DOE/SC-ARM/TR-029

Balloon-Borne Sounding System Handbook

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Atmospheric Radiation Measurement
Climate Research Facility
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1. General Overview

The balloon-borne sounding system (BBSS) provides in situ measurements (vertical profiles) of both the thermodynamic state of the atmosphere and the wind speed and direction.

2. Contacts

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3. Deployment Locations, History, and Significant Events

At the North Slope of Alaska (NSA) locale[1]–

- Barrow, (Great White, C1) 71.32N, 156.62W, 27 m
  - *Production system: digiCORA-III s/n W03202* (April 24, 2002 – present)
  - *Atmospheric infrared sounder (AIRS) validation IOP system: pcCORA* (July 22, 2002 – present)
  - *Spare system: digiCORA-II s/n R41204* (August 15, 2004 – present)
  - *Production system: National Oceanic and Atmospheric Administration (NOAA)/Cross-chain Loran Atmospheric Sounding System (CLASS)* (May 20, 1998 – May 4, 2002)
  - Updated digiCORA-III to v3.12 (July 3, 2005)
  - Updated digiCORA-III to v3.51 September 19, 2006
  - Increased reported precision of RH from 1.0% to 0.1% (September 29, 2006)
  - Updated digiCORA-III to v3.52 January 30, 2007

At the Tropical Western Pacific (TWP) locale–

- Manus Island, PNG (C1) 2.06S, 147.43E, 4 m
  - *Production system: digiCORA-III (MW-31) s/n B31401*
  - Assigned WMO station identifier (044 block 92)
  - Installed Synergetics DCP 07/2000
  - Replaced old production system (s/n T32102) with digiCORA-III v3.52 June 16, 2007
  - Increased reported precision of RH from 1.0% to 0.1% (June 16, 2007)

- Republic of Nauru (C2) 0.52S, 166.92E, 7 m
  - *Production system: digiCORA-III (MW-31) s/n B131402*
  - Assigned WMO station identifier (532 block 91)
  - Installed Synergetics DCP 07/2000
  - Replaced old production system (s/n S35304) with digiCORA-III v3.52 August 18, 2007
  - Increased reported precision of RH from 1.0% to 0.1% (August 18, 2007)

- Darwin, Australia (C3)[2] 12.42S, 130.88E, 30 m
  - *Production system: digiCORA-III (June 7, 2004 – present)*
  - *Production system: pcCORA (February 1, 2002? – June 6, 2004)*
  - WMO station identifier (120 block 94)
  - Operated by Australian Bureau of Meteorology (BOM)

At the Southern Great Plains (SGP) site–

- Central Facility (CF) (C1) 36.61N, 97.49W, 315 m
  - *Production system: pcCORA* (May 27, 1992 – April 12, 1999)
  - *Production system: digiCORA-II s/n R48501* (April 13, 1999 – July 31, 2002)
  - *Production system: digiCORA-III s/n W09201* (August 1, 2002 – present)
  - *AIRS validation IOP system (S01): digiCORA-I s/n 574791*
  - *AIRS validation IOP system (S02): digiCORA-I s/n 708515*
  - System installed May 27, 1992

[1] See discussion of NSA radiosonde systems in Section 5.3 (User Notes)
[2] See discussion of Darwin radiosonde systems in Section 5.3 (User Notes)

  - Started regular (19:30) soundings July 14, 1992
  - Started ground checks January 21, 1993
  - Changed to high resolution sampling (2-sec) May 20, 1993
  - Installed RESEARCH software March 30, 1994
  - Started RESEARCH mode soundings April 7, 1994
  - Stopped RESEARCH mode soundings May 21, 1994
  - Stopped ground checks August 3, 1994
  - Installed RAWDATA software November 15, 1994
  - Assigned WMO station identifier (646 block 74) August 19, 1996
  - Software upgrade to generate WMO-coded messages for NWS March 24, 1997
  - Installed MW-15 digiCORA-II September 1, 1997 for WVIOP
  - Changed regular sounding schedule from 5 per day to 3 per day November 14, 1997
  - Added 0530 Universal Time Coordinates (UTC) sounding to regular schedule (1130, 2030, 2330) November 30, 1998
  - Updated PC-CORA and digiCORA-II and MF-12 for Y2K June 9, 1999
  - Stopped RESEARCH mode for winds November 24, 2000
  - Began operational use of RS-90 radiosondes May 1, 2001
  - Changed sounding schedule to 0530, 1130, 1730, 2330 August 1, 2001
  - Transferred PC-CORA to NSA June 24, 2002
  - Began digiCORA-III (MW-21) transition IOP July 10, 2002
  - Updated digiCORA-III to v3.12 and RB-21 antenna July 27, 2005
  - Updated digiCORA-III to v3.51 September 19, 2006.
  - Increased reported precision of RH from 1.0% to 0.1% (September 29, 2006)
  - Updated digiCORA-III to v3.52 January 30, 2007

- Hillsboro, Kansas (boundary facility [BF]1) 38.30N, 97.30W, 447 m
  - *Production system: digiCORA-I s/n 530483 (January 18, 1994 – November 22, 1997)*
  - Installed January 18, 1994
  - Started RESEARCH mode soundings April 7, 1994
  - Stopped RESEARCH mode soundings May 21, 1994
  - Installed directional antenna March 28, 1996
  - Assigned WMO station identifier (547 block 74) August 19, 1996
  - Started automatic generation of WMO-coded messages October 28, 1996
  - Added global positioning system (GPS) windfinding capability March 25, 1997
  - Suspended daily soundings at all BFs November 22, 1997
  - Updated digiCORA and MF-12 for Y2K June 11, 1999
  - Stopped RESEARCH mode for winds November 24, 2000
  - Updated digiCORA and RB-21 for RS92 July 27, 2005

- Vici, Oklahoma (BF4) 36.07N, 99.20W, 622 m
  - *Production system: digiCORA-I s/n 574791* (January 18, 1994 – November 22, 1997)
  - Installed January 18, 1994
  - Started RESEARCH mode soundings April 7, 1994
  - Stopped RESEARCH mode soundings May 21, 1994
  - Installed directional antenna August 1, 1996
  - Assigned WMO station identifier (641 block 74) August 19, 1996

  - Started automatic generation of WMO-coded messages October 28, 1996
  - Added GPS windfinding capability March 26, 1997
  - Suspended daily soundings at all BFs November 22, 1997
  - Updated digiCORA and MF-12 for Y2K June 11, 1999
  - Stopped RESEARCH mode for winds November 24, 2000
  - Updated digiCORA and RB-21 for RS92 July 27, 2005

- Morris, Oklahoma (BF5) 35.68N, 95.85W, 217 m
  - *Production system: digiCORA-I s/n 574792* (January 18, 1994 – November 22, 1997)
  - Installed January 18, 1994
  - Started RESEARCH mode soundings April 7, 1994
  - Stopped RESEARCH mode soundings May 21, 1994
  - Assigned WMO station identifier (650 block 74) August 19, 1996
  - Started automatic generation of WMO-coded messages October 28, 1996
  - Added GPS windfinding capability March 27, 1997
  - Suspended daily soundings at all BFs November 22, 1997
  - Updated digiCORA and MF-12 for Y2K June 11, 1999
  - Stopped RESEARCH mode for winds November 24, 2000
  - Updated digiCORA and RB-21 for RS92

- Purcell, Oklahoma (BF6) 34.97N, 97.42W, 344 m
  - *Production system: digiCORA-I s/n 708515* (October 13, 1994 – November 22, 1997)
  - Installed October 13, 1994
  - Removed borrowed directional antenna February 17, 1995
  - Installed new directional antenna October 2, 1995
  - Assigned WMO station identifier (651 block 74) August 19, 1996
  - Started automatic generation of WMO-coded messages October 31, 1996
  - Added GPS windfinding capability March 25, 1997
  - Suspend daily soundings at all BFs November 22, 1997
  - Updated digiCORA and MF-12 for Y2K June 11, 1999
  - Stopped RESEARCH mode for winds November 24, 2000
  - Updated digiCORA and RB-21 for RS92 July 27, 2005

Table 1 shows the general attributes of each of the Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF)-owned Vaisala ground stations as well as providing a guide to their deployment history during intensive operational periods (IOPs). The IOP designations at the bottom of the table refer to the facility identification code used in the standard ARM data file naming convention. For example, data produced during the AIRS IOP by the MW-11 serial number 574791 (normally assigned to SGP/B4) are named sgpsondewnpnS01.b1.YYYYMMDD.HHMMSS.cdf.

Table 1. ACRF-owned Vaisala radiosonde ground stations

	Common Name												
	digiCORA-I				**digiCORA-II**				**digiCORA-III**				
Model	MW-11	MW-11	MW-11	MW-11	MW-15	MW-15	MW-15	MW-15	MW-21	MW-21	MW-21	MW-31	MW-31
S/N	530483	574791	574792	708515	T32102	S35304	S17401	R41204	W09201	W03202	Z15101	B31401	B31402
Base Location	SGP/B1	SGP/B4	SGP/B5	SGP/B6	AMF/M1	SGP/spare	SGP/spare	SGP/spare	SGP/C1	NSA/C1	AMF/M1	TWP/C1	TWP/C2
Current Location	SGP/IOP	SGP/spare	SGP/IOP	SGP/spare	SGP/C1	SGP/C1	SGP/C1	NSA/C1/GW)	SGP/C1	NSA/C1	AMF/M1	TWP/C1	TWP/C2
Loran equipped	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO
GPS equipped	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
RS08-H compatible	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
RS90 compatible	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
RS92 compatible	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Software version	8.35	8.35	8.35	8.35	8.35	8.35	8.35	8.34	3.52	3.52	3.52	3.52	3.52
IOP Name (site)													
AIRS (I-V)		SGP/S01		SGP/S02		TWP/C2			NSA/C1				
AWEX-G (SGP)	SGP/S03	SGP/S01	SGP/S04	SGP/S02				SGP/S05		SGP/C1			
AWWVIOP (NSA)									NSA/C1 (D[3])				
BLCE (NSA)									NSA/C1 (GW)				
MPACE (NSA)			NSA/S02					NSA/C2	NSA/C1 (D)				
Point Reyes											PYE/M1		
Niamey											NIM/M1		
Black Forest											FKB/M1		
CLASIC (SGP)	SGP/B4	SGP/B1	SGP/B5	SGP/S06									
AIRS/IASI			SGP/S01	SGP/S02				NSA/S01	NSA/C1				

[3] D indicates system was deployed at the NSA Duplex location; GW indicates system was deployed at the NSA Great White location.

4. Near-Real-Time Data Plots

Quicklooks are plots of collected data, of varying sophistication. Plots of ARM sounding data from all sites may be accessed by using the DQ HandS (Data Quality Health and Status) system. Click on the site of interest and choose the radiosonde (SSSsondewnpn.b1) link.

5. Data Description and Examples

5.1 Data File Contents

With the exception of the early NSA data described in Section 5.3, the netCDF ARM radiosonde data files distributed by the ARM Archive are identical to one another regardless of site or ground station of origin. Some of the raw data files produced by the different ground station types are unique, however, and although most users will have no need or interest in accessing these files, they are archived and available by special request. The instrument-created data files are listed in Table 2; examples of the ASCII files are available through the links provided in Section 5.2.

Table 2. Summary of data files created by ARM Vaisala ground stations

Radiosonde System	Filename	Description
pcCORA All files are created and stored on the local instrument computer and transmitted to the site data system when the sounding is completed. The local files are renamed after transfer.	PRT.CUR RAWDATA.CUR EDITED.CUR	Standard ASCII output with processed data: this file is passed to the ingest module to create the netCDF files distributed by the archive Binary raw thermodynamic data directly from the radiosonde Binary copy of processed thermodynamic and wind data
MW-11 and MW-15 (digiCORA-I and -II) The standard ASCII data istransmitted by a serial connection in real-time to the site data system where it is collected in an ASCII file. At the SGP and NSA, these files are recorded on floppy disk for each sounding and not usually archived; at the TWP they are recorded on hard disk, bundled, and sent to the archive. Note that raw files associated with GPS radiosondes will be named "GPSSND.xxx" rather than "LORANC.xxx."	PRT.CUR MPPPTU.RAW LORANC.EDT LORANC.PAR LORANC.DER LORANC.PHA GPSWND.RAW	Standard ASCII output with processed data: this file is passed to the ingest module to create the netCDF files distributed by the archive As defined above Binary copy of processed thermodynamic and wind data Binary position derivative data Binary raw Loran phase data Binary raw GPS wind data

Table 2. (contd)

Radiosonde System	Filename	Description
MW-21 (digiCORA-III) All files are created and stored on the local instrument computer and collected by the site data system when the sounding is completed.	SSSsonderawFF.YYYYMMDDHHMM.raw SSSsondeFF.YYYYMMDDHHMM.ptu SSSsondeFF.YYYYMMDD_HHMMSS.dc3db	Standard ASCII output with processed data: this file is passed to the ingest module to create the netCDF files distributed by the archive ASCII file with raw thermodynamic data directly from the radiosonde Binary sounding database file

5.1.1 Primary Variables and Expected Uncertainty

The following quantities are measured as functions of time during a free-balloon ascent:

- Pressure (hPa) netCDF name = “pres”
- Temperature (°C) netCDF name = “tdry”
- Relative Humidity (%RH) netCDF name = “rh”
- Wind speed (m/s) netCDF name = “wspd”
- Wind direction (deg) netCDF name = “dir”

Secondary (derived) quantities included in the data stream, also measured as functions of time, are:

- Altitude (gpm) netCDF name = “alt”
- Dew Point (°C) netCDF name = “dp”
- Ascent Rate (m/s) netCDF name = “alt”
- Latitude of Sonde (°N) netCDF name = “lat”
- Longitude of Sonde (°W) netCDF name = “lon”
- u-component of wind velocity (m/s) netCDF name = “u_wind”
- v-component of wind velocity (m/s) netCDF name = “v_wind”

5.1.1.1 Definition of Uncertainty

The manufacturer defines the cumulative sensor uncertainty at the 2-sigma (95.5%) confidence level. The uncertainty includes the following factors:

- Repeatability
- Long-term stability
- Measurement conditions
- Dynamic effects (e.g. time lag)
- Electronic effects

Repeatability is estimated from the standard deviation of differences between two successive repeated calibrations (2-sigma). Reproducibility is estimated from the standard deviation of differences in twin soundings.

The manufacturer's specifications and stated uncertainty values for the thermodynamic sensors in each radiosonde type used by ARM are presented in Table 3.

Table 3. Technical specifications and manufacturer's stated uncertainty for the meteorological sensors used in radiosondes employed by the ARM Program

	RS-80H			RS-90 and RS-92 all types		
	Pressure	**Temperature**	**Humidity**	**Pressure**	**Temperature**	**Humidity**
Range	1060 to 3 hPa	-90 to +60°C	0 to 100%RH	1080 to 3 hPa	-90 to +60°C	0 to 100 %RH
Resolution	0.1 hPa	0.1°C	1%RH	0.1 hPa	0.1°C	1%RH*
Response Time	n/a	<2.5 s	1 s (at surface)	n/a	0.4 s (1000 hPa) 2.5 s (10 hPa)	<0.5 s (20°C) <20 s (-40°C)
Repeatability	0.5 hPa	0.2°C	2%RH		0.15°C	2%RH
Reproducibility	0.5 hPa	0.2°C > 50 hPa 0.3°C > 15 hPa 0.4°C < 15 hPa	3%RH		0.2°C > 100 hPa 0.3°C < 20 hPa	3%RH
Uncertainty	n/a	n/a	n/a	n/a	0.5°C	5%RH

*Nominal resolution value – data collected using digiCORA-III ground station may be reported with higher precision.

5.1.2 Secondary/Underlying Variables

This section is not applicable to this instrument.

5.1.3 Diagnostic Variables

This section is not applicable to this instrument.

5.1.4 Data Quality Flags

Some automated data quality checks are included in the processed BBSS netCDF file. Checks now used are based on predefined limits for maximum, minimum, and sample-to-sample change (delta) values of each raw variable. The limits used for BBSS are shown in Table 4.

Table 4. Data quality min/max limits

			SGP			TWP			NSA		
Variable	Name	Units	**Min**	**Max**	**Delta**	**Min**	**Max**	**Delta**	**Min**	**Max**	**Delta**
pres	pressure	hPa	0.0	1100.0	10.0	0.0	1100.0	10.0	0.0	1100.0	50.0
tdry	dry bulb temperature	C	-80.0	50.0	10.0	-80.0	50.0	10.0	-80.0	50.0	50.0
dp	dewpoint temperature	C	-110.0	50.0	----	-110.0	50.0	----	-110.0	50.0	50.0
wspd	wind speed	m/s	0.0	75.0	----	0.0	75.0	----	----	----	----
deg	wind direction	deg	0.0	360.0	----	0.0	360.0	----	----	----	----
rh	relative humidity	pct	0.0	100.0	----	0.0	100.0	----	0.0	100.0	----
u_wind	eastward wind component	m/s	-100.0	100.0	----	-100.0	100.0	----	----	----	----
v_wind	northward wind component	m/s	-100.0	100.0	----	-100.0	100.0	----	----	----	----
wstat	wind status	none	0.0	----	----	0.0	----	----	----	----	----
asc	ascent rate	m/s	-10.0	20.0	5.0	-10.0	20.0	5.0	-10.0	20.0	5.0

An example BBSS file header (Data Object Design), which contains information on BBSS automated QC, may be found for the ARM Mobile Facility (AMF), NSA, SGP, and TWP at SONDE (once there, click on "sondewnpn.b1_new") and for the older NSA data at ISSSONDE (once there, click on "isssonde10s.a1_new").

5.1.5 Dimension Variables

All profile data are one-dimensional arrays in time.

5.2 Annotated Examples

Examples of ASCII files produced by ARM Vaisala ground stations.

- Standard output file (PRT.CUR and SSSsonderawFF.YYYYMMDDhhmmss.raw)
- Raw thermodynamic data file[4] (SSSsondeFF.YYYYMMDDhhmmss.ptu)

5.3 User Notes and Known Problems

Soundings at the North Slope of Alaska

The BBSS system originally located at Barrow was an old CLASS-type that was originally operated by NOAA's Climate Measurements and Diagnostics Laboratory on TWP's Manus site. The early (May 20, 1998 – May 4, 2002) NSA radiosonde filenames (e.g., nsaisssonde10sC1.LL.YYYYMMDD.HHMMSS) reflect this provenance. The "iss" refers to the integrated sounding system of which this unit was once a part and the "10s" refers to the fact that each sample in the output file is calculated from a 10-second window of the raw (~1.5-second) data. As in all ARM data filenames, the LL indicates the data level, and the YYYYMMDD.HHMMSS have their usual meanings. The CLASS system was replaced with a Vaisala digiCORA-III system in late April 2002. Since that time, radiosonde data collected at the NSA conforms with the ARM standard and, with the exception of wind information, is identical to the radiosonde data collected at the SGP and TWP (C1 and C2).

The NSA CLASS system (despite its name) was based on Omega windfinding. The Omega navigation system was turned off in September 1997 and we use pressure, temperature, humidity (PTU)- only radiosondes at NSA. After switching to the Vaisala ground station in 2002, ARM continued the practice of (with a few IOP and test exceptions) using PTU sondes for production soundings at NSA. This decision was made by ARM management based on balancing the scientific value of wind profiles against the added operational cost of using wind-finding radiosondes.

Soundings at Darwin, Tropical Western Pacific (TWP/C3)

ARM obtains radiosonde data at Darwin (C3) through a collaborative agreement with the Australian Bureau of Meteorology (BoM). Under this agreement, BoM supplies the raw radiosonde data to ARM

[4] Raw thermodynamic ASCII files are produced regularly only by the digiCORA-III systems at AMF, NSA, and SGP. Similar files can be provided for other systems/locations on request to the instrument mentors.

and ARM reformats it and ingests it to produce ARM-standard netCDF files that are distributed to the scientific community through the ARM Archive. Prior to 23:15 (UTC) on January 18, 2006, when they began using Vaisala RS92 radiosondes, the BoM used Vaisala RS80 radiosondes at Darwin. Wind-finding is done by radar tracking. Although there are four soundings per day at Darwin, only two soundings (nominally done at 00Z and 12Z, usually launched at 23:15 and 11:15 UTC) include all thermodynamic data and winds. The other two soundings (04:30 and 16:30 UTC) are wind-only. Temperature and relative humidity data in the wind-only sounding data files are coded as “missing.”

General Problems with Radiosonde Data

Several situations may arise during a sounding that may affect the quality of the data but which may not be flagged or otherwise corrected, and the user should be aware of these. Among these are incorrect surface conditions, humidity sensor saturation or icing, interference, and signal confusion from other radiosondes. General data quality reports (DQRs) have been issued describing these conditions, which the user is urged to read and understand. Specific DQRs are issued for those cases when incorrect surface conditions are included in the soundings. Cases of sensor saturation, which may lead to unrealistic lapse rates or humidity values aloft, and cases of sonde-to-sonde interference, which may result in incorrect data values, are not generally called out in individual DQRs.

Dry Bias

A general problem with Vaisala RS-80H (the type used by ARM from May 1992 through spring 2002) radiosondes is that they seem to exhibit a dry bias; that is, the relative humidity values reported are too low. The amount of the error varies with several factors including the ambient temperature and relative humidity and the age of the radiosonde but may be as great as 10% relative humidity. The dry bias results from contamination of the humidity sensor during storage. Starting in August of 1998 (week 33), Vaisala changed their packaging to reduce the problem. Another packaging change was made in August of 2000 that substantially reduced the bias problem from the RS-80 series of sondes. Although more recent types of sondes (RS90, RS92) do not seem to suffer from the same type of contamination-related bias problem, they do seem to be biased dry during the daytime because of solar heating of the humidity sensor during flight. This effect depends on altitude and location and is most pronounced in the upper troposphere at lower latitudes where solar effects are greatest. More detailed information may be found in a frequently asked question in Section 5.4, called “**What is this about ‘dry bias’ in Vaisala radiosondes?”**

RESEARCH Mode Altitude

Another issue involves soundings that are done in so-called RESEARCH mode for PTU. These soundings, which may be identified by data platform name wXpr, were done regularly at the SGP from April 27, 1994, to May 21, 1994; other isolated cases may exist in the archived data. Soundings done using RESEARCH mode (for PTU) Vaisala processing have a negative bias in the calculation of sonde altitude. This bias results from neglecting the sensed relative humidity when calculating air density when integrating the hydrostatic equation. In essence, the Vaisala RESEARCH mode (PTU) processing assumes a dry atmosphere when calculating sonde altitude. The magnitude of the bias is cumulative with height and will depend on the vertical distribution of moisture, but it can be as much as 20 m at the tropopause (the RESEARCH-mode sounding altitudes will be smaller than altitudes calculated by using sensed relative humidity). This problem applies to all soundings done in ‘WXPR’ mode, where X is either R or N. In particular, all soundings done during the April 1994 (RCS) IOP (April 7, 1994, to May 21, 1994) are affected as well as those occasional inadvertent WXPR soundings. Note that the only variable affected is 'alt.'

Users interested in corrected data for this period should obtain filenames as listed below. They can be retrieved via the Query Interface at the Archive or by special request to Archive User Services (armarchive@ornl.gov).

- DsgpsondeptucalcB1.c1
- DsgpsondeptucalcB4.c1
- DsgpsondeptucalcB5.c1
- DsgpsondeptucalcC1.c1

STATUS Message

Soundings done at the SGP (BFs and CF digiCORA) and at the TWP include a STATUS message in the netCDF metadata. This status message contains information about the overall quality of the sounding. Among the information included in the STATUS message is the percent of good telemetry, and the percent of samples that did not pass the internal quality checks. For sounding data collected with one of our digiCORA-III ground stations, the message includes the type of radiosonde used. The format of the STATUS message is explained in Section 5.4.

5.4 Frequently Asked Questions

Why are some BBSS data files from the NSA named differently than SGP and TWP files?

As noted in Section 5.3, the original BBSS system located at Barrow was an old CLASS-type that was originally operated on Manus by the Climate Monitoring and Diagnostic Laboratory. The NSA filenames (e.g., nsaisssonde10sC1.LL.YYYY MMDD.HHMMSS) reflect this provenance. The "iss" refers to the integrated sounding system of which this unit was once a part and the "10s" refers to the fact that each sample in the output file is calculated from a 10-second window of the raw (~1.5-second) data. As in all ARM data filenames, the LL indicates the data level, and the YYYYMMDD.HHMMSS have their usual meanings.

Radiosonde data files from the SGP, TWP, and recent (since 2002) files from NSA are named SSSsondewXpXFF.LL.YYYYMMDD.HHMMSS. The "SSS" refers to the site identifier (NSA, SGP, or TWP), the wXpX indicates the type of processing mode that was applied to the data (X={N,R}, where N is "nominal" and R is "research"), FF identifies the facility within the site (for the NSA, FF={C1,C2,S0x}, for the SGP, FF={B1,B4,B5,B6,C1,S0x}, for the TWP, FF={C1,C2,C3}, and for the AMF, FF=M1).

Why do the NSA BBSS files not have any wind data?

The NSA CLASS system (despite its name) was based on Omega windfinding. The Omega navigation system was turned off in September 1997 and we use PTU only radiosondes at NSA. After switching to a Vaisala ground station in 2002, ARM management decided to continue using PTU-only radiosondes at NSA with exceptions for testing and those IOPs that required wind-finding radiosondes.

Why are some of the TWP C3 (Darwin) BBSS files missing temperature and relative humidity data?

The Australian BoM supplies ARM with radisonde data from their Darwin airport station. Although the BoM does four soundings per day at Darwin, only two soundings (nominally done at 00Z and 12Z, usually launched at 23:15 and 11:15 UTC) include all thermodynamic data and winds. The other two soundings (04:30 and 16:30 UTC) are wind-only. Temperature and relative humidity data in the wind-only sounding data files are coded as "missing."

What is RESEARCH mode?

The standard datastream output by the BBSS ground station is passed through different levels of processing by the ground station before being sent to the site data system. The ground station processing consists of filtering, editing, and interpolation. Different sets of algorithms are applied to the wind and thermodynamic data. Data treated by the standard processing algorithms (full filtering, editing, and interpolation) are termed "NOMINAL" and identified in the data filename by the letter "n" following either the "w" (for winds) or "p" (for PTU). Thus, a sounding file with nominal processing applied to both winds and thermodynamic data would be named SSSsondewnpnFF. In RESEARCH mode the only processing applied to the PTU data is an 11-second window median filter (to eliminate telemetry noise). No other processing (including radiation correction of the temperature) is done. For winds, no editing, filtering, or interpolation is done in RESEARCH mode. Until November 24, 2000, the standard processing mode for SGP soundings was wrpn. Since November 24, 2000, we have been using wnpn processing modes for SGP soundings (see BCR-00304 for further discussion).

How do I parse the sonde serial number?

The radiosonde serial numbers are assigned when the sensor packs are calibrated. The numbers encode the date of calibration as well as other information. Before October 1995, the serial number code (for RS-80s) was

```
DDMMYTTPP, in which

  DD = day of the month (1-31)
  MM = month (1-12) + facility identifier (00, 20, 40, or 80)
   Y = last digit of the year
  TT = calibration tray identifier
  PP = position in calibration tray
```

More recent RS-80 radiosonde serial numbers are coded

```
YWWDTTTNN, in which

   Y = last digit of the year
  WW = week number (1-53)
   D = day of the week (1-7) Monday=1
 TTT = calibration tray identifier
  NN = position in calibration tray
```

RS-90 radiosondes and RS-92 radiosondes (no distinction between the types in serial number) are coded

```
YWWDSSSS, in which

   Y = alphabetic code for the year (T=1998, U=1999, etc.)
  WW = week number (1-53)
   D = day of the week (1-7) Monday=1
SSSS = sequence number
```

How do I decode the 'Launch Status' metadata?

The Launch Status word is coded as follows:

```
SmSmSmSmSmSmSmSmSmSm NNNNNNNNNNNNNNN
IIiii
YrYrMoMoDaDa HrHrMnMn
SnSnSnSnSnSnSnSnSn
PcoPcoPco TcoTcoTco UcoUcoUco
ChnChnChn
PacPacPac PmdPmdPmd PrjPrjPrj
TacTacTac TmdTmdTmd TrjTrjTrj
UacUacUac UmdUmdUmd UrjUrjUrj
PmiPmiPmi TmiTmiTmi UmiUmiUmi
TiTiTi RRR HeHeHe
AoAoAo BoBoBo CoCoCo
DoDoDo EoEoEo FoFoFo
GoGoGo HoHoHo
aoaoao bobobo cococo
```

Where:

```
SmSmSm...       sounding number
NNN...          station name
II              WMO block number
iii             international station number
YrYrMoMoDaDa    date of sounding
HrHrMnMn        time of balloon release
SnSnSn...       radiosonde serial number
PcoPcoPco       ground check correction for pressure
                in tenths of a hPa
TcoTcoTco       ground check correction for temperature
                in tenths of a °C
UcoUcoUco       ground check correction for humidity
                in %RH
ChnChnChn       percentage of successful attempts to
                identify signal sequence
PacPacPac       accepted levels of P (%)
PmdPmdPmd       replaced levels of P (%)
PrjPrjPrj       rejected levels of P (%)
TacTacTac
```

```
TmdTmdTmd       as for P
TrjTrjTrj
UacUacUac
UmdUmdUmd       as for P, T
UrjUrjUrj
PmiPmiPmi       maximum interpolated layer in 10
TmiTmiTmi       second units for PTU profiles
UmiUmiUmi
TiTiTi          duration of ascent in 10 second units
RRR             reason for termination
                001     stop command
                004     maximum interpolation time of
                        pressure or temperature exceeded
                005     increasing pressure
                006     prelaunch set limit exceeded
                010     no PTU signal
HeHeHe          altitude reach in units of 100m
```

For Loran soundings (SGP)

```
AoAoAo          station in wind calculations (%)
BoBoBo          Master stations are AoAoAo and
...             GoGoGo.  Others are slave stations
HoHoHo

cococo
```

For GPS soundings (TWP)

```
AoAoAo          percentage of valid raw wind levels
BoBoBo          percentage of valid raw wind levels
                which have at least 5 satellites in track
CoCoCo          percentage of valid raw wind levels
                which have at leave 4 satellites in track
DoDoDo          percentage of raw wind levels rejected
                due to poor PDOP
EoEoEo          percentage of raw wind levels which
                have unidentified channel in solution
FoFoFo          not used
GoGoGo          10*mean track count of all levels
HoHoHo          10*mean track count of valid levels
aoaoao          cumulative minutes of long (>1min) time gaps
bobobo          not used
cococo          not used
```

What is this about "dry bias" in Vaisala radiosondes?

Since the beginning of the program, ARM has conducted ongoing data quality studies involving comparisons among different instruments. One of the oldest of these compares the perceptible water vapor (PWV) retrieved from the microwave radiometer (MWR) with the PWV calculated from the radiosonde soundings. Over the years, these comparisons have helped to detect problems with both these and other instruments. After collecting years of data it became apparent that sequences of radiosonde launches showed lower PWV than the MWR. At first this finding was thought to be due to batch-to-batch calibration variations. Indeed, ARM discovered that a large batch of Vaisala radiosondes were incorrectly calibrated in November 1994 (see DQR960229.1).

More recent work has shown that the batch-to-batch variability in relative humidity results from contamination of the humidity sensor by organic vapors originating in the plastic parts of the radiosonde. The effect of the contamination is to reduce the number of polymer binding sites available for water vapor and thus bias the sensor output low. A Problem Identification Report (PIF990129.5) describing the bias problem has been filed.

Vaisala has developed a proprietary processing algorithm that is supposed to correct the radiosonde data for the dry bias. The problem and the algorithm is described in some detail in Lesht (1999) and Miller et al. (1999).

6. Data Quality

6.1 Data Quality Health and Status

The following links go to current data quality health and status results:

- DQ HandS (Data Quality Health and Status)
- NCVweb for interactive data plotting using.

The tables and graphs shown contain the techniques used by ARM's data quality analysts, instrument mentors, and site scientists to monitor and diagnose data quality.

Click on one of the links below to look at the current/recent data quality or operational health and status of BBSS. These various sources will provide you with an idea of how ARM data quality analysts, instrument mentors, site scientists, and site operators closely monitor instrument performance in the real time.

- **SGP**

  Data Quality Health and Status
  Sounding Status Reports
  Prelaunch Logs

- **NSA**

  Sounding Logs

- **TWP**

  DSView

6.2 Data Reviews by Instrument Mentor

The BBSS Instrument Mentors perform a number of tasks to assure the quality of BBSS data. Data quality control procedures for this system are considered **mature**.

- QC frequency: Daily
- QC delay: Real-time; weekly
- QC type: Min/max/delta flags; graphical plots; mentor reviews
- Inputs: Raw data files
- Outputs: Hard copy plot of every sounding
- Reference: None

Standard BBSS data are subject to several levels of quality control and quality assurance. The process of converting the raw 1.5-second PTU samples to values output every 2 seconds involves filtering, editing, and interpolation intended to provide the best estimate of the atmospheric state at every level. The details of the processing are not well documented. They are being analyzed by the instrument mentor and more information will be provided when it is available.

Daily logs that include operator comments regarding the system and a listing of DQ flags set during the ingest are sent to instrument mentor. He reviews these logs practically every day.

The mentor makes a hard copy plot of every sounding daily. He examines the plots for features that may suggest a DQ problem that did not set one of the automatic flags. The plots also are used to verify and evaluate the DQ problems identified by the automatic procedures. If a problem is significant enough to highlight, he writes and submits a DQR for data users and submits a DQPR to site operators (SGP) to initiate corrective maintenance.

The mentor receives weekly output from the ongoing Quality Measurement Experiment (QME) involving the BBSS and the MWR (QMEMWRCOL). He processes this output to evaluate the longer-term performance of the radiosondes by comparison with the MWR, with special attention to sonde calibration lot. If it appears that a particular calibration lot may have a DQ problem, he (1) issues a request to site operations personnel to hold all remaining radiosondes from the questionable lot, (2) issues a DQR related to all soundings done using radiosondes from the questionable lot, and (3) contacts the manufacturer to arrange for special retesting of the sondes from the questionable lot.

The mentor also does a weekly comparison of the surface values of pressure, temperature, and humidity for each sounding with the coincident measurements obtained by the collocated temperature, humidity, winds, and pressure system (THWAPS). These comparisons help to highlight operator data entry problems or calibration errors. Sample comparisons (left) and sounding profiles (right) are provided in Figure 1.

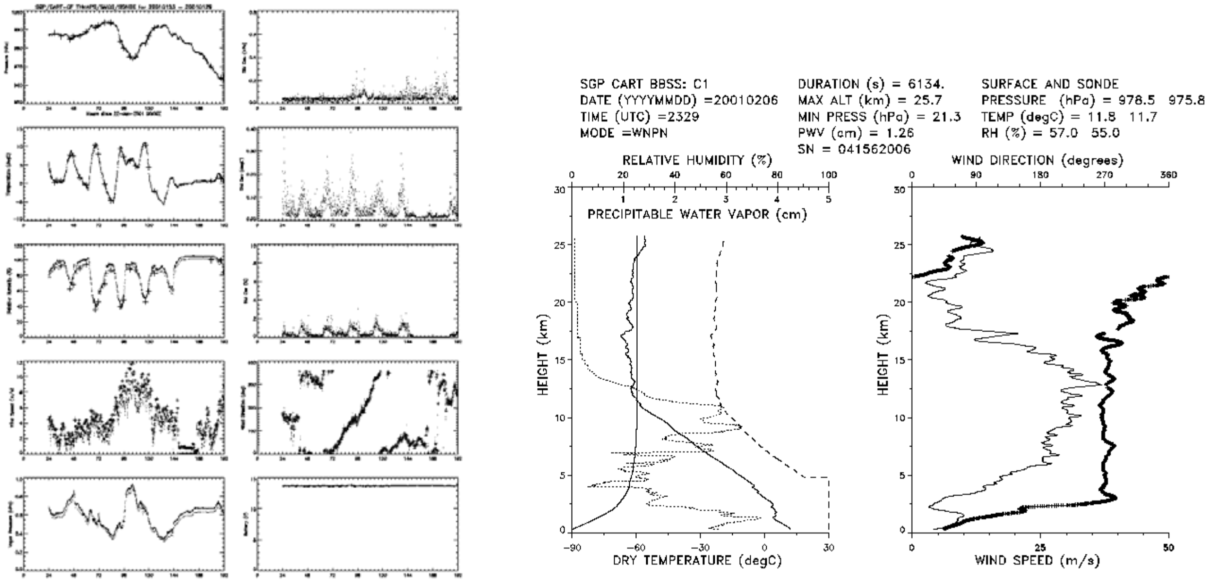

Figure 1. Sample comparisons of sounding profiles

6.3 Data Assessments by Site Scientist/Data Quality Office

The **SGP Site Scientist Team and Data Quality Office** extract automated flag information from BBSS files to produce tables of color-coded flag status. It also performs visual inspections of Skew-T/log p plots (from the NSDL Quicklooks Website), comparisons of sonde and 60-m tower temperature and relative humidity (CF site only), and comparison plots of THWAPS, Surface Meteorological Observing Station, EBBR, and cloud mask for temperature, humidity, and pressure (CF only). A weekly assessment report is issued to the Instrument Mentor and SGP Site Operations in which data are verified as suitable for use, or irregularities are noted. Such mentor and site scientist results then trigger the writing of appropriate DQPRs (SGP) to initiate corrective maintenance and ARM DQRs for data users.

To see these color status tables and BBSS plots, go to the SGP Data Quality Health and Status site. Once there, you will see a color status table for the current month. To see the color status for the launches of a particular day, pick a site and day, toggle “Submit Request,” and this will reveal the color status tables of the launches made that day. If you place your mouse over non-green boxes, a pop-up will reveal which flags were tripped and at what percentage. Click on “Diagnostic Plot” for the launch you are interested in to see its visuals and the NSDL quicklook for the Skew-T/log p.

The **NSA Site Scientist Team** makes visual inspections of various sonde quicklooks and VAP-like quicklooks it has developed. For the sondes, profiles of air temperature, dewpoint temperature, relative humidity, and water vapor are produced at 10-second averages over 0-1 km and 0-10 km profiles, respectively. Total column water vapor is also derived and compared to that from the MWR to detect possible discrepancies. On-line versions of such plots can be seen from the NSA quicklook server links in “**Data Quicklooks (near real-time)”** below.

Two sample sonde diagnostic plots that can be found on the NSA quicklook server are shown in Figure 2, one for the 0-1 km profile (left) and another for 0-10 km profile (right).

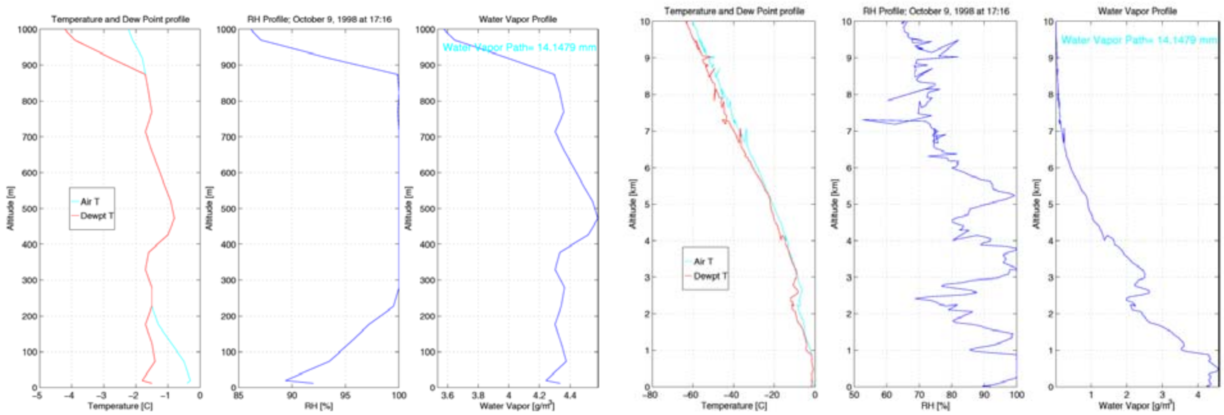

Figure 2. Sample sonde diagnostic plots

The **TWP Site Scientist Team** tests for missing sondes. Total column water vapor is derived and compared to that from the MWR to detect possible discrepancies. Diagnostic plots and further sonde checks are currently under construction.

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. Despite extensive instrumentation deployed at the ACRF 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 "value-added" products and can help fill some of the unmet measurement needs of the program. Conversely, ARM produces some "value-added" products not 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" "value-added" products. A special class of "value-added" product called a 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.

BBSS-related "value-added" products include:

- LSSONDE – Produces radiosonde profiles in which the moisture profile is scaled to match MWR total perceptible water vapor.

BBSS-related QMEs include:

- QMEMWRCOL – Results from this QME are used to evaluate the MWR and radiosondes.
- QMEMWRPROF – Comparisons of retrieved water vapor and temperature profiles from mwrprof with radiosonde profiles.

- QMEAERIPROF – This QME helps to assess the ability of the radiosondes and in situ tower measurements to observe moisture and temperature in the atmosphere.
- QMEAERILBLCLOUDS – Uses radiosonde pressure, temperature, and moisture data as input.

7. Instrument Details

7.1 Detailed Description

7.1.1 List of Components

The BBSSs consist of disposable radiosondes and fixed ground stations. All facilities use the same basic radiosondes, but the ground stations differ somewhat. Each ACRF site uses Vaisala ground stations.

Radiosondes:

ARM practice has been to adopt the most advanced radiosonde technology provided by Vaisala as soon as it has been proven. ARM was the first large-scale program to use the advanced H-Humicap in the RS80 family of radiosondes, the first research program to make the transition to the dual-humicap RS90 family, and the first program to use the RS92 family. Before making the change between radiosonde types, ARM conducted month-long transition IOPs during which the new type of radiosonde was flown alongside the type being replaced. Each of these experiments took place at the SGP.

- Manufacturer: Vaisala, Inc.
- AMF
  - RS92-SGP (GPS windfinding)
- SGP
  - RS80-15LH (Loran-C windfinding, H-Humicap, 403 MHz) through April 2001
  - RS90-AL (Loran-C windfinding, dual humicap) beginning May 2001
  - RS92-KL (Loran-C windfinding, dual humicap) beginning 17:30 UTC February 9, 2005
- TWP
  - RS80-15GH (GPS windfinding, H-Humicap, 403 MHz) through May 2002
  - RS90-AG (GPS windfinding, dual humicap) beginning June 2002
  - RS92-SGP (SGP windfinding, dual humicap) beginning April 2005
  - RS80-15 (Radar-tracked winds) at Darwin (C3) to January 18, 2006 (1630 UTC)
  - RS92-15 (Radar-tracked winds) at Darwin (C3) beginnin January 18, 2006 (2315 UTC)
- NSA
  - RS80-15H (PTU only, H-Humicap, 403 MHz) used with CLASS through April 2002
  - RS90-A (PTU only, dual humicap) beginning April 25, 2002
  - RS90-AG Occasionally in use beginning April 25, 2002
  - RS92-K (PTU only) and RS92-SGP (GPS windfinding) in use occasionally beginning January 2005.

Ground Stations:

The essential attributes of the ground stations employed by ARM are reported in Tables 1 and 2.

7.1.2 System Configuration and Measurement Methods

Original sampling rate (May 27, 1992, to May 30, 1993):

The raw sampling rate of thermodynamic sensors is approximately 1.5 seconds. The rate at which processed data is output to the datastream is programmable. For the first several months of operation at the SGP site, we used a scheme in which PTU and wind data were output at three different rates, depending on the time into the sounding. These sampling rates were as follows:

- Sample output every 10 seconds from 0 to 120 seconds into the flight.
- Sample output every 30 seconds from 120 to 900 seconds into the flight.
- Sample output every 60 seconds from 900 seconds to the end of the flight.

Sampling rate (NSA) to May 1, 2002:

- Thermodynamic variables (PTU) output every ten seconds throughout the flight.
- Wind variables (speed, direction) were not measured.

Sampling rate (SGP/TWP) from June 1, 1993, to November 24, 2000:

- Thermodynamic variables (PTU) output every two seconds throughout the flight.
- Wind variables (speed, direction):
  - Output every ten seconds (SGP)
  - Output every two seconds (TWP).

Current Sampling rate (SGP/TWP/NSA):

- Thermodynamic variables (PTU) output every two seconds throughout the flight.
- Wind variables (speed, direction) output every two seconds throughout the flight.

Balloons and rate of ascent:

ARM uses 350-gal balloons at all sites. The nominal ascent rate is approximately 5 m/s, although this is variable during the flight. The data file includes a variable ‘asc’ which, for each sample, estimates the current rate of ascent. This rate is actually a 30-second average rise rate based on the calculated sonde altitudes.

Software Configuration of the SGP digiCORA Systems

The following links are to the current software configuration listings for the Vaisala MW-11 and MW-15 digiCORA systems now in use at the NSA, SGP, and TWP sites. As shown in Table 1, the MW-11 systems are nominally assigned to BF1 (Hillsboro, Kansas), BF4 (Vici, Oklahoma), BF5

(Morris, Oklahoma), and BF6 (Purcell, Oklahoma). Three MW-15 systems are assigned to TWP (C1, C2, spare) and one to SGP (spare). The configuration listings show the installed software applications as well as their version numbers.

SGP

BF1
BF4
BF5
BF6
Spare

TWP

C1
C2
Spare

7.1.3 Specifications

The manufacturer's specifications for the thermodynamic sensors are as follows:

```
PRESSURE
  Type:       Capacitive aneroid
  Range:      1060 hPa to 3 hPa
  Resolution: 0.1 hPa
  Accuracy:   0.5 hPa

TEMPERATURE
  Type:       Capacitive bead
  Range:      +60°C to -90°C
  Resolution: 0.1°C
  Accuracy:   0.2°C
  Lag:        <2.5 s (6 m/s flow at 1000 hPa)

HUMIDITY
  Type:       H-HUMICAP thin film capacitor
  Range:      0 to 100 %RH
  Resolution: 1 %RH
  Accuracy:   2 %RH (0 to 80 %RH)
              3 %RH (80 to 100 %RH)
  Lag:        1 s (6 m/s flow at 1000 hPa, +20°C)
```

Note that the "accuracy" figures given by the manufacturer represent the standard deviation of the differences obtained from repeated calibrations. As such, these values are more properly termed "precision." Operational experience at the SGP site (Lesht 1995) showed that the root mean square error in RH was approximately 1% RH at low humidity and surface temperature and that the root mean square error in temperature was approximately 0.3°C.

Winds

Wind information (SGP) is obtained by tracking the radiosonde's position using the Loran-C navigation system. The accuracy of the wind information depends on the configuration of the Loran-C stations that are used to locate the sonde. Loran-C coverage in the SGP area is fairly good, and we estimate the accuracy of the wind speed to be approximately 0.5 m/s.

We use GPS wind-finding at the TWP locations. This satellite-based navigation system is very precise and we estimate the accuracy of the wind velocity to be 0.2 m/s.

7.2 Theory of Operation

This section is under construction.

7.3 Calibration

7.3.1 Calibration Theory

This section is under construction.

7.3.2 Calibration Procedures

This section is under construction.

7.3.3 Calibration History

This section is not applicable to this instrument.

7.4 Operation and Maintenance

7.4.1 User Manual

Each site maintains its own radiosonde launch procedures. The Vaisala User's Manual for the digiCORA-III system may be accessed here.

7.4.2 Routine and Corrective Maintenance Documentation

The following link points to the General Preventative Maintenance Procedures in place for all sites

7.4.3 Software Documentation

This section is under construction.

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.

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