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DOE/SC-ARM-TR-183

Interpolated Sonde and Gridded Sonde Value-Added Products

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ARM

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
GRIDDEDSONDE	Gridded Sonde VAP
INTERPSONDE	Interpolated Sonde VAP
KAZRCOR	KAZR Corrected Data VAP
MWR	microwave radiometer
MWRRET	MWR Retrievals VAP
PWV	precipitable water vapor
QC	quality control
RH	relative humidity
SGP	Southern Great Plains
VAP	value-added product

Contents

Figures

Tables

1.0 Introduction

Standard Atmospheric Radiation Measurement (ARM) user facility sounding files provide atmospheric state data in one dimension of increasing time and height per sonde launch. Many applications require a quick estimate of the atmospheric state at higher time resolution. The INTERPSONDE (i.e., Interpolated Sonde) Value-Added Product (VAP) transforms sounding data into continuous daily files on a fixed time-height grid, at 1-minute time resolution, on 332 levels, from the surface up to a limit of approximately 40 km. The grid extends that high so the full height of soundings can be captured; however, most soundings terminate at an altitude between 25 and 30 km, above which no data are provided. Between soundings, the VAP linearly interpolates atmospheric state variables in time for each height level. In addition, INTERPSONDE provides relative humidity scaled to microwave radiometer (MWR) observations.

Figure 1 through Figure 3 present sample data from INTERPSONDE collected at the ARM Southern Great Plains (SGP) C1 site over 5 days: July 1-5, 2015. In Figure 1, the blue vertical lines represent times for which sounding data exists. The red contour represents gaps between soundings, where data are interpolated. Figure 2 and Figure 3 show resultant fields of temperature and relative humidity, respectively.

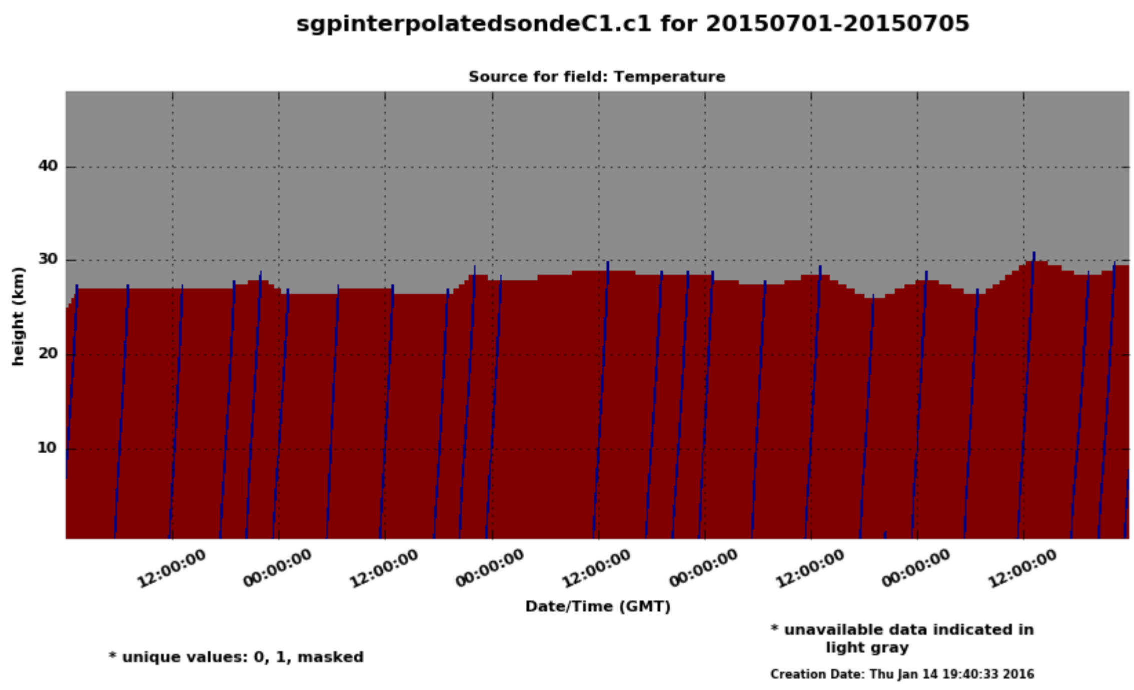

Figure 1. INTERPSONDE output profiles at the SGP C1 site (July 1-5, 2015). Blue areas reflect the collected sounding data while red areas are the linearly interpolated data.

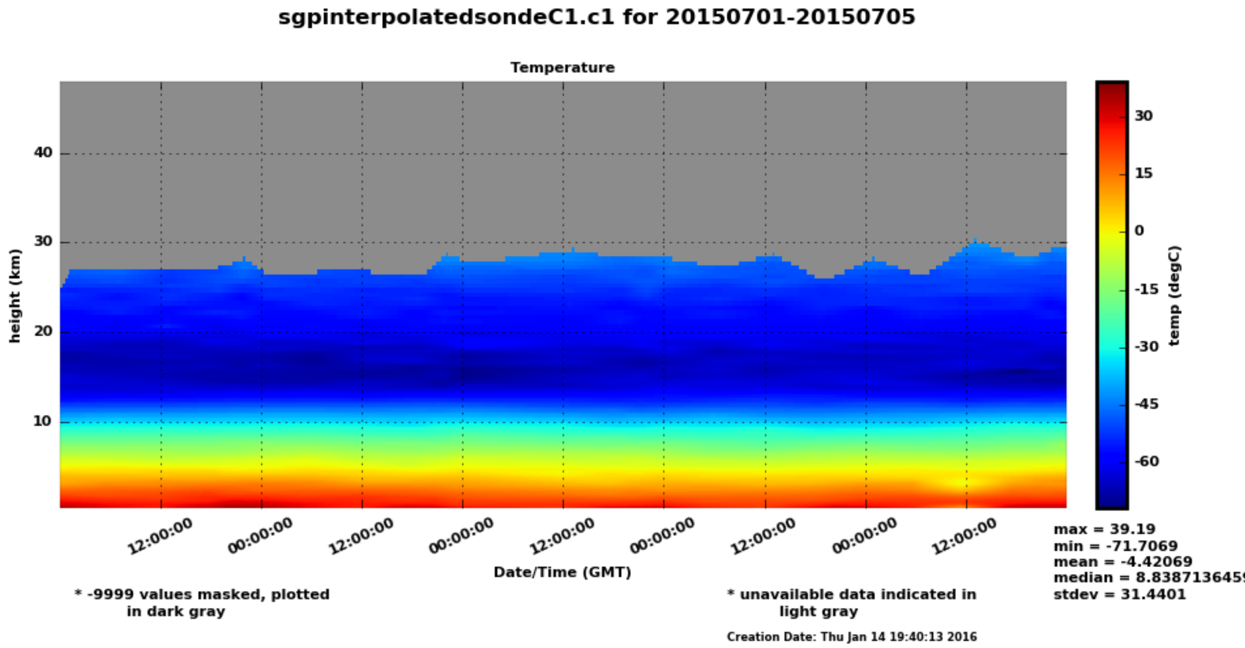

Figure 2. INTERPSONDE temperature output profiles at the SGP C1 site (July 1-5, 2015).

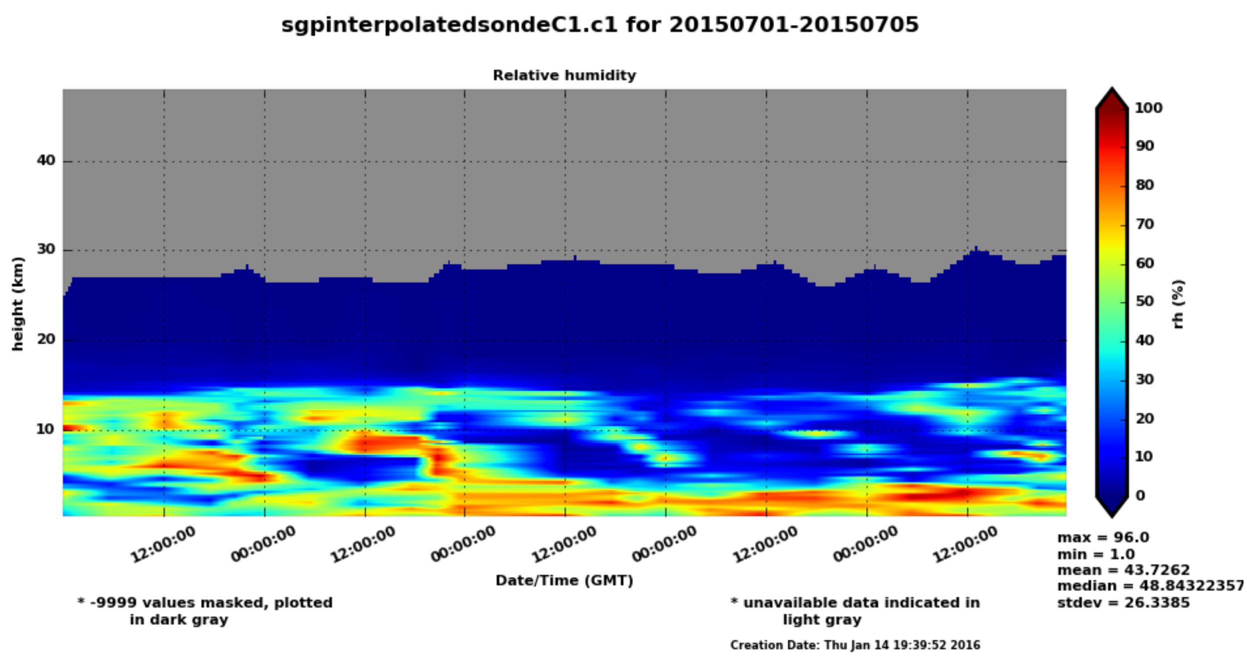

Figure 3. INTERPSONDE relative humidity output profiles at the SGP C1 site (July 1-5, 2015).

2.0 Input Data

The current version of INTERPSONDE only accepts sounding data and precipitable water vapor (PWV) estimates from MWR measurements as input, making it a true "interpolated sonde" product. Previous versions of INTERPSONDE incorporated surface and tower meteorology.

2.1 GRIDDEDSONDE

INTERPSONDE is ultimately generated from sounding files, but indirectly, through an intermediate product, known as the Gridded Sonde VAP (GRIDDEDSONDE), which is described in this section. GRIDDEDSONDE simply transforms standard ARM-format soundings files from one-dimensional, increasing in time and height, to a two-dimensional time-height grid, identical to the INTERPSONDE grid. To illustrate, the data provided by GRIDDEDSONDE is represented by the blue vertical lines in Figure 1. Note that each sounding value interpolated onto the fixed grid extends ±7.5 minutes, such that each blue vertical bar in Figure 1 is 15 minutes wide.

GRIDDEDSONDE accepts the ARM SONDEADJUST VAP (sondeadjust.c1) (Troyan 2011) for older soundings and original ARM sounding data files for newer and improved soundings (sondewnpn.b1). The SONDEADJUST VAP corrects Viasala radiosonde observations for known humidity biases (e.g., Milosevich et al. 2009). New Viasala software that accounts for these humidity biases was adopted by ARM beginning in 2001, thus negating the need for the SONDEADJUST VAP. Dates on which GRIDDEDSONDE switches from using SONDEADJUST to using sondewnpn will vary from site to site, as shown in Table 1.

Table 1. Date of last SONDEADJUST.

Site.Facility	Dates of Last SONDEADJUST	Site.Facility	Dates of Last SONDEADJUST
GAN.M1	February 9, 2012	TWP.C1	September 8, 2011
NSA.C1	July 16, 2012	TWP.C2	April 5, 2012
SGP.C1	August 32, 2012	TWP.C3	December 18, 2012

GAN is the ARM site on Gan Island in the Indian Ocean.
NSA is the ARM site on the North Slope of Alaska.
TWP is the ARM site in the Tropical Western Pacific.

Table 2 lists the input datastreams and variables to GRIDDEDSONDE, and the GRIDDEDSONDE output variable names. The GRIDDEDSONDE output is direct input to INTERPSONDE.

Table 2. Input datastream and variable names, and GRIDDEDSONDE output variables.

Datastream	Input Variables	GRIDDEDSONDE Output Variables
sondeadjust.c1 or sondewnpn.b1	alt	none
sondeadjust.c1 or sondewnpn.b1	pres	bar_pres
sondeadjust.c1 or sondewnpn.b1	dp	dp
sondeadjust.c1	rh_adjust	rh
sondewnpn.b1	rh	rh
sondeadjust.c1 or sondewnpn.b1	temp	temp
sondeadjust.c1 or sondewnpn.b1	u_wind	u_wind
sondeadjust.c1 or sondewnpn.b1	v_wind	v_wind

Note that GRIDDEDSONDE is not provided by ARM as an available datastream; however, the data contained in GRIDDEDSONDE can be gleaned from INTERPSONDE by using the source variables.

2.2 Microwave Radiometer Precipitable Water Vapor

Once data from GRIDDEDSONDE has been interpolated between soundings, INTERPSONDE uses estimates of PWV from MWR measurements as a constraint (Turner et al. 2007). As shown in Table 3, the process first attempts to use PWV estimates from the MWR Retrievals VAP (MWRRET; mwrret1liljclou; Gaustad et al. 2011), if available, and then from MWRLOS. [1]

Table 3. Input datastream and variable names.

Datastream	Input Variable
mwrret1liljclou.c1 or mwrretliljclou.c2	be_pwv
mwrlos.b1	vap

3.0 Algorithm and Methodology

3.1 General Flowchart

The flowchart in Figure 4 depicts the general steps involved in the production of the INTERPSONDE VAP.

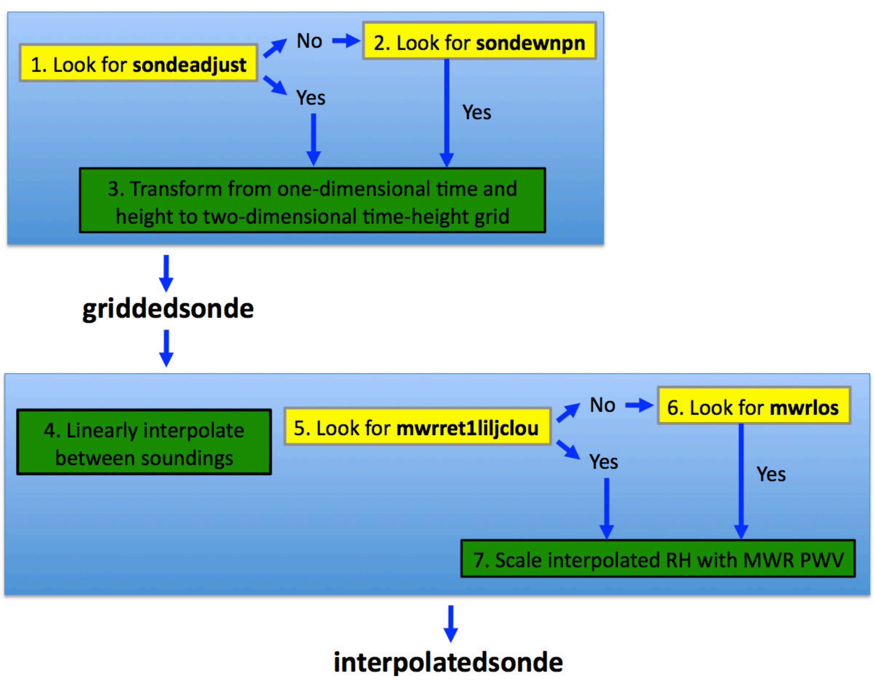

Figure 4. Steps to produce the INTERPSONDE Value-Added Product.

Note that, when processing a day of INTERPSONDE, ±2 days' worth of input data are retrieved. In this way, values may be interpolated in gaps between soundings of up to 5 days.

[1] http://www.arm.gov/data/datastreams/mwrlos

3.2 Relative Humidity Scaling Flowchart

In Figure 5, we expand on step 7 from Figure 4, depicting the steps required to scale the relative humidity.

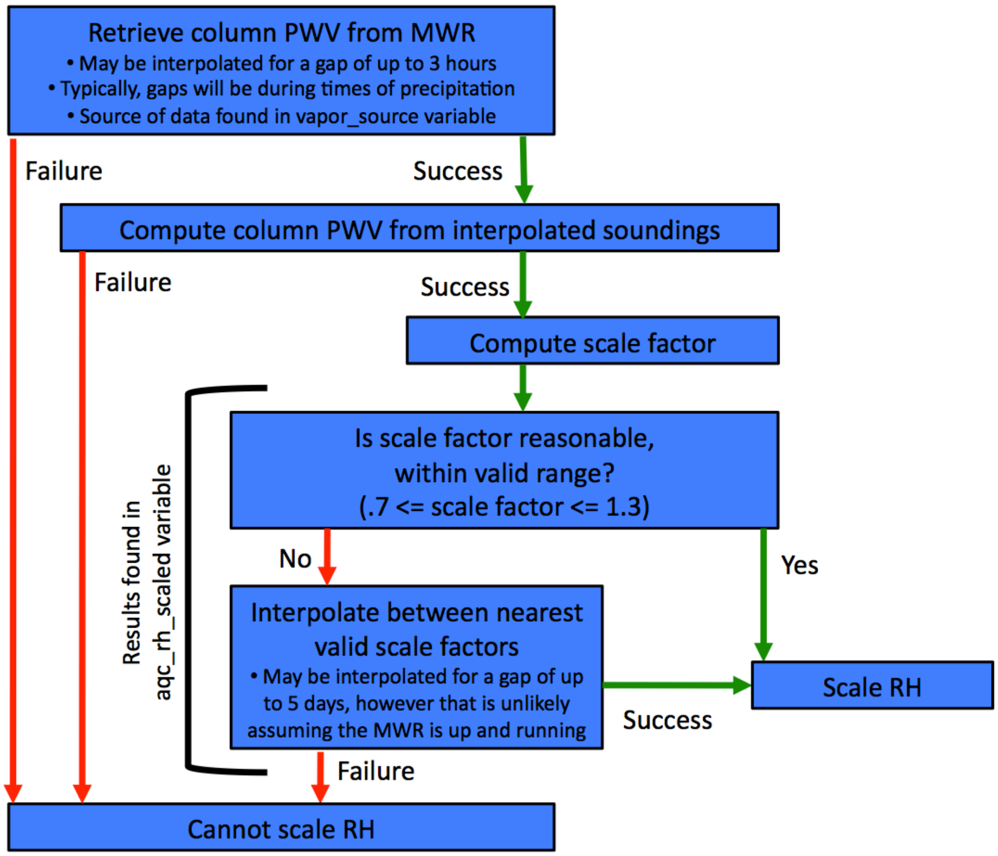

Figure 5. Steps taken to scale relative humidity.

4.0 Output Data

4.1 Output Variables

Table 4 lists the meteorological variables provided by INTERPSONDE, along with long name, an indication of whether quality control (QC) data exists for the variable, and an indication of whether source data is available for the variable. Tests to ensure that values are within a valid range are provided for variables interpolated from GRIDDEDSONDE, as well as the scaled relative humidity. Computed values, such as specific humidity, wind speed, wind direction, and potential temperature, do not require QC tests. Source fields are provided for variables from GRIDDEDSONDE, indicating whether the source is GRIDDEDSONDE itself or interpolation.

Table 4. INTERPSONDE meteorological variables.

Variable Name	Long Name	Units	QC	Source?
precip	Precipitation	Mm	yes	No; static source
temp	Temperature	ºC	Yes	Yes
rh	Relative humidity	%	Yes	Yes
vap_pres	Vapor pressure	kPa	Yes	No; computed
bar_pres	Barometric pressure	kPa	Yes	Yes
wspd	Wind speed	m/s	Yes	No; computed
wdir	Wind direction	degree	yes	No; computed
u_wind	Eastward wind component	m/s	Yes	Yes
v_wind	Northward wind component	m/s	Yes	Yes
dp	Dew-point temperature	ºC	Yes	Yes
potential_temp	Potential temperature	K	Yes	No; computed
sh	Specific humidity	g/g	Yes	No; computed
rh_scaled	Relative humidity scaled using MWR	%	Yes[a]	No[b]

[a] In addition to the general valid range QC provided for rh_scaled, ancillary QC provides additional information, in aqc_rh_scaled, that describes the quality of computed scale factors (Figure 5).
[b] The vapor_source variable provides the source of the PWV used for scaling relative humidity (Figure 5).

4.2 Grid Resolution

Regarding the fixed grid of INTERPSONDE, the temporal resolution of the VAP is 1 minute, and the vertical resolution varies with height as shown in Table 5.

Table 5. Vertical resolution (on 332 levels).

Height (km above ground level)	Resolution (m)
0–3.5	20
3.5–5	50
5–7	100
7–20	200
20–~40	500

5.0 Summary

The INTERPSONDE VAP, a continuous time-height grid of relative humidity-corrected sounding data, is intended to provide input to higher-order products, such as the Merged Soundings (MERGESONDE; Troyan 2012) VAP, which extends INTERPSONDE by incorporating model data. The INTERPSONDE VAP also is used to correct gaseous attenuation of radar reflectivity in products such as the KAZR Corrected Data VAP (KAZRCOR).

6.0 References

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Miloshevich, LM, H Vomel, DN Whiteman, and T Leblanc. 2009. "Accuracy assessment and correction of Vaisala RS92 radiosonde water vapor measurements." *Journal of Geophysical Research – Atmospheres* 114(D11): D11305, https://doi.org/10.1029/2008JD011565

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