Hurricane and Severe Storm Sentinel (HS3) 2012 Global Hawk Dropsonde Project Analysis Summary

National Center for Atmospheric Research *
Earth Observing Lab
Boulder, Colorado

Contacts:

Data Quality
Kate Young (kbeierle@ucar.edu)
Junhong (June) Wang (junhong@ucar.edu)

System & Software Engineering
Terry Hock (hock@ucar.edu)
Dean Lauritsen (lauritsn@ucar.edu)
Charlie Martin (martinc@ucar.edu)

Mailing Address:
NCAR/Earth Observing Laboratory
P.O. Box 3000
1850 Table Mesa Drive
Boulder, CO 80307; USA

Document Version Control

Version	Date	Author	Change Description
1.0	03-20-2013	*K. Young*	Initial Document Release
2.0	5/28/13	*K.Young*	Restored near surface data lost in conversion of files from binary to ascii
3.0		*K. Young*	GPS Filtering of lat, lon and alt
4.0		*K. Young*	RH Dry Bias Correction

5.0	07-29-2016	*K. Young*	RH Dry Bias Correction with recomputing of dewpt
6.0	07-13-2018	*K. Young*	GPS filtering for lat, lon and alt to QC files with the RH Dry Bias Correction

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Table of Contents

Contents

List of Tables

List of Figures

For more information on the NCAR Dropsonde System please visit the following site: http://www.eol.ucar.edu/instrumentation/sounding/dropsonde

Disclaimer: The dropsonde data for this project were quality controlled and are maintained by the Earth Observing Laboratory at the National Center for Atmospheric Research (NCAR). NCAR is sponsored by the National Science Foundation (NSF). In the event that information or plots from this document are used for publication or presentation purposes, please provide appropriate acknowledgement to NSF and NCAR/EOL and make reference to Young et al. (2013, K. Young, J. Wang, T. Hock, D. Lauritsen and C. Martin: HS3 2012 quality controlled global hawk dropsonde data set.

Release Notes:

1. 05/28/2013 corrections to the dropsonde data include:
    - Application of a .4 mb offset to the dropsonde pressure measurements. This is a standard Bernoulli correction applied to the dropsondes that was inadvertently removed, during the first round of quality control, when the data files were recoded. The recoding process is described in section III.

- Near surface data was restored for many data files that had been inadvertently truncated when the raw ascii data was created from the binary data files during post-processing.

I. Dataset Overview

The NASA Hurricane and Severe Storm Sentinel (HS3) is a multi-year investigation aimed at examining hurricane formation and intensity change. The most recent phase of the campaign involved six research flights of the unmanned NOAA/NASA Global Hawk (GH) aircraft conducted between September 7 and 26, 2012. The GH is equipped with an NCAR/NOAA dropsonde system specially designed for remote operation. A total of 337 quality controlled soundings are contained in the final HS3 dropsonde data set. A detailed summary of the six flights is shown in Table 1.

The NASA GH aircraft is an unmanned, high-altitude, long endurance aircraft capable of flying at altitudes above 60,000 feet for up to 30 hour flights. The GH dropsonde system was developed by the Earth Observing Laboratory at the National Center for Atmospheric Research (NCAR/EOL) for NOAA as a collaborative effort. The dropsonde system is a fully automated aircraft dropsonde system controlled from the ground which measures vertical profiles of atmospheric thermodynamic and wind parameters. The GH dropsonde system, which was successfully tested in January 2011, can dispense up to eighty-eight Miniature dropsondes during a single flight, and the aircraft data system can track up to eight dropsondes in the air simultaneously. The system has been previously used to support the NOAA WISPAR field project in early 2011 and HS3 2011 with good success.

Table 1 - Summary of Research Flights

RF#	Name	Dates	Sondes deployed	Soundings in final archive
RF01	Research Flight 1	Sept 07, 2012	30	29
RF02	Research Flight 2	Sept 11, 2012	34	34
RF03	Research Flight 3	Sept 14, 2012	70	70
RF04	Research Flight 4	Sept 19, 2012	76	76
RF05	Research Flight 5	Sept 22, 2012	58	53
RF06	Research Flight 6	Sept 26, 2012	75	75
			Total Soundings	**337**

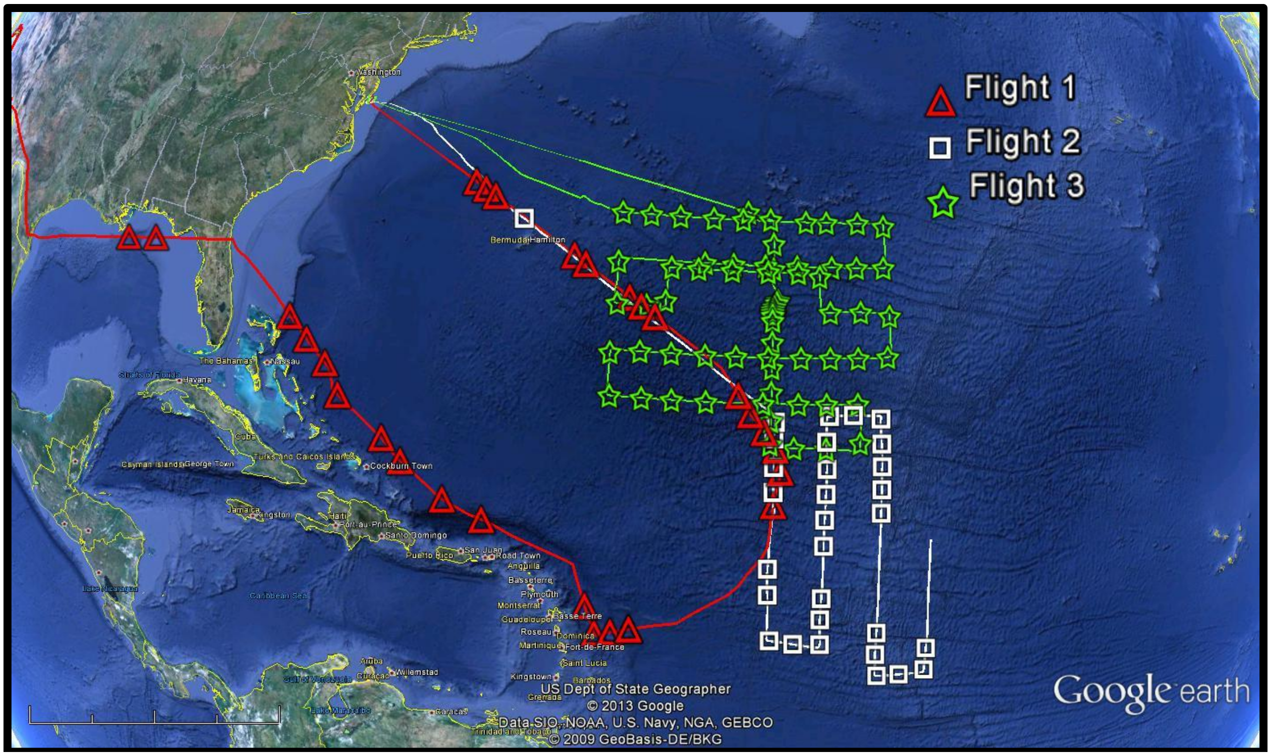

Figure 1 Map of HS3 Project Research Flights 1, 2, and 3, conducted September 7, September 11 and September 14, 2012, respectively.

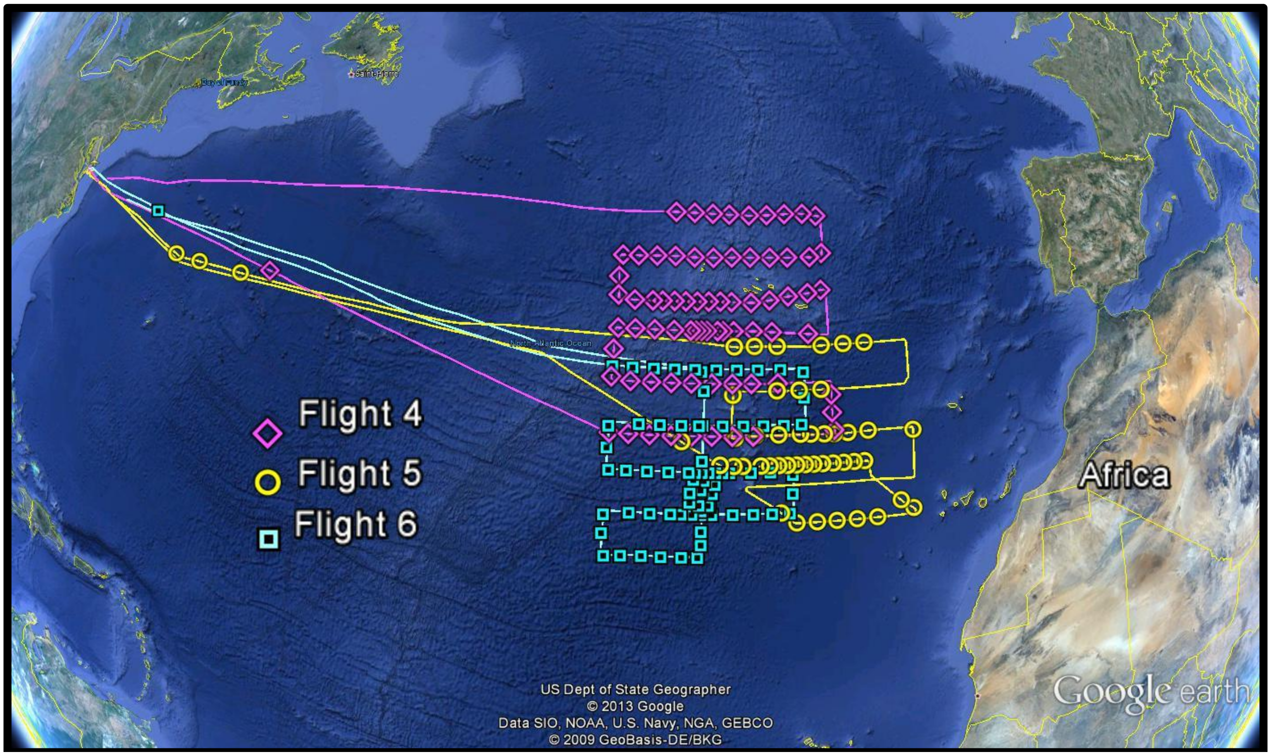

Figure 2 Map of HS3 Project Research Flights 4, 5, and 6, conducted September 19, September 22 and September 26, 2012, respectively.

II. EOL Sounding File Format and Data Specifics

The EOL format is an ASCII text format that includes a header (Table 2), with detailed project and sounding information, and seventeen columns of high resolution data (Table 3). The "QC.eol" files are quarter-second resolution data files with appropriate corrections and quality control measures applied. Note that the thermodynamic data (pressure, temperature and humidity (PTU)) are only available at half-second resolution and wind data is available at quarter-second resolution. The naming convention for these files is "D", followed by "yyyymmdd_hhmmss_P.QC.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 “QC.eol” refers to the EOL file format type.

The header contains 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 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 3.

The variables pressure, temperature, and relative humidity are calibrated values from measurements made by the dropsonde. The dew point is calculated from the relative humidity and temperature. The geopotential altitude is calculated from the hydrostatic equation, typically from the ocean’s surface upward. For dropsondes that failed to transmit useful data to the surface, we integrate geopotential altitude from flight level down. The descent rate of the sonde is computed using the time-differentiated hydrostatic equation. The position (lat, lon) and wind data come directly from the GPS sensor.

Table 2 - EOL Sounding File Format (dropsonde and radiosonde)

```
Data Type/Direction:                    AVAPS SOUNDING DATA, Channel 3/Descending
File Format/Version:                    EOL Sounding Format/1.1
Project Name/Platform:                  NASA HS3 2012, Science Flight 1/Global Hawk, NASA 872 (AV-6)
Launch Site:
Launch Location (lon,lat,alt):          154 26.51'W -154.441874, 27 00.48'N 27.007975, 18420.10
UTC Launch Time (y,m,d,h,m,s):          2012, 09, 07, 02:20:56
Sonde Id/Sonde Type:                    094355195/
Reference Launch Data Source/Time:      IWGADTS Format (IWG1)/02:20:56
System Operator/Comments:               Remote Operator/none, none
Post Processing Comments:               Aspen Version 3.1; Configuration miniDropsonde
/
  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
-------- -- -- ----- ------- ------- ------- ------- ------- ------- ------- ------- ------- -------- ----------- ----------- --------
   -1.00  1 56 45.00   76.30  -66.40 -999.00 -999.00   -4.22   -8.40    9.40   26.70 -999.00 18049.91 -146.474492   19.129230 18080.60
    0.00  1 56 46.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -146.477141   19.131582 18070.77
    0.25  1 56 46.25 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
    0.50  1 56 46.50 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
    0.75  1 56 46.75 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
    1.00  1 56 47.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
    1.25  1 56 47.25 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.0
```

Table 3 - Lists data fields provided in the EOL format ASCII soundings

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	Descent Rate	Meters/Second	Calculated
14	Geopotential Altitude	Meters	Calculated
15	Longitude	Degrees	Measured
16	Latitude	Degrees	Measured
17	GPS Altitude	Meters	Measured

III. Data Quality Control Process

The Global Hawk dropsonde system has been used very successfully in supporting previous field programs; WISPAR (NOAA) and HS3 2011, with minimal issues. During HS3 2012 the system experienced significant **external** RF noise interference in the 400 MHz meteorological band, where the RF telemetry link from the dropsonde to the aircraft operates. This RF noise interference significantly reduced the dropsonde aircraft receiver Signal-to-Noise Ratio (SNR), degrading the telemetry performance of the system. The degraded SNR reduced the amount of data received from the dropsonde as it approached the ocean surface, coinciding with when the sonde is furthest from the aircraft, and also when the aircraft banked during a sounding. The external RF noise negatively impacted the quantity of data collected during flights 2 through 6, however, flight 1 had very good data acquisition for all dropsondes deployed. The RF interfering noise level during flight 1 was substantially lower and therefore, there was minimal impact to the data. There were no changes made to the dropsonde system between flight 1 and 2 through 6. Extensive testing was performed on the Global Hawk, while at Wallops, to try to identify and eliminate the noise emitted from other equipment on the aircraft, however the exact cause of the noise source could not be determined during the field campaign.

1. The raw binary data were subjected to a process referred to as ‘recoding’, used to recapture data lost due to telemetry noise during descent of the dropsonde. All raw binary data from the dropsondes are saved and, with additional effort during post-processing, were appropriately parsed using a technique that looks for dropped telemetry bytes, and attempts to work around lost data. This ‘recoding’ effort essentially decodes each of the data frames, while identifying offsets and adjusting accordingly.

2. Profiles of pressure, temperature, RH, wind speed and descent rate from the raw D-files are examined to determine if all of the files contain data, and to ensure that nothing looks suspicious. Doing this allows us to determine if a sounding was started up, but not launched, or if the data contains any features that warrant further investigation. Corrections are applied where appropriate.

3. All flight level data contained in the sounding files are subjected to an altitude correction that converts GPS altitude to geometic altitude, using the geoid height at a particular location, and then converts geometric to geopotential altitude. This correction, involving the geoid, is only necessary for soundings that require computation of the geopotential altitude from flight level downward (ie when the sounding data does not reach the surface).

4. For the first time, a pressure ground check (GC) correction was applied to the entire profile for each sounding. The surface pressure measured by an independent surface sensor for each dropsonde at the NCAR laboratory (prior to the project) was used as a reference for the correction. The corrected pressure $P = P^{RS} * P_0^{REF} / P_0^{RS}$, where P^{RS} is the pressure measured by radiosonde, P_0^{REF} is the pressure as indicated by the reference sensor in the lab, and P_0^{RS} is the pressure as indicated by the radiosonde in the lab.

5. The raw soundings D-files are then processed through the Atmospheric Sounding Processing ENvironment (ASPEN) software, which analyzes the data, performs smoothing, sensor time response corrections, and removes suspect data points. Due to aberrant noise in the PTU and wind profiles collected during flights two through six, the default ASPEN configuration set used for mini-dropsondes was modified, with extensive testing conducted, in order to ensure that appropriate filtering and smoothing techniques were applied, while retaining the maximum amount of data possible. An example of the improvement made in a single sounding file, by applying all quality control procedures listed above, is shown in Figure 3.

6. Time series plots of quality controlled temperature, RH, wind speed, and fall rate, are used to examine the consistency of soundings launched during each flight, and to show the variability of soundings from different missions. These plots are also used to determine if the sounding did not transmit data to the surface, or if there was a “fast fall” caused by failure of the parachute to properly deploy.

7. Profiles of temperature, RH and winds from the quality controlled soundings are visually evaluated for outliers, or any other obvious issues.

8. Finally, histograms of pressure, temperature, relative humidity, wind speed and wind direction are created to examine the distribution, range, and characteristics of each parameter.

IV. Special Problems to Note (Important Information for Users)

Performing the quality control procedures outlined above allows us to identify and, in many cases, resolve issues that could potentially impact research performed using these data sets.

The following issues were found, and where necessary, corrections were applied:

1. **Data files removed from final archive:** Six soundings were removed from the final archive. Two contained no useful data, and the other four contained very little, if any, data after the sensors reached equilibrium with the outside environment.

Files Not in Final Archive	Notes
RF01/D20120907_070957	NASA reset power to all aircraft instruments during flight
RF05/D20120923_070656	AVAPS chassis hardware fault
RF05/D20120923_071656	AVAPS chassis hardware fault
RF05/D20120923_072622	AVAPS chassis hardware fault
RF05/D20120923_073630	AVAPS chassis hardware fault
RF05/D20120923_074920	AVAPS chassis hardware fault

2. **Fast fall:** Ten soundings were classified as "fast fall drops", meaning the parachute failed to properly deploy resulting in dropsondes falling at an accelerated rate (and sometimes tumbling). When this occurs data acquired from the GPS are often unreliable, therefore wind speed, wind direction and U/V winds are set to missing.

Fast Fall Soundings	
D20120907_075657	D20120915_065705
D20120907_110137	D20120920_030431
D20120907_133926	D20120923_051940
D20120911_185139	D20120923_090119*
D20120915_051846	D20120926_231334

*indicates partial fast fall where parachute eventually opened and ascent rate slowed. Winds were only set to missing during period of accelerated descent.

3. **No Temperature Data:** One sounding file (D20120914_193503) contains no temperature data. The sensor appears to have broken at launch. The values recorded in the original data files were unrealistic and therefore all temperature values were set to missing.

4. **PTU Data Not to Surface -** Seventy sounding files did not contain useful pressure or temperature data to the surface, therefore geopotential altitudes were computed from flight level downward.

5. **No Geopotential Altitude –** The following soundings contain no calculated geopotential altitude because the near surface pressure and temperature data was either too sparse or too noisy to compute altitude from the surface up, and computing the altitudes from flight level down resulted in negative near-surface geopotential altitudes.

No Geopotential Altitude		
D20120914_184846	D20120926_191548	D20120926_212357
D20120920_083216	D20120926_192724	
D20120926_182203	D20120926_195640	

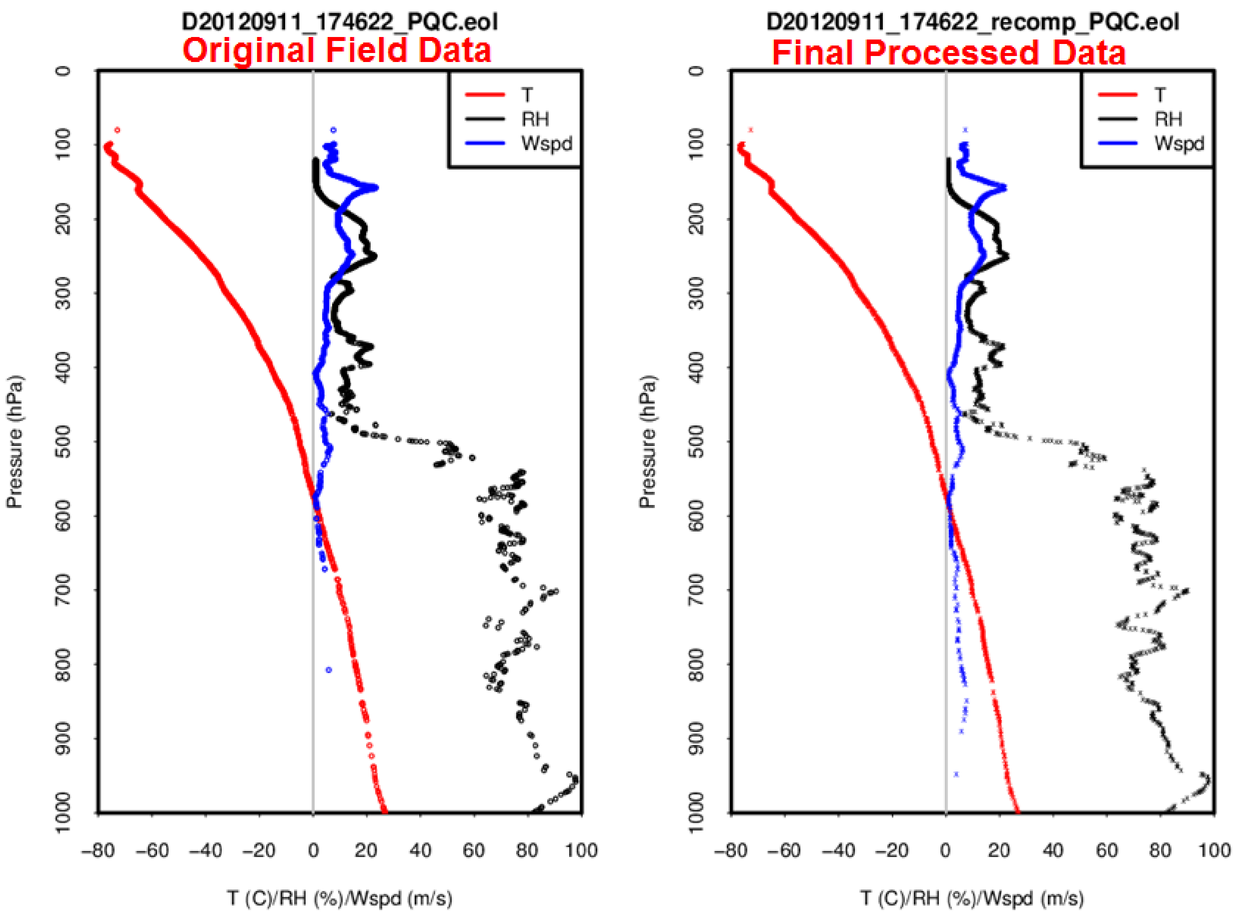

Figure 3 Quality controlled temperature, RH and wind speed profiles shown, left, after running the raw file through ASPEN during the field project and, right, after recoding raw binary data and modifying ASPEN configuration to retain the maximum amount of data possible.