Hurricane and Severe Storm Sentinel (HS3) 2011 Dropsonde Project Analysis Summary

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Document Version Control

Version	Date	Author	Change Description
1.0	11- 11-2011	*K. Young*	Initial Document Release
2.0	5-26-2016	*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 a 'V2' in the filename.
3.0	09-06-2016	*K. Young*	Dewpoint temperature was recalculated using the corrected RH measurements (V2.0)

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

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. (2011, K. Young, J. Wang, T. Hock, D. Lauritsen and C. Martin, 2011: HS3 2011 quality controlled dropsonde data set.

UCAR/NCAR - Earth Observing Laboratory. 2016. HS3 2011 Global Hawk Dropsonde Data, Version 3.0. UCAR/NCAR - Earth Observing Laboratory. http://dx.doi.org/10.5065/D6MC8X7N. Accessed 29 Aug 2016.

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 two research flights of the unmanned NOAA/NASA Global Hawk (GH) aircraft on September 9 and September 14, 2011. The GH is equipped with an NCAR/NOAA dropsonde system specially designed for remote operation. The first flight (Figure 1), conducted over the Eastern Pacific was to compare the temperature and humidity profiles from the S-HIS and HAMSR remote sensors with in situ measurements provided by the dropsondes. The second flight (Figure 2), over the Gulf of Mexico, was aimed at collecting GH dropsonde data for inter-comparison with AVAPS II dropsonde data from the NOAA G-IV. A total of 79 quality controlled soundings are contained in the final HS3 dropsonde data set. A detailed summary of the two 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 hours at a time. 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.

Table 1 - Summary of Science Flights

RF#	Name	Dates	Sondes deployed	Soundings in final archive
RF01	Science Flight 1	Sept 9, 2011	45	45
RF02	Science Flight 2	Sept 14, 2011	35	34

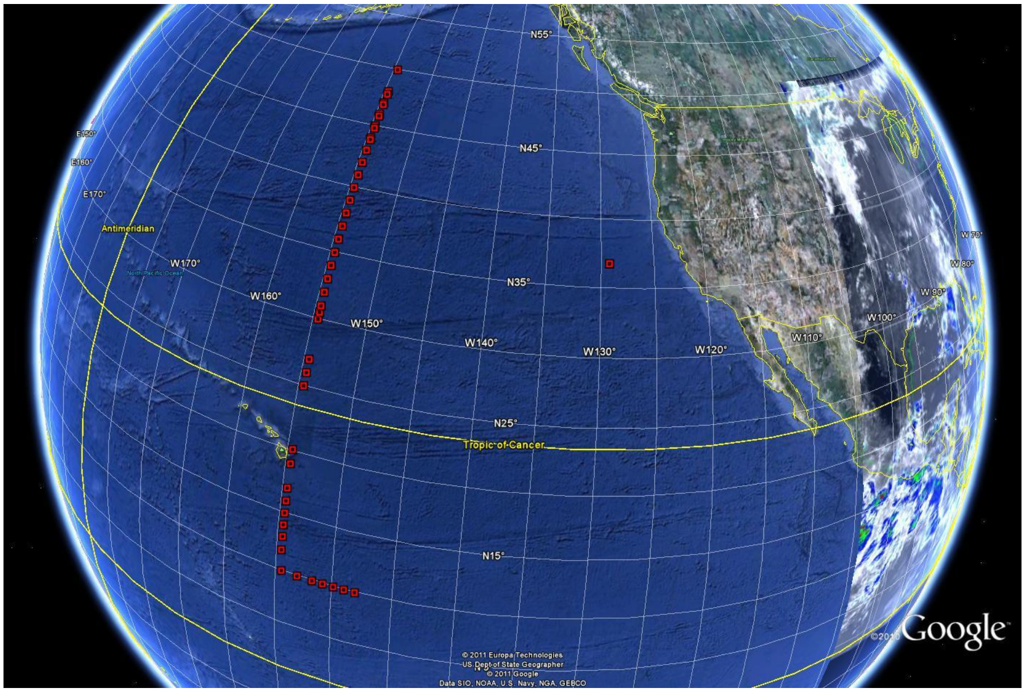

Figure 1- Map of Science Flight 1 over the Eastern Pacific
The red squares indicate the launch locations of 45 dropsondes deployed.

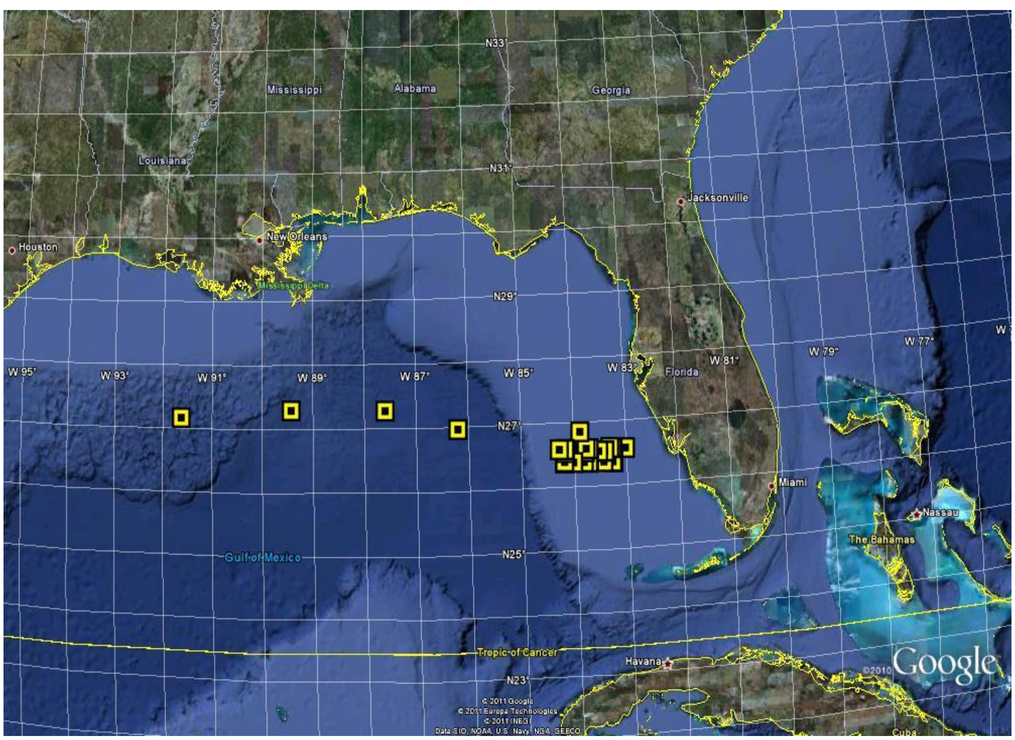

Figure 2 - Map of Science Flight 2 over the Gulf of Mexico
The yellow squares indicate the launch locations of 34 dropsondes deployed.

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_QC_V2.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, 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 3/Descending
File Format/Version:                     EOL Sounding Format/1.1
Project Name/Platform:                   NASA HS3 2011, 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):           2011, 09, 09, 14:10:07
Sonde Id/Sonde Type:                     094355195/
Reference Launch Data Source/Time:       IWGADTS Format (IWG1)/14:10:07
System Operator/Comments:                Remote Operator/none, none
Post Processing Comments:     Aspen Version 3.1; Created on 14 Oct 2011 20:12 UTC; Configuration GHdropsonde; 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
-------- -- -- ----- ------- ------- ------- ------- ------- ------- ------- ------- ------- -------- ----------- ----------- --------
   -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

1. Profiles of pressure, temperature, RH, wind speed and descent rate from the raw D-files are first 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.

2. The raw soundings 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.

3. Time series plots of quality controlled temperature (Figure 3), RH, wind speed, and fall rate (Figure 4), 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.

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

5. 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

6. 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 (Tables 4 & 5):

1. One sounding was removed from the final archive because the file contained no data. Analysis of supplementary engineering data determined this to be a bad sonde.

2. **Data not to the surface:** One dropsonde from Flight #2 experienced a loss of signal and failed to transmit useful data to the surface (Figure 3). Four additional soundings from Flight #2 contained sparse near surface data that was discarded by ASPEN during QC. As a result, geopotential altitude in these soundings was calculated from the flight level downward. The drops from flight #2 with sparse data may have been due to the aircraft banking where the 400 MHz telemetry antenna to receive the sonde data signal was shadowed.

3. **Partial fast fall:** Four soundings were classified as "partial fast fall drops", meaning the parachute deployed late (Figure 4). Failure of the parachute to properly deploy results in dropsondes falling at an accelerated rate (and sometimes tumbling) causing wind speed and

direction to be unreliable. For these soundings, wind speed and direction and U/V winds are set to missing where the fall rate is accelerated.

4. **Thin Temperature Sensor:** Five dropsondes deployed from Science Flight 1 were outfitted with a thin temperature sensor (like those used in the RS-92 radiosondes). The goal was to test the survivability of the sensors after ejection from the aircraft and for inter-comparisons with the standard dropsonde temperature sensors. Two of the five dropsondes were found to exhibit a significant warm bias, believed to be caused by damage to the sensor sustained during launch. The other three dropsondes exhibited no evidence of damage. The thin temperature sensors had increased detail in the temperature structure due to the smaller mass, and thus faster response time of the sensors.

5. **No GPS data:** There were three soundings with no GPS data. These soundings have no wind or position (lat, lon and GPS height) data in the final QCed files.

6. **No PTU data:** One sounding file contains no PTU data.

Table 4 - Summary Statistics for Flight 1

Total	45 (45 in final archive)		
Complete Profiles of PTH & wind data	39		No issues or corrections required (includes 5 thin temperature sensor soundings).
Thin T sensor	5	D20110909_101803* D20110909_102808 D20110909_103908 D20110909_105033* D20110909_110129	* Significant systematic warm bias (2) No corrections applied. Use temperature data with caution.
No GPS	2	D20110909_141007 D20110909_180007	No corrections applied. Wind and GPS Alt data are missing.
Partial Fast Fall	2	D20110909_095342 D20110909_131529	Parachute opened late. Wind data where fast fall occurred are set to missing.

Table 5 - Summary Statistics for Flight 2

Science FL #2	# of Files	Filenames	Comments/Corrections
Total	35 (34 in final archive)	D20110914_141323	One file contained no data and was removed from final archive.
Complete Profiles of PTH & wind data	25		No issues, or corrections required

No PTU	1	D20110914_130859	No correction applied, wind data only.
No GPS	1	D20110914_145614	No corrections applied. Wind and GPS Alt data are missing.
Partial Fast Fall	2	D20110914_082348 D20110914_131639	Parachute opened late. Wind data where fast fall occurred are set to missing.
Not to surface	5	D20110914_095358 D20110914_112654 D20110914_121144 D20110914_125019 D20110914_140948	Geopotential height integrated from flight level down.

Table 6 – Summary of Soundings (Both Flights)

	Total Soundings	Science Flight 1	Science Flight 2
Total dropsondes released	80	45	35
Thin temperature sensors	5	5	0
Complete wind and PTH profiles	64	39	25
Partial data (missing wind or PTH data)	15	6	9
Unusable sounding, no data	1	0	1

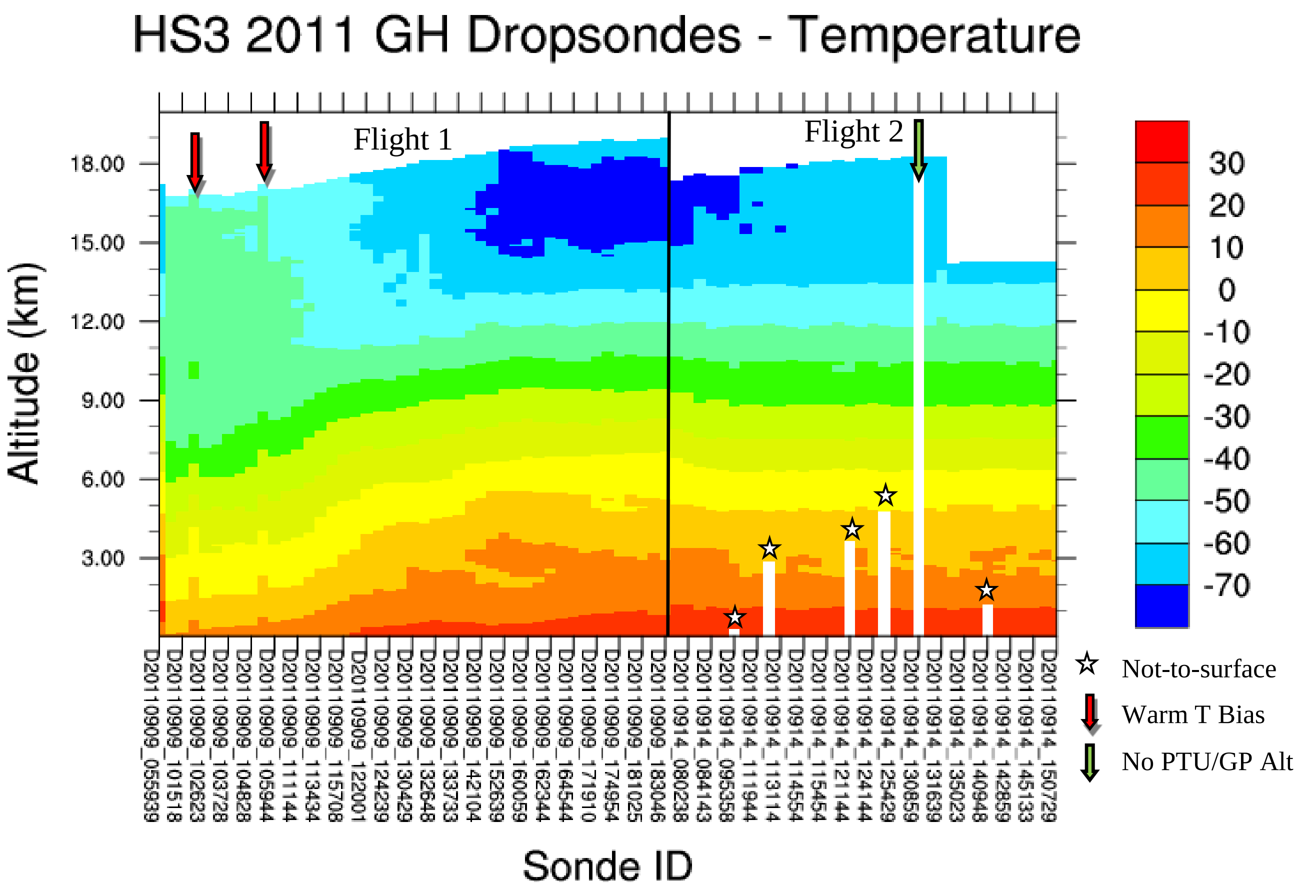

Figure 3- Temperature (°C) profiles of final QCed data for all 79 soundings

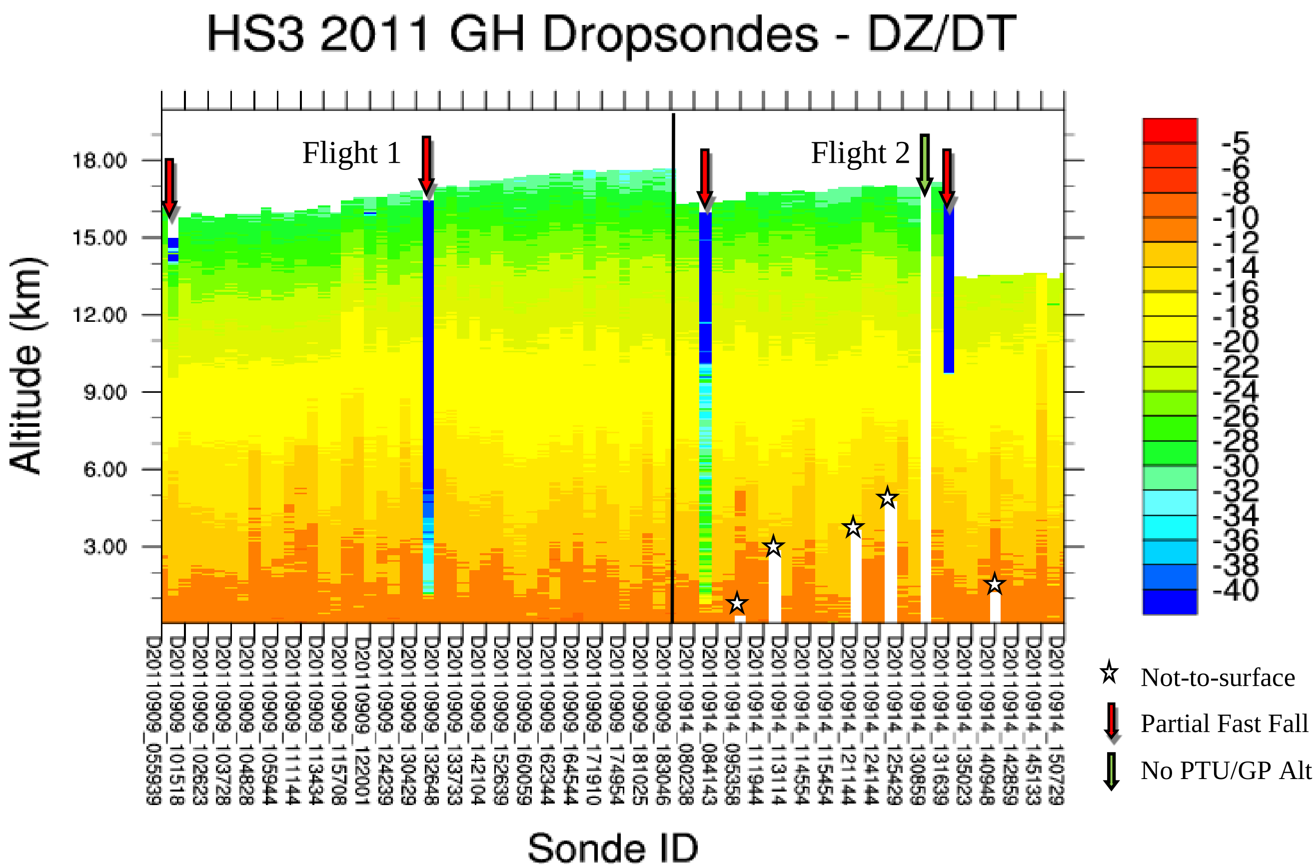

Figure 4 - Pressure-calculated fall rate (m/s) profiles of final QCed data for all 79 soundings. Those that fell at an accelerated rate are indicated by red arrows.

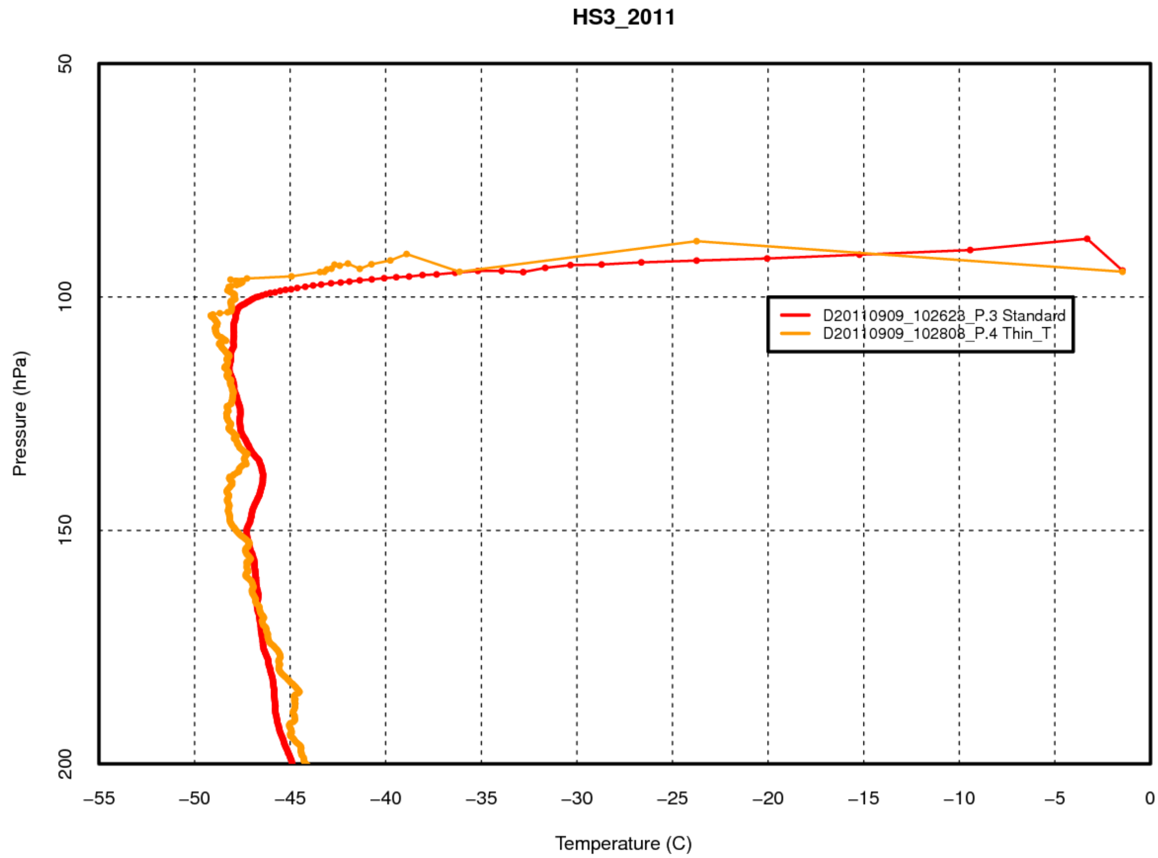

Figure 5 - Comparsion between thin and standard temperature sensors. The plot shows the thin T sensor has faster response and provides greater detail of the thermodynamic structure.