Verification of the Origins of Rotation in Thunderstorms Experiment-Southeast 2016 (VORTEX-SE_2016) MSU Mobile Radiosonde Data Set

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2.0 Dataset Overview

Mississippi State University (MSU) utilized three mobile radiosonde systems to release radiosondes at locations around northeastern Mississippi, northern Alabama and southwestern Tennessee (Figure 1) during VORTEX-SE_2016 Intensive Observation Periods (IOPs). The choices for the locations and times of the releases were made in collaboration with other VORTEX-SE PIs. Two different radiosonde systems were used by MSU during VORTEX-SE_2016, iMet (10 second resolution) from one vehicle and Windsond (1 second resolution) from two vehicles. This data set includes a total of 69 radiosondes (23 iMet and 46 Windsond) from the three MSU systems during the VORTEX-SE_2016 field season (12 March to 1 May 2016).

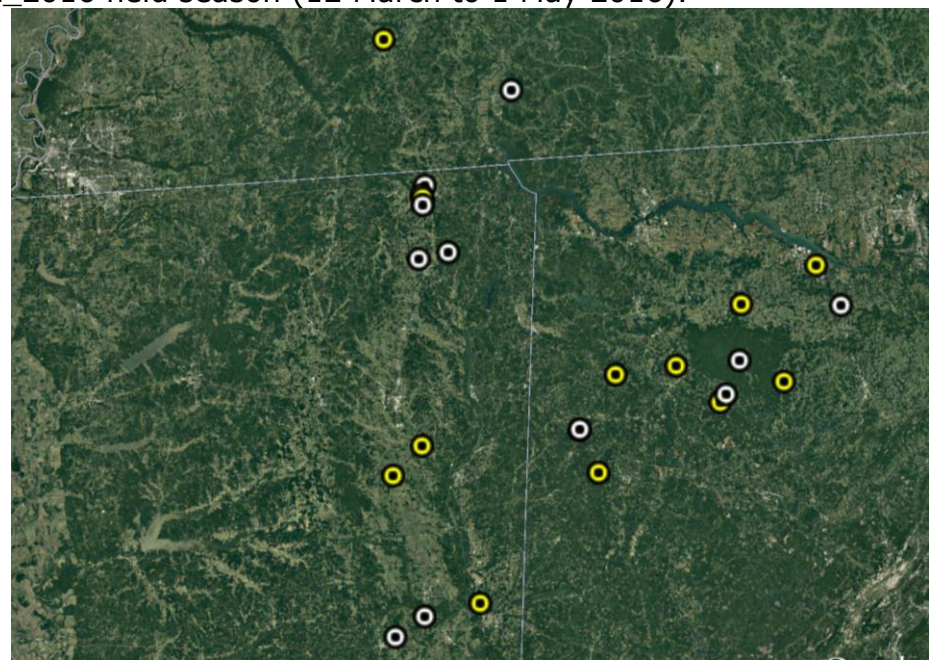

Figure 1. Location of the MSU mobile radiosonde sites (iMet in white, Windsond in yellow.

3.0 Project Overview

The **Verification of the Origins of Rotation in Tornadoes Experiment-Southeast (VORTEX-SE)** is a research program to understand how environmental factors characteristic of the southeastern United States affect the formation, intensity, structure, and path of tornadoes in this region. VORTEX-SE will also determine the best methods for communicating forecast uncertainty related to these events to the public, and evaluate public response. For the 2016 field season a large array of fixed and mobile ground instrumentation were deployed around Huntsville, AL from 1 March to 1 May 2016. Further information on VORTEX-SE is available at the VORTEX-SE web site at NCAR/EOL: https://www.eol.ucar.edu/field_projects/vortex-se and information on the VORTEX-SE_2016 deployments is available at the VORTEX-SE_2016 Field Catalog: http://catalog.eol.ucar.edu/vortex-se_2016.

4.0 EOL Sounding Composite (ESC) File Format Description

The ESC is a columnar ASCII format consisting of 15 header records for each sounding followed by the data records with associated data quality flags.

3.1 Header Records

The header records (15 total records) contain a variety of metadata about the sounding (i.e. location, time, radiosonde type, etc). The first five header lines contain information identifying the sounding, and have a rigidly defined form. The following 7 header lines are used for auxiliary information and comments about the sounding, and may vary from dataset to dataset. The last 3 header records contain header information for the data columns. Line 13 holds the field names, line 14 the field units, and line 15 contains dashes ('-' characters) delineating the extent of the field.

The file standard header lines are as follows:

Line	Label (padded to 35 char)	Contents
1	Data Type:	Description of the type and resolution of data
2	Project ID:	Short name for the field project
3	Release Site Type/Site ID:	Description of the release site.
4	Release Location (lon,lat,alt):	Location of the release site.
5	UTC Release Time (y,m,d,h,m,s):	Time of release.

The release location is given as:
lon (deg min), lat (deg min), lon (dec. deg), lat (dec. deg), alt (m)

Longitude in deg min is in the format: ddd mm.mm'W where ddd is the number of degrees (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 time of release is given as: yyyy, mm, dd, hh:nn:ss.
Where yyyy is the year, mm is the month, dd is the day of month, and hh:nn:ss are the UTC hour, minute, and second respectively.

The seven non-standard header lines may contain any label and contents. The labels are padded to 35 characters to match the standard header lines. Records for this data set include the following non-standard header lines:

Line	Label (padded to 35 char)	Contents
6	Radiosonde Type	
7	Ground Station Software	

3.2 Data Records

The data records each contain time from release, pressure, temperature, dew point, relative humidity, U and V wind components, wind speed and direction, ascent rate, balloon position data, altitude, and quality control flags (see the QC code description). Each data line contains 21 fields, separated by spaces, with a total width of 130 characters. The data are right-justified within the fields. All fields have one decimal place of precision, with the exception of latitude and longitude, which have three decimal places of precision. The contents and sizes of the 21 fields that appear in each data record are as follows:

Field	Width	Format	Parameter	Units	Missing Value
1	6	F6.1	Time since release	Seconds	9999.0
2	6	F6.1	Pressure	Millibars	9999.0
3	5	F5.1	Dry-bulb Temperature	Degrees C	999.0
4	5	F5.1	Dew Point Temperature	Degrees C	999.0
5	5	F5.1	Relative Humidity	Percent	999.0
6	6	F6.1	U Wind Comp	m/s	9999.0
7	6	F6.1	V Wind Comp	m/s	9999.0
8	5	F5.1	Wind speed	m/s	999.0
9	5	F5.1	Wind direction	Degrees	999.0
10	5	F5.1	Ascent Rate	m/s	999.0
11	8	F8.3	Longitude	Degrees	9999.0
12	7	F7.3	Latitude	Degrees	999.0
13	5	F5.1	Elevation Angle	Degrees	999.0
14	5	F5.1	Mixing Ratio	g/kg	999.0
15	7	F7.1	Altitude	Meters	99999.0
16	4	F4.1	QC for Pressure	Code	99.0
17	4	F4.1	QC for Temperature	Code	99.0
18	4	F4.1	QC for Humidity	Code	99.0
19	4	F4.1	QC for U Wind	Code	99.0
20	4	F4.1	QC for V Wind	Code	99.0
21	4	F4.1	QC for Ascent Rate	Code	99.0

Fields 16 through 21 contain the data quality flags from the NCAR/Earth Observing Laboratory (EOL) sounding quality control procedures. The data quality flags are defined as follows:

Code	Description
1.0	Checked, datum seems physically reasonable. ("GOOD")
2.0	Checked, datum seems questionable on a physical basis. ("MAYBE")
3.0	Checked, datum seems to be in error. ("BAD")
4.0	Checked, datum is interpolated. ("ESTIMATED")
9.0	Checked, datum is missing. ("MISSING")
99.0	Unchecked (QC information is "missing".) ("UNCHECKED")

3.3 Data Specifics

The data are in files by day, so all soundings for a particular day are concatenated into a single file ordered by time. The file naming convention is:

MSU_yyyymmdd.cls where yyyy is the year, mm is the month, and dd is the day of the month.

MSU utilized two different radiosonde systems in its three vehicles for VORTEX-SE_2016. One vehicle used InterMet's iMet-1-ABxn 403 MHz radiosondes and the iMetOS-II software version 03.49.03C. See Table 1 for iMet instrument accuracy. The iMet radiosondes recorded data every 10 seconds. The other two vehicles used the Windsond S1H2 radiosonde and the WS-250 receiver with software version 2.53. See Table 2 for Windsond instrument accuracy. The Windsond radiosondes recorded data every 1 second.

The radiosonde type is identified in the "Radiosonde Type" record of the header of each sounding.

Table 1: Manufacturer-stated accuracy for each of the variables sampled by the iMet-1-ABxn radiosondes (available from http://intermetsystems.com/ee/pdf/iMet-1-ABxn_Data_150316.pdf)

Temperature accuracy	**0.2°C**
Humidity accuracy	5%
Pressure accuracy	0.5 hPa

Table 2: Manufacturer-stated accuracy for each of the variables sampled by the Windsond S1H2 radiosondes (available from http://windsond.com/Product_catalogue_Windsond_Aug2015.pdf)

Temperature accuracy	**0.3°C**
Humidity accuracy	2%
Pressure accuracy	1.0 hPa

3.4 Sample Data

The following is a sample of the MSU mobile high resolution radiosonde data in ESC format.

```
Data Type:                      MSU_iMet Mobile Sounding Data/Ascending
Project ID:                     VORTEX-SE_2016
Release Site Type/Site ID:      Olivet, TN
Release Location (lon,lat,alt):  088 09.59'W, 35 14.67'N, -88.160, 35.245, 137.0
UTC Release Time (y,m,d,h,m,s):  2016, 03, 14, 06:08:20
Radiosonde Type:                iMet-1-ABxn
```

```
Ground Station Software:          iMet OS II software version 3.49.03C
/
/
/
/
Nominal Release Time (y,m,d,h,m,s):2016, 03, 14, 06:08:20
 Time  Press  Temp  Dewpt  RH    Ucmp   Vcmp   spd   dir   Wcmp     Lon      Lat    Ele   MixR   Alt    Qp   Qt   Qrh  Qu   Qv   QdZ
  sec    mb     C     C     %     m/s    m/s    m/s   deg   m/s      deg      deg    deg   g/kg    m    code code code code code code
------ ------ ----- ----- ----- ------ ------ ----- ----- ----- -------- -------- ----- ----- ------- ---- ---- ---- ---- ---- ----
   0.0  992.5  19.3  13.5  69.0    0.0    1.5   1.5 180.0 999.0  -88.160  35.244 999.0   9.9   137.0 99.0 99.0 99.0 99.0 99.0  9.0
  10.0  987.0  20.3  13.6  65.2    0.5    3.9   3.9 187.0   4.8 9999.000 999.000 999.0  10.0   185.1 99.0 99.0 99.0 99.0 99.0 99.0
  20.0  980.5  19.9  12.8  63.4    0.6    4.3   4.4 188.0   5.7 9999.000 999.000 999.0   9.6   241.7 99.0 99.0 99.0 99.0 99.0 99.0
```

3.5 Station List

This was a mobile system.

4.0 Data Quality Control Procedures

1. The raw iMet data were initially processed using the iMetOS-II software. ULM performed additional post-processing that included filtering obvious outlier data as well as removing any data after balloon burst.

2. NCAR/EOL converted each sounding from its original format into the ESC format described above.

3. NCAR/EOL passed each sounding 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.

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

4.1 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).

4.1.1 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

4.1.2 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

4.2 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.

4.3 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.

Items for both iMet and Windsond radiosondes:

Relative humidity and dew point data – The mixing ratio was the provided moisture parameter. NCAR/EOL derived the RH and dew point data from the provided mixing ratio, pressure and temperature data. The mixing ratio was provided at 0.01 g/kg resolution, so there is a "blocky" appearance (particularly at low mixing ratio values) to the derived RH and dew point data.

Geopotential altitude data – The raw data file contained altitude above ground level data. We used the hypsometric equation to derive the geopotential altitude values.

Items for iMet radiosondes:

Other issues for iMet radiosondes

20160324 1705 Hartselle, AL	wetbulbing 686mb
20160331 1902 Corinth, MS	Wind speed spike 461-434mb
20160427 1800 Jacinto, MS	Wind speed spike 251-230mb
20160429 2000 Starkville, MS	Pressure and temperature problems 412-395mb and above 334mb
20160429 2130 Tibbee, MS	No data above 535mb, temperature data issues above 637mb
20160430 1803 Hamilton, AL	Wind data issues above 135mb
20150501 1933 Grayson, AL	Pressure and temperature issues 367-340mb
20160501 2034 TannerAL	No data above 610 mb

Items for Windsond radiosondes:

Wind data oscillations – There are high frequency oscillations in the wind data of all Windsond radiosondes. The oscillations are most obvious in the wind speed but are also present in the wind direction. This is likely due to the rotation of the radiosonde as a pendulum under the balloon and the unfiltered nature of the wind data.

Wind direction 221 degree problem – The wind direction occasionally jumps to a value of 221.0. These have been flagged as bad.

Temperature data bias – Many of the Windsond radiosondes released during daylight hours have a substantial (5-10C) warm bias. The Windsond software does correct for radiation, however the radiation shield is not stable on the sensor and is prone to being blown off.

Other issues for Windsond radiosondes

20160312 2359 – no data above 532mb.
20160313 0001 – no data above 700mb

20160313 0420 – no temperature or RH data above 708mb
20160313 0428 – no data above 600mb
20160324 1629 – sounding very warm relative to other sites
20160324 1657 – sounding very warm relative to other sites
20160324 1729 – sounding very warm relative to other sites
20160324 1758 – sounding very warm relative to other sites
20160324 1821 – no data above 675mb
20160324 1835 – Above 763mb temperature is very warm. No data above 745mb.
20160331 1801 – both soundings very warm relative to other sites
20160331 1901 – sounding very warm relative to other sites
20160331 1903 – sounding very warm relative to other sites
20160331 2000 – sounding very warm relative to other sites
20160331 2001 – sounding very warm relative to other sites
20160331 2100 – sounding very warm relative to other sites
20160331 2102 – sounding very warm relative to other sites
20160331 2201 – sounding very warm relative to other sites
20160331 2206 – sounding very warm relative to other sites
20160331 2333 – no data above 801mb
20160401 0154 – little data above 650mb
20160427 1802 – sounding very warm relative to other sites
20160427 1805 – sounding very warm relative to other sites
20160427 1901 – sounding very warm relative to other sites
20160427 1910 – sounding very warm relative to other sites
20160427 1957 – sounding very warm relative to other sites
20160427 2059 – sounding very warm relative to other sites
20160427 2200 – sounding warm relative to other sites
20160430 1646 – sounding very warm relative to other sites
20160430 1756 – sounding very warm relative to other sites
20160430 1757 – sounding very warm relative to other sites
20160430 1956 – sounding very warm relative to other sites
20160430 2200 – sounding warm relative to other sites
20160501 1833 – no wind data above 733mb

5.0 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.