Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX II) 2010 Quality Controlled Radiosonde Data Set

Contents:

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For more information on the NCAR Earth Observing Laboratory Integrated Sounding System (ISS), or on the GPS Advanced Upper-Air Sounding System (GAUS), please visit:
ISS: http://www.eol.ucar.edu/instrumentation/sounding/iss
GAUS: http://www.eol.ucar.edu/instrumentation/sounding/iss/gaus

I. ISS Project/Dataset Overview

The Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX) is a project aimed at investigating tornado genesis and examining tornado structure and evolution using a suite of atmospheric instruments. VORTEX II is the second phase of a field campaign aimed at collecting data to help researchers improve tornado forecast and warning times. The first phase of VORTEX took place between May and June of 2009. The second phase was conducted between May 6 and June 15, 2010. Both phases included the use of four mobile GPS Advanced Upper-Air Sounding (GAUS) systems. Two of the systems were operated by the NOAA Storm Systems Laboratory (NSSL), and two systems were operated by the National Center for Atmospheric Research (NCAR). Data was collected while targeting storms throughout the Central United States (Figure 1). The final archive for the 2010 field season includes a total of 360 quality controlled radiosonde soundings.

The NCAR/EOL GPS Advanced Upper-air Sounding system (GAUS) incorporates Vaisala RS92 radiosondes, has portability, built-in test capability and flexibility for multiple channel operations, and delivers users high precision GPS measurements of radiosonde positions. The Vaisala RS92 radiosonde delivers high quality wind measurements from the ground with code-correlating GPS technology, as well as pressure, temperature and humidity measurements all transmitted digitally to the receiving station. Digital technology reduces missing data due to noise and increases overall reliability of the system. The Vaisala RS92 provides much better humidity measurements with a heated twin-sensor design and incorporates a reconditioning procedure before launch.

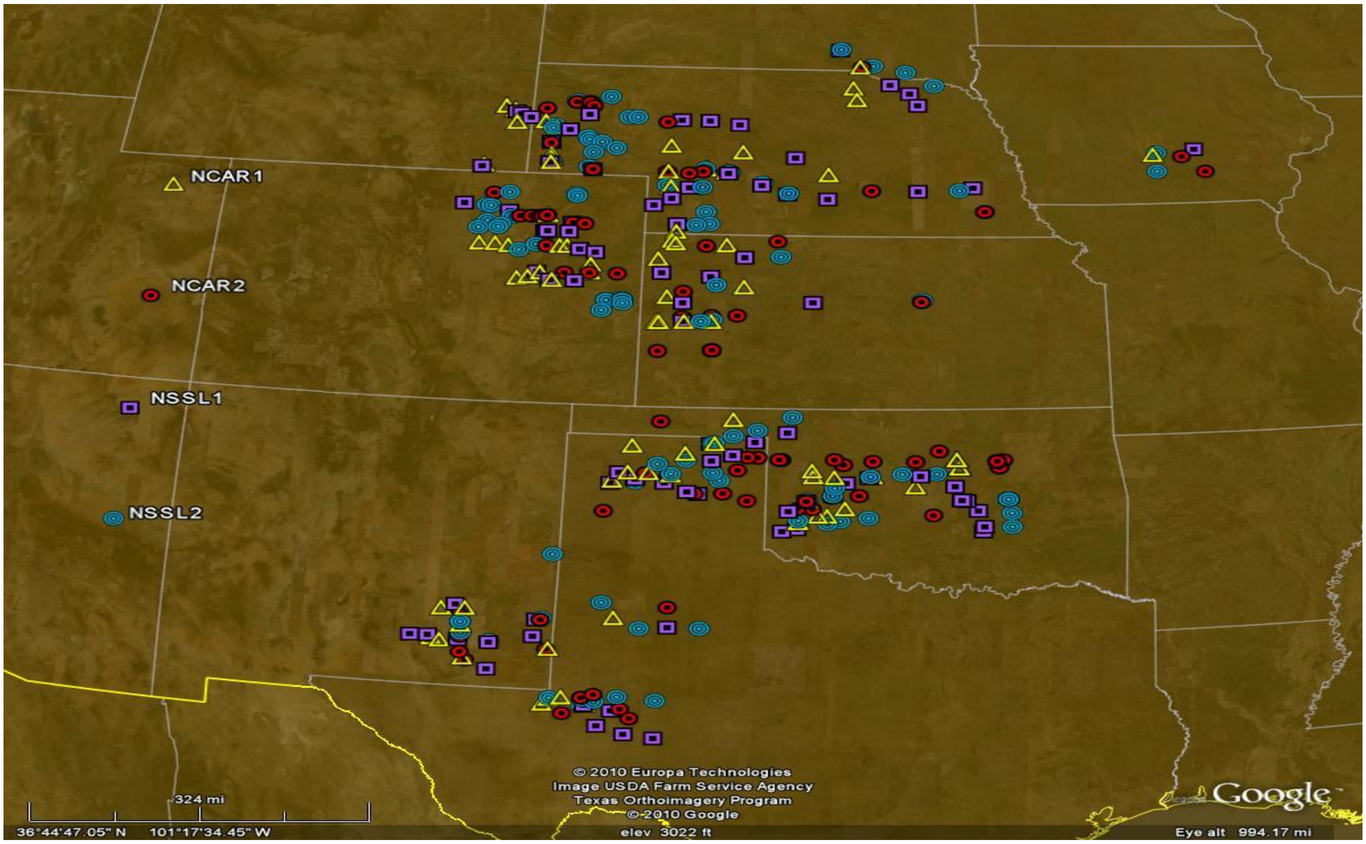

Figure 1. Radiosonde launches performed by four sounding systems, two operated by NSSL, and two operated by NCAR. The legend shows the symbol indicating the sounding system, and each color on the map indicates launches that occurred on a particular day.

II. EOL File Format

The EOL format is an ascii text format that includes a header, with detailed project and sounding information, and seventeen columns of high resolution data (Table 1). The "D" files are one second resolution data files with appropriate corrections and quality control measures applied. The naming convention for these files is - "D", followed by "yyyymmdd_hhmmss_P.1QC.eol" where yyyy = year, mm = month, hh = hour of the day GMT, mm = minute of the hour, ss = second of the hour (which refer to the launch time of the sonde) and ".eol" refers to the file format type.

The header records contain information including data type, project name, site location, actual release time, and other specialized information. The first seven header lines contain information identifying the sounding. The release location is given as : lon (deg min), lon (dec. deg), lat (deg min), lat (dec. deg), altitude (meters). Longitude in deg min is in the format: ddd mm.mm'W where ddd is the number of degrees from True North (with leading zeros if necessary), mm.mm is the decimal number of minutes, and W represents W or E for west or east longitude, respectively. Latitude has the same format as longitude, except there are only two digits for degrees and N or S for north/south latitude. The following three header lines contain information about the aircraft data system and auxiliary information and comments about the sounding. The last 3 header lines contain header information for the data columns. Line 12 holds the field names, line 13 the field units, and line 14 contains dashes (--- characters) signifying the end of the header. Data fields are listed below in Table 2.

```
Data Type/Direction:                       GAUS SOUNDING DATA/Ascending
File Format/Version:                       EOL Sounding Format/1.0
Project Name/Platform:                     VORTEX2/NCAR1 MGAUS
Launch Site:                               Mobile System
Launch Location (lon,lat,alt):             97 06.78'W -97.113000, 36 06.78'N 36.113056
UTC Launch Time (y,m,d,h,m,s):             2008, 05, 10, 17:34:01
Sonde Id/Sonde Type:                       101374323/Vaisala RS92-SGP (ccGPS)
Reference Launch Data Source/Time:         Vaisala WXT510/17:33:59
System Operator/Comments:                  Adam French/lost contact just over 200 mb
Post Processing Comments:                  Aspen Version 2.8.1.8, Configuration upsonde-1s
/
Time --UTC--   Press Temp Dewpt RH Uwind Vwind Wspd  Dir dZ  GeoPoAlt Lon Lat  GPSAlt
sec  hh mm ss   mb    C    C     %  m/s   m/s   m/s  deg m/s    m     deg deg    m
```

Table 1. Example of the EOL format used for both dropsonde and radiosonde sounding files

Field No.	Parameter	Units	Measured/Calculated
1	Time	Seconds	-------------
2	UTC Hour	Hours	-------------
3	UTC Minute	Minutes	-------------
4	UTC Second	Seconds	-------------
5	Pressure	Millibars	Measured
6	Dry-bulb Temp	Degrees C	Measured
7	Dewpoint Temp	Degrees C	Calculated
8	Relative Humidity	Percent	Measured
9	U Wind Component	Meters/Second	Calculated

10	V Wind Component	Meters/Second	Calculated
11	Wind Speed	Meters/Second	Measured
12	Wind Direction	Degrees	Measured
13	Ascension Rate	Meters/Second	Calculated
14	Geopotential Altitude	Meters	Calculated
15	Longitude	Degrees	Measured
16	Latitude	Degrees	Measured
17	GPS Altitude	Meters	Measured

Table 2. Lists all parameters provided in the sounding files, their unit of measurement, and if the values are measured or calculated.

III. Data File Specifics

The files contain data calculated at one-second intervals. The variables pressure, temperature, and relative humidity are calibrated values from measurements made by the radiosonde. The dew point is calculated from the relative humidity and temperature. The geopotential altitude is calculated from the hydrostatic equation using pressure, temperature, and relative humidity. The rate of ascent is calculated from pressure. The radiosonde position (lat, lon, GPSAlt) and winds are measured by use of a GPS receiver in the sonde. The quality of the GPS altitude is somewhat questionable. The accuracy of the sensor is typically +/-30 m, and may show large variability. For this reason, investigators are encouraged to use geopotential altitude over GPS altitude. These raw wind values are subjected to a digital filter to remove low frequency oscillations due to the sonde pendulum motion beneath the balloon when run through NCAR's Atmospheric Sounding Processing ENvironment (ASPEN) software.

IV. Data Quality Control and Results

1. Profiles of the raw soundings are first examined to determine if there are any errors with the launch detect, or if system lock-up occurred, as a result of weakening of the sonde signal, which could result in a loss of data and an incorrect launch time.

2. All of the soundings are then subjected to a radiation correction that takes into account the solar angle at time of launch, and removes solar heating that could skew the temperature measurements.

3. Scatter plots of the raw data are created to check differences in pressure, temperature and RH between the surface met and the last available surface radiosonde measurement before launch.

4. The raw soundings are run through ASPEN, which analyzes the data, performs smoothing, and removes suspect data points.

5. We create profiles of temperature, RH, wind speed and wind direction of the quality controlled soundings which enable us to visually evaluate the soundings for outliers, or any other obvious problems.

Performing the QC steps above allows us to identify and, in some cases, correct errors that could potentially impact research performed using these data sets. During processing of the sounding data the following issues were found, and where possible, corrections were applied:

1. The following soundings were removed from the final archive. They either contained little, or no data. The file, D20100506_175825_P.1, removed from the NCAR2 archive was originally launched and successfully tracked by NSSL2 (D20100506_175148_P.1). NCAR2 acquired the signal while the radiosonde was in flight and duplicate files were created. Additionally, file D20100523_210348_P.1 was launched by NCAR2, but was also tracked by NSSL1. This file can be found in the NCAR2 data archive.

NCAR1	NCAR2	NSSL1
D19180725_083010_P.1	D20100506_175825_P.1	D20100523_210348_P.1
D20100506_173713_P.1	D20100524_210551_P.1	
D20100506_175248_P.1		
D20100521_225651_P.1		

2. Many of the soundings in the VORTEX II data set were found to have saturated layers. For most of these cases, where extreme cold and moist conditions occurred concurrently, the hygrometer measurements exceeded the maximum possible relative humidity with respect to water (100%). For these soundings, RH values exceeding 100% were set to 100%.

3. The soundings listed below experienced strong vertical winds or icing on the balloon that caused the radiosonde to descend for a brief period of time during its ascent. These files were processed through ASPEN, but since ASPEN can only handle monotonically changing pressure, it removes any portion of the file where the radiosonde experiences increasing changes in pressures. In order to include these unique features in the final sounding file, we used the raw data from the descending portion and copied it into the quality controlled file. Data obtained during these downdraft or icing events have not been quality controlled, however based on visual examination the data do look clean and free of significant errors.

NCAR1	NCAR2	NSSL1	NSSL2
D20100514_200006_P.1	D20100507_011736_P.1	D20100513_003143_P.1	D20100512_235103_P.1
D20100514_220126_P.1	D20100514_195704_P.1	D20100522_002538_P.1	D20100514_194628_P.1
D20100518_234032_P.1	D20100514_204539_P.1	D20100606_225626_P.1	D20100514_221538_P.1
D20100519_003312_P.1	D20100514_221215_P.1	D20100613_210122_P.1	D20100517_230919_P.1
D20100524_221440_P.1	D20100519_215819_P.1		D20100519_215813_P.1
D20100526_003312_P.1	D20100519_230108_P.1		D20100525_222806_P.1
D20100604_013244_P.1	D20100523_221311_P.1		D20100608_013616_P.1
	D20100526_231738_P.1		D20100612_211224_P.1
	D20100601_231820_P.1		D20100613_205907_P.1
	D20100604_002841_P.1		D20100614_190322_P.1

	D20100607_011834_P.1		
	D20100608_022552_P.1		
	D20100613_230956_P.1		
	D20100614_200437_P.1		

4. The sounding, D20100604_231910_P.1 from NCAR1, has a brief period of missing data just above the surface, after launch. This was most likely caused by release of the balloon before all steps of the sounding system software were complete. The missing data could not be recovered and geopotential altitude, which is typically calculated from the surface upward, has been set to missing. Based on visual analysis and comparison with other sounding files from the same date, the GPS altitude does appear to be reasonable and may be used in lieu of geopotential altitude.

5. The soundings listed below experienced errors with the automatic launch detect. Late launch detect occurs most often when the sonde is not able to collect a sufficient amount of surface data prior to launch, causing a delay in the launch detect mechanism which relies on change in pressure to determine when the balloon release occurs. No data is lost when this occurs, however data recorded prior to launch detect is recorded as "pre-launch" rather than "in-flight", and the filenames and launch times are incorrect.
Early launch detects are rare, but can occur with rapid changes in pressure while the radiosonde sits on the ground prior to launch. In these cases surface data may be collected that is incorrectly flagged as "in-flight", and the launch time will be incorrect. These soundings have all been corrected for delays in the launch detect and the original and new filenames are listed below.

NCAR1 **Original Filename**	**Corrected Filename**	**Launch Detect Error**
D20100524_203430_P.1	D20100524_203359_P.1	Late
D20100518_234920_P.1	D20100518_234032_P.1	Late
D20100522_021335_P.1	D20100522_013317_P.1	Late
D20100604_004320_P.1	D20100604_004230_P.1	Late
D20100605_001022_P.1	D20100604_231910_P.1	Late
D20100608_010353_P.1	D20100608_010014_P.1	Late
D20100611_001114_P.1	D20100610_235402_P.1	Late
D20100524_221339_P.1	D20100524_221440_P.1	Early
NCAR2 **Original Filename**	**Corrected Filename**	**Launch Detect Error**
D20100510_235807_P.1	D20100510_235611_P.1	Late
D20100524_191959_P.1	D20100524_191930_P.1	Late
D20100608_002251_P.1	D20100607_234843_P.1	Late
D20100608_004845_P.1	D20100608_003625_P.1	Late
D20100608_023924_P.1	D20100608_022552_P.1	Late
D20100526_002915_P.1	D20100526_003000_P.1	Early
D20100526_010622_P.1	D20100526_010714_P.1	Early
NSSL2 **Original Filename**	**Corrected Filename**	**Launch Detect Error**
D20100612_005643_P.1	D20100612_001014_P.1	Late

6. The following sounding files needed repair because they experienced sounding system lock-up, caused by weakening or loss of the radiosonde signal. The affected sounding files were not saved in the correct file format or to the correct file names. They contained no LAU (launch) or A00 (surface met) data lines, and were missing the standard 19 line tail at the end of the raw data file; all things necessary in order for ASPEN to run properly. Data before the lock-up was preserved, however anything measured after the lock-up has been lost. Filenames for these soundings were changed to reflect the actual launch time determined by pressure change and GPS dz/dt.

NCAR1	**NCAR2**	**NSSL1**	**NSSL2**
D20100510_173401_P.1	D20100516_003406_P.1	D20100607_012755_P.1	D20100613_163555_P.1
D20100519_225950_P.1	D20100525_232715_P.1	D20100607_000042_P.1	D20100613_195813_P.1
D2010056_232040_P.1	D20100603_202826_P.1	D20100613_220309_P.1	
D20100527_001954_P.1	D20100604_213900_P.1		
D20100604_004320_P.1	D20100614_200437_P.1		
D20100607_010743_P.1			

7. The following radiosondes reported incorrect measurements from one or both hygrometers. The table below includes the names of the files and the individual corrections applied. For some, we were unable to determine which hygrometer was malfunctioning, so no correction could be applied. The plots below (Figure 2) show examples of radiosonde data with problem hygrometers.

NCAR2	**Correction**
D20100510_235807_P.1	Set all RH to missing
D20100523_221311_P.1	Adjusted measurements from RH2 sensor into agreement with RH1
D20100605_223608_P.1	No correction applied
NSSL1	**Correction**
D20100613_195953_P.1	RH2 hygrometer was broken (reporting missing values) resulting in intermittent loss of data.
NSSL2	
D20100519_012951_P.1	Set RH above 214 mb to values reported from RH2 sensor
D20100510_234450_P.1	No T/RH measurements recorded

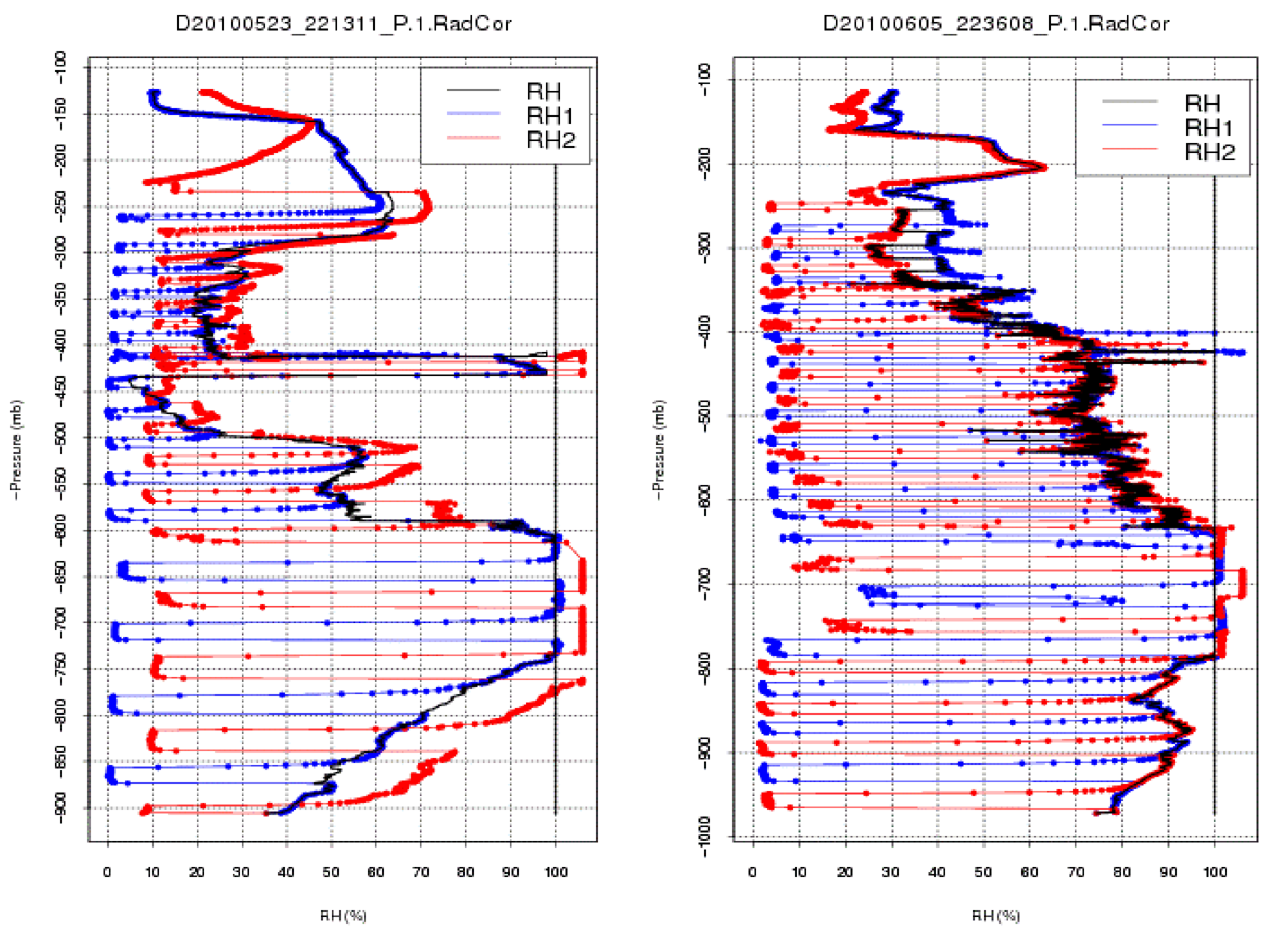

Figure 2 shows profiles of soundings where one of the two hygrometers measured incorrectly. The profile on the left shows measurement offsets from the RH2 sensor. The final RH, after correction, is shown in black. The profile on the right has an offset of one sensor above 350 mb. We were unable to determine which sensor is incorrect, so no correction was applied.

8. Each of the four sounding systems employed the use of a surface met sensor as an independent reference measurement for comparison with the surface pre-launch radiosonde data. The NSSL1 and NSSL2 systems used a hand-held kestrel surface instrument, while the NCAR systems both used a WXT surface met sensor. Comparison between the kestrel surface data and pre-launch radiosonde data revealed a consistent .5 mb pressure offset, with the kestrel sensor measuring lower pressure values than the radiosonde. ASPEN considers the surface met data as “truth” and will discard any sounding pressure values larger than those measured by the surface met sensor. In order to avoid data loss near the surface, the kestrel surface met data was removed (from the A00 line in the raw data file) and replaced with radiosonde data collected just prior to launch.

9. A number of soundings, listed below, lost temperature and RH prematurely. We suspect the T/RH sensor arm may have sustained damage, or may have broken completely, when traveling through a severe storm. An example of one such sounding is shown in Figure 3.

NCAR1	NCAR2	NSSL1	NSSL2
D20100514_205649_P.1	D20100512_233441_P.1	D20100518_225519_P.1	D20100511_002313_P.1
D20100520_003905_P.1	D20100513_005911_P.1	D20100604_002849_P.1	D20100514_183147_P.1
D20100607_010743_P.1	D20100514_221215_P.1	D20100607_234157_P.1	D20100514_212745_P.1
	D20100604_002841_P.1		D20100519_003824_P.1
	D20100607_234843_P.1		D20100608_022607_P.1
	D20100608_003624_P.1		
	D20100608_014057_P.1		

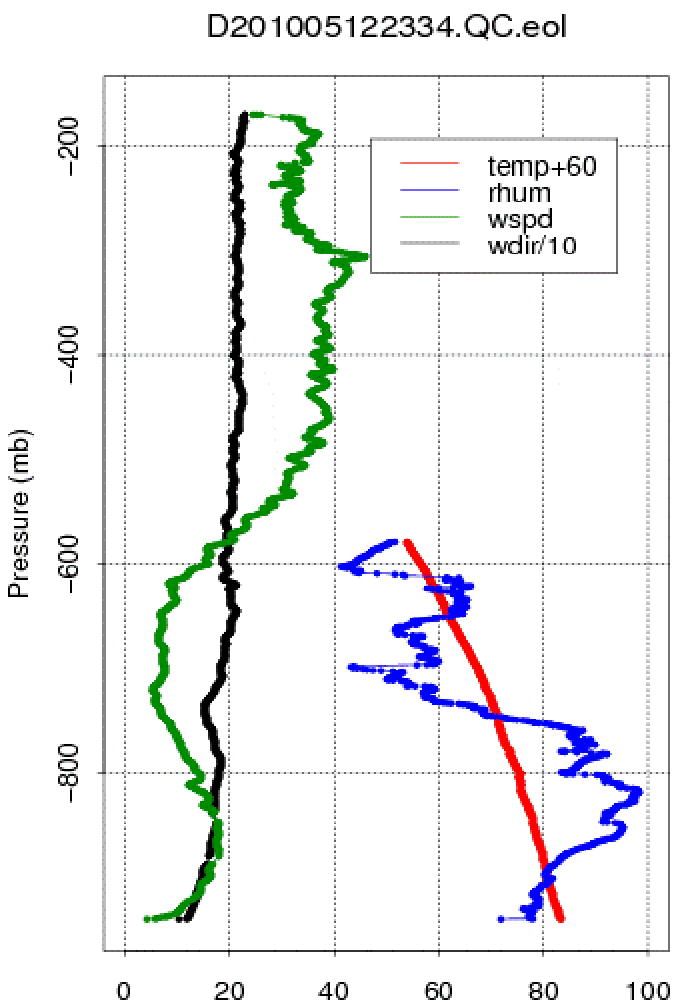

Figure 3 Sounding profile shows an example where temperature and RH end prematurely, likely caused by damage to the sensor arm while encountering volatile atmospheric conditions.