ARM TR-035

Surface and Tower Meteorological Instrumentation at Barrow

Handbook

April 2008

Atmospheric Radiation Measurement
Climate Research Facility
U.S. Department of Energy

Work supported by the U.S. Department of Energy
Office of Science, Office of Biological and Environmental Research

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Surface and Tower Meteorological Instrumentation at Barrow (METTWR4H) Handbook

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1. General Overview

The Barrow meteorology station (BMET) uses mainly conventional *in situ* sensors mounted at four different heights (2m, 10m, 20m and 40m) on a 40 m tower to obtain profiles of wind speed, wind direction, air temperature, dew point and humidity. It also obtains barometric pressure, visibility and precipitation data from sensors at the base of the tower. Additionally, a Chilled Mirror Hygrometer and an Ultrasonic wind speed sensor are located near the 2m level for comparison purposes.

2. Contacts

2.1 Mentor

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2.2 Instrument Developer

Wind Speed and Direction, Temperature and Relative Humidity, Barometric Pressure, Present Weather Sensor
Vaisala
100 Commerce Way
Woburn, MA 01801-1068
Phone: 617-933-4500
Fax: 617-933-8029
Web page: http://www.vaisala.com

Aspirated Radiation Shields
R.M. Young Company
2801 Aero-Park Drive
Traverse City, MI 49686
Phone: 231-946-3980
Fax: 231-946-4772
Web page: http://www.youngusa.com

Chilled-Mirror Hygrometer
Technical Services Laboratory, Inc.
95 Ready Ave.
Fort Walton Beach, FL 32548
Phone: 850-243-3722

Precipitation
Scientific Technology, Inc.
205 Perry Parkway, Suite 14
Gaithsburg, MD 20877-2141
Phone: 301-948-6070
Fax: 301-948-4674

Computer
Dell Optiplex GX270 SFF
Web page: http://www.dell.com

Datalogger and Ethernet Devices
Campbell Scientific Inc.
815 W. 1800 N.
Logan, UT 84321
Phone: 801-753-2342
Fax: 801-750-9540
Web page: http://www.campbellsci.com

Fiber Driver
Allied Telesys
19800 North Creek Parkway, Suite 200
Bothell, WA 98011
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Fax: 425-489-9191
Toll-free: 1-800-424-6596 (US only)
Web page: http://alliedtelesyn.com

3. Deployment Locations and History

The original configuration and collection system was installed in March 1998. In October 2003 the configuration and collection system was changed considerably. Information on the data, sensors and measurement methods prior to October 2003 can be found at Barrow Meteorology Station (BMET).

Table 1. Location and History

Location	Date Installed	Date Removed	Status
NSA/C1	10/2003		Operational

4. Near-Real-Time Data Plots

Near-real-time data plots can be found at the following locations:

- http://www.nsdl.arm.gov/Visualization/quicklook_interface.shtml
- http://www.nsdl.arm.gov/Visualization/ncvweb.shtml.

5. Data Description and Examples

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

Table 2. Primary Variables

Quantity	Variable	Unit	Measurement Level	Measurement Interval	Resolution
2m Arithmetic Mean Wind Speed	WS2m_S_WVT	m/s	2m	1 min	0.001
2m Vector Averaged Wind Speed	WS2m_U_WVT	m/s	2m	1 min	0.001
2m Vector Averaged Wind Direction	WD2m_DU_WVT	deg	2m	1 min	0.001
Standard Deviation of 2m Vector Averaged Wind Direction	WD2m_SDU_WVT	deg	2m	1 min	0.01
10m Arithmetic Mean Wind Speed	WS10m_S_WVT	m/s	10m	1 min	0.001
10m Vector Averaged Wind Speed	WS10m_U_WVT	m/s	10m	1 min	0.001
10m Vector Averaged Wind Direction	WD10m_DU_WVT	deg	10m	1 min	0.001
Standard Deviation of 10m Vector Averaged Wind Direction	WD10m_SDU_WVT	deg	10m	1 min	0.01
20m Arithmetic Mean Wind Speed	WS20m_S_WVT	m/s	20m	1 min	0.001
20m Vector Averaged Wind Speed	WS20m_U_WVT	m/s	20m	1 min	0.001
20m Vector Averaged Wind Direction	WD20m_DU_WVT	deg	20m	1 min	0.001
Standard Deviation of 20m Vector Averaged Wind Direction	WD20m_SDU_WVT	deg	20m	1 min	0.01
40m Arithmetic Mean Wind Speed	WS40m_S_WVT	m/s	40m	1 min	0.001
40m Vector Averaged Wind Speed	WS40m_U_WVT	m/s	40m	1 min	0.001
40m Vector Averaged Wind Direction	WD40m_DU_WVT	deg	40m	1 min	0.001
Standard Deviation of 40m Vector Averaged Wind Direction	WD40m_SDU_WVT	deg	40m	1 min	0.01
Sonic Arithmetic Mean Wind Speed	SonicWs_S_WVT	m/s	2m	1 min	0.001

Table 2. (cont'd)

Quantity	Variable	Unit	Measurement Level	Measurement Interval	Resolution
Sonic Vector Averaged Wind Speed	SonicWs_U_WVT	m/s	2m	1 min	0.001
sonic Vector Averaged Wind Direction	SonicWD_DU_WVT	deg	2m	1 min	0.001
Standard Deviation of Sonic Vector Averaged Wind Direction	SonicWD_SDU_WVT	deg	2m	1 min	0.01
2m Average Temperature	T2m_AVG	C	2m	1 min	0.001
2m Average Relative Humidity	RH2m_AVG	%	2m	1 min	0.01
2m Average Calculated Dew Point	DP2m_AVG	C	2m	1 min	0.001
2m Average Calculated Vapor Pressure	VP2m_AVG	kPa	2m	1 min	0.001
10m Average Temperature	T10m_AVG	C	10m	1 min	0.001
10m Average Relative Humidity	RH10m_AVG	%	10m	1 min	0.01
10m Average Calculated Dew Point	DP10m_AVG	C	10m	1 min	0.001
10m Average Calculated Vapor Pressure	VP10m_AVG	kPa	10m	1 min	0.001
20m Average Temperature	T20m_AVG	C	20m	1 min	0.001
20m Average Relative Humidity	RH20m_AVG	%	20m	1 min	0.01
20m Average Calculated Dew Point	DP20m_AVG	C	20m	1 min	0.001
20m Average Calculated Vapor Pressure	VP20m_AVG	kPa	20m	1 min	0.001
40m Average Temperature	T40m_AVG	C	40m	1 min	0.001
40m Average Relative Humidity	RH40m_AVG	%	40m	1 min	0.01
40m Average Calculated Dew Point	DP40m_AVG	C	40m	1 min	0.001
40m Average Calculated Vapor Pressure	VP40m_AVG	kPa	40m	1 min	0.001
Atmospheric Pressure	AtmPress	hPa	1m	1 min	0.1
1 minute Average Visibility	AvgVis1mi	m	2m	1 min	1
10 minute Average Visibility	AvgVis10m	m	2m	1 min	1
Instant Present Weather Code	InstPWCod	N/A	2m	1 min	N/A

Table 2. (cont'd)

Quantity	Variable	Unit	Measurement Level	Measurement Interval	Resolution
15 minute Present Weather Code	PWcod15mi	N/A	2m	1 min	N/A
1 hour Present Weather Code	PWCod1hr	N/A	2m	1 min	N/A
Precipitation Rate	PCPRate	mm/hr	2m	1 min	0.01
Cumulative Water Sum	CumH2O	mm	2m	1 min	0.01
Cumulative Snow Sum	CumSnow	mm	2m	1 min	0.01
Chilled Mirror Temperature	CMHTemp	C	1m	1 min	0.01
Chilled Mirror Dew Point	CMHDP	C	1m	1 min	0.01
Chilled Mirror Calculated Saturation Vapor Pressure	SatVPCMH	kPa	1m	1 min	0.01
Chilled Mirror Calculated Vapor Pressure	VPCMH	kPa	1m	1 min	0.01
Chilled Mirror Calculated Relative Humidity	CMHRH	%	1m	1 min	0.1

5.1.1.1 Definition of Uncertainty

We define uncertainty as the range of probable maximum deviation of a measured value from the true value within a 95% confidence interval. Given a bias (mean) error *B* and uncorrelated random errors characterized by a variance σ^2, the root-mean-square error (RMSE) is defined as the vector sum of these,

$$RMSE = \left(B^2 + \sigma^2\right)^{1/2}$$

(*B* may be generalized to be the sum of the various contributors to the bias and σ^2 the sum of the variances of the contributors to the random errors). To determine the 95% confidence interval we use the Student's *t* distribution: $t_{n;0.025} \approx 2$, assuming the RMSE was computed for a reasonably large ensemble. Then the *uncertainty* is calculated as twice the RMSE.

5.1.2 Secondary/Underlying Variables

This section is not applicable to this instrument.

5.1.3 Diagnostic Variables

Table 3. Diagnostic Variables

Quantity	Variable	Measurement Interval
2m Average QLI Input Voltage	Volt2m_Avg	1 min
2m Average QLI Reference Temperature	RefT2m_AVG	1 min
10m Average QLI Input Voltage	Volt10m_Avg	1 min
10m Average QLI Reference Temperature	RefT10m_AVG	1 min
20m Average QLI Input Voltage	Volt20m_Avg	1 min
20m Average QLI Reference Temperature	RefT20m_AVG	1 min
40m Average QLI Input Voltage	Volt40m_Avg	1 min
40m Average QLI Reference Temperature	RefT40m_AVG	1 min
Present Weather Sensor Alarm	PWSAlarm	1 min
Standard Deviation of 2m Temperature	T2m_STD	1 min
Standard Deviation of 2m Relative Humidity	RH2m_STD	1 min
Standard Deviation of 2m Calculated Dew Point	DP2m_STD	1 min
Standard Deviation of 2m Calculated Vapor Pressure	VP2m_STD	1 min
Standard Deviation of 10m Temperature	T10m_STD	1 min
Standard Deviation of 10m Relative Humidity	RH10m_STD	1 min
Standard Deviation of 10m Calculated Dew Point	DP10m_STD	1 min
Standard Deviation of 10m Calculated Vapor Pressure	VP10m_STD	1 min
Standard Deviation of 20m Temperature	T20m_STD	1 min
Standard Deviation of 20m Relative Humidity	RH20m_STD	1 min
Standard Deviation of 20m Calculated Dew Point	DP20m_STD	1 min
Standard Deviation of 20m Calculated Vapor Pressure	VP20m_STD	1 min
Standard Deviation of 40m Temperature	T40m_STD	1 min
Standard Deviation of 40m Relative Humidity	RH40m_STD	1 min
Standard Deviation of 40m Calculated Dew Point	DP40m_STD	1 min
Standard Deviation of 40m Calculated Vapor Pressure	VP40m_STD	1 min
Average X Component of Sonic Wind Speed	SonicX_Avg	1 min
Average Y Component of Sonic Wind Speed	SonicY_AVG	1 min
Average Sonic Static Speed of Sound	SonicS_AVG	1 min
Datalogger Battery Voltage	Batt_Volt	1 min

5.1.4 Data Quality Flags

Table 4. Quality Check Variables

Quantity	Variable	Measurement Interval	Min	Max	Delta
Sample time	qc_time	1 min			N/A
2m Arithmetic Mean Wind Speed	qc_WS2m_S_WVT	1 min	0	100	20
2m Vector Averaged Wind Speed	qc_WS2m_U_WVT	1 min	0	100	20
2m Vector Averaged Wind Direction	qc_WD2m_SDU_WVT	1 min	0	360	N/A
10m Arithmetic Mean Wind Speed	qc_WS10m_S_WVT	1 min	0	100	20
10m Vector Averaged Wind Speed	qc_WS10m_U_WVT	1 min	0	100	20
10m Vector Averaged Wind Direction	qc_WD10m_SDU_WVT	1 min	0	360	N/A
20m Arithmetic Mean Wind Speed	qc_WS20m_S_WVT	1 min	0	100	20
20m Vector Averaged Wind Speed	qc_WS20m_U_WVT	1 min	0	100	20
20m Vector Averaged Wind Direction	qc_WD20m_SDU_WVT	1 min	0	360	N/A
40m Arithmetic Mean Wind Speed	qc_WS40m_S_WVT	1 min	0	100	20
40m Vector Averaged Wind Speed	qc_WS40m_U_WVT	1 min	0	100	20
40m Vector Averaged Wind Direction	qc_WD40m_SDU_WVT	1 min	0	360	N/A
Sonic Arithmetic Mean Wind Speed	qc_SonicWS_S_WVT	1 min	0	100	20
Sonic Vector Averaged Wind Speed	qc_SonicWS_U_WVT	1 min	0	100	20
Sonic Vector Averaged Wind Direction	qc_Sonic_SDU_WVT	1 min	0	360	N/A
2m Average Temperature	qc_T2m_AVG	1 min	-60	30	10
2m Average Relative Humidity	qc_RH2m_AVG	1 min	-2	104	30
2m Average Calculated Dew Point	qc_DP2m_AVG	1 min	-60	30	10
2m Average Calculated Vapor Pressure	qc_VP2m_AVG	1 min	0.001	4.3	1
10m Average Temperature	qc_T10m_AVG	1 min	-60	30	10
10m Average Relative Humidity	qc_RH10m_AVG	1 min	-2	104	30
10m Average Calculated Dew Point	qc_DP10m_AVG	1 min	-60	30	10

Table 4. (cont'd)

Quantity	Variable	Measurement Interval	Min	Max	Delta
10m Average Calculated Vapor Pressure	qc_VP10m_AVG	1 min	0.001	4.3	1
20m Average Temperature	qc_T20m_AVG	1 min	-60	30	10
20m Average Relative Humidity	qc_RH20m_AVG	1 min	-2	104	30
20m Average Calculated Dew Point	qc_DP20m_AVG	1 min	-60	30	10
20m Average Calculated Vapor Pressure	qc_VP20m_AVG	1 min	0.001	4.3	1
40m Average Temperature	qc_T40m_AVG	1 min	-60	30	10
40m Average Relative Humidity	qc_RH40m_AVG	1 min	-2	104	30
40m Average Calculated Dew Point	qc_DP40m_AVG	1 min	-60	30	10
40m Average Calculated Vapor Pressure	qc_VP40m_AVG	1 min	0.001	4.3	1
Atmospheric Pressure	qc_AtmPress	1 min	800	1100	10
1 minute Average Visibility	qc_AvgVis1mi	1 min	0	50000	N/A
10 minute Average Visibility	qc_AvgVis10m	1 min	0	50000	N/A
Instant Present Weather Code	qc_InstPWCod	1 min	0	99	N/A
15 minute Present Weather Code	qc_PWcod15mi	1 min	0	99	N/A
1 hour Present Weather Code	qc_PWCod1hr	1 min	0	99	N/A
Precipitation Rate	qc_PCPRate	1 min	0	999	100
Cumulative Water Sum	qc_CumH2O	1 min	0	99	10
Cumulative Snow Sum	qc_CumSnow	1 min	0	999	100
Chilled Mirror Temperature	qc_CMHTemp	1 min	-60	30	10
Chilled Mirror Dew Point	qc_CMHDP	1 min	-60	30	10
Chilled Mirror Calculated Saturation Vapor Pressure	qc_SatVPCMH	1 min	0.001	4.3	1
Chilled Mirror Calculated Vapor Pressure	qc_VPCMH	1 min	0.001	4.3	1
Chilled Mirror Calculated Relative Humidity	qc_CMHRH	1 min	0	101	30

5.1.5 Dimension Variables

Table 5. Dimension Variables

Variable	Measurement Interval	Unit
base_time	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
time_offset	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
time	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
lat	1 min	degrees
lon	1 min	degrees
alt	1 min	meters above sea level

5.2 Annotated Examples

This section is not applicable to this instrument.

5.3 User Notes and Known Problems

The 40-meter tower that the sensors are mounted on is misaligned to true north by 30 degrees. In most instances this error is corrected by programming. Unfortunately from 10/31/2003 through 10/20/2005 this correction was not applied. The wind data during this time is 30 degrees east of what it should be. In other words, until reprocessing corrects this error, users should subtract 30 degrees from the wind direction data.

Once a day the Chilled Mirror Hygrometer goes through a daily self-test. This is done to remove contaminants from the mirror. It also allows the CMH to assess the level of contamination remaining on the mirror. When the self-test occurs the mirror is heated to above ambient causing the dew point, RH, vapor pressure and saturation vapor pressure data during the time of self-test and recovery to be incorrect. See Figure 1 below.

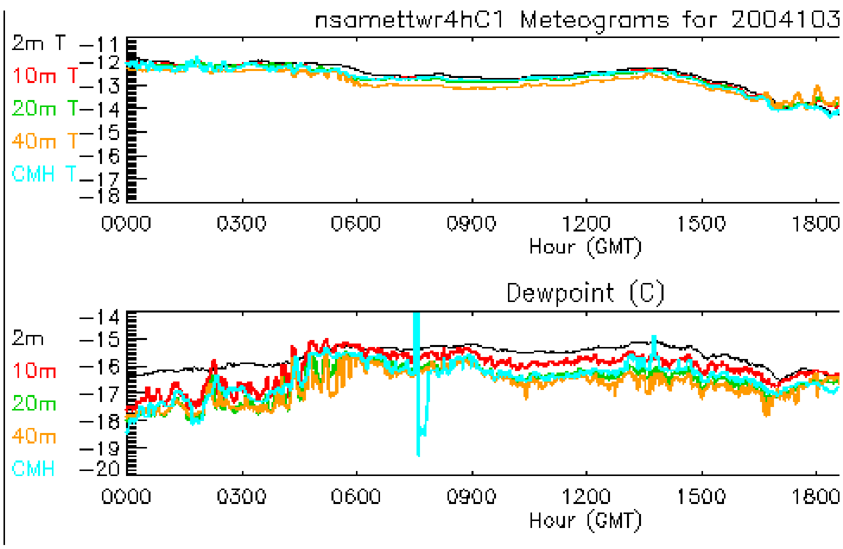

Figure 1. CMH Daily Self Test

When the CMH does through the daily self-test and autobalance of the mirror it has to heat the mirror to remove contaminants and make a measurement of the cleanliness of the mirror. After the reading is finished it must cool the mirror back to ambient dew point temperatures. When the dew point depression is large enough this dynamic adjustment does not take much time. When the dew point depression is small and the temperatures are below freezing this dynamic adjustment can take up to a few hours. When the dew point depression is small the system has a tendency to overdrive the mirror colder than the ambient dew point and followed be warmer than the ambient as it tries to return the mirror to the dew point temperature. See Figure 2 for and example plot of this situation. The best way to describe what is happening is to imagine a plot of a sinusoidal curve (the mirror dew point) moving above and below the actual dew point curve as the CMH control circuits try to equilibrate the mirror with the environment. As time progresses the siunusiodal curve moves asymptotically toward the actual ambient dew point values. If the ambient dew point is changing rapidly at the time of autobalance adjustment the time to equilibrate is even longer.

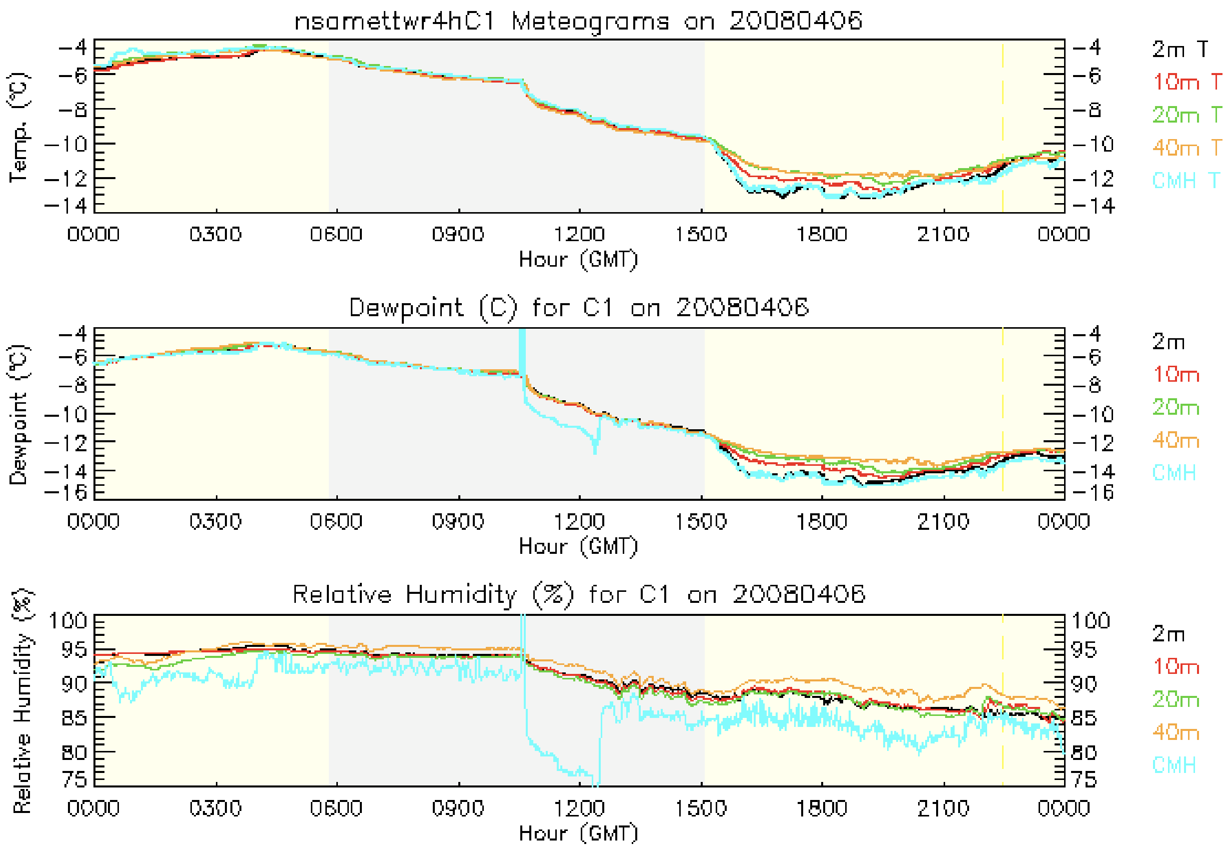

Figure 2. CMH Autobalance Recovery Issue

At times the data from the wind speed and direction sensors is missed when it is sent from the QLI50 Data Collector to the Serial Data Multiplexer. When this occurs a spike is noticed in the data as the program tries to convert –6999 or –9999 data into vector averages. See Figure 3 below.

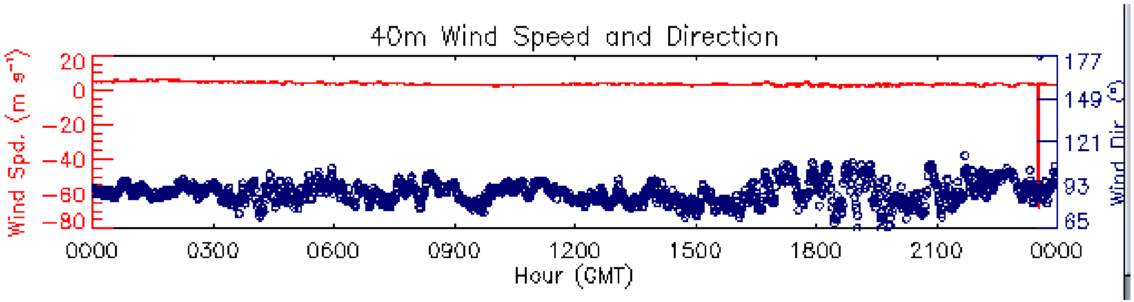

Figure 3. Wind Speed spike at the 40m level

At times the data from the Ultrasonic wind speed and direction sensor is poor due to heavy, wet snow. When this occurs the Ultrasonic sensor outputs –6999 or –9999. The datalogger attempts to convert the poor or missing data values to vector averages. As the missing or poor data may only be a few seconds in a minute the values are averaged into the minute values and show up as spikes in the data. See Figure 4 below.

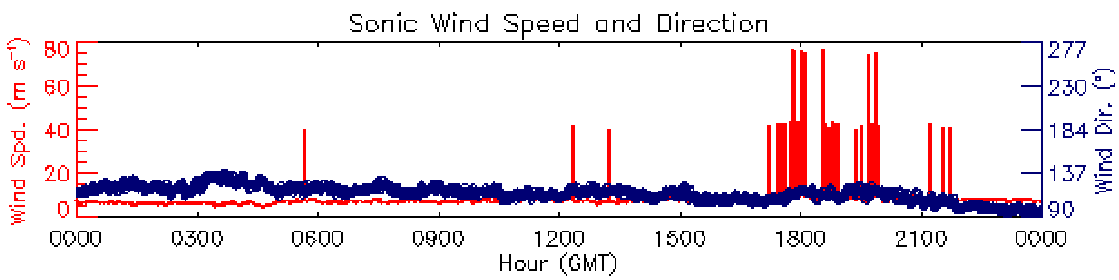

Figure 4. Ultrasonic Data Spikes

5.4 Frequently Asked Questions

This section is not applicable to this instrument.

6. Data Quality

6.1 Data Quality Health and Status

- Data Quality Health and Status (DQ HandS) http://dq.arm.gov
- NCVweb - for interactive data plotting using http://dq.arm.gov/ncvweb/ncvweb.cgi

6.2 Data Reviews by Instrument Mentor

This section is not applicable to this instrument.

6.3 Data Assessments by Site Scientist/Data Quality Office

The ARM Data Quality Office uses the Data Quality Assessment (DQA) system to inform the ARM Site Operators, Site Scientists, and Instrument Team members of instrument and data flow problems as well as general data quality observations. The routine assessment reports are performed on the most recently-collected ARM data, and used with the Data Quality Problem reports tool to initiate and track the problem resolution process.

http://dq.arm.gov/weekly_reports/weekly_reports.html

6.4 Value-Added Procedures and Quality Measurement Experiments

Many of the scientific needs of the ARM Program are met through the analysis and processing of existing data products into "value-added" products or VAPs. Despite extensive instrumentation deployed at the ARM CART sites, there will always be quantities of interest that are either impractical or impossible to measure directly or routinely. Physical models using ARM instrument data as inputs are implemented as VAPs and can help fill some of the unmet measurement needs of the program. Conversely, ARM produces some VAPs not in order to fill unmet measurement needs, but instead to improve the quality of existing measurements. In addition, when more than one measurement is available, ARM also produces "best estimate" VAPs. A special class of VAP called a Quality Measurement Experiment (QME) does not output geophysical parameters of scientific interest. Rather, a QME adds value to the input datastreams by providing for continuous assessment of the quality of the input data based on internal consistency checks, comparisons between independent similar measurements, or comparisons between measurement with modeled results, and so forth. For more information, see the VAPs and QMEs web page.

7. Instrument Details

7.1 Detailed Description

7.1.1 List of Components

Wind Speed Sensor: A Vaisala WAA251 cup anemometer is used to measure the horizontal wind speed.

Wind Direction Sensor: A Vaisala WAV151 wind vane with heated shaft is used to measure wind direction.

Wind Speed and Direction Sensor: A Vaisala WS425 ultrasonic wind sensor is used to measure the horizontal wind speed and direction at the 2m level at Barrow.

Temperature and Relative Humidity Sensor: A Vaisala HMP45D temperature and relative humidity probe is used to measure air temperature and relative humidity.

Ambient Temperature and Dew Point Temperature: A Technical Services Laboratory Model 1088 hygrothermometer (CMH) is used to measure air temperature and dew point.

Visibility and Precipitation Sensor: A Vaisala FD12P present weather sensor (PWS) is used to measure present weather, visibility and precipitation.

Barometric Pressure Sensor: A Vaisala PTB201A digital barometer is used to measure the station pressure (not corrected to sea level).

7.1.2 System Configuration and Measurement Methods

QLI50 Sensor Collectors

Vaisala QLI50 sensor collectors are used to collect data from the wind speed, wind direction, temperature and relative humidity probes. The QLI50s determine the frequency of the WAA-252 anemometer signals by measuring and averaging the time between pulses. The GRAY code output from the WAV-151 wind vanes is read and converted to angles. The QLI-50s supply a constant current to the HMP45D platinum resistance detectors and relative humidity circuitry, measure the returned voltages, and convert the voltages to temperatures and relative humidity values. The QLI50s also use the temperature and relative humidity data to calculate dew point temperatures. The QLI50s also convert the temperature and relative humidity data to dew point values using the following equation:

$$TDEW = ((c*b)/((c*(a/2)) + b)) - 273.16$$

where a = ln(100/X2), b = (1.0*a) – (2.1*X1) + 2711.5, c = X1 + 273.16

X1 = measured air temperature (deg C)

X2 = measured relative humidity (%)

The QLI50s convert the analog data from the sensors to a digital format. The QLI50s send the data automatically once per second to a Campbell Scientific SDM-SI04 serial data multiplexer. The data is sent via RS-232 to the SDM. The QLI-50s are set for Automatic messaging (AMES 2) at 1-second intervals (REP A 1). A Vaisala WHP25 supplies power to the QLI50s.

Power Supplies

Vaisala WHP25 power supplies are used to power the QLI50 sensor collectors; the HMP45D temperature relative humidity probes and the heating system for the wind speed and wind direction sensors. The output voltage of the WHP25’s is 24VAC. AC to DC converters are used to power the aspirators, which contain the temperature and relative humidity probes.

Serial Data Multiplexer

Campbell Scientific serial data multiplexers (SDM-SI04) are used to collect data from the serial devices and serial sensors. The barometer, present weather sensor (PWS), chilled mirror hygrometer (CMH), and the QLI50 sensor collector send data to the SDM. The SDM converts the serial data it collects to a form the CR23X datalogger can understand using complex filters supplied by the user. The SDM stores complex commands required to request data from the smart serial devices such as the PWS, CMH and barometer. These commands are also user supplied. Each SDM has four serial ports that are independently configured to communicate with different sensors. At Barrow, two SDM’s are used; one to communicate with the four QLI50s at each of the four levels (2m, 10m, 20m, 40m), the other is used to communicate with the PWS, CMH, and barometer.

CR23X Datalogger

A Campbell Scientific CR23X datalogger is used to acquire and process the data collected by the SDM from the various sensors. Once per minute the datalogger prompts the SDM to request data from the PWS, CMH and barometer. The datalogger also waits for the one-second data from the SDM connected to the QLI’s at once-per-second intervals. At Barrow, the datalogger also collects data from the ultrasonic wind sensor at one-second intervals using Campbell Scientifics’ SDI-12 communication protocol. The one-second data from the QLI50s and the ultrasonic are accumulated in the logger in order to calculate the one-minute data values and statistics. The one-minute data from the barometer and the PWS is stored while the CMH data is converted from Fahrenheit to Celsius and relative humidity is calculated from the Celsius temperature and dew point. The following equations are used to convert the temperature and dew point data from the CMH to RH values using calculated vapor pressure and saturation vapor pressure:

If temperatures are less than 0 deg C:

Saturation VP = (6.1359*(EXP((22.452*CMHTemp)/ (272.55 + CMHTemp))))*0.1

VP = (6.1359*(EXP((22.542*CMHDP)/(272.55 + CMHDP))))*0.1

If temperatures are greater than or equal to 0 deg C:

Saturation VP = (6.1365*(EXP((17.502*CMHTemp)/(240.97 + CMHTemp))))*0.1

VP = (6.1365*(EXP((17.502*CMHDP)/(240.97 + CMHDP))))*0.1

RH = 100*(VP/SatVP)

where CMHTemp = (5/9)*(measured CMH Temp in F – 32.0)

CMHDP = (5/9)*(measured CMH DP in F – 32)

Once-per-minute data is sent from the CR23X to the PC upon request. The data is sent via Ethernet through a Campbell Scientific NL-100 network interface, then to an Allied Telesyn media converter through which the data is sent to a partner media converter via fiber optic cable. Once the data reach the end of the fiber, the media converter sends the data through Ethernet cable to a network switch and then onto the PC. The CR23X datalogger includes a 4 Mbyte extended memory option allowing the storage of over 2 million data points in the event of a communication outage. The datalogger has an extended temperature option giving it a valid operating temperature range of –40 to +60 C. The CR23X has been modified so that the Input/Output connectors are removable, allowing for quick connect/disconnect for easy datalogger replacement.

NL-100 Network Link Interface

A Campbell Scientific NL-100 network interface is used to communicate with the Campbell Scientific CR23X datalogger. The NL100 uses an Ethernet 10 Base-T communications link between itself and the Allied Telesyn media converter. The NL100 is configured to act as a Serial Server in the TCP/IP network. The unique IP address for the system is stored within the NL100.

AT-MC13 Ethernet Media Converters

The AT-MC13 media converters are used to convert the data from the CR23X (through the NL100) to fiber optics. Converting to fiber optics and using the media converters allows for a 2Km maximum operating distance of the network. Two media converters are used; one is located at the base of the towers in the datalogger enclosure, the other is located inside the building at each location. The media converters operate at 10 Mbps and feature half- and full-duplex operation. The media converters also have a MIDI/MDI-X switch. This switch is used to configure the twisted pair port on the media converter as either MIDI or MIDI-X eliminating the need for crossover cables regardless of the type of network device that is connected to the unit. The media converters also have a Fiber Link Test switch that allows testing of the fiber optic connection without requiring the twisted pair port to be connected.

Computer

The PC used at both Barrow and Atqasuk is a Dell Optiplex GX270 Small Form Factor with a 15" flat panel monitor. The PC contains a Celeron 2.00 GHz, 400 Front Side Bus, and 128K Cache processor. It has 512mb of DDR non-ECC SD-RAM and an Integrated DVMT Video card. The hard drive is an 80 GB EIDE 7200 RPM drive. It also has internal Dell business audio speakers, an integrated Intel Gigabit (10/100/1000) network interface card and an 8x DVD-ROM. The operating system installed on the PC is Microsoft Windows XP Professional using NTFS. The PC was configured to conform to the ARM core PC requirements. The PC is configured to automatically restart and logon after power disruption eliminating the need for human intervention. Campbell Scientifics' LoggerNet software is loaded on the PC and is configured to initialize at start up. LoggerNet is the software application that enables communication and control of the CR23X datalogger. Radmin software is also loaded on the PC allowing remote connection to or control of the local PC. A share-ware program called InternetTime is used to verify and adjust the time of the PC clock once a day. A PERL script called "split_working_cdl.pl" is used to handle the output data file from the LoggerNet software. This script has been installed on both systems in C:\ARM\bin and is scheduled to run once an hour in the LoggerNet task manager. This script creates uniquely named hourly files and places the files in a folder from which the Data Collection System can access, collect and delete them. FTP software allows the Data Collection System to access the PC.

LoggerNet

LoggerNet software is an application that allows the set up, configuration, and retrieval of data from a network of Campbell Scientific dataloggers. LoggerNet also allows sharing of data over an Ethernet communications network. LoggerNet is written using advanced "client-server" architecture. The server is a software program that runs in the background, handling all of the datalogger communications. The server also takes care of storing the data and providing information to manage the datalogger network. Client software programs in LoggerNet are used to create datalogger programs, view and graph data, verify communications on the network, and run other software or tasks.

7.1.3 Specifications

Wind Speed Sensor

The anemometers have heated cups and shafts to prevent ice build up. The anemometers employ a photo-chopper to produce a 10 Hz per m/s signal. Vaisala quotes a starting threshold of <0.5 m/s, a distance constant of 2.7 m, and a linear output with an accuracy of +/- 0.17 m/s from 0.4 to 75 m/s.

Wind Direction Sensor

The vanes use an optically detected GRAY code disk with a 5.6o resolution. Vaisala quotes a starting threshold of 0.4 m/s, a damping ratio of 0.14, and overshoot ratio of 0.65 and a delay distance of 0.4 m.

Wind Speed and Direction Sensor

The WS425 uses ultrasound to determine the horizontal wind speed and direction. It measures the transit time it takes for the pulse to travel from one transducer head to another. For wind speed, Vaisala quotes a starting threshold and delay distance of virtually zero, measurement range of 1 to 65 m/s, resolution of 0.1 m/s, and an accuracy of +/- 0.135 or 3% of reading (whichever is greater) over the measuring range. For wind direction, Vaisala quotes the same starting threshold and delay distance as above, a resolution of 1o, and an accuracy of +/- 2o. The maximum reading rate for this sensor is once per second.

Temperature and Relative Humidity Sensor

The probes are mounted on each level (2m, 10m, 20m, and 40m). Each probe contains a Vaisala HUMICAP sensor and associated electronics along with a 4-wire, platinum resistance temperature detector. The relative humidity output is an analog signal, with 0 to 1V corresponding to an RH of 0 to 100%. Vaisala quotes the accuracy of the RH signal to be +/- 2% for 0 to 90 % and +/- 3% for 90 to 100%. The RH sensor has a response time of 15 seconds. The long-term stability is quoted to be better than 1% RH per year and a temperature dependence of +/- 0.05% RH/oC. The measurement range of the RTD is quoted as –40 to +60 oC. Each temperature and relative humidity probe is mounted in a R.M. Young Model 43408-2 aspirated radiation shield. A brushless DC blower provides aspiration.

Ambient Temperature and Dew Point Temperature

The sensor is mounted near the lowest level temperature and relative humidity probe near the base of the tower. The Model 1088 measures temperature and dew point over the range of –80 to +130o F. The accuracy of the temperature measurement is +/- 1o RMS in the range of –60 to +122o F and +/- 2o F RMS through the remainder of the range. The accuracy of the dew point temperature is +/- 2o F RMS from 30 to 86o F, +/- 3o F RMS from –10 to 30o F, +/- 4o F from –30 to -10o F. No accuracy data for the dew point measurement is available for the rest of the range. The model 1088 consists of two component units, the aspirator and the transmitter. The aspirator contains the dew point assembly and temperature sensor. All of the associated electronics are contained in the transmitter. Data is sent via RS-232 to the collection system when the sensor is polled.

Visibility and Precipitation Sensor

A Vaisala FD12P present weather sensor (PWS) is a microprocessor- controlled intelligent device that uses a forward scatter visibility meter, a capacitive rain detector, and a platinum resistance temperature detector to measure visibility and precipitation. The LED light source has a peak-radiated power of 40 mW. The visibility measurement is accurate to +/-10% for ranges between 10 and 10,000 m and +/- 20% for ranges between 10,000 and 50,000 m. The accuracy of the precipitation intensity measurement is +/- 30% for the range of 0.5 to 20 mm/hr. The LED transmitted light intensity is monitored and used to compensate for temperature and aging effects. Data is sent via RS-232 to the collection system when the sensor is polled.

Barometric Pressure Sensor

The barometer uses a Vaisala BAROCAP silicon capacitive absolute pressure sensor. Vaisala quotes the operating temperature as –40 to +60o C and the pressure measurement range as 500 to 1100 hPa. The total accuracy over the measurement range is given to be +/- 0.15 hPa. Data is sent via RS-232 to the collection system when the sensor is polled.

7.2 Theory of Operation

Surface meteorological data is collected at the ARM Climate Research Facility (ACRF) North Slope of Alaska (NSA) site at two locations, Barrow, Alaska and Atqasuk, Alaska. At the site in Barrow, data is collected at the base of a 40-meter tower and at 4 levels on the tower; 2-meter, 10-meter, 20-meter and 40-meter. Temperature, relative humidity, wind speed and wind direction are collected at each level.

The data is collected at the base of the tower using Campbell Scientific CR23X dataloggers. The dataloggers are polled once a minute by Campbell Scientific LoggerNet software. The LoggerNet software runs on a Dell Optiplex GX270 small form-factor computer using Microsoft XP Professional as the operating system. The computer system is configured such that if power is interrupted it will automatically restart eliminating the need for human intervention. The LoggerNet software has been added to the start menu so that it will automatically begin to collect data from the dataloggers as soon as the system has re-booted.

The data from the dataloggers is stored in a single location and the data is appended to an ever-increasing file. A PERL script has been written to search the data file once an hour to capture a single hours worth of data (00 – 59) and copy the data to another file location with a unique time and date name. The file is then deleted preventing a large, single file that continues to grow. The hourly files created by the PERL script are collected once an hour using FTP and the collected file is then deleted from the local PC.

Remote Administrator (RAdmin) software has been loaded to both computers so that remote access is available for loading new programs, troubleshooting, etc. Access is limited to the site observers, mentors, and selected operations personnel.

Temperature, relative humidity, wind speed and direction are collected once per second from the different levels of each tower. The one-second analog data is collected by a Vaisala QLI data collector and is sent via serial cables to the CR23X datalogger once per second where it is accumulated to create one-minute averages and other calculated variables. Data is collected from the other sensors near the base of each tower once each minute. The Present Weather Sensor (PWS), Chilled Mirror Hygrometer (CMH) and barometric data are collected once per minute at each location. At Barrow an ultrasonic wind speed sensor has also been mounted at the 2-meter level and data from it is collected once per minute. Data from each of the sensors at the base of the tower transmit their data via serial cable except for the ultrasonic wind sensor. The ultrasonic wind sensor transmits its data via Serial Data Interface (SDI-12), a communication protocol created by Campbell Scientific.

The serial data from all sensors is sent to, or requested by, a Campbell Scientific serial data multiplexer (SDM-SIO4). Each SDM-SIO4 has four ports and a unique address so that multiple SDMs can be connected to each logger. The Barrow system has two SDMs. Each SDM contains programming for the communication protocols (baud rate, data bits, etc) and filters so data can be converted to a form the CR23X can accept.

The data collected by the logger is requested by the LoggerNet system once per minute. The data is sent by the CR23X datalogger to the computer via a network connection. A Campbell Scientific NL-100 network interface is used to send the data via an RS-232 serial connection from the logger to the computer. The NL-100 allows each datalogger to have a unique network address. The data is passed from the NL-100 to an Allied Telesyn AT-MC13 media converter via a Cat-5 Ethernet cable. The media converter sends the data via a fiber optic cable to another media converter inside the building where it is sent through a network switch and onto the computer. See Figure 1: Network Diagram.

The data that is collected from the datalogger can be viewed locally at each sites computer. A program contained in the LoggerNet software package called Real Time Monitor and Control (RTMC) is used to plot graphs of the data and view data values, allowing observers to verify proper operation of the system and sensors. The raw one-second data can also be viewed to assist in troubleshooting.

7.3 Calibration

7.3.1 Theory

The BMET is not calibrated as a system. The sensors along with the Sensor Collectors and the instruments are calibrated separately. The system was installed using components that had a current calibration.

7.3.2 Procedures

Daily Checks

The data from the tower are checked each day during daily rounds. Temperature and relative humidity data from the 2m level and the CMH are compared to determine if the data appear reasonable. The T/RH data between the difference levels is compared also to determine if the data appear to be reasonable. Any discrepancies are noted on the daily rounds forms. The wind speed and direction is compared and checked against local conditions. The barometric and present weather data is checked to determine if what is being reported also appears reasonable. For example, if the present weather sensor is reporting 100m visibility and heavy snow when it is clear and sunny out, this indicates a problem with the present weather sensor and is noted. The present weather sensor also has an alarm value. If everything is working properly the alarm reading is 0, if there is a problem the alarm reading will be 1. Data from the barometer should be between 800 and 1100 hPa. If the barometric data is outside of these values then it is noted on the daily forms. A view screen has been built which displays 24 hours of data graphed along with text values for the current readings. The graphs allow checks of the data to be made to determine if problems have occurred during the most recent 24 hours. Long gaps in data, long periods of or many data spikes, and flat line data (no change in values over extended periods) will be apparent and are noted on the daily forms.

Monthly Checks

Once a month the auto balance dial reading is taken for the CMH. The auto balance reading is an indication of the contamination on the surface of the mirror. This value is recorded once a month on the daily forms. When the reading reaches or exceeds 500, the mirror is cleaned and the entire sensor is recalibrated.

Six-Month Checks

<u>Present Weather Sensor</u>
The lenses of the present weather sensor are cleaned along with the capacitive rain detector every six months.

Chilled Mirror Hygrometer
The CMH is cleaned and recalibrated every six months to ensure proper functioning and that reasonable data is returned from the sensor.

Annual Checks

Cup Anemometers and Wind Direction Vanes
The bearings in these sensors are checked once a year. The cups and vane are inspected for any signs of damage. If any irregularity is observed, the respective anemometer or wind direction sensor is replaced.

HMP45D Temperature and Relative Humidity Probes
The filters on the probes need to be checked once a year and replaced if dirty.

PTB201 or PTB220 Digital Barometer
The reading of the digital barometer is compared with the reference digital barometer.

FD12P Present Weather Sensor
The visibility calibration is checked once a year using the FDA12 calibration kit.

Two-Year Checks and Replacement

Wind Speed and Direction Sensors

he calibration of the current cup anemometers and the frequency measuring portion of the QLI50 Sensor Collectors is checked by using the R. M. Young Model 18810 Anemometer Drive to spin the anemometer shafts for at least one minute at the different rpms. The calibration of the current wind vanes and decoding portion of the QLI50 Sensor Collector is also checked. The sensors are then replaced and the newly installed sensors are checked to ensure the values fall within manufacturers specifications.

Temperature and Relative Humidity Sensors
The calibration of the current temperature and relative humidity probe is checked by comparing it to the reference probe. The probe is then replaced with one that has a current calibration. The calibration of the newly replaced probe is also checked before returning to service.

7.3.3 History

All equipment were calibrated at the manufacturer's prior to installation.

A field check calibration on the instruments was made on September 18, 1999. All were within tolerances.

On Octobert 13, 2001, all wind speed, wind direction, and temperature/humidity sensors were replaced and a field calibration check on the instruments was completed. All were within tolerances.

Serial Numbers:
2m T/RH: W2110041 Wind Speed: U37502 Wind Direction: V34549
10m T/RH: W2110042 Wind Speed: U51103 Wind Direction: V35301
20m T/RH: W2110045 Wind Speed: U51102 Wind Direction: V36303
40m T/RH: W2110047 Wind Speed: U37501 Wind Direction: V34547

PWS calibrated.
On September 18, 2002, the 20m wind speed sensor was replaced.
Serial Number: W46210

On October 18, 2003, all wind speed sensors and direction sensors and T/RH probes were replaced and a field calibration check on the instruments was completed. All were within tolerances.
Serial Numbers:
2m T/RH: Y4320176 Wind Speed: W51302 Wind Direction: V36303
10m T/RH: Y4320177 Wind Speed: X09304 Wind Direction: W39549
20m T/RH: V4940011 Wind Speed: W51310 Wind Direction: V48511
40m T/RH: W2110042 Wind Speed: U51102 Wind Direction: W14224
PWS calibrated

On Sep 08, 2004 the 20m T/RH probe was replaced.
Serial Number: W2110041

On August 23, 2005 all wind speed and directions sensors and T/RH probes were replaced and a field calibration check on the instruments was completed. All were within tolerances.
Serial Numbers:
2m T/RH: V4940014 Wind Speed: U21110 Wind Direction: W23228
10m T/RH: U4940013 Wind Speed: W51301 Wind Direction: V34549
20m T/RH: Y4320178 Wind Speed: U46210 Wind Direction: V34547
40m T/RH: V4940011 Wind Speed: U21107 Wind Direction: W07444
PWS calibrated and CMH cleaned and calibrated.

On April 11, 2006 the CMH was cleaned and calibrated.

On July 18, 2006 the PWS was cleaned and calibrated.

On September 21, 2006 the 2m wind speed and direction sensors were field calibration checked and the T/RH probe was replaced.
2m T/RH : Y321077

On October 18, 2006 the 10,20 and 40m lwind speed and direction sensors were field calibration checked and the T/RH probes were replaced.
10m T/RH: A3930010
20m T/RH: W2110047
40m T/RH: A3930011
20m Wind Direction: U48511
40m Wind Direction: U48507

On October 19, 2006 the CMH was cleaned and calibrated.

On December 12, 2006 the CMH was cleaned.
On March 1, 2007 the CMH was cleaned and calibrated.
Sensor head 1619 installed.
Transmit logic board 1425 installed.

On March 14, 2007 the CMH was cleaned and calibrated.

On May 22, 2007 the 20m and 40m wind direction sensors were replaced:
20m Wind Direction: W14224
40m Wind Direction: V36303

7.4 Operation and Maintenance

7.4.1 User Manual

This section is not applicable to this instrument.

7.4.2 Routine and Corrective Maintenance Documentation

This section is not applicable to this instrument.

7.4.3 Software Documentation

See http://science.arm.gov/tool/dod/showdod.php?Inst=mettwr4h.

7.4.4 Additional Documentation

This section is not applicable to this instrument.

7.5 Glossary

See the ARM Glossary.

7.6 Acronyms

See the ARM Acronyms and Abbreviations.

7.7 Citable References

None.