DOE/SC-ARM/TR-124

Interpolated Sounding Value-Added Product

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DISCLAIMER

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1.0 Introduction

The Interpolated Sounding (INTERPSONDE) value-added product (VAP) uses a combination of observations from radiosonde soundings, the microwave radiometer (MWR), and surface meteorological instruments in order to define profiles of the atmospheric thermodynamic state at one-minute temporal intervals and a total of at least 266 altitude levels. This VAP is part of the Merged Sounding (MERGESONDE) suite of VAPs. INTERPSONDE is the profile of the atmospheric thermodynamic state created using the algorithms of MERGESONDE without including the model data from the European Centre for Medium-range Weather Forecasting (ECMWF). More specifically, INTERPSONDE VAP represents an intermediate step within the larger MERGESONDE process.

There are several noteworthy aspects of INTERPSONDE:

- The maximum number of altitude levels is 316. This is identical to version 2 of MERGESONDE. Without the ECMWF model data to complete the profile in altitudes above the normal range of balloon-borne radiosondes (usually at a maximum height of 20 km—266 altitude levels—above ground level), the regions above the radiosondes have no data. All fields in this region are assigned values of -9999. The decision to maintain uniform altitudes is based on the needs of the users.
- Data are only produced on days when there is at least one radiosonde launched. Unlike the MERGESONDE products where ECMWF fills in the spaces where there are no radiosondes, INTERPSONDE has no profile data that can serve this purpose. MERGESONDE creates two entire profiles—one strictly based on the radiosonde data and one strictly based on ECMWF model output—that are then combined using a sophisticated weighing function. INTERPSONDE only performs a linear interpolation between radiosonde points.
- The INTERPSONDE VAP was created because MERGESONDE requires a delay of between a week and seven weeks while the monthly ECMWF files are produced. Ingest of radiosonde, surface, and MWR data is almost instantaneous, but ECMWF is not available until the second week of the next month. For many users, this is a reasonable wait time. For some applications, a near-time atmospheric state product is needed. This is when INTERPSONDE is necessary.
- INTERPSONDE users also included scientists who would like no model data included in the atmospheric state calculations. They are only concerned with the instrument-derived values and not with having a long data set of daily profiles. It would be impossible to separate the influence of ECMWF data on a MERGESONDE profile, so this product is invaluable to their efforts.

Figure 1 shows a sample of INTERPSONDE at the Southern Great Plains (SGP) site. An example of INTERPSONDE at Niamey, Niger, is shown in Figure 2.

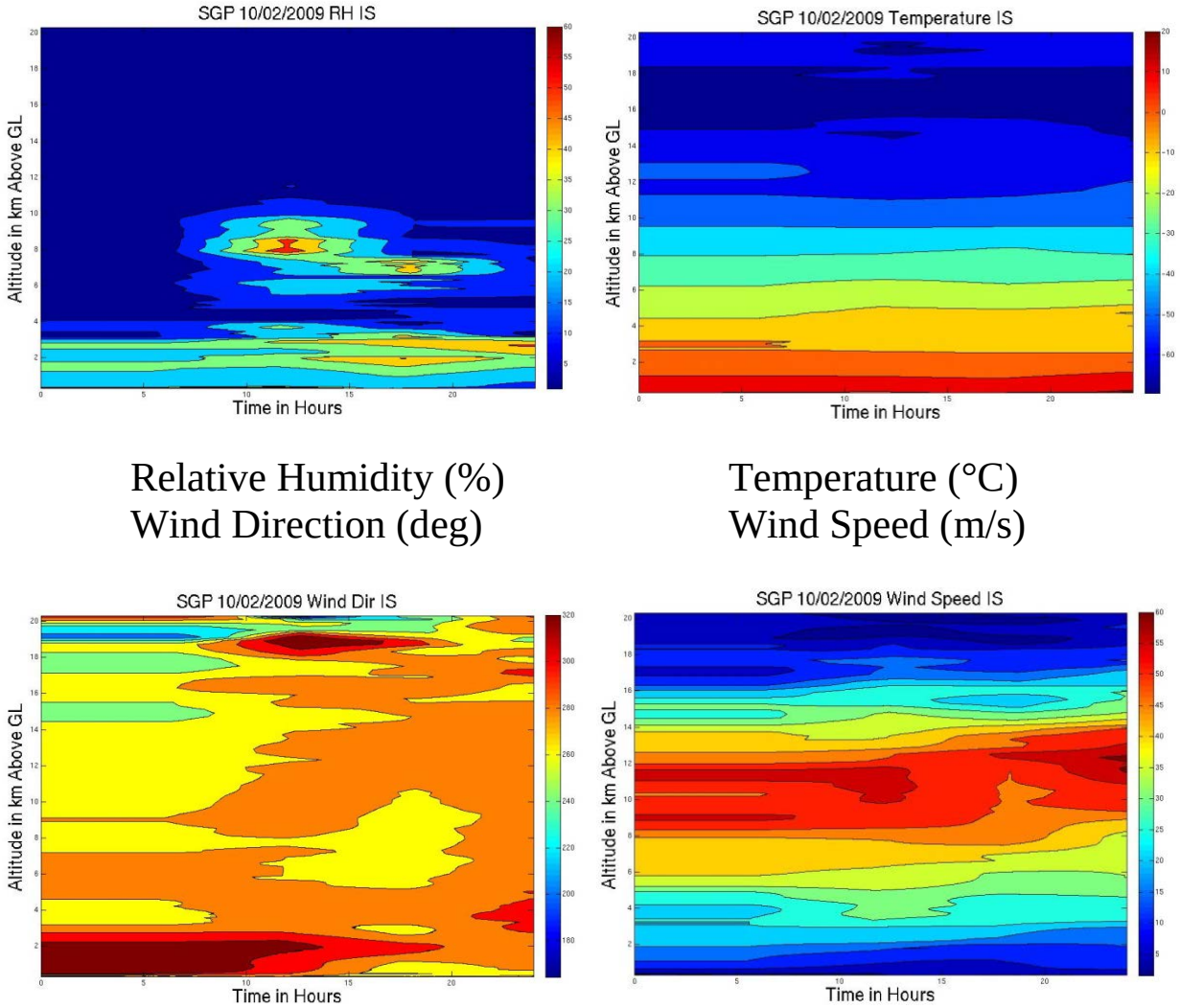


Figure 1. INTERPSONDE output profiles for temperature, relative humidity, wind direction, and wind speed at the SGP Central Facility on October 2, 2009. Maximum altitude is 20 kilometers above ground level (y-axis); time is in minutes (x-axis).

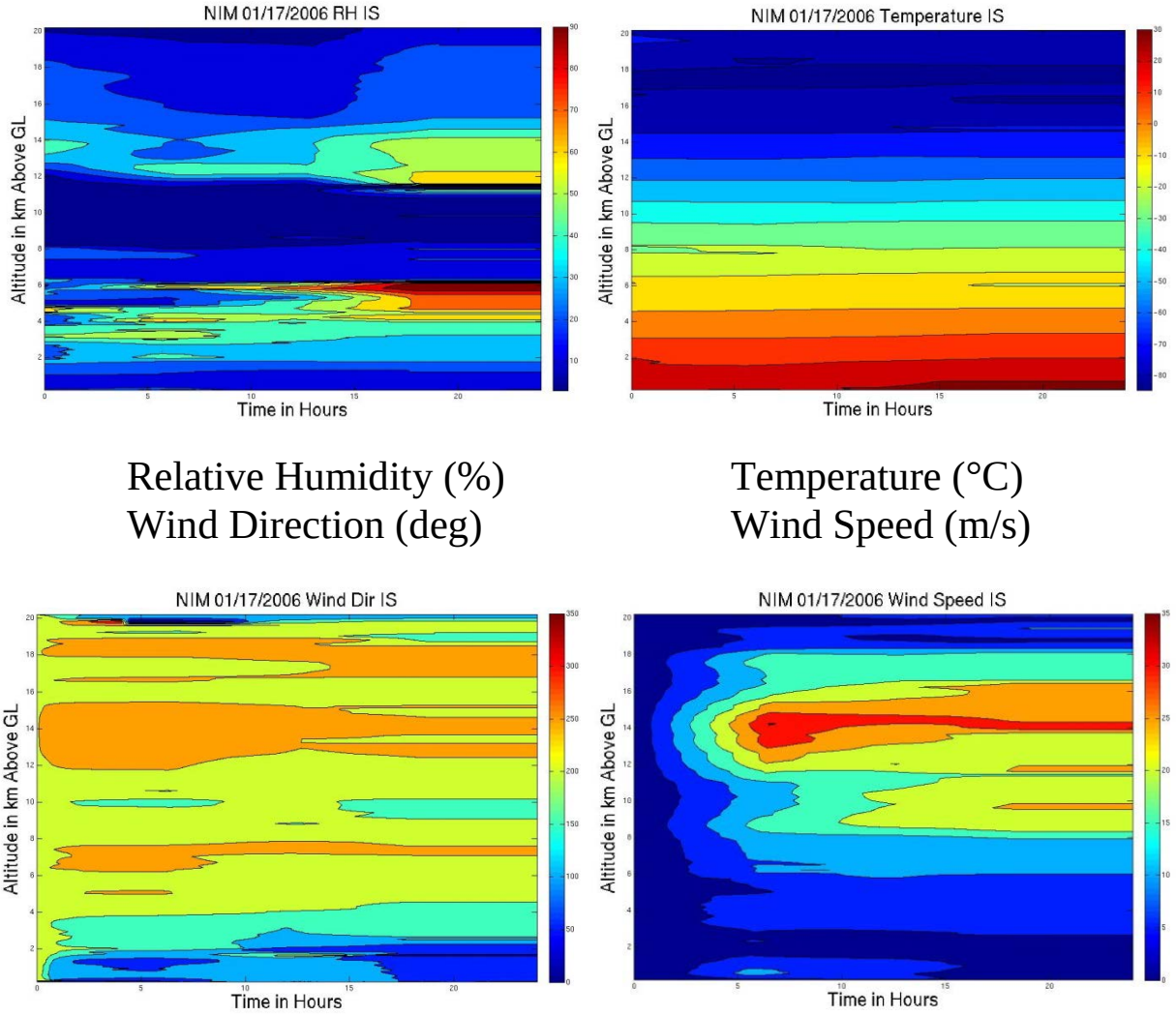


Figure 2. INTERPSONDE output profiles for temperature, relative humidity wind direction, and wind speed at the Atmospheric Radiation Measurement (ARM) Mobile Facility site in Niamey, Niger, on January 17, 2006. Maximum altitude is 20 kilometers above ground level (y-axis); time is in minutes (x-axis).

1.1 General Description

INTERPSONDE produces a thermodynamic profile of the atmosphere from the surface to approximately 60 kilometers above ground level (AGL). The number of vertical bins match those from version 2 of MERGESONDE, but once the maximum extent of the radiosondes has been attained, all data fields are reduced to missing values of -9999. The temporal resolution is one minute, whereas the vertical resolution varies with height. Table 1 lists the vertical resolutions for above-ground altitude resolutions.

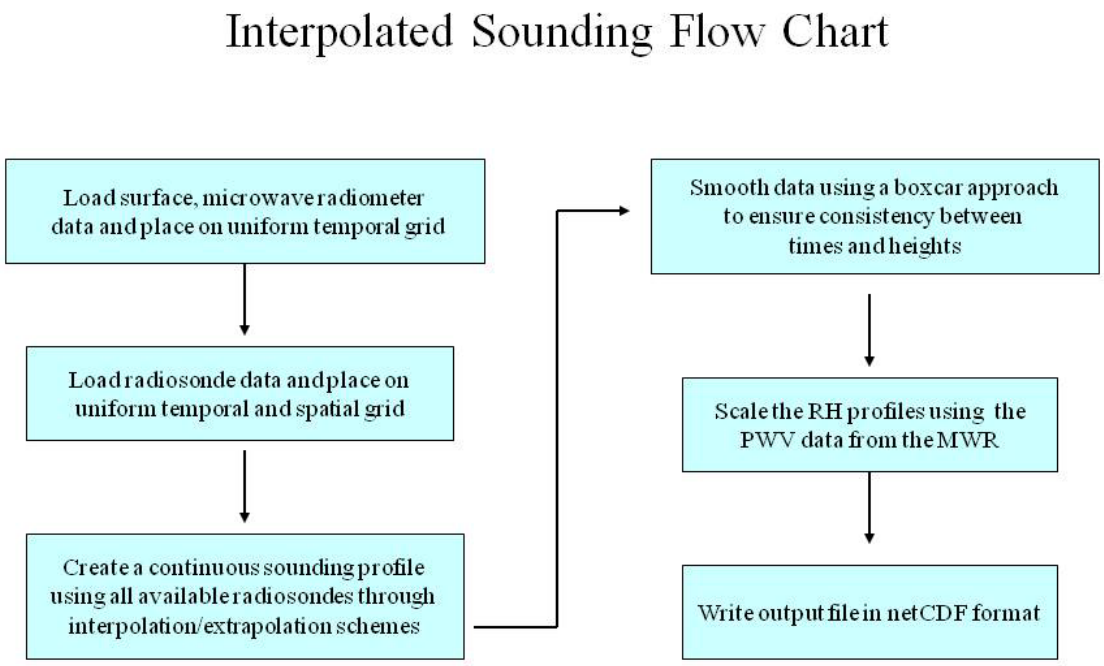
Table 1. Altitude resolutions.

Altitude Range	Resolution
0–3 kilometers AGL	20 meters
3–13 kilometers AGL	50 meters
13–16 kilometers AGL	100 meters
16–20 kilometers AGL	200 meters
20–60 kilometers AGL	200 meters

The outputted thermodynamic profile is created using interpolation/extrapolation techniques upon the radiosonde data. At any given altitude, there are a given number of radiosonde observations that depend upon the day of the week, the site, the launch data, and the ascent of the balloon flight. These values are used as the basis for interpolating across times and altitudes. Surface meteorology and meteorological tower instruments are used as boundary conditions for the lowest levels of the atmosphere. Additional datastreams from the Microwave Radiometer Retrievals (MWRRET) VAP are used to access accurate MWR precipitable water vapor data needed to constrain the total column water vapor and scale the relative humidity within the one-minute profiles.

2.0 Algorithm and Methodology

1. Load all applicable datastreams.
2. Place all data onto a common grid of 1-minute time resolution and 266 altitude bins.
3. Complete radiosonde profile.
    a. Fill data gaps between adjacent radiosonde times using linear interpolation.
4. Smooth data.
    b. Use a box-car approach to find the average of the four nearest neighbors.
    c. If the relative average is more than 20% different from the center point, replace the center with the five-point average.
    d. This is done for all variables at each time and height.
    e. Calculate relative humidity using MWR data as the scale factor, using precipitable water vapor (PWV) for the procedure.
5. Ensure no physically impossible situations exist.



3.0 Data

The files that are used as input are listed in Table 2 below. Only the three major regions are listed; the locations of the mobile facility will each have similar files. The '#' indicates the unique number associated with each site: '1' for Manus, '2' for Nauru, and '3' for Darwin.

Table 2. INTERPSONDE input files.

Instrument	SGP	NSA	TWP
Radiosondes – ARM *Version 2 radiosonde files:*	sgpsondewrpnC1 *sgpsondeadjustC1*	nsasondewnpnC1 *nsasondeadjustC1*	twpsondewnpnC# *twpsondeadjustC#*
– National Weather Service (NWS)		nsa06snwsupabrwX1*	
– Intensive Operational Period (IOP)		nsasondewnpnS01	
Surface or Tower Meteorology	sgp1smosE13 or sgpmetC1	nsamettwr4hC1 or nsametC1	twpsmet60sC# or twpmet#
Microwave Radiometer (physical/statistical)	sgpmwrret1liljclouC1	nsamwrret1liljclouC1	twpmwrret1liljclouC#
Microwave Radiometer (MWR-LOS)**	sgpmwrlosC1	nsamwrlosC1	twpmwrlosC#

* The Relative Humidity field from this radiosonde is not used.
** Microwave Radiometer line-of-sight (MWR-LOS) is used only when the mwrret1liljclouC1 datastream is not available.

3.1 Value-Added Output

The value of this VAP is that variables found at relatively sparse times and heights throughout a 24-hour period now encompass the entire day at one-minute time intervals and all heights. Sparse, discrete data have become dense and continuous. These high-resolution data are important for higher-order VAPs for determining cloud microphysical properties.

Additionally, fields such as potential temperature and relative humidity (RH) scaled by the PWV from the MWR are calculated and outputted. Since these fields are not included as inputs from any platform, they are considered value-added fields.

3.2 Data Quality Assessment Included

Standard Data Quality variables are attached to the product. Included in these variables are:

qc_time, qc_precip, qc_temp, qc_rh, qc_vap_pres, qc_bar_pres, qc_wspd, and qc_wdir

In fact, all physical variables have a quality control field associated with them. As per the Quality Control (QC) Standards, each variable has a bit-packed quality control variable named qc_xxxx immediately following field xxxx.

In addition to the QC variables required by the ARM Data Quality Office, there is another output field which is used to show status of a given data point. This is **vapor_source** (which describes the type of MWR data used, see below).

3.3 Output Products

The INTERPSONDE VAP generates only one datastream per version per site. Using the standard VAP naming conventions, we have the following filenames:

Southern Great Plains (SGP): sgpinterpolatedsondeC1.c1

North Slope of Alaska (NSA): nsainterpolatedsondeC1.c1

Tropical Western Pacific (TWP):

Manus:	twpinterpolatedsondeC1.c1
Nauru:	twpinterpolatedsondeC2.c1
Darwin:	twpinterpolatedsondeC3.c1

ARM Mobile Facility (AMF) sites will be named according to their official prefix. To date, the INTERPSONDE files produced for the AMF deployments are:

Point Reyes, California (PYE):	pyeinterpolatedsondeM1.c1
Niamey, Niger (NIM):	niminterpolatedsondeM1.c1
Heselbach, Germany (FKB):	fkbinterpolatedsondeM1.c1
Shouxian, China (HFE):	hfeinterpolatedsondeM1.c1
Graciosa Island, Azores (GRW):	grwinterpolatedsondeM1.c1

3.4 Descriptions of Products

Table 3 summarizes the variables from the input datastreams that are used to create the output file. The only other important field that is not included on this table is the PWV, which is from the MWR datastream.

Table 3. Location of variables used in and produced by INTERPSONDE.

	Radiosonde	Surface Meteorological Instruments	Output
Barometric Pressure	X	X	X
Temperature	X	X	X
Relative Humidity	X	X	X
Wind Speed/Direction	X	X	X
U- and V-Wind	X		X
Dew Point	X		X
Vapor Pressure		X	X
Specific Humidity			X
Precipitation		X	X
Potential Temp			X
Scaled RH			X

3.5 Description of Data Quality Fields

The Data Quality fields with their attributes are listed below. The fields to which they are associated have been excluded. The QC fields follow the field of the actual item. In addition to these QC fields, there are several status fields, which are listed below. These fields describe the way in which the product was created.

```
netcdf niminterpolatedsondeM1.c1.20060117.000000 {
dimensions:
        time = UNLIMITED ; // (1440 currently)
        height = 316 ;
variables:
        int base_time ;
                base_time:string = "17-Jan-2006,0:00:00 GMT" ;
                base_time:long_name = "Base time in Epoch" ;
                base_time:units = "seconds since 1970-1-1 0:00:00 0:00" ;
        double time_offset(time) ;
                time_offset:long_name = "Time offset from base_time" ;
                time_offset:units = "seconds since 2006-01-17 00:00:00 0:00" ;
        double time(time) ;
```

```
                time:long_name = "Time offset from midnight" ;
                time:units = "seconds since 2006-01-17 00:00:00 0:00" ;
        int qc_time(time) ;
                qc_time:long_name = "Quality check results on field: Time offset from midnight" ;
                qc_time:units = "unitless" ;
                qc_time:description = "This field contains bit packed values which should be interpreted as listed.
No bits set (zero) represents good data." ;
                qc_time:bit_1_description = "Delta time between current and previous samples is zero." ;
                qc_time:bit_1_assessment = "Bad" ;
                qc_time:bit_2_description = "Delta time between current and previous samples is less than the
delta_t_lower_limit field attribute." ;
                qc_time:bit_2_assessment = "Bad" ;
                qc_time:bit_3_description = "Delta time between current and previous samples is greater than the
delta_t_upper_limit field attribute." ;
                qc_time:bit_3_assessment = "Bad" ;
                qc_time:delta_t_lower_limit = 20. ;
                qc_time:delta_t_upper_limit = 20. ;
                qc_time:prior_sample_flag = 1 ;
                qc_time:comment = "If the \'prior_sample_flag\' is set the first sample time from a new raw file
will be compared against the time just previous to it in the stored data. If it is not set the qc_time value for the first
sample will be set to 0." ;
        float height(height) ;
                height:long_name = "Height" ;
                height:units = "km" ;
                height:comment = "Height represents km above mean sea level" ;
        float precip(time) ;
                precip:long_name = "Precipitation" ;
                precip:units = "mm" ;
                precip:missing_value = -9999.f ;
        int qc_precip(time) ;
                qc_precip:long_name = "Quality check results on field: Precipitation" ;
                qc_precip:units = "unitless" ;
                qc_precip:description = "This field contains bit packed values which should be interpreted as
listed. No bits set (zero) represents good data." ;
                qc_precip:bit_1_description = "Data value not available in input file, data value set to -9999 in
output file." ;
                qc_precip:bit_1_assessment = "Bad" ;
        float temp(time, height) ;
                temp:long_name = "Temperature" ;
                temp:units = "C" ;
                temp:valid_min = -90.f ;
                temp:valid_max = 50.f ;
                temp:missing_value = -9999.f ;
        int qc_temp(time, height) ;
                qc_temp:long_name = "Quality check results on field: Temperature" ;
                qc_temp:units = "unitless" ;
                qc_temp:description = "This field contains bit packed values which should be interpreted as listed.
No bits set (zero) represents good data." ;
                qc_temp:bit_1_description = "Value is less than the valid_min." ;
                qc_temp:bit_1_assessment = "Indeterminate" ;
                qc_temp:bit_2_description = "Value is greater than the valid_max." ;
                qc_temp:bit_2_assessment = "Indeterminate" ;
                qc_temp:bit_3_description = "Data value not available in input file, data value set to -9999 in
output file." ;
                qc_temp:bit_3_assessment = "Bad" ;
        float rh(time, height) ;
```

rh:long_name = "Relative humidity" ;
rh:units = "%" ;
rh:valid_min = 0.f ;
rh:valid_max = 105.f ;
rh:missing_value = -9999.f ;
int qc_rh(time, height) ;
qc_rh:long_name = "Quality check results on field: Relative humidity" ;
qc_rh:units = "unitless" ;
qc_rh:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_rh:bit_1_description = "Value is less than the valid_min." ;
qc_rh:bit_1_assessment = "Indeterminate" ;
qc_rh:bit_2_description = "Value is greater than the valid_max." ;
qc_rh:bit_2_assessment = "Indeterminate" ;
qc_rh:bit_3_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_rh:bit_3_assessment = "Bad" ;
float vap_pres(time, height) ;
vap_pres:long_name = "Vapor pressure" ;
vap_pres:units = "kPa" ;
vap_pres:missing_value = -9999.f ;
int qc_vap_pres(time, height) ;
qc_vap_pres:long_name = "Quality check results on field: Vapor pressure" ;
qc_vap_pres:units = "unitless" ;
qc_vap_pres:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_vap_pres:bit_1_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_vap_pres:bit_1_assessment = "Bad" ;
float bar_pres(time, height) ;
bar_pres:long_name = "Barometric pressure" ;
bar_pres:units = "kPa" ;
bar_pres:valid_min = 0.f ;
bar_pres:valid_max = 110.f ;
bar_pres:missing_value = -9999.f ;
int qc_bar_pres(time, height) ;
qc_bar_pres:long_name = "Quality check results on field: Barometric pressure" ;
qc_bar_pres:units = "unitless" ;
qc_bar_pres:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_bar_pres:bit_1_description = "Value is less than the valid_min." ;
qc_bar_pres:bit_1_assessment = "Indeterminate" ;
qc_bar_pres:bit_2_description = "Value is greater than the valid_max." ;
qc_bar_pres:bit_2_assessment = "Indeterminate" ;
qc_bar_pres:bit_3_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_bar_pres:bit_3_assessment = "Bad" ;
float wspd(time, height) ;
wspd:long_name = "Wind speed" ;
wspd:units = "m/s" ;
wspd:valid_min = 0.f ;
wspd:valid_max = 100.f ;
wspd:missing_value = -9999.f ;
int qc_wspd(time, height) ;
qc_wspd:long_name = "Quality check results on field: Wind speed" ;
qc_wspd:units = "unitless" ;

qc_wspd:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_wspd:bit_1_description = "Value is less than the valid_min." ;
qc_wspd:bit_1_assessment = "Indeterminate" ;
qc_wspd:bit_2_description = "Value is greater than the valid_max." ;
qc_wspd:bit_2_assessment = "Indeterminate" ;
qc_wspd:bit_3_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_wspd:bit_3_assessment = "Bad" ;
float wdir(time, height) ;
wdir:long_name = "Wind direction" ;
wdir:units = "deg" ;
wdir:valid_min = 0.f ;
wdir:valid_max = 360.f ;
wdir:missing_value = -9999.f ;
int qc_wdir(time, height) ;
qc_wdir:long_name = "Quality check results on field: Wind direction" ;
qc_wdir:units = "unitless" ;
qc_wdir:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_wdir:bit_1_description = "Value is less than the valid_min." ;
qc_wdir:bit_1_assessment = "Indeterminate" ;
qc_wdir:bit_2_description = "Value is greater than the valid_max." ;
qc_wdir:bit_2_assessment = "Indeterminate" ;
qc_wdir:bit_3_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_wdir:bit_3_assessment = "Bad" ;
float u_wind(time, height) ;
u_wind:long_name = "Eastward wind component" ;
u_wind:units = "m/s" ;
u_wind:valid_min = -75.f ;
u_wind:valid_max = 75.f ;
u_wind:missing_value = -9999.f ;
int qc_u_wind(time, height) ;
qc_u_wind:long_name = "Quality check results on field: Eastward wind component" ;
qc_u_wind:units = "unitless" ;
qc_u_wind:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_u_wind:bit_1_description = "Value is less than the valid_min." ;
qc_u_wind:bit_1_assessment = "Indeterminate" ;
qc_u_wind:bit_2_description = "Value is greater than the valid_max." ;
qc_u_wind:bit_2_assessment = "Indeterminate" ;
qc_u_wind:bit_3_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_u_wind:bit_3_assessment = "Bad" ;
float v_wind(time, height) ;
v_wind:long_name = "Northward wind component" ;
v_wind:units = "m/s" ;
v_wind:valid_min = -75.f ;
v_wind:valid_max = 75.f ;
v_wind:missing_value = -9999.f ;
int qc_v_wind(time, height) ;
qc_v_wind:long_name = "Quality check results on field: Northward wind component" ;
qc_v_wind:units = "unitless" ;
qc_v_wind:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;

qc_v_wind:bit_1_description = "Value is less than the valid_min." ;
qc_v_wind:bit_1_assessment = "Indeterminate" ;
qc_v_wind:bit_2_description = "Value is greater than the valid_max." ;
qc_v_wind:bit_2_assessment = "Indeterminate" ;
qc_v_wind:bit_3_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_v_wind:bit_3_assessment = "Bad" ;
float dp(time, height) ;
dp:long_name = "Dewpoint temperature" ;
dp:units = "C" ;
dp:valid_min = -110.f ;
dp:valid_max = 50.f ;
dp:missing_value = -9999.f ;
int qc_dp(time, height) ;
qc_dp:long_name = "Quality check results on field: Dewpoint temperature" ;
qc_dp:units = "unitless" ;
qc_dp:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_dp:bit_1_description = "Value is less than the valid_min." ;
qc_dp:bit_1_assessment = "Indeterminate" ;
qc_dp:bit_2_description = "Value is greater than the valid_max." ;
qc_dp:bit_2_assessment = "Indeterminate" ;
qc_dp:bit_3_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_dp:bit_3_assessment = "Bad" ;
float potential_temp(time, height) ;
potential_temp:long_name = "Potential temperature" ;
potential_temp:units = "K" ;
potential_temp:missing_value = -9999.f ;
int qc_potential_temp(time, height) ;
qc_potential_temp:long_name = "Quality check results on field: Potential temperature" ;
qc_potential_temp:units = "unitless" ;
qc_potential_temp:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_potential_temp:bit_1_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_potential_temp:bit_1_assessment = "Bad" ;
float sh(time, height) ;
sh:long_name = "Specific humidity" ;
sh:units = "g/g" ;
sh:missing_value = -9999.f ;
int qc_sh(time, height) ;
qc_sh:long_name = "Quality check results on field: Specific humidity" ;
qc_sh:units = "unitless" ;
qc_sh:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_sh:bit_1_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_sh:bit_1_assessment = "Bad" ;
float rh_scaled(time, height) ;
rh_scaled:long_name = "Relative humidity scaled using MWR" ;
rh_scaled:units = "%" ;
rh_scaled:valid_min = 0.f ;
rh_scaled:valid_max = 105.f ;
rh_scaled:missing_value = -9999.f ;
int qc_rh_scaled(time, height) ;

qc_rh_scaled:long_name = "Quality check results on field: Relative humidity scaled using MWR" ;
qc_rh_scaled:units = "unitless" ;
qc_rh_scaled:description = "This field contains bit packed values which should be interpreted as listed. No bits set (zero) represents good data." ;
qc_rh_scaled:bit_1_description = "Value is less than the valid_min." ;
qc_rh_scaled:bit_1_assessment = "Indeterminate" ;
qc_rh_scaled:bit_2_description = "Value is greater than the valid_max." ;
qc_rh_scaled:bit_2_assessment = "Indeterminate" ;
qc_rh_scaled:bit_3_description = "Data value not available in input file, data value set to -9999 in output file." ;
qc_rh_scaled:bit_3_assessment = "Bad" ;
float vapor_source(time, height) ;
vapor_source:long_name = "Source of the MWR Data used to Produce Scaled RH Field" ;
vapor_source:units = "unitless" ;
vapor_source:comment_1 = "0 -- Vapor from mwrret1liljclou not flagged as bad from qc_be_pwv" ;
vapor_source:comment_2 = "1 -- Vapor from mwrret1liljclou flagged as bad from qc_be_pwv, data not scaled" ;
vapor_source:comment_3 = "2 -- Vapor from mwrlos not flagged as bad or indeterminate from qc_vap" ;
vapor_source:comment_4 = "3 -- Vapor from mwrlos flagged as bad or indeterminate from qc_vap, data not scaled" ;
vapor_source:comment_5 = "4 -- No Vapor from MWR, data not scaled" ;
vapor_source:missing_value = -9999.f ;
float lat ;
lat:long_name = "North latitude" ;
lat:units = "degree_N" ;
lat:valid_min = -90.f ;
lat:valid_max = 90.f ;
float lon ;
lon:long_name = "East longitude" ;
lon:units = "degree_E" ;
lon:valid_min = -180.f ;
lon:valid_max = 180.f ;
float alt ;
alt:long_name = "Altitude above mean sea level" ;
alt:units = "m" ;

3.6 VAP Status and Version History

This is the initial production release of INTERPSONDE.

3.7 Time Periods Processed

As of March 1, 2013, data have been processed as follows:

Table 4. Time periods for which data have been processed.

Site	Available Time Period
SGP	2008–2012
NSA	2008–2012
MAN	2008–2012
NAU	2008–2012
DAR	2008–2012
PYE	2005
NIM	2006
FKB	2007
HFE	2008
GRW	2009–2010

3.8 Version Information

This is the initial production release of INTERPSONDE.

4.0 Contacts

4.1 Translator

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