DOE/SC-ARM-TR-029

Balloon-Borne Sounding System (SONDE) Instrument Handbook

D Holdridge

November 2020

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

Acronyms and Abbreviations

ADC	ARM Data Center
AIRS	atmospheric infrared sounder
AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
ASCII	American Standard Code for Information Interchange
BBSS	older ARM name for SONDE
BF	boundary facility
BoM	Bureau of Meteorology (Australia)
CF	Central Facility
CLASS	Cross-chain Loran Atmospheric Sounding System
DQPR	Data Quality Problem Report
DQR	Data Quality Report
EBBR	energy balance Bowen ratio station
ECMWF	European Centre for Medium-Range Weather Forecasts
ENA	Eastern North Atlantic
GMT	Greenwich Mean Time
GPS	Global Positioning System
ID	identification
IOP	intensive operational period
MET	surface meteorological instrumentation
MWR	microwave radiometer
netCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NSA	North Slope of Alaska
PNG	Papua New Guinea
PTU	pressure, temperature, relative humidity
PWV	precipitable water vapor
QC	quality control
QME	Quality Measurement Experiment
RH	relative humidity
SGP	Southern Great Plains
SONDE	balloon-borne sounding system
TWP	Tropical Western Pacific
UTC	Coordinated Universal Time
VAP	value-added product
WMO	World Meteorological Organization

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1.0 General Overview

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

2.0 Contacts

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3.0 Deployment Locations, History, and Significant Events

As of August 2020:

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

- Barrow, (Great White, C1) 71.32N, 156.62W, 27 m
  - Production system: digiCORA-III Autosonde AS14/15 s/n F04101 (June 10, 2011–present)
  - Production system: digiCORA-III s/n W03202 (April 24, 2002–June 10, 2010) (disposed August 3, 2017)
  - Atmospheric infrared sounder (AIRS) validation intensive operational period (IOP) system: pcCORA (July 22, 2002–October 31, 2002)
  - Spare system: digiCORA-II s/n R41204 (August 15, 2004–January 1, 2008)
  - 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
  - Updated digiCORA-III to v3.61.1 June 7, 2009
  - Attached GC25 via cable June 7, 2009
  - Applied Vaisala GPS Hotfix June 24, 2009
  - Installed Vaisala Autosonde AS14 system, June 2011
  - Autosonde software upgrade v3.64.1 July 16, 2012
  - Upgraded autosonde to AS15 MW41 September 15, 2017
  - First RS41-Southern Great Plains (SGP) launch October 18, 2017
  - Changed World Meteorological Organization (WMO) identification (ID) (from 07027) to National Weather Service ID (07026) as part of cooperative agreement February 11, 2019
  - Began launching National Weather Service radiosondes (1101, 2301GMT) February 12, 2019
  - Updated autosonde AS15 to be explosion-proof September 16, 2019
  - Installed National Weather Service hydrogen generator September 16, 2019
  - Official startup of hydrogen generator after Sandia National Laboratories approvals December 16, 2019

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

At the Tropical Western Pacific (TWP) locale:

- Manus Island, Papua New Guinea (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)
  - Applied Vaisala GPS Hotfix June 24, 2009
  - Updated digiCORA-III to v3.61.1 December 7, 2009
  - Updated DigiCORA-III software to v3.64.1 September 9, 2011
  - Site Operations End July 7, 2014 s/n B31401 moved to use as a spare
- Republic of Nauru (C2) 0.52S, 166.92E, 7 m
  - Production system: digiCORA-III (MW-31) s/n B31402
  - 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)
  - Applied Vaisala GPS Hotfix June 24, 2009
  - Updated digiCORA-III to v3.61.1 January 7, 2010
  - Updated DigiCORA-III software to v3.64.1 April 4, 2012
  - Site Operations End August 30, 2013 s/n B31402 moved to use as a spare
- 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)
  - Data collection ends December 31, 2014

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)

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

- Production system: digiCORA-II s/n R48501 (April 13, 1999–July 31, 2002)
- Production system: digiCORA-III s/n W09201 (August 1, 2002–May 12, 2010)
- Production system: digiCORA-III s/n E50402 (May 12, 2010–present)
- AIRS validation IOP system (S01): digiCORA-I s/n 574791 (disposed Oct 2, 2014)
- AIRS validation IOP system (S02): digiCORA-I s/n 708515 (disposed Oct 2, 2014)
- System installed May 27, 1992
- 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 upgraded to generate WMO-coded messages for National Weather Service March 24, 1997
- Installed MW-15 digiCORA-II September 1, 1997 for water vapor IOP
- Changed regular sounding schedule from 5 per day to 3 per day November 14, 1997
- Added 0530 Coordinated Universal Time (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
- Attached GC25 via cable June 17, 2009
- Applied Vaisala GPS Hotfix July 22, 2009

- Updated digiCORA-III to v3.61.1 November 30, 2009
- Installed new MW-31 DigiCORA-III system s/n E50402
- Updated DigiCORA-III software to v3.64.1 April 2, 2012
- Upgraded system to MW41 v2.04 April 12, 2017
- First RS41-SGP launch November 13, 2017

- 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 GPS wind-finding 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
  - Routine balloon operations end December 2002
- 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 wind-finding 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

- Routine balloon operations end December 2002

- 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 wind-finding 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
  - Routine balloon operations end December 2002
- 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 wind-finding 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
  - Routine balloon operations end December 2002
- First ARM Mobile Facility (AMF1)
  - Production system: DigiCORA-III s/n W09201 (February 2005−May 2012)
  - Production system: DigiCORA-III s/n G45502 (May 2012–present)
  - Upgraded system to MW41 v2.04 April 27, 2018
  - First RS41-SGP launch May 2, 2018

- Second ARM Mobile Facility (AMF2)
  - Production system: DigiCORA-III s/n E50401 (November 15, 2010–present)
  - Upgraded system to MW41 v2.04 September 25, 2018
  - First RS41-SGP launch September 25, 2018
- Third ARM Mobile Facility (AMF3)
  - Production system: DigiCORA-III s/n H27504 (September 1, 2013–present)
  - Upgraded system to MW41v2.04 May 19, 2017
  - First RS41-SGP launch November 15, 2018
- The Eastern North Atlantic (Azores) site (ENA)
  - Production system: DigiCORA-III s/n H27505 (September 1, 2013–present)
  - Upgraded system to MW41v2.04 April 11, 2018
  - Upgraded MW41 software to v2.14, installed new python script December 4, 2019
  - First RS41-SGP launched January 12, 2019
- Spare systems (may or may not be in use, see Table 2 for details)
  - MW41 s/n B31401
  - MW41 s/n B31402
  - MW41 s/n J34403
  - MW41 s/n M32304
  - MW41 s/n M34206

Table 1 shows the general attributes of each of the Atmospheric Radiation Measurement (ARM) user facility-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. ARM-owned Vaisala radiosonde ground stations (retired).

	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	3.61.1	3.61.1	3.61.1	3.61.1	3.61.1
Operational status	Retired	Retired	Retired	Retired	Retired	Retired	Retired	Retired	Replaced w/ M36105*	Replaced w/ M36104*	Replaced w/ M36103*	Spare – In use*	Spare – In use*

Field campaign deployment													
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)				
MASRAD - Point Reyes											PYE/M1		
RADAGAST-Niamey											NIM/M1		
COPS-Black Forest											FKB/M1		
CLASIC (SGP)	SGP/B4	SGP/B1	SGP/B5	SGP/S06									
AIRS/IASI			SGP/S01	SGP/S02				NSA/S01	NSA/C1				
HFE - China											HFE/M1		
CAP-MBL									GRW/M1				
GVAX									PGH/M1				

Table 2 shows ARM's current inventory (as of 2020) of deployed/deployable MW41 Vaisala ground stations.

*Please see Table 2: Current ARM-owned Vaisala radiosonde ground stations (2020).

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

Table 2. ARM-owned Vaisala radiosonde ground stations (as of August 2020).

	Common name											
	Manual launch systems											Autosonde AS15
Model	MW41	MW41	MW41	MW41	MW41	MW41	MW41	MW41	MW41	MW41	MW41	MW41
S/N	E50402	M32304	M34206	M36104	B31401	J34403	H27505	G45502	E50401	H27504	B31402	F04101
Base location	SGP/C1	SGP/Spare	SGP/Spare	NSA/S01	SGP/Spare	SGP/Spare	ENA/C1	AMF1	AMF2	AMF3	SGP/Spare	NSA/C1
Assignment	SGP/C1	SGP/S01	SGP/S02	NSA/S01	Spare	Spare	ENA/C1	AMF1	AMF2	OLI/M1	Spare	NSA/C1
GPS equipped	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	NO
RS41 compatible	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Software updates	4/12/2017 v2.04	4/12/2017 v2.04	4/12/2017 v2.04	4/12/2017 v2.04	8/11/2017 v2.04	4/12/2017 v2.04	4/11/2018 v2.04	4/27/2018 v2.04	9/25/2018 v2.04	5/19/2017 v2.04	11/30/2018 v2.04	2017 v2.10.2
						1/10/2020 v2.14	12/4/2019 v2.14					7/20/2020 v2.11
RS41 first launch[2]	11/13/2017	1/14/2018		2/27/2018		4/25/2018	1/12/2019	5/2/2018	9/25/2018	11/15/2018	11/30/2018	10/18/2017
Operational status	Fixed site - Routine	IOP/Spare	IOP/Spare	IOP/Spare	IOP/Spare	IOP/Spare	Fixed site -Routine	IOP/Spare	IOP/Spare	AMF site - Routine	IOP/Spare	Fixed site - Routine

Field Campaign Deployment												
STORMVEX									SBS/M1			
AMIE-GAN									GAN/M1			
TCAP								PVC/M1				
MAGIC									MAG/M1			
AMF3										OLI/M1		
GOAMAZON								MAO/M1				
BAECC									TMP/M1			
ACAPEX									ACX/M1			
AWARE								AWR/S1			AWR/S1	
LASIC								ASI/S1				
MAECUS									MAR/M1		MAR/M1	
CACTI								COR/S1			COR/M1	
COMBLE								ANX/M1			ANX/M1	
JPSS/RIVAL	SGP/C1	SGP/S01	SGP/S02	NSA/S01	NSA/S02	ENA/S01	ENA/C1					NSA/C1

[2] MW41 software install date and RS41 first launch date do not align because all remaining RS92 radiosonde stock was launched before beginning on new RS41 radiosonde stock.

4.0 Near-Real-Time Data Plots

The ARM Data Quality Office (https://dq.arm.gov/) provides several tools in which to view data. Plots of ARM sounding data from all sites may be accessed by using DQ-Explorer (https://dq.arm.gov/dq-explorer/cgi-bin/main), DQ-Plotbrowser (https://dq.arm.gov/dq-plotbrowser/), or DQ-Zoom (https://dq.arm.gov/dq-zoom/).

5.0 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 Data Center (ADC) 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 3; examples of the ASCII files are available through the links provided in Section 5.2.

Table 3. 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 ADC. Binary raw thermodynamic data directly from the radiosonde Binary copy of processed thermodynamic and wind data
MW11 and MW15 (digiCORA-I and -II) The standard ASCII data are transmitted by a serial connection in real time to the site data system where they are 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 ADC.	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 ADC. 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

Radiosonde system	Filename	Description
Note that raw files associated with GPS radiosondes will be named "GPSSND.xxx" rather than "LORANC.xxx."		
MW21 (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 ADC. • ASCII file with raw thermodynamic data directly from the radiosonde • Binary sounding database file
MW31 (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 ADC. • ASCII file with raw thermodynamic data directly from the radiosonde Binary sounding database file
MW41 All files are created and stored on the local instrument computer and collected by the site data system when the sounding is completed.	SSSsonde-curFF.YYYYMMDD.HHMM.raw SSSFF__MW41_YYYYMMDD_HHMMss.mwx	• Standard ASCII output with processed data: this file is passed to the ingest module to create the netCDF files distributed by the ADC. • Backup data file containing multiple separate XML-formatted datafiles, each of them having a different category of data.

5.1.1 Data Availability

ARM archives all data in the ARM Data Center managed by Oak Ridge National Laboratory. For details on all sonde data available for download, please see:

https://adc.arm.gov/discovery/#/results/instrument_class_code::sonde (click on the Data Product name "sondewnpn" to expand the selection for all sites).

5.1.2 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 datastream, also measured as functions of time, are:

- Altitude (masl) netCDF name = “alt”
- Dew point (°C) netCDF name = “dp”
- Ascent rate (m/s) netCDF name = “asc”
- 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”

5.1.2.1 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 4.

Table 4. Technical specifications and manufacturer's stated uncertainty for the meteorological sensors used in radiosondes used by the ARM facility.

	RS-80H			RS-90 and RS-92 all types			RS-41 all types		
	Pressure	**Temperature**	**Humidity**	**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	surface pressure 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[4]	0.01 hPa	0.01°C	0.1% 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)	n/a	0.5 s (1000mb)	< 0.3 s (20 ºC) < 10 s (, -40 ºC)
Repeatability	0.5 hPa	0.2°C	2%RH	0.4 hPa	0.15°C	2%RH	0.4 hPa	0.1 °C	2%RH
Reproducibility	0.5 hPa	0.2°C > 50 hPa 0.3°C > 15 hPa 0.4°C < 15 hPa	3%RH	0.5 hPa	0.2°C > 100 hPa 0.3°C < 20 hPa	3%RH	0.5 hPa	0.15 °C	2%RH
Uncertainty	n/a	n/a	n/a	1.0 hPa	0.5°C	5%RH	1.0 hPa	0.3 °C	4%RH

5.1.3 Secondary/Underlying Variables

This section is not applicable to this instrument.

5.1.4 Diagnostic Variables

This section is not applicable to this instrument.

5.1.5 Data Quality Flags

Some automated data quality checks are included in the processed SONDE 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 SONDE are shown in Table 5.

An example SONDE file header (Data Object Design), which contains information on SONDE automated QC, for the SGP can be found at https://adc.arm.gov/headers/sgpsondewnpnC1.b1.header.txt and for the older NSA data at ISSSONDE.

[4] Nominal resolution value – data collected using digiCORA-III ground station may be reported with higher precision.
All values taken from Vaisala datasheets.

Table 5. Data quality min/max limits.

Variable	Name	Units	SGP			TWP			NSA		
			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

5.1.6 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[5] (SSSsondeFF.YYYYMMDDhhmmss.ptu)

5.3 User Notes and Known Problems

Soundings at the North Slope of Alaska

The SONDE 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

[5] Raw thermodynamic ASCII files are produced regularly only by the digiCORA-III systems at AMFs, ENA, NSA, and SGP. MW41 systems do not produce the .ptu files.

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 wind-finding. 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, In Australia's Northern Territory (C3), through a collaborative agreement with the Australian Bureau of Meteorology (BoM). Under this agreement, BoM supplies the raw radiosonde data to ARM and ARM reformats it and ingests it to produce ARM-standard netCDF files that are distributed to the scientific community through the ADC. 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 ADC or by special request to ADC 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 SONDE data files from the NSA named differently than SGP and TWP files?

As noted in Section 5.3, the original SONDE 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 wind-finding. 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 SONDE 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, RS-92 and RS-41 radiosondes (no distinction between the types in serial number) are coded:

```
YWWDSSSS, in which

   Y = alphabetic code for the year (T=1998, U=1999, … J=2013, K=2014, etc.)[6]
  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
```

[6] The letter "O" is skipped in the year sequencing.

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

```
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
```

NOTE: In RS41 data files, not all codes are available due to change in Vaisala output files formatting.

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

Since the beginning of the facility, ARM has conducted ongoing data quality studies involving comparisons among different instruments. One of the oldest of these compares the precipitable 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).

6.0 Data Quality

6.1 Data Visualization

Users may access data plotting and analysis tools provided by ARM's Data Quality Office:

- DQ-Explorer (https://dq.arm.gov/dq-explorer/cgi-bin/main)
- DQ-Plotbrowser (https://dq.arm.gov/dq-plotbrowser/)
- DQ-Zoom (https://dq.arm.gov/dq-zoom/)

6.2 Data Reviews by Instrument Mentor

The SONDE instrument mentors perform a number of tasks to assure the quality of SONDE/BBSS data.

Standard SONDE data are subject to several levels of quality control and quality assurance. The Vaisala software processes the PTU data to output files that 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 by Vaisala.

Radiosonde data plots are evaluated by the mentor and by the ARM Data Quality Office frequently. Daily checks are done to make sure all scheduled launches were performed as expected. If any issues are found with the data or the instrument, a Data Quality Problem Report (DQPR) is submitted to alert all stakeholders of the problem and corrective measures are taken to solve any issues or initiate repairs. If launches are missing for 24+ hours a Data Quality Report (DQR) is submitted to alert users to the issue cause and/or missing data.

6.3 Data Assessments by Site Scientist/Data Quality Office

The Data Quality Office extracts automated flag information from SONDE files to produce tables of color-coded flag status. It also performs visual inspections of Skew-T/log p plots, comparisons of sonde and 60-m tower temperature and relative humidity and comparison plots of surface meteorological instrumentation (MET), energy balance Bowen ratio station (EBBR), and cloud mask for temperature, humidity, and pressure. A weekly assessment report is issued to the instrument mentor in which data are verified as suitable for use, or irregularities are noted. Such mentor results then trigger the writing of appropriate DQPRs to initiate corrective maintenance and ARM DQRs for data users.

6.4 Value-Added Procedures and Quality Measurement Experiments

Many of the scientific needs of the ARM 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 facility. Conversely, ARM produces some VAPs 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” 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 ARM VAPs web page.

SONDE-related VAPs include:

- INTERPSONDE − Transforms sounding data into continuous daily files on a fixed time-height grid, from the surface up to a limit of approximately 40 kilometers, at one-minute time resolution.

- LSSONDE – Produces radiosonde profiles in which the moisture profile is scaled to match MWR total perceptible water vapor.
- MERGESONDE − Uses a combination of observations from radiosonde soundings, microwave radiometers, surface meteorological instruments, and European Centre for Medium-Range Weather Forecasts (ECMWF) model output.
- SONDEADJUST − Produces data that correct documented biases in radiosonde humidity measurements. *inactive
- SONDECALC – Recalculated wind/pressure/temp/rh. *inactive
- SONDEGRID – Gridded sonde VAP product.

SONDE-related QMEs include:

- QMEMWRCOL – Results from this QME are used to evaluate the MWR and radiosondes. *inactive

7.0 Instrument Details

7.1 Detailed Description

7.1.1 List of Components

The SONDEs consist of disposable radiosondes and fixed ground stations. All facilities use the same Vaisala radiosondes and ground stations. NSA employs a robotic Vaisala Autosonde launcher.

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 facility to use the advanced H-Humicap in the RS80 family of radiosondes, the first research facility to make the transition to the dual-Humicap RS90 family, and the first facility 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. For specific RS92-RS41 comparison, please see "*Comparison of Vaisala radiosondes RS41 and RS92 at the ARM Southern Great Plains site*". All sites transitioned to Vaisala RS41 radiosondes as their supplies of RS92 radiosondes were exhausted. Specific transition dates are listed below.

- Manufacturer: Vaisala, Inc.
- Radiosonde Model Manufacturer Data Sheets:

  RS80: (RS80 Specs.docx)

  RS90: https://www.vaisala.com/sites/default/files/documents/VN159_Measurement_Accuracy_and_Repeatability_of_Vaisala_RS90_Radiosonde.pdf (See Table 2) [Vaisala Radiosonde RS90-AL: Technical Information: Ref. B210310en-B {Vaisala RS90-AL Radiosonde.PDF}]

RS92: https://www.vaisala.com/sites/default/files/documents/RS92SGP-Datasheet-B210358EN-F-LOW.pdf

RS41: https://www.vaisala.com/sites/default/files/documents/RS41-SGP-Datasheet-B211444EN.pdf

- AMF (AMF1, AMF2, AMF3)
  - RS92-SGP (GPS wind-finding)
  - RS41-SGPD (GPS wind-finding)
    - AMF1 May 2, 2018
    - AMF2 September 25, 2018
    - AMF3 November 15, 2018
- SGP
  - RS80-15LH (Loran-C wind-finding, H-Humicap, 403 MHz) through April 2001
  - RS90-AL (Loran-C wind-finding, dual Humicap) beginning May 2001
  - RS92-KL (Loran-C wind-finding, dual Humicap) beginning 17:30 UTC February 9, 2005−February 8, 2010
  - RS92-SGP (GPS wind-finding) February 8, 2010–November 13, 2017
  - RS41-SGPD (GPS wind-finding) November 13, 2017–present
- TWP
  - RS80-15GH (GPS wind-finding, H-Humicap, 403 MHz) through May 2002
  - RS90-AG (GPS wind-finding, dual Humicap) beginning June 2002
  - RS92-SGP (SGP wind-finding, 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) beginning 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 wind-finding) in use occasionally beginning January 2005.
  - RS92-SGP (GPS wind-finding)
  - RS92-SGPA (GPS wind-finding) Autosonde June 2011
  - RS41-SGPD (GPS wind-finding) Autosonde October, 18, 2017

- ENA
  - RS92-SGP (GPS wind-finding) September 1, 2013
  - RS41-SGPS (GPS wind-finding) January, 12, 2019

Ground Stations:

The essential attributes of the ground stations used 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 10 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 10 seconds (SGP)
  - Output every two seconds (TWP).

Sampling rate for RS92 radiosondes:

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

Sampling rate for RS41 radiosondes at all sites:

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

Balloons and rate of ascent:

ARM uses 350-gram balloons at all sites. The nominal ascent rate is approximately 5-5.5 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 past 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 were nominally assigned to BF1 (Hillsboro, Kansas), BF4 (Vici, Oklahoma), BF5 (Morris, Oklahoma), and BF6 (Purcell, Oklahoma). Three MW-15 systems were 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. NOTE: All of these systems are obsolete and decommissioned. All sites use Vaisala DigaCORA MW41 systems. Please refer to Tables 1 and 2 for system use dates.

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:

RS41

```
PRESSURE
  Type:       Silicon Capacitor
  Range:      Surface pressure to 3 hPa
  Resolution: 0.01 hPa

TEMPERATURE
  Type:       Platinum Resistor
  Range:      +60°C to -95°C
  Resolution: 0.01°C
  Accuracy:   0.2°C
  Response:   0.5 s (6 m/s flow at 1000 hPa)

HUMIDITY
  Type:       H-HUMICAP thin film capacitor
  Range:      0 to 100 %RH
  Resolution: 0.1 %RH
```

```
  Accuracy:    2 %RH (0 to 80 %RH)
               3 %RH (80 to 100 %RH)
  Response:    < 0.3 s (6 m/s flow at 1000 hPa, +20°C
               < 10 s  (6 m/s flow at 1000 hPa, -40°C
```

RS92

```
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.

ARM switched to the use of GPS wind-finding at SGP after the Loran-C system was shut down on February 8, 2010. The SGP was the last site to switch from Loran-C to GPS radiosondes. The 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. See also manufacturer user manual references below:

- MW31 DigiCORA-III User's Guide
- MW41 Techical Reference

7.4.2 Routine and Corrective Maintenance Documentation

Preventive Maintenance Document

7.4.3 Software Documentation

This section is not applicable to this instrument.

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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