Hurricane and Severe Storm Sentinel (HS3) 2014 Global Hawk Dropsonde Data Analysis Summary

HS3-2014 Dropsonde Data Quality Report

March 25

2016

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. (2016, T. Hock and C. Martin: HS3-2014 Dropsonde Data Quality Report.)

UCAR/NCAR - Earth Observing Laboratory. 2016. HS3 2014 Global Hawk Dropsonde Data, Version 3.0. UCAR/NCAR - Earth Observing Laboratory. http://dx.doi.org/10.5065/D6GB2243. Accessed 29 Aug 2016.

HS3-2014 Quality Controlled Dropsonde Data Set

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Document Version Control

Version	Date	Author	Change Description
1.0	3/31/2015	*K. Young*	Initial Document Release
2.0	5/25/2016	*K. Young*	A dry bias in the RD94 and mini-dropsonde (NRD94) relative humidity measurements was discovered in data collected from 2010 to present, including all of the HS3 dropsonde datasets. The dry bias is strongly temperature dependent. It is considered small at warm temperatures and it becomes stronger at cold temperatures. This RH dry bias has been corrected for. The dropsonde files that have received this correction contain an indicator in the header of the file, 'TDDryBiasCorrApplied', and an indicator in the filename, 'V2'.
3.0	8/29/2016	*K. Young*	Dewpoint temperature was recalculated using the corrected RH measurements (V2.0)

* The National Center for Atmospheric Research is managed by University Corporation for Atmospheric Research and sponsored by the National Science Foundation.

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I. Dataset Overview

The NASA Hurricane and Severe Storm Sentinel (HS3) 2014 was the third science field campaign of a multi-year investigation aimed at examining hurricane formation and intensity change. The 2014 phase of the campaign involved eleven research flights of the unmanned NOAA/NASA Global Hawk (GH) aircraft conducted between August 26 and September 30. The GH is equipped with an NCAR/NOAA dropsonde system specially designed for remote operation. A total of 656 quality controlled soundings are contained in the final HS3 dropsonde data set. A detailed summary of the eleven 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 with typical flight durations of 25 hours. 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 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.

Table 1 - Summary of Research Flights

Research Flight	Dates	Sondes deployed	Soundings in final archive
RF01	Aug 26, 2014	81	81
RF02	Aug 29, 2014	70	69
RF03	Sept 02 , 2014	50	50
RF04	Sept 05, 2014	59	59
RF05	Sept 11, 2014	64	60
RF06	Sept 14, 2014	80	80
RF07	Sept 16, 2014	88	87
RF08	Sept 18, 2014	50	50
RF09	Sept 22, 2014	40	40
RF10	Sept 28, 2014	65	65
RF11	Sept 30, 2014	15	15
Total		662	656 *

* There were AVAPS system issues which prevented data collection of 5 sondes launched.

For more information on the **HS3-2014 project** please visit:

https://espo.nasa.gov/missions/hs3/

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

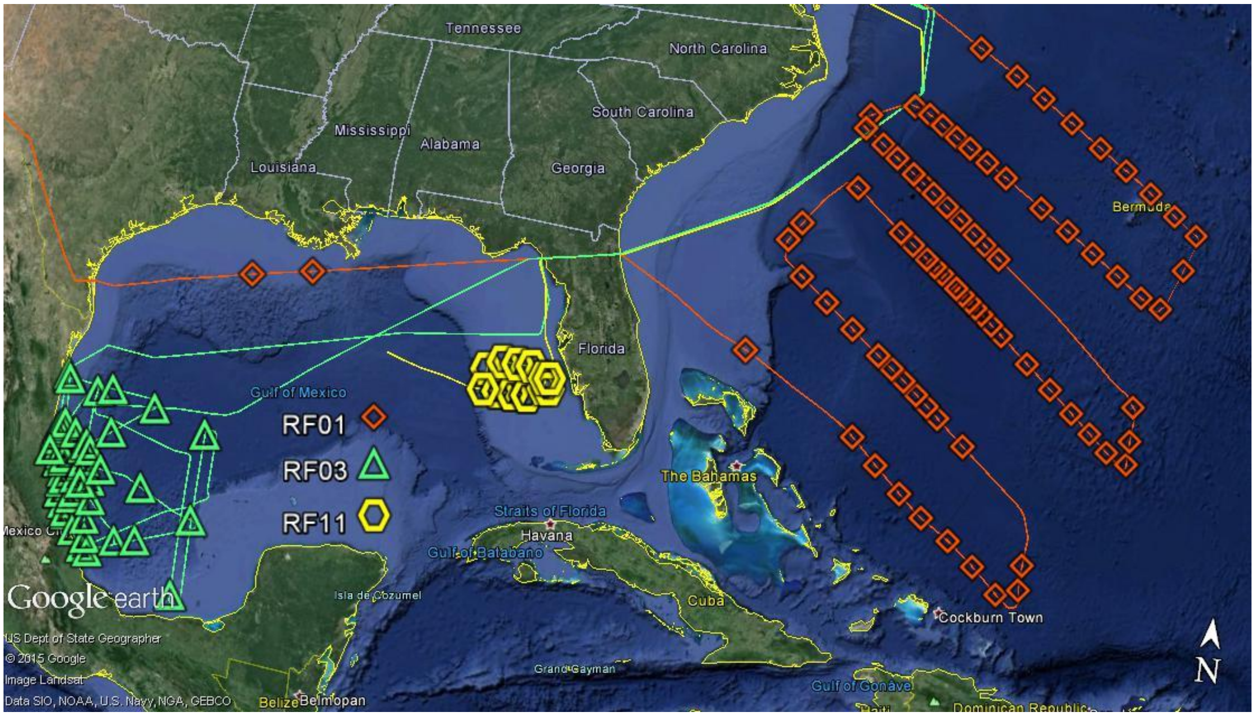

Figure 1 Map of HS3-2014 Research Flights 1, 3 and 11.
Points indicate dropsonde launch locations. Lines connecting the dropsonde locations represent the aircraft flight tracks.

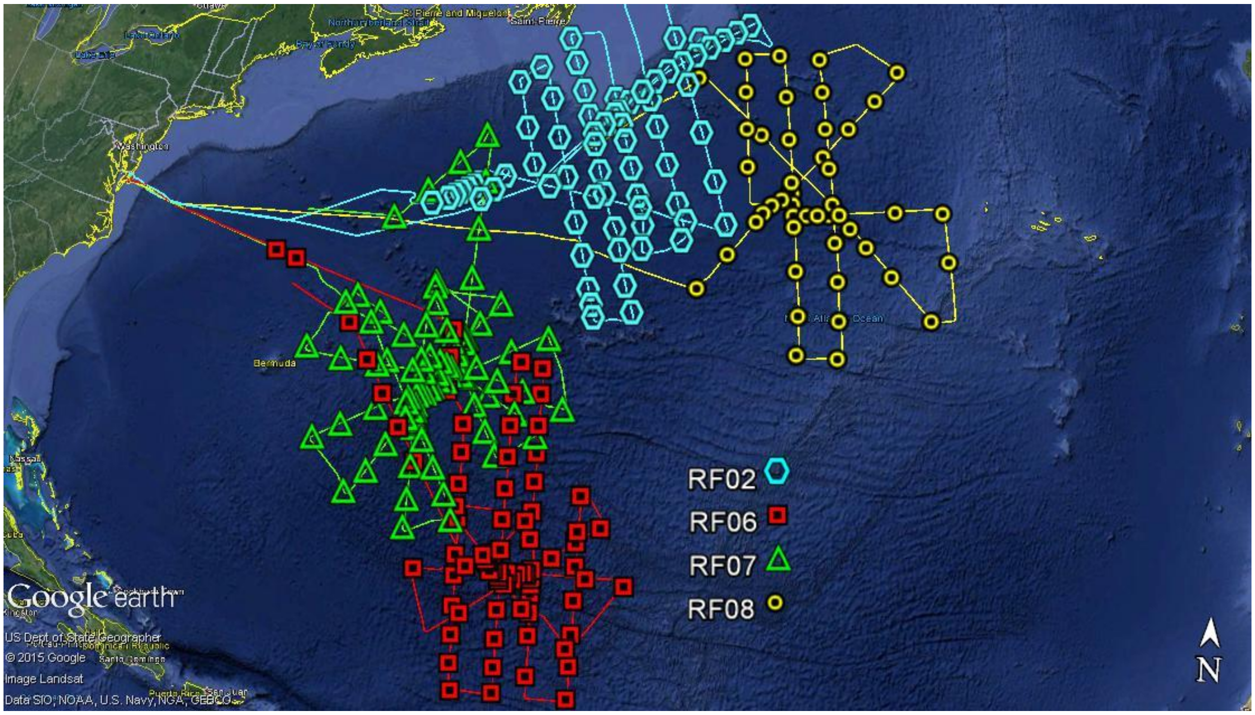

Figure 2 Map of HS3-2014 Research Flights 2, 6, 7, 8.

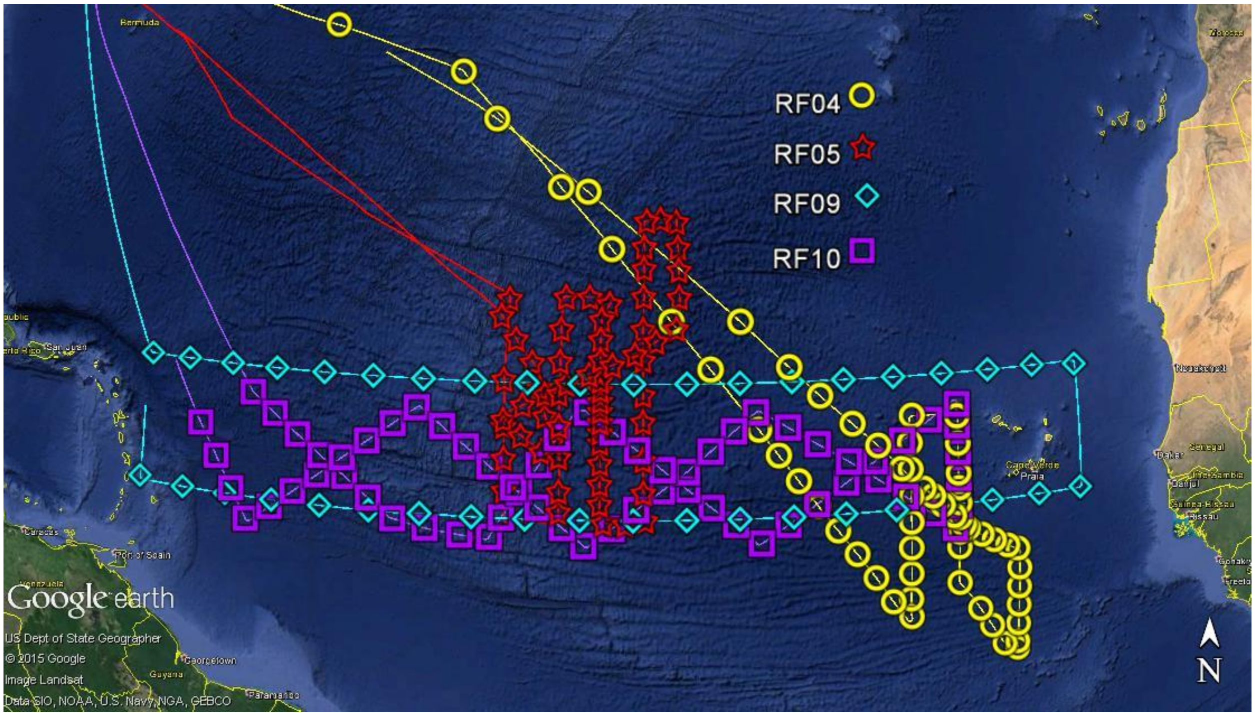

Figure 3 Map of HS3-2014 Research Flights 4, 5, 9 and 10.
Points indicate dropsonde launch locations. Lines connecting the dropsonde locations represent the aircraft flight tracks

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/ 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 quality controlled, 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, 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 last line of the header contains information about the current version of ASPEN and its configuration used for the final data QC. It also contains a flag, 'TDDryBiasCorrApplied', indicating the files have been corrected for a temperature dependent dry bias in the relative humidity measurements (for more information, please see 'Data Quality Control Process' in Section II.

The variables pressure, temperature, and relative humidity are calibrated values from measurements made by the dropsonde. The AVAPS software applies a .4 mb dynamic correction to the pressure measurements, in real time. The dew point is calculated from the relative humidity and temperature using the vapor pressure equation (Bolton 1980).. 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. The uncertainty of the GPS altitude is estimated to be less than 20 m. Investigators should follow meteorological convention and use geopotential altitude.

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

```
Data Type/Direction:                    AVAPS SOUNDING DATA, Channel 2/Descending
File Format/Version:                    EOL Sounding Format/1.1
Project Name/Platform:                  NASA HS3 2014,/Northrup/Grumman Global Hawk, NASA 872 (AV-6)
Launch Site:
Launch Location (lon,lat,alt):          52 20.57'W -52.342787, 30 38.85'N 30.647524, 17988.17
UTC Launch Time (y,m,d,h,m,s):          2014, 09, 14, 20:07:49
Sonde Id/Sonde Type:                    134835033/
Reference Launch Data Source/Time:      IWGADTS Format (IWG1)/20:07:49
System Operator/Comments:               Remote Operator/none, none
Post Processing Comments:  Aspen Version 3.1-7741; Created on 10 Feb 2015 23:53 UTC; Configuration mini-dropsonde;TDDryBiasCorrApplied
/
  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 3 - Lists data fields provided in the EOL format ASCII soundings

Field	Parameter	Units	Measured/Calculated
1	Time	Seconds	-------------
2	UTC Hour	Hours	-------------
3	UTC Minute	Minutes	-------------
4	UTC Second	Seconds	-------------
5	Pressure	Millibars	Measured
6	Air 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

1. 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 identify features that may warrant further investigation. Corrections are applied where appropriate.

2. A pressure correction was applied to the entire profile for each sounding during the QC process. The pressure correction value is unique for each sonde and is determined in the final testing of the dropsonde during production. During the final testing of the dropsonde an independent precision pressure sensor is used as the reference for determining the pressure offset value from the dropsonde pressure measurement. The corrected pressure $P = P_{RS} + (P_{0REF} - P_{0RS})$, where P_{RS} is the pressure measured by the dropsonde, P_{0REF} is the pressure as indicated by the reference sensor and P_{0RS} is the pressure as indicated by the dropsonde during calibration testing. This pressure correction is typically 1 mb or less. This correction is not implemented on real-time data in the field.

3. All aircraft flight level data contained in the sounding files are subjected to an altitude correction that converts GPS altitude (ie Ellipsoid height) to geopotential altitude. Ensuring an accurate flight level geopotential altitude is important for both soundings made over land and for dropsondes that do not transmit useful data all the way to the sea surface, as they require calculation of the geopotential altitude from flight level downward.

4. All dropsonde GPS altitude measurements have been improved by removing an existing geoid correction, applied in real-time from the dropsonde GPS sensor, and replacing it with a more accurate measurement of geoid height from Earth Gravitational Model 1996 (EMG96). On average the difference between the two is approximately 1.6 m, but the scatter is quite significant (Figure 4), making this correction necessary.

5. The raw soundings D-files with the corrected pressure offset and updated flight level data 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. The ASPEN software version and configuration file used for this program are included in the header of each "QC.eol" sounding file.

   For more information on ASPEN or to download the software please visit: http://www.eol.ucar.edu/software/aspen

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. A dry bias in the relative humidity measurements was discovered, in the Spring of 2016, in all RD94 dropsondes from 2010 to present and all mini-dropsondes (NRD94) collected. This dry bias is strongly temperature dependent and most significant at cold temperatures. It is considered small at warm temperatures. All sounding files undergoing post-processing have been corrected for this error and contain the flag, 'TDDryBiasCorrApplied', in the last line of the header to confirm that this correction has been applied. For more information on the dry bias, please access the technical note, linked below, which contains information on the origin, magnitude and impact of the dry bias.

   NCAR/EOL Technical Note: Dropsonde Dry Bias

   https://www.eol.ucar.edu/system/files/software/Aspen/Windows/W7/documents/Tech%20Note%20Dropsonde_Dry_Bias_20160527_v1.3.pdf

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

IV. Special Issues 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, noted in table 4, were found. Where necessary, corrections have been applied. Following the table are more detailed descriptions of the data quality issues discovered and information on how they were addressed.

Table 4 – Summary of Data Quality Issues Found with the HS3 Dropsonde Data

Data Quality Issue	# of soundings
Files with no useful data	4
Slow Falls	1
Fast Falls	2
Dropsondes over water, data not to surface	13

1. **Files Containing No Useful Atmospheric Data:** Three dropsondes were deployed but contained no useful atmospheric data. These files have been excluded from the final archive.

Files Not in Final Archive	Notes
RF05 D20140912_145806	Instruments were launched, however the soundings ended prematurely and contained no useful data.
RF05 D20140912_150818	
RF05 D20140912_151842	

2. **Slow Fall:** One dropsonde, D20140827_012751, was equipped with a larger parachute to experiment with improving the vertical resolution of the measurements by slowing the ascent rate. (Figure 5)

3. **Fast Fall:** Two soundings were classified as "fast fall drops", meaning the parachute failed to properly deploy resulting in dropsondes falling at an accelerated rate. When a fast fall occurs, GPS wind measurements can be unreliable (due to irregular motion of the dropsonde) and a lag in the response of the T/RH and sensors may occur. In extreme cases where tumbling of the sondes results in very noisy winds, those data are set to missing. For these two sondes the fall velocities were extremely high (~40 m/s), indicating the parachute deployed but did not properly inflate. The orientation of the dropsondes was vertical and the wind data were deemed acceptable and were retained in the final data archive. For the soundings listed below, we strongly caution data users about the validity of wind speed, wind direction, U/V winds, Temperature and RH data contained in each profile.

Fast Fall Soundings	
RF01	D20140827_070257
RF08	D20140918_165838

4. **Data not to surface:** There were thirteen soundings classified as dropsondes that did not transmit data to the surface. The loss of data at the surface was due to Radio Frequency Interference in the 400 MHz Meteorological band.

Not to surface			
D20140827_025641	D20140912_144722	D20140916_220457	D20140918_203051
D20140905_232628	D20140916_155522	D20140916_221540	
D20140912_143108	D20140916_175315	D20140917_024132	
D20140912_143714	D20140916_175526		

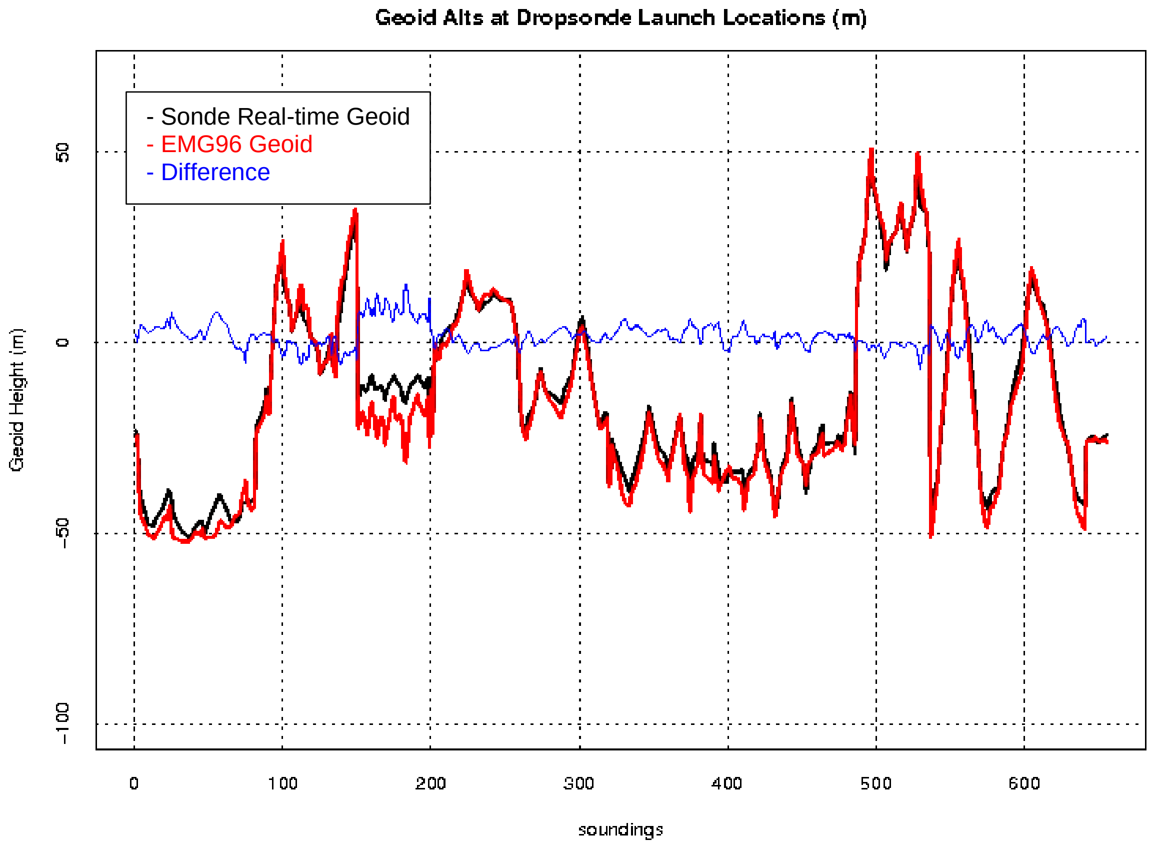

Figure 4 Sonde GPS and EMG96 Geoid Altitudes and difference.
Black line shows dropsonde geoid values originally contained in real-time dropsonde GPS altitudes. Red line shows the geoid measurements from the EMG96 which replaced the dropsonde geoid values.

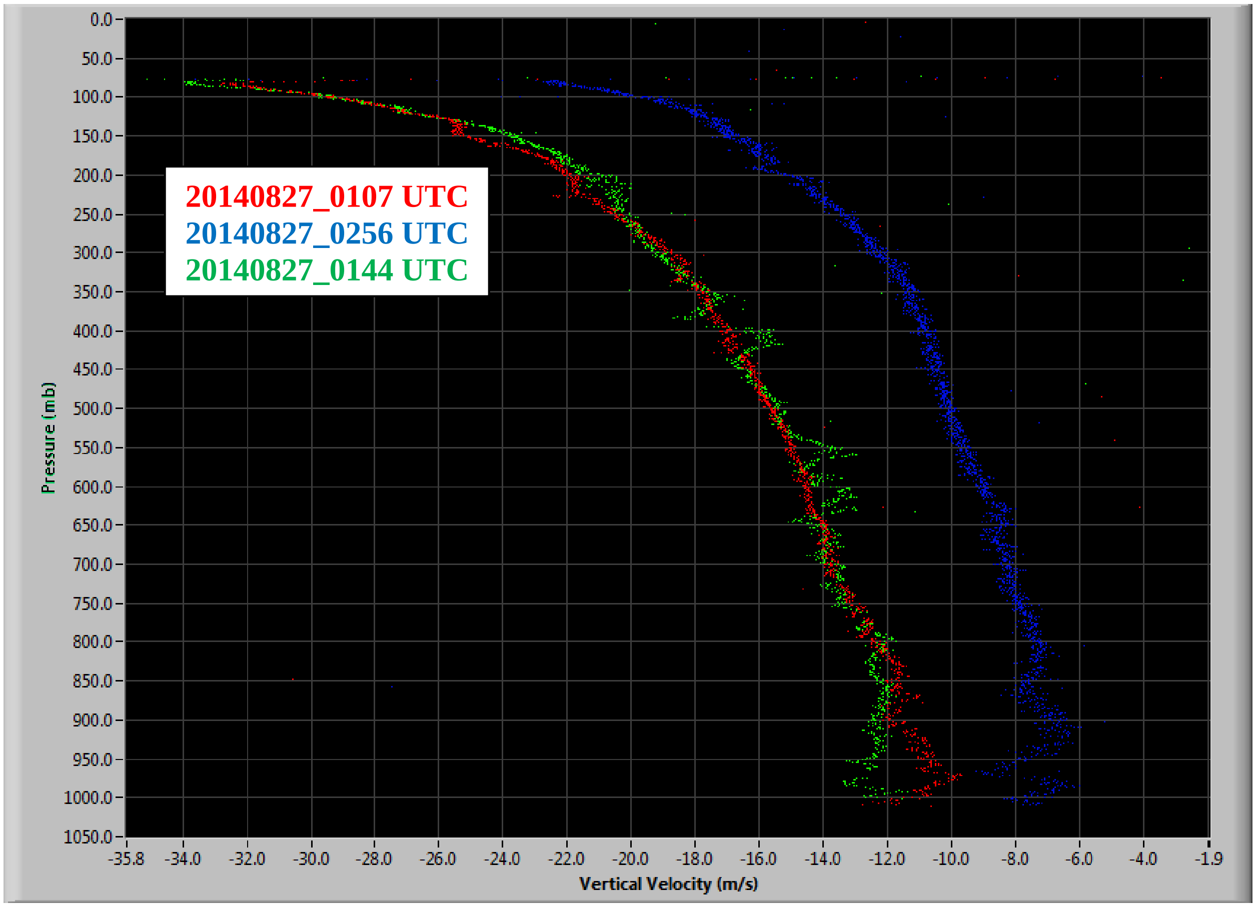

Figure 5 Profiles of typical vertical fall rates and large parachute fall rate.
Plot of three dropsondes deployed on Research Flight 01 Aug, 27 at 0107, 0256 and 0144 UTC. The blue profile shows descent rates of a dropsonde equipped with a larger parachute.