Verification of the Origins of Rotation in Thunderstorms Experiment-Southeast 2017 (VORTEX-SE_2017) 5 hPa Resolution Sounding Composite Data Set

1.0 Contacts:

NCAR/EOL Processing and Quality Control:
Scot Loehrer (NCAR/EOL)
loehrer@ucar.edu

2.0 Dataset Overview

This data set contains a composite of upper air sounding data from all sources for the Verification of the Origins of Rotation in Thunderstorms Experiment-Southeast 2017 (VORTEX-SE_2017) project interpolated to 5hPa vertical levels. The composite includes 1803 soundings from all VORTEX-SE 2017 sounding systems (Colorado State University, Mississippi State University, NOAA/ATDD, Purdue University, Texas Tech University, University of Louisiana Monroe, and University of Alabama Huntsville) as well as those from the National Weather Service (Figure 1):

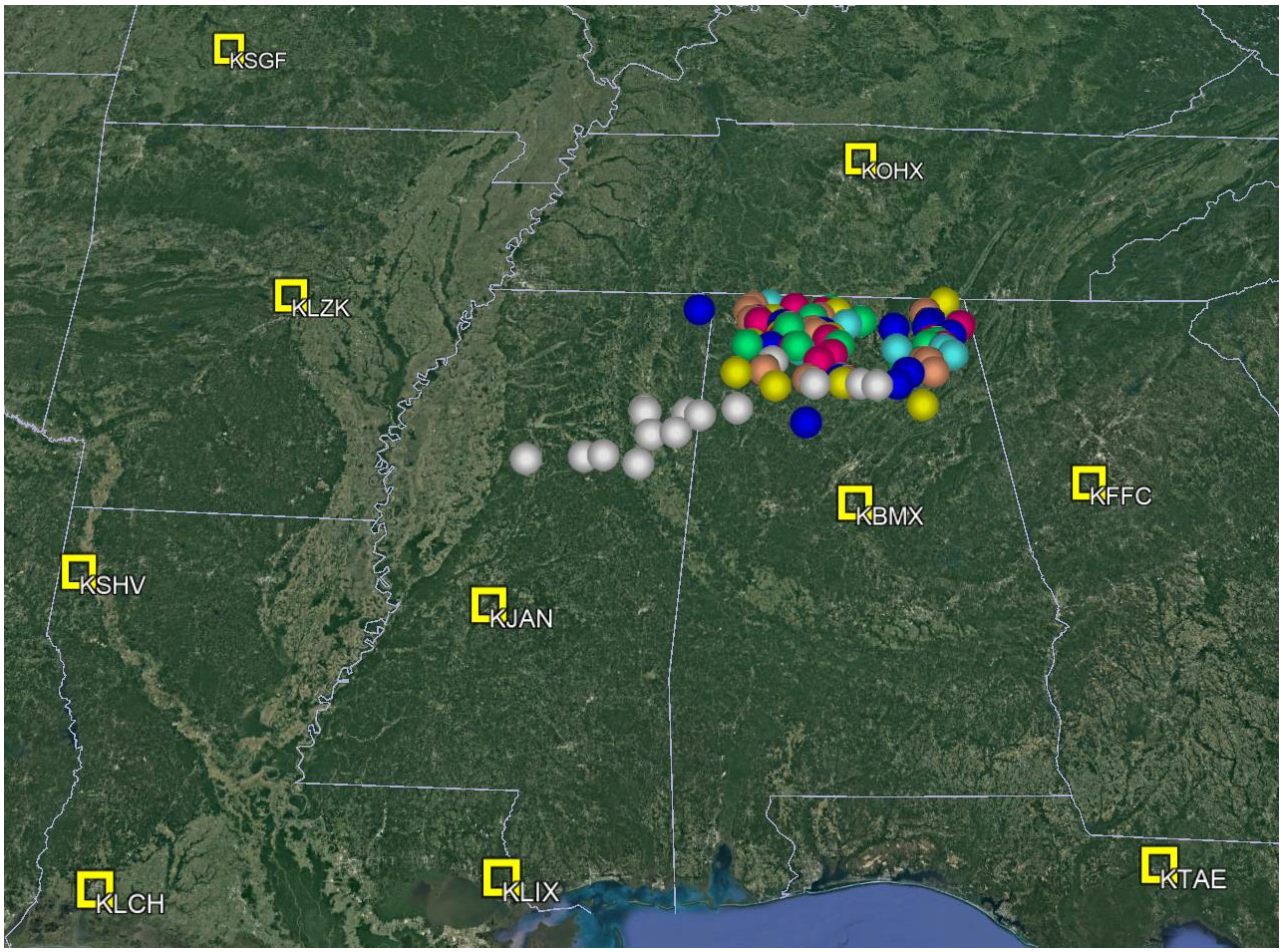

Figure 1. Locations of the soundings included in the VORTEX-SE 2017 composite data set. The NWS sites are the yellow squares. The university sites are filled circles, Purdue (pink), ULM (peach), NOAA/ATDD(dark blue), CSU (yellow), MSU (white), TTU (cyan), and UAH (green).

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 2017 field season a large array of fixed and mobile ground instrumentation were deployed around northern Alabama from 1 March to 9 May 2017. 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_2017 Field Catalog: http://catalog.eol.ucar.edu/vortex-se_2017.

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.

4.1 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	Type of radiosonde
7	Radiosonde Serial Number	
8	Ground Station Software	

The nominal release time for these soundings is the same as the actual time.

4.2 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	Azimuth Angle	Degrees	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")

4.3 Data Specifics

Details on the radiosonde systems included in this data set are included in this section. Links are included to the documentation for the individual sounding data sets for details on processing and quality control.

Colorado State Univesity (CSU) Mobile Radiosondes

32 Vaisala RS41-SGP radiosondes (1 second vertical resolution)
http://data.eol.ucar.edu/datafile/nph-get/541.020/readme_VORTEX-SE_2017_CSU_mobile_radiosonde_ESC.pdf

Mississippi State University (MSU) Mobile Radiosondes

69 Windsond S1H2 radiosondes (1 second vertical resolution)
http://data.eol.ucar.edu/datafile/nph-get/541.032/readme_VORTEX-SE_2017_MSU_mobile_radiosonde_ESC.pdf

National Weather Service Radiosondes

1430 total radiosondes
KBMX, KFFC, KJAN, KLZK, KOHX, KSHV, and KTAE utilized the Lockheed Martin Sippican LMS-6 Radiosonde with the capacitance RH sensor and GPS windfinding
KLCH, KLIX, and KSGF utilized the Vaisala RS92-NGP radiosonde with twin alternatively heated Humicap capacitance RH sensors and GPS windfinding
All at 1 second resolution
http://data.eol.ucar.edu/datafile/nph-get/541.006/readme_V-SE_2017_NWS_radiosonde.pdf

NOAA/ATDD Mobile Radiosondes

55 radiosondes at 1 second resolution
NOAA/ATDD utilized GRAW DFM-09 radiosondes using GPS for windfinding
http://data.eol.ucar.edu/datafile/nph-get/527.007/readme_VORTEX-SE_2016_ATDD_mobile_radiosonde.pdf

Purdue University Mobile Radiosondes

18 radiosondes at 30m vertical resolution
Purdue utilized WindSond S1H3-S radiosondes
http://data.eol.ucar.edu/datafile/nph-get/541.019/readme_VORTEX-SE_2017_Purdue_mobile_radiosonde_ESC.pdf

Texas Tech University Mobile Radiosondes

22 radiosondes at 2 second resolution
TTU utilized Vaisala RS-92-SGPD radiosondes
http://data.eol.ucar.edu/datafile/nph-get/541.010/readme_VORTEX-SE_2017_TTU_mobile_radiosonde_ESC.pdf

University of Louisiana at Monroe Mobile Radiosondes

79 radiosondes at 5 second resolution
ULM utilized InterMet's iMet-1-ABxn radiosondes
http://data.eol.ucar.edu/datafile/nph-get/541.023/readme_VSE2017_High_Res_Composite_V1_1.pdf

High Resolution Radiosonde Composite

This data set contains soundings from the High Resolution Radiosonde Composite interpolated to 5 mb vertical levels.
http://data.eol.ucar.edu/datafile/nph-get/541.045/readme_VORTEX-SE_2017_ULM_mobile_radiosonde_ESC.pdf

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:

VSE-2017_5hpa_yyyymmdd.cls where yyyy is the year, mm is the month, and dd is the day of the month.

4.4 Sample Data

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

```
Data Type:                          NOAA ATDD2 Mobile Sounding Data/Ascending
Project ID:                         VORTEX-SE_2017
Release Site Type/Site ID:          Cullman, AL
Release Location (lon,lat,alt):     086 47.82'W, 34 11.67'N, -86.797, 34.195, 245.0
UTC Release Time (y,m,d,h,m,s):     2017, 03, 25, 15:10:00
Radiosonde Type:                    GRAW DFM-09
Ground Station Software:            Version 5.10.12.3
/
/
/
/
Nominal Release Time (y,m,d,h,m,s):2017, 03, 25, 15:10:00
 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 9999.0 999.0 999.0 999.0 9999.0 9999.0 999.0 999.0 999.0  -86.797  34.194 999.0 999.0   245.0  9.0  9.0  9.0  9.0  9.0  9.0
   1.0  992.2  18.5   8.8  53.1   -0.1    4.2   4.2 179.0   6.0  -86.797  34.194 999.0   7.2   251.0  1.0  1.0  1.0  1.0  1.0 99.0
   2.0  991.5  18.6   9.4  55.1   -0.1    4.3   4.3 178.0   6.0  -86.797  34.194 999.0   7.6   257.0  1.0  1.0  1.0  1.0  1.0 99.0
```

4.5 Station List

Site ID	WMO ID	Site Name	State	Latitude	Longitude	Elev (m)
KBMX	72230	Birmingham	AL	33.180	-86.783	174
KFFC	72215	Peachtree City	GA	33.356	-84.567	245
KJAN	72235	Jackson	MS	32.320	-90.080	91
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
KOHX	72327	Nashville	TN	36.247	-86.562	180
KSGF	72440	Springfield	MO	37.236	-93.402	391

KSHV	72248	Shreveport	LA	32.452	-93.842	85
KTAE	72214	Tallahassee	FL	30.446	-84.300	53

The non-NWS data were all mobile systems with multiple release locations.

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.

4. Each sounding was interpolated to 5 hPa vertical resolution.

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	V	Q

	> 150	V	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	P, T, TH	Q
	> 1mb/s or < -1mb/s	P, T, TH	Q
	> 2mb/s or < -2mb/s	P, T, TH	B
Temperature	< -15°C/km	P, T, RH	Q
	< -30°C/km	P, T, RH	B
	> 50°C/km	P, T, RH	Q
	> 100°C/km	P, T, RH	B
Ascent Rate	> 3m/s or < -3m/s	P	Q
	> 5m/s or < -5m/s	P	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 5 hPa Interpolation Procedures

The surface data point was kept as the initial level in each sounding. The first interpolated data point was at the next lowest pressure evenly divisible by 5 and then every 5 hPa pressure level beyond that point to either 50 hPa or the lowest pressure level reached by the radiosonde, whichever came first. The first 15 lines of each file (the header information) were kept without change.

For the interpolation, the software searched for two data points around the desired pressure level. The search was conducted by looking for two valid (i.e. non-missing) data points around the desired pressure level, while also paying attention to the time difference between the two data points as well as their quality control flags. There was

a search for the two best possible data points to use in the interpolation. If the desired pressure level was within the original dataset, that data point was used without interpolation.

There was first a search for values flagged as good within some time range (50 sec for temperature, humidity, and wind and 100 sec for pressure; hereafter termed the ARANGE) and the interpolated data point was flagged as good. Failing that, it searched for values flagged as estimated within the same time range and the interpolated data point was flagged as estimated. Then the search went for good values within a wider time range (100 sec for temperature, humidity, and wind and 200 sec for pressure; hereafter termed the BRANGE) the flag for the interpolated data point here was then degraded (even though two `good' data points were used there was a significant time difference between them) to questionable. Then, in turn, estimated values within the BRANGE were used (flag set to questionable), questionable values within the BRANGE (flag set to bad), good values greater than the BRANGE apart (flag set to bad), estimated values greater than BRANGE apart (flag set to bad), questionable values greater than BRANGE apart (flag set to bad), finally any bad values (flag set to bad). This search was conducted separately for each interpolated variable (pressure, temperature, relative humidity, and the u and v wind components.

Thus for each interpolated data point, the quality control flag was set to the worst case among the data points used in the interpolation, except, for each time range apart, the quality control flag was degraded one level (i.e. good to questionable, etc).

The quality control flags should be carefully heeded in these files. While some of the data may look good, it may have been interpolated over large pressure intervals, and thus be suspect.

For each interpolated data point the dew point was calculated from the temperature and relative humidity (Bolton 1980) and the total wind speed and direction were calculated from the interpolated u and v component values. Also, the altitude and time were interpolated using the same data points used for the pressure interpolation. The ascension rate was recalculated based on the time and altitude values from the two data points used to interpolate the 5 hPa data point. Thus the ascension rate values do not reflect the values based on the interpolated data. The latitude and longitude values were interpolated using the same data points used in the wind component interpolation.

5.4 Data Quality Issues of Note

See the readme files linked above for details on the data quality issues in each individual sounding data set.

6.0 References

Baldwin, M., Dawson, D. 2018. Purdue University Mobile Radiosonde Data. Version 1.1. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D66Q1VZ9. Accessed 08 Jan 2019.

Brown, M. 2018. MSU Mobile Radiosonde Data. Version 1.1. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D6H70DKK. Accessed 08 Jan 2019.

Bruning, E. 2017. Texas Tech University (TTU) Mobile Radiosonde Data. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D6H993W0. Accessed 08 Jan 2019.

Lee, T., Buban, M., Meyers, T. 2017. NOAA/ATDD Mobile Radiosonde Data. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D6R78CXV. Accessed 08 Jan 2019.

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. https://doi.org/10.1175/1520-0477(1996)077%3C2651:TCUASD%3E2.0.CO;2

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.

Murphy, T. 2018. ULM Mobile Radiosonde Data. Version 1.2. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D6ZK5FD4.

Schumacher, R., Nielsen, E. 2018. CSU Mobile Radiosonde Data. Version 2.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D62J69KP. Accessed 08 Jan 2019.

UCAR/NCAR - Earth Observing Laboratory. 2017. National Weather Service High Resolution Radiosonde Data (ESC Format). Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.5065/D6DR2SXM. Accessed 08 Jan 2019.

UCAR/NCAR - Earth Observing Laboratory. 2019. Multi-Network Composite Highest Resolution Radiosonde Data. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.26023/QX9B-RHFF-Y40D. Accessed 24 Jan 2020.