Hurricane and Severe Storm Sentinel (HS3) 2013 Global Hawk Dropsonde Data Analysis Summary

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Document Version Control

Version	Date	Author	Change Description
1.0	12-15-2013	*K. Young*	Initial Document Release
2.0	04-10-2013	*K. Young*	Geopotential Alt Correction for Data to Surface
3.0	05-06-2015	*K. Young*	GPS Lat/Lon (Type 2) Gross Error Filtering
4.0	05-25-2016	*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’
5.0	09-06-2016		Dewpoint temperature was recalculated using the corrected RH measurements (V4.0)

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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. (2013, K. Young, J. Wang, T. Hock, D. Lauritsen and C. Martin: HS3 2013 quality controlled global hawk dropsonde data set.

UCAR/NCAR - Earth Observing Laboratory. 2016. HS3 2013 Global Hawk Dropsonde Data, Version 5.0. UCAR/NCAR - Earth Observing Laboratory. http://dx.doi.org/10.5065/D6736P31. 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 2013 phase of the campaign involved seven research flights of the unmanned NOAA/NASA Global Hawk (GH) aircraft conducted between August 20 and September 20. The GH is equipped with an NCAR/NOAA dropsonde system specially designed for remote operation. A total of 433 quality controlled soundings are contained in the final HS3 dropsonde data set. A detailed summary of the seven 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

RF#	Name	Dates	Sondes deployed	Soundings in final archive
RF01	Research Flight 1*	Aug 20, 2013	15	15
RF02	Research Flight 2	Aug 24, 2013	54	54
RF03	Research Flight 3	Aug 29, 2013	72	72
RF04	Research Flight 4	Sept 04, 2013	80	80
RF05	Research Flight 5	Sept 07, 2013	57	57
RF06	Research Flight 6	Sept 16, 2013	67	67
RF07	Research Flight 7	Sept 19, 2013	88	88

* During Research Flight 1, the Global Hawk aircraft MCPS for EIP 16 failed, this unit powered the Dropsonde data system and aircraft nose camera, with loss of power to the Dropsonde data system this prevented the continuation of Dropsonde operations during this flight.

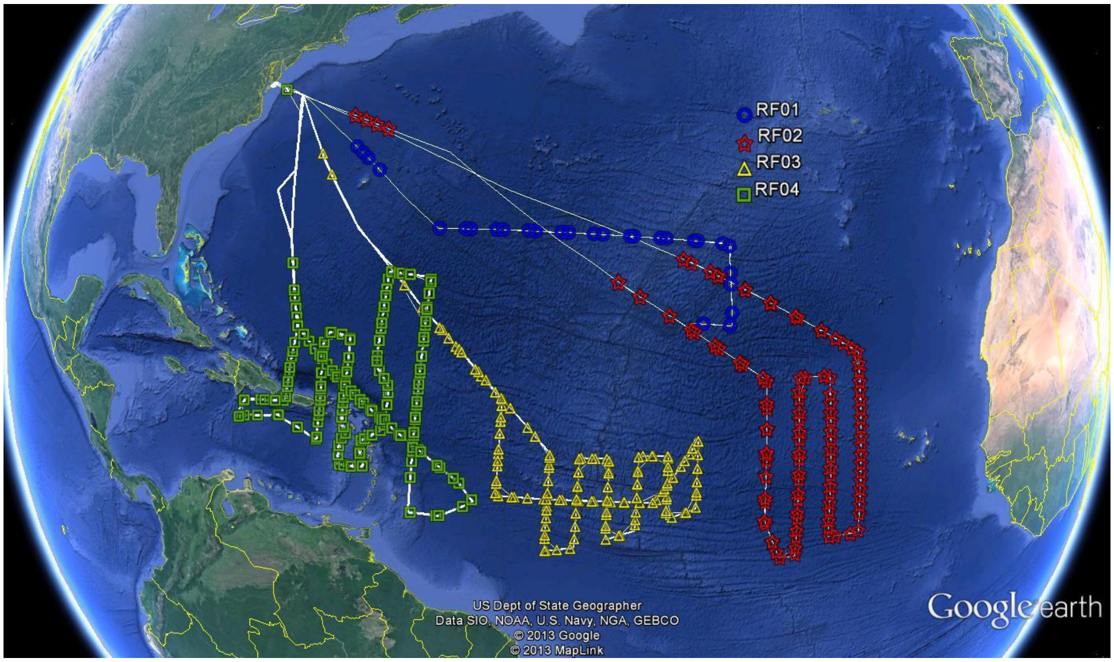

Figure 1 Map of HS3 Research Flights 1 thru 4, conducted August 20, 24, 29 and September 4, 2013.

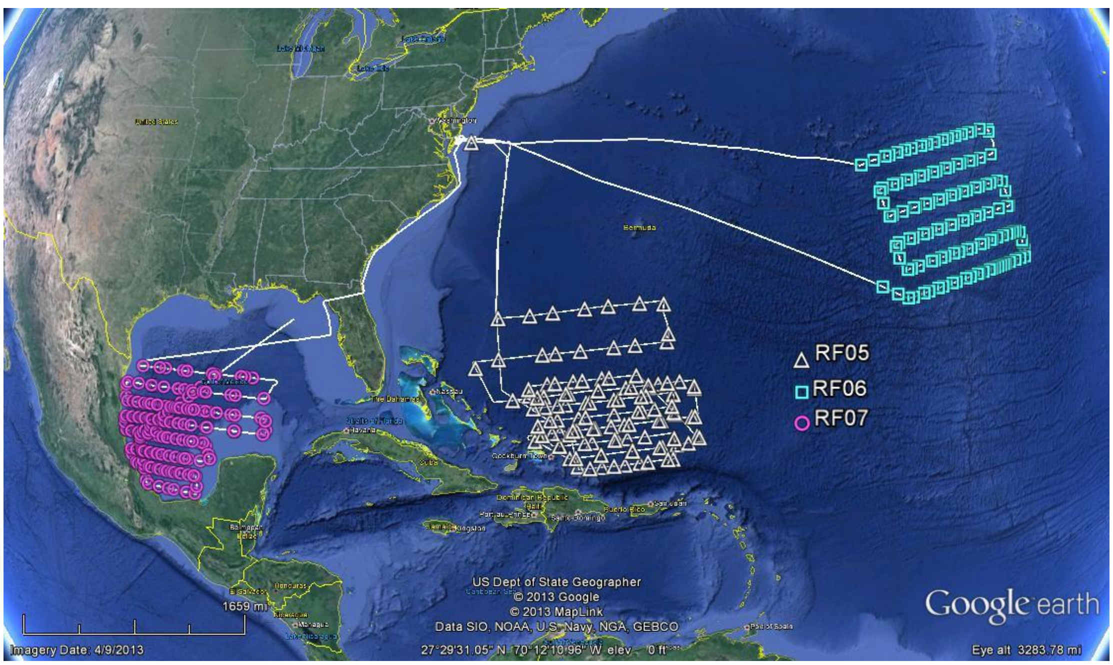

Figure 2 Map of HS3 Research Flights 5, 6, and 7, conducted September 07, 16 and 19, 2013.

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_V4.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 3/Descending
File Format/Version:                 EOL Sounding Format/1.1
Project Name/Platform:               NASA HS3 2013, 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

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. 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 integration of the geopotential altitude from flight level downward (ie when the sounding data does not transmit data the surface).

3. 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 $P = P_{DS} * P_{0\_REF} / P_{0\_DS}$, where P_{DS} is the pressure measured by dropsonde, P_{0_REF} is the pressure as indicated by the reference sensor in the lab, and P_{0_DS} is the pressure as indicated by the dropsonde in the lab.

4. 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.

5. 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.

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

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. 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. A 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. **Not to surface:** Nine sounding files did not contain useful pressure or temperature data to the surface, therefore geopotential altitudes were computed from flight level downward.

Not to Surface Soundings		
D20130820_204123	D20130907_145824	D20130919_210157
D20130829_233725	D20130908_025654	D20130920_024011
D20130905_094658	D20130916_195650	D20130920_050113

2. **Fast fall soundings:** Twenty one soundings were classified as "fast falls", and six were classified as "partial fast fall", meaning the parachute failed to properly deploy resulting in dropsondes falling at an accelerated rate (and sometimes tumbling). When this occurs the wind data may not represent the true atmospheric winds as the sonde may not be tracking the wind, since the parachute is not properly deployed, therefore wind speed, wind direction and U/V winds should be used with caution.

Fast Fall Soundings		
D20130824_190522	D20130905_032608	D20130917_001147
D20130824_200857	D20130905_045514	D20130917_031634
D20130829_191152	D20130905_084119	D20130917_033256
D20130830_040226	D20130907_171941	D20130919_184143
D20130830_063442	D20130907_202114	D20130919_195957
D20130904_203908	D20130908_050323	D20130919_201852
D20130905_022045	D20130908_061549	D20130919_223928

Partial Fast Fall Soundings	
D20130820_145557	D20130905_053459
D20130824_221217	D20130908_053803
D20130904_234858	D20130920_052145

3. **Increased surface winds:** Forty five data files, listed in the table below, contained large increasing spikes in the near surface wind profile, thought to be caused possibly by GPS multipath near the ocean's surface. The wind speed and wind direction values recorded in the original data files were unrealistic (Figure 3) and therefore were manually set to missing.

Surface Winds Removed			
D20130820_184550	D20130905_015748	D20130908_013801	D20130917_040302
D20130824_124349	D20130905_041459	D20130908_040248	D20130917_050110
D20130824_125244	D20130905_050521	D20130908_041510	D20130917_052227
D20130824_173724	D20130905_062711	D20130908_054944	D20130919_230512
D20130824_222609	D20130905_064704	D20130908_062752	D20130919_234206
D20130825_024906	D20130905_072754	D20130916_184753	D20130920_002814
D20130825_030105	D20130905_085609	D20130916_204747	D20130920_005738
D20130825_043630	D20130905_093445	D20130916_225226	D20130920_010800

D20130829_200921	D20130907_195218	D20130916_234428	D20130919_205736
D20130829_232802	D20130907_203658	D20130916_235558	
D20130829_234614	D20130907_215028	D20130917_023848	
D20130904_231700	D20130908_005846	D20130917_031122	

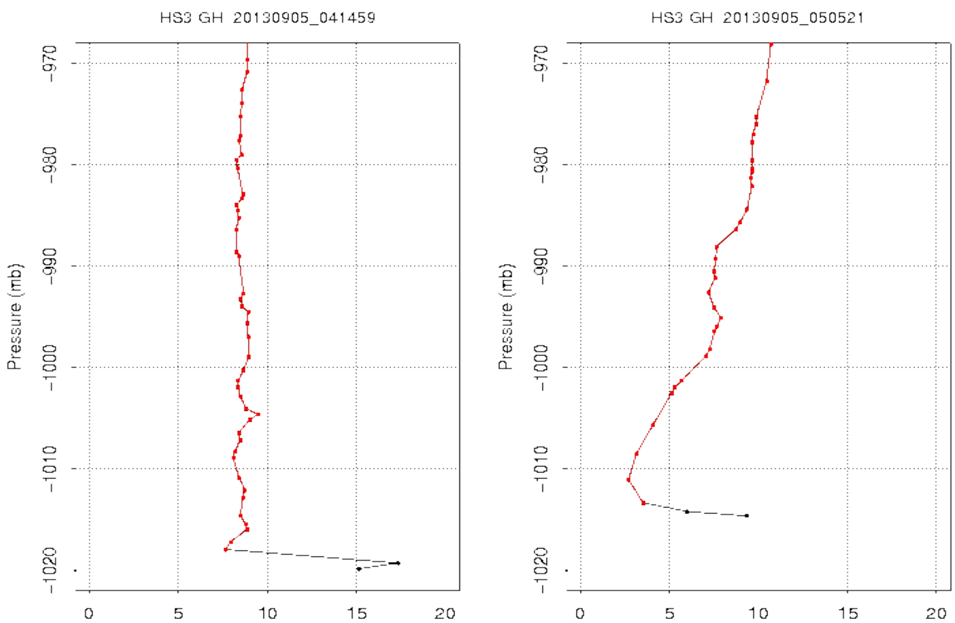

Figure 3 Shows two examples of increased surface winds before (black) and after (red) correction.

V. Appendix A

Quality Control Procedures:

1. Evaluate raw data profiles
2. Categorize according to data quality issues
3. Determine appropriate ASPEN QC configuration
4. Identify soundings ‘not to sfc’
5. Apply Geoid height correction to ‘not to sfc’ soundings
6. Apply pressure correction
7. Evaluate fast fall sounding winds - set to missing if needed
8. Evaluate sounding with increased surface winds
9. Process through Batch ASPEN
10. Create QCed waterfall/timeseries plots
11. Create histograms to examine range and distribution of P,T,U and Wspd
12. Evaluate individual QC profile