DOE/SC-ARM/TR-068

ARM

CLIMATE RESEARCH FACILITY

Surface Temperature Humidity Reference System

HANDBOOK

February 2011

U.S. DEPARTMENT OF ENERGY | Office of Science

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

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Surface Temperature and Humidity Reference System (SURTHREF) Handbook

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1.0 General Overview

The Surface Temperature and Relative Humidity (SURTHREF) system is intended to provide accurate reference values of ambient temperature and relative humidity for comparison with radiosonde prelaunch values.

2.0 Contacts

2.1 Mentor

Michael T. Ritsche
Scientific Associate
Argonne National Laboratory
Bldg. 203
Argonne, IL 60439
Phone: (630) 252-1554
Fax: (630) 252-5498
Email: mtritsche@anl.gov

Jenni Prell
Associate Mentor
Argonne National Laboratory
Bldg. 203
Argonne, IL 60439
Phone: (630) 252-7662
Fax: (630) 252-5498
Email: Jprell@anl.gov

2.2 Vendor / Instrument Developer

Data logger
Campbell Scientific Inc.
815 W. 1800 N.
Logan, UT 84321
Phone: (801) 753-2342
Fax: (801) 750-9540
Website: http://www.campbellsci.com

Temperature/Relative Humidity Probe
Vaisala
100 Commerce Way
Woburn, MA 01801-1068
Phone: (617) 933-4500
Fax: (617) 933-8029
Website: http://www.vaisala.com

Rotronic
160 E. Main St
Huntington, NY 11743
Phone: (631) 427-3898
Fax: (631) 427-3902
Website: http://www.rotronic-usa.com/

3.0 Deployment Locations and History

The SURTHREF is located at the SGP Central Facility site in Oklahoma and was installed in July 2005.

4.0 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

5.0 Data Description and Examples

5.1 Data File Contents

There are six temperature and relative humidity probes. Three probes (V1, V2, and V3) are from Vaisala, Inc. Three probes (R1, R2, and R3) are from Rotronic, Inc.

5.1.1 Primary Variables and Expected Uncertainty

Table 1. Primary variables.

Quantity	Variable	Unit	Measurement Interval	Resolution
Temperature V1 Average	temp_V1_avg	C	1 min	0.01
Temperature V2 Average	temp_V2_avg	C	1 min	0.01
Temperature V3 Average	temp_V3_avg	C	1 min	0.01
Temperature R1 Average	temp_R1_avg	C	1 min	0.01
Temperature R2 Average	temp_R2_avg	C	1 min	0.01
Temperature R3 Average	temp_R3_avg	C	1 min	0.01
Relative Humidity V1 Average	RH_V1_avg	%	1 min	0.1
Relative Humidity V2 Average	RH_V2_avg	%	1 min	0.1
Relative Humidity V3 Average	RH_V3_avg	%	1 min	0.1

Quantity	Variable	Unit	Measurement Interval	Resolution
Relative Humidity R1 Average	RH_R1_avg	%	1 min	0.1
Relative Humidity R2 Average	RH_R2_avg	%	1 min	0.1
Relative Humidity R3 Average	RH_R3_avg	%	1 min	0.1
Sonde Present Bit Flag	count	N/A	1 min	1
Temperature V1 Maximum	temp_V1_max	C	1 min	0.01
Temperature V2 Maximum	temp_V2_max	C	1 min	0.01
Temperature V3 Maximum	temp_V3_max	C	1 min	0.01
Temperature R1 Maximum	temp_R1_max	C	1 min	0.01
Temperature R2 Maximum	temp_R2_max	C	1 min	0.01
Temperature R3 Maximum	temp_R3_max	C	1 min	0.01
Relative Humidity V1 Maximum	RH_V1_max	%	1 min	0.1
Relative Humidity V2 Maximum	RH_V2_max	%	1 min	0.1
Relative Humidity V3 Maximum	RH_V3_max	%	1 min	0.1
Relative Humidity R1 Maximum	RH_R1_max	%	1 min	0.1
Relative Humidity R2 Maximum	RH_R2_max	%	1 min	0.1
Relative Humidity R3 Maximum	RH_R3_max	%	1 min	0.1
Temperature V1 Minimum	temp_V1_min	C	1 min	0.01
Temperature V2 Minimum	temp_V2_min	C	1 min	0.01
Temperature V3 Minimum	temp_V3_min	C	1 min	0.01
Temperature R1 Minimum	temp_R1_min	C	1 min	0.01
Temperature R2 Minimum	temp_R2_min	C	1 min	0.01
Temperature R3 Minimum	temp_R3_min	C	1 min	0.01
Relative Humidity V1 Minimum	RH_V1_min	%	1 min	0.1
Relative Humidity V2 Minimum	RH_V2_min	%	1 min	0.1
Relative Humidity V3 Minimum	RH_V3_min	%	1 min	0.1
Relative Humidity R1 Minimum	RH_R1_min	%	1 min	0.1
Relative Humidity R2 Minimum	RH_R2_min	%	1 min	0.1
Relative Humidity R3 Minimum	RH_R3_min	%	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

None.

5.1.3 Diagnostic Variables

Table 2. Diagnostic variables.

Quantity	Variable	Measurement Interval
Standard Deviation of Temperature V1	temp_V1_std	1 min
Standard Deviation of Temperature V2	temp_V2_std	1 min
Standard Deviation of Temperature V3	temp_V3_std	1 min
Standard Deviation of Temperature R1	temp_R1_std	1 min
Standard Deviation of Temperature R2	temp_R2_std	1 min
Standard Deviation of Temperature R3	temp_R3_std	1 min
Standard Deviation of Relative Humidity V1	RH_V1_std	1 min
Standard Deviation of Relative Humidity V2	RH_V2_std	1 min
Standard Deviation of Relative Humidity V3	RH_V3_std	1 min
Standard Deviation of Relative Humidity R1	RH_R1_std	1 min
Standard Deviation of Relative Humidity R2	RH_R2_std	1 min
Standard Deviation of Relative Humidity R3	RH_R3_std	1 min
Logger Panel Temperature	logger_temp	1 min

5.1.4 Data Quality Flags

Table 3. Data quality flags.

Quantity	Variable	Measurement Interval	Min	Max	Delta
Sample Time	qc_time	1 min			
Sonde Present Bit Flag	qc_count	1 min	0	60	N/A
Average Temperature V1	qc_temp_V1_avg	1 min	-40	50	10
Average Temperature V2	qc_temp_V2_avg	1 min	-40	50	10
Average Temperature V3	qc_temp_V3_avg	1 min	-40	50	10
Average Temperature R1	qc_temp_R1_avg	1 min	-40	50	10
Average Temperature R2	qc_temp_R2_avg	1 min	-40	50	10
Average Temperature R3	qc_temp_R3_avg	1 min	-40	50	10
Average Relative Humidity V1	qc_RH_V1_avg	1 min	-2	104	30
Average Relative Humidity V2	qc_RH_V2_avg	1 min	-2	104	30
Average Relative Humidity V3	qc_RH_V3_avg	1 min	-2	104	30
Average Relative Humidity R1	qc_RH_R1_avg	1 min	-2	104	30
Average Relative Humidity R2	qc_RH_R2_avg	1 min	-2	104	30
Average Relative Humidity R3	qc_RH_R3_avg	1 min	-2	104	30
Maximum Temperature V1	qc_temp_V1_max	1 min	-40	50	10
Maximum Temperature V2	qc_temp_V2_max	1 min	-40	50	10
Maximum Temperature V3	qc_temp_V3_max	1 min	-40	50	10
Maximum Temperature R1	qc_temp_R1_max	1 min	-40	50	10
Maximum Temperature R2	qc_temp_R2_max	1 min	-40	50	10
Maximum Temperature R3	qc_temp_R3_max	1 min	-40	50	10
Maximum Relative Humidity V1	qc_RH_V1_max	1 min	-2	104	30
Maximum Relative Humidity V2	qc_RH_V2_max	1 min	-2	104	30
Maximum Relative Humidity V3	qc_RH_V3_max	1 min	-2	104	30
Maximum Relative Humidity R1	qc_RH_R1_max	1 min	-2	104	30
Maximum Relative Humidity R2	qc_RH_R2_max	1 min	-2	104	30
Maximum Relative Humidity R3	qc_RH_R3_max	1 min	-2	104	30
Minimum Temperature V1	qc_temp_V1_min	1 min	-40	50	10
Minimum Temperature V2	qc_temp_V2_min	1 min	-40	50	10
Minimum Temperature V3	qc_temp_V3_min	1 min	-40	50	10
Minimum Temperature R1	qc_temp_R1_min	1 min	-40	50	10
Minimum Temperature R2	qc_temp_R2_min	1 min	-40	50	10
Minimum Temperature R3	qc_temp_R3_min	1 min	-40	50	10
Minimum Relative Humidity V1	qc_RH_V1_min	1 min	-2	104	30
Minimum Relative Humidity V2	qc_RH_V2_min	1 min	-2	104	30
Minimum Relative Humidity V3	qc_RH_V3_min	1 min	-2	104	30
Minimum Relative Humidity R1	qc_RH_R1_min	1 min	-2	104	30
Minimum Relative Humidity R2	qc_RH_R2_min	1 min	-2	104	30
Minimum Relative Humidity R3	qc_RH_R3_min	1 min	-2	104	30

5.1.5 Dimension Variables

Table 4. Dimension variables.

Quantity	Variable	Measurement Interval	Unit
Base time in Epoch	base_time	5 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
Time offset from base_time	time_offset	5 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
Time offset form midnight	time	5 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
north latitude	lat	5 min	degrees
east longitude	lon	5 min	degrees
Altitude	alt	5 min	meters above sea level

NOTE: lat/lon/alt refers to the ground where the instrument is sited, NOT the height of the sensor.

5.2 Annotated Examples

None.

5.3 User Notes and Known Problems

In 2007 it was found that there is a temperature dependency on RH% measurements by either the Rotronic sensor or the Vaisala sensor or both. Figure 1 shows the dependency of the RH readings with respect to temperature. Contributing to the problem is the fact that both the Rotronic and Vaisala probes are calibrated at one temperature for a variety of RH readings. Calibrations of the various RH values at different temperatures need to be done to characterize the dependency and to account and correct for it.

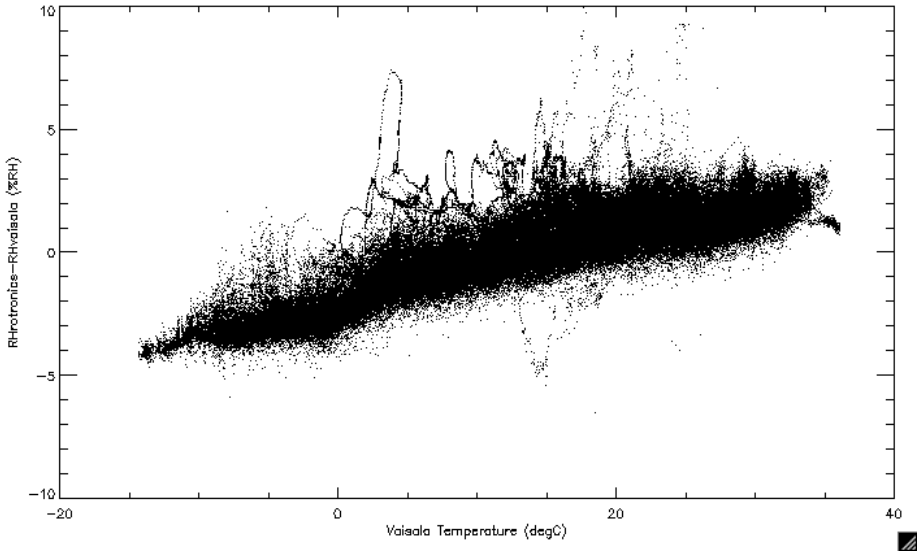

Figure 1. Rotronic RH values—Vaisala RH values at various temperatures (taken from Vaisala probes).

5.4 Frequently Asked Questions

None.

6.0 Data Quality

6.1 Data Quality Health and Status

Data Quality Health and Status (DQ HandS)

NCVweb

6.2 Data Reviews by Instrument Mentor

None.

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. These forms can be found at http://www.db.arm.gov/.

6.4 Value-Added Products and Quality Measurement Experiments

Many of the scientific needs of the Atmospheric Radiation Measurement (ARM) Climate Research Facility are met through the analysis and processing of existing data products into "value-added" products (VAPs). Despite extensive instrumentation deployed at the ARM 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 to fill unmet measurement needs, but 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. Instead, a QME adds value to the input data streams 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 at http://www.arm.gov/data/vaps.

7.0 Instrument Details

7.1 Detailed Description

7.1.1 List of Components

Temperature and relative humidity sensors:

- Three Vaisala HMP-4D Series probes.
- Three Rotronic MP100H Series probes.

Data logger: Campbell Scientific Model CR23X Micrologger.

Meteorological Instrument Shelter: The shelter is a standard NWS "Stevenson screen" modified to allow operator access on two sides. The shelter dimensions are 20" x30" x34".

Aspirated Chamber: The chamber is fabricated from white polypropylene plastics. Its dimensions are 11"x13"x18" (volume = 1.49 ft^3). One end is open and covered with a removable plate containing a 7" x7.5" access port. Two muffin fans, each rated at 115 cfm, are mounted at the far end. The fans produce an estimated face flow of 10.49 fps or 3.2 m/s. The chamber has six sensor ports on its top surface to accommodate standard temperature and relative humidity probes.

Sonde positioning platform: A polypropylene platform is mounted approximately 1" above the bottom of the aspirated chamber. The platform is equipped with moveable guides for positioning radiosondes. A user-controlled switch is mounted on the side of the Aspirated Chamber to indicate when a radiosonde is placed in or removed from the chamber.

7.1.2 System Configuration and Measurement Methods

The SURTHREF system is intended to be used as a ground reference point for radiosonde launches. Radiosondes are placed inside the aspirator so that comparisons between the 6 T/RH probes and the radiosonde can be accomplished. It is possible that in the future a VAP will be created so that the radiosonde surface values can be corrected. In order for there to be an exact determination of when the radiosonde is inside the aspirator box, a user-operated switch is installed. When the operator places the radiosonde inside the aspirator box, they flip the switch. The datalogger program counts the number of seconds of each minute that the switch is in the "up" position. Any count greater than zero suggests that the radiosonde is in the aspirator.

The data logger measures each input once every second. The temperature and relative humidity data is averaged for each of the six probes once per minute, and minimums and maximum are calculated along with a total count of how many seconds the "Radiosonde Present" switch was in the up position.

7.1.3 Specifications

Temperature and Relative Humidity Probes:

Vaisala HMP-45D T/RH probe:

- **Temperature**: Precision: 0.01 C; Uncertainty: See "Data Acquisition Errors"
- **RH:** Precision: 0.1% RH; Uncertainty: +/-2.0% RH (0% to 90% RH), +/-3.0% RH (90% to 100% RH)

Rotronic MP100H T/RH probe:

- **Temperature**: Precision: 0.01 C; Uncertainty: +/- 0.2 C.
- **RH:** Precision: 0.1% RH; Uncertainty: +/-1.5%.

Data Acquisition Errors

The Campbell Scientific CR23X A/D converter accuracy is +/-0.1 % of full-scale range. The time base accuracy is +/-1 min per month, or about 23 ppm. The collector computer checks the datalogger clock once per day and corrects it if it is off by more than 2 seconds.

7.2 Theory of Operation

The SURTHREF system is a combination of three temperature and relative humidity probes from two different manufacturers for a total of six probes. Although the primary use of the system is intended to provide accurate reference values of ambient temperature and relative humidity for comparison with radiosonde prelaunch values, the system includes a data logger to record time series of the measured variables.

7.3 Calibration

7.3.1 Theory

7.3.2 Procedures

See Section 7.4.1 of the SURTHREF User Manual for procedures.

7.3.3 History

The SURTHREF System was installed in July 2005 with recently calibrated sensors.

7.4 Operation and Maintenance

7.4.1 User Manual

See the SURTHREF User Manual.

7.4.2 Routine and Corrective Maintenance Documentation

This section is not applicable to this instrument.

7.4.3 Software Documentation

ARM netCDF file header descriptions may be found for the SURTHREF system at https://engineering.arm.gov/tool/dod/showdod.php?Inst=surthref&View=dev.

7.4.4 Additional Documentation

This section is not applicable to this instrument.

7.5 Glossary

Relative humidity: Percentage of saturated vapor pressure at the specified temperature.

See the ARM Glossary at http://www.arm.gov/about/glossary.

7.6 Acronyms

AC	alternating current
A/D	Analog to Digital converter
DQA	Data Quality Assessment
NIST	National Institute of Standards and Technology
QME	Quality Measurement Experiment
RH	Relative Humidity
rms	root mean square
SGP	Southern Great Plains
SONDE	balloon-borne sounding system
T/RH	temperature/relative humidity (sensor)
VAP	value-added product

Also see the ARM Acronyms and Abbreviations at http://www.arm.gov/about/acronyms.

7.7 Citable References

None.

www.arm.gov

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