Taylor Ranch

METEOROLOGICAL MONITORING QUALITY ASSURANCE PROJECT PLAN FOR THE MOUNTAIN CLOUD CHEMISTRY PROJECT

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3.1 Project Description and Organization

The measurement of standard meteorological parameters at designated summit and forest sites participating in the EPA Mountain Cloud Chemistry Project (MCCP) will be coordinated by the Meteorology and Climate Center, Associated Weather Services, Inc. (AWS). Baseline meteorological parameters to be measured at all sites are: air temperature, relative humidity, wind speed, wind direction and global solar radiation. Additional parameters -- atmospheric pressure and precipitation -- will be measured at selected sites. The monitoring effort will follow a Research Protocol/Methodology (RPM) described in the document "Meteorological Site Technician Handbook", hereafter referred to as the RPM Manual. The meteorological measurements will be used to complement other research and monitoring efforts at each MCCP site, and to interpret and characterize atmospheric conditions during acid deposition events. The measurement program will commence in 1986, and will be conducted during the warm months of the year.

Because of the research orientation of the MCCP and also the remote and environmentally extreme character of the sites, the Quality Assurance Plan described herein is tentative and subject to revision as actual monitoring experience is gained. Any revisions are subject to approval by the MCCP Quality Assurance Officer.

This Quality Assurance Plan applies to all designated MCCP participating sites with the exception of the Tennessee Valley Authority's Whitetop Mountain facility, and all sites operated by Atmospheric Environment of Canada.

3.2 QA Objectives for Measurement Data

Quality assurance objectives for the seven meteorological parameters are listed in Table 3.2.1. Indicated in the table are methods and units of measurement, accuracy requirements for laboratory, field, and dual instrument checks, and the calibration sources. The procedures used to determine accuracy and precision are described in sections 2.4 and 2.9 and the Appendices.

TABLE 3.2.1
QUALITY ASSURANCE OBJECTIVES FOR METEOROLOGICAL MONITORING

PARAMETER	METHOD	UNITS	ABSOLUTE ACCURACY*	CALIBRATION SOURCE
Air Temperature	Thermistor	°C	2°C (lab, field and dual)	Mercury-in-glass Thermometer (NBS Traceable)
Relative Humidity	Capacitor	%	5% (lab & dual) 15% (field)	Known Salt Solutions (NBS Traceable)
Wind Speed	Propellor Anemometer w/ 6-pole magnet	m/s	3 H_z (lab) 1 m/s (field & dual)	Wind Speed Generator and Torque Watch
Wind Direction	Vane Potentiometer	degrees	0.028 vdc (lab) 10° (field & dual)	Alignment Calibrator & Torque Weight
Solar Radiation	Silicon Photocell	W/m^2	10% of reference (lab and dual)	Shelf Standard (NBS Traceable)
Pressure	Piezoresistive	millibars	1% of reference (lab and dual)	Hand-held Barometer (NBS Traceable)
Precipitation	Tipping Bucket	mm	5% (lab) 10% (field & dual)	Burette
Data Logger	CMOS, microprocessor-based		Variable - refer to Appendix A	Combination multisource/ multimeter (NBS Traceable

* Values shown are for lab, field and/or dual calibration checks, which are described in a following section.

3.3 Sampling and Measurement Procedure

The meteorological package (sensors and data logger) will be located at designated MCCP monitoring sites. Sensors for wind speed and direction, air temperature, relative humidity and solar radiation will be mounted on an existing tower or building, and will be at least 3 m in height above the nearest vegetation. The temperature and relative humidity sensors will be housed within an aspirated radiation shield. The pressure sensor, if used, will be located in an adjacent shelter or building, as will the data logger. The precipitation sensor, if used, will be located on or in proximity to the tower/building, and must have an unobstructed vertical view.

All sensors will be commercially available products of known quality and reputation. The methods of measurement are noted in Table 3.2.1; the RPM manual identifies and describes the specific sensors to be used. The data logger to be used is the Campbell Scientific 21XL Micrologger, which also is described in detail in the RPM Manual. Provisions for lightning protection, such as lightning rods and spark gaps, will be incorporated into the meteorological package. The meteorological package will be operated and maintained according to the RPM Manual.

The meteorological data will be sampled automatically at 10 second or more frequent intervals, and stored in the data logger's intermediate storage. The data logger processes these data values in real time to form and subsequently store sequential 15 minute data arrays in final storage. Time and data tags are generated with each array.

3.4 Calibration Procedures and Frequency

For each parameter measured, Table 3.4.1 lists the schedule of calibration checks for each meteorological sensor. There are three types of calibration checks: lab, field, and dual. The table includes the frequency at which each check is performed by AWS personnel. Section II of the RPM Manual includes complete field type check instructions and sheets. Appendix A includes complete lab type check instructions and form sheets. Appendix B includes complete dual type check instructions and form sheets.

The dual type calibration checks fulfill two purposes. One, to perform a more rigorous calibration check (than the scheduled field checks) on each sensor at the monitoring period's approximate midway point. Second, to experimentally compute the precision of each sensor in order to assess each method's applicability. A specific program will be uploaded into the 21XL to aid in the precision checks. Upon their completion, the original program will be restored.

Corrective action, if a sensor fails a calibration check, is to have the check repeated. A second failure requires the

temporary replacement and/or removal of the sensor after contacting AWS personnel for instructions. Upon determining the cause of failure, appropriate steps should be taken to eliminate that cause. Any failed sensor must be recalibrated before reinstallation in the field.

TABLE 3.4.1

CALIBRATION CHECK SCHEDULE

Parameter	Type Check	Occurrence
Wind Speed & Wind Direction	Lab	Predeployment
	Field	Prestudy
		Prior to final removal
	Dual	Approx. midway of year
		Post study
Precipitation	Lab	Predeployment
	Field	Prestudy
		Prior to final removal
	Dual	Approx. midway of year
		Post study
Temperature/ Relative Humidity	Lab	Predeployment
	Field	Prestudy
		Prior to final removal
	Dual	Approx. midway of year
		Post study
Solar Radiation	Lab	Predeployment
	Dual	Approx. midway of year
		Post study
Barometric Pressure	Lab	Predeployment *
		Prestudy
		Prior to final removal
	Dual	Approx. midway of year
		Post study
Data Logger	Lab	Predeployment
		Post study

* Applicable to sensors usable at sea level.

3.5 Data Reduction and Validation

The data logger will be preprogrammed to automatically transfer the stored data to cassette tape every time 512 data points have accumulated. The cassette tape has a capacity of over two weeks. At least once per week, the site technician will remove the cassette tape containing the data, replace it with a designated tape in the recorder, and transport it to the research facility's microcomputer. There the data will be transferred onto computer hard disk and paper hard copy for limited, on-site data storage and analysis. The cassette tapes are mailed within two days to the Management Center (W. S. Fleming & Associates). They are transferred to Associated Weather Services and their data dumped to a PC and then relayed to the VAX computer of the Data Management Center (W. S. Fleming & Associates). The cassettes are then returned to the Management Center where they are archived. The cassette tapes containing the raw data will be stored for at least two years.

Prior to sending the cassettes, intermediate data validation routines will be run at the research site for the newly retrieved raw data. This will alert the on-site meteorological technician to possible measurement problems. Similar, but more comprehensive, validation routines will be run on the same data by the VAX, followed by appropriate corrective actions as discussed below.

The validation measures on the 15-minute data arrays will include range testing, consistency checks and relationship test, as described in Table 3.5.1. These measures are experimental and subject to revision as further monitoring experience is gained.

A permanent hard-copy record of data validation violations will be produced following the VAX validation runs. Each violation will then be reviewed manually by the QA staff, and a decision made as to data acceptance. The data violation review will include discussions with the site technician as well as data comparisons with adjacent 15-minute readings and with prevailing weather conditions in the region. Other corrective actions are discussed below.

If a value is determined to be questionable, bad, or otherwise compromised, it will be assigned an appropriate quality flag. If deemed acceptable as is, the data value will be flagged as "good". The flag assignment will be manually entered on the permanent hard-copy record of data validation violations, and these flags will also appear in the permanently archived data files. Table 3.5.2 lists the proposed data quality flags. These flags are subject to addition and modification. In addition to the automatic data validation checks, copies of each site's logbook will be reviewed periodically to ensure that periods when instruments were not operating under normal conditions (such as during calibration) were appropriately flagged in the final data base.

A variety of other corrective actions will be activated depending on the specific data validation violation and subsequent findings. The possible corrective actions include:

(a) Check with the site technician to make sure the instrument was in a standard operational mode;
(b) Perform a quality control check of the instrument;
(c) Inspect instrument function and cable, and connection quality;
(d) Check electrical service, climate control system, and data logger power transformer;
(e) Check data logger operation and its internal program;
(f) Repeat transfer of data onto microcomputer or over phone lines;
(g) Repair/replace unit and/or cables;
(h) Compare data value with prevailing regional weather conditions;
(i) Check accuracy of sunrise/sunset time calculations.

A troubleshooting guide is provided in Section VIII of the RPM Manual. All corrective actions taken will be documented in writing.

TABLE 3.5.1

DATA VALIDATION MEASURES

Range Tests

BATTERY VOLTAGE .LE. 11.8

JULIAN DAY .GT. 366 OR .LT. 1

TIME .GT. 2359 OR .LT. 0

STATION ID .NE. station id

AVE WIND SPEED .LT. 0 OR .GT. maximum allowable windspeed (value is site dependent)

AVE WIND DIRECT .LT. 0 OR .GT. 360

AVE INTERNAL TEMP .LT. 0 OR .GT. 37.7 ^{o}C

AVE AMBIENT TEMP .LT. ambient temp minimum OR .GT. ambient temp maximum (value is site and season dependent)

AVE REL HUMIDITY .LT. 10 OR .GT. 100%

AVE SOLAR RADIATION .LT. 0 OR .GT. solar radiation maximum (value is site and season dependent)

AVE PRESSURE .LT. barometric pressure minimum OR .GT. barometric pressure maximum (value is site dependent)

PRECIPITATION .LT. 0 OR .GT. 25.4mm

MAX WIND SPEED .GT. (1.15 * maximum allowable windspeed)

MIN WIND SPEED .LT. 0

TIME NOT A FIFTEEN MINUTE INTERVAL

Consistency Checks

AVE AMBIENT TEMP UNCHANGED +- 1C
OVER 12 OR MORE CONSECUTIVE HOURS

RELATIVE HUMIDITY UNCHANGED +- 10%
OVER 24 OR MORE CONSECUTIVE HOURS

AVE WIND SPEED UNCHANGED +-1ms-1
OVER 12 OR MORE CONSECUTIVE HOURS

AVE WIND DIRECT UNCHANGED +- 10 deg.
OVER 18 OR MORE CONSECUTIVE HOURS

AVE SOLAR RADIATION UNCHANGED +-50Wm-2
OVER 18 OR MORE CONSECUTIVE HOURS

PRESSURE UNCHANGED +-2mb
OVER 18 OR MORE CONSECUTIVE HOURS

Relationship Tests

AVE WIND SPEED .GT. 0
AND
STD DEV WIND SPEED .EQ.0

AVE WIND SPEED .EQ. 0
AND
STD DEV WIND SPEED .NE. 0

AVE WIND SPEED .EQ. 0
AND
STD DEV WID DIRECT .GT. 0.05

AVE WIND SPEED .GT. 0.25
AND
STD DEV WIND DIRECT .EQ. 0

AVE REL HUMIDITY .GT. 90%
AND
AVE AMBIENT TEMP .GE. 23°C

TIME .GT. after sunset time
OR .LT. before sunrise time
AND
AVE SOLAR RADIATION .GT. 4.0 Wm^{-2}

AVE AMBIENT TEMP .LT. 0°C
AND
PRECIPITATION .GT. 0mm

RELATIVE HUMIDITY .GE. 100%
AND
SOLAR RADIATION .GT. 440 Wm^{-2}

TABLE 3.5.2
DATA QUALITY FLAGS

Flag Code	Definition
0	Data good
1	Data missing
2	Data questionable
3	Data questionable, but within acceptable accuracy limits of sensor; most probable actual value is 100% (refers to relative humidity)
4	Data questionable, but within acceptable accuracy limits of sensor; most probable actual value is 0 Wm^{-2} (refers to solar radiation)
5	Data questionable; data logger battery voltage less than 12.0 V.
6	Data invalid (bad data)
7	Portions of Period not sampled

3.6 Internal Quality Control Checks

Routine quality control checks of the meteorological package will be performed according to procedures described in Sections I and II of the RPM Manual. These checks have the following schedule:

PARAMETER	QC CHECK	MAINTENANCE
Wind Speed	monthly	per visit
Wind Direction	monthly	per visit
Temperature	weekly	per visit
Relative Humidity	weekly	per visit
Precipitation	monthly	weekly, and after any precipitation
Solar Radiation	n/a	per visit
Barometric Pressure	n/a	per visit
Data Logger	n/a	per visit

The site maintenance checks are listed in the Site Visit Checklist found in Section I of the RPM Manual. Any problems found will be noted in the site's logbook.

The quality control check procedures and forms are contained in Section II of the RPM Manual.

If equipment does not pass the maintenance and QC checks, the corrective actions taken are:

(1) Repeat the Check.
(2) Note all results.
(3) If the check fails again, contact AWS personnel.

3.7 System Audits

System audits will be performed by a group completely independent of the monitoring program. Audits should be performed at the beginning of the monitoring program shortly before data acquisition has begun, and yearly thereafter. Auditors will have access to all site logs and will review instrument siting and installation, daily operation procedures, preventive maintenance activities and calibration methods. Documentation for calibrations and site QC checks will be maintained at the QA office. External audits will be performed on this documentation using the attached external audit form.

3.8 Preventive Maintenance

Preventive maintenance procedures are described in the RPM Manual (refer to Sections I, V, VI and IX.) Site visits will be conducted at least once per week by a trained site technician.

In addition, sites will be visited periodically by AWS personnel and the Project QA Officer to review routine maintenance records and performance, and to oversee/conduct calibrations.

Routine preventive maintenance during each site visit will include:

(1) visual inspection of grounds, tower, sensors, cabling and shelter;
(2) a check of recorder operation and wiring connections, including time checks and adjustments, if necessary;
(3) scheduled replacing or refurbishing of parts or sensors;

(4) a survey of current sensor output values and their reasonableness compared with existing weather conditions and redundant sensors, if available;
(5) a review of stored data for anomalous behavior;
(6) maintenance of a logbook containing a preventive maintenance checklist and room for comments related to servicing, repairs, and observations of particular interest.

Any problems will be reported to AWS.

To minimize downtime in the case of equipment failure requiring repair by the manufacturer, a complete operational backup system will be stored at AWS. Replacement parts from the backup will substitute for parts sent out for repairs.

There will be a formal training program for the technicians responsible for maintaining the meteorological package. An RPM Manual has been prepared and will be issued to each technician. The training program will include sensor assembly, operation and calibration, troubleshooting, data transfer, preventive maintenance and quality control procedures, and documentation. Completion of this program will certify the technician to operate and maintain the equipment, and certify other technicians at his/her site.

3.9 Specific Routine Procedures Used to Assess Data Accuracy and Precision

Accuracy and precision tests of the equipment will be conducted via pre-monitoring, post-monitoring, and mid-monitoring calibrations as described in the Calibration Procedures and Frequency section above. A calibration form will be completed giving the results of the accuracy and precision tests.

3.10 Corrective Action

Unless otherwise stated in this document or the RPM Manual, corrective action will be determined on a case by case basis by AWS.

3.11 QA Reports to Management

QA reports will be submitted quarterly to project management. These reports will include a review of data recovery, calibration results, and audit results as well as notification of of significant QA problems and recommended solutions.