TORUS-LItE: 5hPa Resolution Radiosonde Composite

Author: UCAR/NCAR - Earth Observing Laboratory

Processing and Quality Control: Scot Loehrer, Linda Cully, and Daniel Choi (NCAR/EOL)

Dataset Contact: Scot Loehrer (loehrer@ucar.edu)

1.0 Data Set Description

Interpolated 5hPa vertical resolution radiosonde data from research and operational sources during the Targeted Observation by Radars and UAS of Supercells - Left-flank Intensive Experiment (TORUS-LItE) campaign converted into a common format (EOL Sounding Composite format which is a columnar ASCII format). The composite includes data from radiosondes from locations around the central United States. The radiosondes were released by NOAA/NSSL (one platforms) and NOAA/NWS (19 sites).

Data Version: 1.0

Data Status: Final

Time Period: 21 May to 16 June 2023

Physical Location: 29.375 to 48.206N and 93.402 to 108.477W

Data Frequency: Varies by location

Vertical Resolution: 5 hPa

Data Source: NOAA/NSSL and NOAA/NWS

Data Restrictions: Limited to TORUS investigators through 16 June 2024. Open access thereafter.

1.1 TORUS Description

TORUS (Targeted Observation by Radars and UAS of Supercells) was a nomadic field campaign during the spring storm seasons (May and June) of 2019 and 2022 over a domain covering much of the central United States where there exists significant point probabilities of tornado-bearing supercell storms. TORUS-LItE was an extension of TORUS in May and June 2023. TORUS aimed to use the data collected to improve the conceptual model of supercell thunderstorms (the parent storms of these most destructive tornadoes) by exposing how small-scale structures within these storms might lead to tornado formation. These structures were hypothesized to be nearly invisible to all but the most precise research-grade instruments.

But by revealing the hidden composition of severe storms and associating it to known characteristics of the regularly-observed larger scale environment, the TORUS project could improve supercell and tornado forecasts. During the TORUS-LItE campaign additional instrumentation included Unoccupied Aircraft Systems (UAS) as well as mobile radars, radiosondes, lidars, and mobile mesonets. Information on TORUS-LItE operations and Intensive Observation Periods (IOPs) can be found in the TORUS-LItE Field Catalog (https://catalog.eol.ucar.edu/torus-lite) and additional background information can be found at the TORUS website (https://www.eol.ucar.edu/field_projects/torus).

2.0 Instrument Description

2.1 Instrumentation

2.1 Instrumentation

NSSL Lidar used Vaisala RS41-SGP radiosondes which were received and processed by the Vaisala MW41 sounding system.

NWS KABQ, KABR, KAMA, KBIS, KDVN, KEPZ, KGGW, KLBF, KMAF, KMPX, KOAX, KRIW, KSGF. and KUNR used GRAW DFM-17 radiosondes with a capacitance humidity sensor

NWS KDDC, KFWD, KOUN, and KTOP used Vaisala RS41 with pressure derived from GPS height/DigiCORA MW41 / Humicap capacitance sensor with active de-icing method

NWS KEWX used Vaisala RS41/AUTOSONDE radiosondes (DigiCORA MW41) with a Humicap capacitance humidity sensor with active de-icing method.

.

2.2 Station Locations

Site ID	Source	Site Name	State	Latitude	Longitude	Elev (m)
NSSL_Lidar	NSSL	Lidar		mobile	mobile	
KABQ	NWS	Albuquerque	NM	35.038	-106.623	1619
KABR	NWS	Aberdeen	SD	45.455	-98.414	398
KAMA	NWS	Amarillo	TX	35.233	-101.709	1094

KBIS	NWS	Bismarck	ND	46.772	-100.762	506
KDDC	NWS	Dodge City	KS	37.762	-99.969	790
KDVN	NWS	Quad Cities	IA	41.613	-90.580	120
KEPZ	NWS	Santa Teresa	NM	31.873	-106.697	1254
KEWX	NWS	Del Rio	TX	29.374	-100.918	313
KFWD	NWS	Fort Worth	TX	32.835	-97.298	199
KGGW	NWS	Glasgow	MT	48.206	-106.626	692
KLBF	NWS	North Platte	NE	41.134	-100.700	849
KMAF	NWS	Midland	TX	31.943	-102.190	874
KMPX	NWS	Chanhassen	MN	44.849	-93.564	290
KOAX	NWS	Omaha	NE	41.319	-96.383	352
KOUN	NWS	Norman	OK	35.230	-97.470	362
KRIW	NWS	Riverton	WY	43.065	-108.477	1699
KSGF	NWS	Springfield	MO	37.236	-93.402	391
KTOP	NWS	Topeka	KS	39.070	-95.620	268
KUNR	NWS	Rapid City	SD	44.073	-103.210	1029

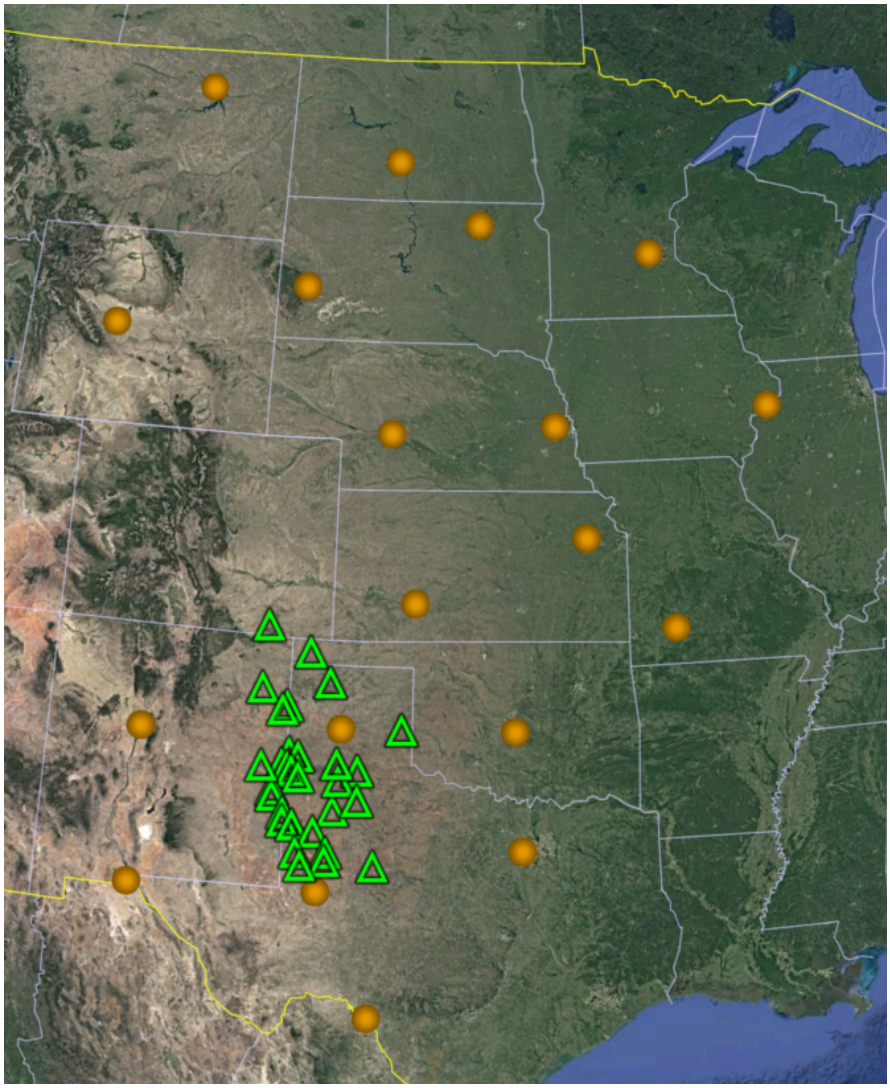

Figure 1. Map of TORUS-LItE radiosonde composite locations. Orange circles are NWS sites, the white squares are NSSL Far Field sites, and the green triangles are NSSL Lidar sites.

The NSSL Lidar platform operated only during TORUS-LItE IOP operations. Soundings were released at varying intervals depending on weather. A total of 30 soundings are included in the dataset.

The NWS stations typically released two radiosondes per day at 00 and 12 UTC with occasional special releases typically at 18 UTC. A total of 926 NWS soundings are included in the dataset, with 48 from KABQ, 48 from KABR, 51 from KAMA, 48 from KBIS, 49 from KDDC, 48 from KDVN, 48 from KEPZ, 46 from KEWX, 50 from KFWD, 49 from KGGW, 49 from KLBF, 49 from KMAF, 48 from KMPX, 48 from KOAX, 57 from KOUN, 48 from KRIW, 48 from KSGF, 46 from KTOP, and 48 from KUNR.

3.0 Data Collection and Processing

This dataset takes the data from the TORUS_LItE High Resolution Radiosonde Composite and interpolates the data to a consistent 5hPa vertical resolution. A total of 926 soundings are included in this dataset.

Complete information on the collection procedures at each site can be found in the documentation at their respective dataset pages in the NCAR/EOL Field Data Archive:

NSSL Sites: https://doi.org/10.26023/PTPY-W6JZ-EV0D

NWS Sites: https://doi.org/10.26023/YGDV-H6P4-EP0E

The procedures used to develop the High Resolution Radiosonde Composite upon which these data are based can be found in the documentation at its dataset page in the NCAR/EOL Field Data Archive:

High Resolution Composite: https://doi.org/10.26023/TGQV-GDR6-580B

3.1 5hPa 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.

4.0 Data Format

The data are in files by day and include radiosonde data from all sites for the day concatenated into a single file. The file naming convention is: TORUS_LItE_5mb_yyyymmdd.cls where yyyymmdd is the UTC year, month, and day of month.

The final dataset is in the EOL Sounding Composite (ESC) format. ESC is a columnar ASCII format that consists of 15 header records for each sounding with the remaining records containing the radiosonde data and their 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	Contents

1	Data Type:	Description of the type and resolution of data
2	Project ID:	Short name for the field campaign
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. They typically include things such as radiosonde type, radiosonde serial number, sensor information, balloon information, and/or ground station software.

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	6.1	Time since release	Seconds	9999.0
2	6	6.1	Pressure	hPa	9999.0
3	5	5.1	Temperature	°C	999.0

4	5	5.1	Dew Point Temperature	°C	999.0
5	5	5.1	Relative Humidity	Percent	999.0
6	6	6.1	U Wind Component	m/s	9999.0
7	6	6.1	V Wind Component	m/s	9999.0
8	5	5.1	Wind Speed	m/s	999.0
9	5	5.1	Wind Direction	Degrees	999.0
10	5	5.1	Ascent Rate	m/s	999.0
11	8	8.3	Longitude	Degrees	9999.0
12	7	7.3	Latitude	Degrees	999.0
13	5	5.1	Elevation Angle	Degrees	999.0
14	5	5.1	Azimuth Angle	Degrees	999.0
15	7	7.1	Geopotential Altitude	Meters	99999.0
16	4	4.1	QC code for Pressure	Code	99.0
17	4	4.1	QC Code for Temperature	Code	99.0
18	4	4.1	QC Code for Humidity	Code	99.0
19	4	4.1	QC Code for U Wind	Code	99.0
20	4	4.1	QC Code for V Wind	Code	99.0
21	4	4.1	QC Code 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. (“QUESTIONABLE”)
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”)

5.0 Data Remarks

See the respective FDA dataset pages linked in Section 3.1 for any details on data quality issues.

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.

UCAR/NCAR - Earth Observing Laboratory. 2023. TORUS-LItE: Multi-Network Composite Highest Resolution Radiosonde Data. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.26023/TGQV-GDR6-580B. Accessed 29 Aug 2023.

UCAR/NCAR - Earth Observing Laboratory. 2023. TORUS-LItE: National Weather Service High Resolution Radiosonde Data. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.26023/YGDV-H6P4-EP0E. Accessed 21 Aug 2023.

Waugh, S. 2023. TORUS-LItE: NSSL Mobile Sounding Quality Controlled (QC) Data. Version 1.0. UCAR/NCAR - Earth Observing Laboratory. https://doi.org/10.26023/PTPY-W6JZ-EV0D. Accessed 21 Aug 2023.