Tropical Cyclone Intensity (TCI) Experiment
National Weather Service High Resolution Radiosonde
2016 Hurricane Matthew Data Set

1.0 Contacts:

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2.0 Dataset Overview

The National Weather Service (NWS) routinely releases radiosondes at 00 and 12 UTC with occasional special releases at sites throughout the United States. This data set includes the quality controlled TCI NWS soundings released at sites that released special radiosondes during the course of Hurricane Matthew. Data are included from 20 NWS stations around the southeastern United States (Figure 1) during the entire life cycle of Matthew from 28 September to 9 October 2016. A total of 604 quality-controlled, high vertical resolution (1-second) soundings are contained in the final TCI 2016 Hurricane Matthew data set.

Figure 1. Hurricane Matthew best track and NWS sounding locations.

3.0 Project Overview

The goal of the Tropical Cyclone Intensity (TCI) initiative was to improve the prediction of tropical cyclone intensity and structure changes with a specific focus on an improved understanding of tropical cyclone upper-level outflow layer processes and dynamics. The primary TCI observations were taken by the NASA WB-57 aircraft and the High Definition Sounding System (HDSS) dropsondes and Hurricane Imaging Radiometer (HIRAD). TCI worked closely with the NOAA SHOUT (Sensing Hazards with Operational Unmanned Technology) project which utilized a NASA Global Hawk. TCI also partnered with the routine operations of the USAF C-130, NOAA P-3, and NOAA G-IV aircraft. During the 2016 season TCI did not operate any flights but had dropsondes that could be used during other flights.

4.0 EOL File Format Description

The EOL format is an ASCII text format that includes a header (Table 1), with detailed project and sounding information, and seventeen columns of high resolution data (Table 2).

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 2.

The files contain data calculated at one-second intervals. We have utilized the processed PTU and GPS data from the Radiosonde Replacement System (RRS) sounding systems to generate these files. The raw position, temperature and RH data are normalized by linear interpolation into 1 second processed data. The raw pressure data are normalized by least square interpolation into 1 second processed data. The pressure data are smoothed over 11 seconds of corrected pressure and the result is applied to the 6th corrected pressure within the 11 second spread. The temperature data are smoothed over 9 seconds of uncorrected temperature and the result is applied to the 5th uncorrected temperature within the 9 second spread. There must be at least 2 good raw temperature elements with the 9 second spread.

The following corrections were applied by the RRS sounding system.

Pressure correction - pressure correction is used to compensate for offsets of the radiosonde pressure sensor as compared to the station's pressure sensor. The pressure offset is determined during the radiosonde baseline operations. The correction is applied to the uncorrected pressure prior to pressure

smoothing.

This correction is defined as:

Pc = Pu * (Pstn/Psonde)
where Pc is the corrected pressure
Pu is the uncorrected pressure
Pstn is the station pressure
Psonde is the radiosonde surface pressure

Temperature correction - temperature correction is used to compensate for solar radiation. The correction is applied to the smoothed temperature. These corrections are proprietary to Sippican.

Table 1 - EOL Sounding File Format (dropsonde and radiosonde)

```
Data Type/Direction:                    GAUS SOUNDING DATA/Ascending
File Format/Version:                    EOL Sounding Format/1.1
Project Name/Platform:                  DYNAMO/NCAR GAUS
Launch Site:                            Diego Garcia
Launch Location (lon,lat,alt):          72 25.59'E 72.426578, 7 18.85'S -7.314117, 2.0
UTC Launch Time (y,m,d,h,m,s):          2011, 11, 27, 14:15:07
Sonde Id/Sonde Type:                    001434642/Vaisala RS92-SGP (ccGPS)
Reference Launch Data Source/Time:      Campbell Scientific CR10/14:!5:03
System Operator/Comments:               Steph S/none, Good Sounding
Post Processing Comments:               Aspen Version 3.1; Created on 22 June 2012 15:11 UTC; Configuration upsonde-ls

/
  Time    -- UTC --   Press    Temp    Dewpt     RH     Uwind    Vwind    Wspd     Dir      dZ     GeoPoAlt     Lon          Lat       GPSAlt   Uwind   Vwind_f
   sec    hh mm  ss     mb       C       C        %      m/s      m/s      m/s     deg      m/s       m         deg          deg         m      m/s      m/s
-------- -- -- ----- -------- ------- ------- ------- -------- -------- -------- ------- -------- --------- ----------- ----------- -------- ------ --------
```

Table 2 - 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

4.1 Data Specifics

The files contain data at one-second intervals.

The file naming convention is XXXX_DYYYYMMDD_HHmmSS_P.1.eol

Where XXXX is the Site ID, D is the letter D, YYYY is the year, MM is the month, DD is the day of the month, HH is the hour, mm the minute and SS the seconds. All times are UTC.

Vaisala RS92-NGP radiosondes were used by KBRO, KJAX, KKEY, KLCH, KLIX, KMFL, KMHX, and TJSJ.

Lockheed Martin Sippican LMS-6 radiosondes were used by KBMX, KCHS, KFFC, KFWD, KGSO, KJAN, KLZK, KOHX, KSHV, KTAE, and KTBW.

All sounding sites used GPS for windfinding.

4.2 Sample Data

The following is a sample of the TCI NWS high resolution radiosonde data in EOL format.

```
Data Type/Direction:                        National Weather Service Sounding/Ascending
File Format/Version:                        EOL Sounding Format/1.1
Project Name/Platform:                      TCI
Launch Site:                                KTBW Tampa Bay, FL / 72210
Launch Location (lon,lat,alt):              082 24.08'W -82.401000, 27 42.32'N  27.705000,    13.00
UTC Launch Time (y,m,d,h,m,s):              2015, 08, 24, 23:02:11
Sonde Id/Sonde Type:                        88084424/Lockheed Martin Sippican LMS-6 GPS Radiosonde
Reference Launch Data Source/Time:
System Operator/Comments:
Post Processing/Comments:
/
  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 23  2 11.00 1010.40   30.50    24.90    72.00     1.90    -0.70     2.00  290.20 -999.00     13.00  -82.401000    27.705000  -
999.00
    0.00 23  2 12.00 1009.70   30.50    24.20    69.30     1.80    -0.60     1.90  288.40    6.00     19.00  -82.401000    27.705000  -
999.00
    1.00 23  2 13.00 1009.10   30.30    23.90    68.60     1.70    -0.50     1.80  286.40    6.00     25.00  -82.401000    27.705000  -
999.00
```

4.3 Station List

Site ID	WMO ID	Site Name	State	Latitude	Longitude	Elev (m)
KBMX	72230	Birmingham	AL	33.180	-86.783	174
KBRO	72250	Brownsville	TX	25.916	-97.420	7
KCHS	72208	Charleston	SC	32.895	-80.028	13
KCRP	72251	Corpus Christi	TX	27.779	-97.505	15
KFFC	72215	Peachtree City	GA	33.356	-84.567	245
KFWD	72249	Fort Worth	TX	32.835	-97.298	195
KGSO	72317	Greensboro	NC	36.098	-79.943	276
KJAN	72235	Jackson	MS	32.320	-90.080	91
KJAX	72206	Jacksonville	FL	30.483	-81.701	10
KKEY	72201	Key West	FL	24.553	-81.789	13
KLCH	72240	Lake Charles	LA	30.126	-93.217	5

KLIX	72233	Slidell	LA	30.338	-89.825	10
KLZK	72340	Little Rock	AR	34.836	-92.260	173
KMFL	72202	Miami	FL	25.756	-80.384	4
KMHX	72305	Newport	NC	34.776	-76.878	11
KOHX	72327	Nashville	TN	36.247	-86.562	180
KSHV	72248	Shreveport	LA	32.452	-93.842	85
KTAE	72214	Tallahassee	FL	30.446	-84.300	53
KTBW	72210	Tampa Bay	FL	27.705	-82.401	13
TJSJ	78526	San Juan	PR	18.431	-65.992	3

5.0 Data Quality Control Procedures

1. Each sounding was converted from its original format into the ESC format described above.

2. Each sounding was passed through a set of automated data quality checks which included basic gross limit checks as well as rate of change checks. This is further described in Section 4.1.

3. Each sounding was visually examined utilizing the NCAR/EOL XQC sounding quality control software. This is further described in Section 4.2.

5.1 Automated Data Quality Checks

This data set was passed through a set of automated data quality checks. This procedure includes both gross limit checks on all parameters as well as rate-of-change checks on temperature, pressure, and ascent rate. A version of these checks is described in Loehrer et al. (1996) and Loehrer et al. (1998).

5.1.1 Gross Limit Checks

These checks were conducted on each sounding and the data quality flags in the ESC files were adjusted as appropriate. Only the data point under examination was flagged. All checks also produced warning messages that specified the location of the problem and the severity of the issue. These warning messages where then summarized statistically and examined to determine any consistent issues.

For this data set NCAR/EOL conducted the following gross limit checks. In the table P = pressure, T = temperature, RH = relative humidity, U = U wind component, V = V wind component, B= bad, and Q = questionable.

Parameter	Check	Parameter(s) Flagged	Flag Applied
Pressure	<0 or > 1050	P	B
Altitude	< 0 or >40000	P, T, RH	Q
Temperature	< -90 or > 45	T	B
Dew Point	< -99.9 or > 33 > T	RH T, RH	Q Q
Wind Speed	< 0 or > 100 > 150	U, V U, V	Q B

U Wind	< 0 or > 100 > 150	U U	Q B
V Wind	< 0 or > 100 > 150	V V	Q B
Wind Direction	< 0 or > 360	U, V	B
Ascent Rate	< -10 or > 10	P, T, RH	Q

5.1.2 Vertical Consistency Checks

These checks were conducted on each sounding and the data quality flags in the ESC files were adjusted as appropriate. These checks were started at the surface and compared each neighboring data record. In the case of checks that ensured that the values increased/decreased as expected, only the data point under examination was flagged. However, for the other checks, all of the data points used in the examination were flagged. All items within the table are as previously defined. All checks also produced warning messages that specified the location of the problem and the severity of the issue. These warning messages where then summarized statistically and examined to determine any consistent issues.

Parameter	Check	Parameter(s) Flagged	Flag Applied
Time	Decreasing/equal	None	None.
Altitude	Decreasing/equal	P, T, RH	Q
Pressure	Increasing/equal > 1mb/s or < -1mb/s > 2mb/s or < -2mb/s	P, T, TH P, T, TH P, T, TH	Q Q B
Temperature	< -15°C/km < -30°C/km > 50°C/km > 100°C/km	P, T, RH P, T, RH P, T, RH P, T, RH	Q B Q B
Ascent Rate	> 3m/s or < -3m/s > 5m/s or < -5m/s	P P	Q B

5.2 Visual Data Quality Checks

Each sounding was visually examined using the NCAR/EOL XQC sounding data quality control software. This software allows the user to view a skew-t/log-p diagram of each sounding and apply data quality flags as appropriate. The user can zoom in on sections of soundings for detailed examination and can adjust the data quality flags for an individual point, sections of soundings, or entire soundings for each parameter individually. The software also allows the user to override the quality flags applied by the automated procedure.

5.3 Data Quality Issues of Note

The data quality control procedures outlined above allows us to identify and, in some cases, resolve issues that could potentially impact research performed using these data sets. The following issues were noted in these soundings.

KBRO201609281135 – Limited GPS and wind data.
KCRP201610092301 – limited GPS and wind data from 745-417mb
KFFC201610041105 – wetbulbing ~812mb

KGSO201610070500 – wetbulbing ~750mb
KGSO201610081813 – no data above 514mb; large temp drop from 660-610mb, recovers by 585mb.
KGSO201610091100 – no moisture data above 590mb.
KJAX201610011115 – wetbulbing ~695mb, recovers by 645mb.
KMHX201610051730 – wetbulbing ~884mb, recovers by ~815mb.
KOHX201609301136 – no GPS or wind data
KTBW201610030008 – large temperature increase from 610-576mb, drops back by 534mb.

6.0 References

Loehrer, S. M., T. A. Edmands, and J. A. Moore, 1996: TOGA COARE upper-air sounding data archive: development and quality control procedures. Bull. Amer. Meteor. Soc., 77, 2651-2671.

Loehrer, S. M., S. F. Williams, and J. A. Moore, 1998: Results from UCAR/JOSS quality control of atmospheric soundings from field projects. Preprints, Tenth Symposium on Meteorological Observations and Instrumentation, Phoenix, AZ, Amer. Meteor. Soc., 1-6.