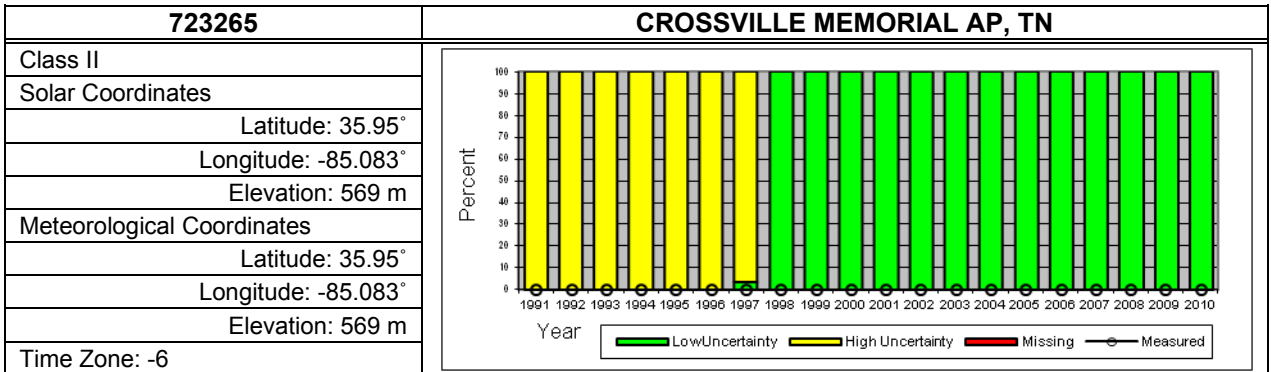
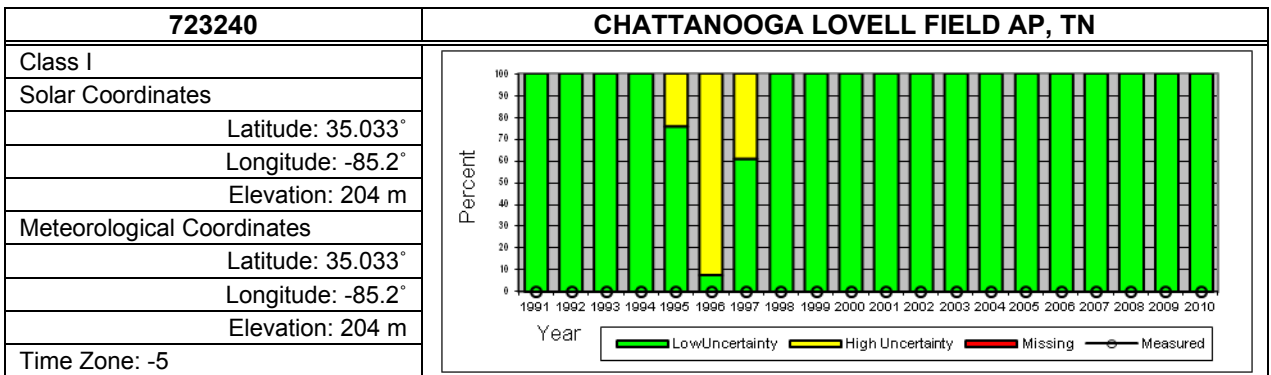
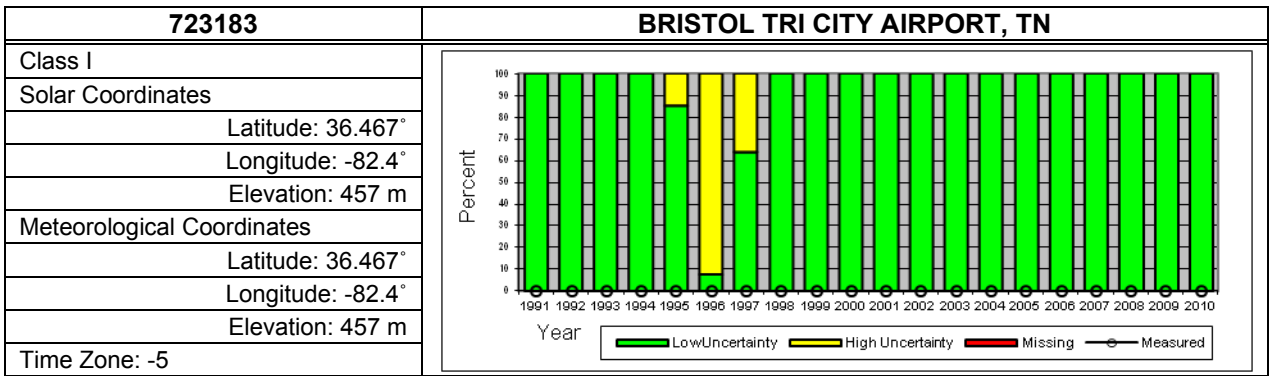


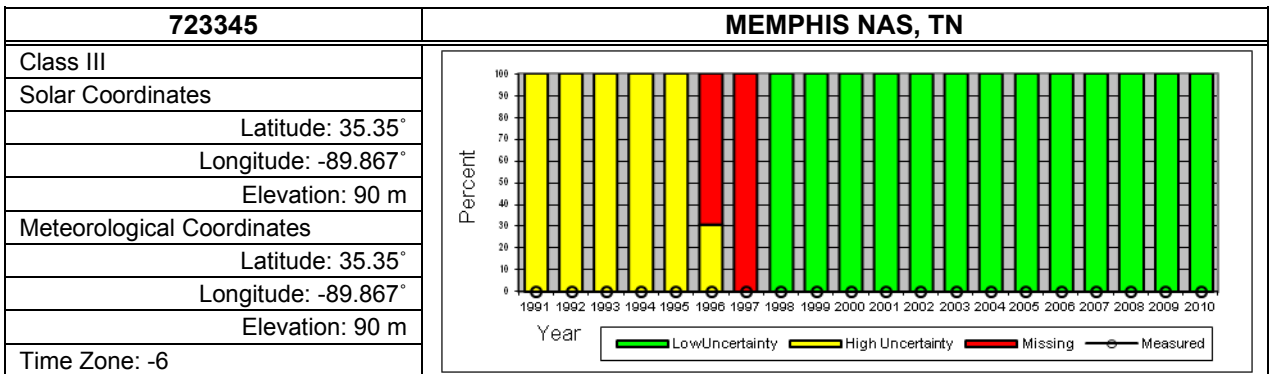
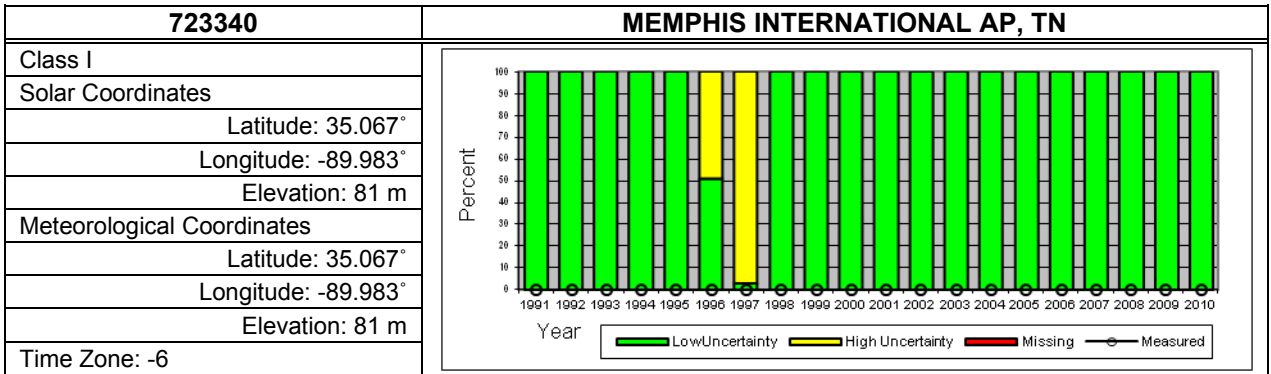
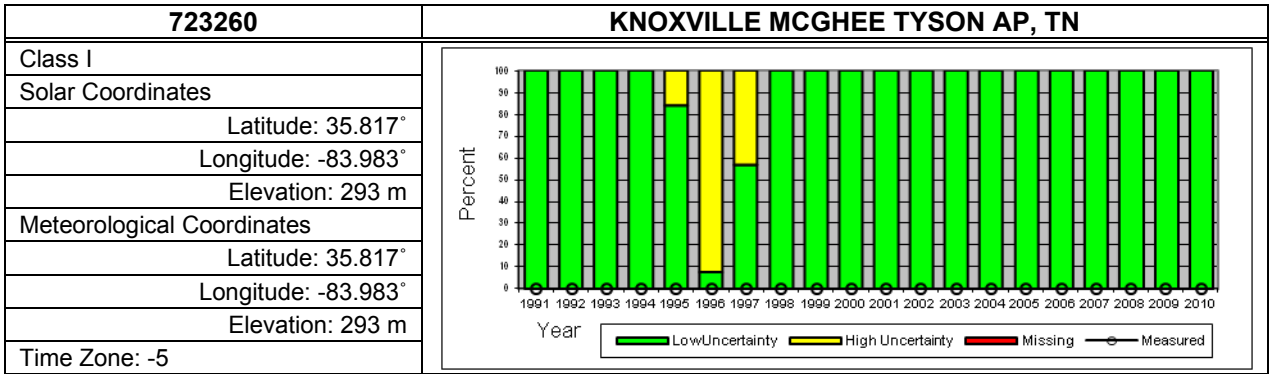
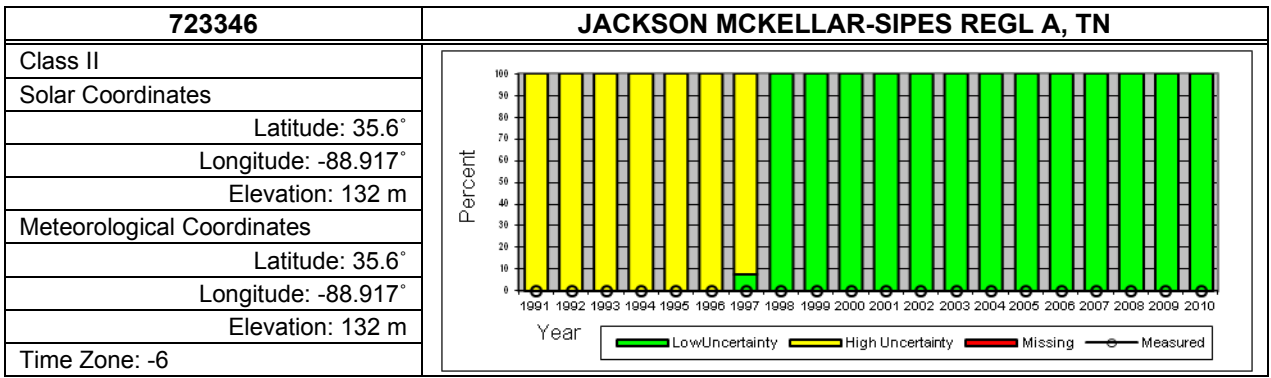


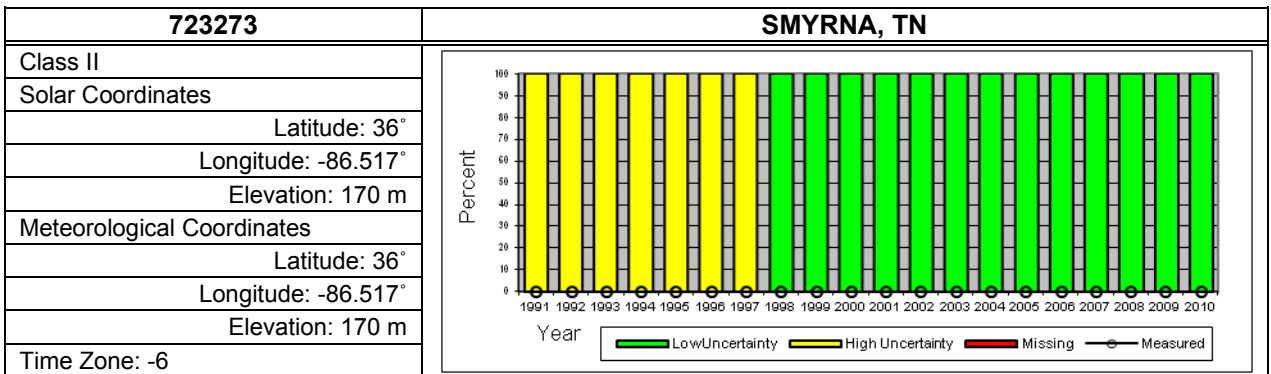
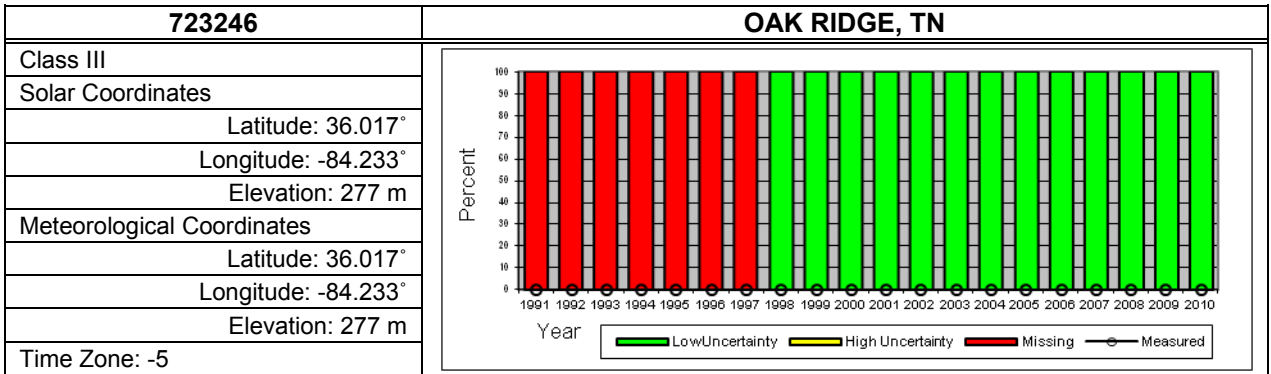
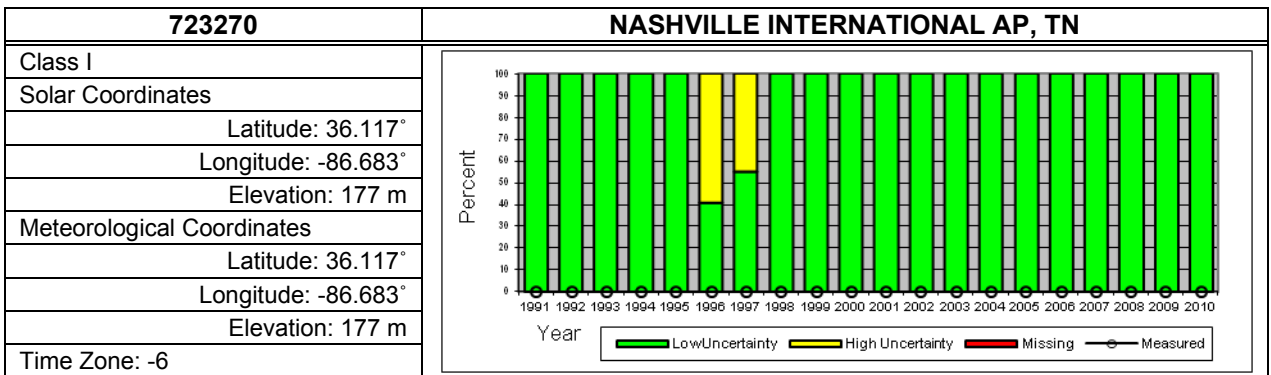
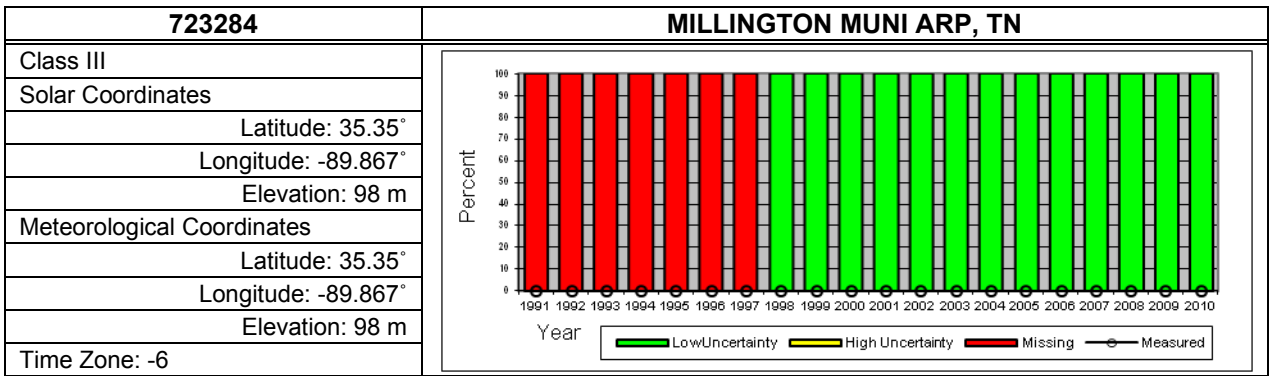


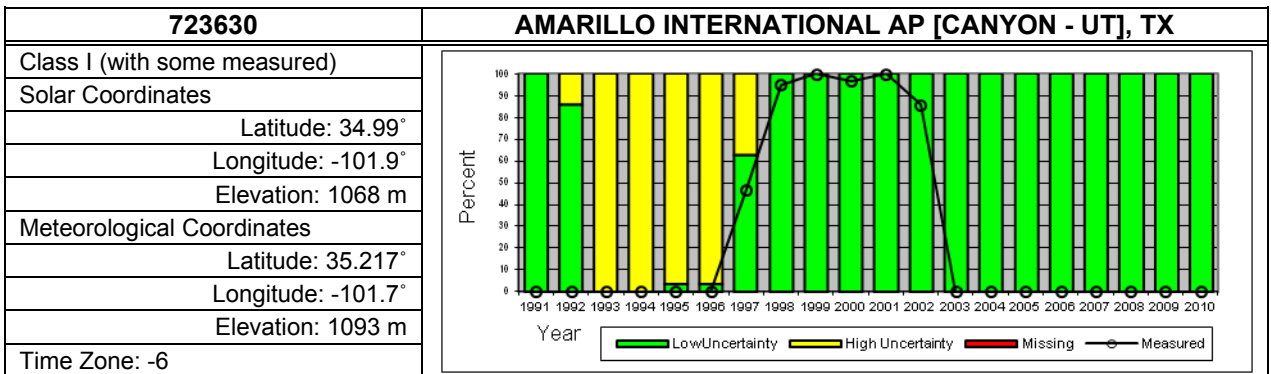
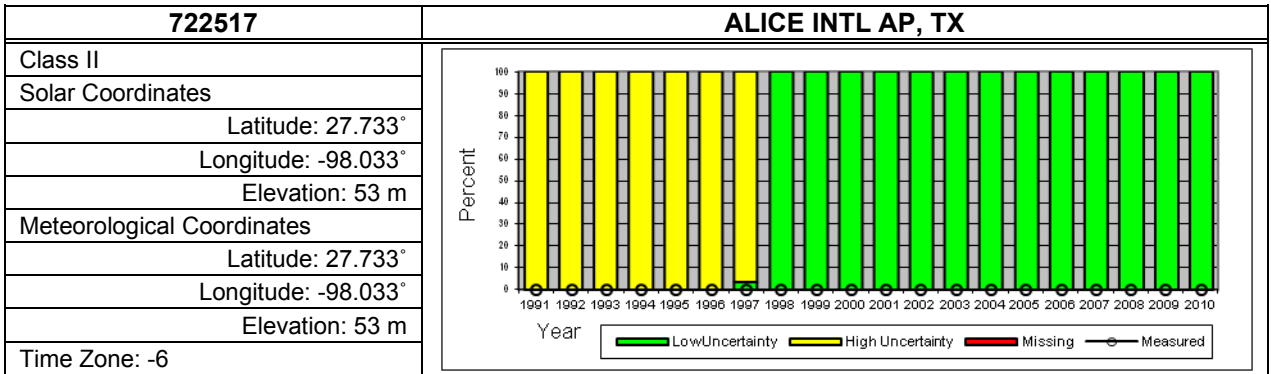
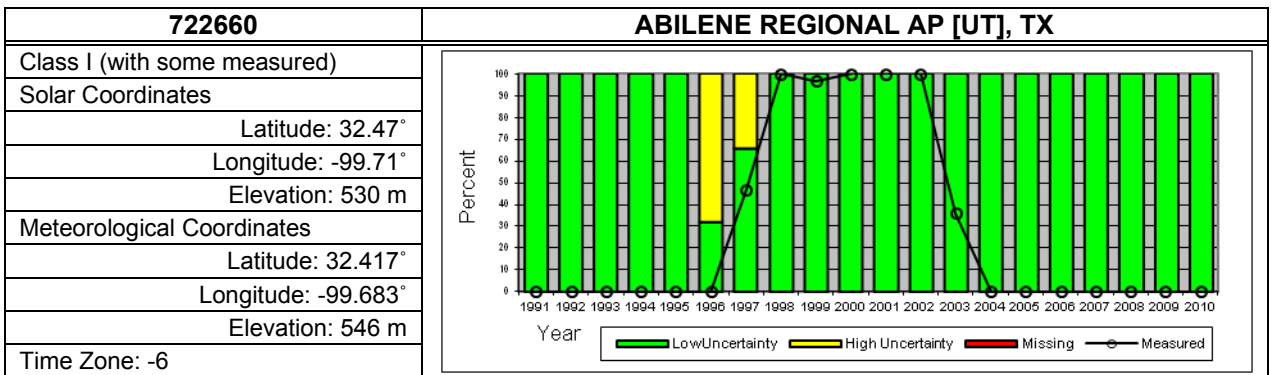
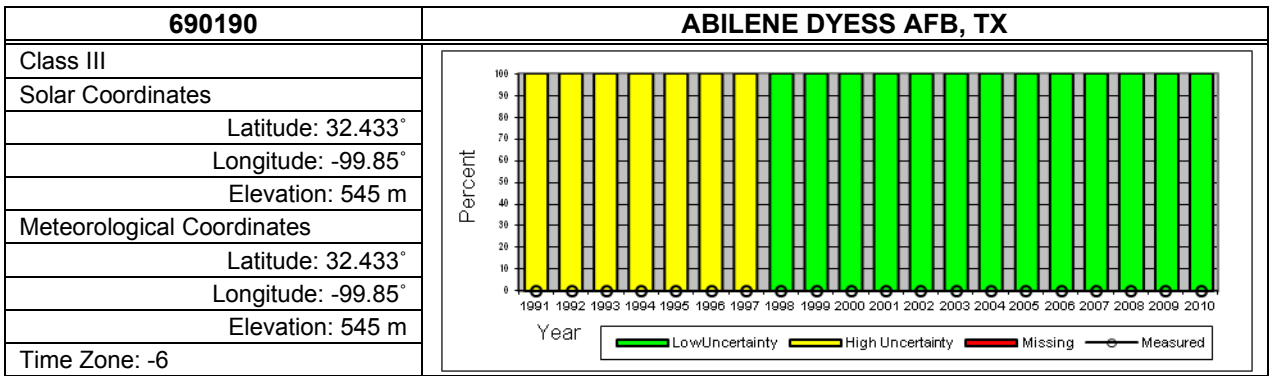


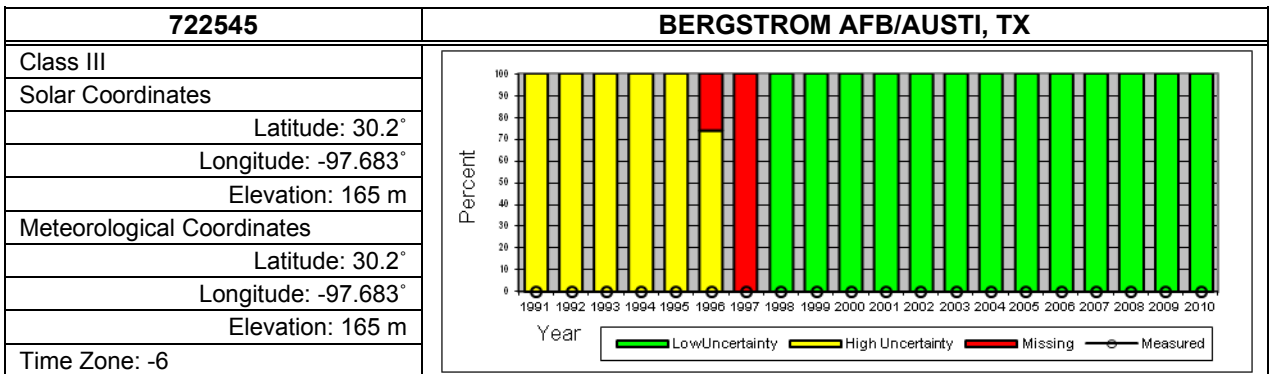
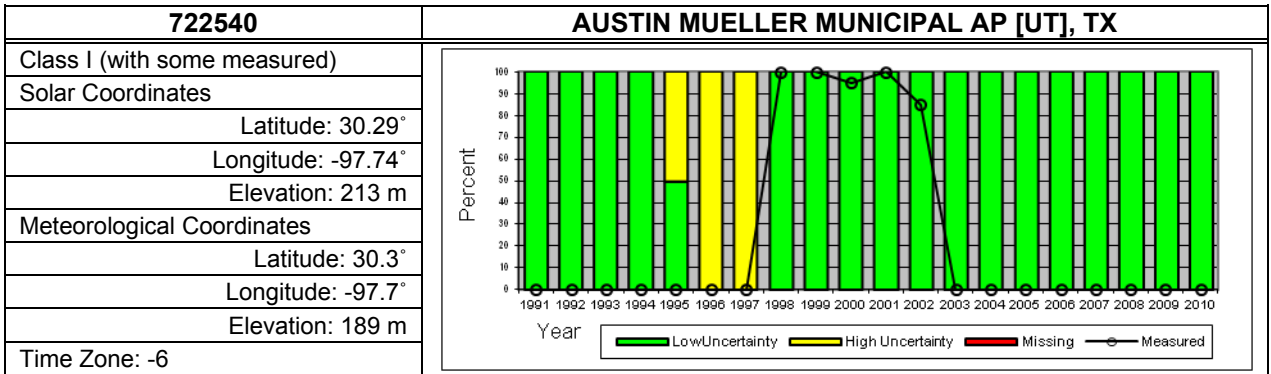
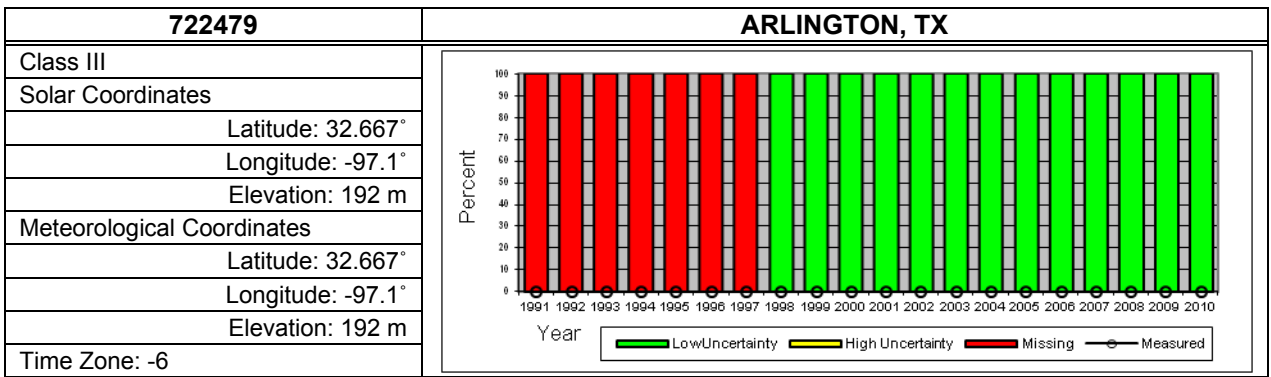
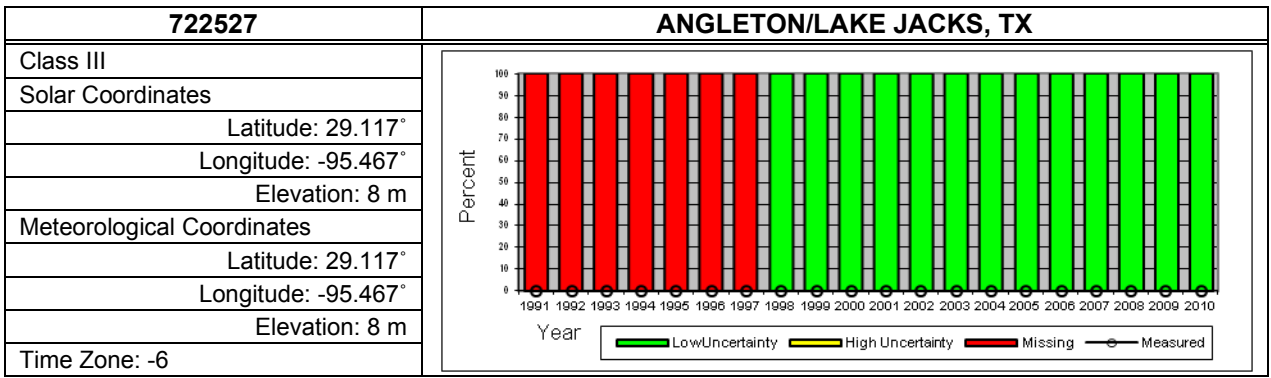


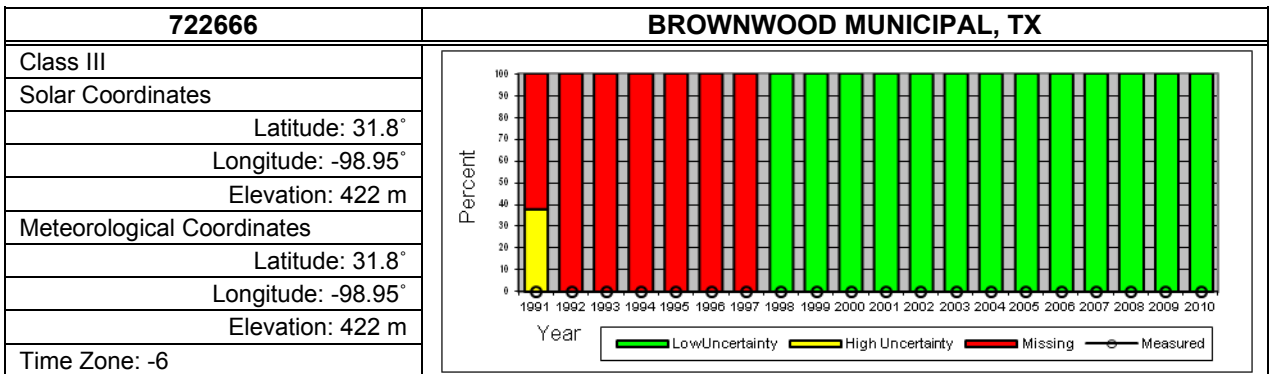
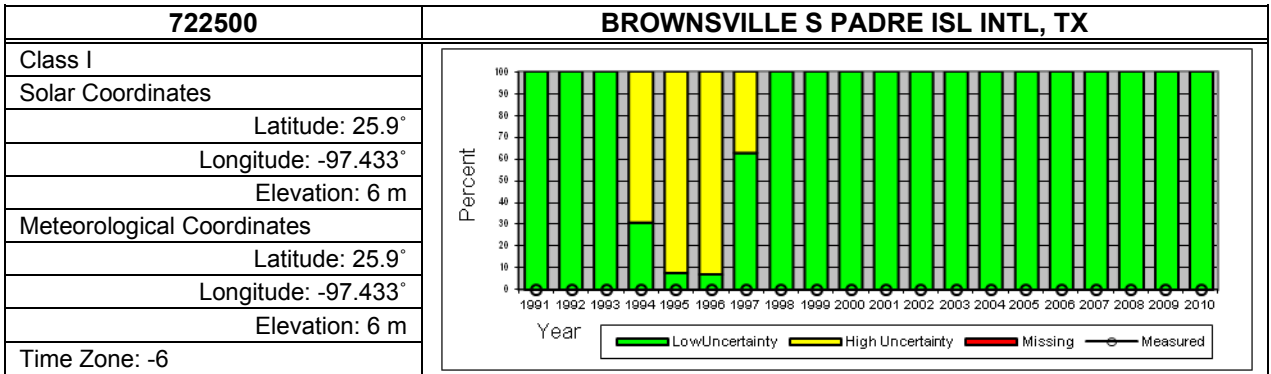
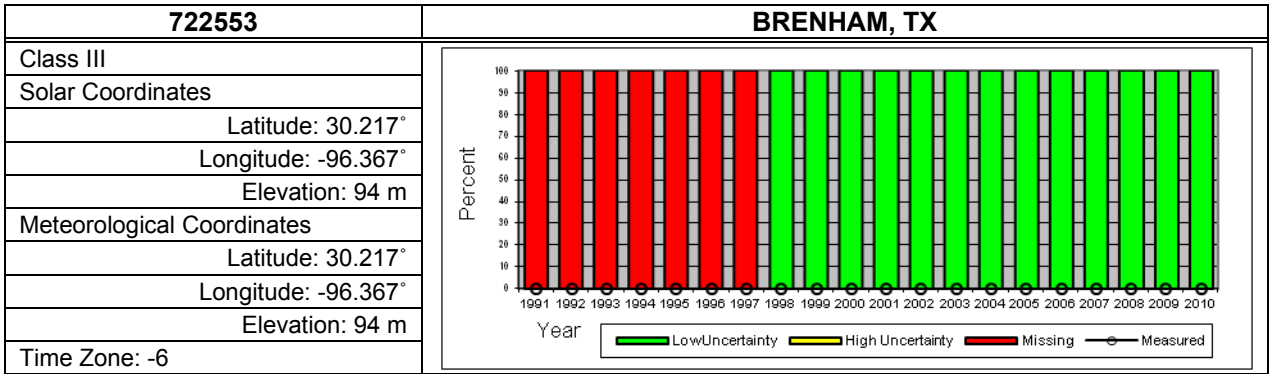
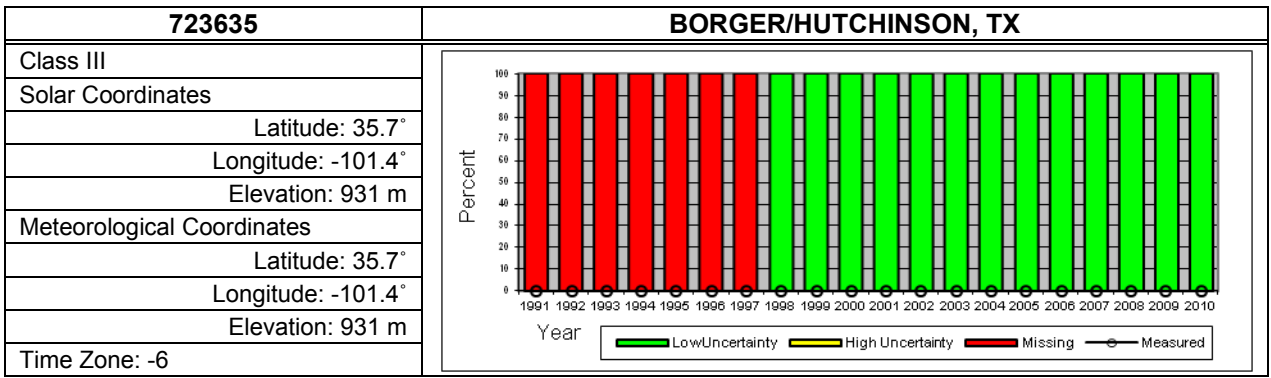


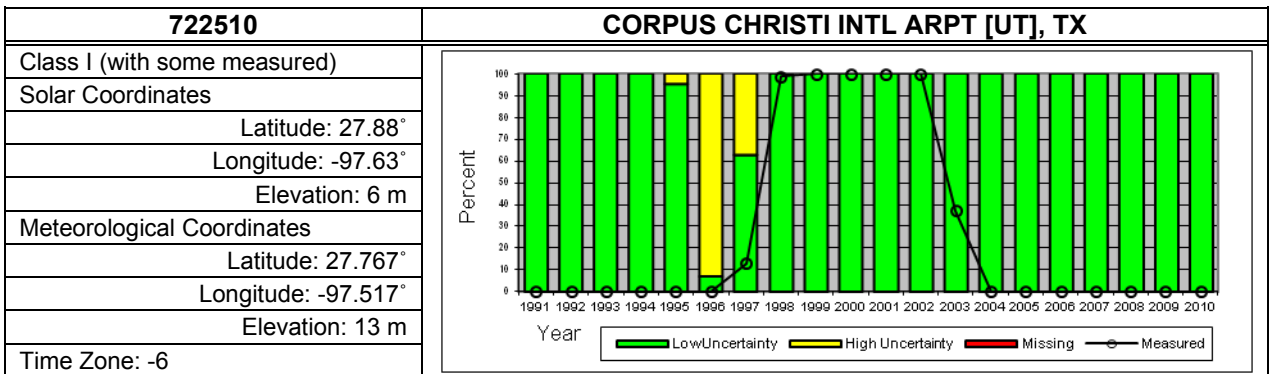
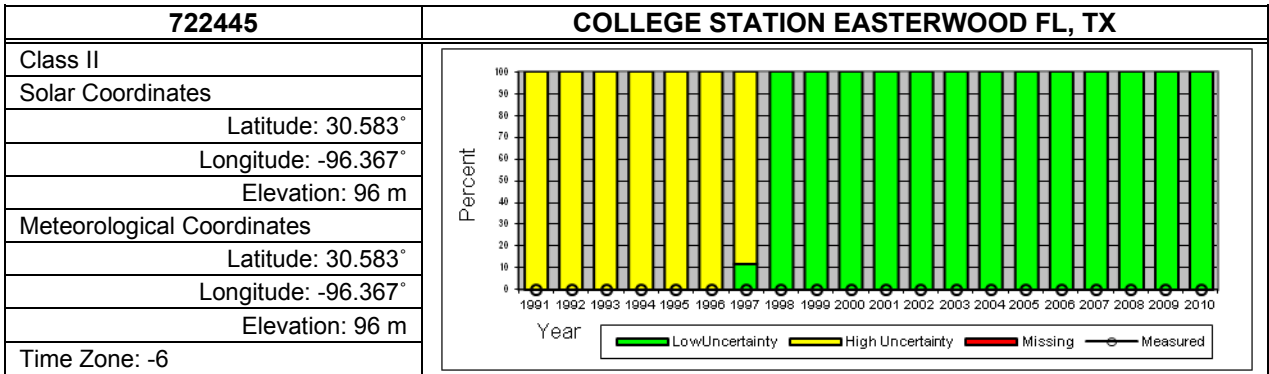
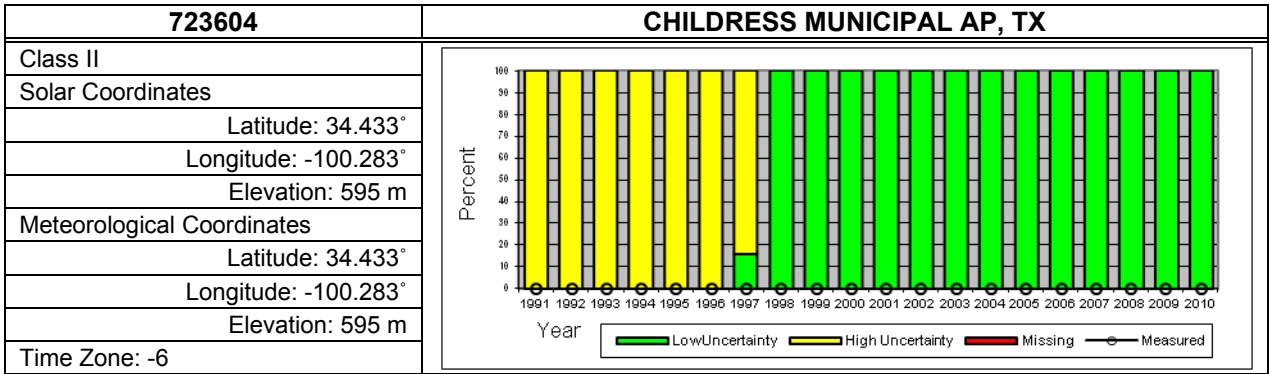
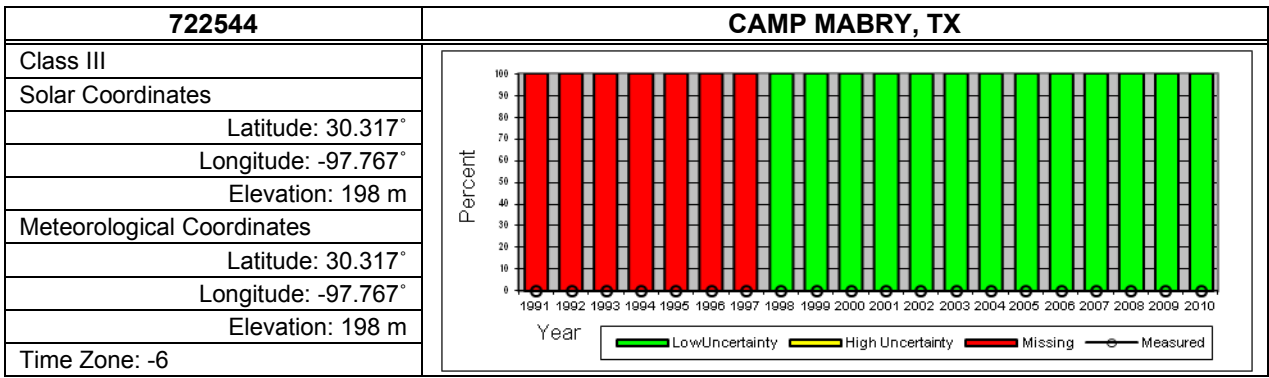


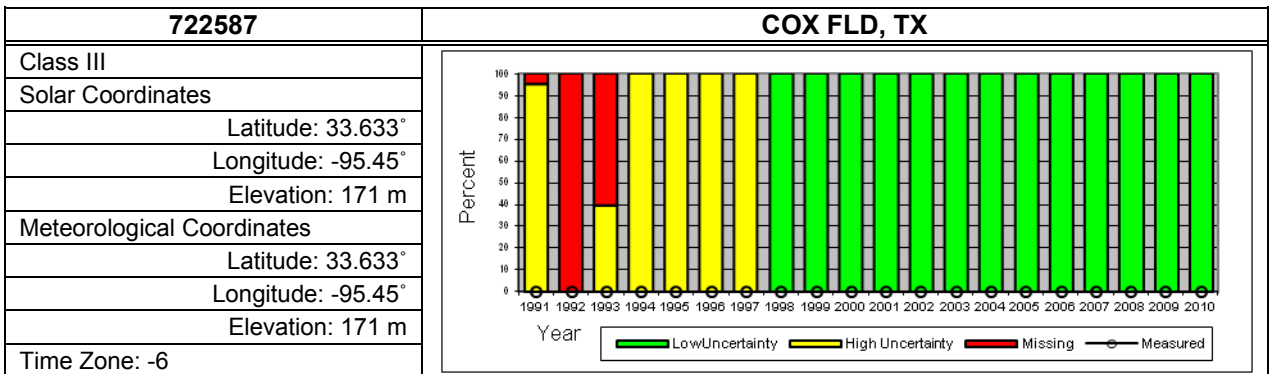
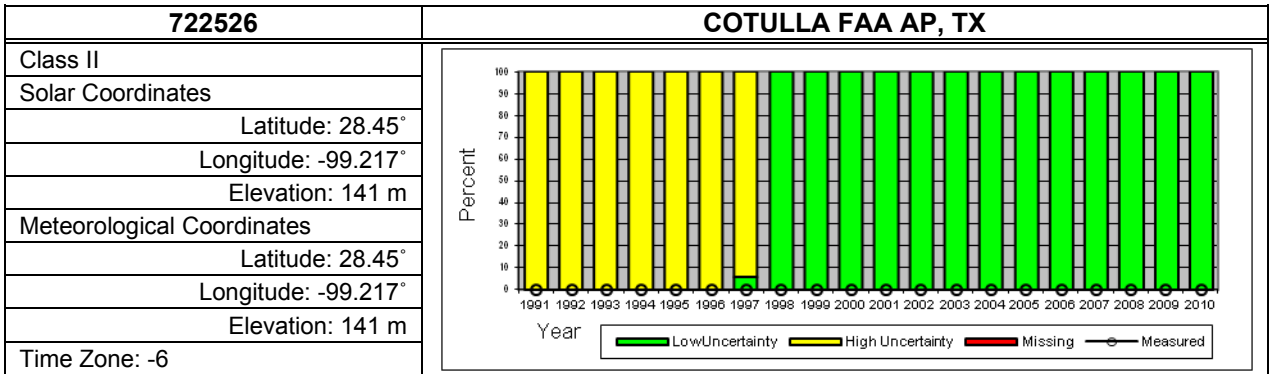
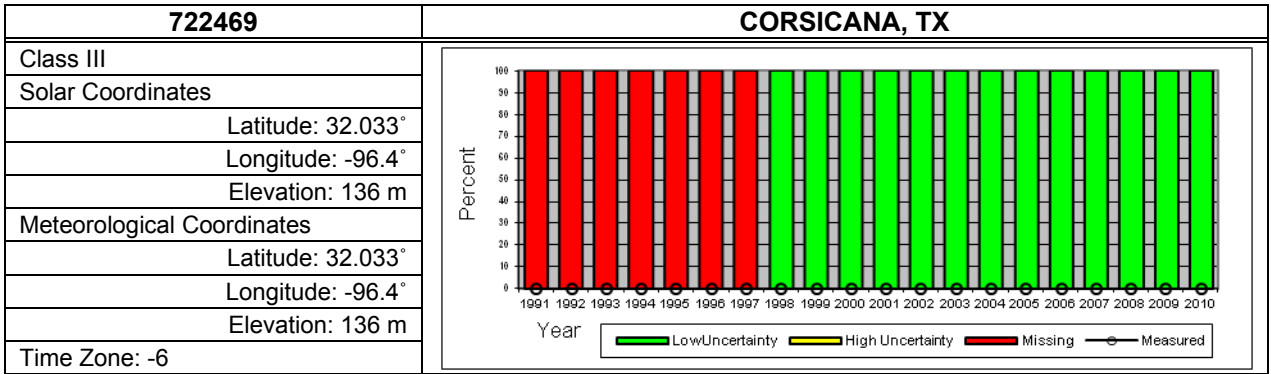
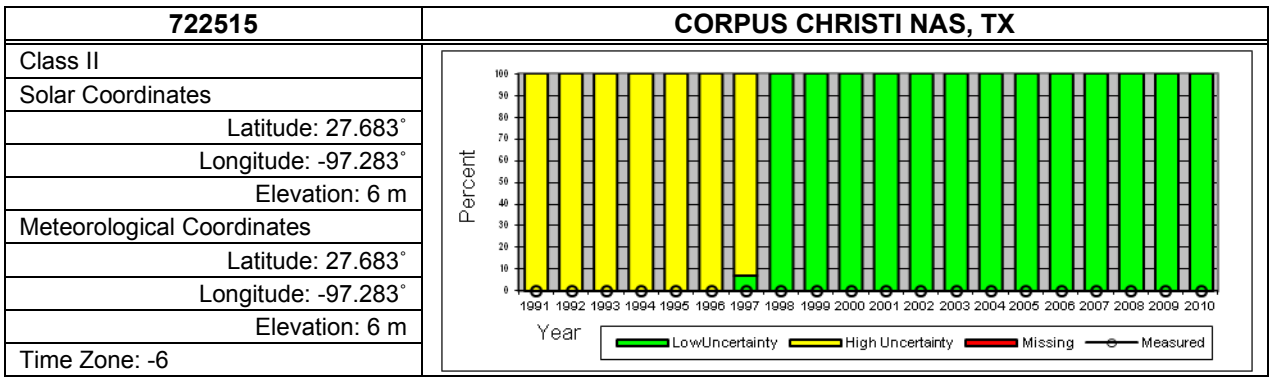




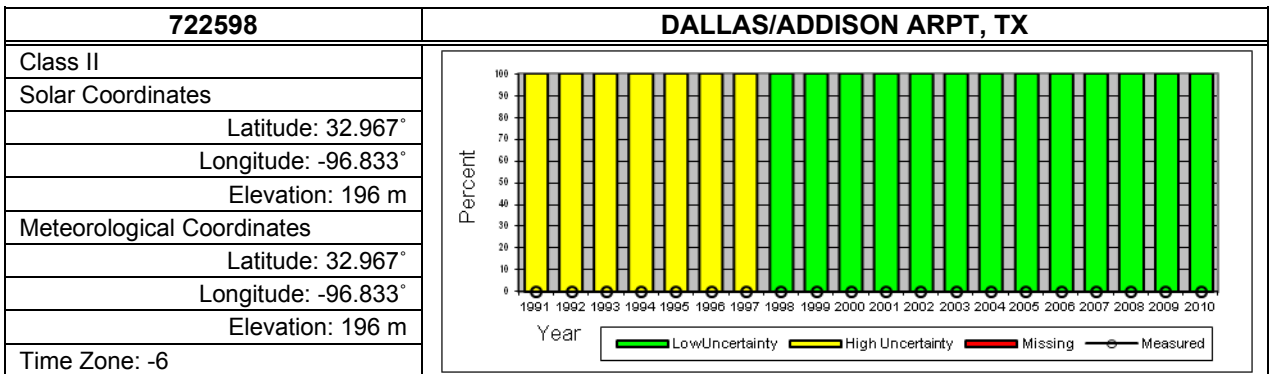
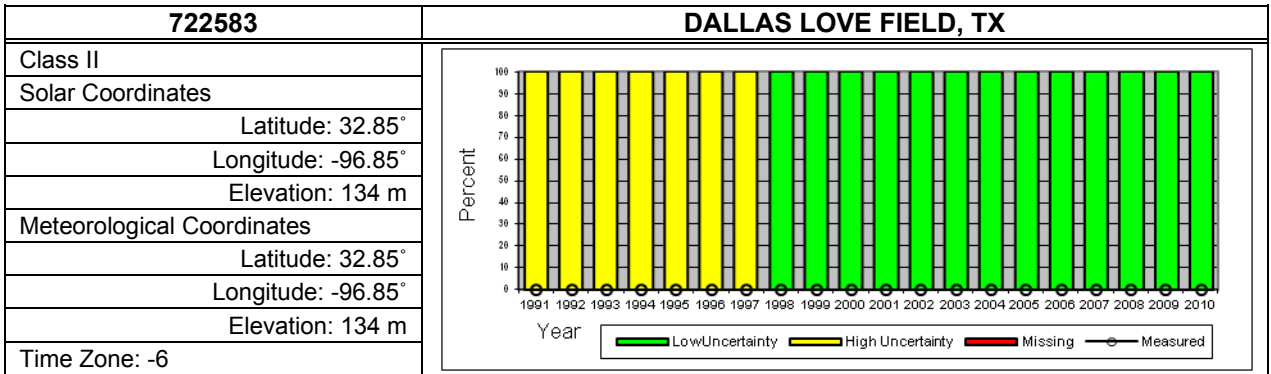
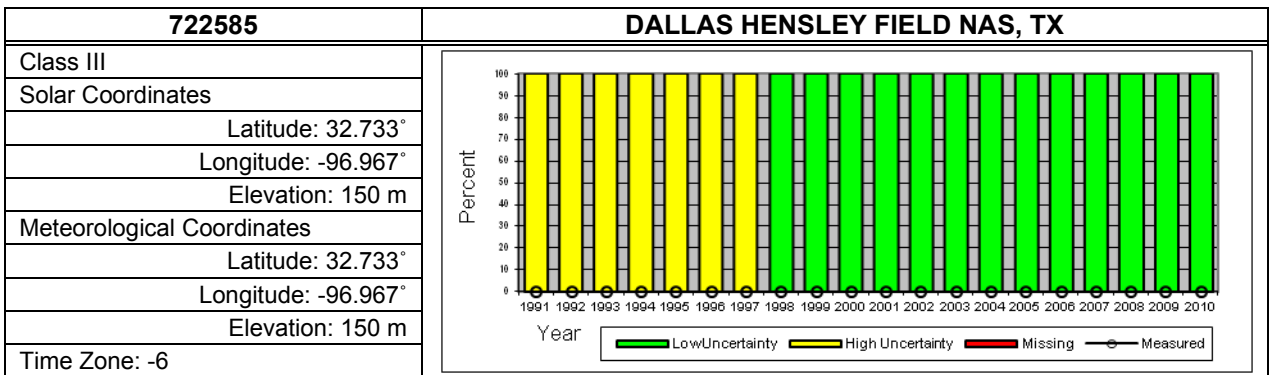
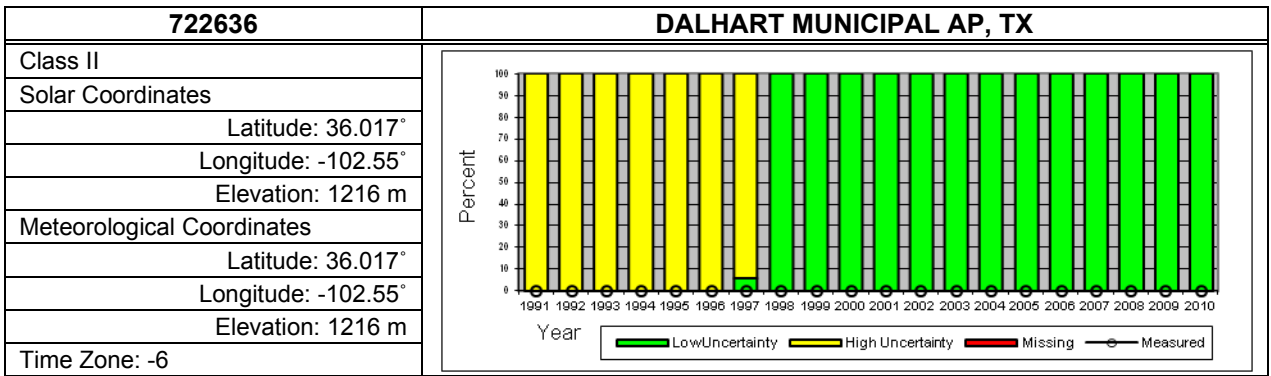


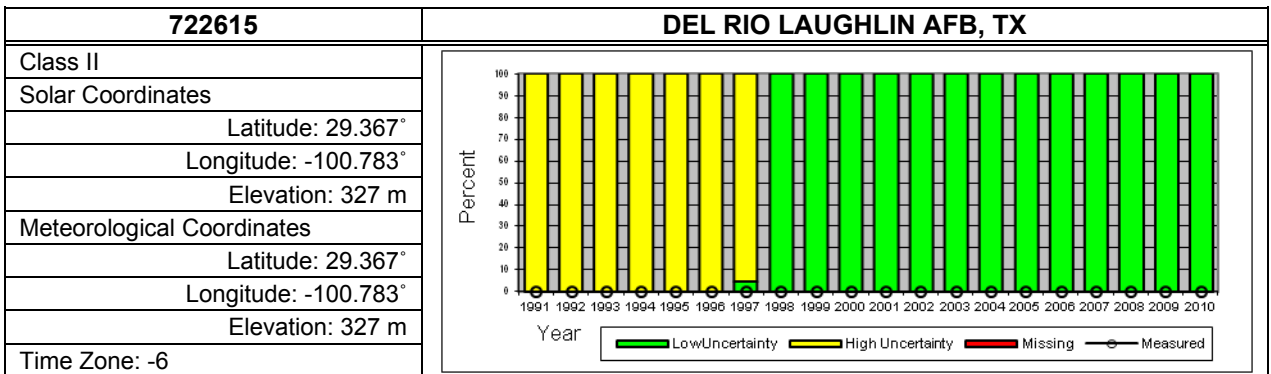
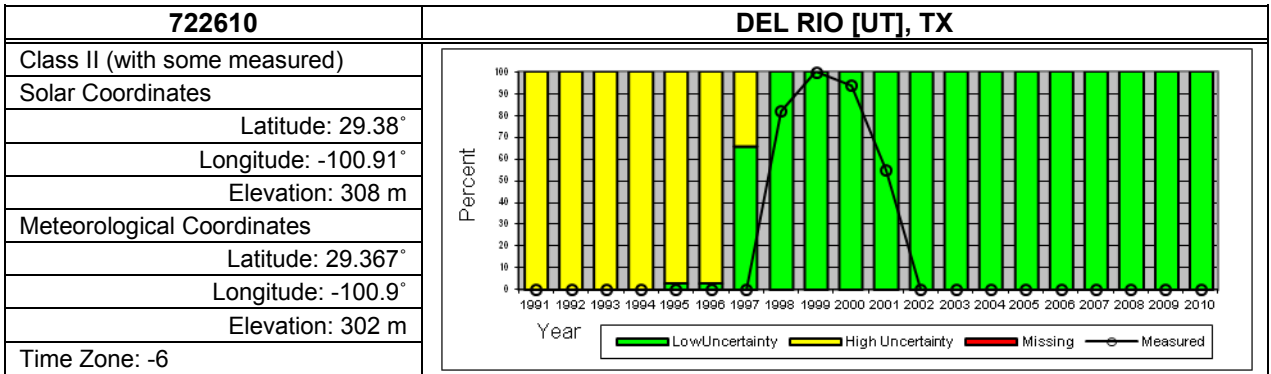
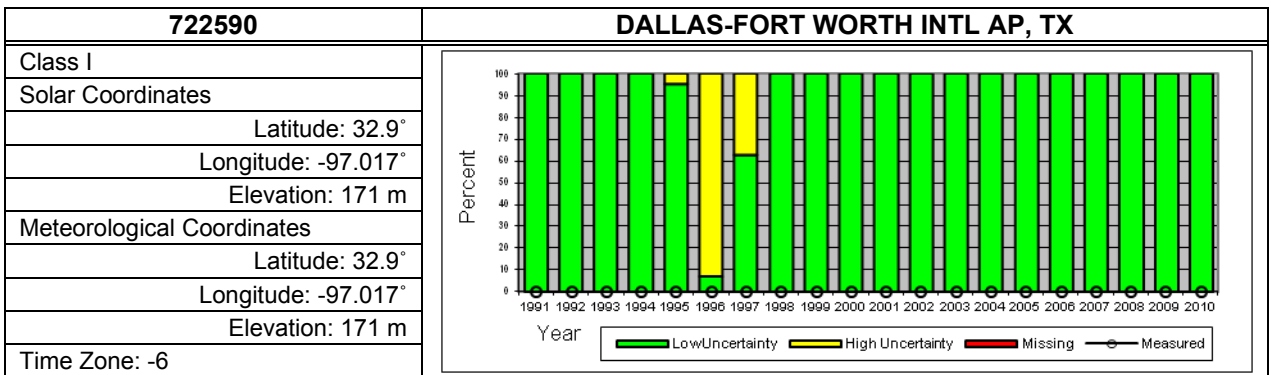
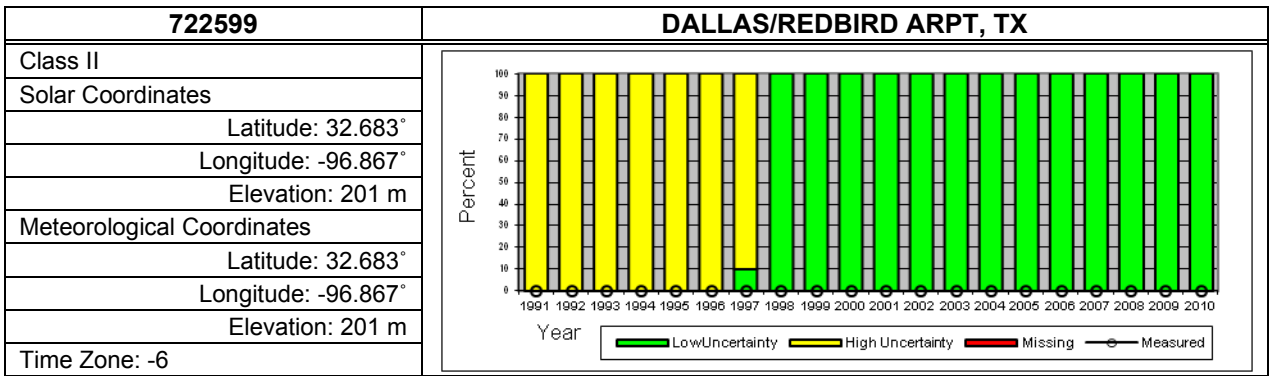


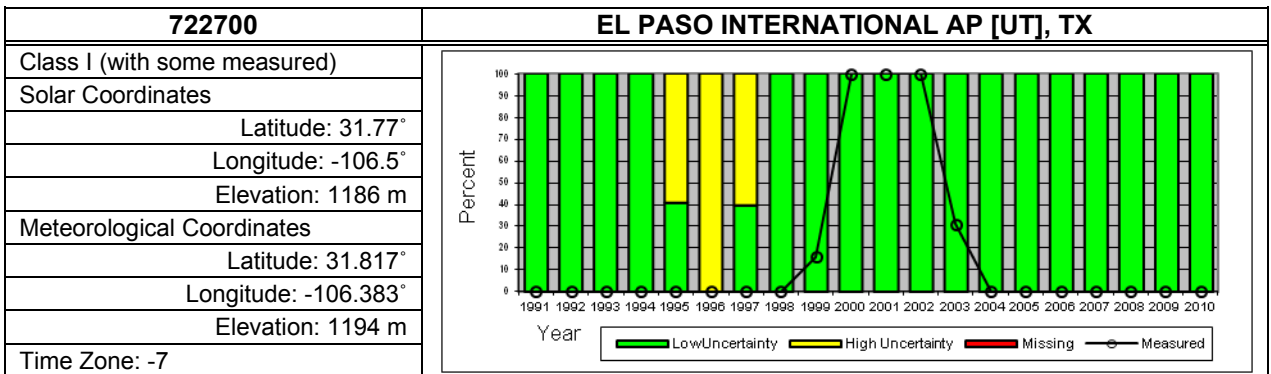
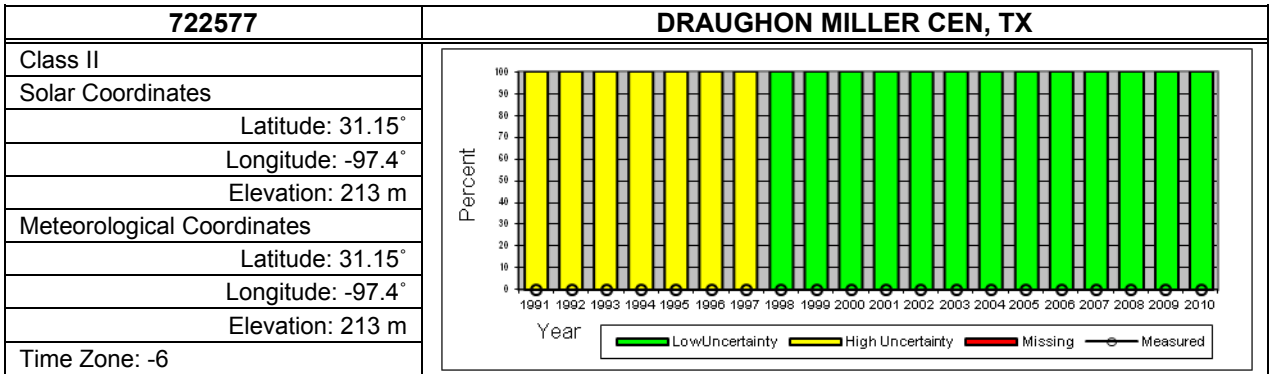
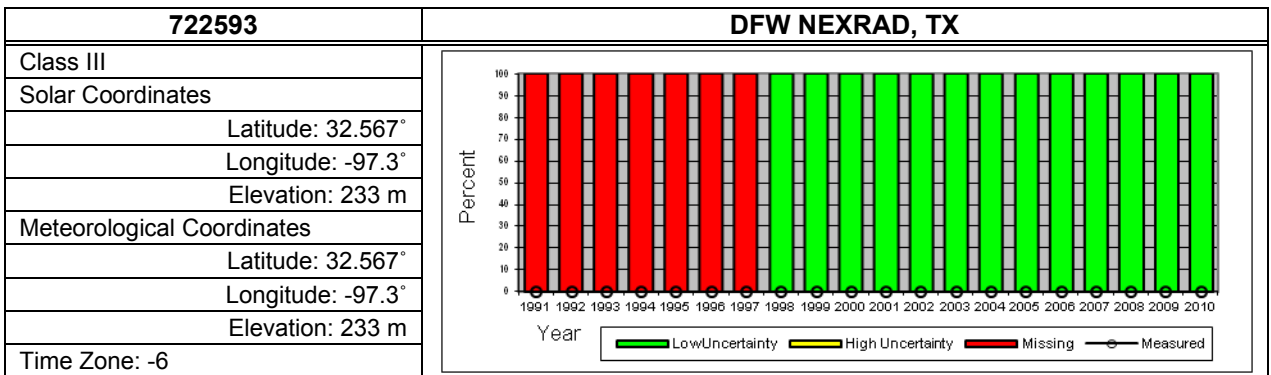
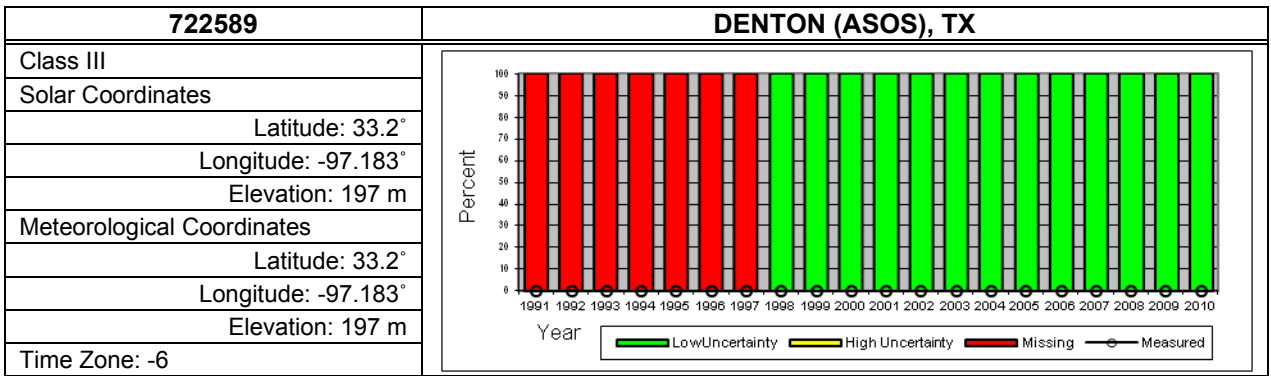


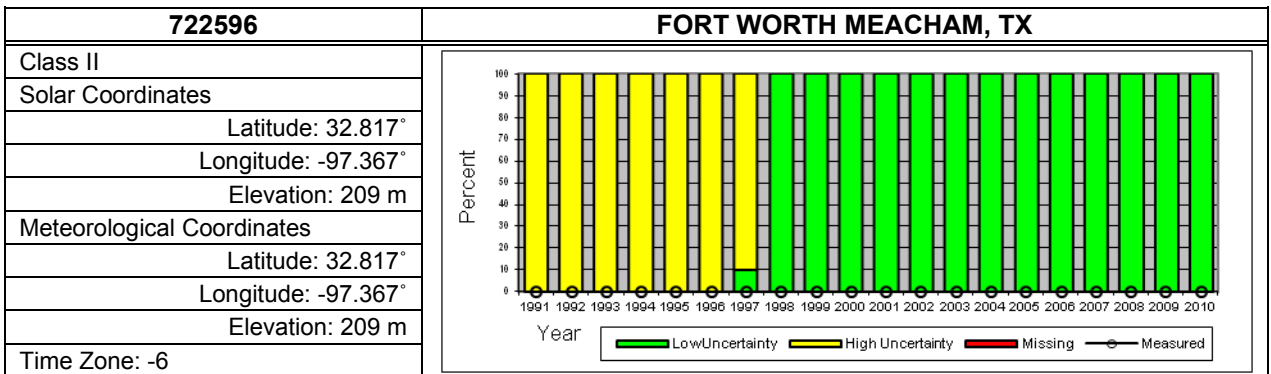
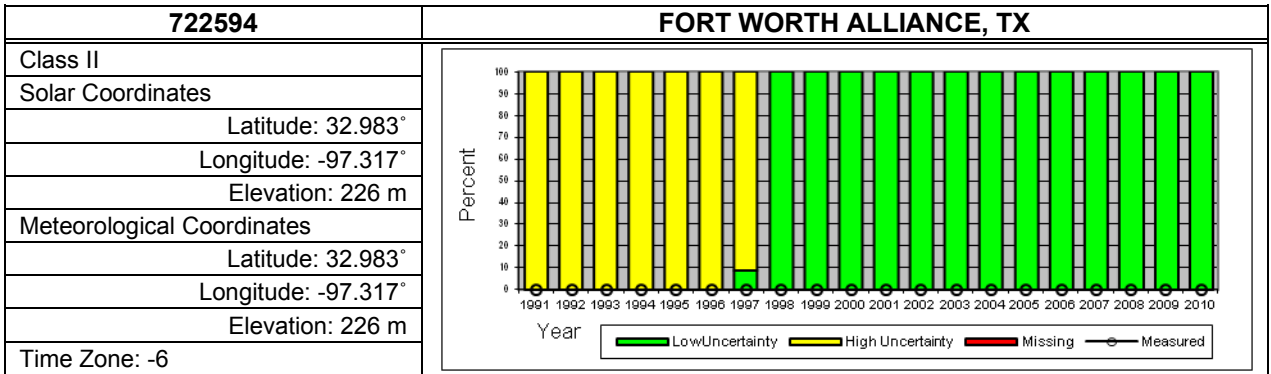
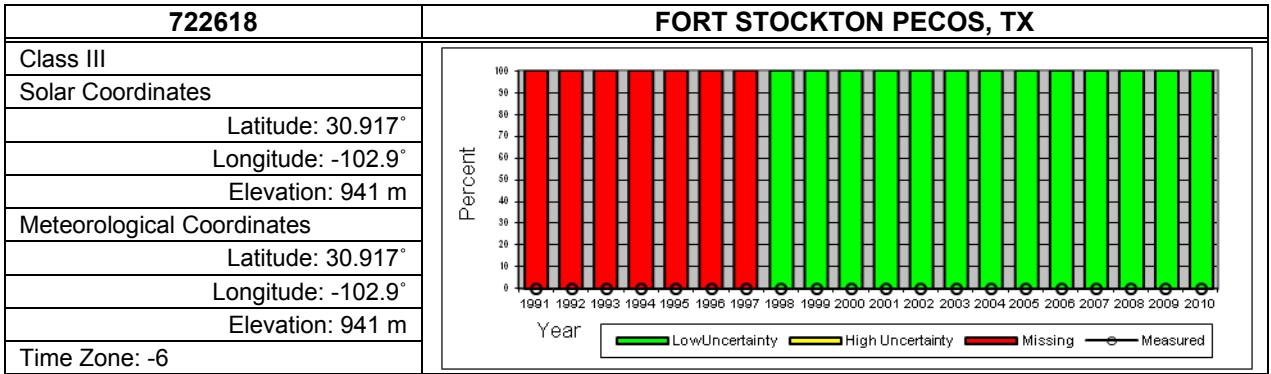
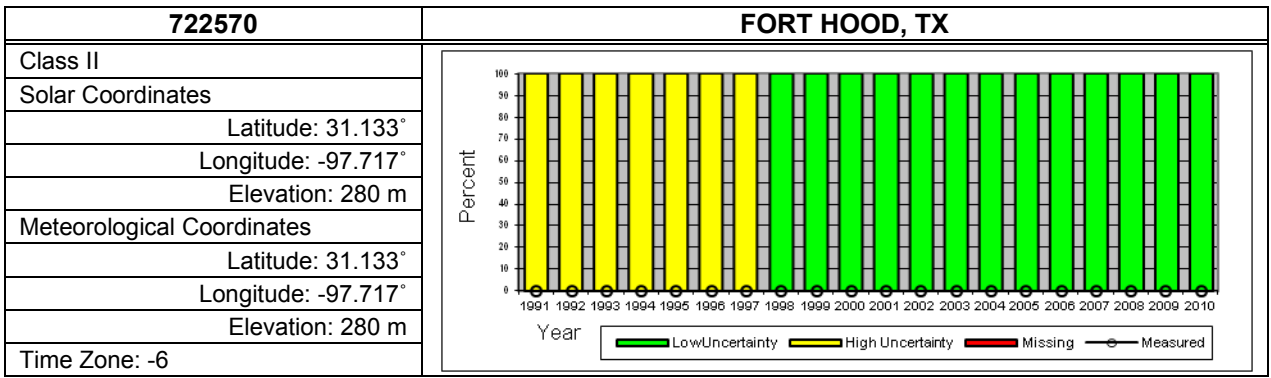


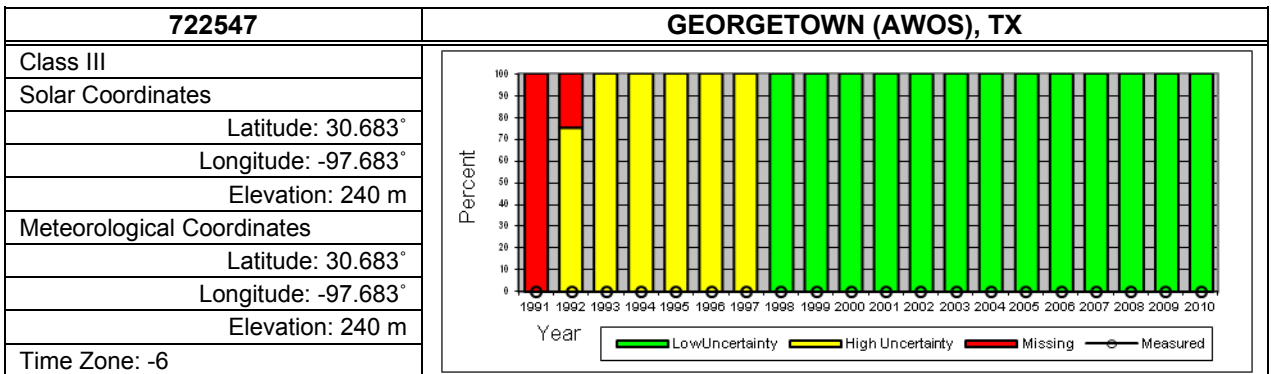
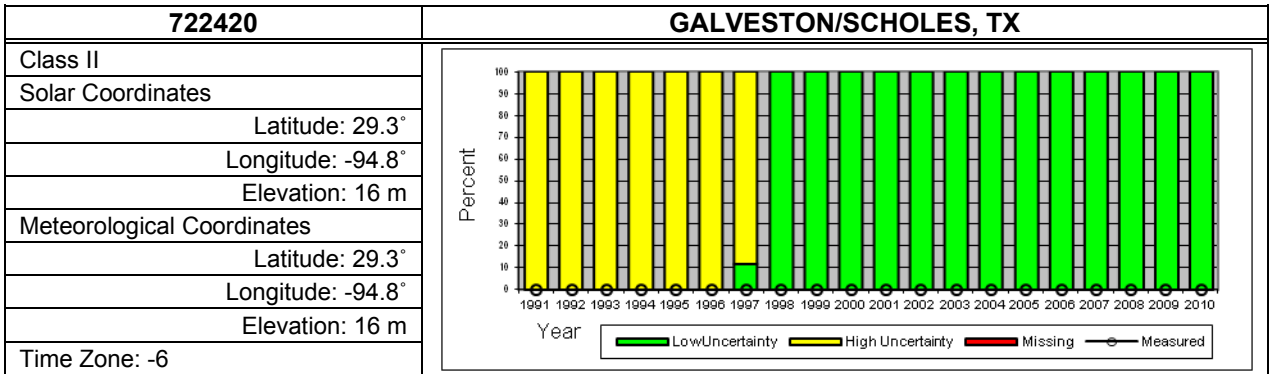
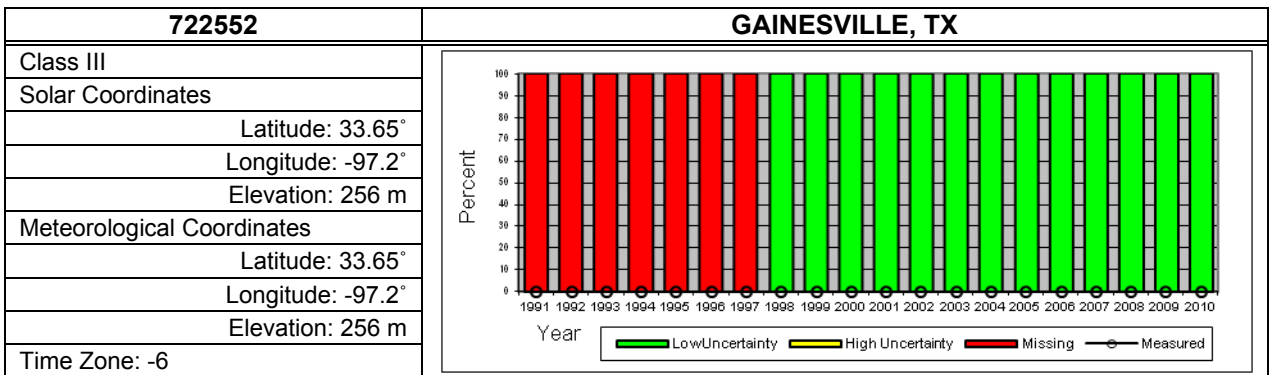
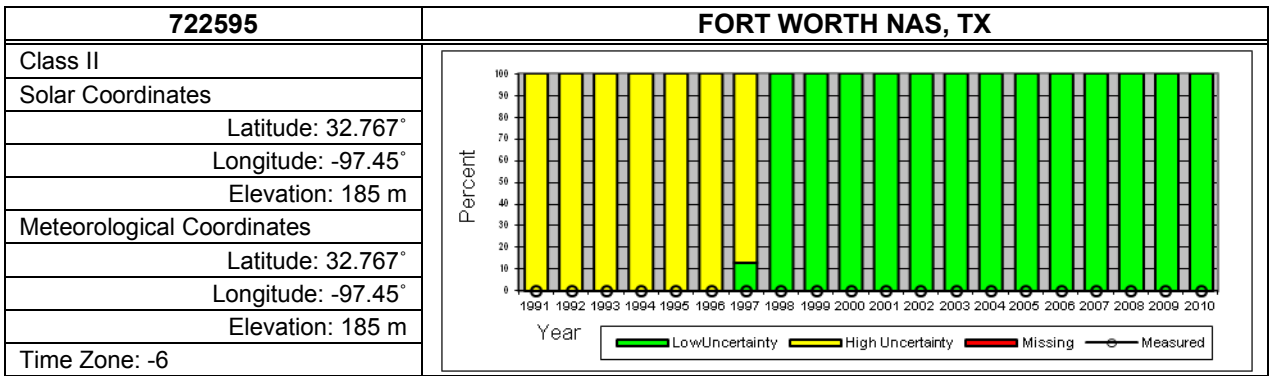


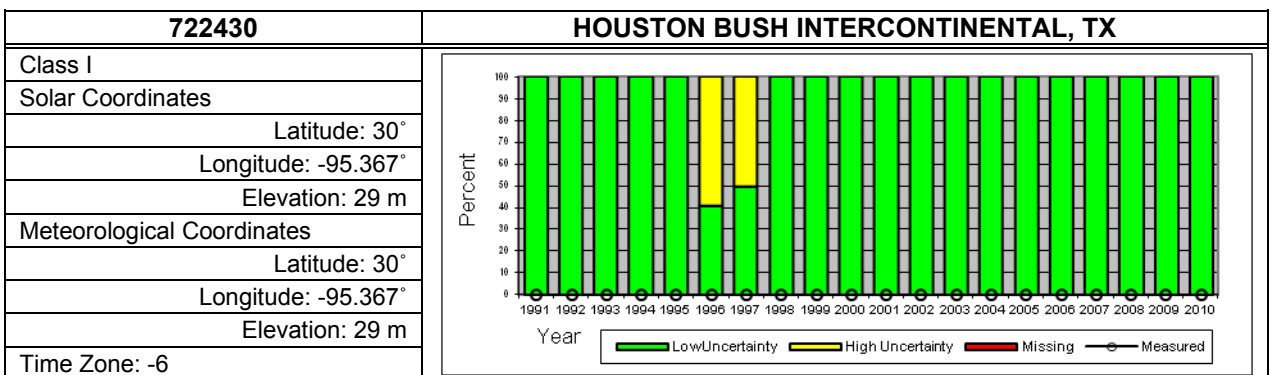
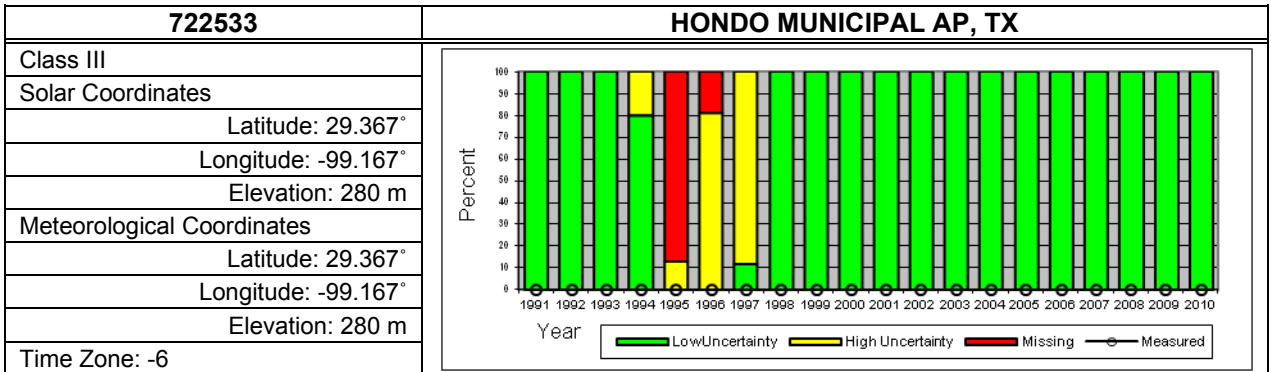
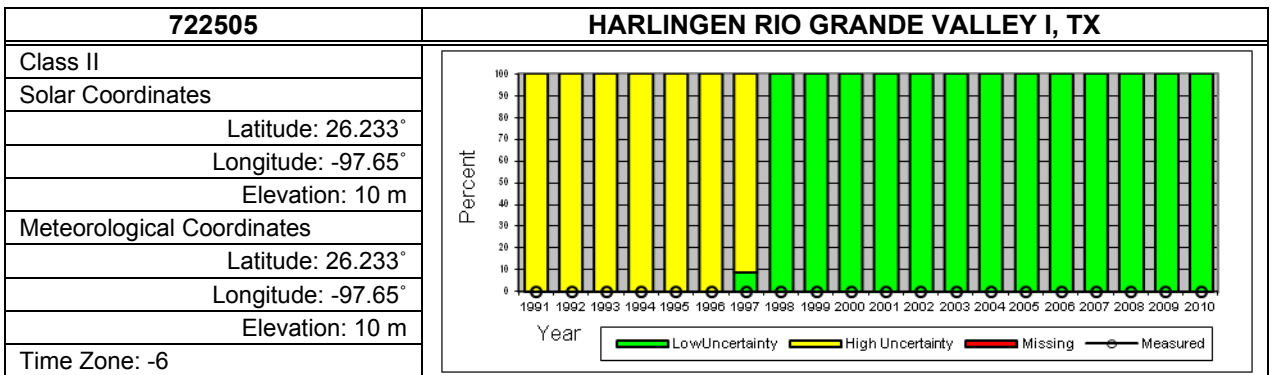
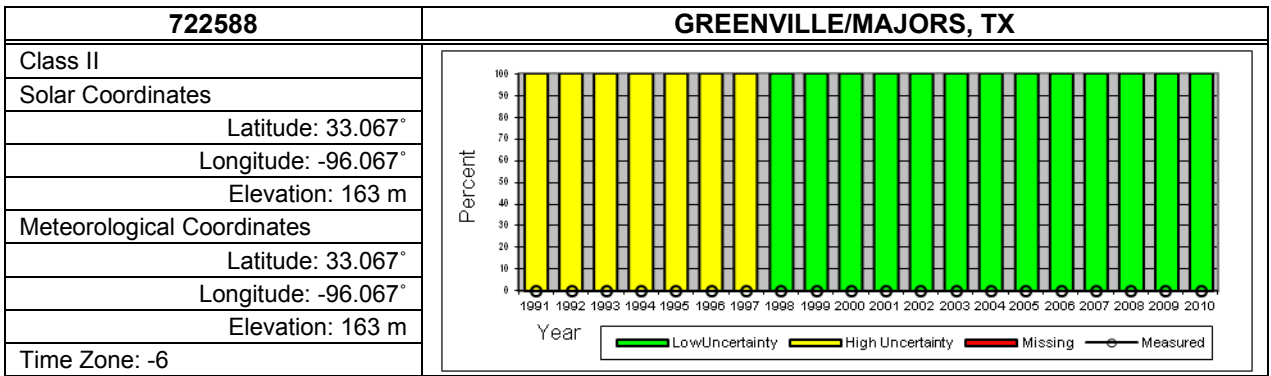


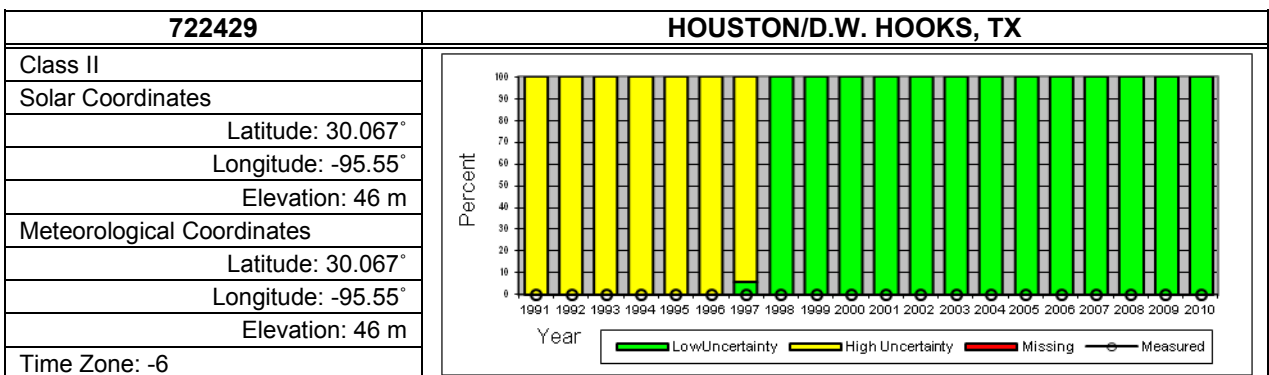
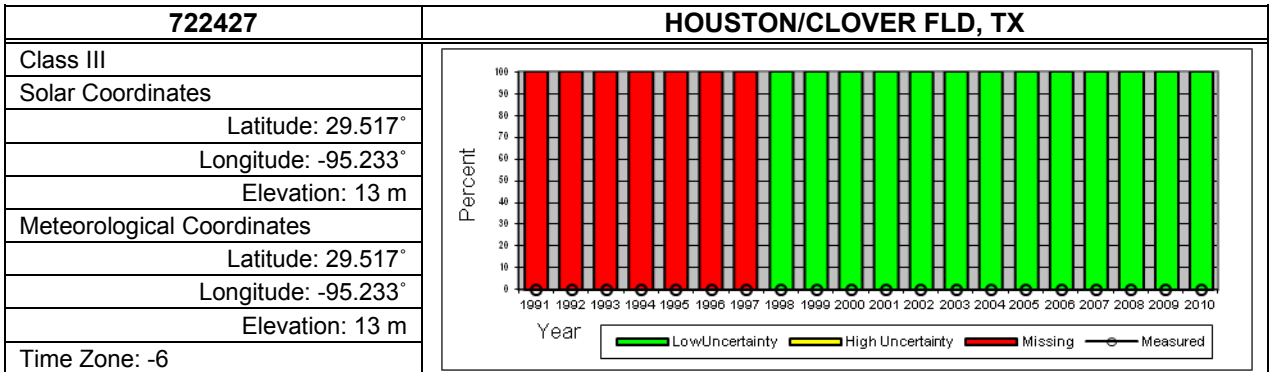
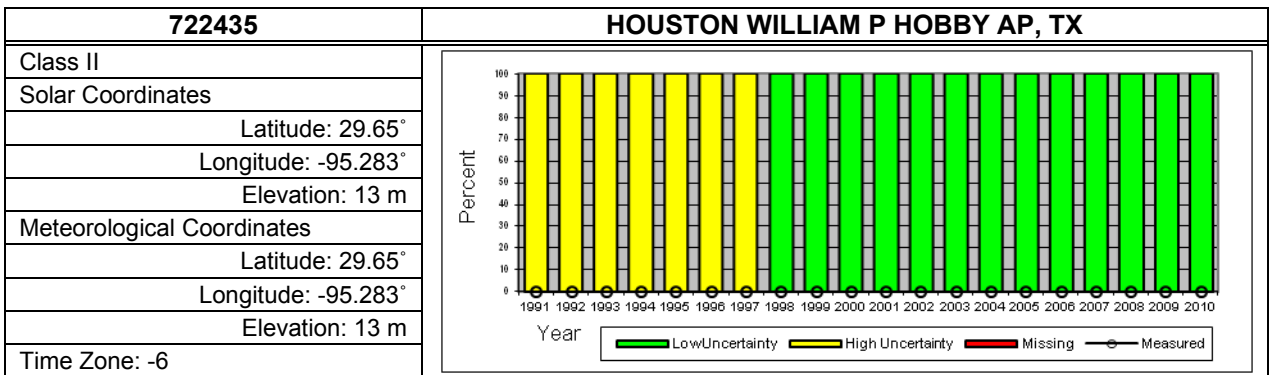
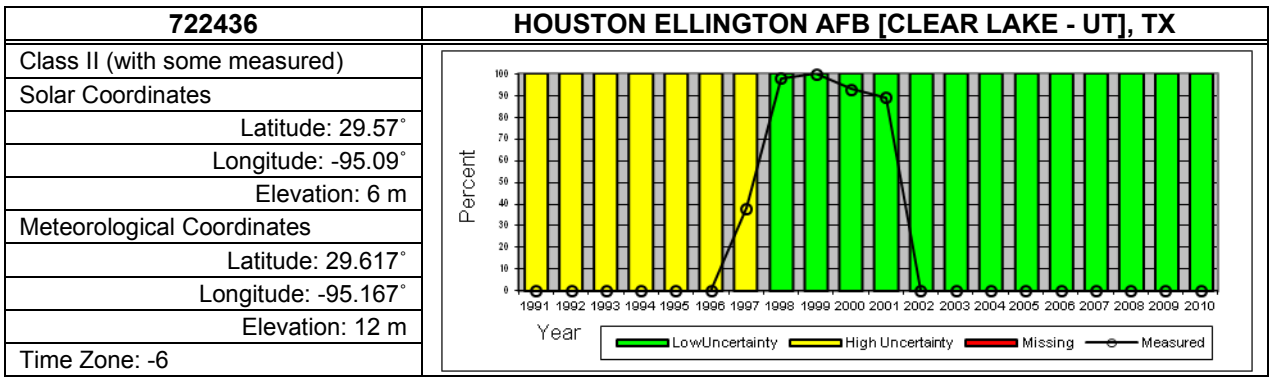


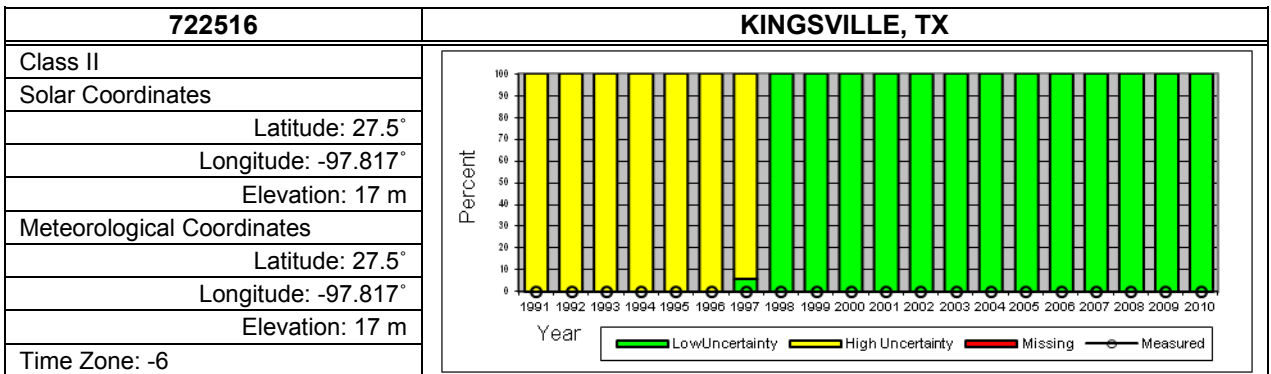
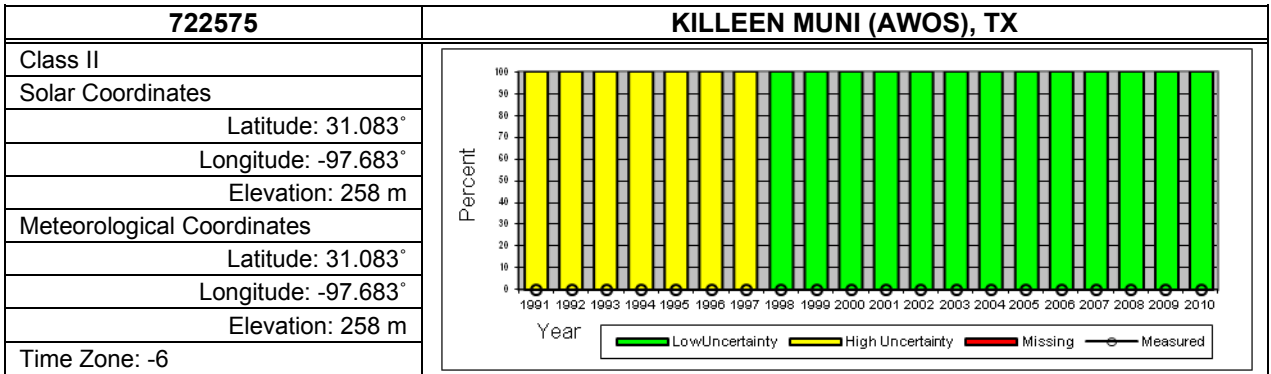
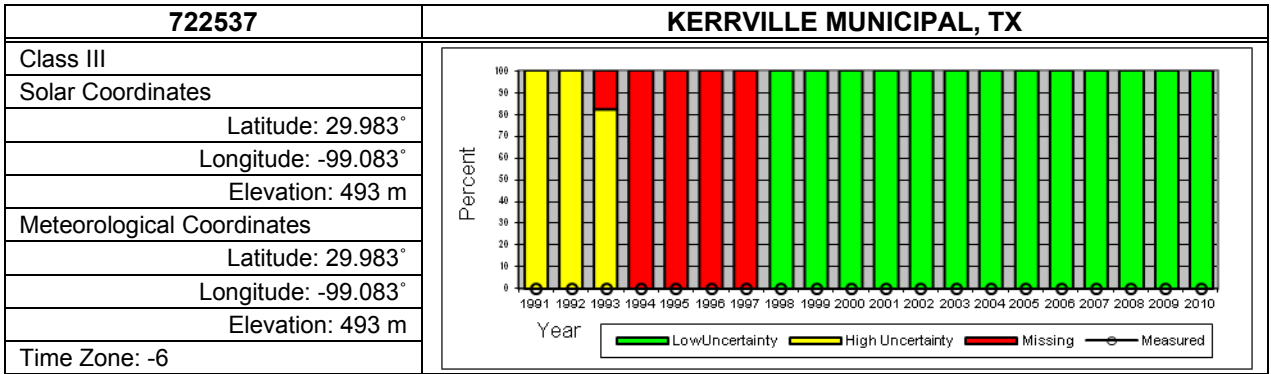
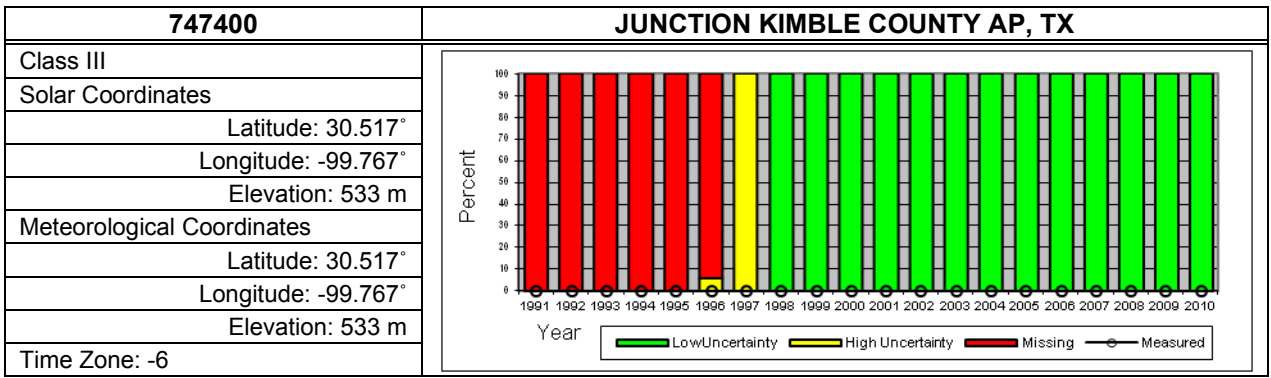




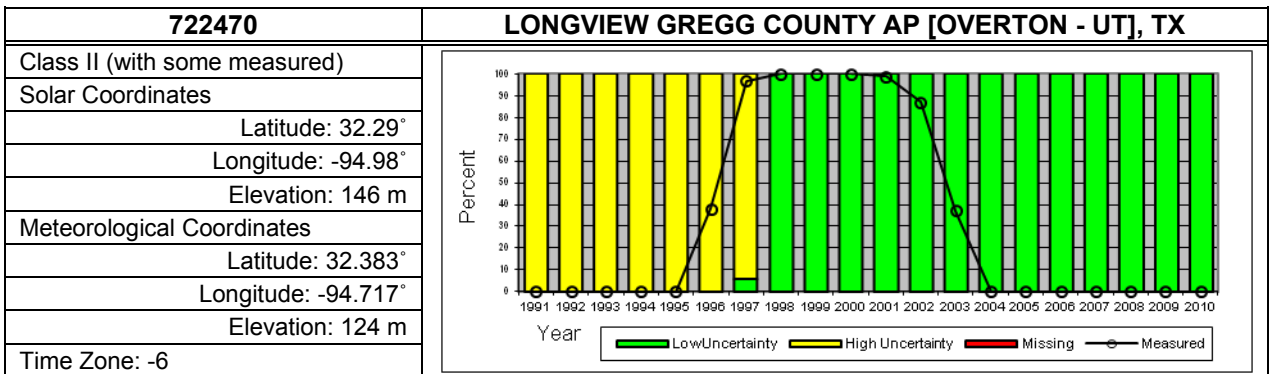
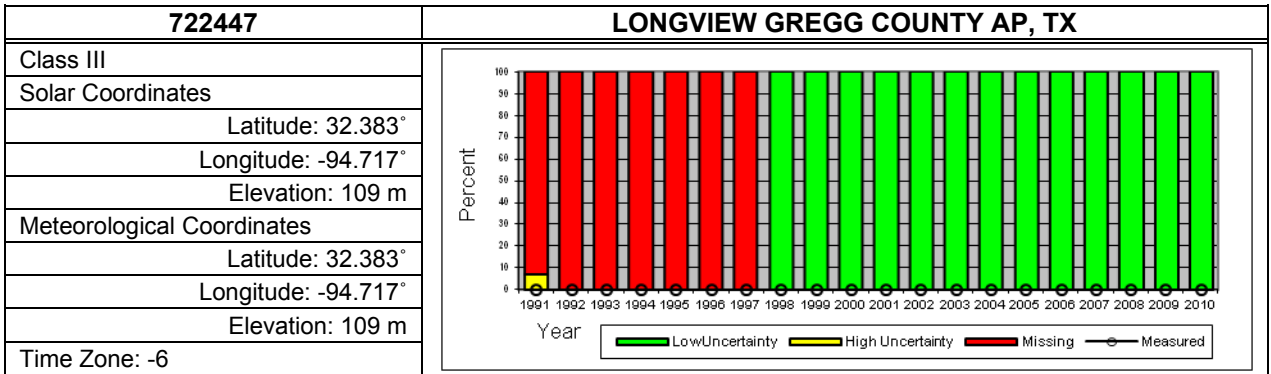
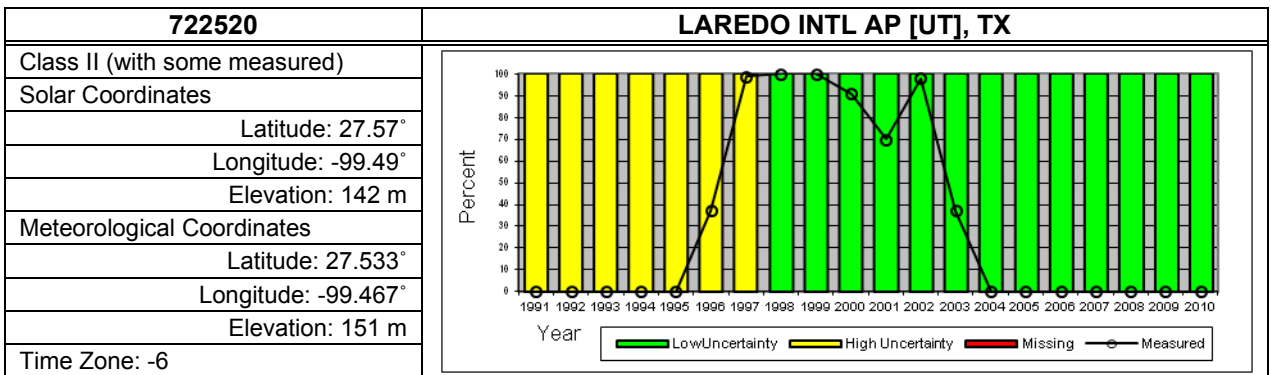
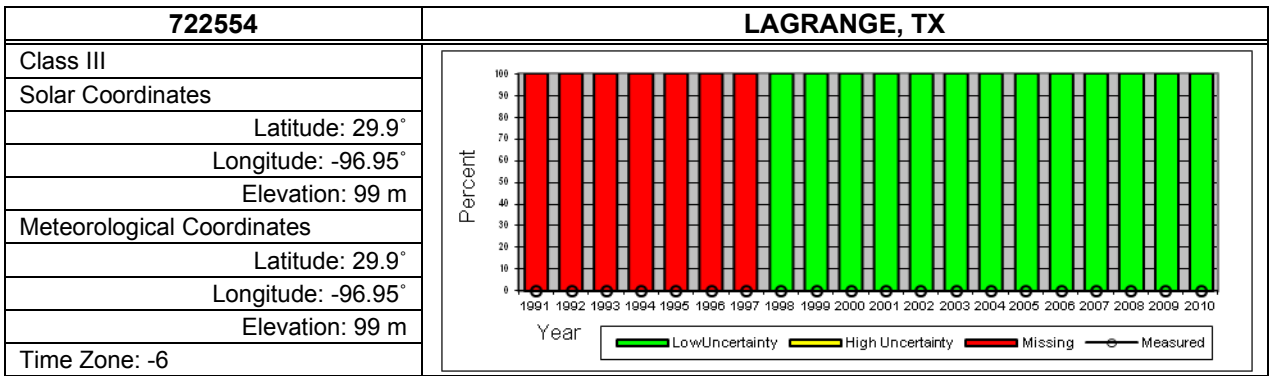


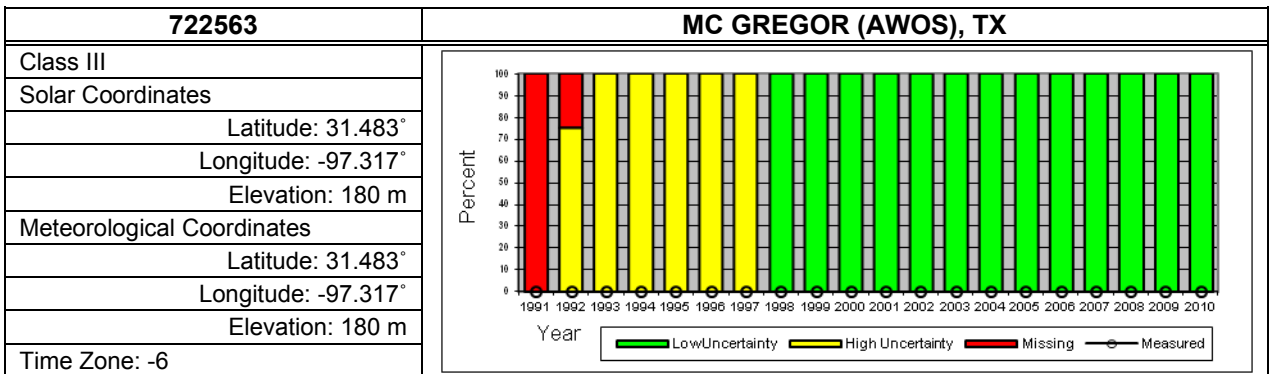
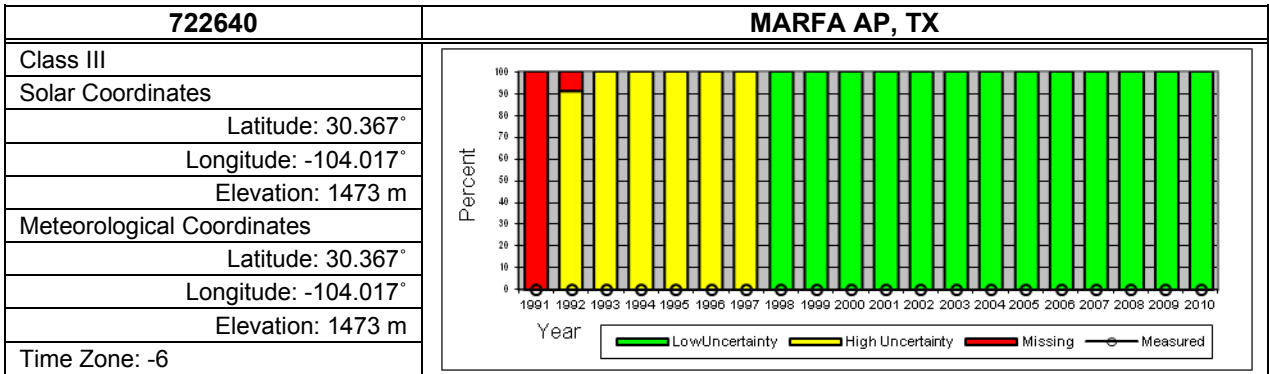
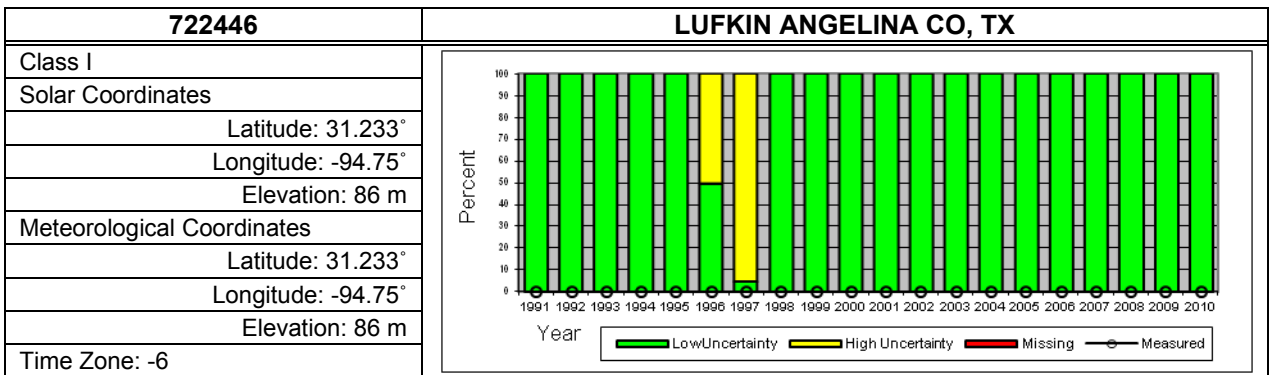
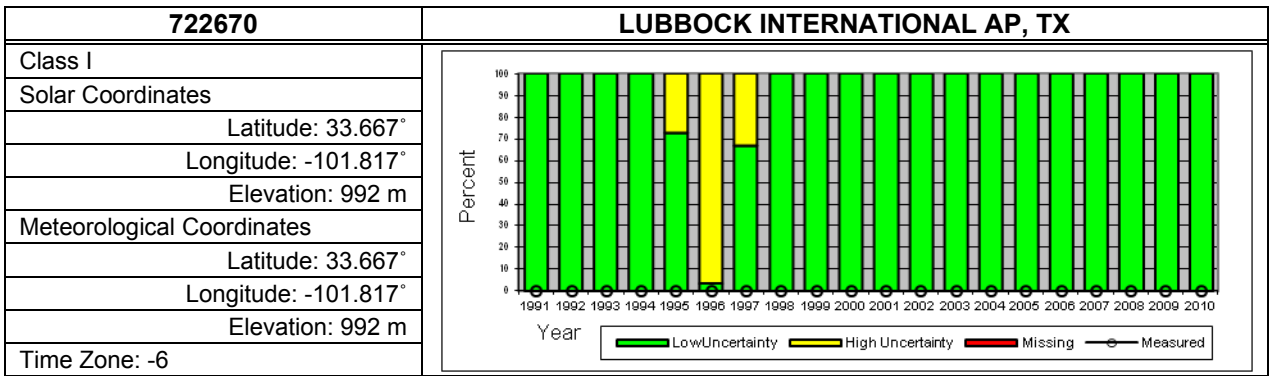


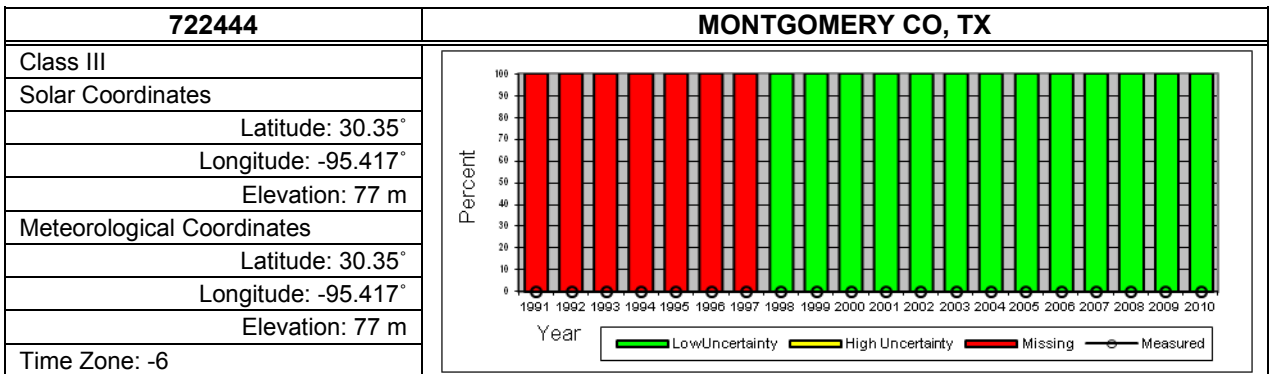
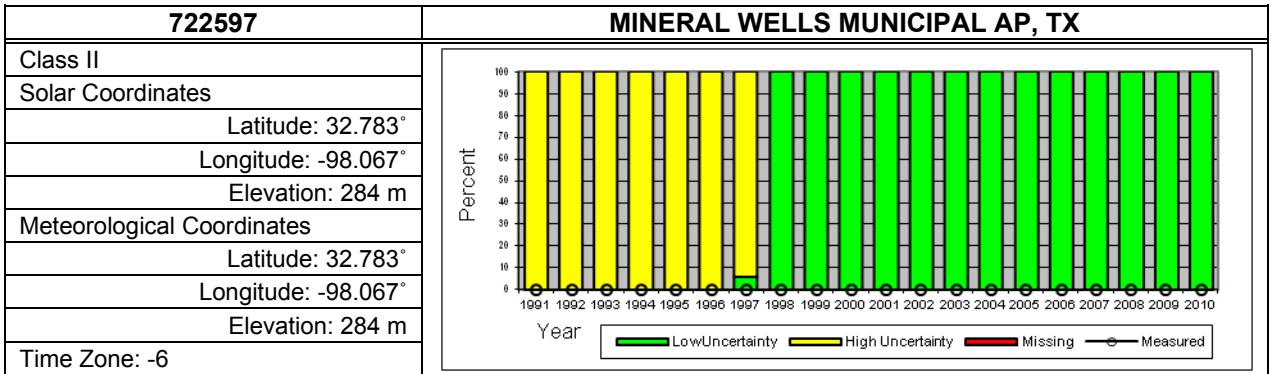
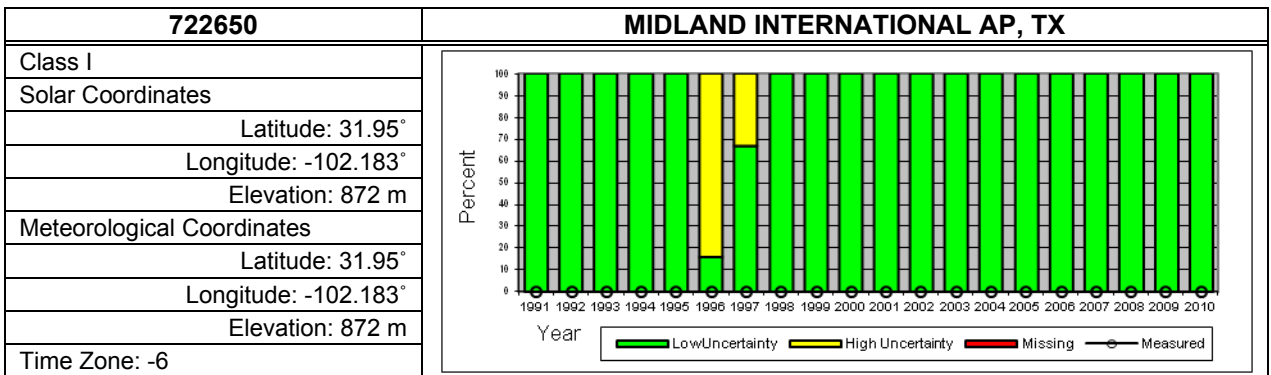
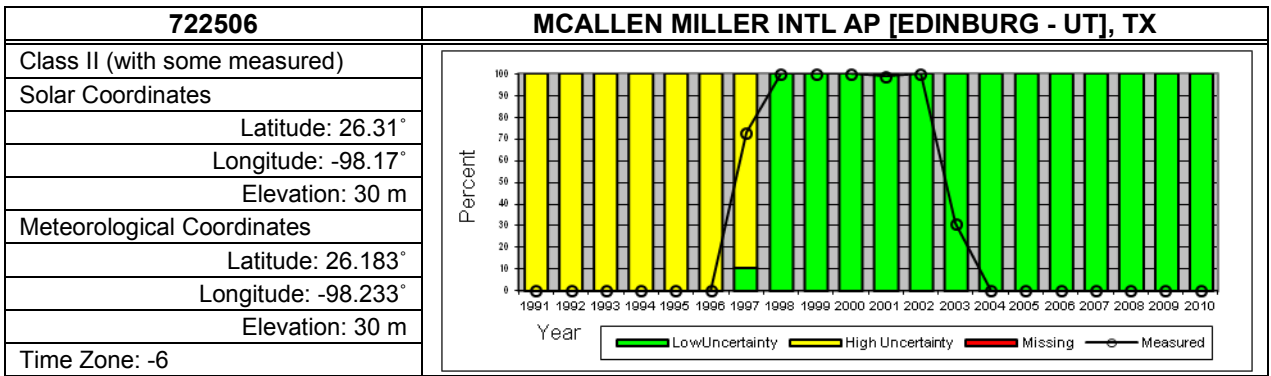


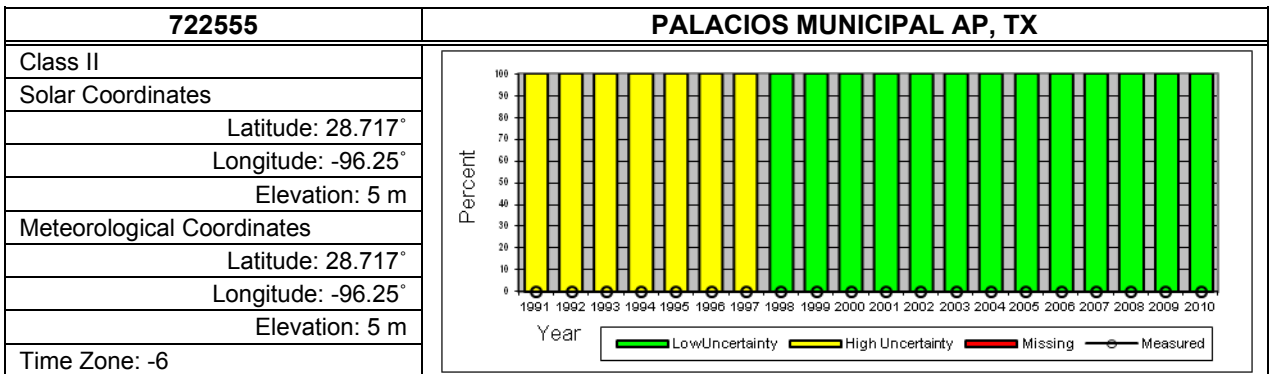
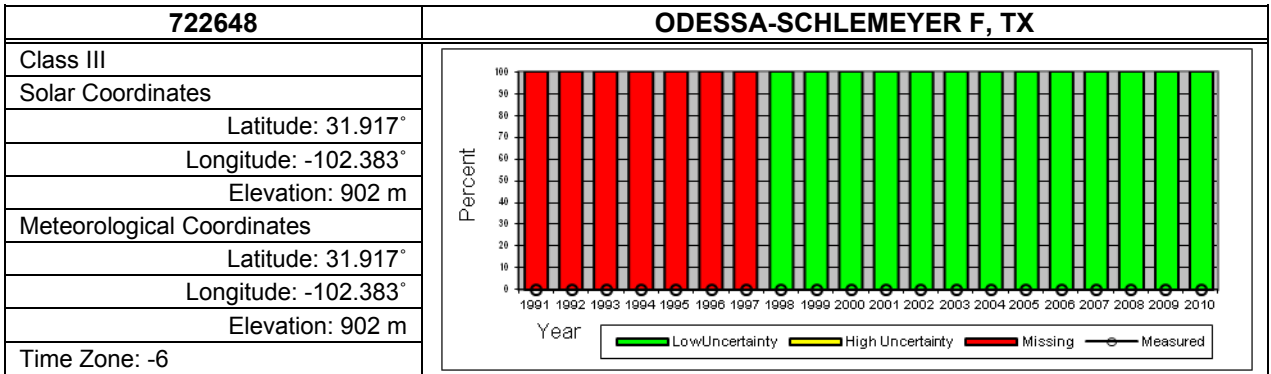
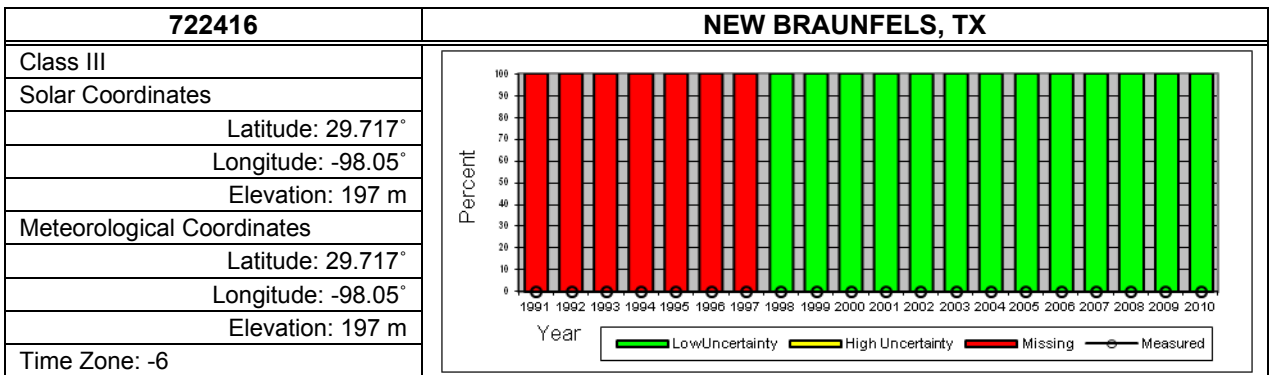
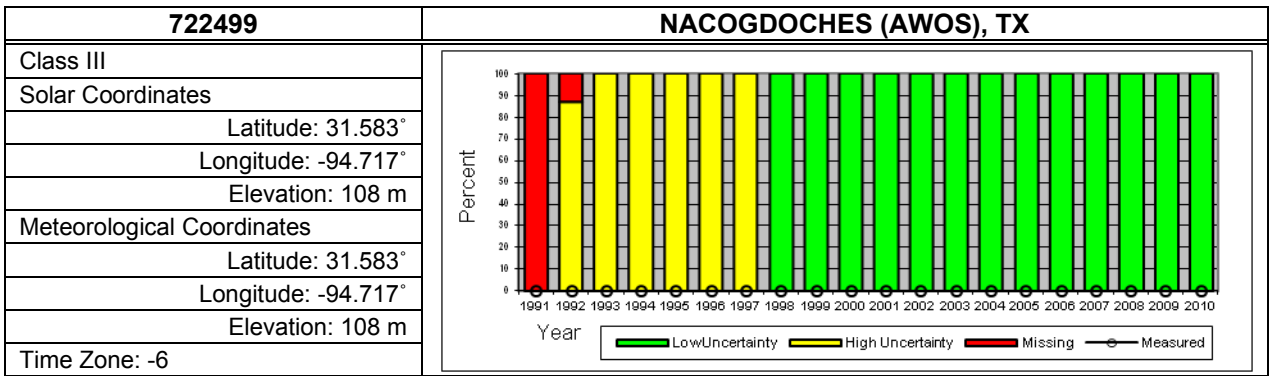


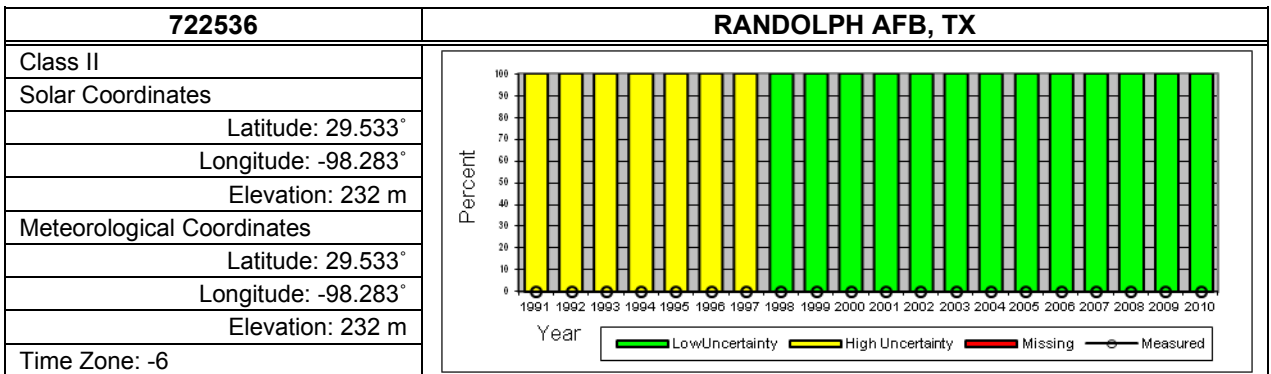
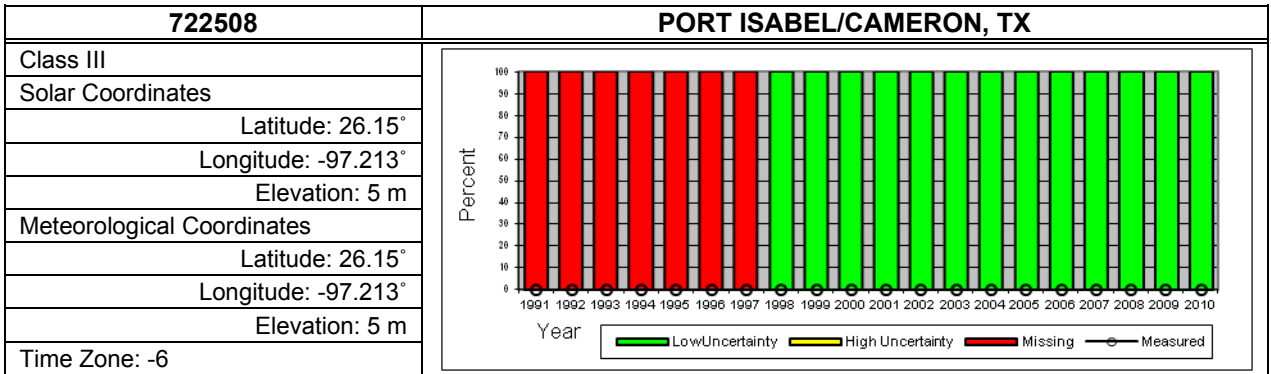
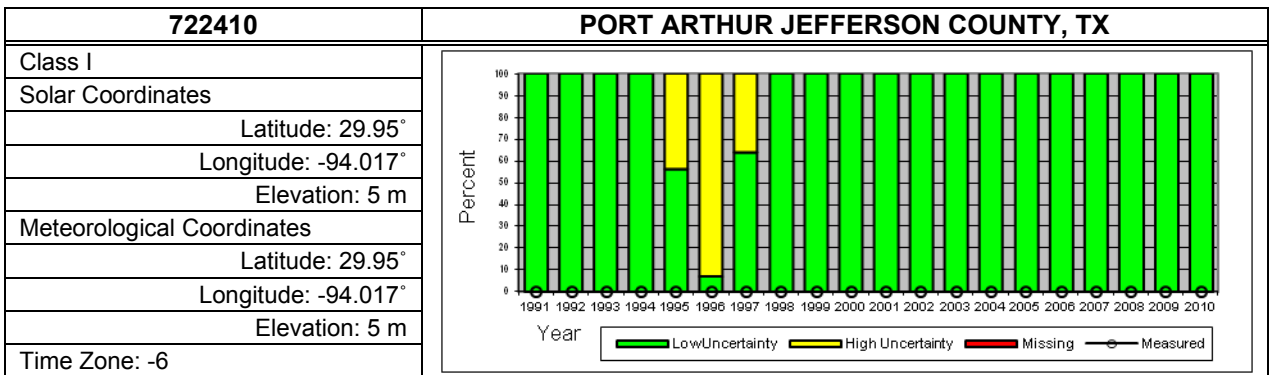
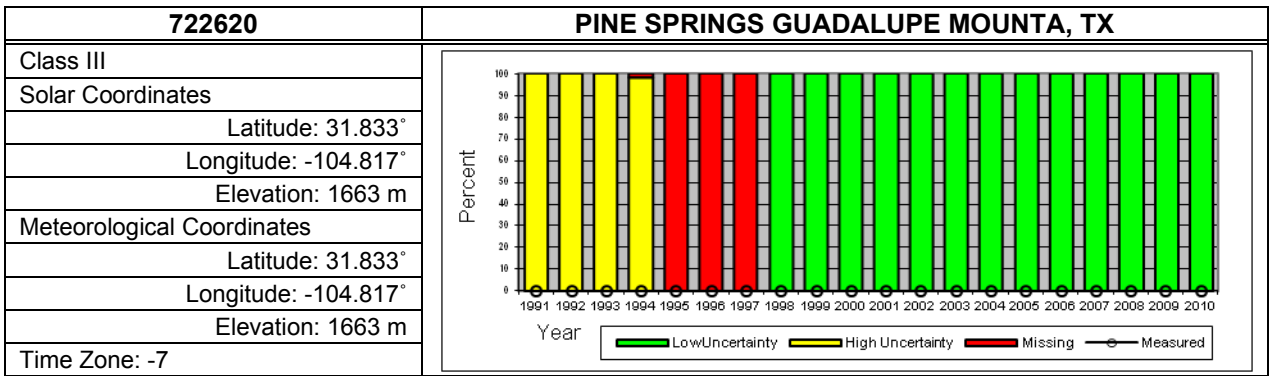


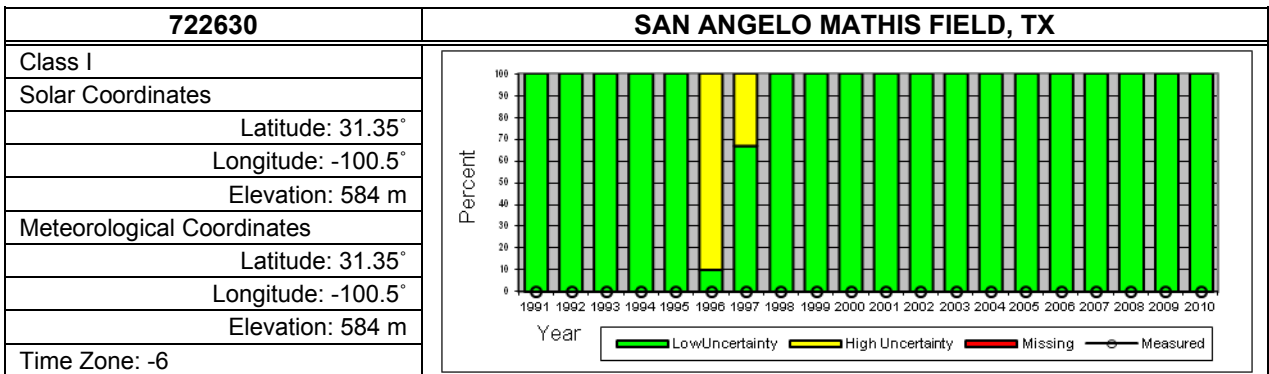
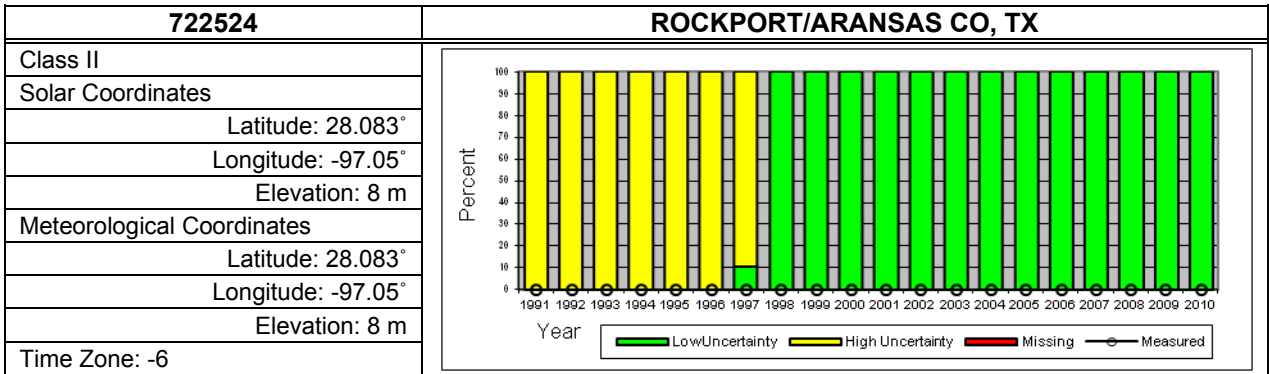
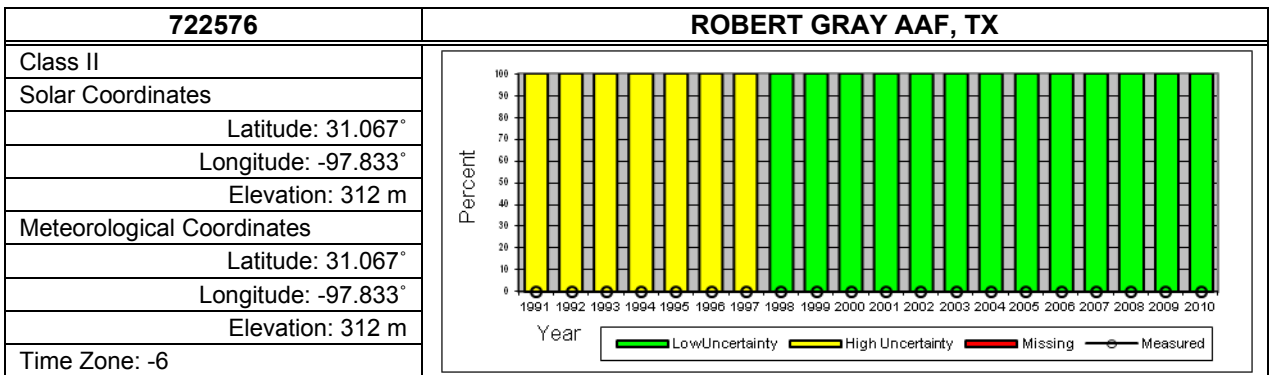
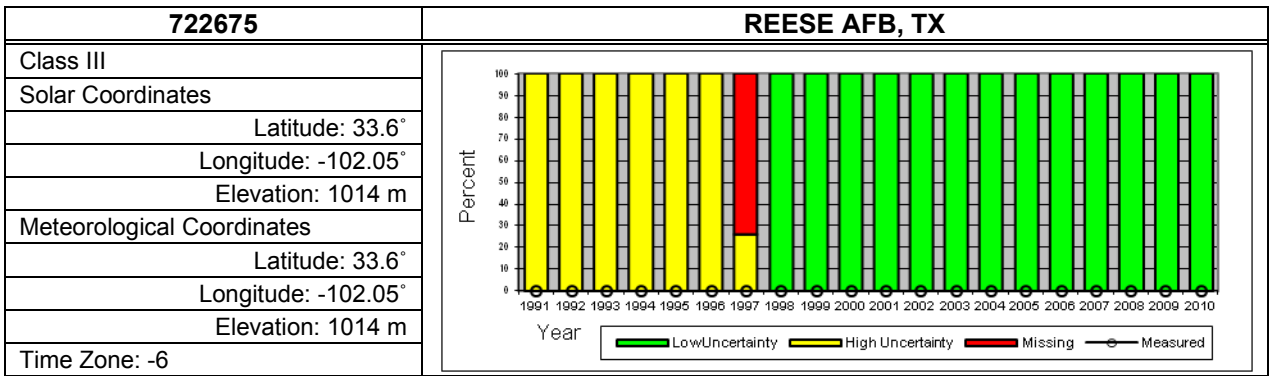


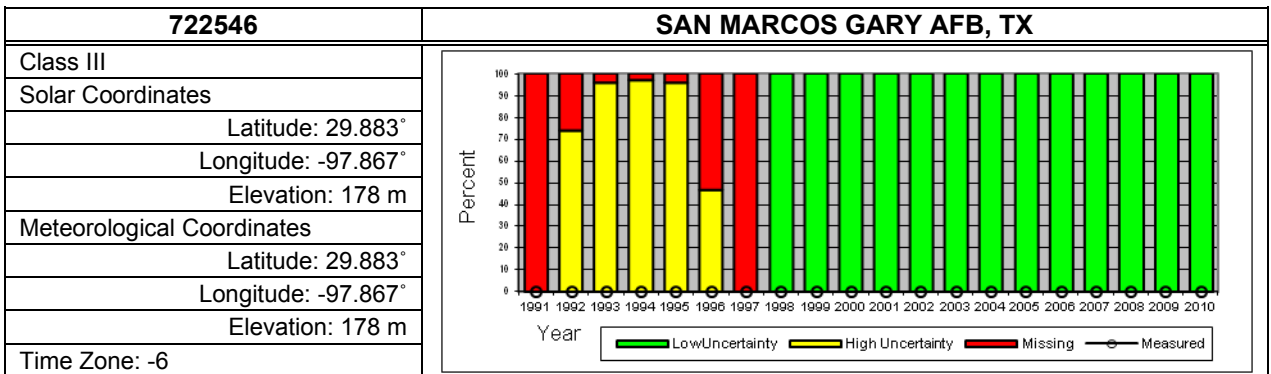
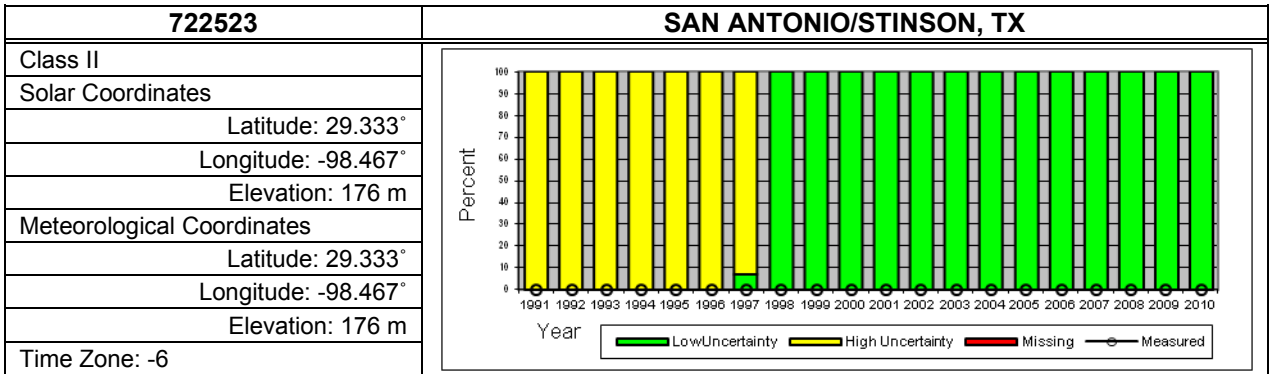
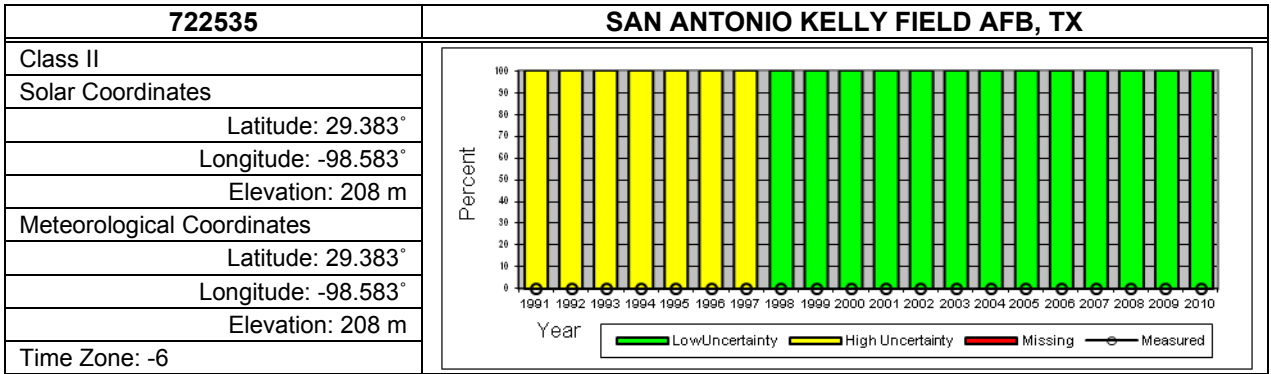
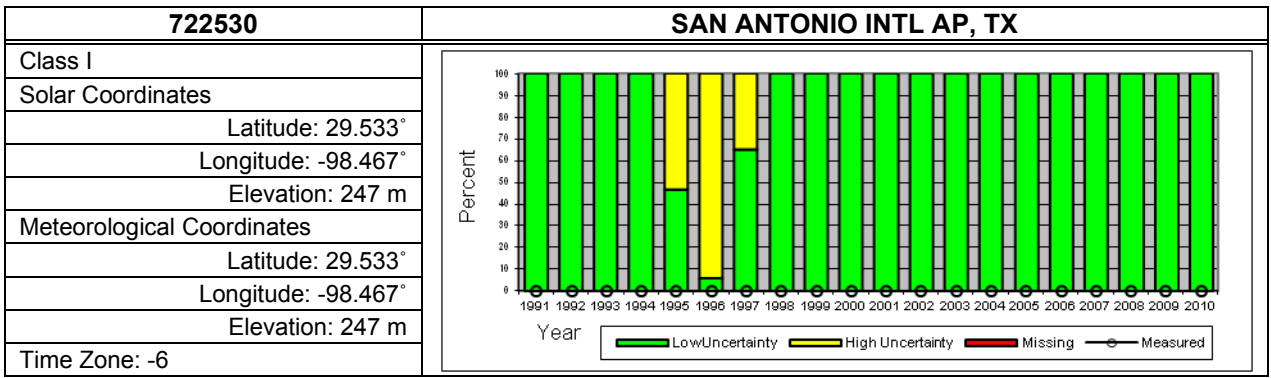


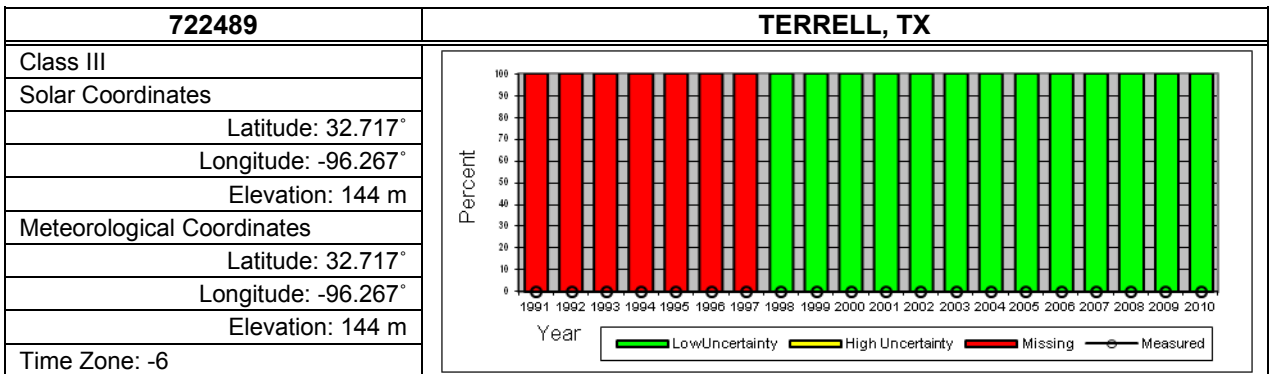
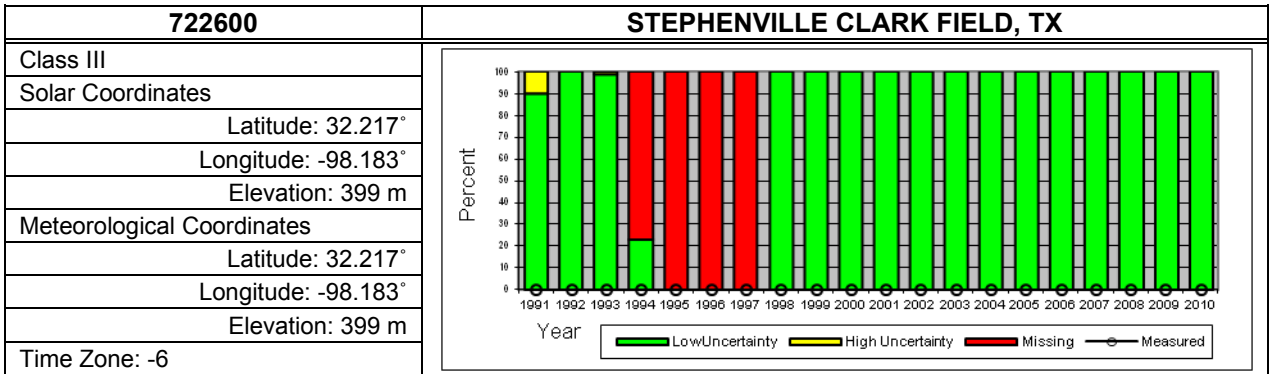
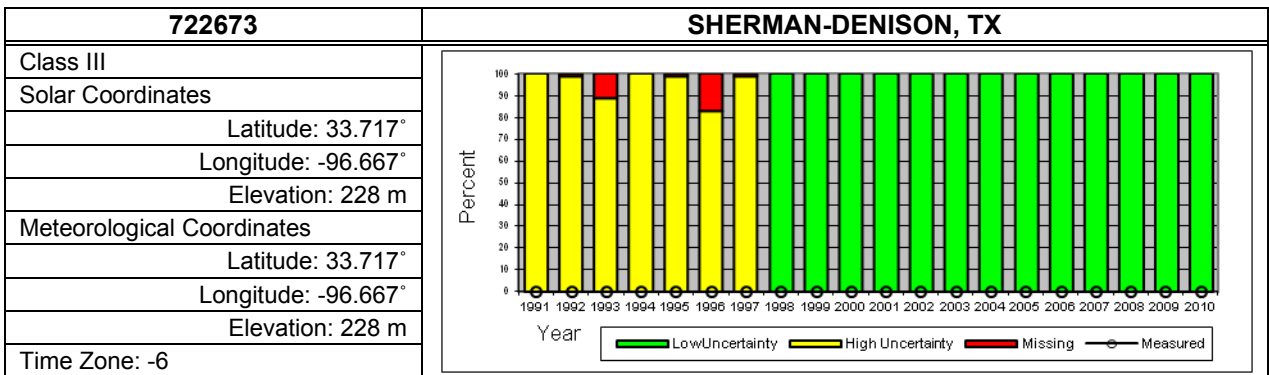
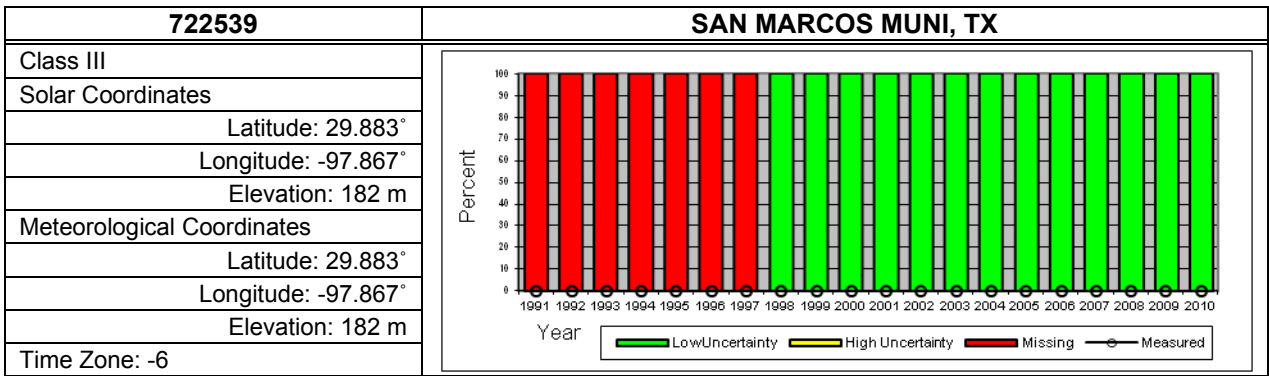




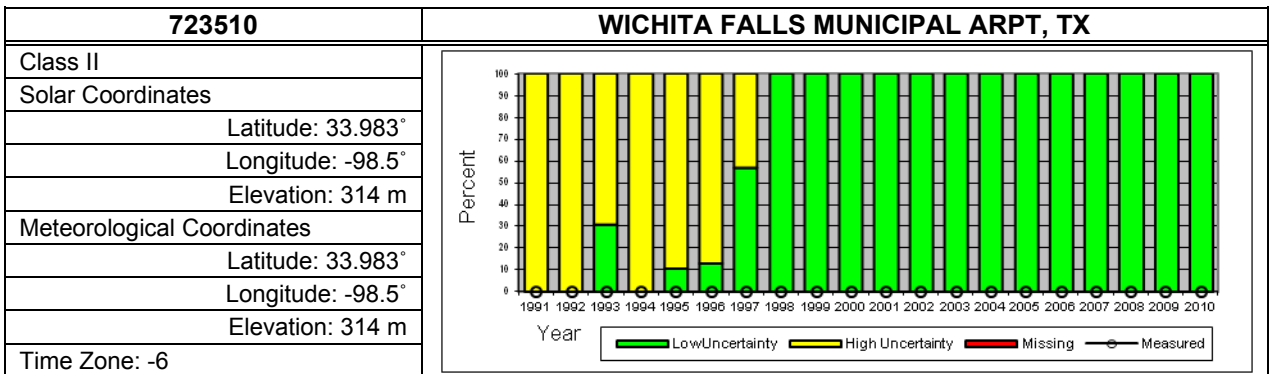
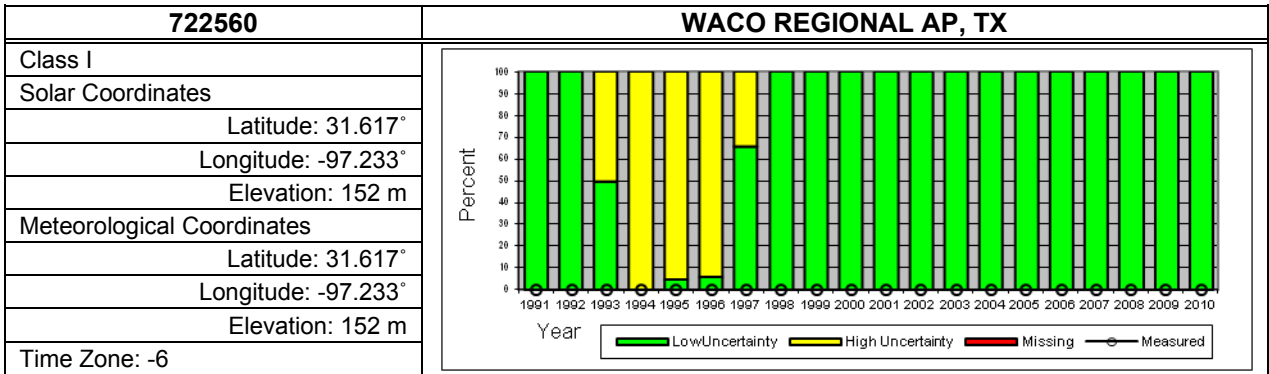
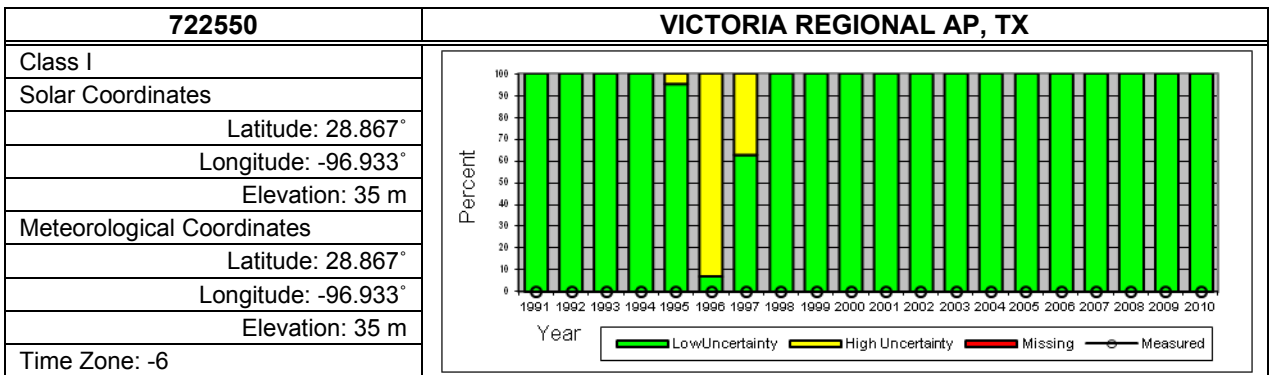
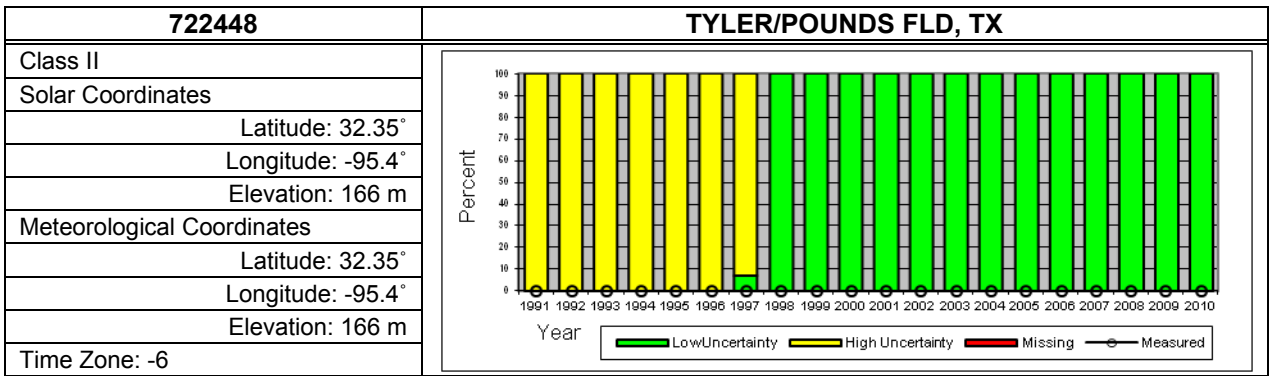


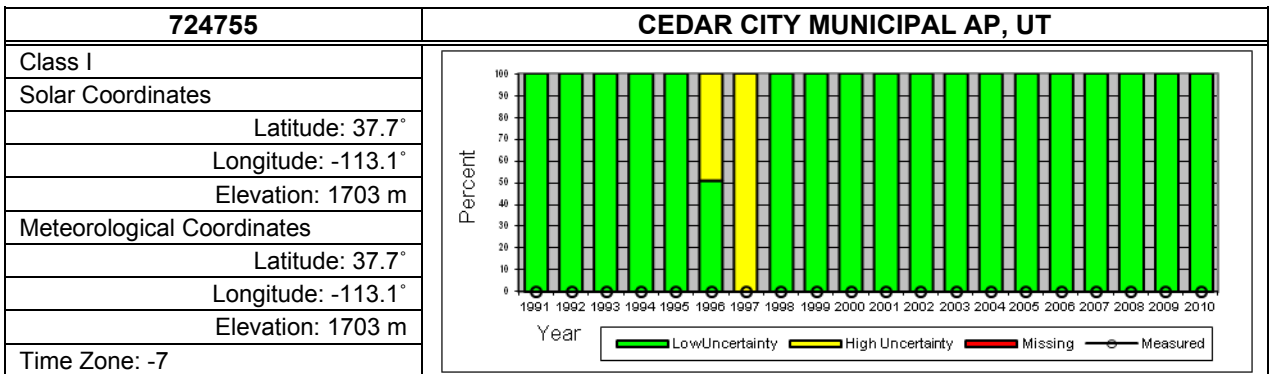
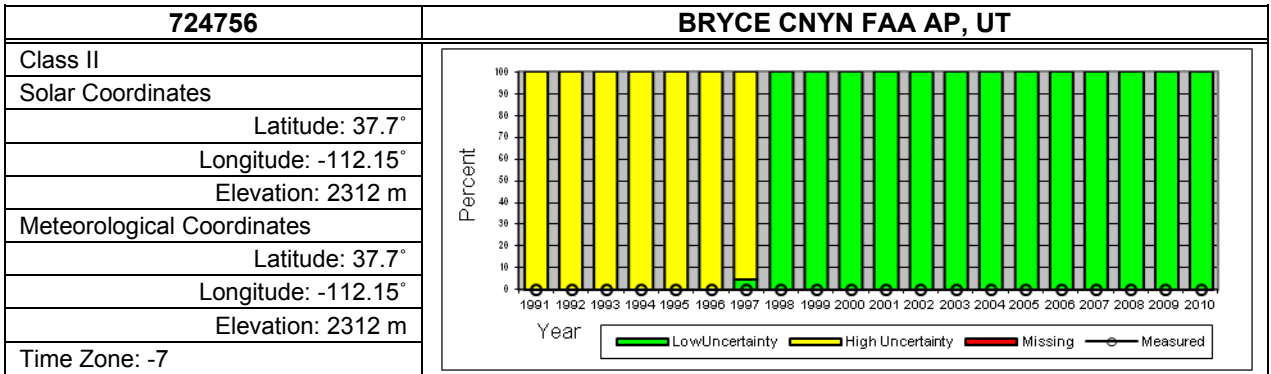
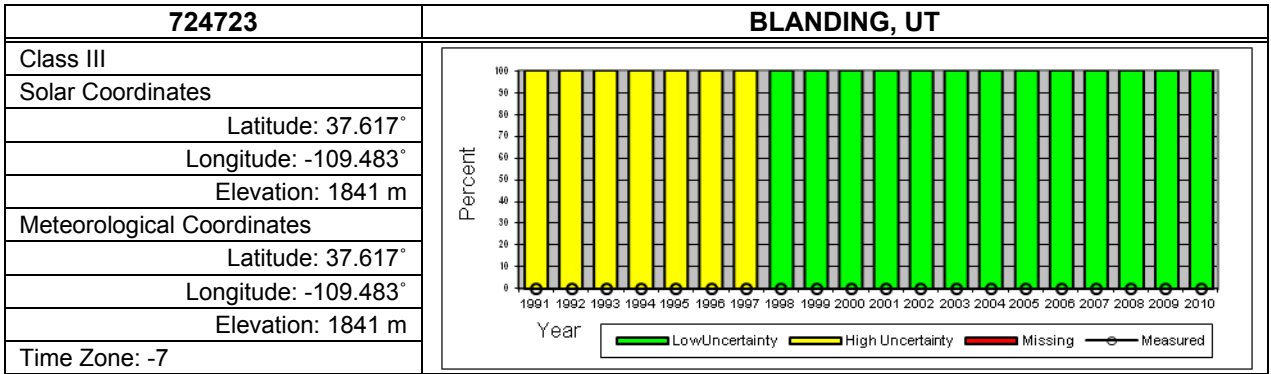
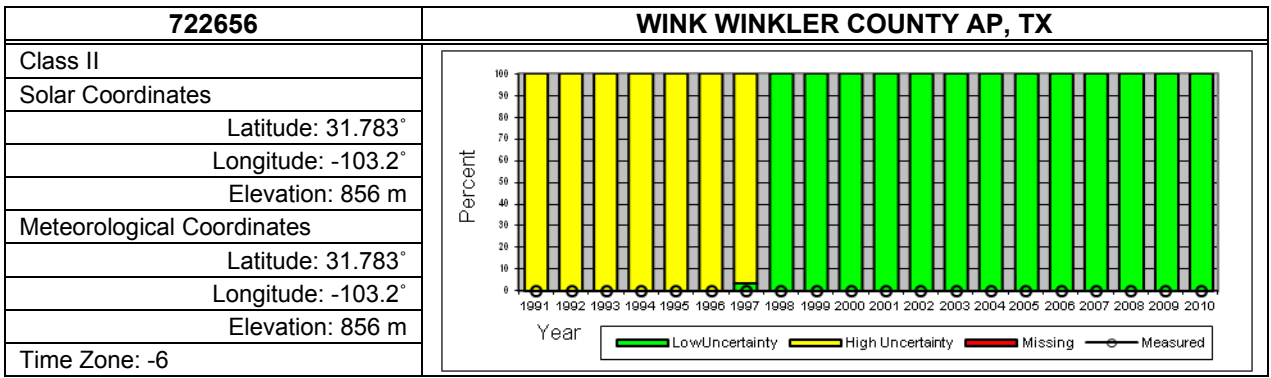


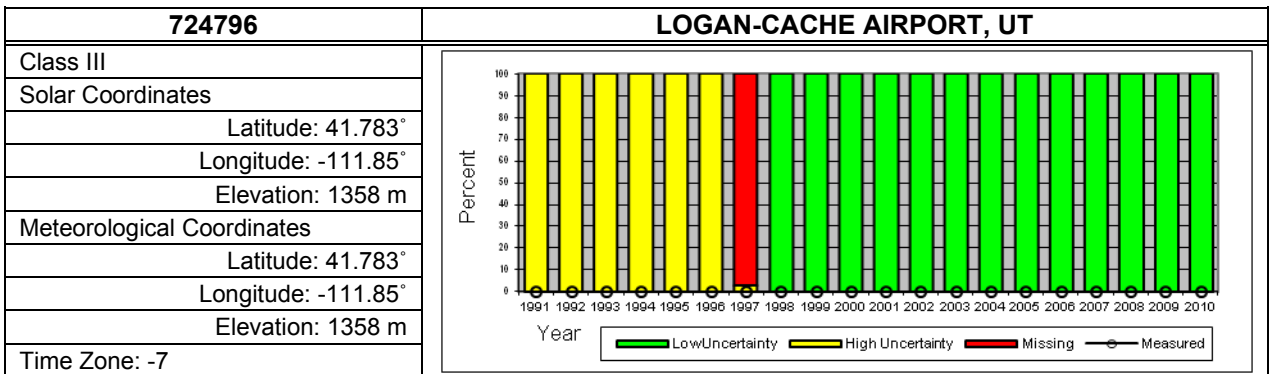
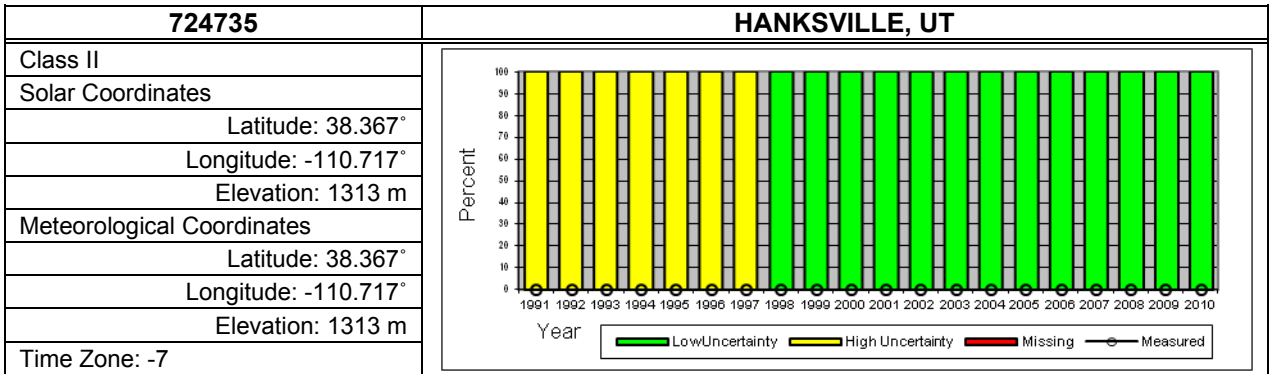
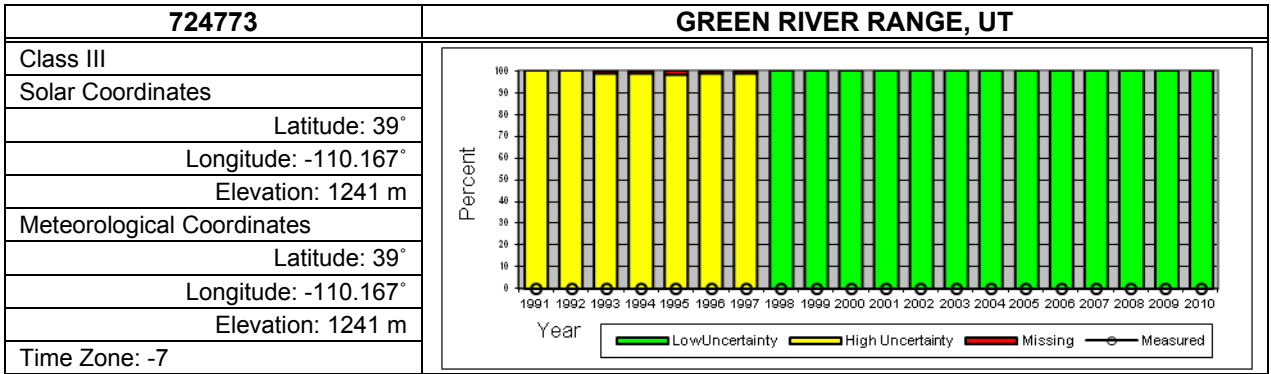
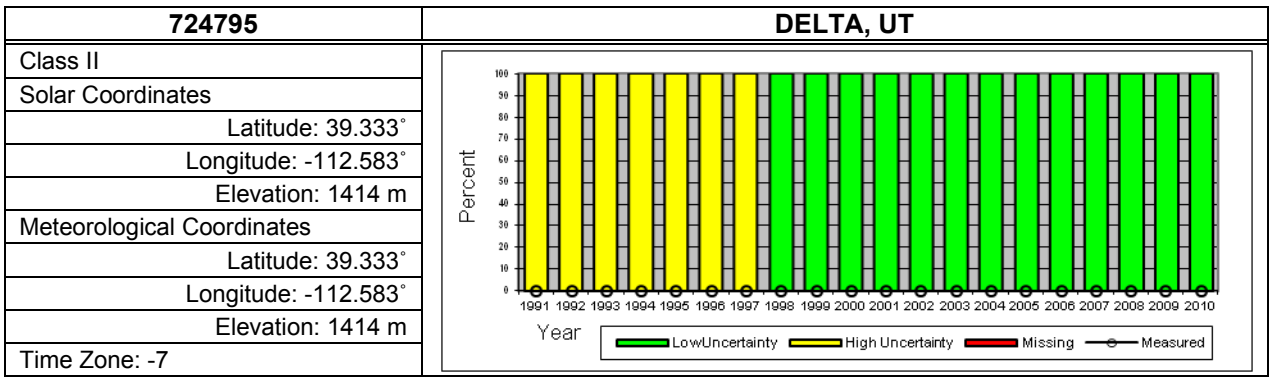


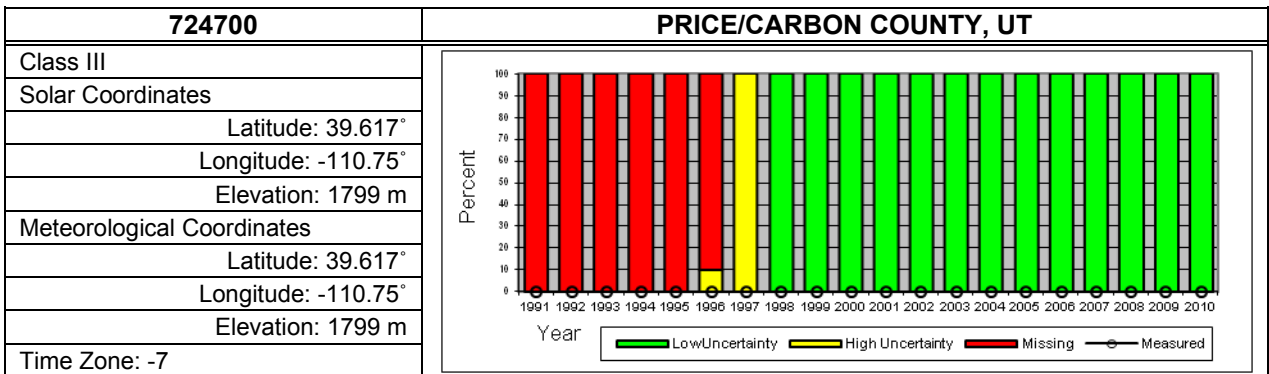
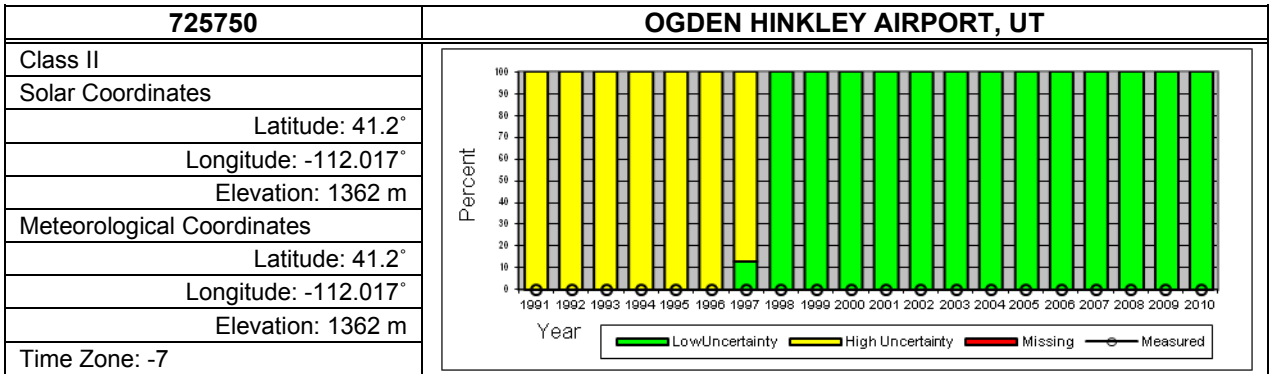
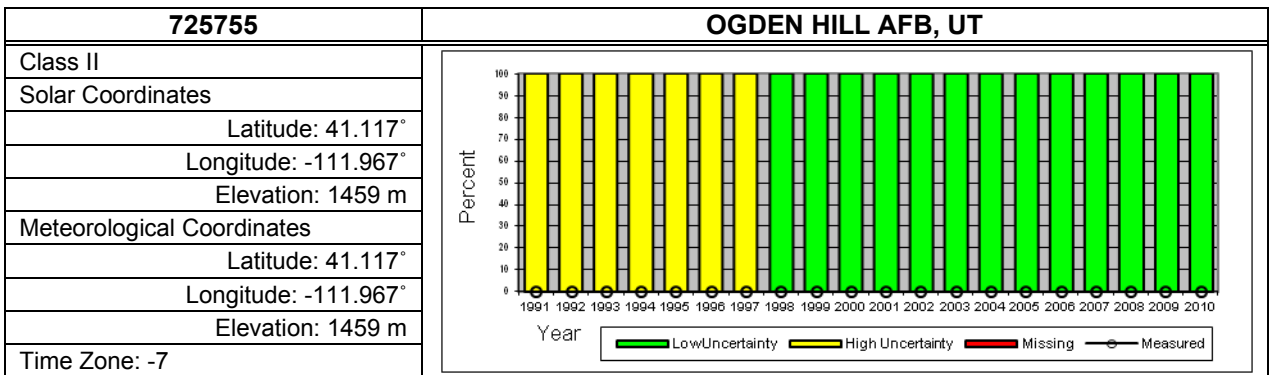
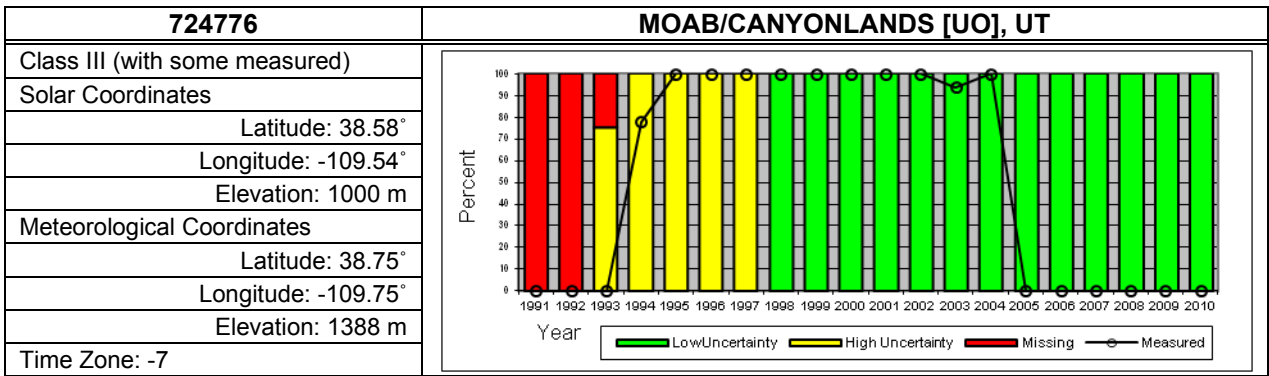


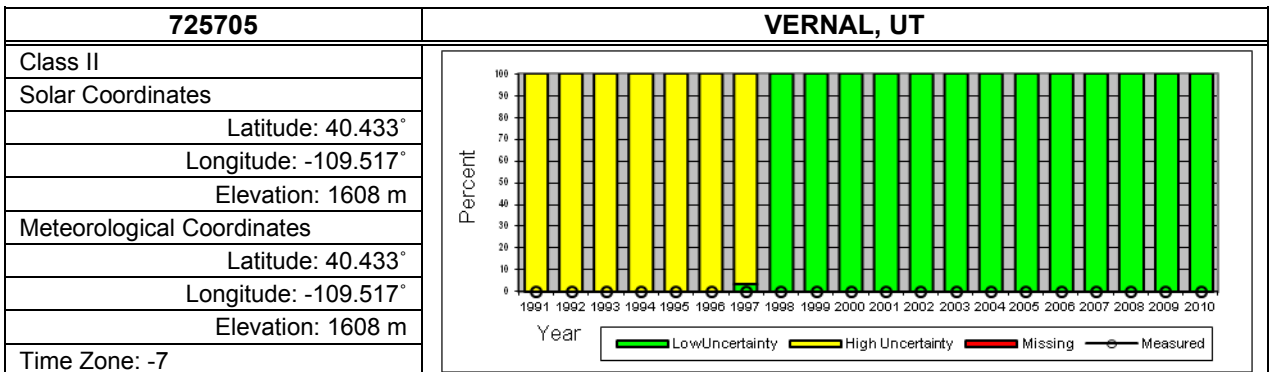
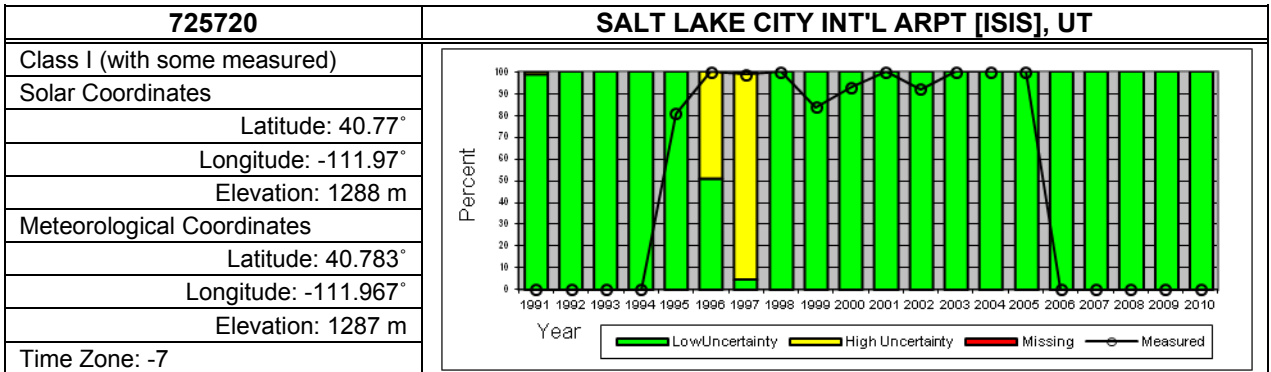
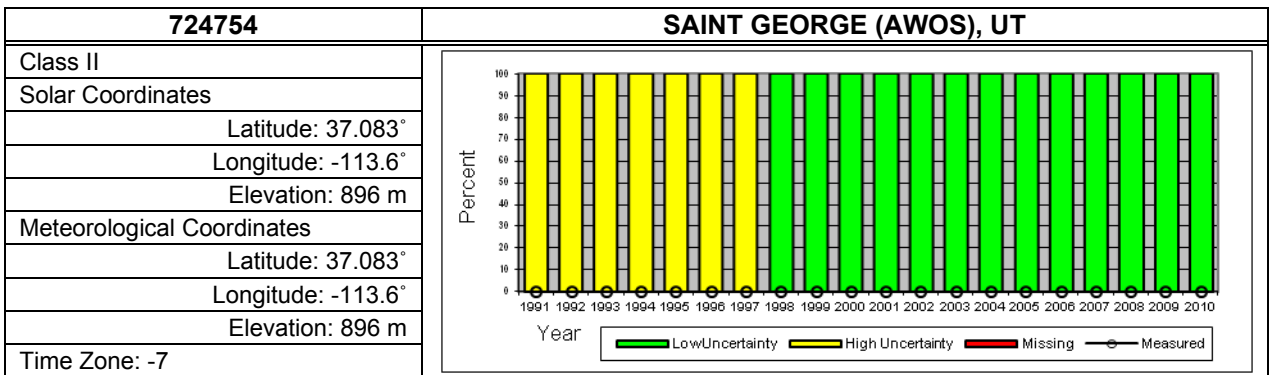
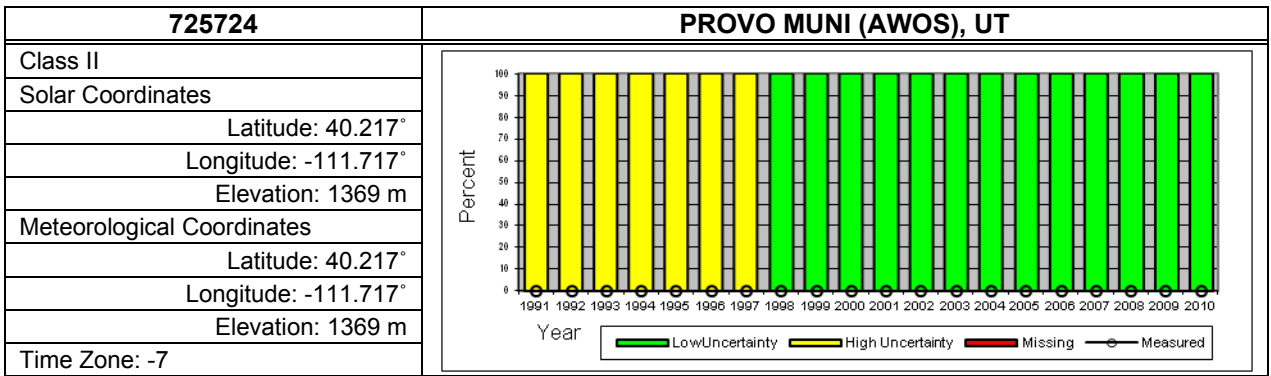


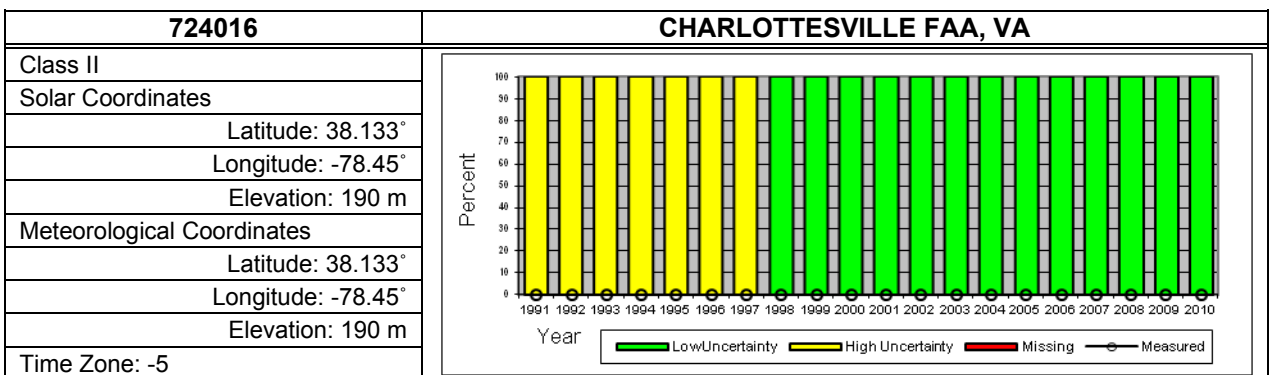
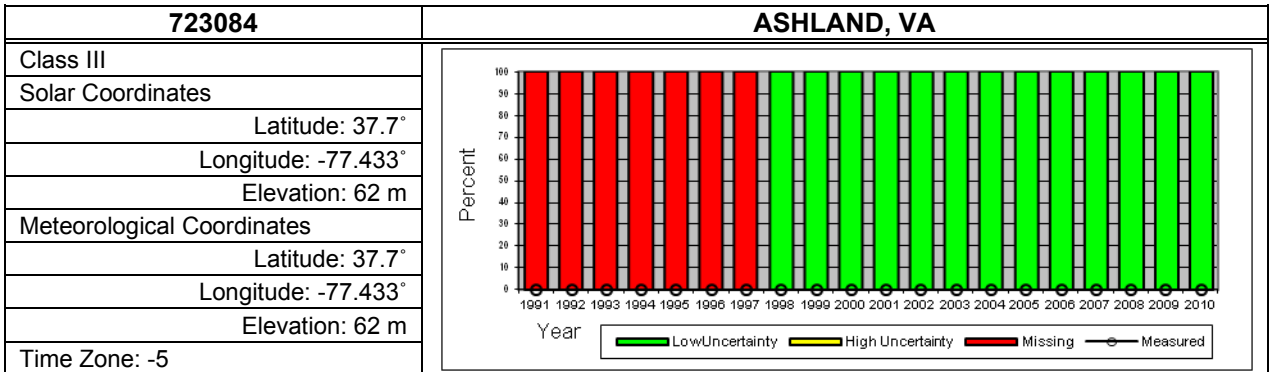
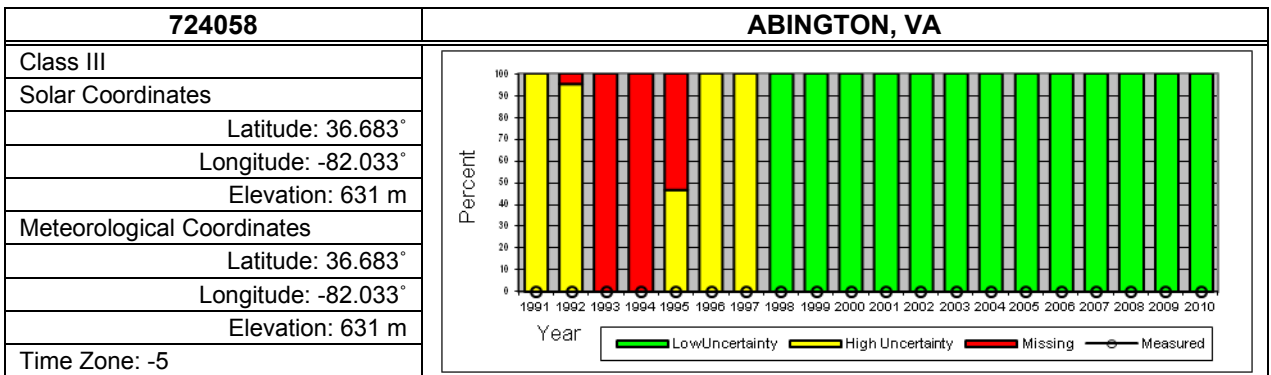
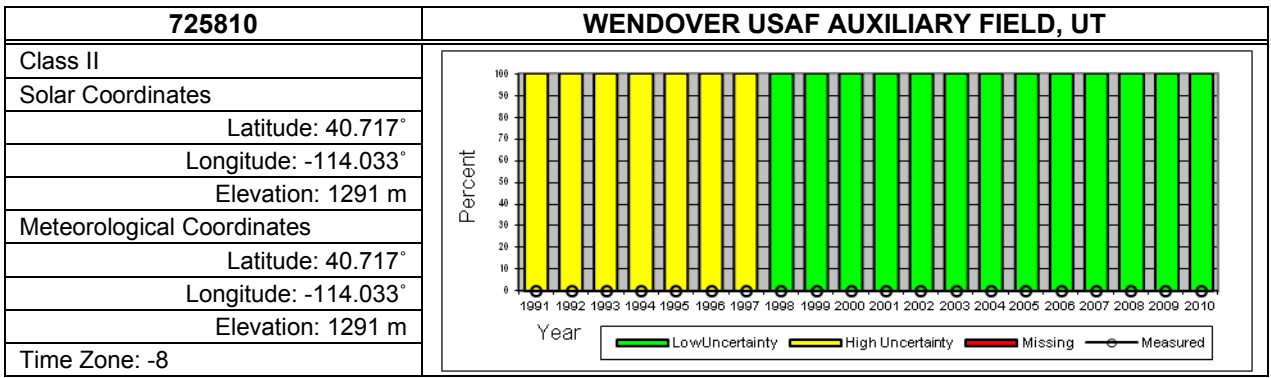


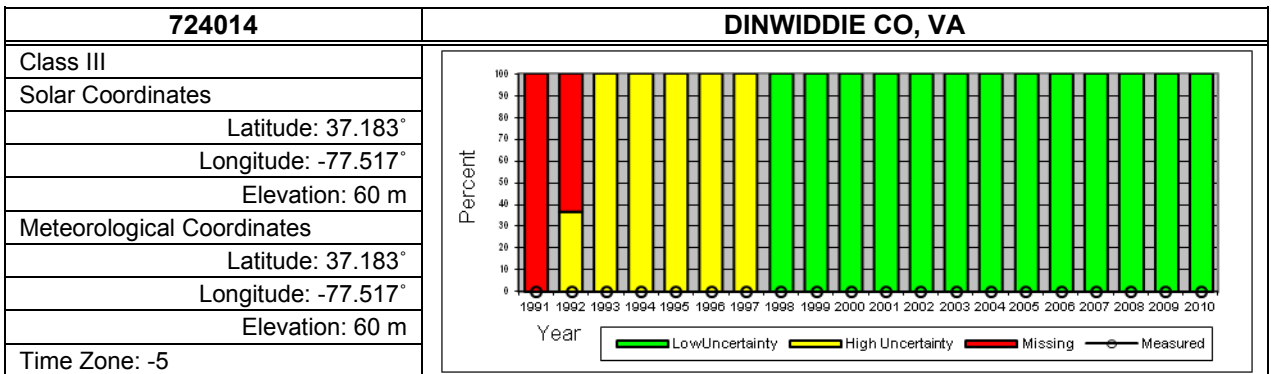
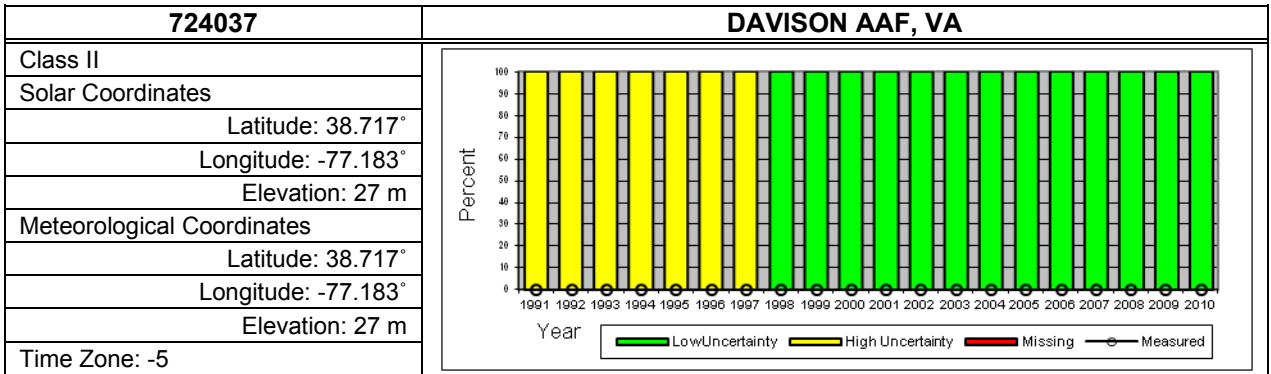
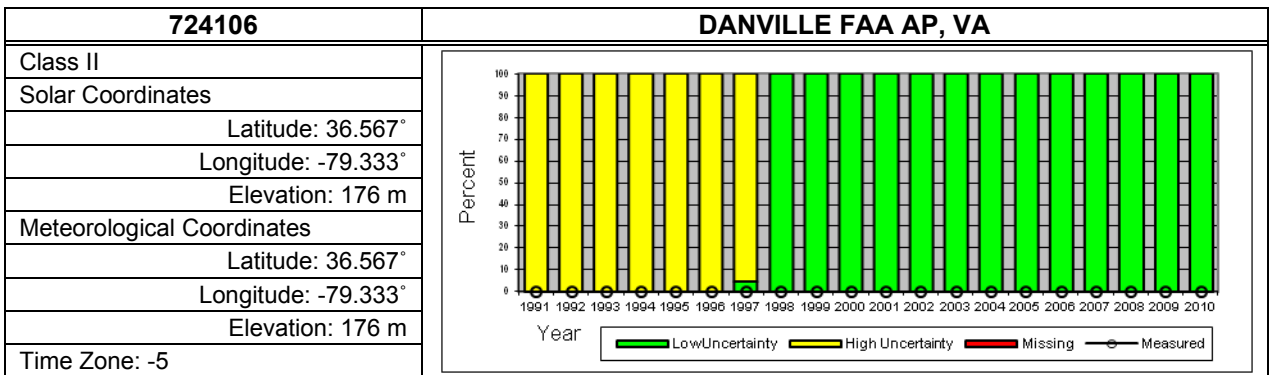
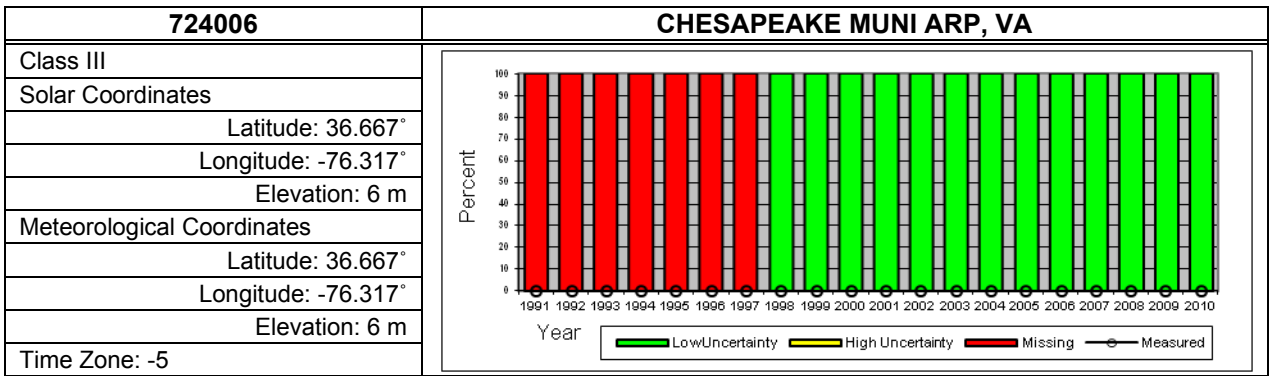


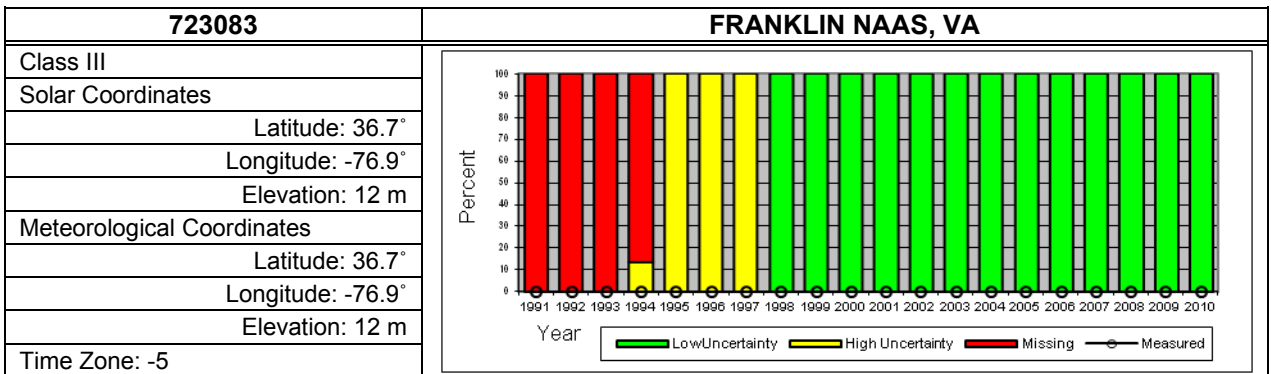
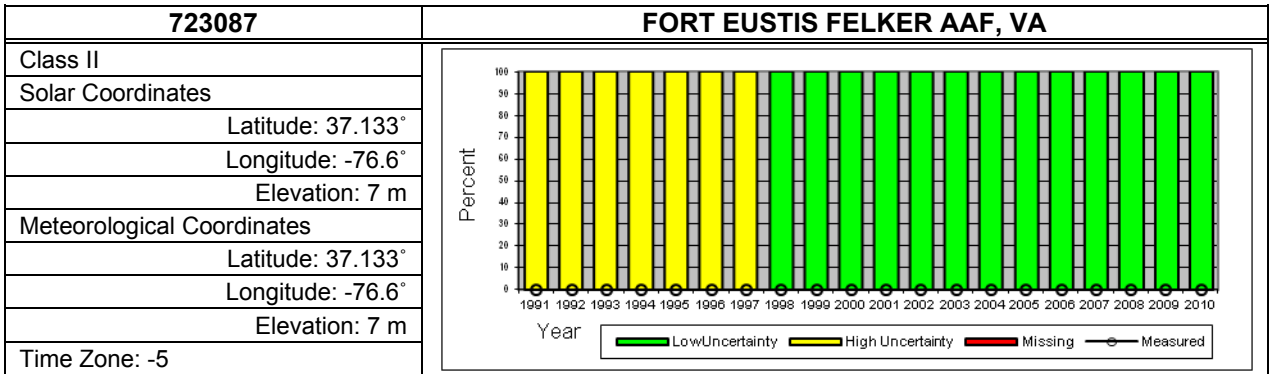
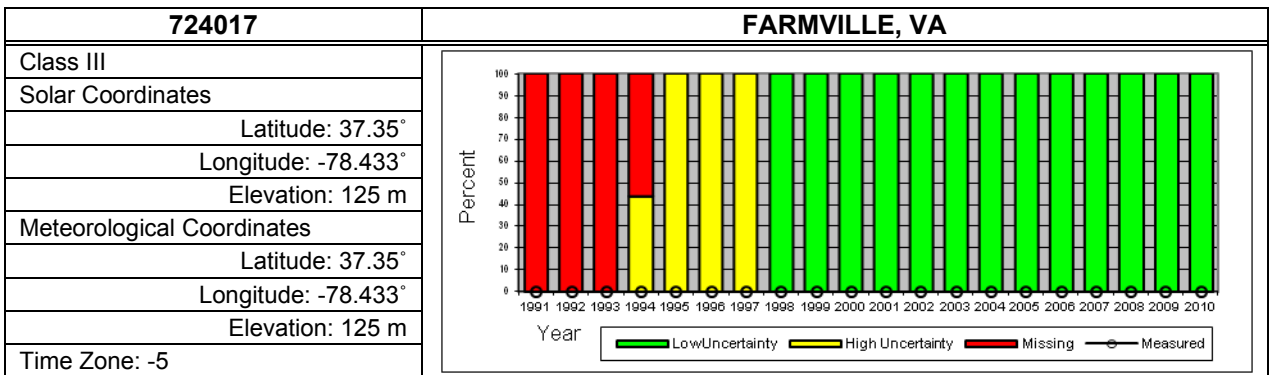
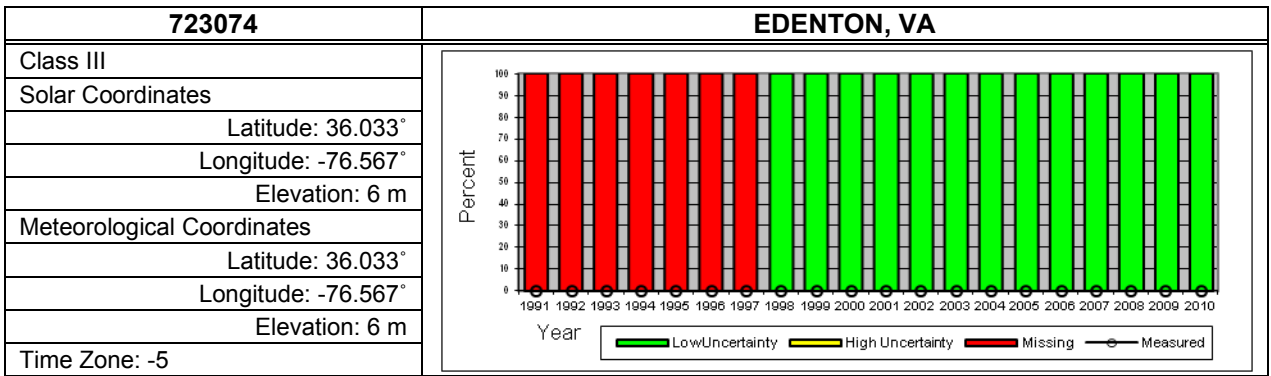




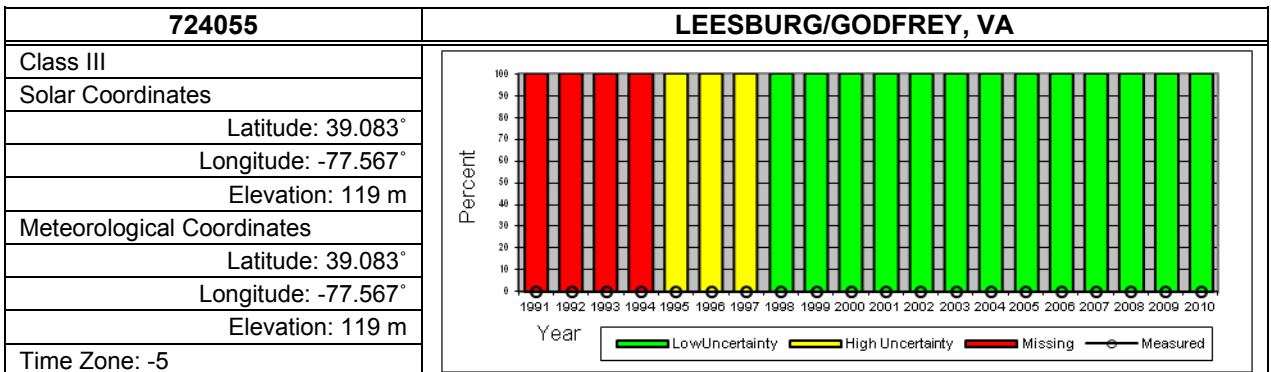
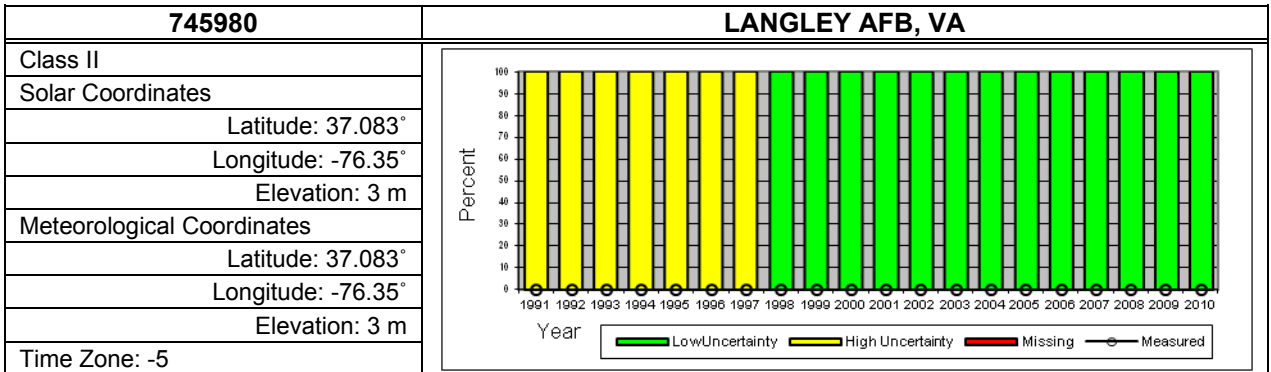
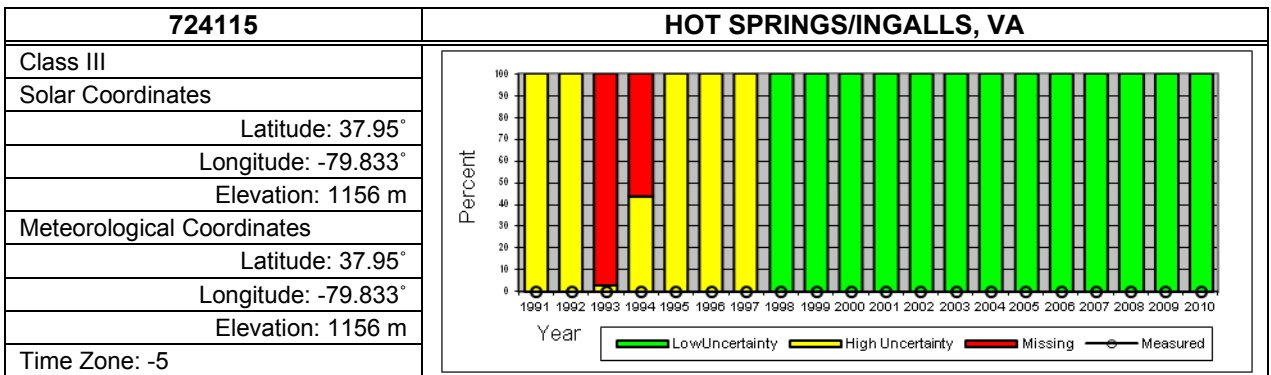
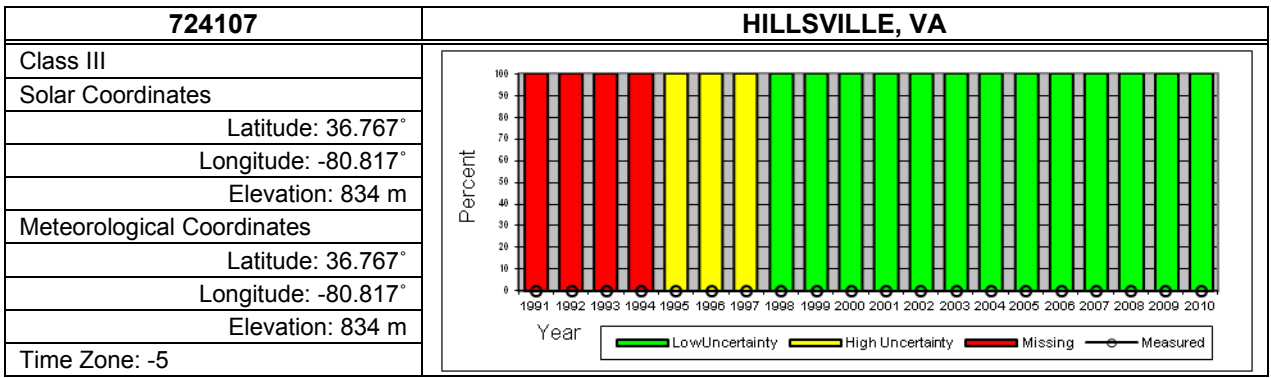


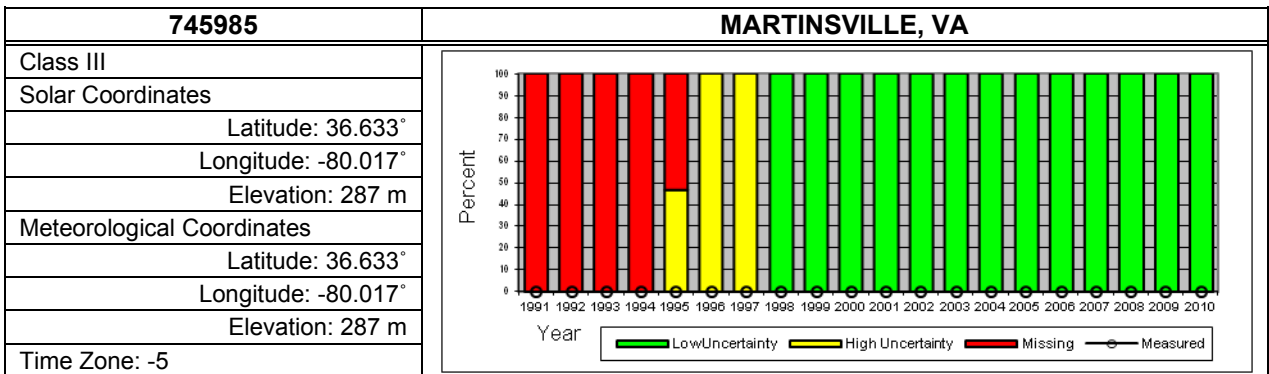
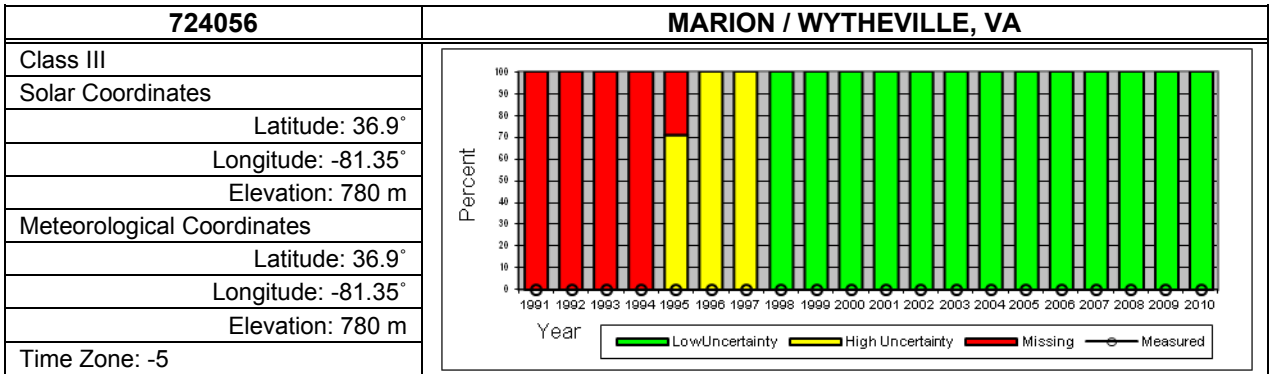
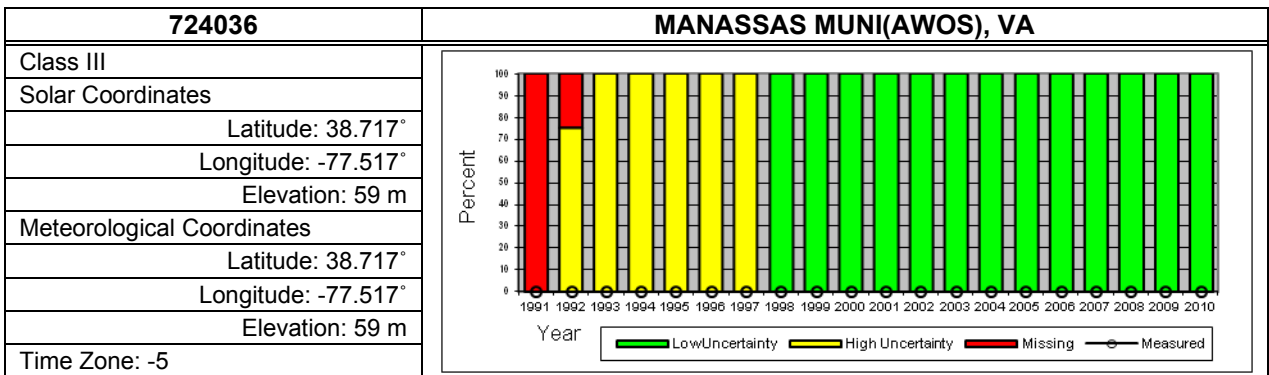
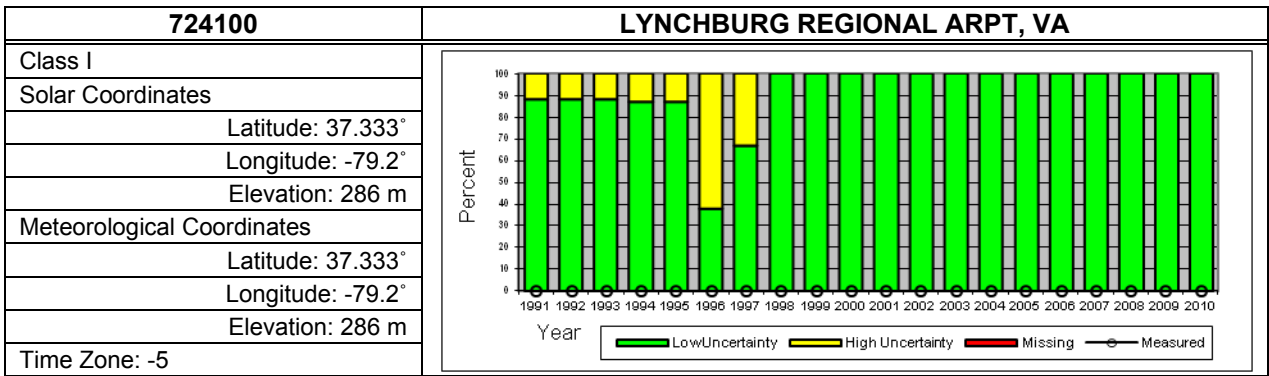


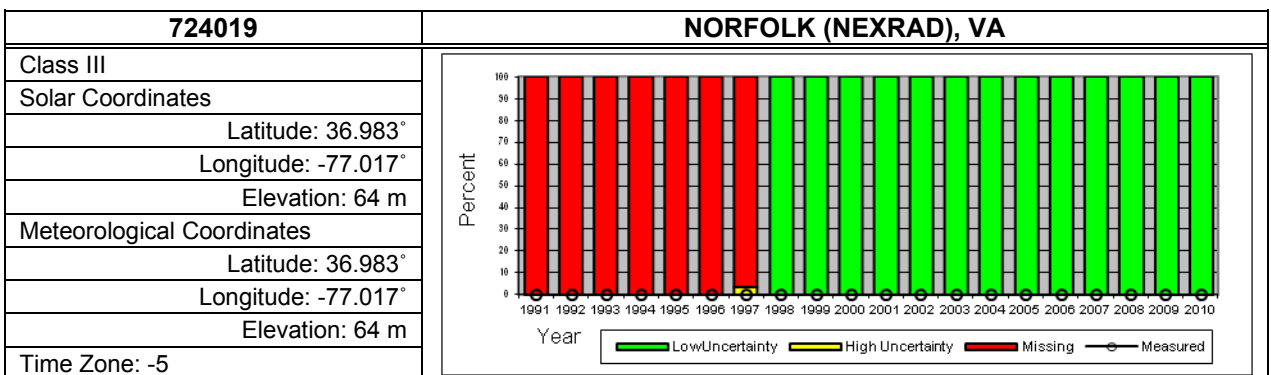
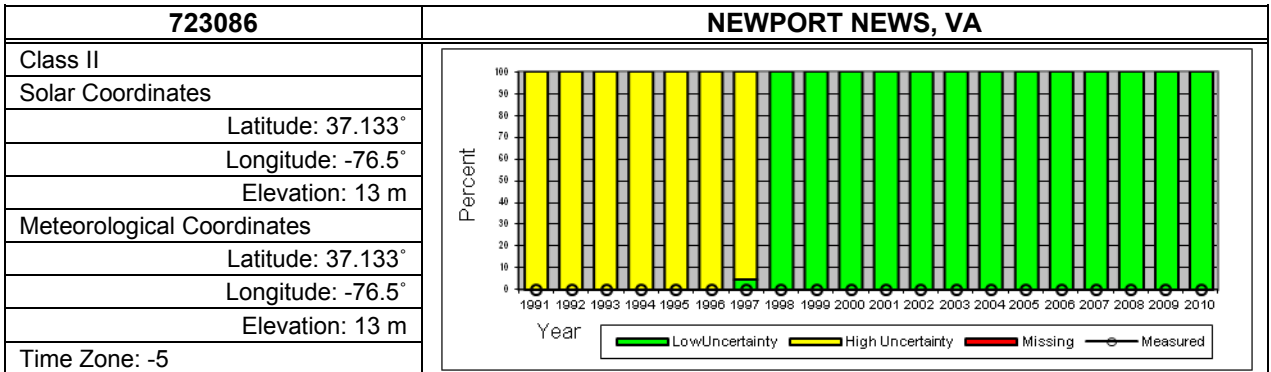
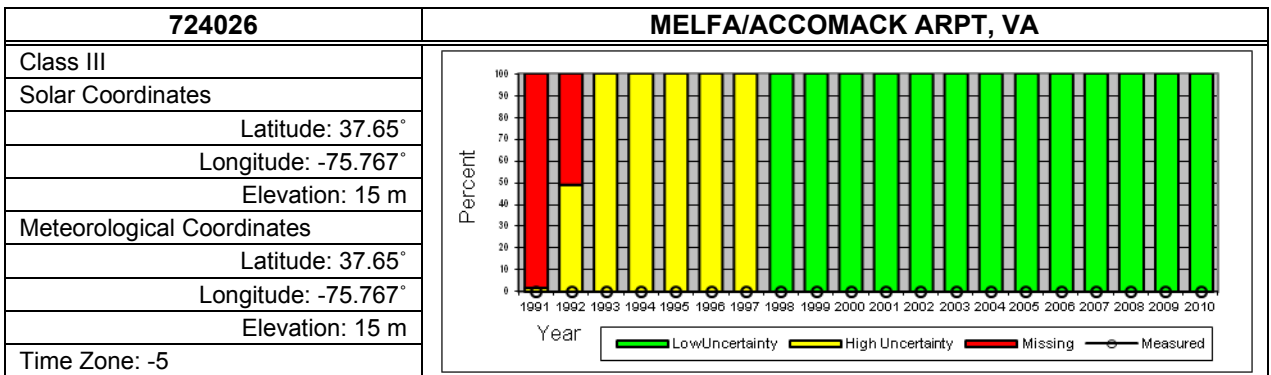
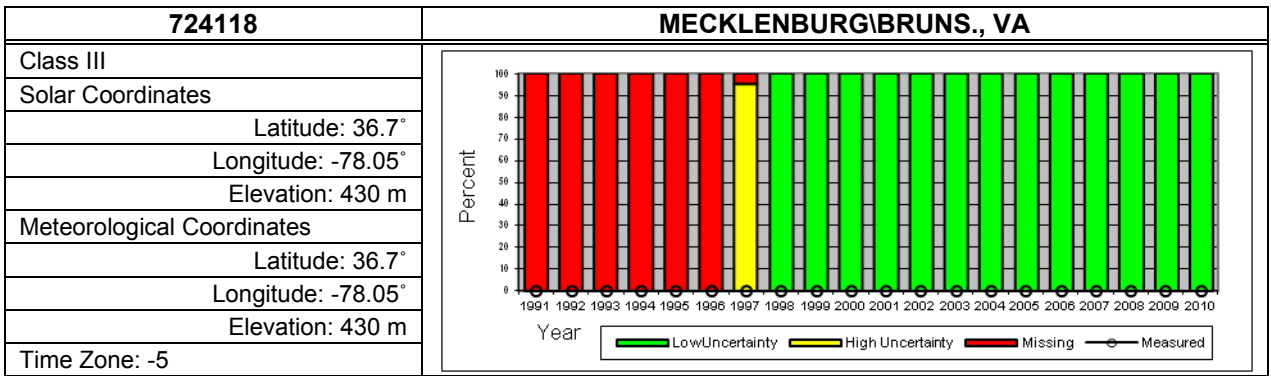


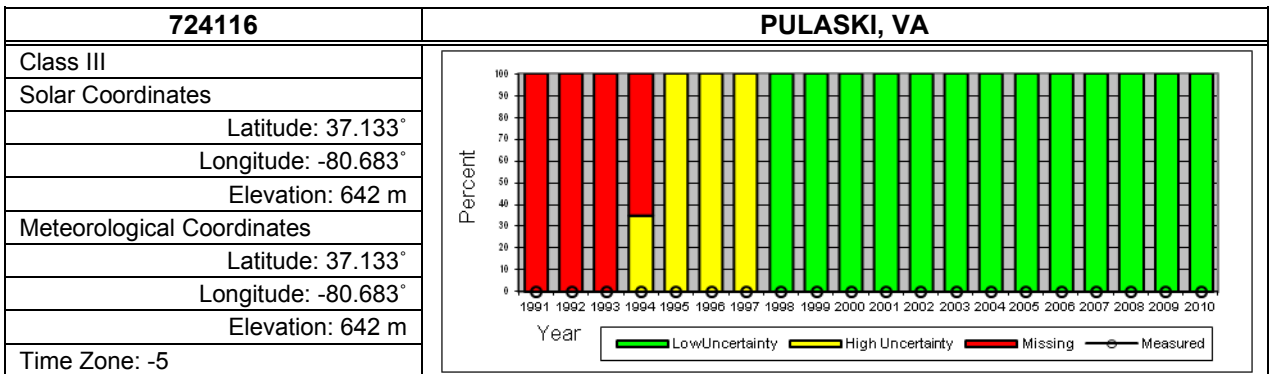
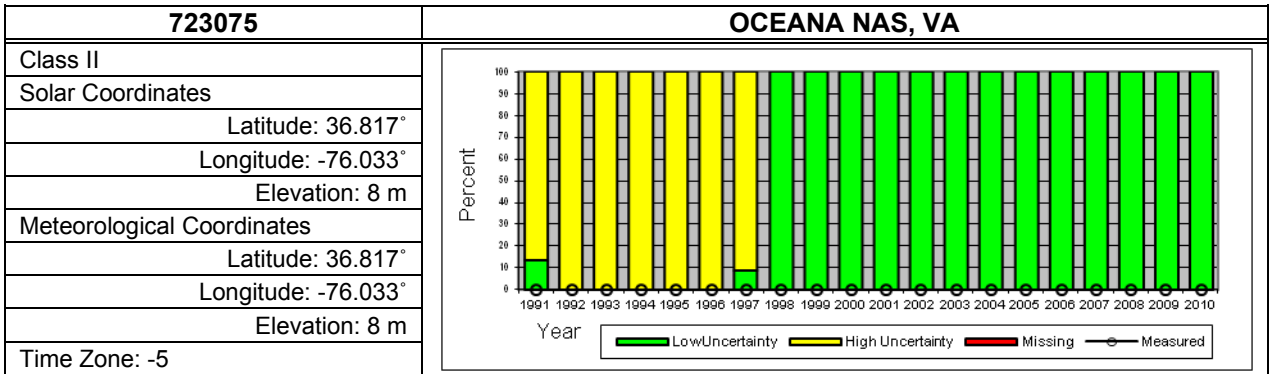
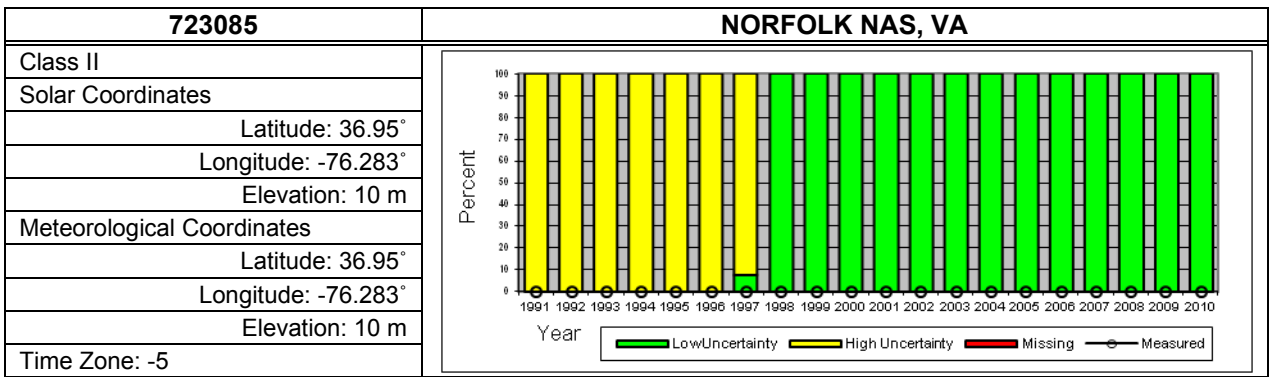
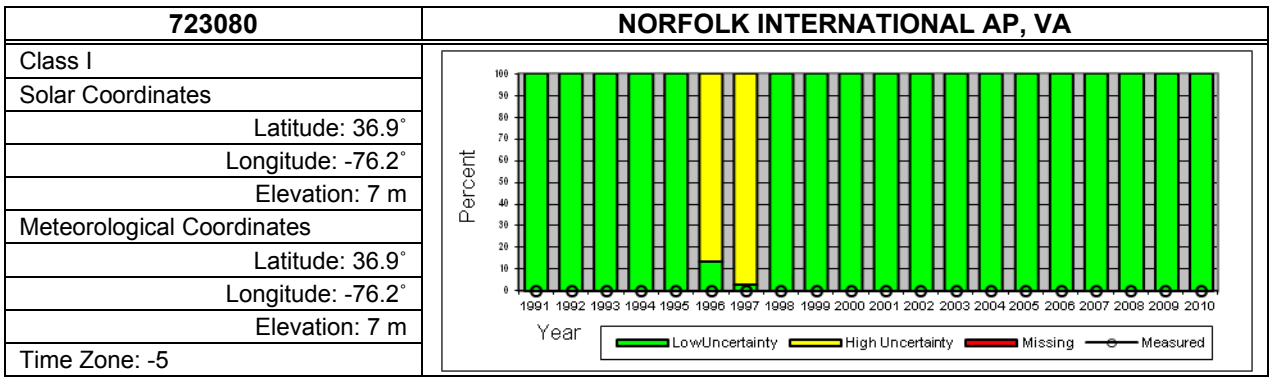


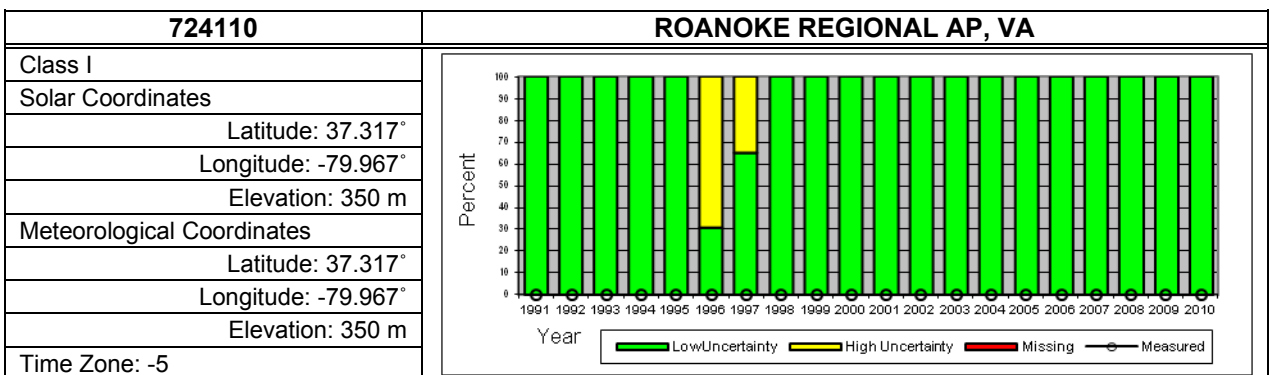
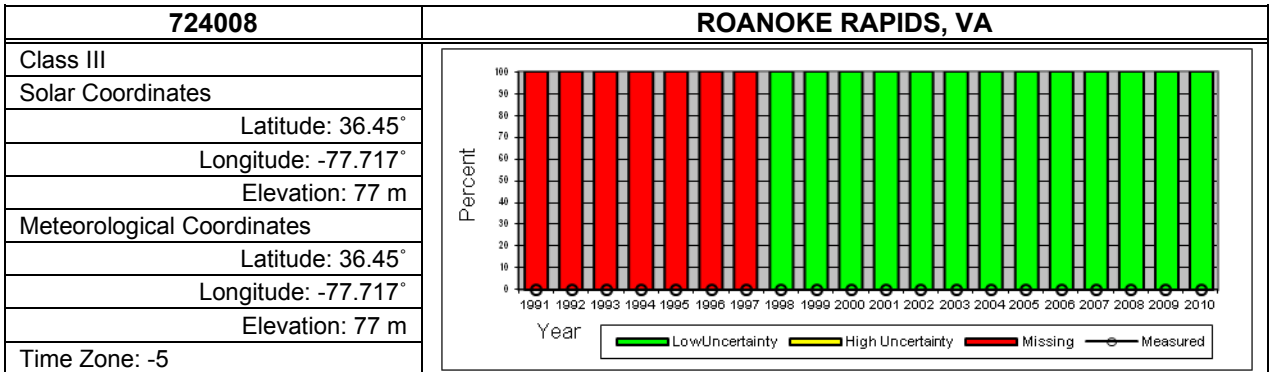
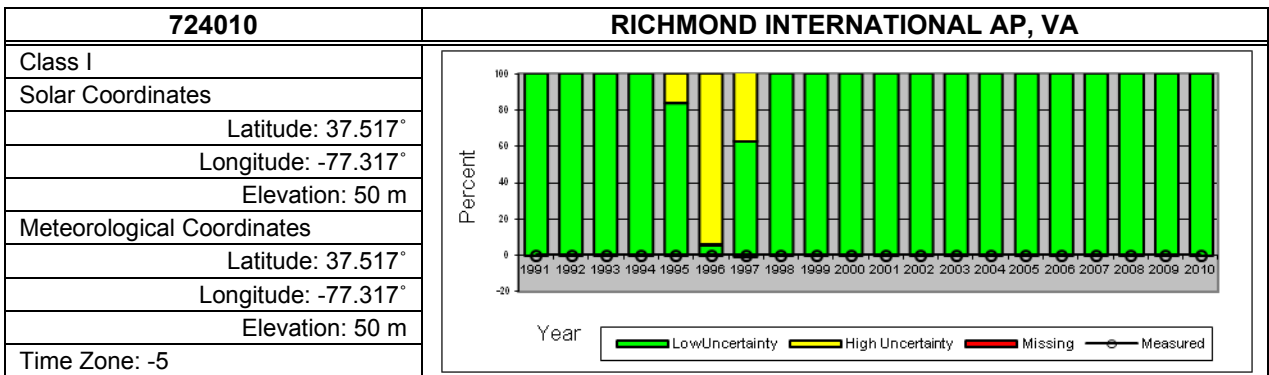
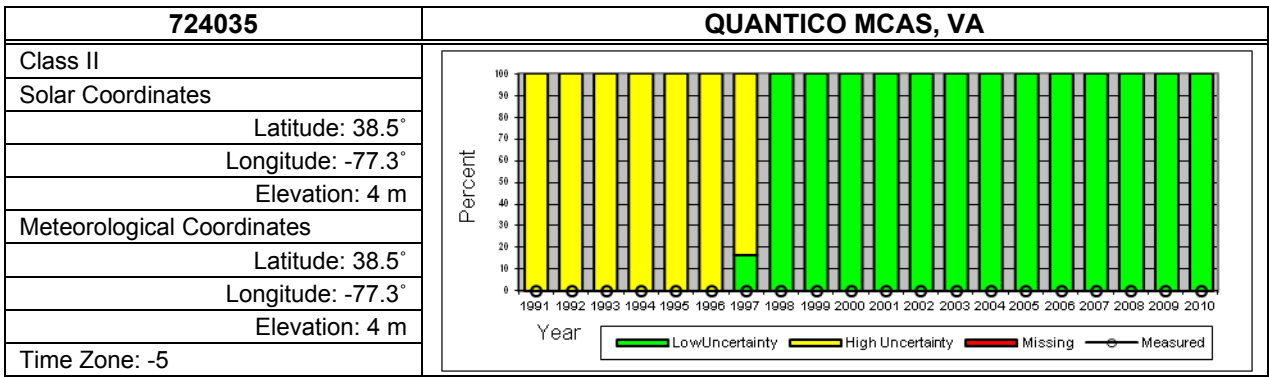


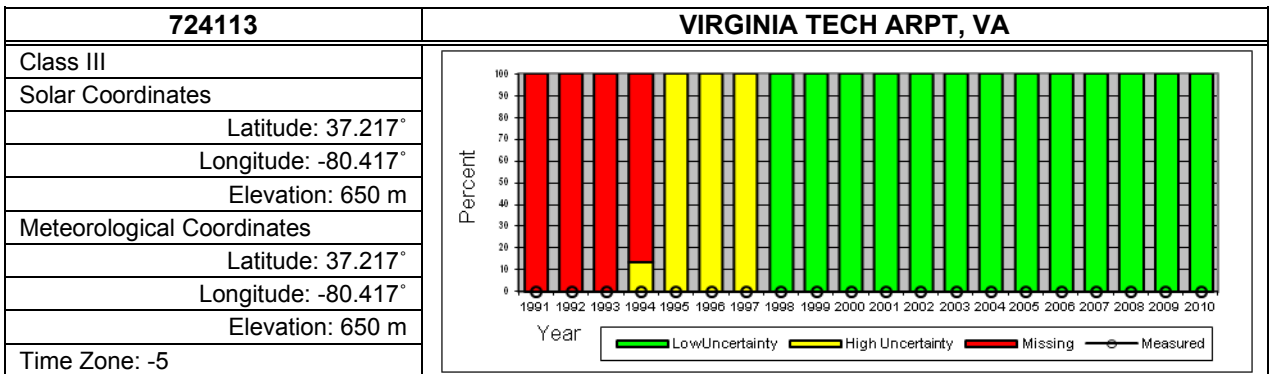
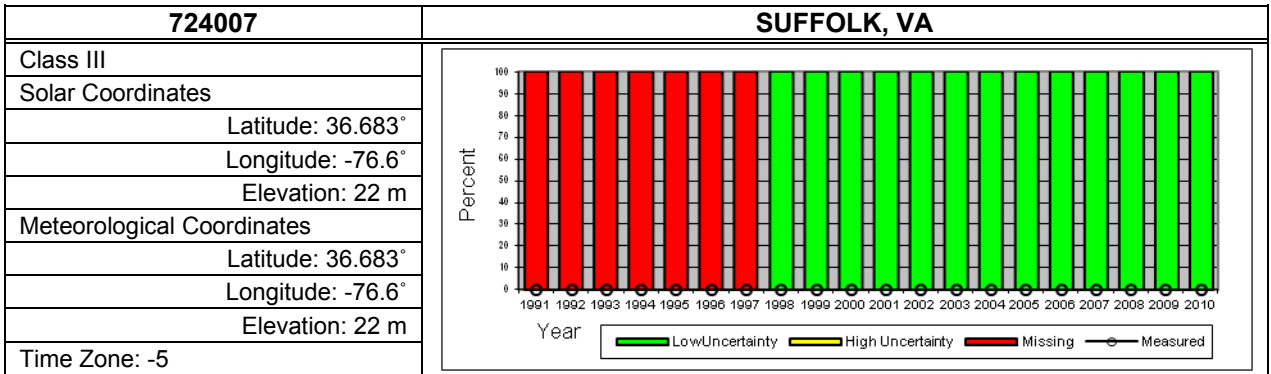
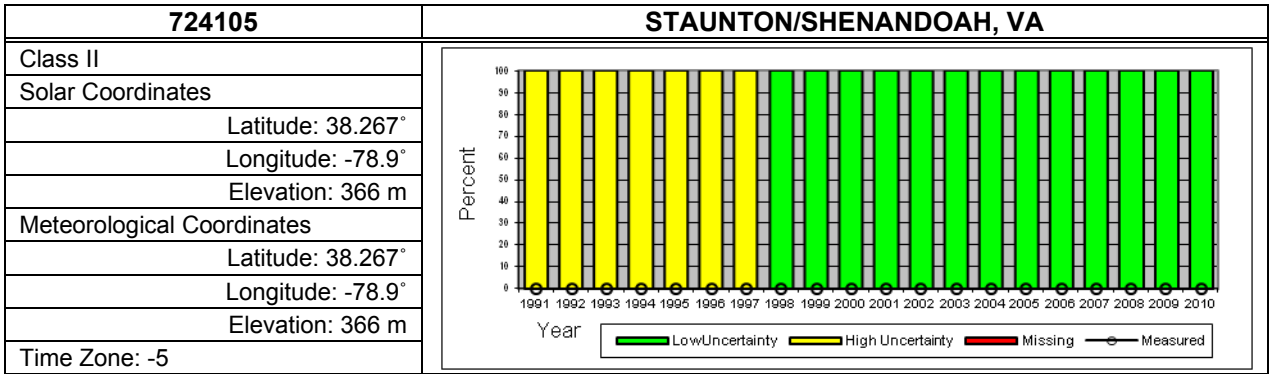
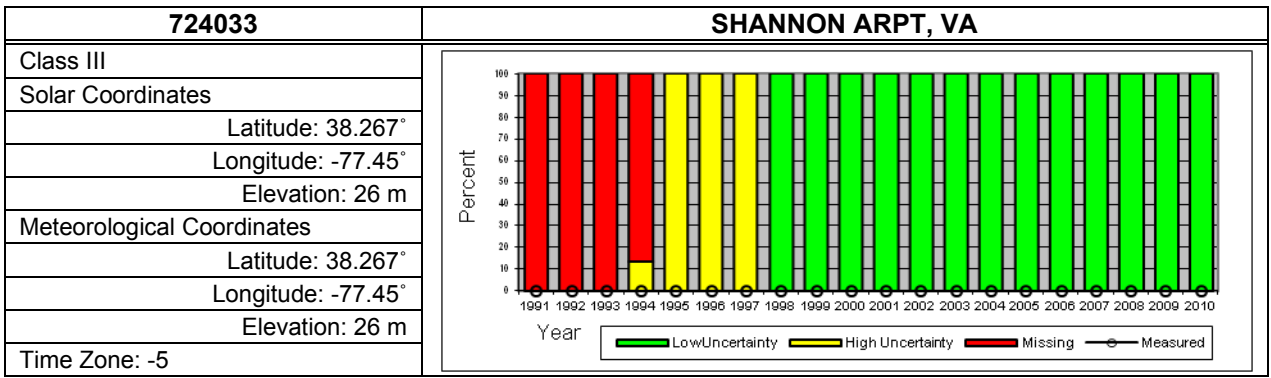


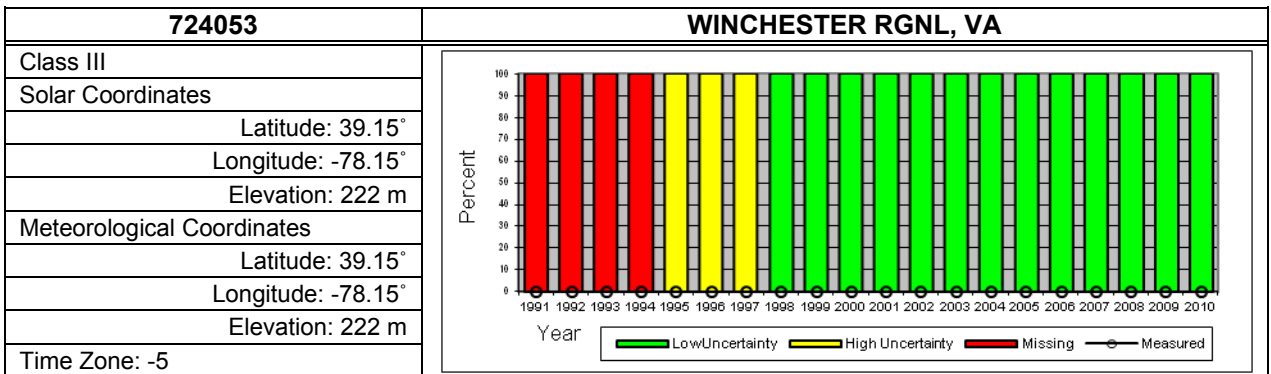
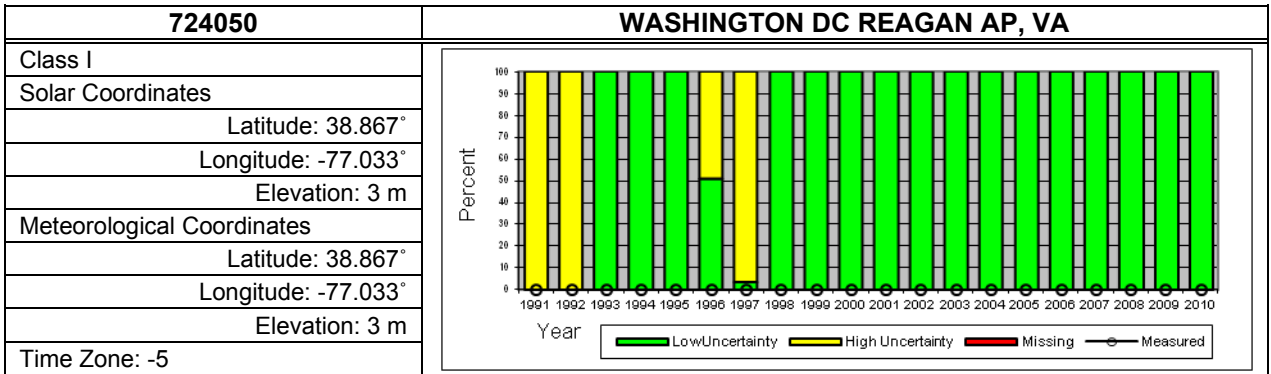
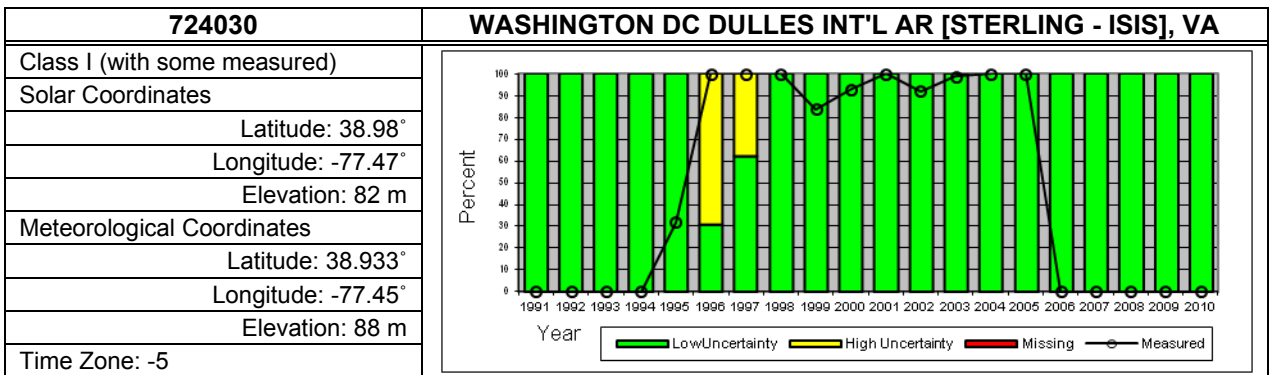
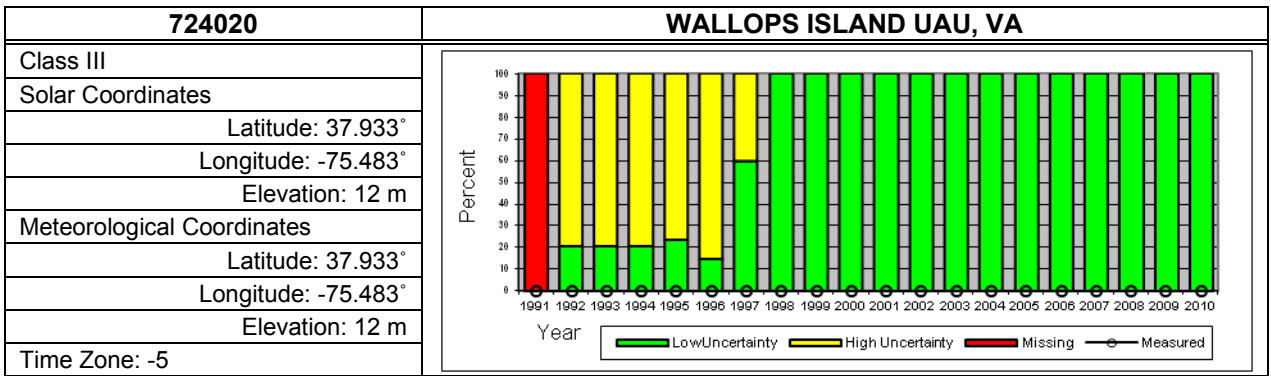


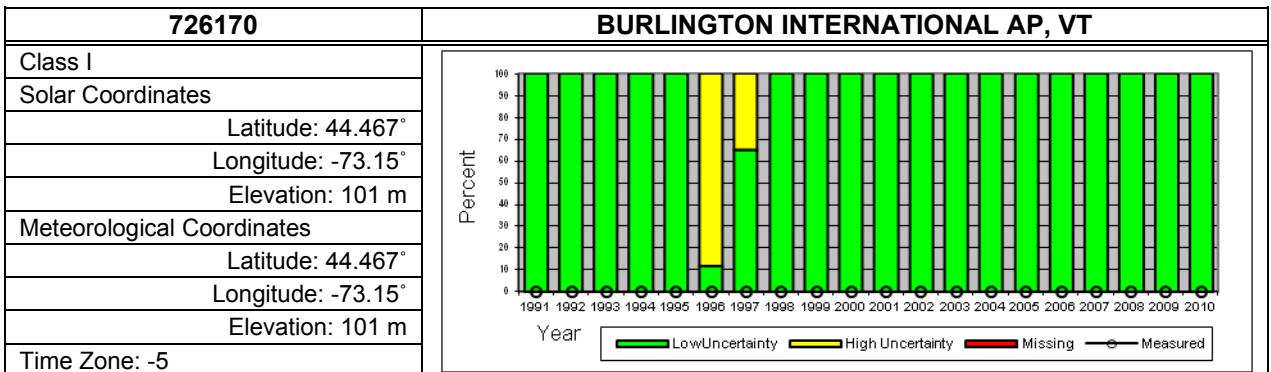
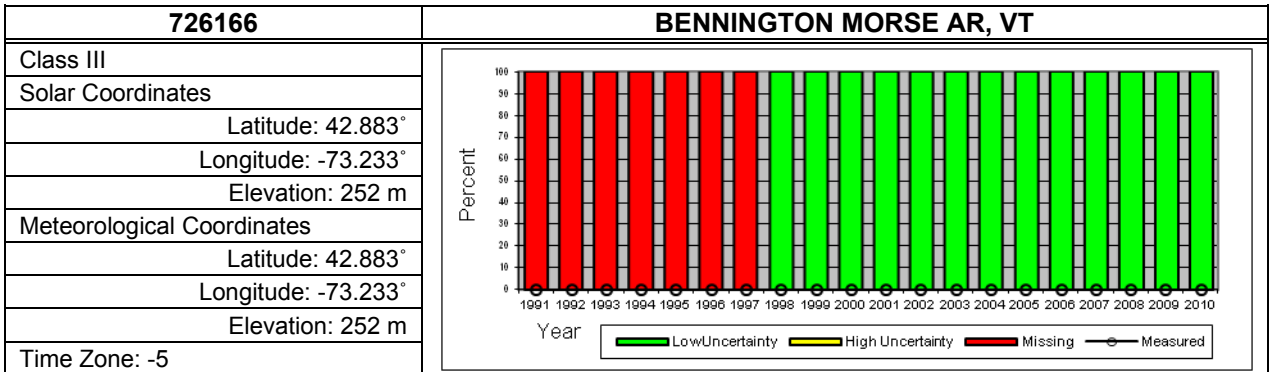
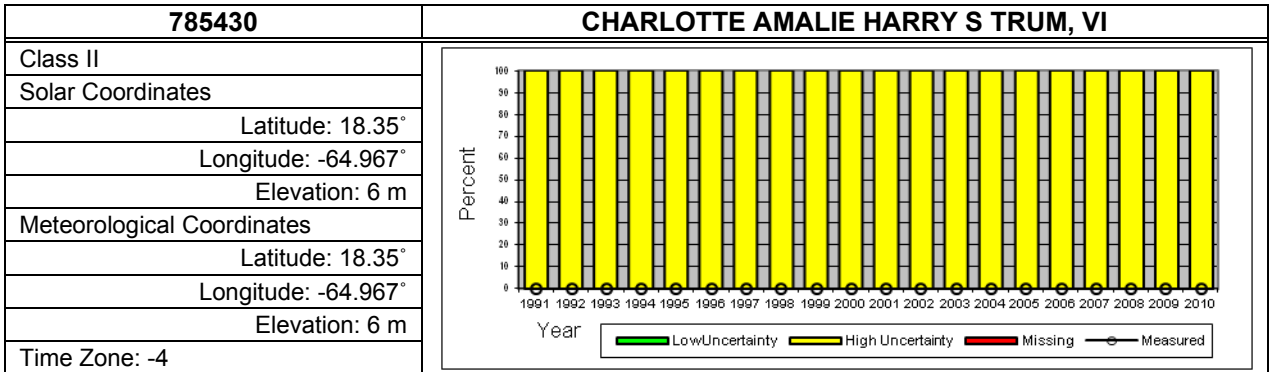
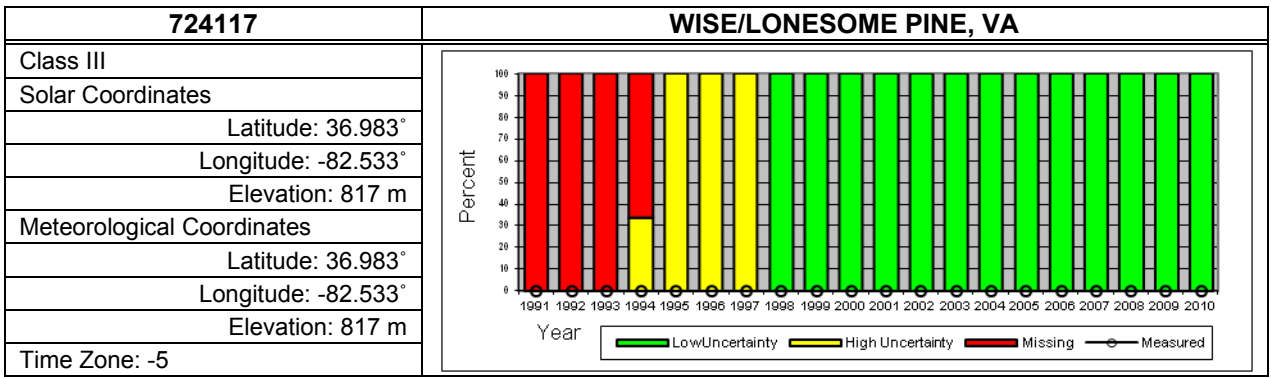




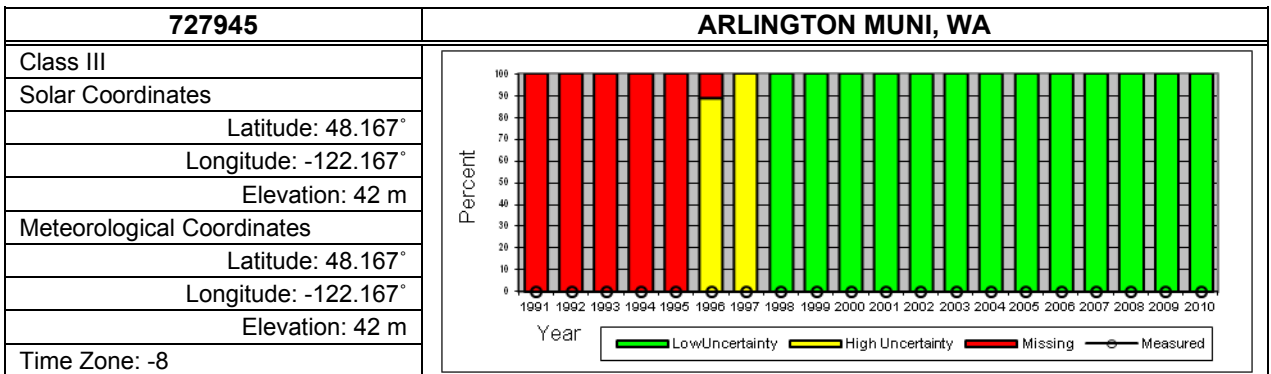
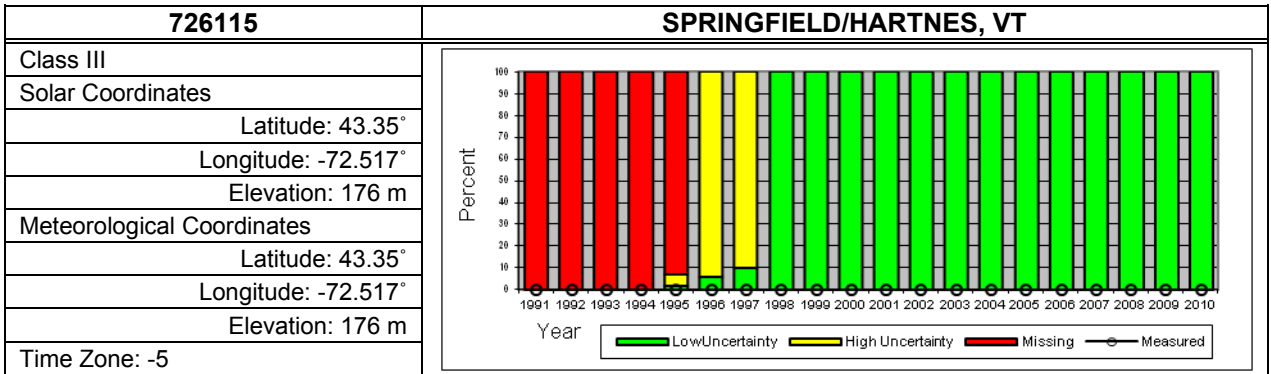
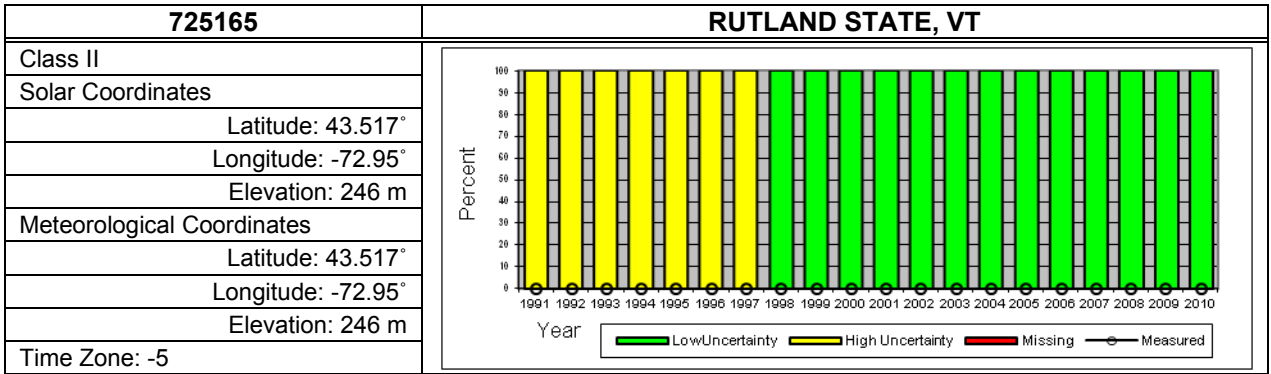
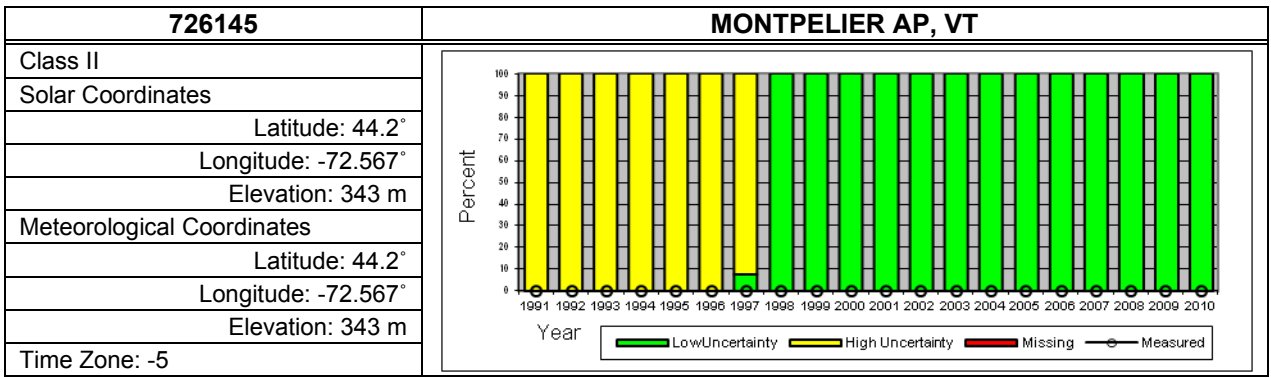


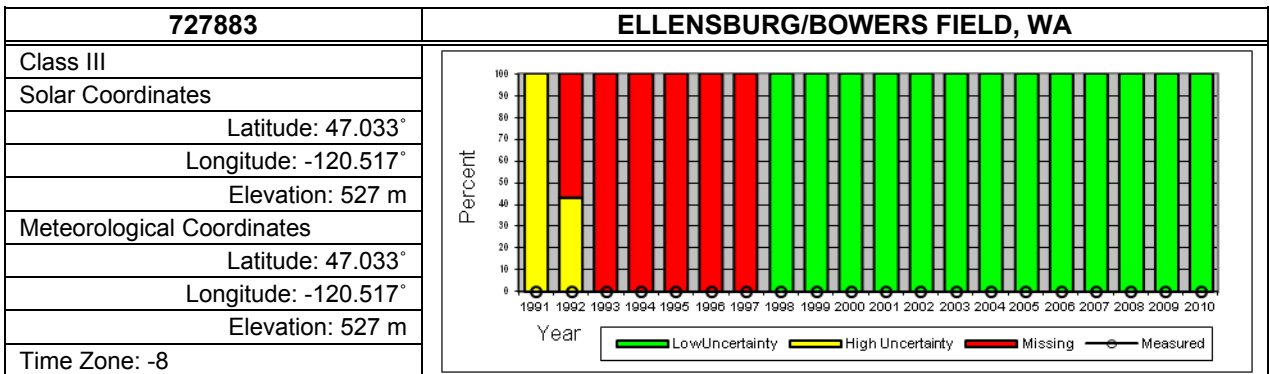
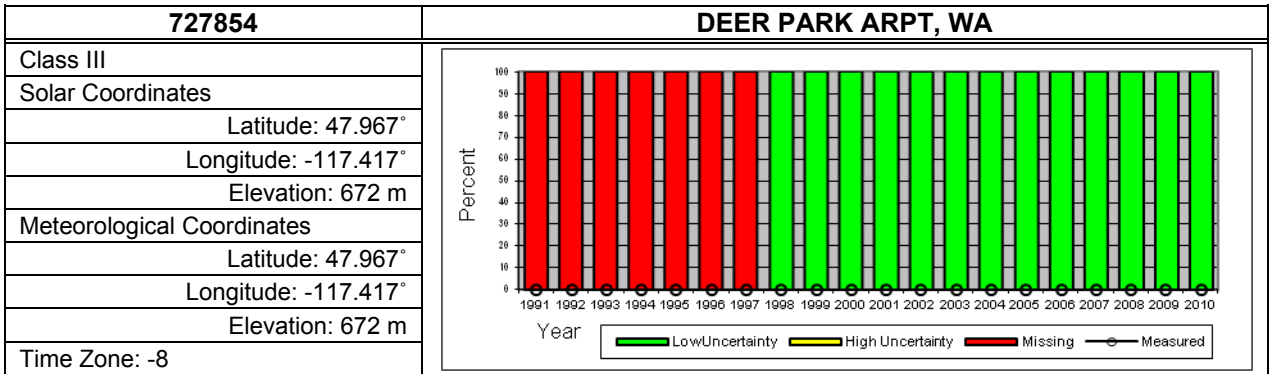
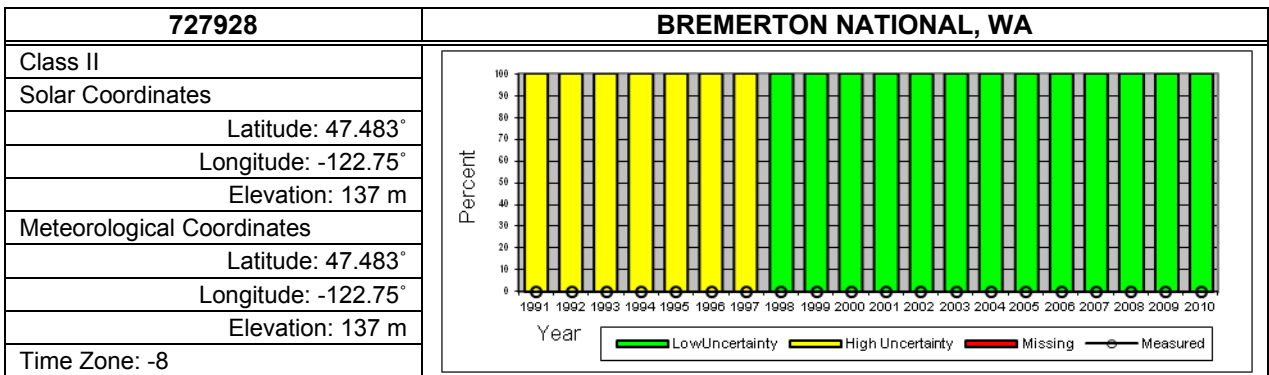
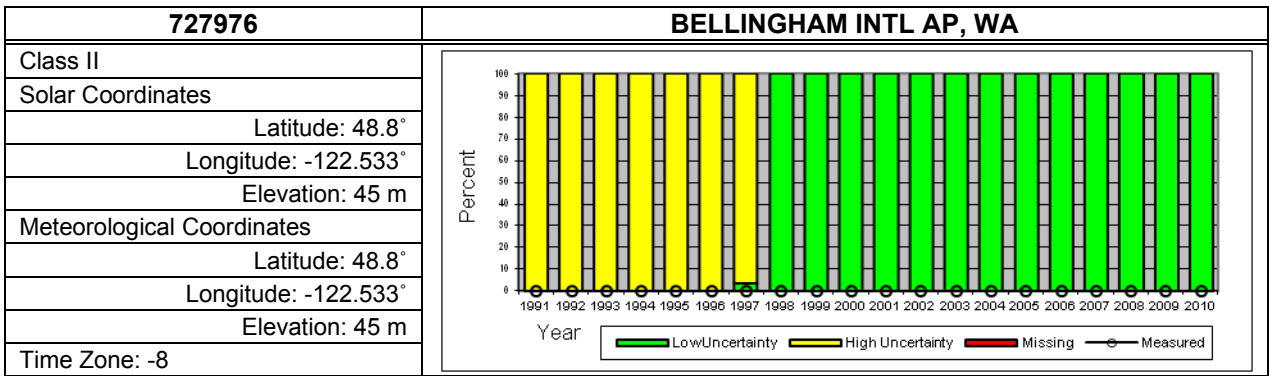


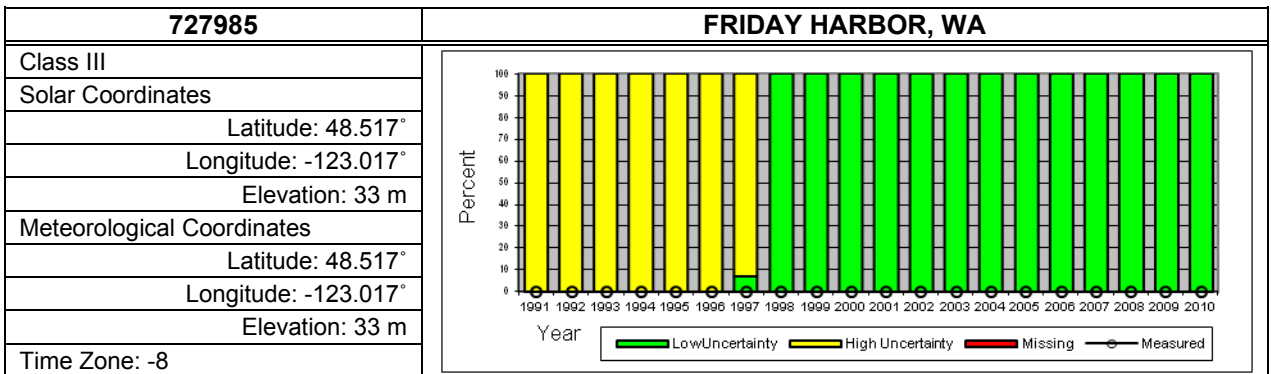
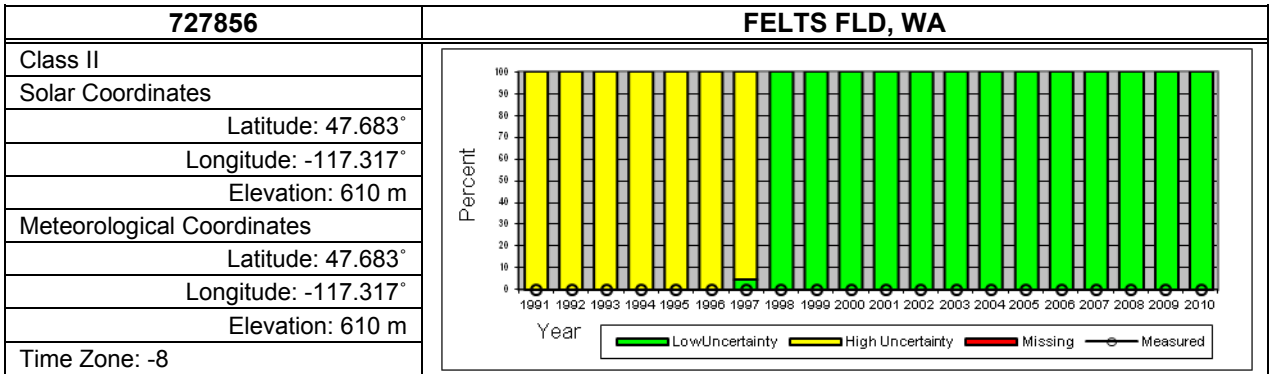
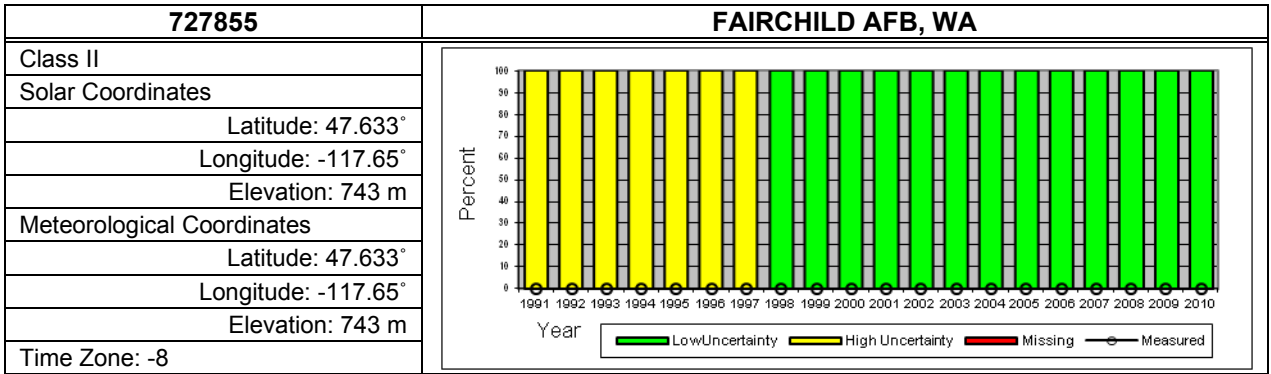
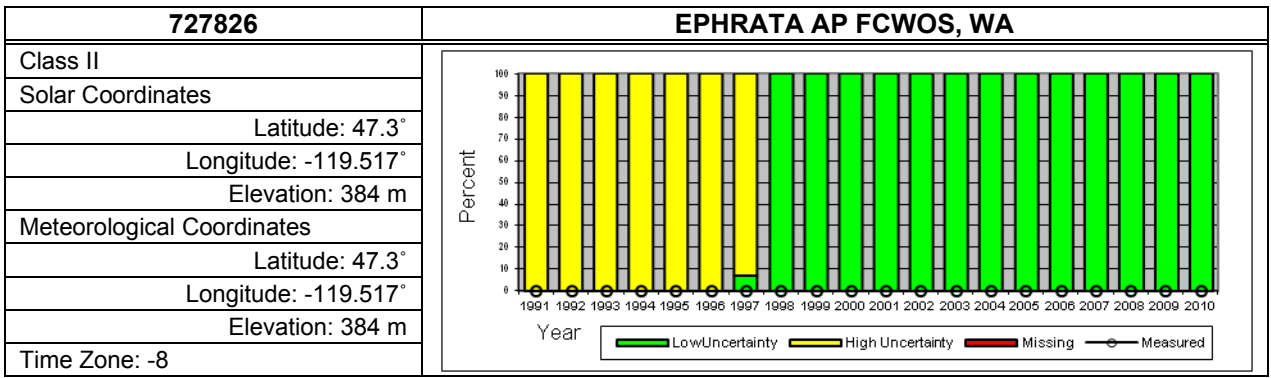


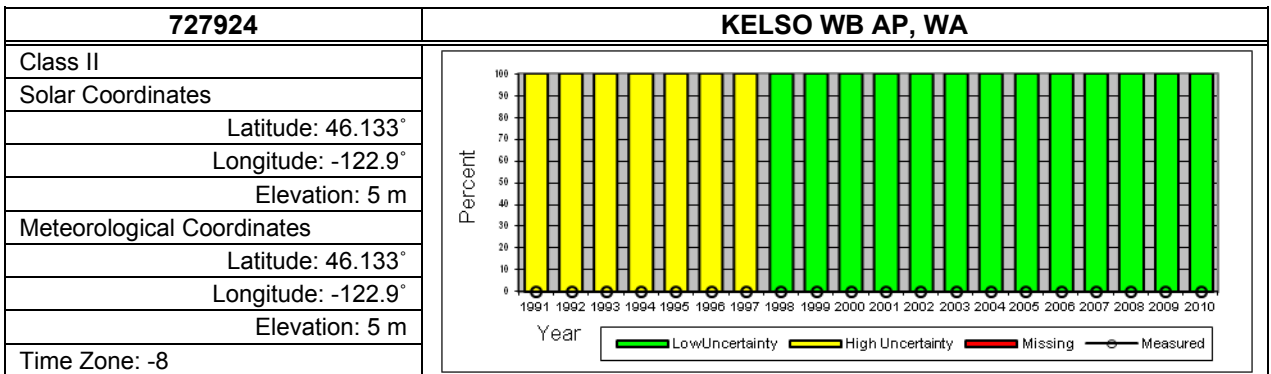
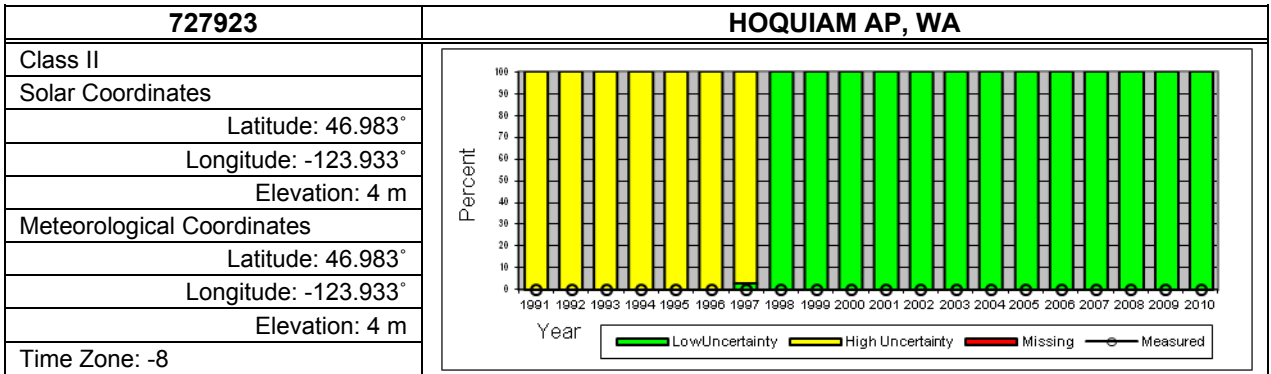
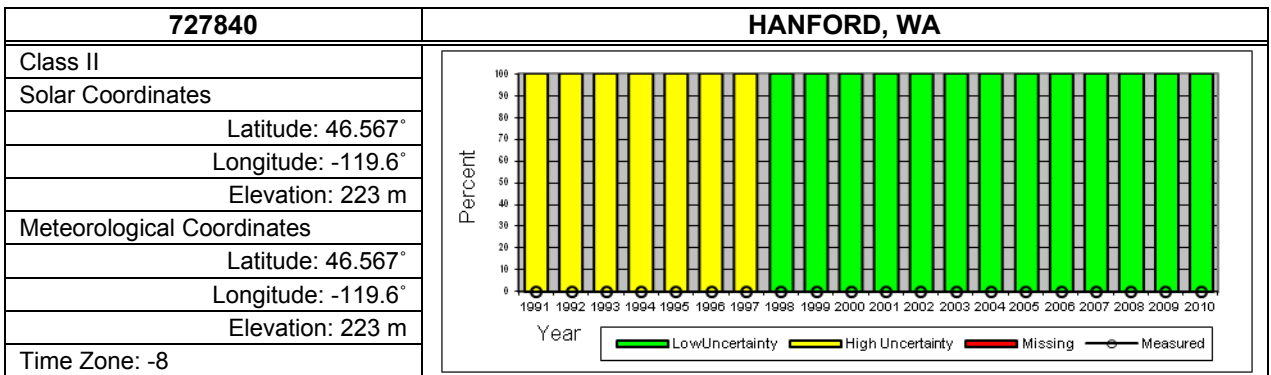
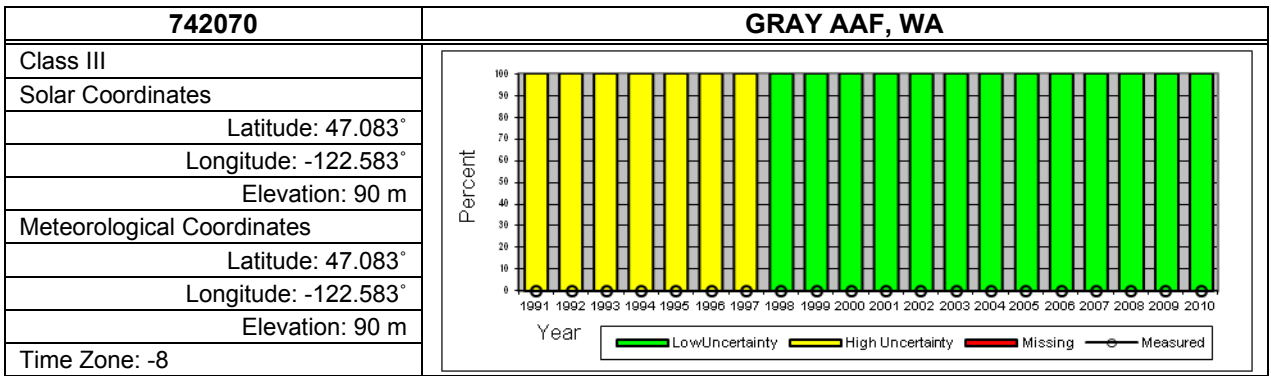


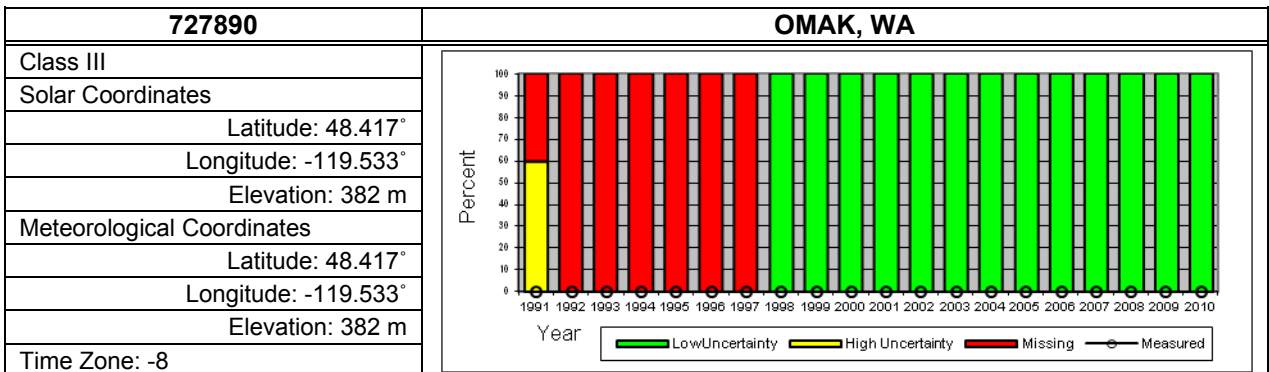
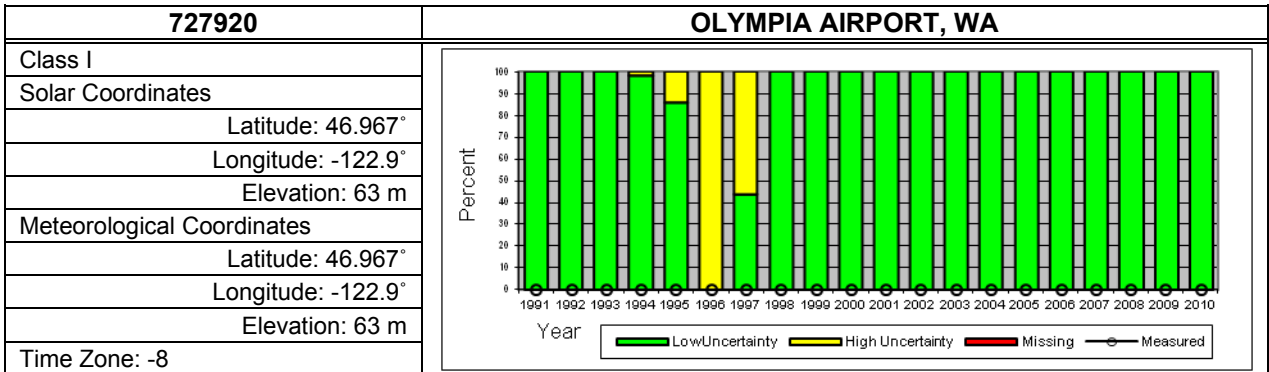
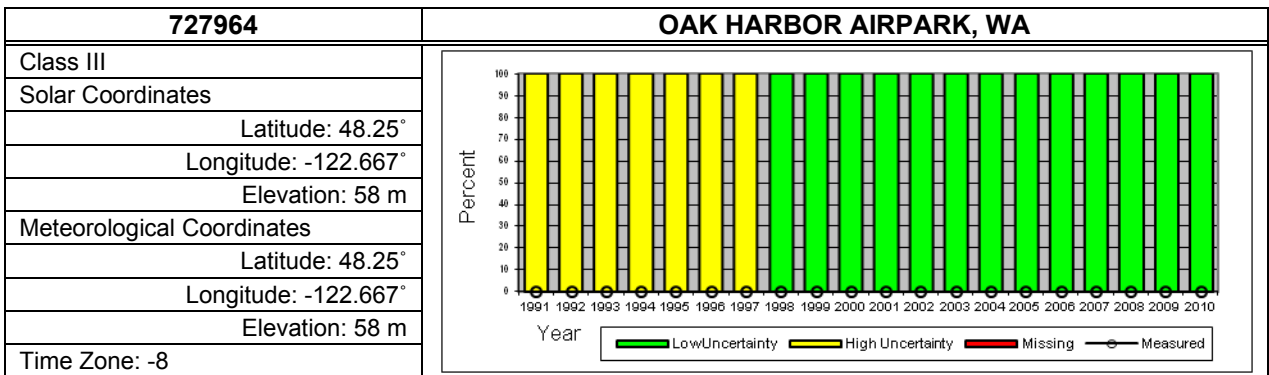
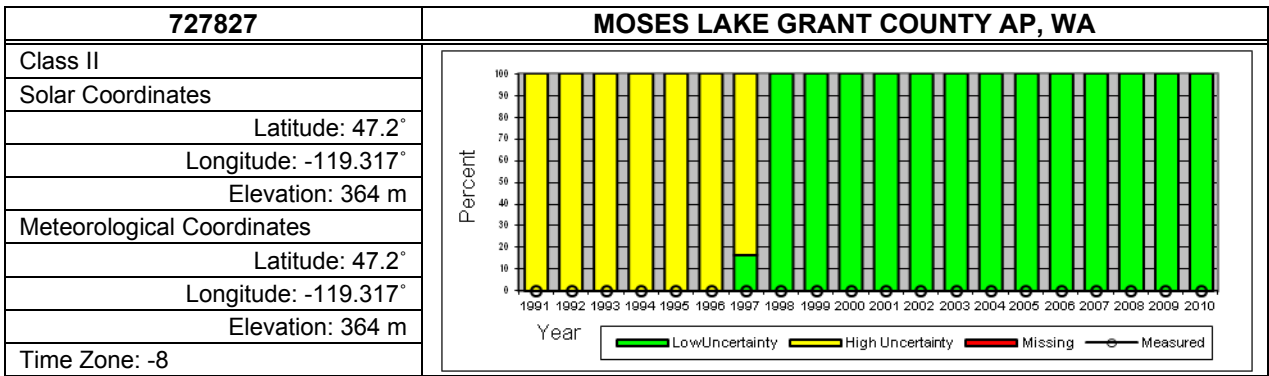


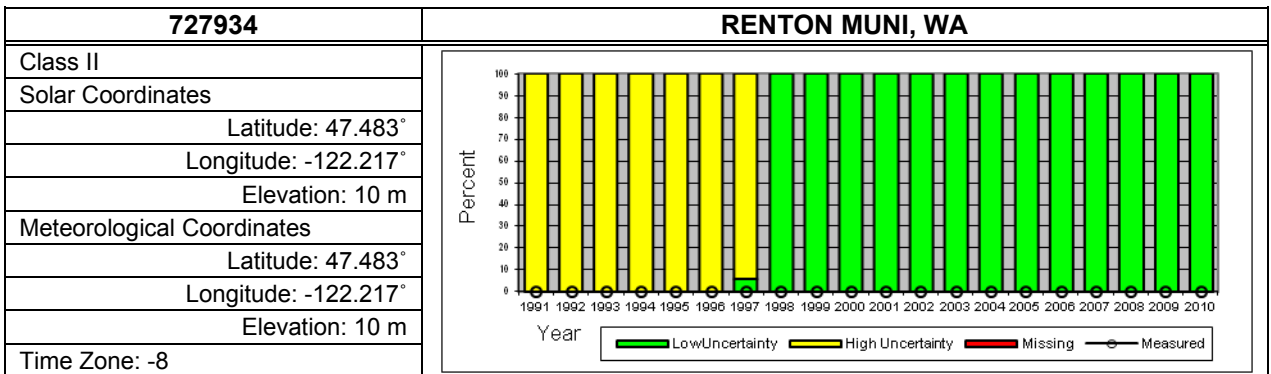
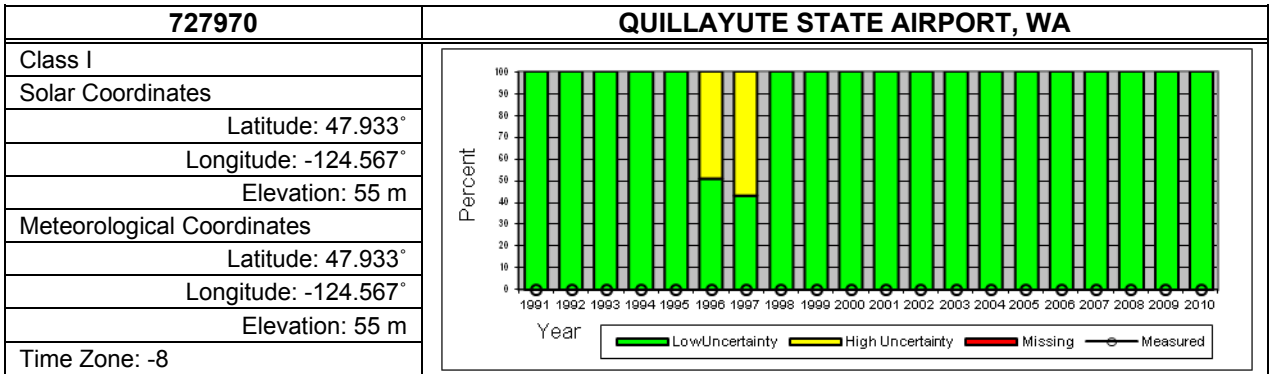
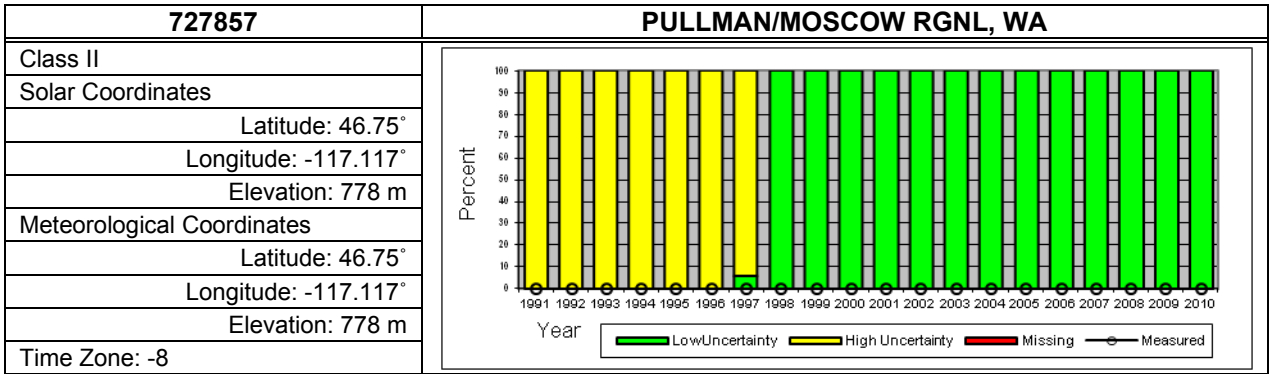
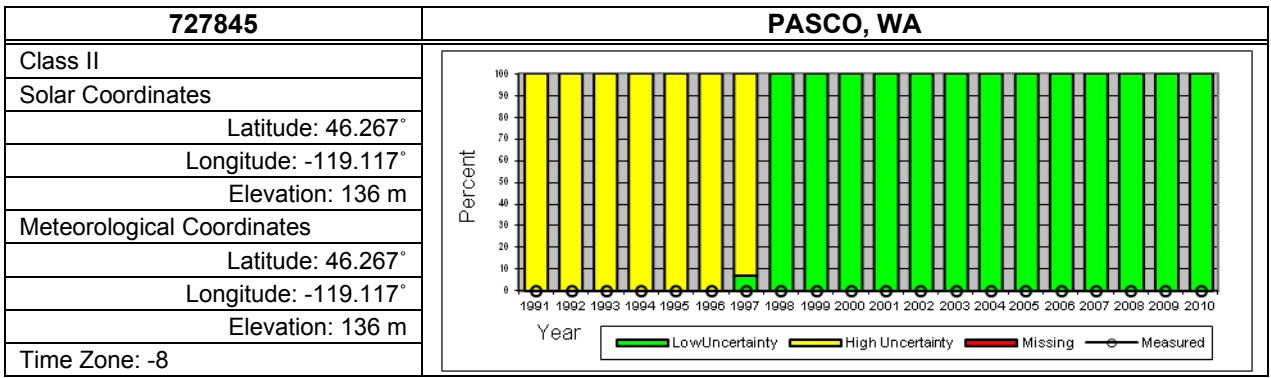


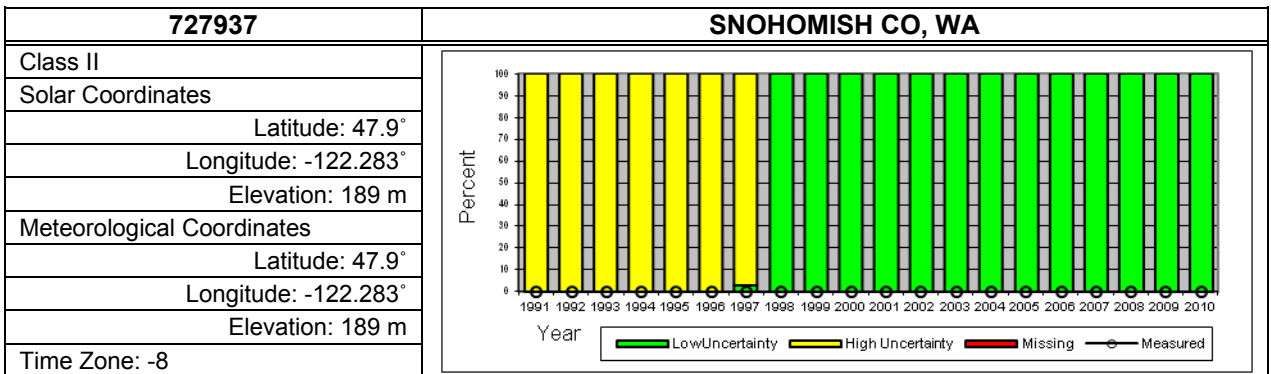
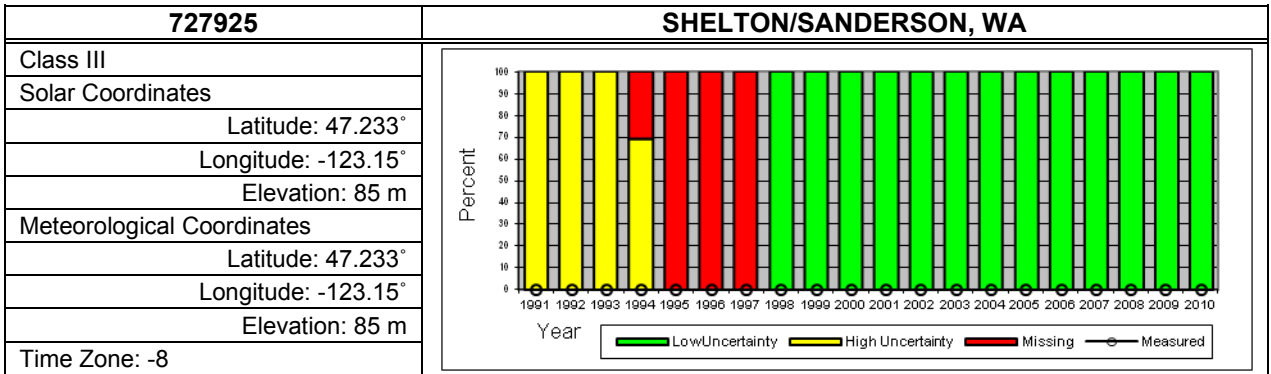
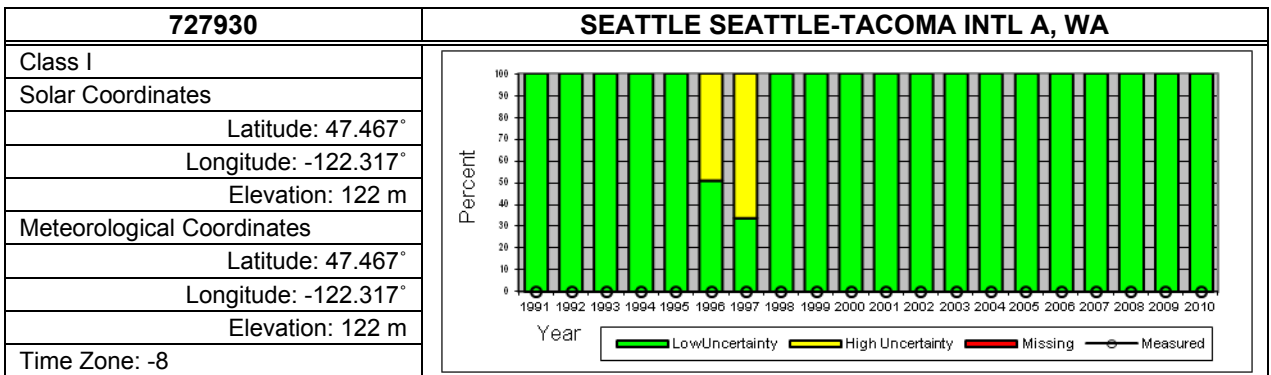
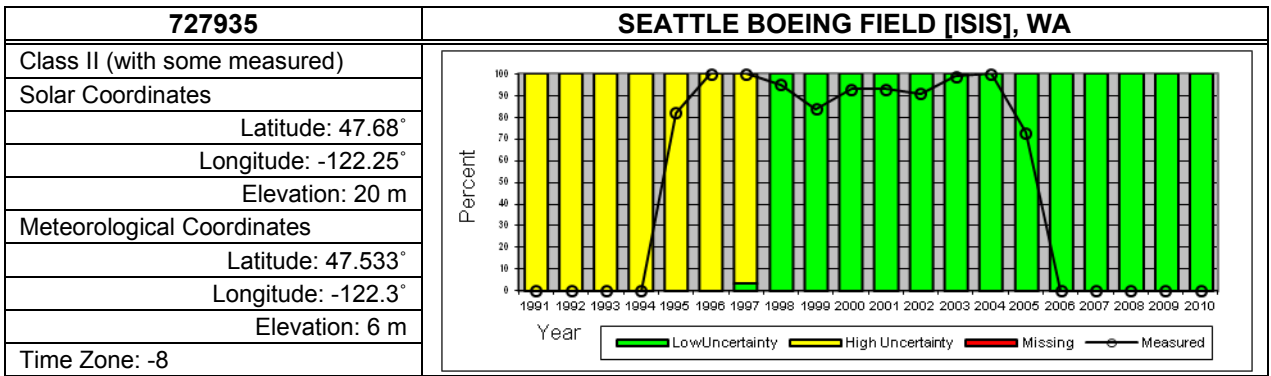


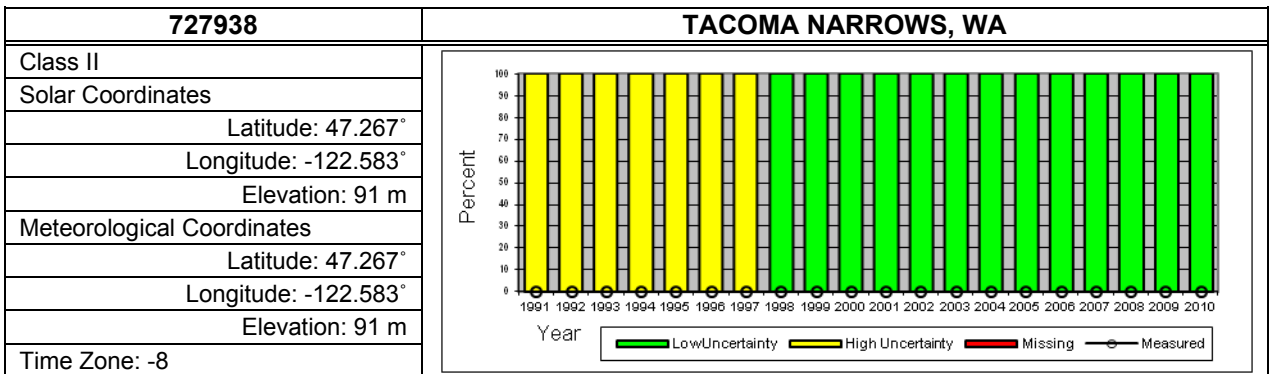
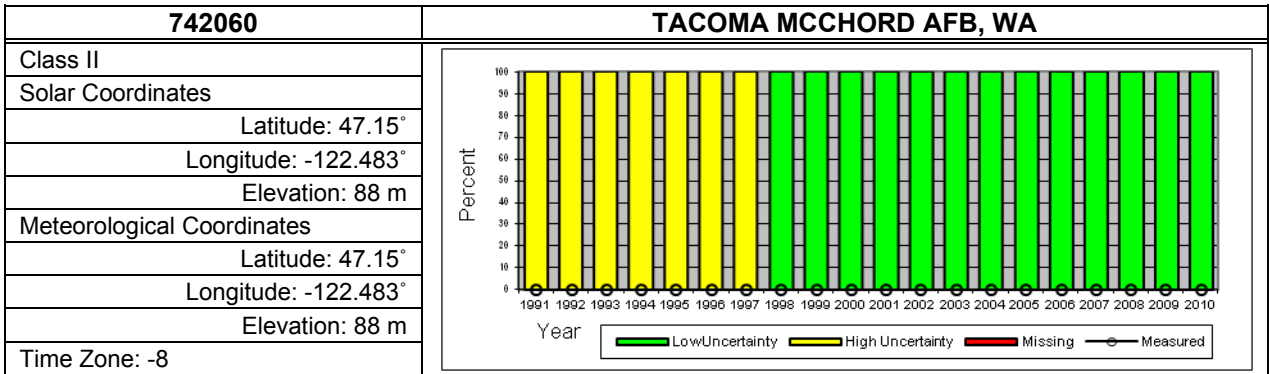
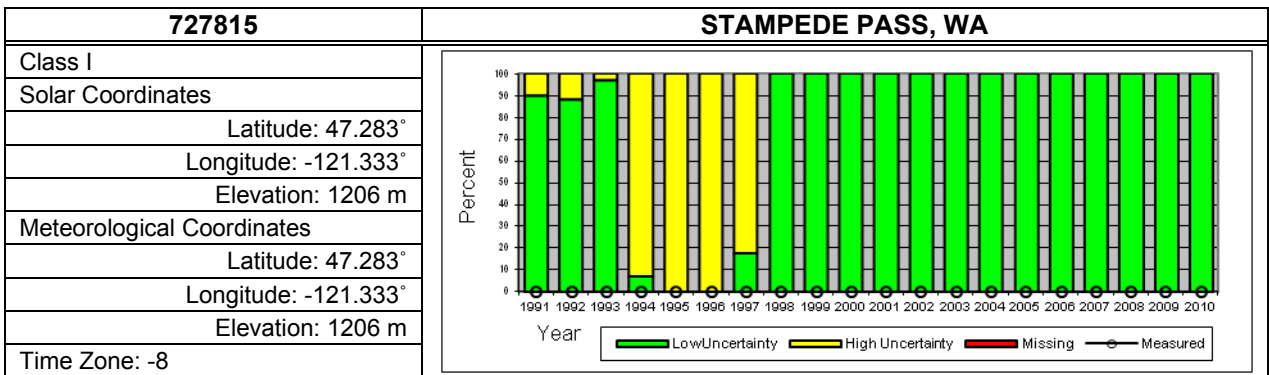
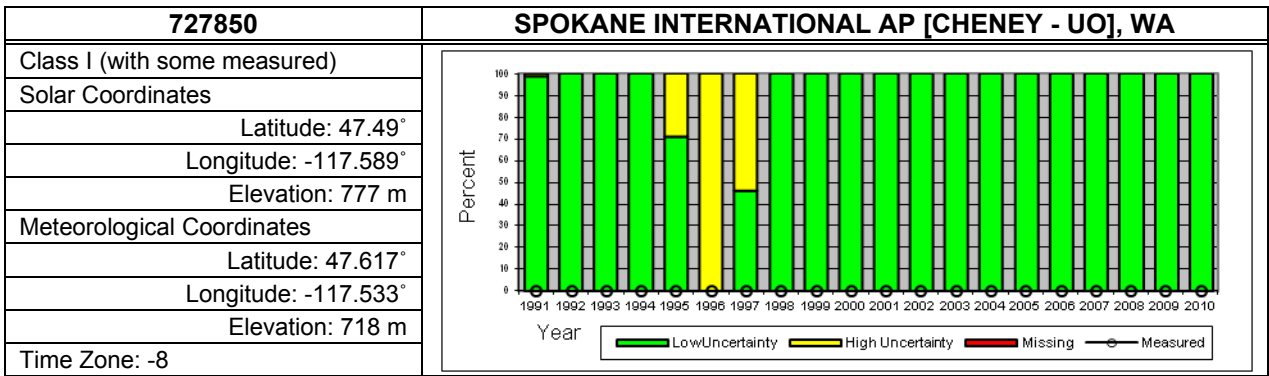




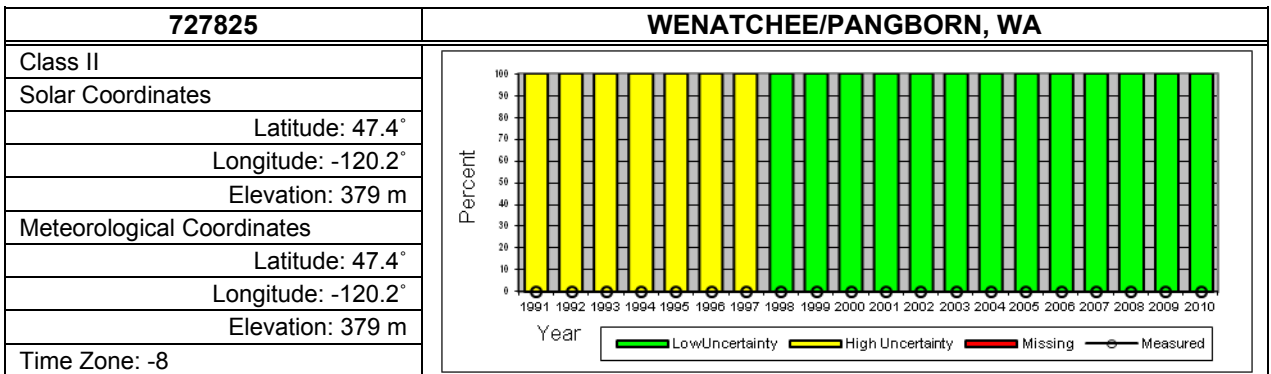
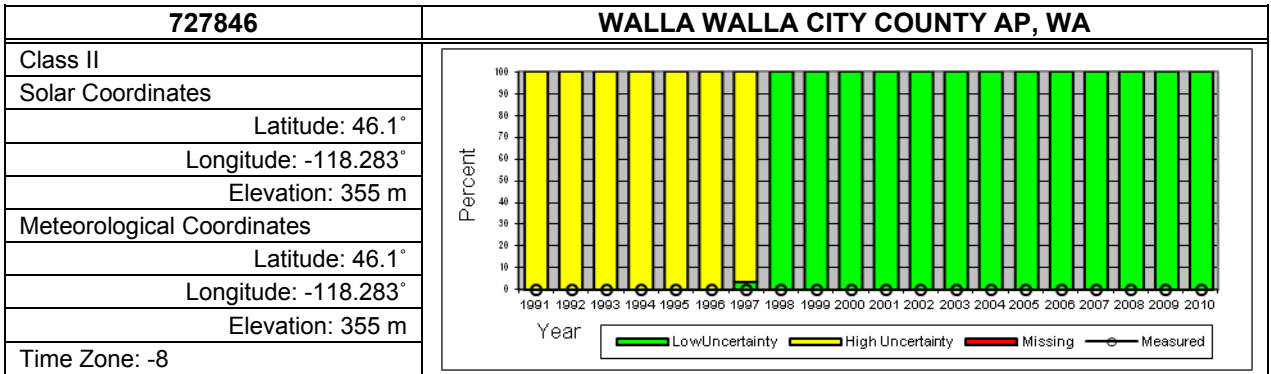
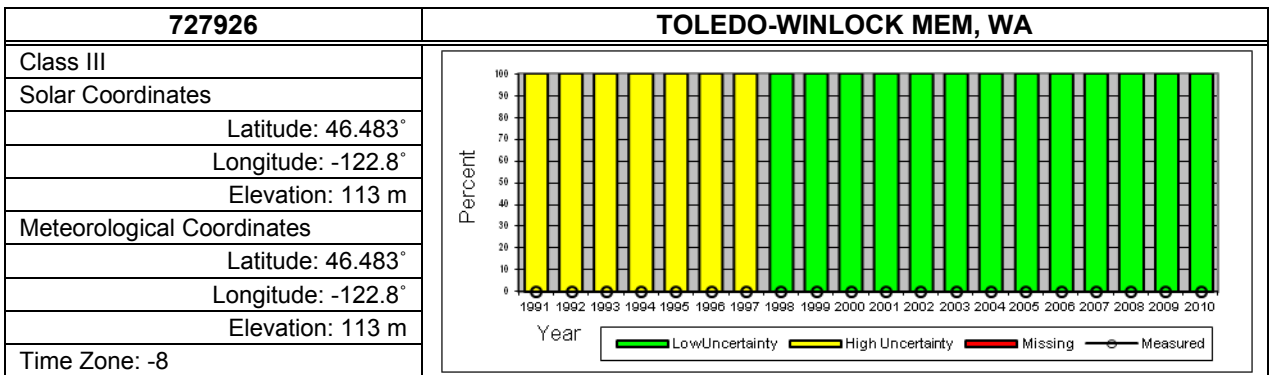
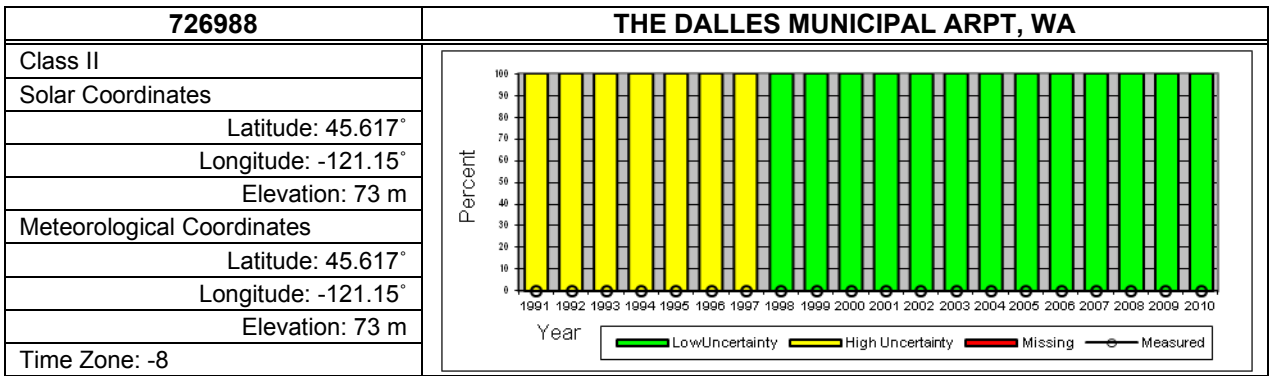


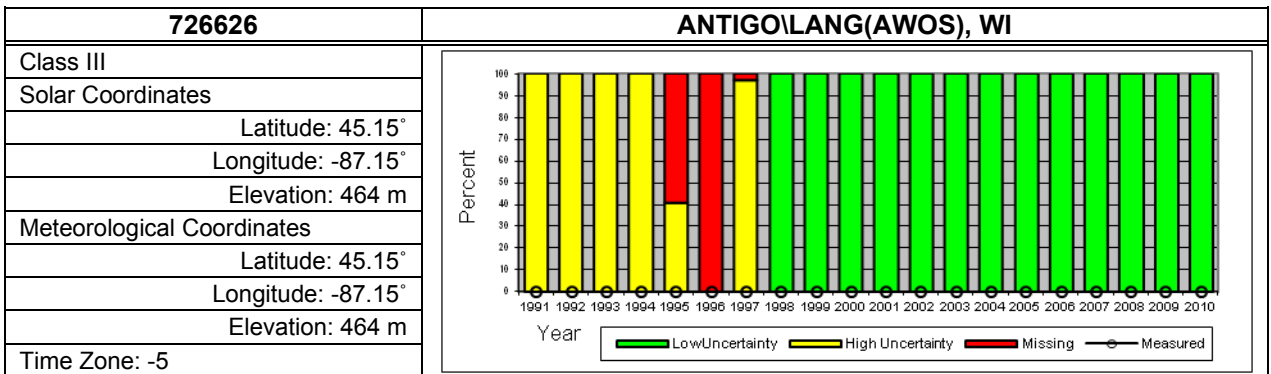
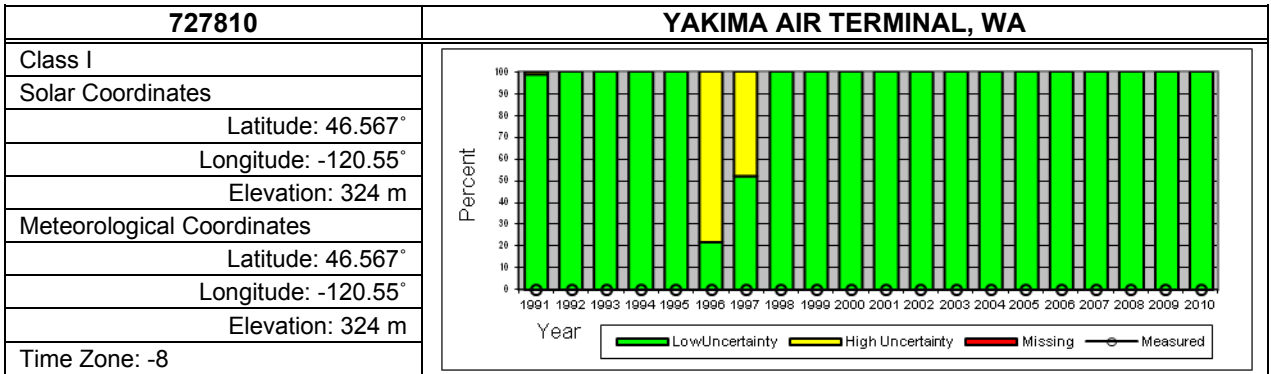
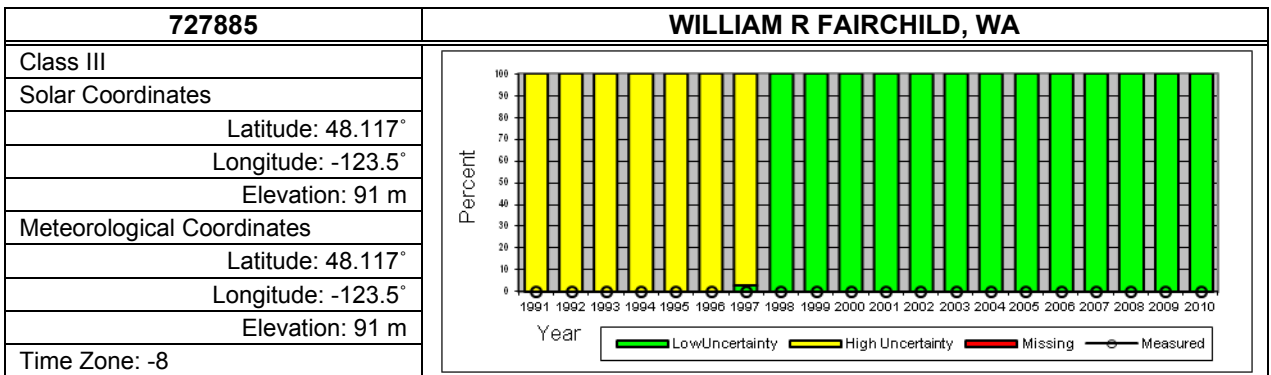
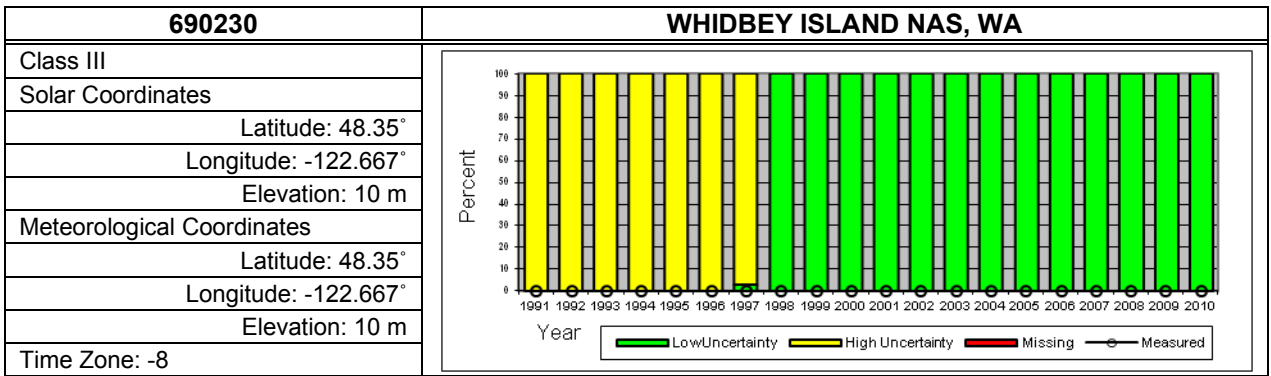


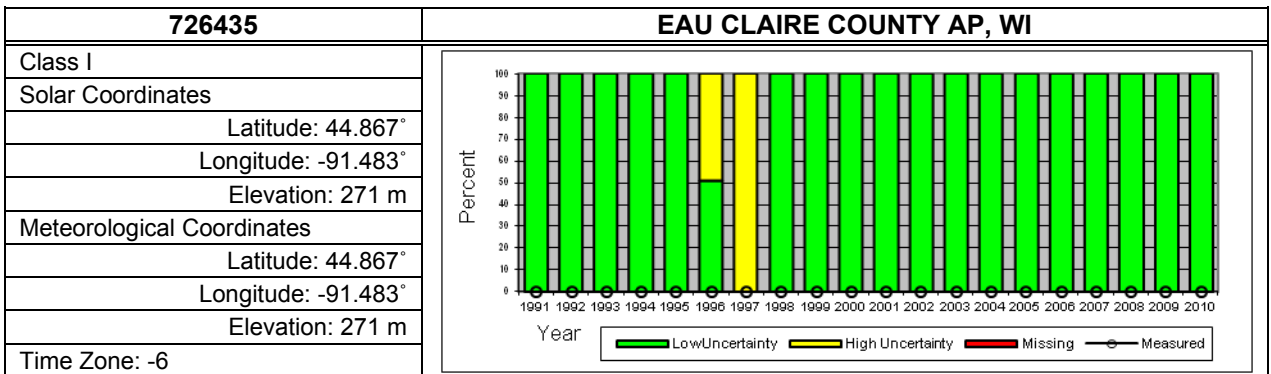
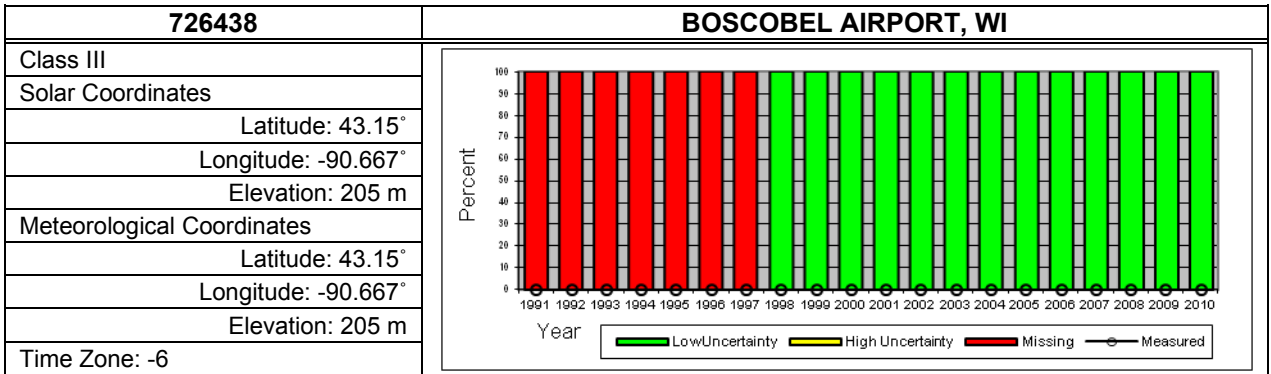
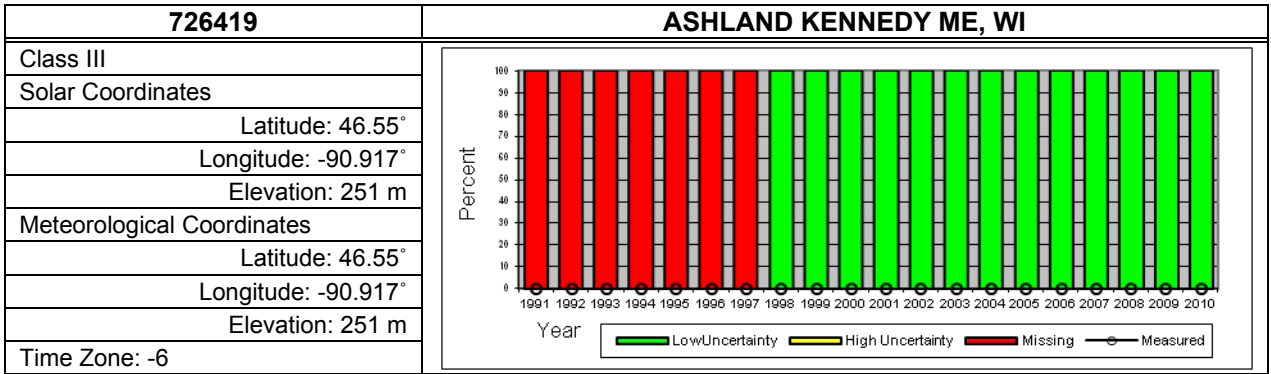
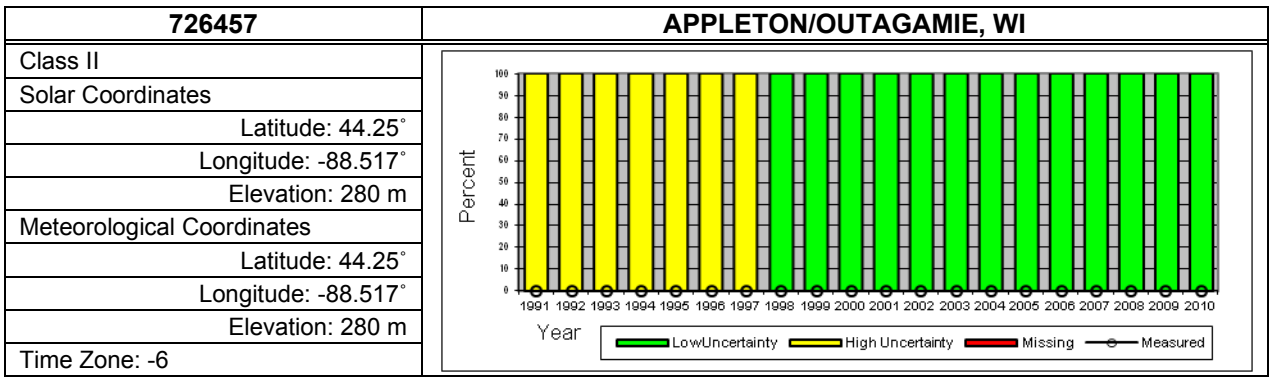


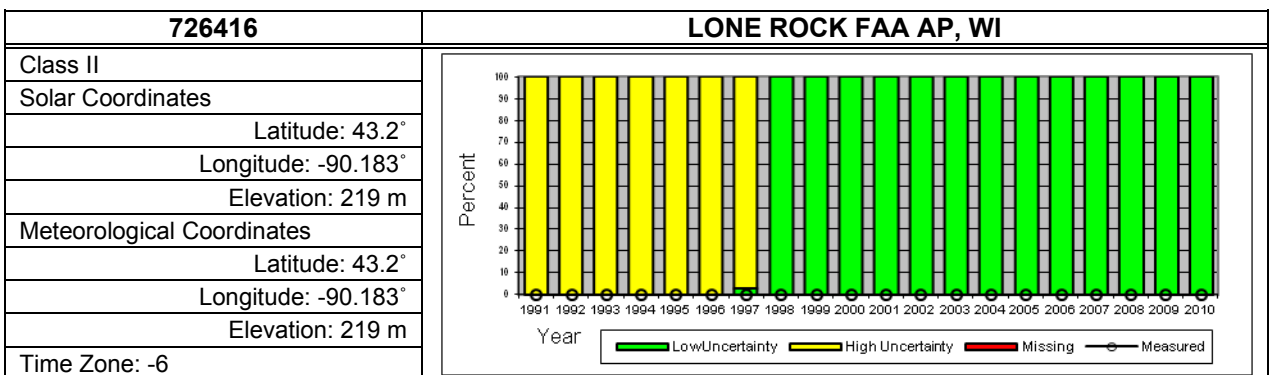
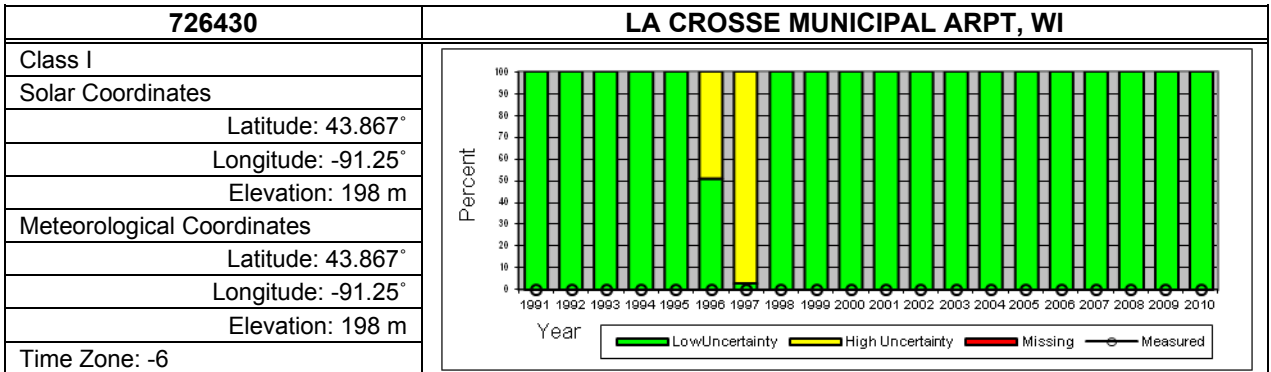
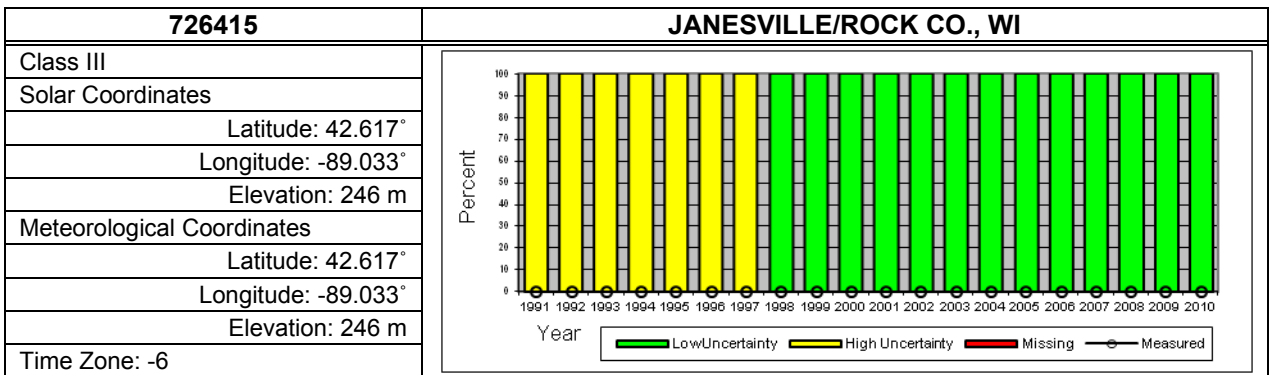
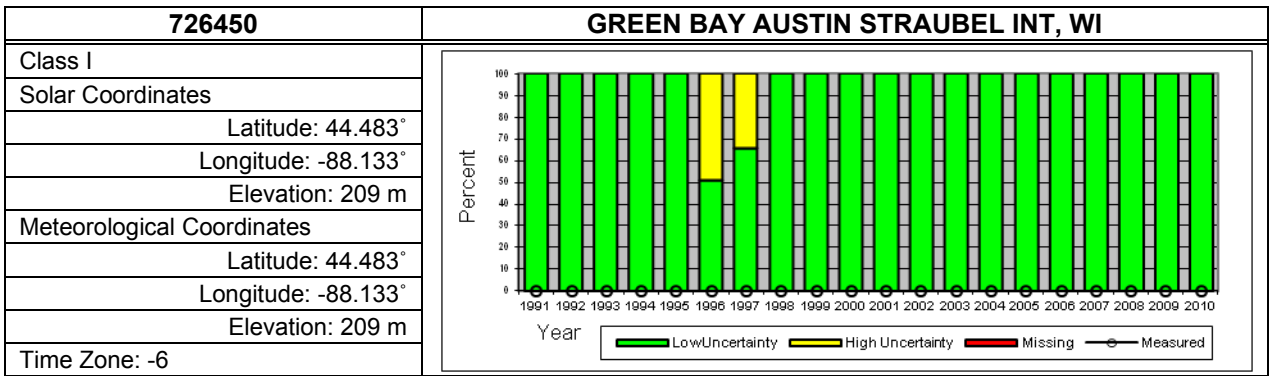


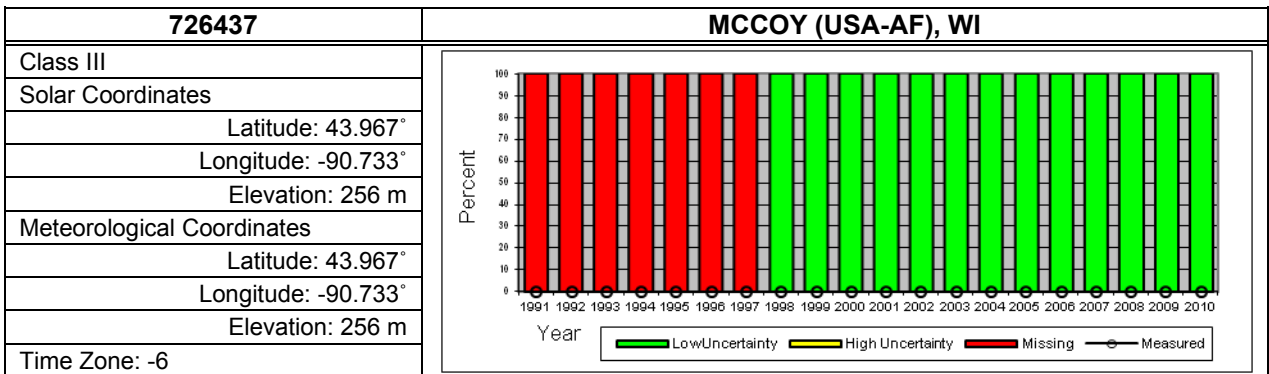
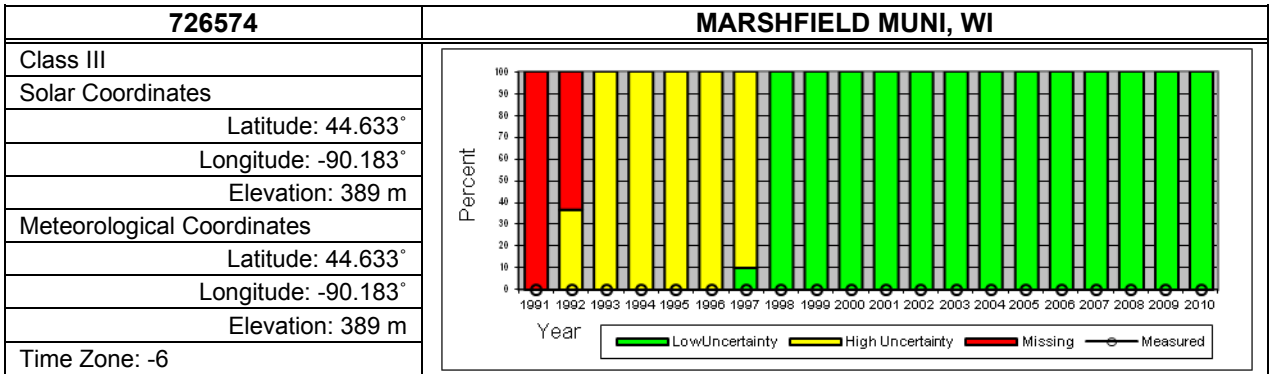
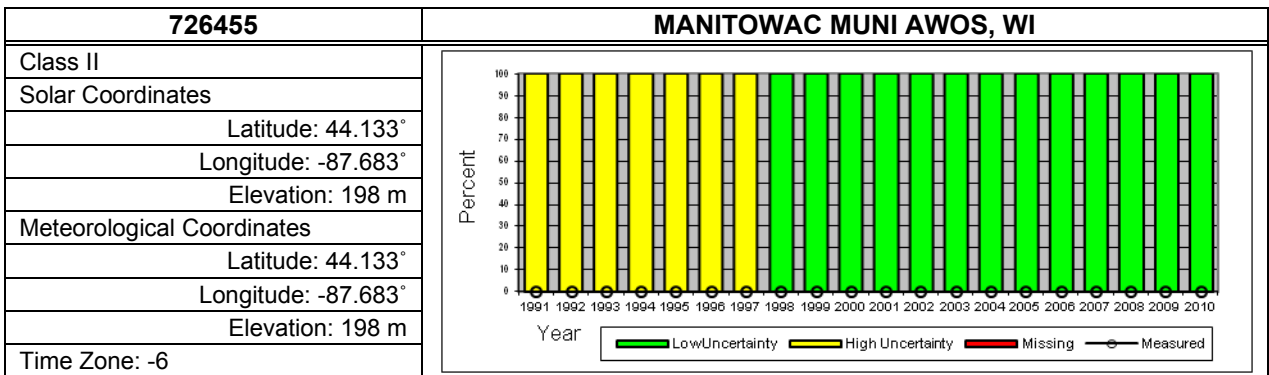
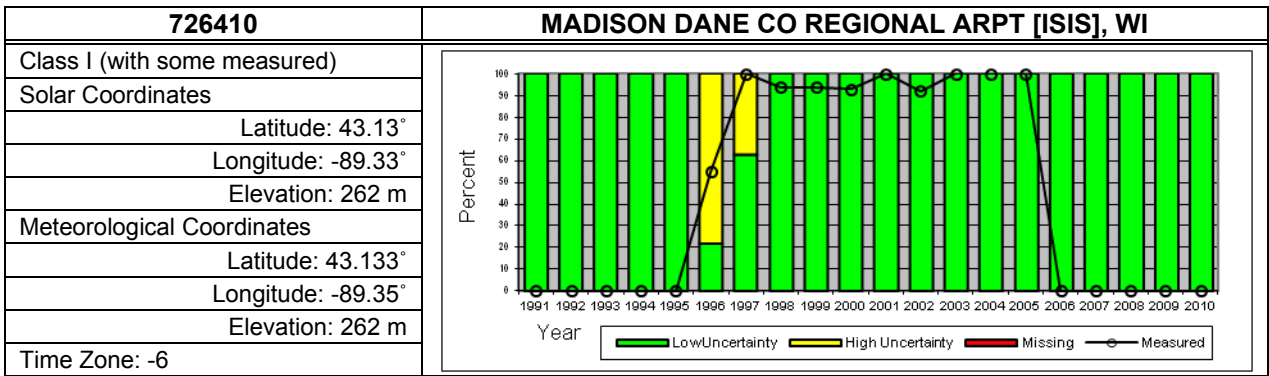


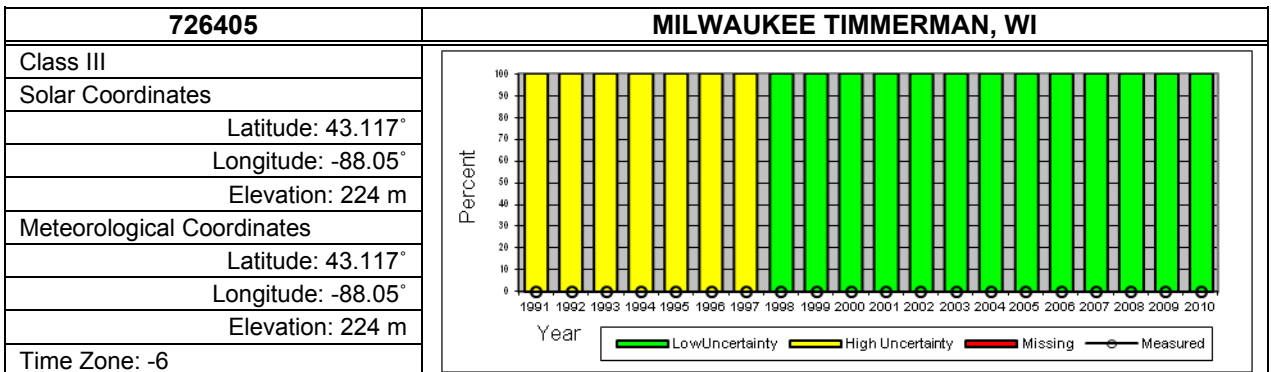
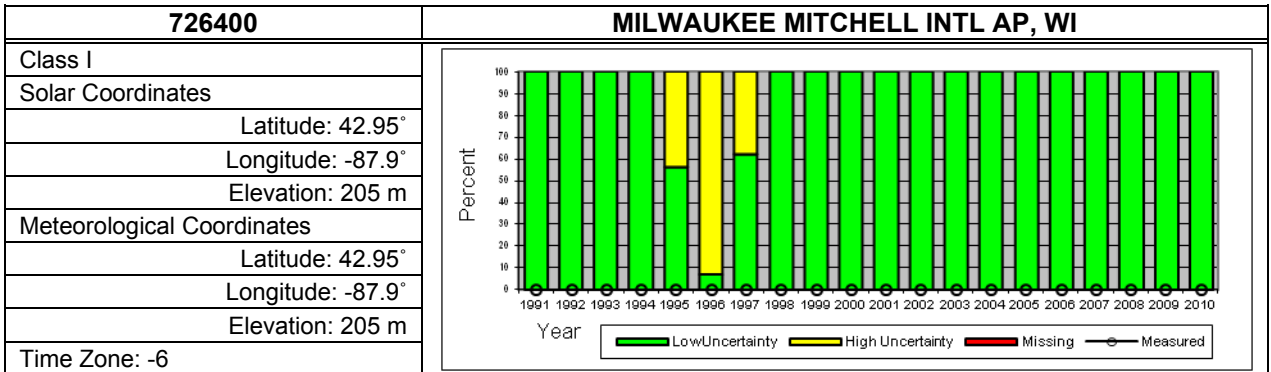
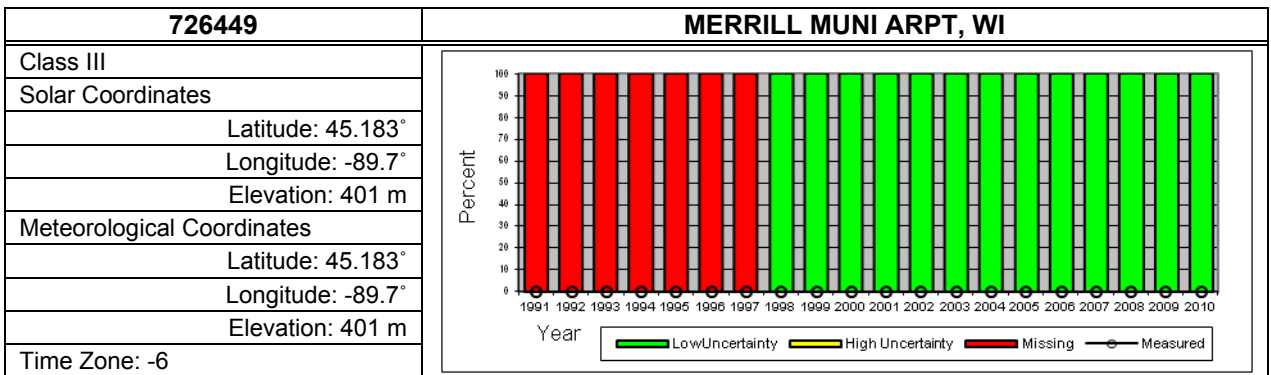
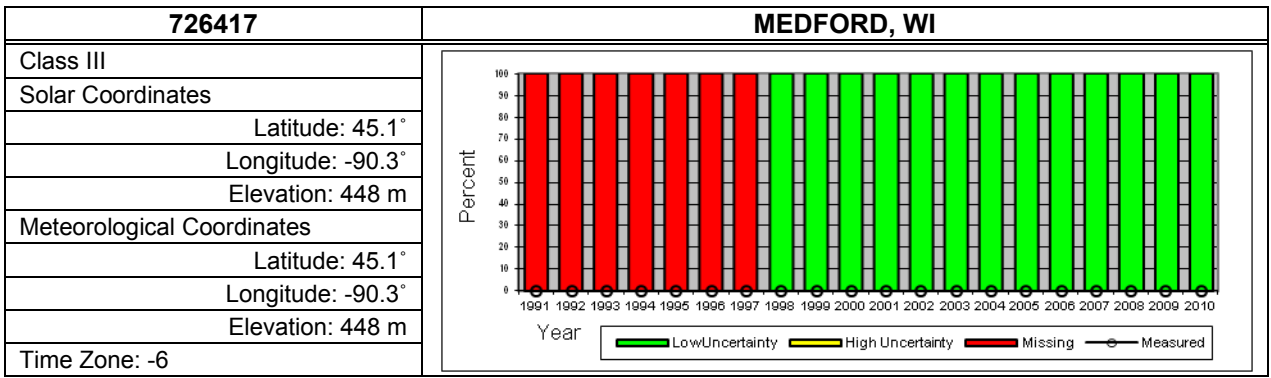


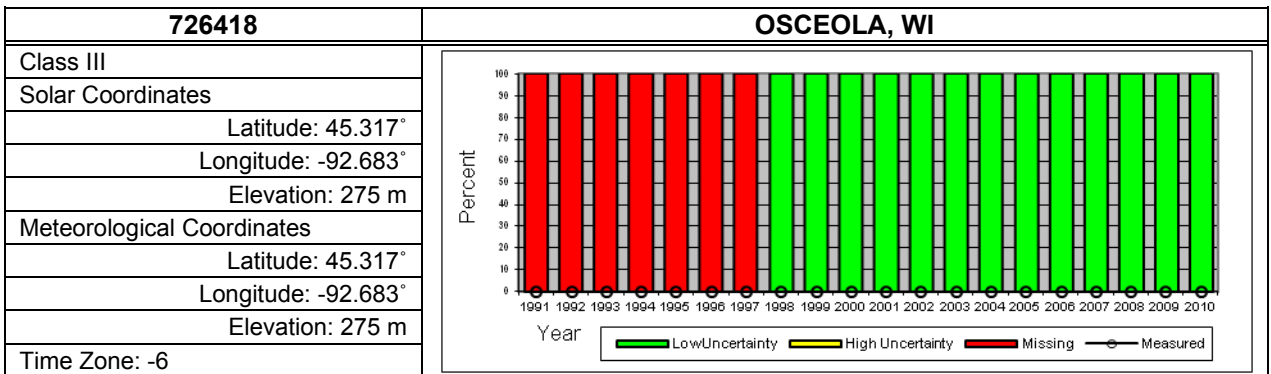
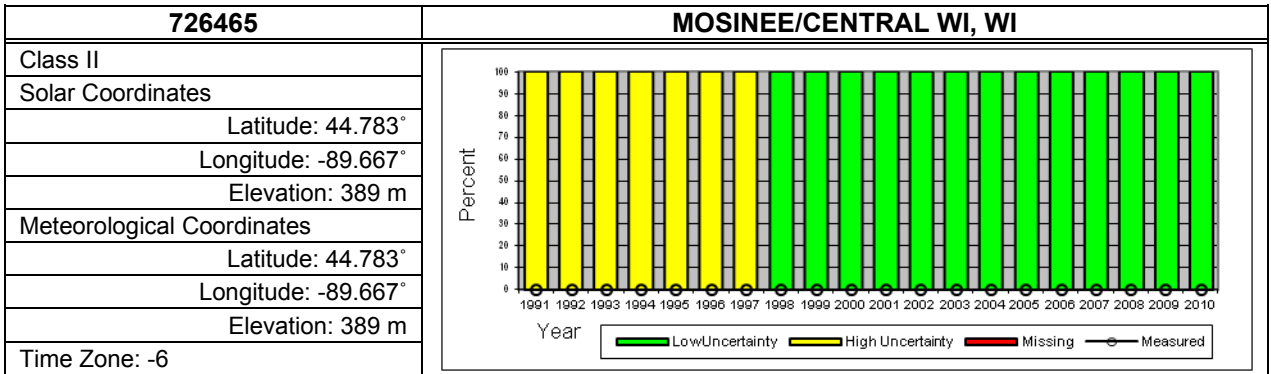
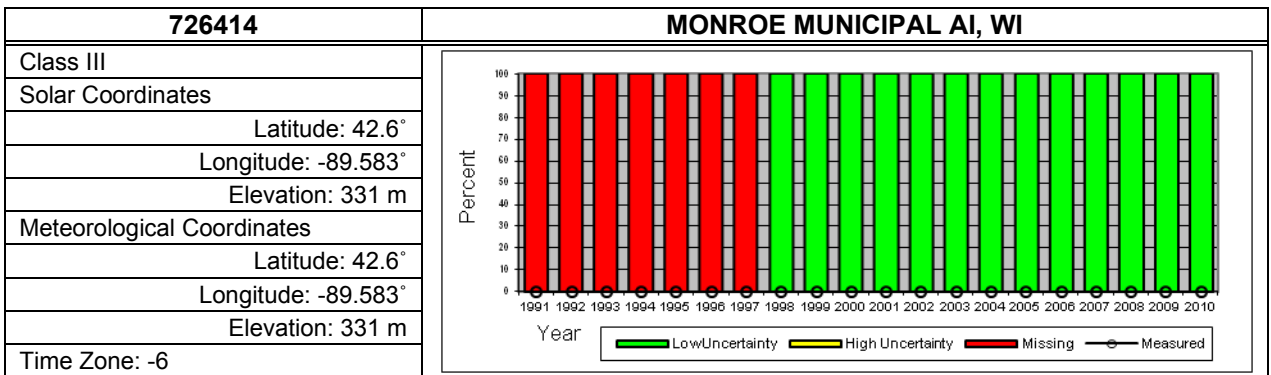
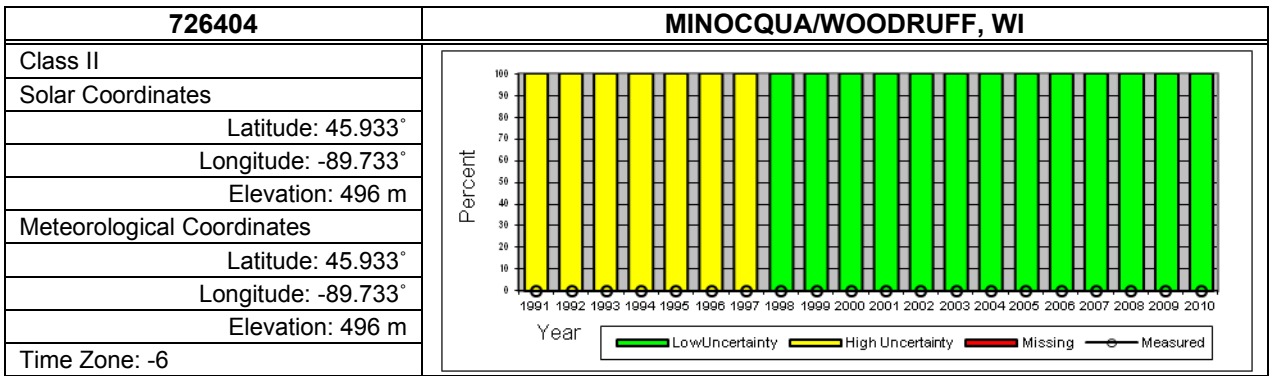


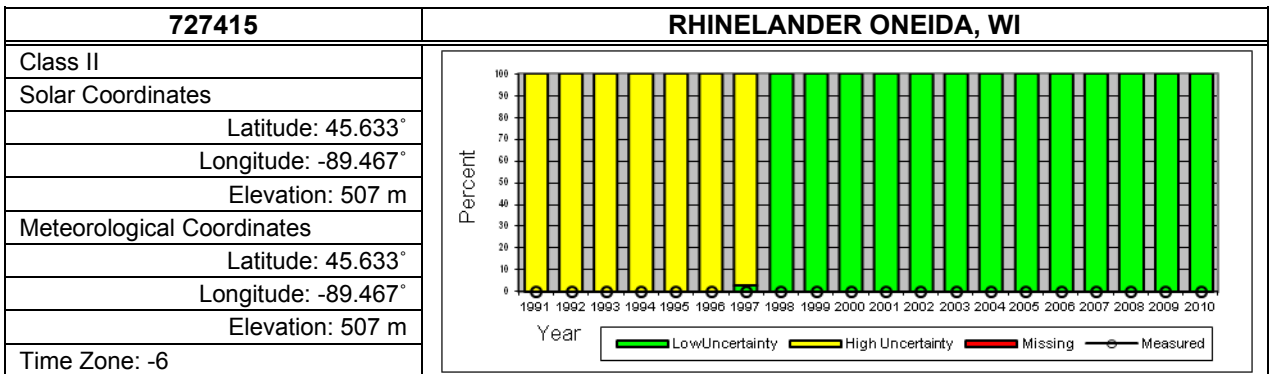
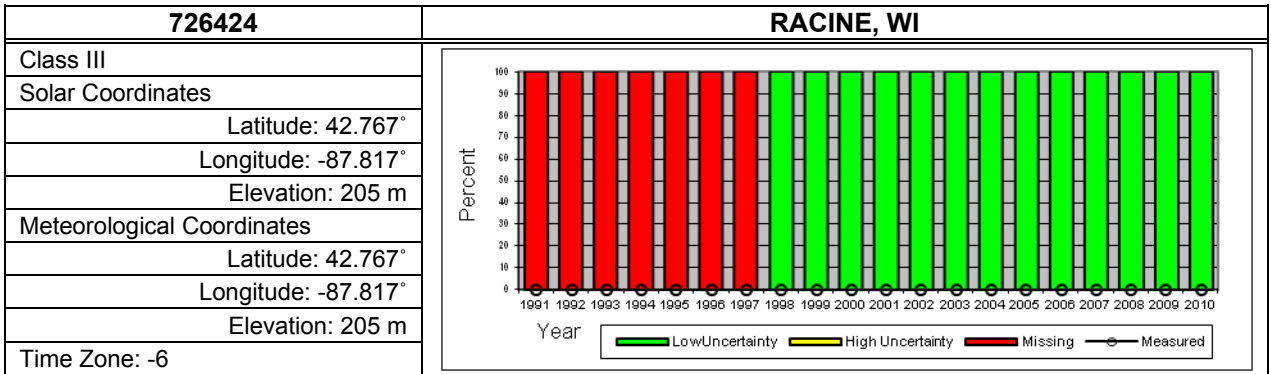
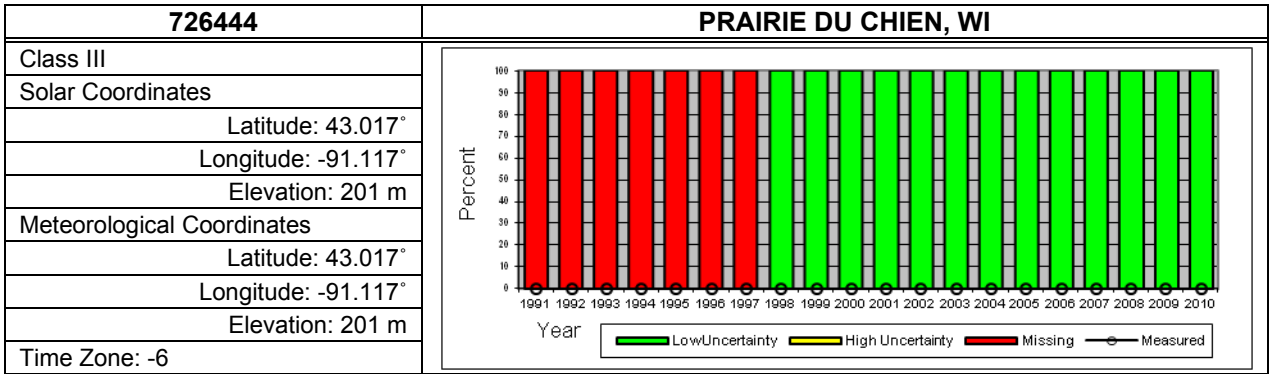
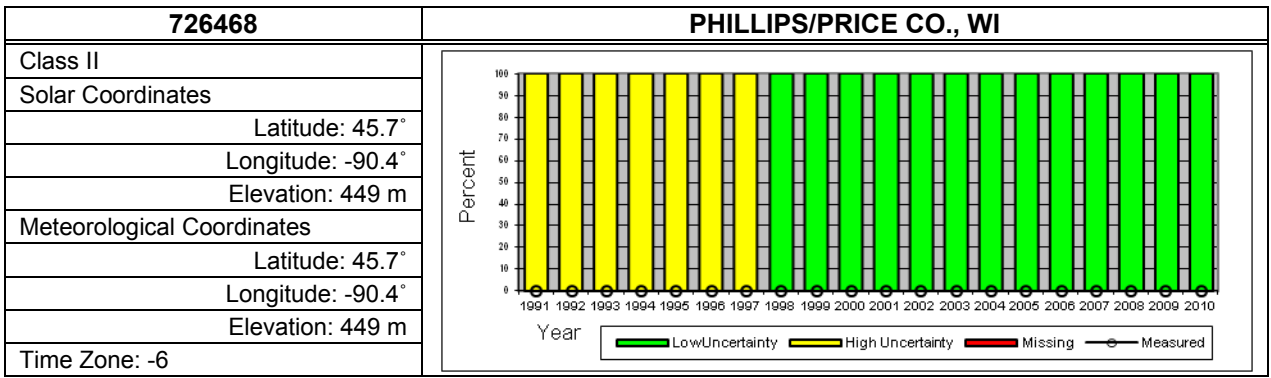




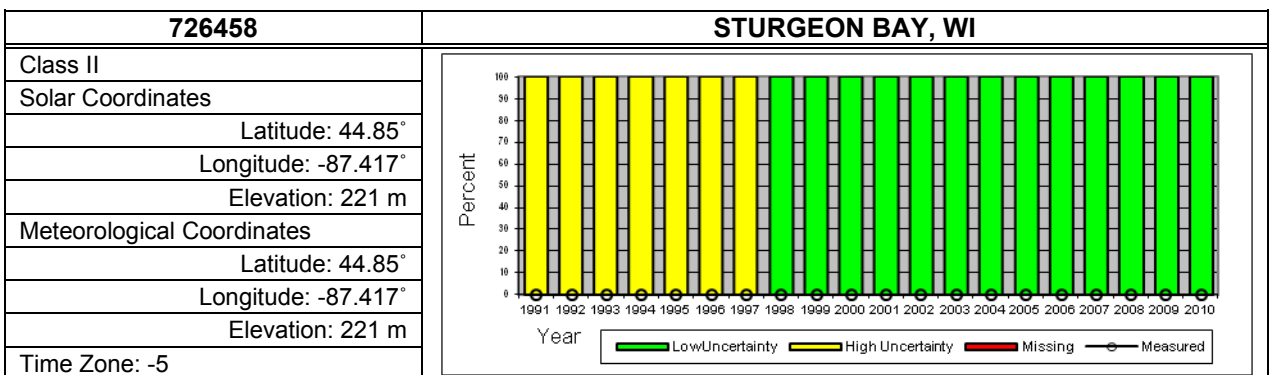
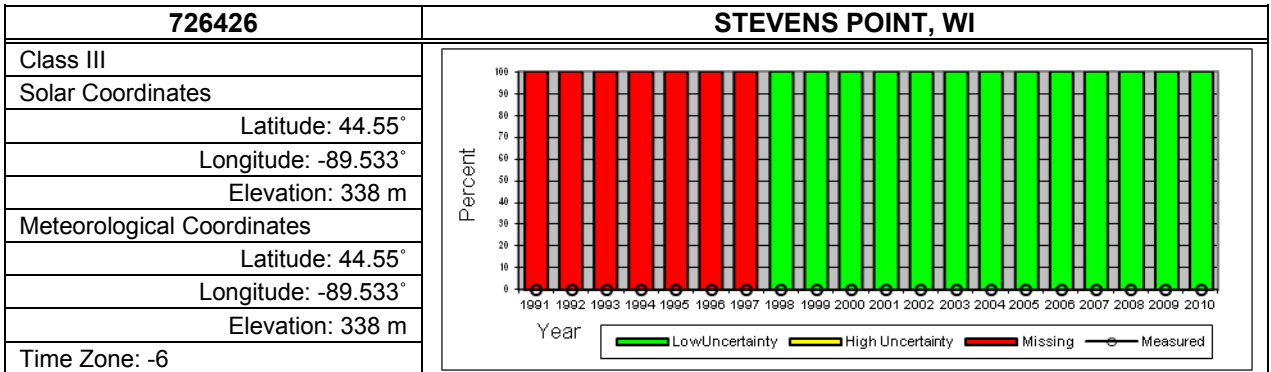
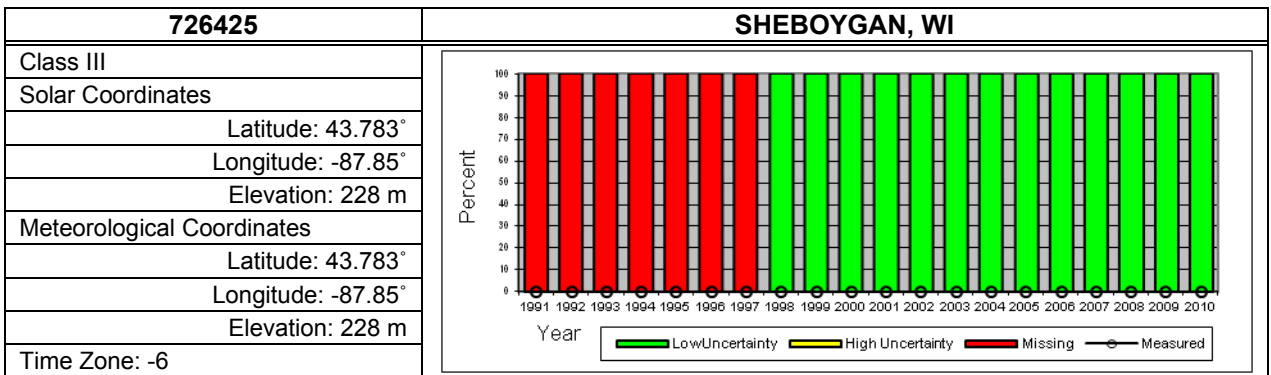
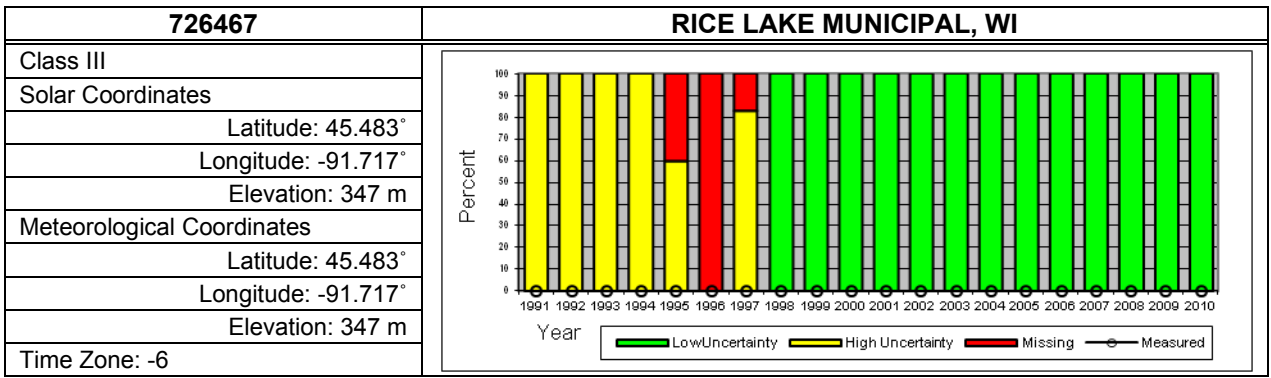


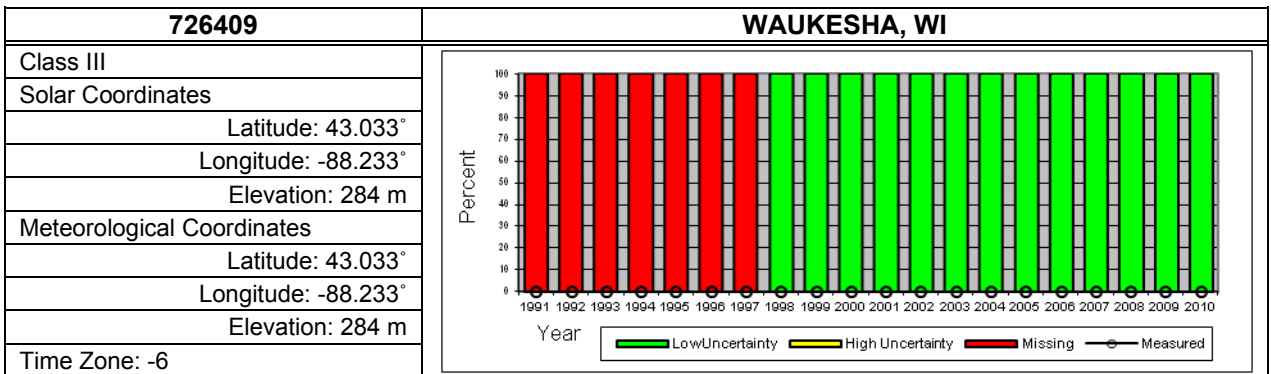
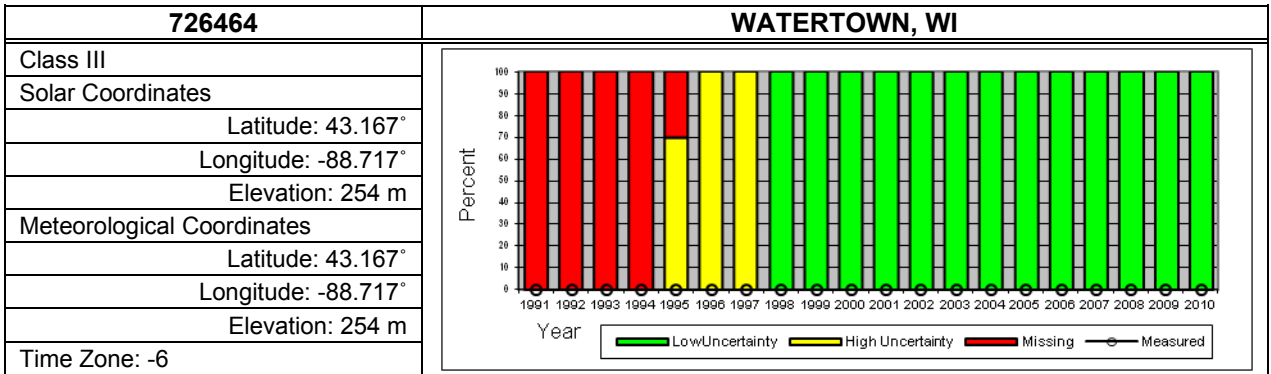
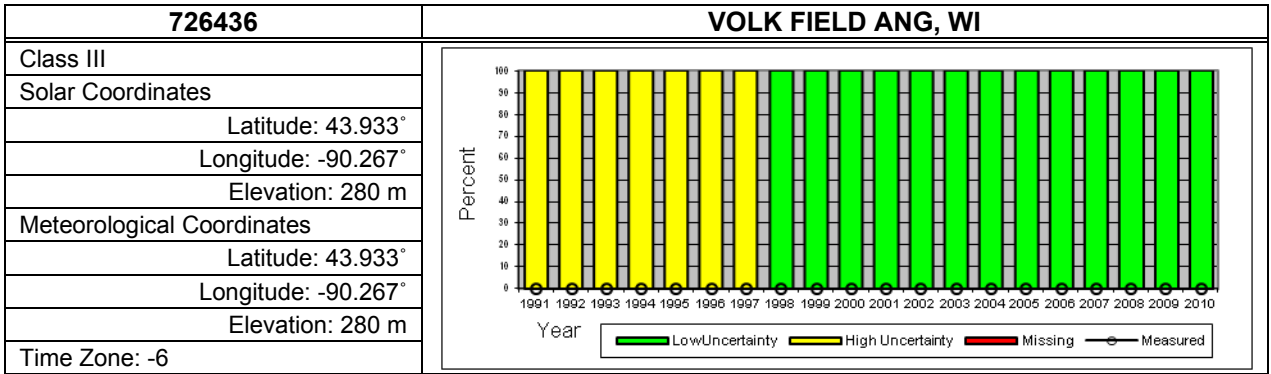
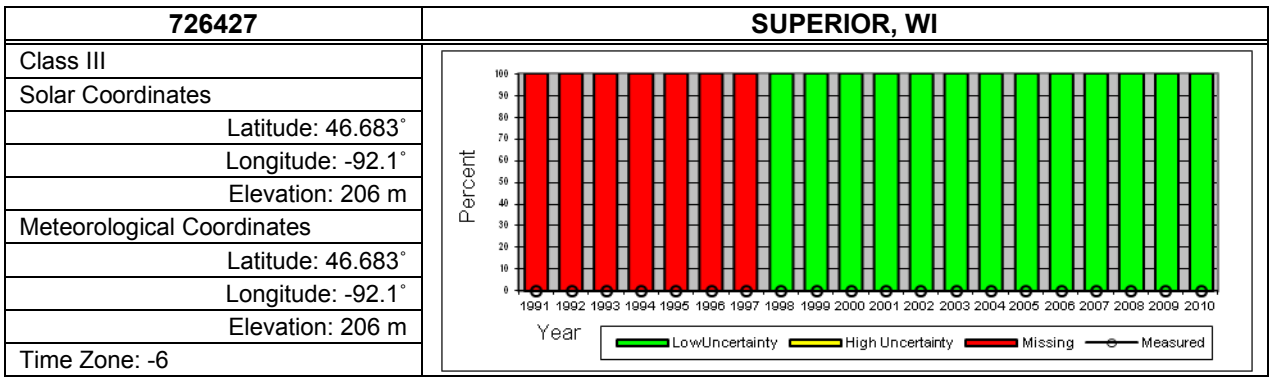


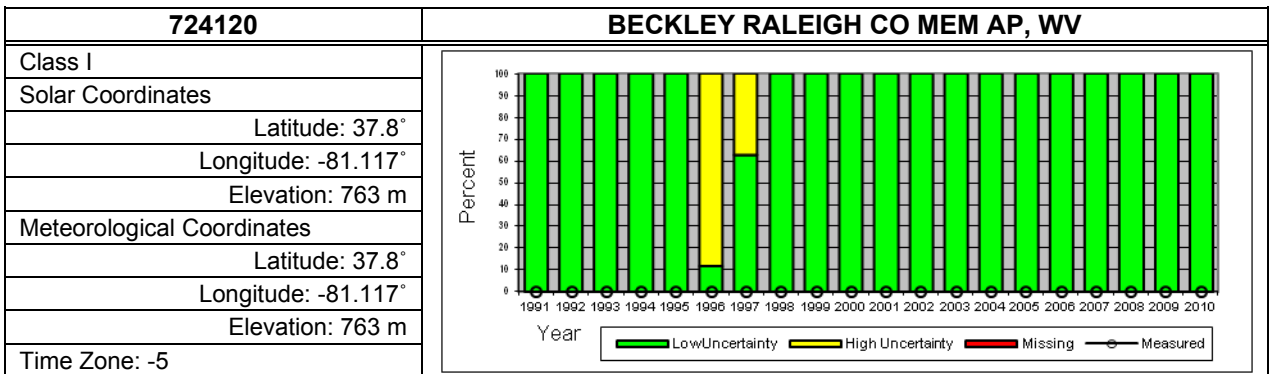
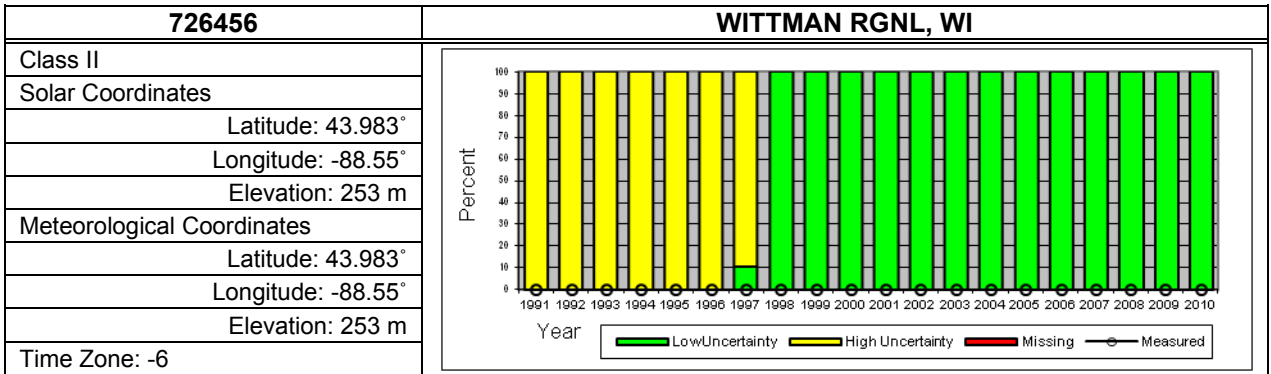
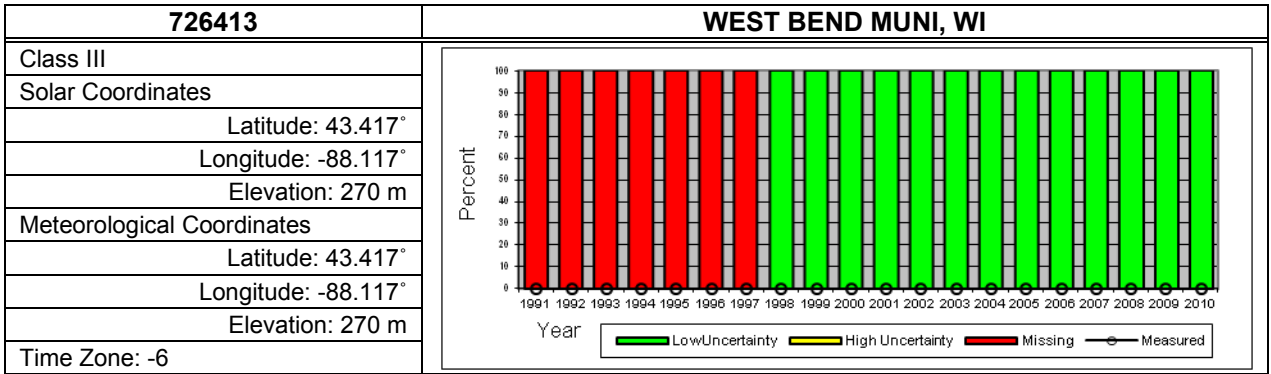
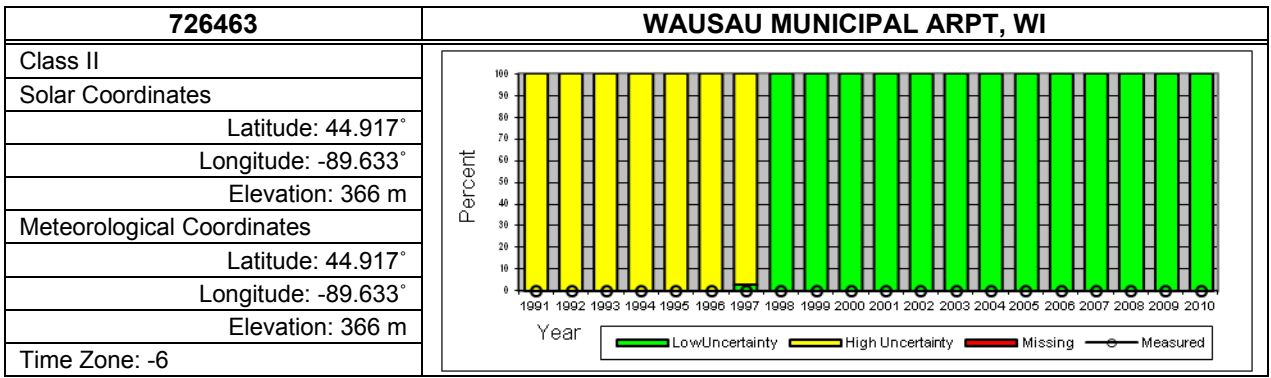


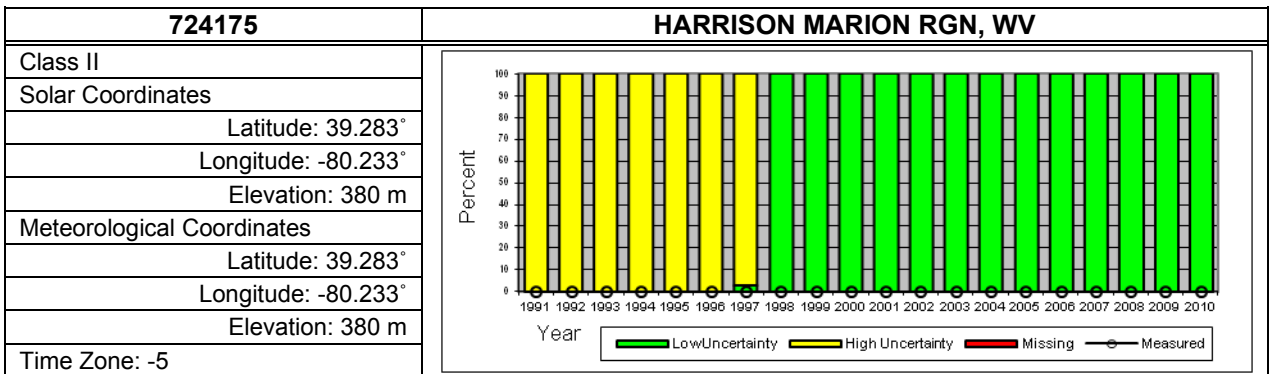
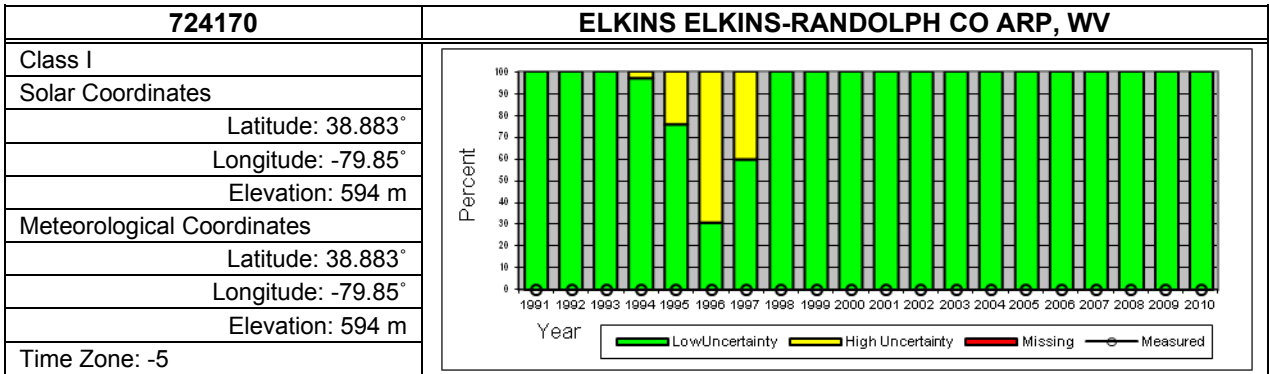
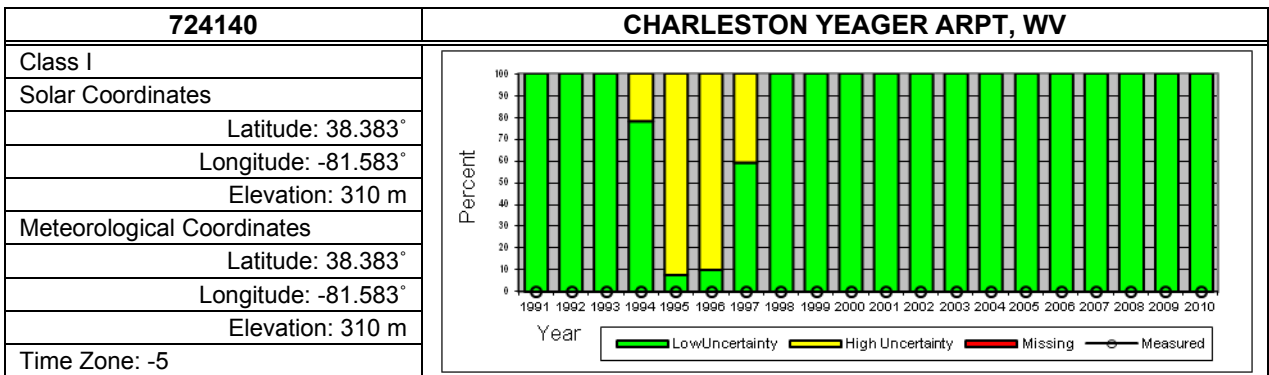
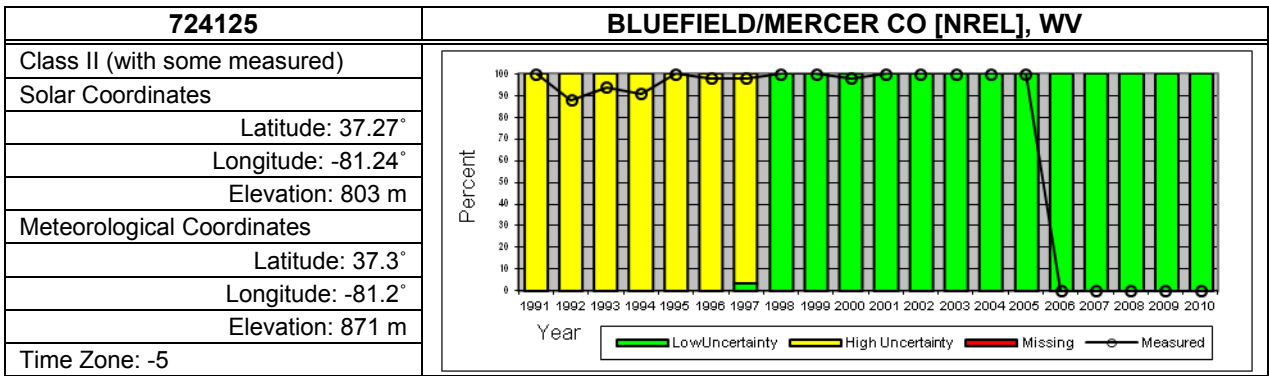


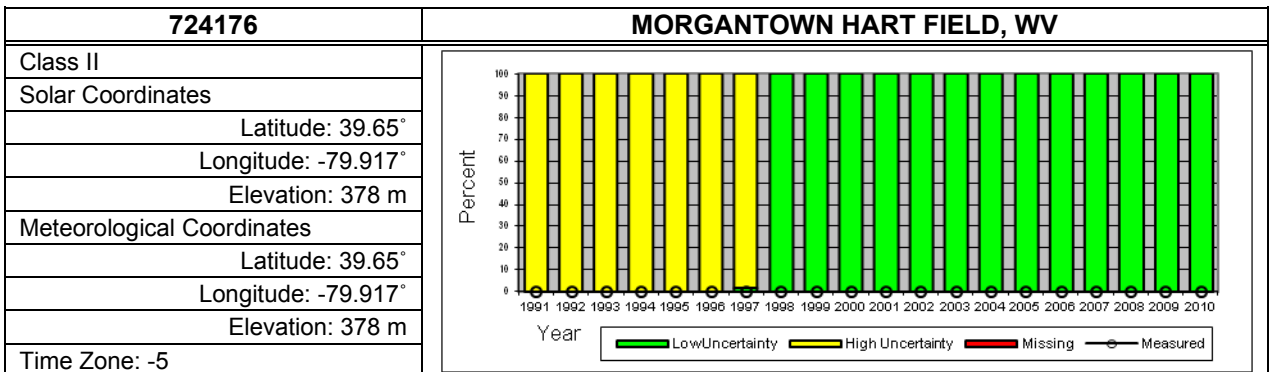
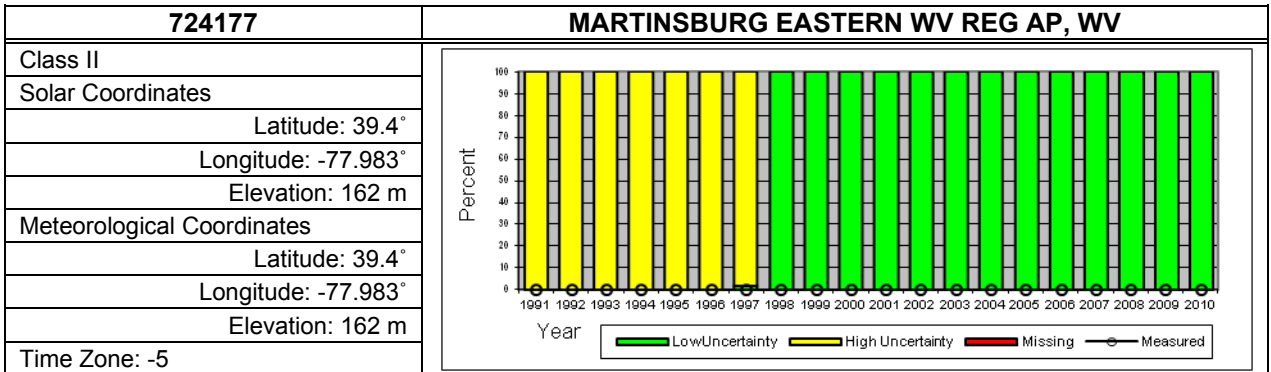
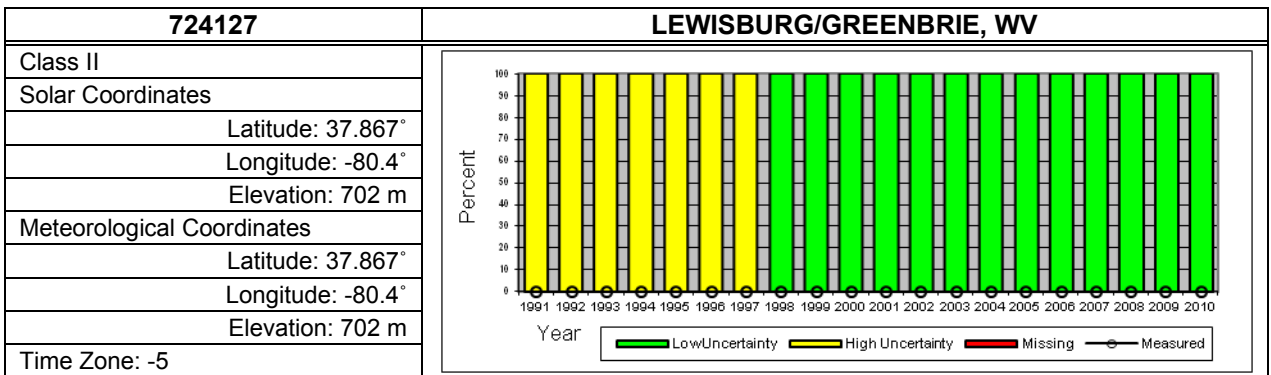
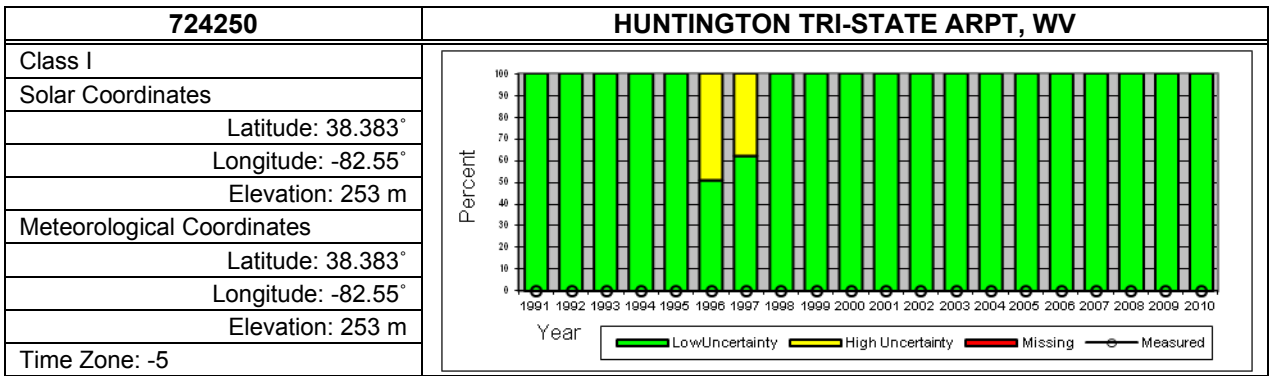


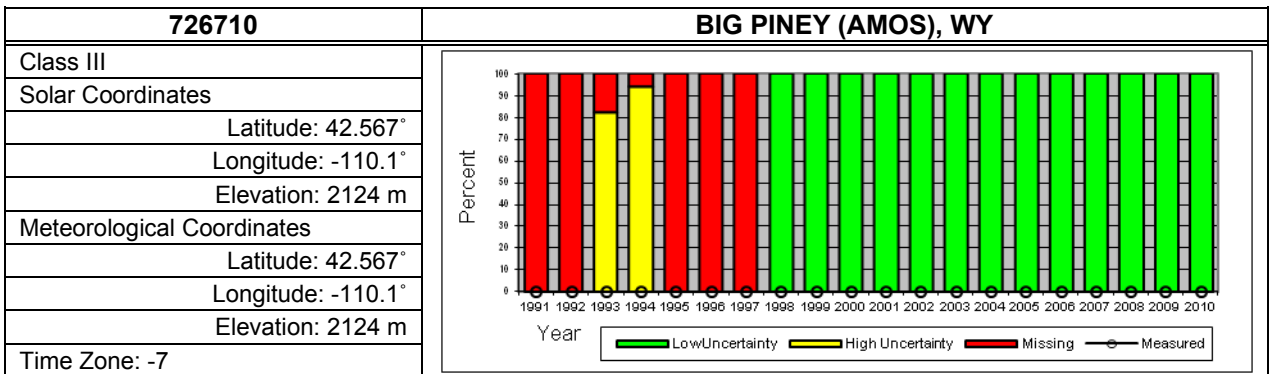
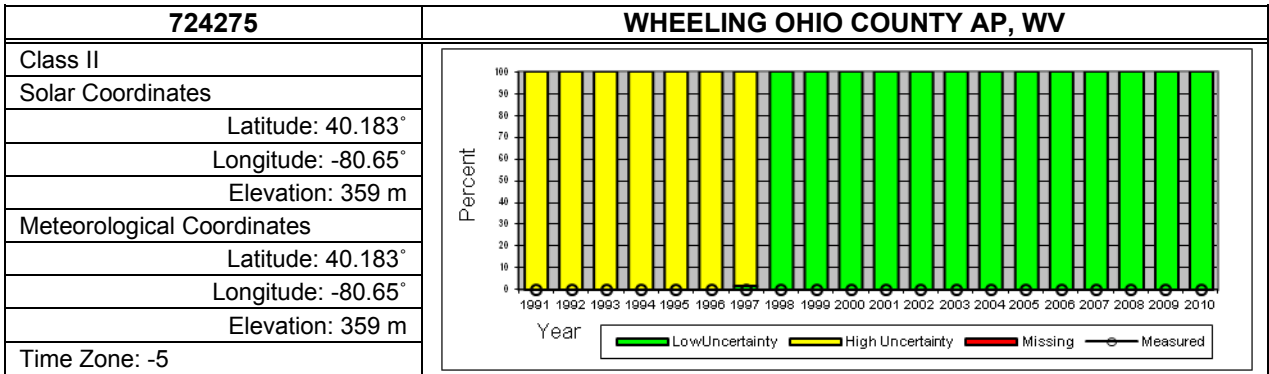
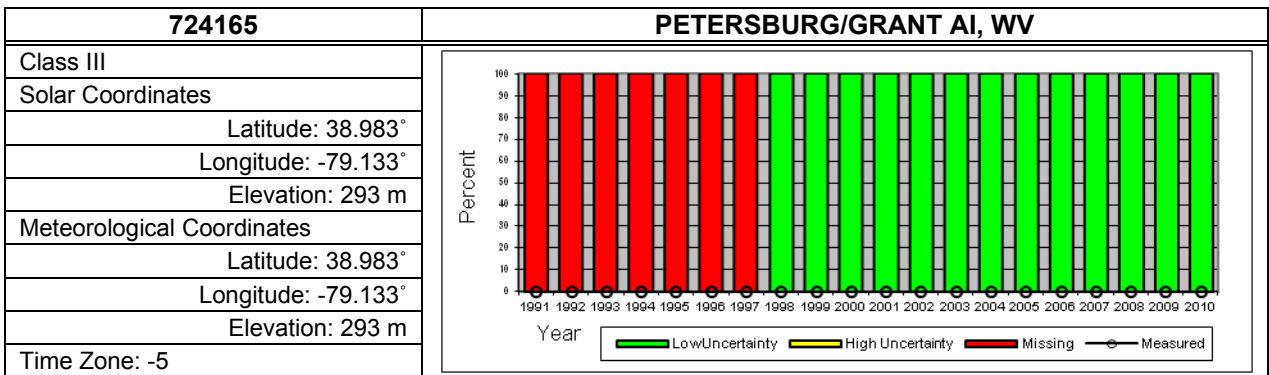
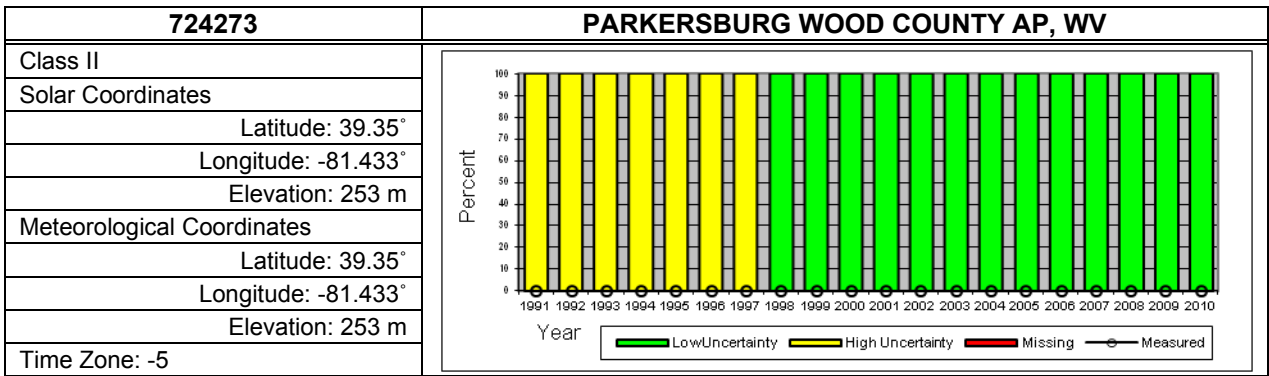


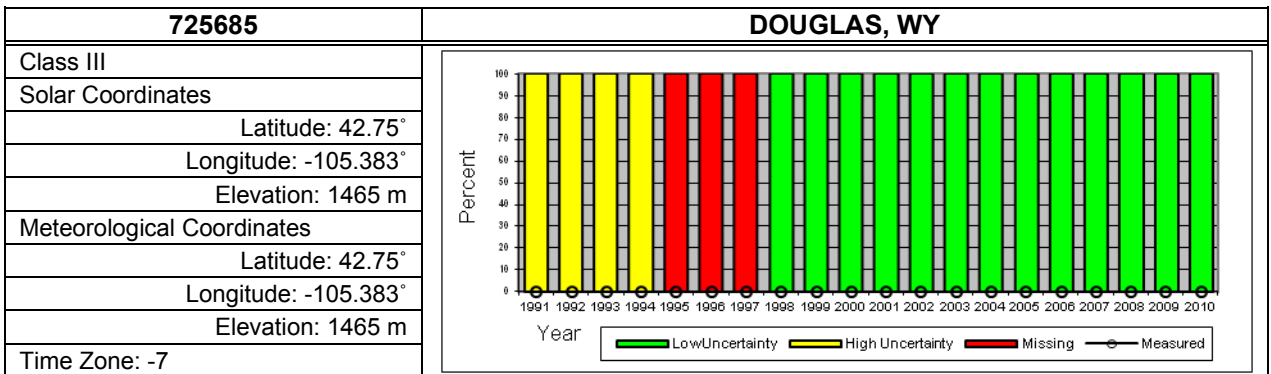
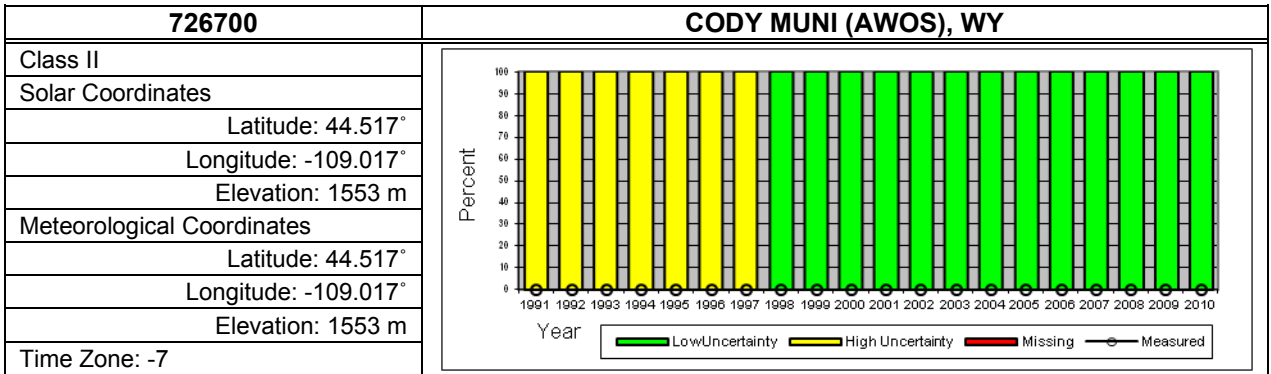
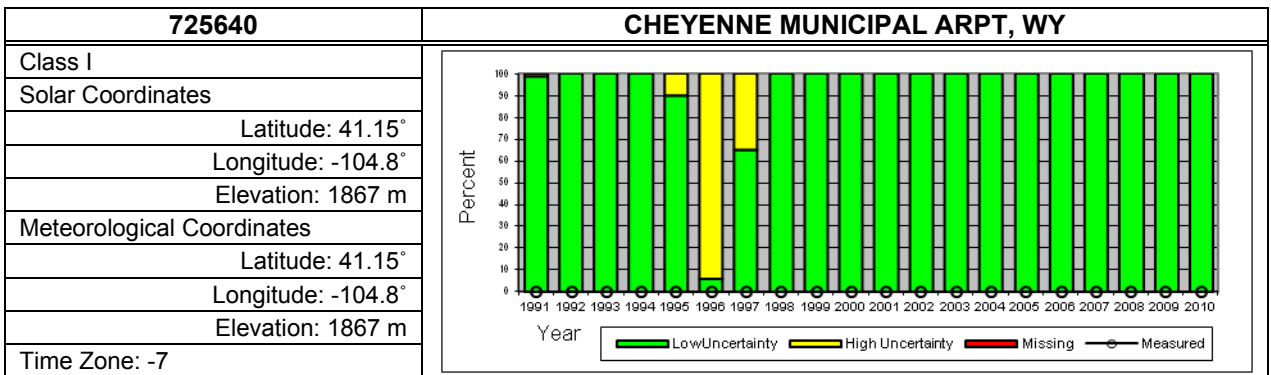
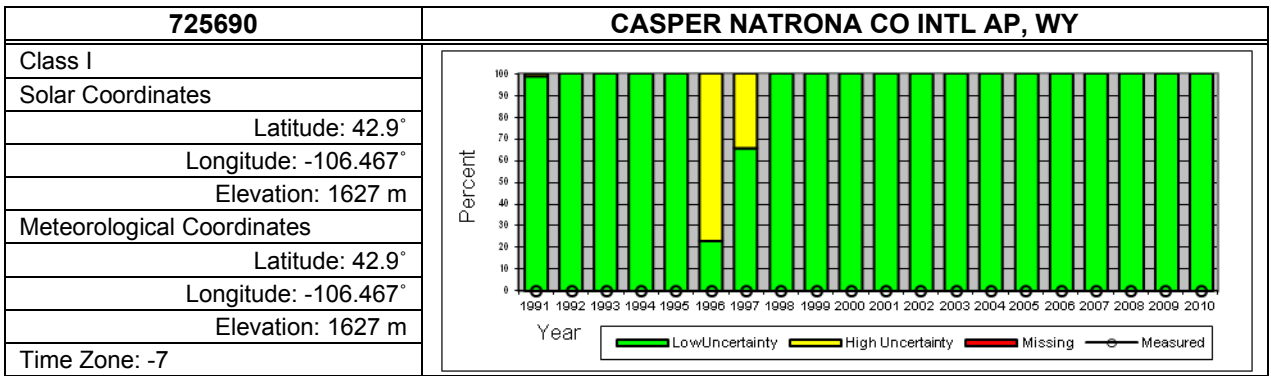


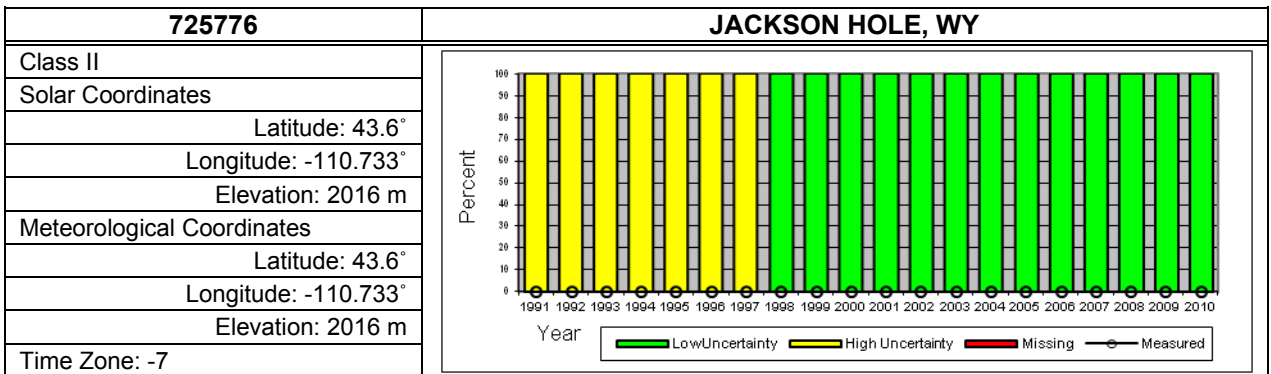
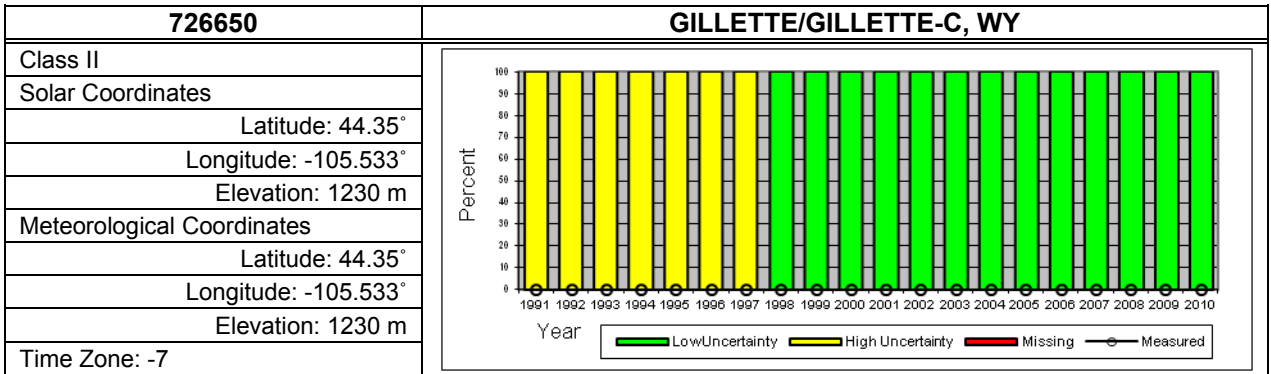
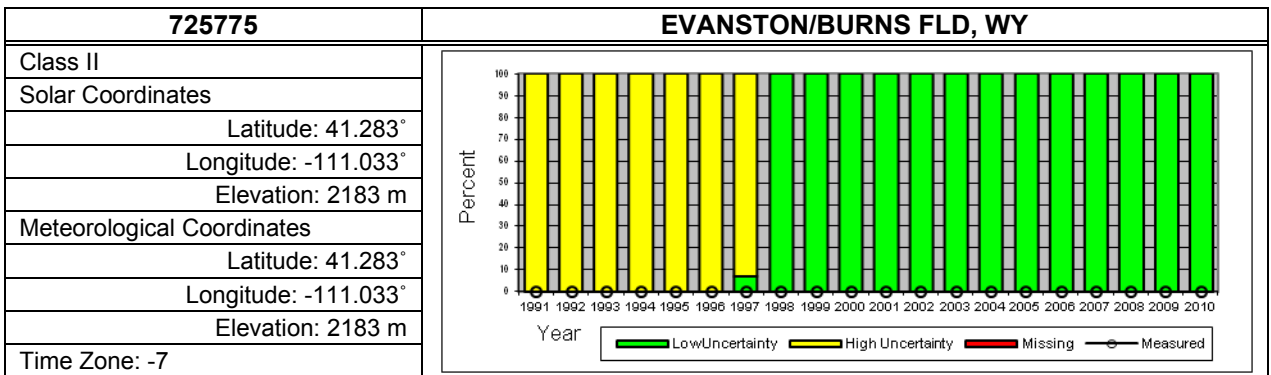
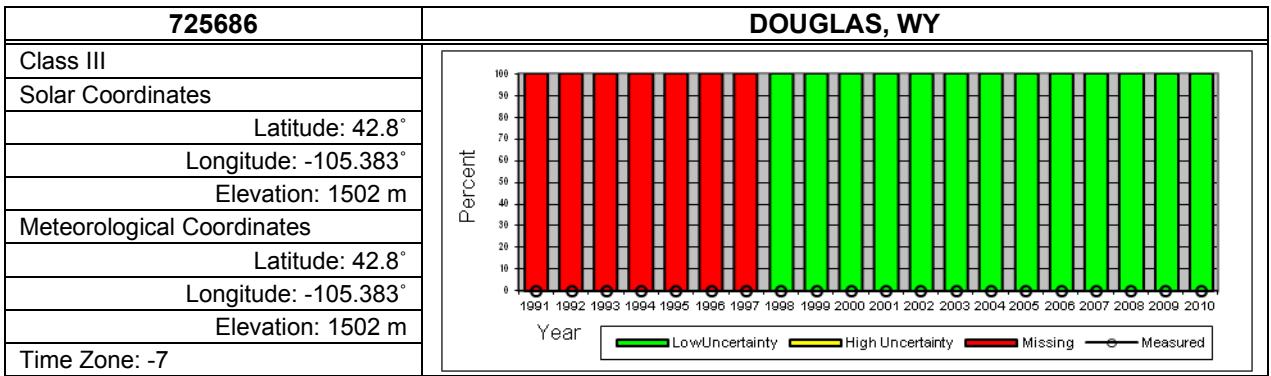




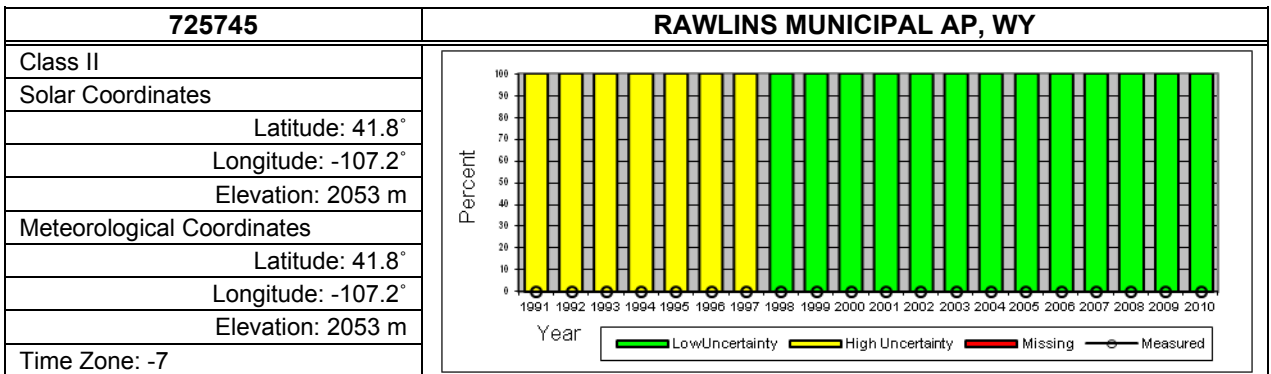
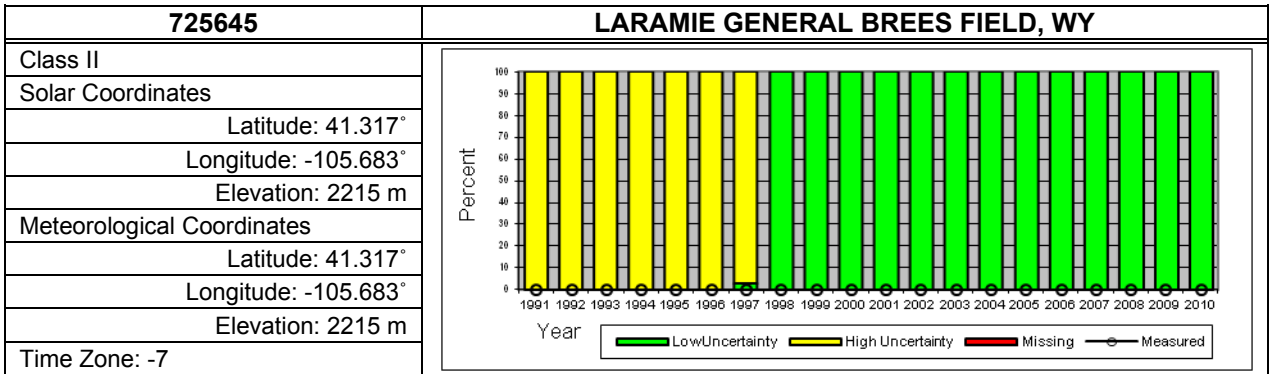
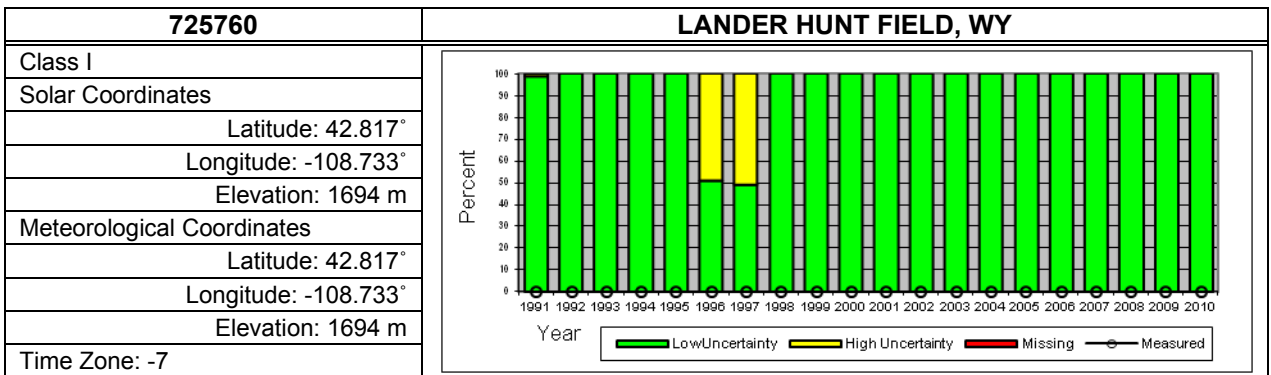
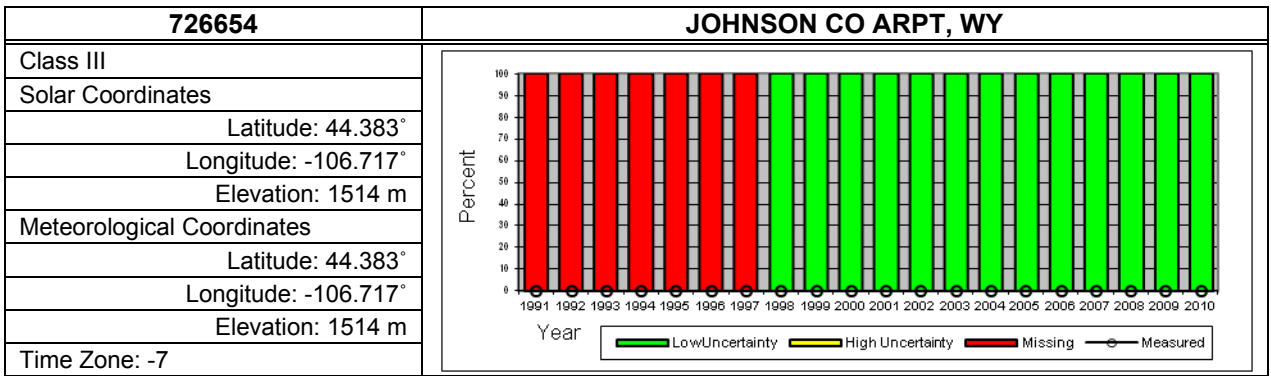


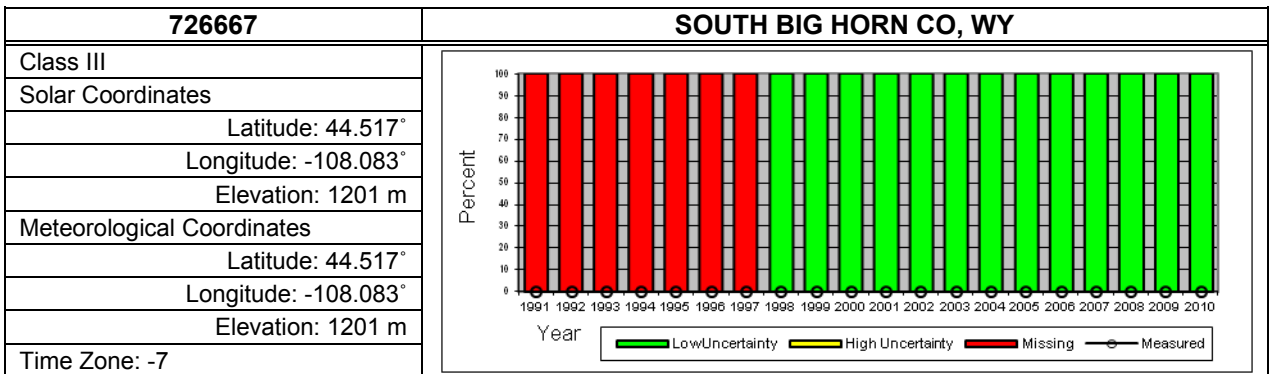
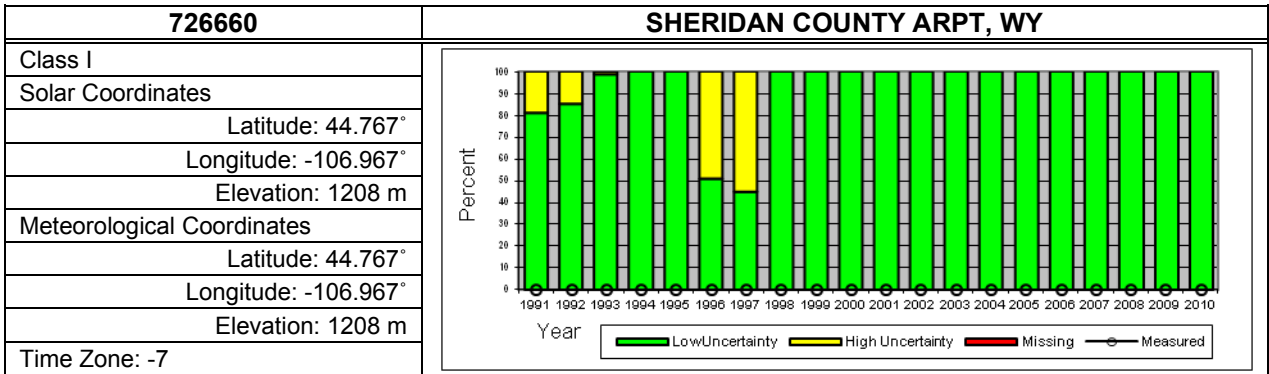
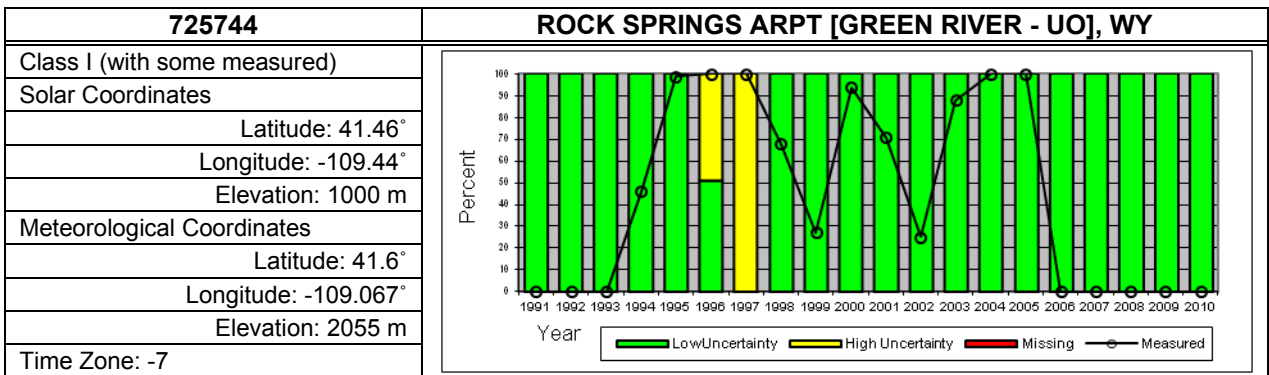
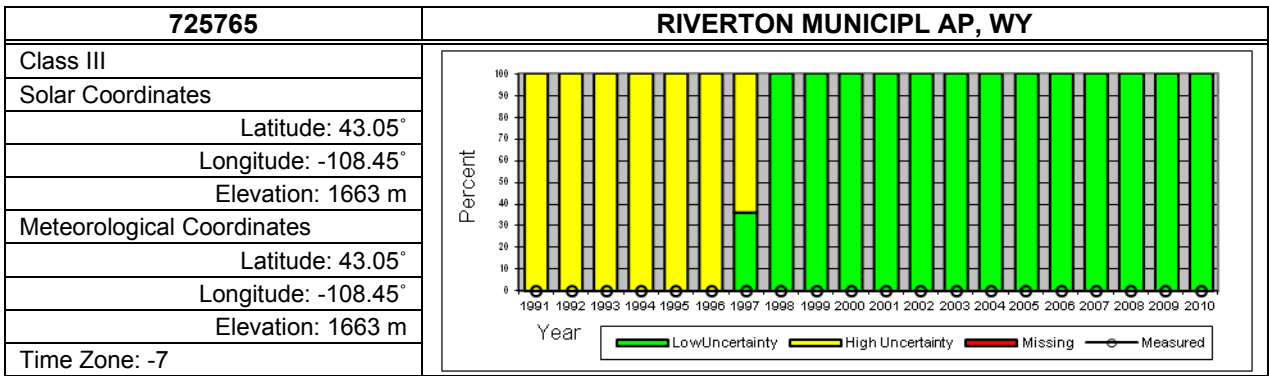












725763	TORRINGTON MUNICIPA, WY
Class III	<p>Percent</p> <p>Year</p> <p>Legend: LowUncertainty (green), High Uncertainty (yellow), Missing (red), Measured (grey circles)</p>
Solar Coordinates	
Latitude: 42.3°	
Longitude: -104.9°	
Elevation: 1281 m	
Meteorological Coordinates	
Latitude: 42.3°	
Longitude: -104.9°	
Elevation: 1281 m	
Time Zone: -7	

726665	WORLAND MUNICIPAL, WY
Class II	<p>Percent</p> <p>Year</p> <p>Legend: LowUncertainty (green), High Uncertainty (yellow), Missing (red), Measured (grey circles)</p>
Solar Coordinates	
Latitude: 43.967°	
Longitude: -107.95°	
Elevation: 1294 m	
Meteorological Coordinates	
Latitude: 43.967°	
Longitude: -107.95°	
Elevation: 1294 m	
Time Zone: -7	

**Table A-1. Index of Sites by ID**

<b>ID</b>	<b>Station</b>	<b>State</b>	<b>Class</b>	<b>Solar</b>	<b>Page</b>
690140	EL TORO MCAS	CA	III		A56
690150	TWENTYNINE PALMS	CA	III		A74
690160	TUSTIN MCAF	CA	III		A73
690190	ABILENE DYESS AFB	TX	III		A302
690230	WHIDBEY ISLAND NAS	WA	III		A348
699604	YUMA MCAS	AZ	III		A49
700197	SELAWIK	AK	III		A25
700260	BARROW W POST-W ROGERS ARPT [NSA - ARM]	AK	II	*	A4
700300	WAINWRIGHT LIZ 3	AK	III		A31
700634	KUPARUK AIRPORT	AK	III		A18
700636	PRUDHOE BAY	AK	III		A24
700637	DEADHORSE	AK	II		A7
700860	BARTER IS WSO AP	AK	III		A4
701043	POINT HOPE (AWOS)	AK	II		A22
701195	SHISHMAREF (AWOS)	AK	II		A26
701210	POINT LAY (DEW)	AK	III		A23
701213	POINT LAY LIZ 2	AK	III		A23
701330	KOTZEBUE RALPH WEIN MEMORIAL	AK	II		A17
701333	DEERING	AK	III		A8
701335	NOATAK	AK	III		A21
701486	NIVALINA	AK	III		A20
701625	ANAKTUVUK PASS	AK	III		A2
701718	AMBLER	AK	II		A2
701740	BETTLES FIELD	AK	II		A5
701745	CHANDALAR LAKE	AK	III		A6
701780	TANANA RALPH M CALHOUN MEM AP	AK	II		A29
701940	FORT YUKON	AK	II		A10
701945	ARCTIC VILLAGE	AK	III		A4
701975	EAGLE	AK	III		A8
701995	GOLOVIN	AK	III		A11
702000	NOME MUNICIPAL ARPT	AK	II		A21
702005	SAINT MARY'S (AWOS)	AK	II		A24
702006	KALTAG	AK	III		A15
702035	SAVOONGA	AK	III		A25
702040	GAMBELL	AK	II		A11
702070	UNALAKLEET FIELD	AK	II		A30
702075	ANVIK	AK	III		A4
702084	EMMONAK	AK	II		A9
702185	MEKORYUK	AK	II		A19
702186	HOOPER BAY	AK	II		A14
702190	BETHEL AIRPORT	AK	II		A5

ID	Station	State	Class	Solar	Page
702223	KOYUK	AK	III		A17
702225	HUSLIA	AK	III		A14
702310	MCGRATH ARPT	AK	II		A18
702312	FAREWELL FAA AP	AK	III		A10
702320	ANIAK AIRPORT	AK	II		A3
702325	WASILLA	AK	III		A31
702460	MINCHUMINA	AK	II		A20
702490	PUNTILLA	AK	III		A24
702495	HAYES RIVER	AK	II		A13
702510	TALKEETNA STATE ARPT	AK	II		A29
702590	KENAI MUNICIPAL AP	AK	II		A16
702595	SOLDOTNA	AK	III		A28
702600	NENANA MUNICIPAL AP	AK	II		A20
702606	CHULITNA	AK	II		A7
702607	HOONAH	AK	II		A14
702610	FAIRBANKS INTL ARPT	AK	II		A10
702615	WAINWRIGHT AAF	AK	III		A30
702645	MCKINLEY PARK	AK	III		A19
702647	HEALY RIVER AIRPORT	AK	II		A13
702648	CANTWELL	AK	III		A6
702650	FAIRBANKS/EIELSON A	AK	II		A10
702670	BIG DELTA ALLEN AAF	AK	II		A5
702675	PAXSON	AK	III		A22
702695	SUTTON	AK	III		A28
702700	FT. RICHARDSON/BRYA	AK	III		A11
702710	GULKANA INTERMEDIATE FIELD	AK	II		A12
702711	SHEEP MTN	AK	III		A26
702715	EUREKA	AK	III		A9
702716	TAHNETA PASS	AK	III		A29
702720	ANCHORAGE/ELMENDORF	AK	II		A3
702725	LAKE HOOD SEAPLANE	AK	III		A18
702730	ANCHORAGE INTL AP	AK	II		A2
702735	ANCHORAGE MERRILL FIELD	AK	II		A3
702740	PALMER MUNICIPAL	AK	II		A22
702746	BIRCHWOOD	AK	III		A6
702750	VALDEZ WSO	AK	III		A30
702755	MCCARTHY	AK	III		A18
702756	VALDEZ PIONEER FIEL	AK	II		A30
702757	WHITTIER	AK	II		A31
702770	SEWARD	AK	II		A26
702910	NORTHWAY AIRPORT	AK	II		A21
702913	NABESNA/DEVIL MTN	AK	III		A20

ID	Station	State	Class	Solar	Page
702915	SLANA AIRPORT	AK	III		A27
702960	CORDOVA	AK	II		A7
702986	BIG RIVER LAKE	AK	II		A5
703080	ST PAUL ISLAND ARPT	AK	II		A28
703160	COLD BAY ARPT	AK	II		A7
703165	SAND POINT	AK	II		A25
703210	DILLINGHAM (AMOS)	AK	II		A8
703260	KING SALMON ARPT	AK	II		A16
703263	KING SALMON	AK	III		A16
703330	PORT HEIDEN	AK	II		A24
703333	CHIGNIK	AK	III		A6
703334	EGEGIK(AWOS)	AK	III		A9
703400	ILIAMNA ARPT	AK	II		A15
703406	PORT ALSWORTH	AK	III		A23
703407	SLEETMUTE	AK	III		A27
703410	HOMER ARPT	AK	III		A13
703430	MIDDLETON ISLAND AUT	AK	II		A19
703500	KODIAK AIRPORT	AK	II		A17
703604	HOMER	AK	III		A13
703606	TOGIAC VILLAGE AWOS	AK	II		A29
703610	YAKUTAT STATE ARPT	AK	II		A32
703620	SKAGWAY AIRPORT	AK	II		A27
703621	SELDOVIA ARPT	AK	III		A25
703625	HAINES BOAT HARBOR	AK	III		A12
703626	HAINES	AK	III		A12
703644	NUIQSUT	AK	III		A21
703670	GUSTAVUS	AK	II		A12
703710	SITKA JAPONSKI AP	AK	II		A27
703810	JUNEAU INT'L ARPT	AK	II		A15
703816	FUNTER BAY SEAPLANE	AK	III		A11
703817	ELFIN COVE SEAPLANE	AK	III		A9
703835	ST GEORGE ISLAND	AK	III		A28
703855	KAKE SEAPLANE BASE	AK	II		A15
703860	PETERSBURG	AK	II		A22
703870	WRANGELL	AK	II		A31
703884	HYDABURG SEAPLANE	AK	III		A14
703886	PORT ALEXANDER	AK	III		A23
703894	KLAWOCK	AK	III		A17
703950	KETCHIKAN INTL AP	AK	II		A16
703980	ANNETTE ISLAND AP	AK	II		A3
703985	METLA KATLA	AK	III		A19
704140	SHEMYA AFB	AK	II		A26

ID	Station	State	Class	Solar	Page
704540	ADAK NAS	AK	II		A2
704890	DUTCH HARBOR	AK	II		A8
722010	KEY WEST INTL ARPT	FL	I		A92
722011	ORLANDO/KISSIMMEE	FL	III		A97
722014	BROOKSVILLE	FL	III		A88
722015	KEY WEST NAS	FL	II		A92
722016	MARATHON AIRPORT	FL	II		A93
722020	MIAMI INTL AP	FL	I		A94
722021	TAMPA/VANDEBURG	FL	III		A100
722022	BOCA RATON	FL	III		A88
722024	MIAMI/OPA LOCKA	FL	II		A95
722025	FORT LAUDERDALE HOLLYWOOD INT	FL	II		A90
722026	HOMESTEAD AFB	FL	II		A91
722029	MIAMI/KENDALL-TAMIA	FL	II		A95
722030	WEST PALM BEACH INTL ARPT	FL	I		A101
722034	PUNTA GORDA	FL	III		A98
722038	NAPLES MUNICIPAL	FL	II		A95
722039	FORT LAUDERDALE	FL	II		A90
722040	MELBOURNE REGIONAL AP	FL	II		A94
722045	VERO BEACH MUNICIPAL ARPT	FL	I		A101
722046	SPACE COAST RGNL [FSEC]	FL	III	*	A99
722049	POMPANO BEACH	FL	III		A98
722050	ORLANDO INTL ARPT	FL	I		A96
722053	ORLANDO EXECUTIVE AP	FL	II		A96
722055	OCALA MUNI (AWOS)	FL	II		A96
722056	DAYTONA BEACH INTL AP	FL	I		A89
722057	ORLANDO SANFORD AIRPORT	FL	II		A96
722060	JACKSONVILLE INTL ARPT	FL	I		A91
722065	JACKSONVILLE NAS	FL	II		A92
722066	MAYPORT NS	FL	II		A94
722067	JACKSONVILLE CECIL FLD NAS	FL	III		A91
722068	JACKSONVILLE/CRAIG	FL	II		A92
722069	DESTIN FT. WALTON	FL	III		A89
722070	SAVANNAH INTL AP	GA	I		A108
722079	LEXINGTON/DAVIDSON	NC	III		A222
722080	CHARLESTON INTL ARPT	SC	I		A291
722085	BEAUFORT MCAS	SC	II		A291
722090	FT STEWART/WRIGHT	GA	II		A105
722103	ST LUCIE CO INTL	FL	II		A99
722104	ST PETERSBURG ALBERT WHITTED	FL	II		A99
722106	FORT MYERS PAGE FIELD	FL	I		A90
722108	SOUTHWEST FLORIDA I	FL	II		A98

ID	Station	State	Class	Solar	Page
722110	TAMPA INTERNATIONAL AP	FL	I		A100
722115	SARASOTA BRADENTON	FL	II		A98
722116	ST PETERSBURG CLEAR	FL	II		A99
722119	LAKELAND LINDER RGN	FL	II		A93
722123	BARTOW MUNICIPAL	FL	III		A88
722130	WAYCROSS WARE CO AP	GA	III		A110
722134	VIDALIA MUNI ARPT	GA	III		A109
722135	ALMA BACON COUNTY AP	GA	II		A102
722136	BRUNSWICK GOLDEN IS	GA	II		A104
722137	BRUNSWICK MALCOLM MCKINNON AP	GA	II		A104
722140	TALLAHASSEE REGIONAL AP [ISIS]	FL	I	*	A100
722146	GAINESVILLE REGIONAL AP	FL	I		A91
722154	DALTON	GA	III		A105
722156	CARTERSVILLE AIRPRT	GA	III		A104
722160	ALBANY DOUGHERTY COUNTY AP	GA	II		A102
722166	VALDOSTA WB AIRPORT	GA	II		A109
722170	MACON MIDDLE GA REGIONAL AP	GA	I		A107
722175	WARNER ROBINS AFB	GA	II		A109
722176	NEWMAN	GA	III		A108
722180	AUGUSTA BUSH FIELD	GA	I		A103
722185	GAINESVILLE\LEE GIL	GA	III		A106
722190	ATLANTA HARTSFIELD INTL AP	GA	I		A103
722195	FULTON CO ARPT BROW	GA	II		A106
722196	DEKALB PEACHTREE	GA	II		A105
722197	ATLANTA (NEXRAD)	GA	III		A103
722200	APALACHICOLA MUNI AP	FL	III		A87
722210	VALPARAISO ELGIN AFB	FL	II		A101
722213	LEESBURG MUNI ARPT	FL	III		A93
722215	CRESTVIEW BOB SIKES AP	FL	II		A89
722223	PENSACOLA REGIONAL AP	FL	I		A97
722225	PENSACOLA FOREST SHERMAN NAS	FL	II		A97
722226	WHITING FIELD NAAS	FL	II		A102
722230	MOBILE REGIONAL AP	AL	I		A35
722235	MOBILE DOWNTOWN AP	AL	II		A34
722245	PANAMA CITY BAY CO	FL	II		A97
722246	DUKE FIELD AAFB	FL	II		A90
722250	FORT BENNING LAWSON	GA	II		A105
722255	COLUMBUS METROPOLITAN ARPT	GA	I		A104
722260	MONTGOMERY DANNELLY FIELD	AL	I		A35
722265	MAXWELL AFB	AL	II		A34
722267	TROY AF	AL	II		A36
722268	DOTHAN MUNICIPAL AP	AL	II		A33



ID	Station	State	Class	Solar	Page
722269	CAIRNS FIELD FORT RUCKER	AL	II		A33
722270	MARIETTA DOBBINS AFB	GA	II		A107
722279	DECATUR	AL	III		A33
722280	BIRMINGHAM MUNICIPAL AP	AL	I		A32
722284	AUBURN-OPELIKA APT	AL	III		A32
722285	GADSEN MUNI (AWOS)	AL	III		A34
722286	TUSCALOOSA MUNICIPAL AP	AL	II		A36
722287	ANNISTON METROPOLITAN AP	AL	II		A32
722290	CENTREVILLE WSMO	AL	III		A33
722300	SHELBY CO ARPT	AL	III		A35
722310	NEW ORLEANS INTL ARPT	LA	I		A156
722312	HAMMOND	LA	III		A154
722314	NEW IBERIA NAAS	LA	II		A156
722315	NEW ORLEANS LAKEFRONT AP	LA	III		A157
722316	NEW ORLEANS ALVIN CALLENDER F	LA	II		A156
722317	BATON ROUGE RYAN ARPT	LA	I		A153
722319	NATCHITOCHE	LA	III		A156
722329	PATTERSON MEMORIAL	LA	II		A157
722340	MERIDIAN KEY FIELD	MS	I		A209
722345	MERIDIAN NAAS	MS	II		A209
722347	HATTIESBURG MUNI	MS	III		A208
722348	HATTIESBURG LAUREL	MS	II		A207
722350	JACKSON INTERNATIONAL AP	MS	I		A208
722354	HAWKINS FIELD	MS	III		A208
722356	GREENVILLE MUNICIPAL	MS	II		A207
722357	NATCHEZ/HARDY(AWOS)	MS	II		A209
722358	MCCOMB PIKE COUNTY AP	MS	II		A209
722359	GREENWOOD LEFLORE ARPT	MS	II		A207
722366	SLIDELL	LA	III		A158
722390	FORT POLK AAF	LA	II		A154
722400	LAKE CHARLES REGIONAL ARPT	LA	I		A155
722404	LAKE CHARLES WB AIRP	LA	II		A155
722405	LAFAYETTE REGIONAL AP	LA	II		A155
722406	HOUMA-TERREBONNE	LA	II		A154
722410	PORT ARTHUR JEFFERSON COUNTY	TX	I		A319
722416	NEW BRAUNFELS	TX	III		A318
722420	GALVESTON/SCHOLES	TX	II		A311
722427	HOUSTON/CLOVER FLD	TX	III		A313
722429	HOUSTON/D.W. HOOKS	TX	II		A313
722430	HOUSTON BUSH INTERCONTINENTAL	TX	I		A312
722435	HOUSTON WILLIAM P HOBBY AP	TX	II		A313
722436	HOUSTON ELLINGTON AFB [CLEAR LAKE - UT]	TX	II	*	A313

ID	Station	State	Class	Solar	Page
722444	MONTGOMERY CO	TX	III		A317
722445	COLLEGE STATION EASTERWOOD FL	TX	II		A305
722446	LUFKIN ANGELINA CO	TX	I		A316
722447	LONGVIEW GREGG COUNTY AP	TX	III		A315
722448	TYLER/POUNDS FLD	TX	II		A323
722469	CORSICANA	TX	III		A306
722470	LONGVIEW GREGG COUNTY AP [OVERTON - UT]	TX	II	*	A315
722479	ARLINGTON	TX	III		A303
722480	SHREVEPORT REGIONAL ARPT	LA	I		A157
722484	SHREVEPORT DOWNTOWN	LA	III		A157
722485	BARKSDALE AFB	LA	II		A153
722486	MONROE REGIONAL AP	LA	II		A155
722487	ALEXANDRIA ESLER REGIONAL AP	LA	II		A153
722488	VICKSBURG\TALLULAH	LA	III		A158
722489	TERRELL	TX	III		A322
722499	NACOGDOCHES (AWOS)	TX	III		A318
722500	BROWNSVILLE S PADRE ISL INTL	TX	I		A304
722505	HARLINGEN RIO GRANDE VALLEY I	TX	II		A312
722506	MCALLEN MILLER INTL AP [EDINBURG - UT]	TX	II	*	A317
722508	PORT ISABEL/CAMERON	TX	III		A319
722510	CORPUS CHRISTI INTL ARPT [UT]	TX	I	*	A305
722515	CORPUS CHRISTI NAS	TX	II		A306
722516	KINGSVILLE	TX	II		A314
722517	ALICE INTL AP	TX	II		A302
722520	LAREDO INTL AP [UT]	TX	II	*	A315
722523	SAN ANTONIO/STINSON	TX	II		A321
722524	ROCKPORT/ARANSAS CO	TX	II		A320
722526	COTULLA FAA AP	TX	II		A306
722527	ANGLETON/LAKE JACKS	TX	III		A303
722530	SAN ANTONIO INTL AP	TX	I		A321
722533	HONDO MUNICIPAL AP	TX	III		A312
722535	SAN ANTONIO KELLY FIELD AFB	TX	II		A321
722536	RANDOLPH AFB	TX	II		A319
722537	KERRVILLE MUNICIPAL	TX	III		A314
722539	SAN MARCOS MUNI	TX	III		A322
722540	AUSTIN MUELLER MUNICIPAL AP [UT]	TX	I	*	A303
722544	CAMP MABRY	TX	III		A305
722545	BERGSTROM AFB/AUSTI	TX	III		A303
722546	SAN MARCOS GARY AFB	TX	III		A321
722547	GEORGETOWN (AWOS)	TX	III		A311
722550	VICTORIA REGIONAL AP	TX	I		A323
722552	GAINESVILLE	TX	III		A311

ID	Station	State	Class	Solar	Page
722553	BRENHAM	TX	III		A304
722554	LAGRANGE	TX	III		A315
722555	PALACIOS MUNICIPAL AP	TX	II		A318
722560	WACO REGIONAL AP	TX	I		A323
722563	MC GREGOR (AWOS)	TX	III		A316
722570	FORT HOOD	TX	II		A310
722575	KILLEEN MUNI (AWOS)	TX	II		A314
722576	ROBERT GRAY AAF	TX	II		A320
722577	DRAUGHON MILLER CEN	TX	II		A309
722583	DALLAS LOVE FIELD	TX	II		A307
722585	DALLAS HENSLEY FIELD NAS	TX	III		A307
722587	COX FLD	TX	III		A306
722588	GREENVILLE/MAJORS	TX	II		A312
722589	DENTON (ASOS)	TX	III		A309
722590	DALLAS-FORT WORTH INTL AP	TX	I		A308
722593	DFW NEXRAD	TX	III		A309
722594	FORT WORTH ALLIANCE	TX	II		A310
722595	FORT WORTH NAS	TX	II		A311
722596	FORT WORTH MEACHAM	TX	II		A310
722597	MINERAL WELLS MUNICIPAL AP	TX	II		A317
722598	DALLAS/ADDISON ARPT	TX	II		A307
722599	DALLAS/REDBIRD ARPT	TX	II		A308
722600	STEPHENVILLE CLARK FIELD	TX	III		A322
722610	DEL RIO [UT]	TX	II	*	A308
722615	DEL RIO LAUGHLIN AFB	TX	II		A308
722618	FORT STOCKTON PECOS	TX	III		A310
722620	PINE SPRINGS GUADALUPE MOUNTA	TX	III		A319
722630	SAN ANGELO MATHIS FIELD	TX	I		A320
722636	DALHART MUNICIPAL AP	TX	II		A307
722640	MARFA AP	TX	III		A316
722648	ODESSA-SCHLEMEYER F	TX	III		A318
722650	MIDLAND INTERNATIONAL AP	TX	I		A317
722656	WINK WINKLER COUNTY AP	TX	II		A324
722660	ABILENE REGIONAL AP [UT]	TX	I	*	A302
722666	BROWNWOOD MUNICIPAL	TX	III		A304
722670	LUBBOCK INTERNATIONAL AP	TX	I		A316
722673	SHERMAN-DENISON	TX	III		A322
722675	REESE AFB	TX	III		A320
722676	ARTESIA	NM	III		A243
722677	CLINES CORNER	NM	III		A244
722678	RATON	NM	III		A246
722680	ROSWELL INDUSTRIAL AIR PARK	NM	I		A247

ID	Station	State	Class	Solar	Page
722683	SIERRA BLANCA RGNL	NM	III		A247
722686	CLOVIS CANNON AFB	NM	II		A244
722687	CARLSBAD CAVERN CITY AIR TERM	NM	II		A243
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912170	GUAM MARIANA IS	GU	III		A110
912180	ANDERSEN AFB	GU	II		A110
912850	HILO INTERNATIONAL AP	HI	I		A111

## Appendix B: Old and New NSRDB Station Equivalencies

This section lists the original 239 1961–1990 NSRDB sites (in order by WBAN ID) with their equivalent sites in the 1991–2010 NSRDB update and USAF ID. No changes were made between the 2005 and 2010 NSRDB updates. All of the equivalent sites in the updated NSRDB are either Class I or Class II stations, with the exception of Flagstaff, Arizona, Boulder, Colorado, Portland, Oregon, and Cape Hatteras, North Carolina, which are now Class III. Although some sites have slightly different coordinates because of changes in station location or inclusion of different sites with measured solar data, all pairs of sites listed here should be climatically similar.

**Table B-1. Old and New Station Equivalencies**

WBAN	1961-1990 Site	USAF	NSRDB Update Site
03103	Flagstaff, Arizona	723755	FLAGSTAFF PULLIAM ARPT, AZ
03812	Asheville, North Carolina	723150	ASHEVILLE REGIONAL ARPT, NC
03813	Macon, Georgia	722170	MACON MIDDLE GA REGIONAL AP, GA
03820	Augusta, Georgia	722180	AUGUSTA BUSH FIELD, GA
03822	Savannah, Georgia	722070	SAVANNAH INTL AP, GA
03856	Huntsville, Alabama	723230	HUNTSVILLE INTL/JONES FIELD, AL
03860	Huntington, West Virginia	724250	HUNTINGTON TRI-STATE ARPT, WV
03870	Greenville, South Carolina	723120	GREER GREENV'L-SPARTANBRG AP, SC
03927	Fort Worth, Texas	722590	DALLAS-FORT WORTH INTL AP, TX
03928	Wichita, Kansas	724500	WICHITA MID-CONTINENT AP, KS
03937	Lake Charles, Louisiana	722400	LAKE CHARLES REGIONAL ARPT, LA
03940	Jackson, Mississippi	722350	JACKSON INTERNATIONAL AP, MS
03945	Columbia, Missouri	724450	COLUMBIA REGIONAL AIRPORT, MO
03947	Kansas City, Missouri	724460	KANSAS CITY INT'L ARPT, MO
04725	Binghamton, New York	725150	BINGHAMTON EDWIN A LINK FIELD, NY
04751	Bradford, Pennsylvania	725266	BRADFORD REGIONAL AP, PA
11641	San Juan, Puerto Rico	785260	SAN JUAN INTL ARPT, PR
12834	Daytona Beach, Florida	722056	DAYTONA BEACH INTL AP, FL
12836	Key West, Florida	722010	KEY WEST INTL ARPT, FL
12839	Miami, Florida	722020	MIAMI INTL AP, FL
12842	Orlando, Florida	722050	ORLANDO INTL ARPT, FL
12844	West Palm Beach, Florida	722030	WEST PALM BEACH INTL ARPT, FL
12912	Victoria, Texas	722550	VICTORIA REGIONAL AP, TX
12916	New Orleans, Louisiana	722310	NEW ORLEANS INTL ARPT, LA
12917	Port Arthur, Texas	722410	PORT ARTHUR JEFFERSON COUNTY, TX
12919	Brownsville, Texas	722500	BROWNSVILLE S PADRE ISL INTL, TX
12921	San Antonio, Texas	722530	SAN ANTONIO INTL AP, TX
12924	Corpus Christi, Texas	722510	CORPUS CHRISTI INTL ARPT [UT], TX
12960	Houston, Texas	722430	HOUSTON BUSH INTERCONTINENTAL, TX
13722	Raleigh/Durham, North Carolina	723060	RALEIGH DURHAM INTERNATIONAL, NC
13723	Greensboro, North Carolina	723170	GREENSBORO PIEDMONT TRIAD INT, NC
13729	Elkins, West Virginia	724170	ELKINS ELKINS-RANDOLPH CO ARP, WV

<b>WBAN</b>	<b>1961-1990 Site</b>	<b>USAF</b>	<b>NSRDB Update Site</b>
13733	Lynchburg, Virginia	724100	LYNCHBURG REGIONAL ARPT, VA
13737	Norfolk, Virginia	723080	NORFOLK INTERNATIONAL AP, VA
13739	Philadelphia, Pennsylvania	724080	PHILADELPHIA INTERNATIONAL AP, PA
13740	Richmond, Virginia	724010	RICHMOND INTERNATIONAL AP, VA
13741	Roanoke, Virginia	724110	ROANOKE REGIONAL AP, VA
13748	Wilmington, North Carolina	723013	WILMINGTON INTERNATIONAL ARPT, NC
13781	Wilmington, Delaware	724089	WILMINGTON NEW CASTLE CNTY AP, DE
13865	Meridian, Mississippi	722340	MERIDIAN KEY FIELD, MS
13866	Charleston, West Virginia	724140	CHARLESTON YEAGER ARPT, WV
13873	Athens, Georgia	723110	ATHENS BEN EPPS AP, GA
13874	Atlanta, Georgia	722190	ATLANTA HARTSFIELD INTL AP, GA
13876	Birmingham, Alabama	722280	BIRMINGHAM MUNICIPAL AP, AL
13877	Bristol, Tennessee	723183	BRISTOL TRI CITY AIRPORT, TN
13880	Charleston, South Carolina	722080	CHARLESTON INTL ARPT, SC
13881	Charlotte, North Carolina	723140	CHARLOTTE DOUGLAS INTL ARPT, NC
13882	Chattanooga, Tennessee	723240	CHATTANOOGA LOVELL FIELD AP, TN
13883	Columbia, South Carolina	723100	COLUMBIA METRO ARPT, SC
13889	Jacksonville, Florida	722060	JACKSONVILLE INTL ARPT, FL
13891	Knoxville, Tennessee	723260	KNOXVILLE MCGHEE TYSON AP, TN
13893	Memphis, Tennessee	723340	MEMPHIS INTERNATIONAL AP, TN
13894	Mobile, Alabama	722230	MOBILE REGIONAL AP, AL
13895	Montgomery, Alabama	722260	MONTGOMERY DANNELLY FIELD, AL
13897	Nashville, Tennessee	723270	NASHVILLE INTERNATIONAL AP, TN
13957	Shreveport, Louisiana	722480	SHREVEPORT REGIONAL ARPT, LA
13958	Austin, Texas	722540	AUSTIN MUELLER MUNICIPAL AP [UT], TX
13959	Waco, Texas	722560	WACO REGIONAL AP, TX
13962	Abilene, Texas	722660	ABILENE REGIONAL AP [UT], TX
13963	Little Rock, Arkansas	723403	LITTLE ROCK ADAMS FIELD, AR
13964	Fort Smith, Arkansas	723440	FORT SMITH REGIONAL AP, AR
13966	Wichita Falls, Texas	723510	WICHITA FALLS MUNICIPAL ARPT, TX
13967	Oklahoma City, Oklahoma	723530	OKLAHOMA CITY WILL ROGERS WOR, OK
13968	Tulsa, Oklahoma	723560	TULSA INTERNATIONAL AIRPORT, OK
13970	Baton Rouge, Louisiana	722317	BATON ROUGE RYAN ARPT, LA
13985	Dodge City, Kansas	724510	DODGE CITY REGIONAL AP, KS
13994	St. Louis, Missouri	724340	ST LOUIS LAMBERT INT'L ARPT, MO
13995	Springfield, Missouri	724400	SPRINGFIELD REGIONAL ARPT, MO
13996	Topeka, Kansas	724560	TOPEKA MUNICIPAL AP, KS
14607	Caribou, Maine	727120	CARIBOU MUNICIPAL ARPT, ME
14733	Buffalo, New York	725280	BUFFALO NIAGARA INTL AP, NY
14734	Newark, New Jersey	725020	NEWARK INTERNATIONAL ARPT, NJ
14735	Albany, New York	725180	ALBANY COUNTY AP, NY
14737	Allentown, Pennsylvania	725170	ALLENTOWN LEHIGH VALLEY INTL, PA
14739	Boston, Massachusetts	725090	BOSTON LOGAN INT'L ARPT, MA
14740	Hartford, Connecticut	725080	HARTFORD BRADLEY INTL AP, CT
14742	Burlington, Vermont	726170	BURLINGTON INTERNATIONAL AP, VT
14745	Concord, New Hampshire	726050	CONCORD MUNICIPAL ARPT, NH
14751	Harrisburg, Pennsylvania	725118	HARRISBURG CAPITAL CITY ARPT, PA



<b>WBAN</b>	<b>1961-1990 Site</b>	<b>USAF</b>	<b>NSRDB Update Site</b>
14764	Portland, Maine	726060	PORTLAND INTL JETPORT, ME
14765	Providence, Rhode Island	725070	PROVIDENCE T F GREEN STATE AR, RI
14768	Rochester, New York	725290	ROCHESTER GREATER ROCHESTER I, NY
14771	Syracuse, New York	725190	SYRACUSE HANCOCK INT'L ARPT, NY
14777	Wilkes-Barre/Scranton, Pennsylvania	725130	WILKES-BARRE SCRANTON INTL AP, PA
14778	Williamsport, Pennsylvania	725140	WILLIAMSPORT REGIONAL AP, PA
14820	Cleveland, Ohio	725240	CLEVELAND HOPKINS INTL AP, OH
14821	Columbus, Ohio	724280	COLUMBUS PORT COLUMBUS INTL A, OH
14826	Flint, Michigan	726370	FLINT BISHOP INTL ARPT, MI
14827	Fort Wayne, Indiana	725330	FORT WAYNE INTL AP, IN
14836	Lansing, Michigan	725390	LANSING CAPITAL CITY ARPT, MI
14837	Madison, Wisconsin	726410	MADISON DANE CO REGIONAL ARPT [ISIS], WI
14839	Milwaukee, Wisconsin	726400	MILWAUKEE MITCHELL INTL AP, WI
14840	Muskegon, Michigan	726360	MUSKEGON COUNTY ARPT, MI
14842	Peoria, Illinois	725320	PEORIA GREATER PEORIA AP, IL
14847	Sault Ste. Marie, Michigan	727340	SAULT STE MARIE SANDERSON FIE, MI
14848	South Bend, Indiana	725350	SOUTH BEND MICHIANA RGNL AP, IN
14850	Traverse City, Michigan	726387	TRAVERSE CITY CHERRY CAPITAL, MI
14852	Youngstown, Ohio	725250	YOUNGSTOWN REGIONAL AIRPORT, OH
14860	Erie, Pennsylvania	725260	ERIE INTERNATIONAL AP, PA
14891	Mansfield, Ohio	725246	MANSFIELD LAHM MUNICIPAL ARPT, OH
14895	Akron/Canton, Ohio	725210	AKRON AKRON-CANTON REG AP, OH
14898	Green Bay, Wisconsin	726450	GREEN BAY AUSTIN STRAUBEL INT, WI
14913	Duluth, Minnesota	727450	DULUTH INTERNATIONAL ARPT, MN
14914	Fargo, North Dakota	727530	FARGO HECTOR INTERNATIONAL AP, ND
14918	International Falls, Minnesota	727470	INTERNATIONAL FALLS INTL AP, MN
14920	La Crosse, Wisconsin	726430	LA CROSSE MUNICIPAL ARPT, WI
14922	Minneapolis/St. Paul, Minnesota	726580	MINNEAPOLIS-ST PAUL INT'L ARP, MN
14923	Moline, Illinois	725440	MOLINE QUAD CITY INTL AP, IL
14925	Rochester, Minnesota	726440	ROCHESTER INTERNATIONAL ARPT, MN
14926	Saint Cloud, Minnesota	726550	ST CLOUD REGIONAL ARPT, MN
14933	Des Moines, Iowa	725460	DES MOINES INTL AP, IA
14935	Grand Island, Nebraska	725520	GRAND ISLAND CENTRAL NE REGIO, NE
14936	Huron, South Dakota	726540	HURON REGIONAL ARPT, SD
14940	Mason City, Iowa	725485	MASON CITY MUNICIPAL ARPT, IA
14941	Norfolk, Nebraska	725560	NORFOLK KARL STEFAN MEM ARPT, NE
14943	Sioux City, Iowa	725570	SIOUX CITY SIOUX GATEWAY AP, IA
14944	Sioux Falls, South Dakota	726510	SIOUX FALLS FOSS FIELD, SD
14991	Eau Claire, Wisconsin	726435	EAU CLAIRE COUNTY AP, WI
21504	Hilo, Hawaii	912850	HILO INTERNATIONAL AP, HI
22516	Kahului, Hawaii	911900	KAHULUI AIRPORT, HI
22521	Honolulu, Hawaii	911820	HONOLULU INTL ARPT, HI
22536	Lihue, Hawaii	911650	LIHUE AIRPORT, HI
23023	Midland/Odessa, Texas	722650	MIDLAND INTERNATIONAL AP, TX
23034	San Angelo, Texas	722630	SAN ANGELO MATHIS FIELD, TX

<b>WBAN</b>	<b>1961-1990 Site</b>	<b>USAF</b>	<b>NSRDB Update Site</b>
23042	Lubbock, Texas	722670	LUBBOCK INTERNATIONAL AP, TX
23044	El Paso, Texas	722700	EL PASO INTERNATIONAL AP [UT], TX
23047	Amarillo, Texas	723630	AMARILLO INTERNATIONAL AP [CANYON - UT], TX
23048	Tucumcari, New Mexico	723676	TUCUMCARI FAA AP, NM
23050	Albuquerque, New Mexico	723650	ALBUQUERQUE INTL ARPT [ISIS], NM
23061	Alamosa, Colorado	724620	ALAMOSA SAN LUIS VALLEY RGNL, CO
23063	Eagle, Colorado	724675	EAGLE COUNTY AP, CO
23065	Goodland, Kansas	724650	GOODLAND RENNER FIELD, KS
23066	Grand Junction, Colorado	724760	GRAND JUNCTION WALKER FIELD, CO
23129	Long Beach, California	722970	LONG BEACH DAUGHERTY FLD, CA
23153	Tonopah, Nevada	724855	TONOPAH AIRPORT, NV
23154	Ely, Nevada	724860	ELY YELLAND FIELD, NV
23155	Bakersfield, California	723840	BAKERSFIELD MEADOWS FIELD, CA
23160	Tucson, Arizona	722740	TUCSON INTERNATIONAL AP, AZ
23161	Daggett, California	723815	DAGGETT BARSTOW-DAGGETT AP, CA
23169	Las Vegas, Nevada	723860	LAS VEGAS MCCARRAN INTL AP, NV
23174	Los Angeles, California	722950	LOS ANGELES INTL ARPT, CA
23183	Phoenix, Arizona	722780	PHOENIX SKY HARBOR INTL AP, AZ
23184	Prescott, Arizona	723723	PRESCOTT LOVE FIELD, AZ
23185	Reno, Nevada	724880	RENO TAHOE INTERNATIONAL AP, NV
23188	San Diego, California	722900	SAN DIEGO LINDBERGH FIELD, CA
23232	Sacramento, California	724830	SACRAMENTO EXECUTIVE ARPT, CA
23234	San Francisco, California	724940	SAN FRANCISCO INTL AP, CA
23273	Santa Maria, California	723940	SANTA MARIA PUBLIC ARPT, CA
24011	Bismarck, North Dakota	727640	BISMARCK MUNICIPAL ARPT [ISIS], ND
24013	Minot, North Dakota	727676	MINOT FAA AP, ND
24018	Cheyenne, Wyoming	725640	CHEYENNE MUNICIPAL ARPT, WY
24021	Lander, Wyoming	725760	LANDER HUNT FIELD, WY
24023	North Platte, Nebraska	725620	NORTH PLATTE REGIONAL AP, NE
24025	Pierre, South Dakota	726686	PIERRE MUNICIPAL AP, SD
24027	Rock Springs, Wyoming	725744	ROCK SPRINGS ARPT [GREEN RIVER - UO], WY
24028	Scottsbluff, Nebraska	725660	SCOTTSBLUFF W B HEILIG FIELD, NE
24029	Sheridan, Wyoming	726660	SHERIDAN COUNTY ARPT, WY
24033	Billings, Montana	726770	BILLINGS LOGAN INT'L ARPT, MT
24036	Lewistown, Montana	726776	LEWISTOWN MUNICIPAL ARPT, MT
24037	Miles City, Montana	742300	MILES CITY MUNICIPAL ARPT, MT
24089	Casper, Wyoming	725690	CASPER NATRONA CO INTL AP, WY
24090	Rapid City, South Dakota	726620	RAPID CITY REGIONAL ARPT, SD
24121	Elko, Nevada	725825	ELKO MUNICIPAL ARPT, NV
24127	Salt Lake City, Utah	725720	SALT LAKE CITY INT'L ARPT [ISIS], UT
24128	Winnemucca, Nevada	725830	WINNEMUCCA MUNICIPAL ARPT, NV
24131	Boise, Idaho	726810	BOISE AIR TERMINAL [UO], ID
24137	Cut Bank, Montana	727796	CUT BANK MUNI AP, MT
24143	Great Falls, Montana	727750	GREAT FALLS INTL ARPT, MT
24144	Helena, Montana	727720	HELENA REGIONAL AIRPORT, MT
24146	Kalispell, Montana	727790	KALISPELL GLACIER PK INT'L AR, MT

<b>WBAN</b>	<b>1961-1990 Site</b>	<b>USAF</b>	<b>NSRDB Update Site</b>
24153	Missoula, Montana	727730	MISSOULA INTERNATIONAL AP, MT
24155	Pendleton, Oregon	726880	PENDLETON E OR REGIONAL AP, OR
24156	Pocatello, Idaho	725780	POCATELLO REGIONAL AP, ID
24157	Spokane, Washington	727850	SPOKANE INTERNATIONAL AP [CHENEY - UO], WA
24221	Eugene, Oregon	726930	EUGENE MAHLON SWEET ARPT [UO], OR
24225	Medford, Oregon	725970	MEDFORD ROGUE VALLEY INTL AP [ASHLAND - UO], OR
24227	Olympia, Washington	727920	OLYMPIA AIRPORT, WA
24229	Portland, Oregon	726980	PORTLAND INTERNATIONAL AP, OR
24230	Redmond, Oregon	726835	REDMOND ROBERTS FIELD, OR
24232	Salem, Oregon	726940	SALEM MCNARY FIELD, OR
24233	Seattle/Tacoma, Washington	727930	SEATTLE SEATTLE-TACOMA INTL A, WA
24243	Yakima, Washington	727810	YAKIMA AIR TERMINAL, WA
24283	Arcata, California	725945	ARCATA AIRPORT, CA
24284	North Bend, Oregon	726917	NORTH BEND MUNI AIRPORT, OR
25308	Annette, Alaska	703980	ANNETTE ISLAND AP, AK
25339	Yakutat, Alaska	703610	YAKUTAT STATE ARPT, AK
25501	Kodiak, Alaska	703500	KODIAK AIRPORT, AK
25503	King Salmon, Alaska	703260	KING SALMON ARPT, AK
25624	Cold Bay, Alaska	703160	COLD BAY ARPT, AK
25713	St Paul Is., Alaska	703080	ST PAUL ISLAND ARPT, AK
26411	Fairbanks, Alaska	702610	FAIRBANKS INTL ARPT, AK
26415	Big Delta, Alaska	702670	BIG DELTA ALLEN AAF, AK
26425	Gulkana, Alaska	702710	GULKANA INTERMEDIATE FIELD, AK
26451	Anchorage, Alaska	702730	ANCHORAGE INTL AP, AK
26510	McGrath, Alaska	702310	MCGRATH ARPT, AK
26528	Talkeetna, Alaska	702510	TALKEETNA STATE ARPT, AK
26533	Bettles, Alaska	701740	BETTLES FIELD, AK
26615	Bethel, Alaska	702190	BETHEL AIRPORT, AK
26616	Kotzebue, Alaska	701330	KOTZEBUE RALPH WEIN MEMORIAL, AK
26617	Nome, Alaska	702000	NOME MUNICIPAL ARPT, AK
27502	Barrow, Alaska	700260	BARROW W POST-W ROGERS ARPT [NSA - ARM], AK
41415	Guam, Pacific Islands	912120	GUAM WFO, GU
93037	Colorado Springs, Colorado	724660	COLORADO SPRINGS MUNI AP, CO
93058	Pueblo, Colorado	724640	PUEBLO MEMORIAL AP, CO
93129	Cedar City, Utah	724755	CEDAR CITY MUNICIPAL AP, UT
93193	Fresno, California	723890	FRESNO YOSEMITE INTL AP, CA
93721	Baltimore, Maryland	724060	BALTIMORE BLT-WASHNGTN INT'L, MD
93729	Cape Hatteras, North Carolina	723040	CAPE HATTERAS NWS BLDG, NC
93730	Atlantic City, New Jersey	724070	ATLANTIC CITY INTL AP, NJ
93738	Sterling, Virginia	724030	WASHINGTON DC DULLES INT'L AR [STERLING - ISIS], VA
93805	Tallahassee, Florida	722140	TALLAHASSEE REGIONAL AP [ISIS], FL
93814	Covington (Cincinnati, OH), Kentucky	724210	CINCINNATI NORTHERN KY AP, KY
93815	Dayton, Ohio	724290	DAYTON INTERNATIONAL AIRPORT, OH
93817	Evansville, Indiana	724320	EVANSVILLE REGIONAL AP, IN

<b>WBAN</b>	<b>1961-1990 Site</b>	<b>USAF</b>	<b>NSRDB Update Site</b>
93819	Indianapolis, Indiana	724380	INDIANAPOLIS INTL AP, IN
93820	Lexington, Kentucky	724220	LEXINGTON BLUEGRASS AP, KY
93821	Louisville, Kentucky	724230	LOUISVILLE STANDIFORD FIELD, KY
93822	Springfield, Illinois	724390	SPRINGFIELD CAPITAL AP, IL
93842	Columbus, Georgia	722255	COLUMBUS METROPOLITAN ARPT, GA
93987	Lufkin, Texas	722446	LUFKIN ANGELINA CO, TX
94008	Glasgow, Montana	727680	GLASGOW INTL ARPT, MT
94018	Boulder, Colorado	724699	BROOMFIELD/JEFFCO [BOULDER - SURFRAD], CO
94185	Burns, Oregon	726830	BURNS MUNICIPAL ARPT [UO], OR
94224	Astoria, Oregon	727910	ASTORIA REGIONAL AIRPORT, OR
94240	Quillayute, Washington	727970	QUILLAYUTE STATE AIRPORT, WA
94702	Bridgeport, Connecticut	725040	BRIDGEPORT SIKORSKY MEMORIAL, CT
94725	Massena, New York	726223	MASSENA AP, NY
94728	New York City (Central Park), New York	744860	NEW YORK J F KENNEDY INT'L AR, NY
94746	Worcester, Massachusetts	725095	WORCHESTER REGIONAL ARPT, MA
94814	Houghton, Michigan	726380	HOUGHTON LAKE ROSCOMMON CO AR, MI
94822	Rockford, Illinois	725430	ROCKFORD GREATER ROCKFORD AP, IL
94823	Pittsburgh, Pennsylvania	725200	PITTSBURGH INTERNATIONAL AP, PA
94830	Toledo, Ohio	725360	TOLEDO EXPRESS AIRPORT, OH
94846	Chicago, Illinois	725300	CHICAGO OHARE INTL AP, IL
94847	Detroit, Michigan	725370	DETROIT METROPOLITAN ARPT, MI
94849	Alpena, Michigan	726390	ALPENA COUNTY REGIONAL AP, MI
94860	Grand Rapids, Michigan	726350	GRAND RAPIDS KENT COUNTY INT', MI
94910	Waterloo, Iowa	725480	WATERLOO MUNICIPAL AP, IA
94918	Omaha, Nebraska	725500	OMAHA EPPLEY AIRFIELD, NE

## Appendix C: Measured Solar Instrumentation

This section provides details about the instrumentation used for measured solar radiation in the NSRDB update. Table C-1 shows instrumentation by year for each site with measured data.

**Table C-1. Measurement Site Instrumentation by Year, 1991–2005**

ID	Name	9 1	9 2	9 3	9 4	9 5	9 6	9 7	9 8	9 9	0 0	0 1	0 2	0 3	0 4	0 5	
700260	BARROW W POST- W ROGERS ARPT [NSA - ARM]	x	x	x	x	x	x	x	a	a	a	a	a	a	a	a	
722046	SPACE COAST RGNL [FSEC]	x	x	x	x	x	x	x	a	a	a	a	x	x	x	x	
722140	TALLAHASSEE REGIONAL AP [ISIS]	x	x	x	x	a	a	a	a	a	a	a	a	x	x	x	
722436	HOUSTON ELLINGTON AFB [CLEAR LAKE - UT]	x	x	x	x	x	x	a	a	a	a	a	x	x	x	x	
722470	LONGVIEW GREGG COUNTY AP [OVERTON - UT]	x	x	x	x	x	c	c	c	c	c	c	c	c	c	x	x
722506	MCALLEN MILLER INTL AP [EDINBURG - UT]	x	x	x	x	x	x	a	a	a	a	a	a	a	a	x	x
722510	CORPUS CHRISTI INTL ARPT [UT]	x	x	x	x	x	c	c	c	c	c	c	c	c	c	x	x
722520	LAREDO INTL AP [UT]	x	x	x	x	x	c	c	c	c	c	c	c	c	c	x	x
722540	AUSTIN MUELLER MUNICIPAL AP [UT]	x	x	x	x	x	a	a	a	a	a	a	a	a	x	x	x
722610	DEL RIO [UT]	x	x	x	x	x	c	c	c	c	c	c	x	x	x	x	
722660	ABILENE REGIONAL AP [UT]	x	x	x	x	x	x	c	c	c	c	c	c	c	c	x	x
722700	EL PASO INTERNATIONAL AP [UT]	x	x	x	x	x	x	x	x	a	a	a	a	a	a	x	x
723546	PONCA CITY MUNICIPAL AP [SGP - ARM]	x	x	x	a	a	a	a	a	a	a	a	a	a	a	a	a
723630	AMARILLO INTERNATIONAL AP [CANYON - UT]	x	x	x	x	x	x	a	a	a	a	a	a	a	a	x	x
723650	ALBUQUERQUE INTL ARPT [ISIS]	x	x	x	x	a	a	a	a	a	a	a	a	a	a	a	x
723870	MERCURY DESERT ROCK AP [SURFRAD]	x	x	x	x	x	x	x	a	a	a	a	a	a	a	a	a
723898	HANFORD MUNI ARPT [ISIS]	x	x	x	x	a	a	a	a	a	a	a	a	a	a	a	a

ID	Name	9 1	9 2	9 3	9 4	9 5	9 6	9 7	9 8	9 9	0 0	0 1	0 2	0 3	0 4	0 5
724030	WASHINGTON DC DULLES INT'L AR [STERLING - ISIS]	x	x	x	x	x	a	a	a	a	a	a	a	a	a	a
724125	BLUEFIELD/MERCE R CO [NREL]	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
724666	DENVER/ CENTENNIAL [GOLDEN - NREL]	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
724699	BROOMFIELD/JEFF CO [BOULDER - SURFRAD]	x	x	x	x	x	a	a	a	a	a	a	a	a	a	a
724776	MOAB/CANYON- LANDS [UO]	x	x	x	c	c	c	c	c	c	c	c	c	c	c	x
725128	STATE COLLEGE [PENN STATE - SURFRAD]	x	x	x	x	x	x	x	a	a	a	a	a	a	a	a
725315	UNIV OF ILLINOIS WI [BONDVILLE - SURFRAD]	x	x	x	x	a	a	a	a	a	a	a	a	a	a	a
725720	SALT LAKE CITY INT'L ARPT [ISIS]	x	x	x	x	a	a	a	a	a	a	a	a	a	a	a
725744	ROCK SPRINGS ARPT [GREEN RIVER - UO]	x	x	x	x	c	c	c	c	c	c	c	c	c	c	c
725895	KLAMATH FALLS INTL AP [UO]	x	x	x	x	x	x	x	x	b	b	x	x	x	x	x
725970	MEDFORD ROGUE VALLEY INTL AP [ASHLAND - UO]	x	x	x	x	x	x	x	x	x	c	c	c	c	c	c
726410	MADISON DANE CO REGIONAL ARPT [ISIS]	x	x	x	x	x	a	a	a	a	a	a	a	a	a	a
726796	DILLON AIRPORT [UO]	x	x	x	x	x	x	x	x	x	x	x	a	a	a	a
726810	BOISE AIR TERMINAL [UO]	x	x	x	c	c	c	c	c	c	c	c	x	x	x	x
726830	BURNS MUNICIPAL ARPT [UO]	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
726883	HERMISTN MUNI ARPT [UO]	x	x	b	b	b	b	b	b	b	b	b	b	b	b	b
726930	EUGENE MAHLON SWEET ARPT [UO]	b	b	b	b	b	a	a	a	a	a	a	a	a	a	a
727640	BISMARCK MUNICIPAL ARPT [ISIS]	x	x	x	x	a	a	a	a	a	a	a	a	a	a	a
727686	WOLF POINT INTL [FORT PECK - SURFRAD]	x	x	x	x	a	a	a	a	a	a	a	a	a	a	a
727935	SEATTLE BOEING FIELD [ISIS]	x	x	x	x	a	a	a	a	a	a	a	a	a	a	a
746943	ELIZABETH CITY COAST GUARD AI [NREL]	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a

Key

- a – Measured global, direct, and diffuse with thermopile instruments
- b – Measured global and direct with thermopile instruments
- c – Spectrally corrected measured global and diffuse with rotating shadowband radiometer (see Section 2.3.6.1)
- x – No measured data available