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NORTH CAROLINA
Environmental Quality

DAQ-07-003.2 Standard Operating Procedure (SOP)
DAQ-07-003.3 Standard Operating Procedure (SOP)
MetOne AIO2 All-in-One Met Sensor Operator and Coordinator Responsibilities

Revision 0.0
Effective Date: June 07, 2021

1.0 Approval Sign Off-Sheet

I certify that I have read and approve of the contents of the MetOne AIO2 All-in-One Met Sensor Standard Operating Procedure with an effective date of Jun 07, 2021.

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Disclaimer: This document, and any revision hereto, is intended solely as a reference guide to assist individuals in the operation of the instrument, related to the North Carolina Division of Air Quality's Ambient Monitoring Program

SOP Acronym Glossary

ADQ - Audit of data quality

AIO2 – Met One All In One Weather Sensor

AQS - Air Quality System (EPA's Air database)

ARM – Air Resources Manager

CFR – Code of Federal Regulations

Chief – Ambient Monitoring Section chief

CRONUS – Climate Retrieval and Observations Network Of the Southeast Database

CTS – collocated transfer station

DAQ - North Carolina Division of Air Quality

DAS – Data acquisition system

° - degrees

°C – degrees Celsius

°F – degrees Fahrenheit

DEQ – North Carolina Department of Environmental Quality

Director – Division of Air Quality Director

ECB – Electronics and Calibration Branch

Elog – electronic logbook

EPA – United States Environmental Protection Agency

FEM – Federal equivalent method

FRM – Federal reference method

hPa – hectopascal

Hz – Hertz

IBEAM – Internet Based Enterprise Application Management

MDL – Method detection limit

m/s – meters per second

mm - millimeters

mph – miles per hour

PAMS – Photochemical Assessment Monitoring Station

PC – personal computer

PM – Particulate matter

PPB – Projects and Procedures Branch

QA – Quality assurance

QA/QC - Quality assurance/quality control

QAPP - Quality assurance project plan

QC – Quality control

RAMC – Regional Air Monitoring Coordinator

RCO – Raleigh central office

RO – Regional Office

RS – Recommended Standard

SDI – Serial Digital Interface

SOP - Standard operating procedure

SCO – State Climate Office

TSA - Technical systems audit

W/m^2 – Watts per square meter

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2.0 SCOPE AND PURPOSE

While outside entities such as the National Weather Service can provide atmospheric data across the state, there are many instances where knowing the exact conditions of the environment around a site is beneficial to interpreting pollutants. Meteorological data can influence the behavior of pollutants in the atmosphere. It can also be invaluable to determining the impact of commercial activity in the area that can help the North Carolina Division of Air Quality (DAQ) determine if regulatory action is required.

This SOP for the Met One All In One Weather Sensor (AIO2) is for supporting the collection of meteorological data and is also required by the United States Environmental Protection Agency's (EPA) Photochemical Assessment Monitoring Station (PAMS) monitoring program (updated in 40 CFR Part 58, Appendix D, Section 5.0). The purpose of this document is to provide guidance to the operators and coordinators responsible for the AIO2 instrument operation and Level-1/Level-2 data review.

Meteorological parameters that apply to this SOP are: Wind Speed, Wind Direction, Temperature, Relative Humidity, and Barometric Pressure. Meteorological parameters Precipitation, Solar Radiation, UV Radiation, and Mixing Height are dealt with in separate SOPs. Any records generated by the Operator will be reviewed and verified by the Regional Ambient Monitoring Coordinator (RAMC). The Raleigh Central Office (RCO) Chemist validates routine and associated quality control (QC) data monthly. The block of data generated by an individual monitor in one month is defined as the data set. Monthly review has proven to be the most efficient period for these verification and validation activities.

3.0 EQUIPMENT CHECKS

The AIO2 instrument is a single, compact unit for measuring wind speed, wind direction, ambient air temperature, relative humidity, and barometric pressure. It integrates a folded-path, low-power sonic anemometer with a precision thermistor temperature sensor, fast-response capacitive relative humidity sensor, and a state-of-the-art barometric pressure sensor. It also includes an internal flux-gate compass that allows for automatic alignment of wind direction to magnetic north, regardless of the sensor's orientation. The small footprint and power efficiency of the AIO2 make it ideal for many applications and site conditions.

The Met One AIO2 operates on the principal that the speed of the wind affects the time it takes for sound to travel from one point to a second point via a sonic anemometer. The sonic anemometer follows the principles of the doppler effect. If the sound is traveling in the direction of the wind, then the transit time is decreased. If the sound is traveling in a direction opposite the wind, then the transit time is increased.

The AIO2 specifications are:

Parameter	Specification
Wind Speed Operating Range	0 to 75 meters per second (m/s) (0 to 168 miles per hour [mph])
Wind Speed Calibrated Range	0 to 60 m/s (0 to 134 mph)
Wind Speed Accuracy	±0.5m/s or 5% of reading (whichever is greater)
Wind Speed Resolution	0.1 m/s
Wind Direction Range	0 to 360 degrees (°)
Wind Direction Accuracy	±5° (including Compass)
Wind Direction Resolution	1.0°
Alignment Compass Accuracy	±2°
Alignment Compass Resolution	1°
Temperature Range	-40 to +60 degrees Celsius (°C) (-40 to +140 degrees Fahrenheit [°F])
Temperature Accuracy	±0.2°C from 0 to 60°C, ±0.5°C from -40 to 0°C
Temperature Resolution	0.1°C
Relative Humidity Range	0 to 100%
Relative Humidity Accuracy	±3% 25°C
Relative Humidity Resolution	1.0%
Barometric Pressure Range	600 to 1100 hectopascal (hPa)
Barometric Pressure Accuracy	±0.5 hPa 25°C
Barometric Pressure Resolution	0.1 hPa
External Rain Gauge Input	Resolution 0.25 millimeters (mm) or 0.01 inch, user selectable
External Solar Radiation Sensor Input	Measured in Watts per square meter (W/m^2)
Measurement Rate Output	1 Hertz (Hz)
Signal Output Type	RS-232, RS-485, and SDI-12
Operating Temperature	-40 to +60°C (-40 to +140°F)
Operating Relative Humidity	0 to 100%
Dimensions	4.5 inches diameter, 11 inches height
Shipping Weight	6 pounds (including packaging)

NCDAQ uses the AutoMet 580 Datalogger to interact directly with the AIO2. The datalogger's Comet software then sends the data hourly to the Envidas data acquisition software located on the site computer. A user can down the channel for events such as audits or maintenance but cannot edit the data in Envidas. Envista Air Resource Manager (ARM), an editable database used by all level of reviewers, then polls the data hourly to preserve the raw data.

4.0 SITE CHECKS

The site operator shall, when visiting the site for regular gaseous monitor operations, check that the AIO2 is communicating values to the Envidas site computer. On a daily basis, both the site operator and the RAMC shall check that the AIO2 instrument has reported hourly values for wind speed, wind direction, ambient air temperature, relative humidity, and barometric pressure.

4.1 Visual Inspection

While on site, the site operator or RAMC should visually inspect that the unit is undamaged and still securely fastened to the site's tower. The arm of the tower does not need to be lowered to accomplish this. The Operator should also take note of any other environmental factors that could impact the quality of data at the site such as a bird nesting near the AIO2. Any irregularities should be reported to the Electronics and Calibration Branch (ECB).

4.2 Operational Spot Checks

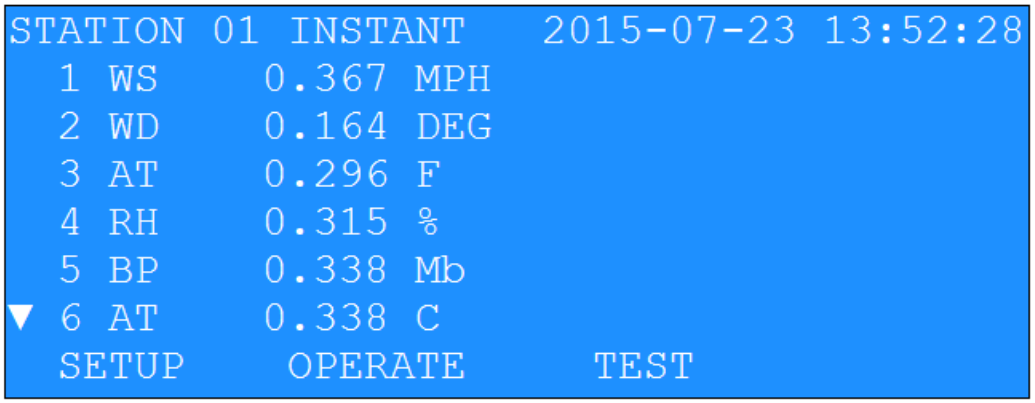
While not required, it is encouraged that the site operator or RAMC use weather events as opportunities to provide an operational spot check. Should an event such as a sudden raise in temperature, atypical humidity, or high wind speeds occur, site operator or RAMC reviewers should check the data collected by the instrument for corresponding readings the next day. Should the instrument fail to show readings that logically match the weather event that occurred, the site operator reviewer should contact the ECB.

For purposes of an operational spot check, readings from the AIO2 do not need to exactly match another source's values but should show the general trend in the same way. For instance, if a day had an unusually high temperature, the AIO2's data should show higher readings for temperature even if the value does not exactly match the other source's value.

4.3 Datalogger Time Check

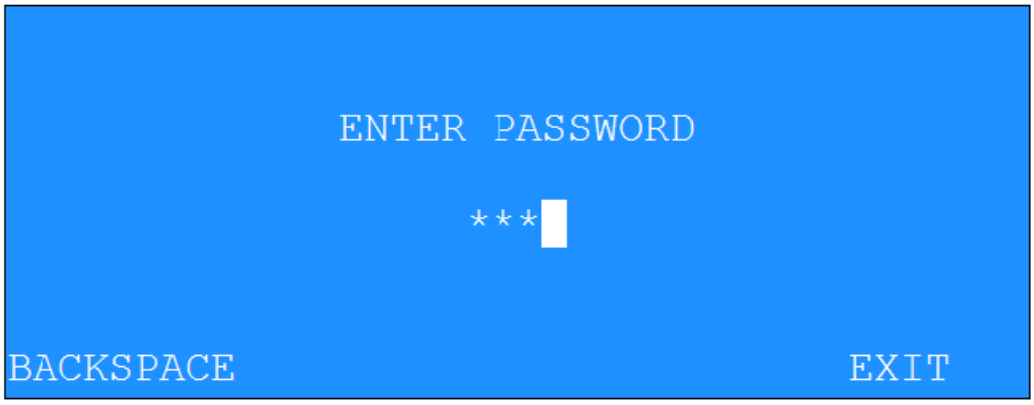
Once a month, the operator should check the AutoMet 580 datalogger to see if the datalogger time stamp has drifted. If the datalogger's time is more than ±2 minutes off from the clock of the site computer, the operator should adjust the datalogger's time to match the site computer's clock.

To change the AutoMet 580 logger clock date and time start from the main screen (show below):

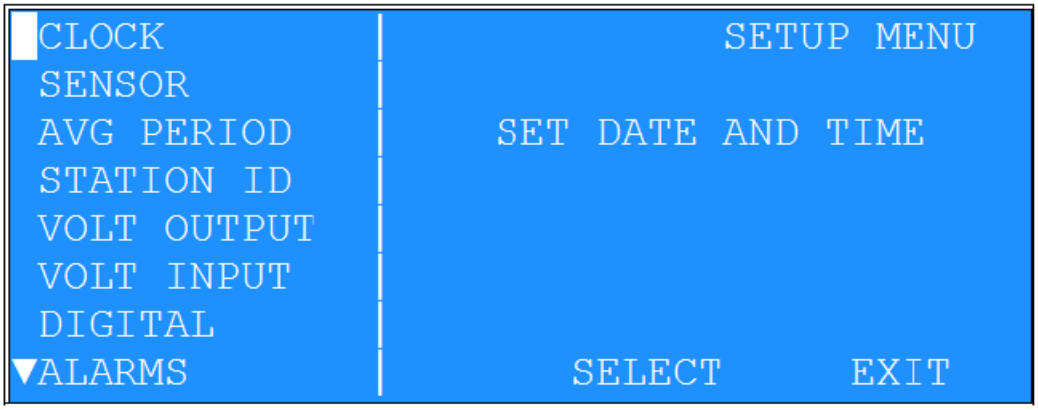


Typical Top Menu Screen

1. Select “SETUP”
2. Password will display, enter F1,F2,F3,F4 to move past the password screen



3. Setup menu should display:



4. Use arrow keys to move cursor next to “CLOCK” and press select

The following screen should appear:

5. Use arrow keys to move cursor to digits that need to be changed. Typically, the minutes will have to be adjusted unless an extended power failure occurred where the date may also have to be adjusted to the current date.
6. Move cursor to the minutes, then press “edit” to give control to the user to change. Use the arrow keys to increase or decrease numbers to match current site computer to within +/-2minutes. Press the “save” button to confirm and store change into logger.

Press the “exit” twice to return to top menu screen. Verify the display date and time on the AutoMet 580 top menu screen matches the site computer to within +/-2minutes.

5.0 DETAILED PROCEDURES

Due to the nature of the AIO2, there is no regular maintenance required to be done by the site operator or RAMC. The AIO2 has no moving parts or pieces that can be manipulated or changed. Meteorological data collected by the AIO2 is unique in their collection and, unlike the criteria pollutants, do not have a daily Precision-Zero-Span for site operators to check the validity of the data collected. Instead, operators must use the collocated transfer station (CTS) method and nearby weather stations to verify that the data collected is reasonable and accurate.

The AIO2 sensors at sites that are not a part of the PAMs program will be audited by the ECB once a calendar year and every 365 days. The AIO2 sensors at sites that are a part of the PAMs program, however, will be audited twice a calendar year and every 182 days. Should the site operator or RAMC believe that the AIO2 is not functioning properly, the ECB should be contacted to request an unscheduled audit.

5.1 Compass Stability

During a 24-hour period starting at 0:00 and ending at 23:59, the compass readings for an AIO2 should not exceed a standard deviation of ±2.0 degrees. If they do, the compass is considered unstable and all wind speed and wind direction data for that period should be null coded.

If a compass is unstable, the ECB should be notified so that they can either resecure the AIO2 to the site's tower or send the AIO2 to the manufacturer for recalibration and recertification.

An unstable compass has no impact on barometric pressure, temperature or relative humidity data.

5.2 Collocated Transfer Station Method

Some sites, such as Millbrook, will have a second AIO2 positioned near it to act as an additional tool to verify the AIO2 data being submitted to the Air Quality System (AQS). This AIO2 will be audited at the same time as the AIO2 being submitted to AQS. This verifying AIO2 is not intended to replace the site's AIO2 if it is not functioning correctly for some reason.

Site Operators and the RAMC should use the criteria below as a verifying method that the site's AIO2 is operating correctly. Should the site's reporting AIO2 not match the verifying AIO2, the ECB should be contacted to perform an audit on site.

Table 1: CTS Criteria

	Wind Speed	Wind Direction	Ambient Temperature	Pressure	Relative Humidity
Average Difference (Bias)	±0.70 m/s	±7.0°	±0.2°C	±0.70 hPa	±4.2%
Standard Deviation (Precision)	±0.35 m/s	±3.5°	±0.1°C	±0.35 hPa	±2.1%

Note: Only Wind speeds above 1 m/s qualify for the CTS Method. Should an hour record a wind speed less than 1 m/s, neither the wind speed nor wind direction for that hour should be factored into the precision or bias.

5.3 Comparing to Nearby Stations

The AIO2 should maintain readings that are comparable to nearby sensors. This comparison shall be reviewed by the RAMC on a monthly basis. Hourly data is available through the State Climate Office (SCO) Climate Retrieval and Observations Network Of the Southeast (CRONOS) Database system. An Example site for Millbrook is the "KRDU" meteorological station located at Raleigh Durham International airport. The data can be requested as Validated or Raw. For the purpose of verifying the operation of the DAQ meteorological data, the Raw version of data should be downloaded from the SCO system. Until the SCO CRONOS system is updated (projected April-2021) the maximum amount of historical data that may be directly downloaded is seven (7) days. The RAMC will have to schedule weekly SCO downloads for use during monthly data validations at the end of the month (https://climate.ncsu.edu/cronos).

For purposes of operational spot checks, sites such as www.wunderground.com can be used as well.

5.4 Rain, Ice, and Snow

Anything that blocks the acoustic signal path will degrade the measurement. If the path is blocked sufficiently, measurements cannot be made. Rain, ice, and snow are common natural events that can block the path. Readings that are impacted by one of these events should be null coded.

6.0 Logbook Submittal and Data Retrieval

6.1 Logbook Submittal

The Elog, or Electronic Logbook, serves as the Transfer Record and Document for evaluating the Success/Failure of the operation of the AIO2 monitoring site and is the essential record for determining the quality of the meteorological data reported from each site.

1. The **Site Operator** must complete the Elog to document the purpose of Every site visit, the observations and findings during the site visit, and the evaluation of the performance of the meteorological monitoring system for each site visit. This includes any and all startups and shutdowns (including severe weather events, temperature extremes, and etc.). The Site Operator must initial and date the last time the Elog was altered.
2. The Site Operator must submit the Elog to the RAMC or Designee for review and comment as soon as reasonably possible after the site visit and at a minimum by the end of each month. Additionally, a Site logbook page should be annotated with any site visit, i.e. shutting down for approaching weather, start-ups and shut downs, and etc. Each site visit should provide an Elog and an entry in the Site logbook stating, at a minimum, with a purpose for the visit.
3. The **RAMC** or Designee must review site operator monthly submitted Elogs for each site in his or her region and evaluate each Elog for completeness and operator adherence to operating procedures. Following that review the RAMC must Initial and submit each logbook to the RCO Chemist for review.
4. The **RCO Chemist** must review the logbooks submitted for completeness and adherence to operating procedures. The RCO Chemist must also review the logbook submitted from each site and from all regions to determine if there is a procedures or pattern of operation that may be negatively impacting the overall operation of the metrological monitoring network and the quality of the metrological data reported.

6.2 Data Retrieval and End Processing

Every business day, the RCO statistician initiates a data review for the previous day by providing a raw data report (in a spreadsheet format) to each Regional Office (RO) (Reference DAQ-15-006.5 Data Validation SOP for Continuous Gaseous and Meteorological Monitors for details on data review). The RCO may request the RO to send additional data that are needed beyond what the RCO requires for verifying any missing data supplied by the RO. These data can be retrieved from the site computer.

7.0 FILE MANAGEMENT

Site operators must have a personal computer (PC) (or laptop) to generate the Elog files from a Microsoft Excel template file. These Elogs are provided by the RCO and updated periodically. The file naming protocol is provided below. A formalized file naming convention has been established and should be used by all operators.

The AIO2 data will be polled and managed by the DAQ Envista ARM database administrator, under the same, established protocols, used for gaseous monitors. The RAMC will submit any logs to RCO P:drive using the same protocols as used for gaseous and particulate monitors (P:\Ambient \Incoming \RegOffices.NC \Raleigh \LogbookReports \YYYY \MET) comparing the SCO hourly data with the AIO2 hourly data.

7.1 File Naming Convention

The Elog template file used at the site should be stored on the PC used for field operations by the field technician. Elogs can also be found in DAQ's Internet Based Enterprise Application Management (IBEAM) system. To access this file, open the Elog template file using Excel. Every time a new Elog is filled out using the template, it must be renamed and saved as a separate and complete workbook (all sheets, i.e., tabs, saved) to preserve the record. Do NOT copy over a previously completed Elog.

NOTE: Refer to the Logbook file naming convention "Policy Memorandum" dated January 1, 2011, located in the DAQ IBEAM module (summarized below).

Renaming and Saving the Elog

1. Open the Elog workbook template file using Excel.
2. Left click the "file" toolbar icon. Scroll down to "save as" and left click.
3. Under file name change workbook file name using the following format: Site ID Met Date Activity. For example, MQ Met 20120730 SV.xlsx is a Site Visit at Millbrook on July 30, 2012
4. Change save location to operator's choice of folders (example: previously created folder named Met).
5. Left click "save".
6. Find the tab needed for the task involved. The first tab selected should be the Logbook. Fill in information as indicated.
7. Open other tabs as needed and fill in information as indicated.
8. Save the workbook when finished entering data.

8.0 Quality Assurance & Data Handling

All site files, Elogs or other supporting documents generated in the field will be stored on dedicated server space in the RO in a folder named for the official site operation files. These files should be transferred to the Official File on a frequent and regular schedule as established by the Region. This is necessary to prevent the potential loss of such files from the field computer and to maintain a record for providing defensible data. This also makes the data easily and readily available for review by the RAMC and transfer to the P: drive for review by the RCO. The files on the site/operator PC can be copied and transferred to the common hard drive via email or flash drive for storage in the official file folder.

The site files should be transferred every three business days and backed up monthly. This serves as a backup system in the event the official PC fails or is removed, or the site files are damaged. These files will be retained for a minimum of five years. When the need arises to review a file for data validation or site operations, the official folder is used, or a hardcopy is created from this file. For details on data validation procedures, please reference DAQ-15-006.5 Data Validation SOP for Continuous Gaseous and Meteorological Monitors. The following validation checks shall be completed every month:

1. Providing proper null codes indicating calibrations, audits etc.
2. Providing missing valid data.
3. Documenting any invalid data as to reason with proper null code.
4. Identifying any data that may be associated with exceptional events.

All data within the DAQ data set must meet the following conventions:

- All data must be reported in Eastern Standard Time year-around.
- Hourly data are reported at the start of the hour (1:00-1:59 is time stamped as 01:00).
- All missing or invalid data must be accounted for by the use of proper null codes. The null codes must be accompanied by the identifying reasons for the missing or invalid data on the monthly data verification and validation pages.
- All data, including any supporting documentation, must be kept for a minimum of three calendar years after the calendar year in which it was collected. Exceptions to this are discussed elsewhere in this SOP.
- Completeness - Data are considered complete if 75 percent or more of the total possible number of observations are present. Continuous measurement criteria for completeness are listed below:
    - 75 percent of the minutes in the hour must be valid; and
    - 75 percent of the hours in a quarter must be valid.

8.1 Monthly Verifications and Validations

Preliminary verification is completed by the RO Operator. The operator must account for and identify the reasons for missing or invalid data within Envista ARM using proper flags and null codes while performing maintenance or shortly thereafter. The operator must review the previous month of data and add any flags or void codes to the Status column as necessary. For each changed status, a comment must be entered with a description of why the status was changed.

The RAMC will perform the second level review of the month of data, adding any additional void codes and comments, and requesting additional information from the operator, as necessary. If required, the RAMC can send data back to the RO Operator for additional comments or to correct any codes. When possible, the data will be verified within 15 workdays from the end of the collection month.

The RCO Chemist performs the final validation of the one-month period of data. Void codes and comments should all be added, and the RCO Chemist can send the data back to the previous reviewer. Final validation of the data should be completed within 30 days of the end of the collection month. Once the data has been approved and has had the "final validation" label applied by the RCO Chemist, it is automatically entered into a queue within Envista ARM. The Database Manager will send all approved data to AQS automatically on a regularly scheduled basis.

In some cases, valid data that are judged to be out of the ordinary are retained and an outlier or validated data flag is added in AQS by the RCO. An example would be high or low values resulting from an event that is not observed by another nearby site. The fully validated file data are then uploaded into AQS by the RCO.

A list of Null Codes that are routinely used during data validation on the AQS monthly summary report are listed in the following table.

Table 2: Commonly Used EPA-AQS Null Value Codes (partial list)

AN	Machine or Equipment Malfunction
AS	Poor Quality Assurance Results
AV	Power Failure
BA	Maintenance and Routine Repairs
BJ	Operator Error
BK	Site Computer/Data Logger Down

8.2 Common Meteorological Trends

The Site Operator, RAMC, and RCO Chemist should use other metrological instrumentation at the site (such as the AIO2) and look for the following trends:

- **Rain measurements vs. Relative Humidity:** As rain measurements are observed, relative humidity should increase.
- **Rain measurements vs. Barometric Pressure:** When barometric pressure is low or decreasing, there is more likely a chance of rain measurements to be observed. When barometric pressure is high or increasing, there is less likely a chance for rain measurements to be observed.
- **Barometric Pressure vs. Barometric Pressure:** Barometric pressure across the state should follow the same general trend across the state with mountainous (higher elevation) sites having lower readings and beach (sea level) sites having higher readings.
- **Barometric Pressure vs. Wind Direction:** During periods where barometric pressure drops, wind direction should undergo a constant change.
- **Barometric Pressure vs. Wind Speed:** As barometric pressure decreases, wind speed should increase.

- **Wind Speed vs. Ambient Temperature:** During periods of large temperature changes, wind speed should increase
- **Wind Speed vs. Wind Direction:** When wind speed increases, there should be changes in wind direction. When wind speed decreases, there should be little change in wind direction.
- **Wind Speed vs. Criteria Pollutant:** With higher wind speeds, higher readings of criteria pollutants should be present.
- **Wind Direction vs. Criteria Pollutant (Only If Near a Point Source):** When the wind is coming from the direction of the point source, higher readings of criteria pollutants should be present.
- **Ambient Temperature vs. Solar Radiation:** During periods of higher solar radiation (Daytime), higher temperatures should be observed. During periods of near zero solar radiation (Nighttime), lower temperatures should be observed.
- **Ambient Temperature vs. Relative Humidity:** In general, relative humidity should go down as ambient temperature goes up.
- **Wind Speed vs. Relative Humidity:** When wind speeds are high, relative humidity should be lower. When wind speeds are low, relative humidity should be higher.
- **Wind Speed vs. Solar Radiation:** Leading up to and around periods of observed measurements of solar radiation, wind speed should show a general increase. During the night hours where there are near zero measurements of solar radiation, wind speeds should show a general decrease.
- **Barometric Pressure vs. Ambient Temperature:** When barometric pressure is high, ambient temperature should read higher. When barometric pressure is low, ambient temperature should read lower.
- **Barometric Pressure vs. Solar Radiation:** When barometric pressure is low or decreasing, there is more likely a chance of overcast and therefore less solar radiation. When barometric pressure is high or increasing, there is more likely a chance for a clear day and more solar radiation.
- **Barometric Pressure vs. Rain Measurements:** When barometric pressure is low or decreasing, there is more likely a chance of rain measurements to be observed. When barometric pressure is high or increasing, there is less likely a chance for rain measurements to be observed.
- **Wind Direction vs. Ambient Temperature:** With greater changes in ambient temperature, a change in wind direction should be observed.

Due to the complexity of meteorological factors, one trend's influence may supersede one of the others. Operators should look at the data using multiple trends to determine which parameter is uncharacteristic.

In general, if the data does not follow these trends, a reviewer should look at nearby weather sites to confirm if a weather event can be confirmed or not and put a QX (does not meet QC criteria) qualifier flag on any data that cannot be confirmed by one of these metrological trends or from the other weather station.

9.0 TROUBLESHOOTING AND CORRECTIVE ACTIONS

In general, troubleshooting and corrective actions should be taken by the ECB. Should an immediate need arise for corrective action, contact the ECB.

10.0 REVISION HISTORY

The following revisions were made:

1. Rev 0 – **TS** 06/07/2021

11.0 REFERENCES

1. See “MODEL AIO 2 ALL IN ONE WEATHER SENSOR OPERATION MANUAL Document No. AIO2-9800 Rev. F”
2. U.S. EPA, (2008) Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements (Version 2.0). Prepared by Office of Air Quality Planning and Standards