TORUS_2022: High Resolution Radiosonde Composite

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1.0 Data Set Description

High vertical resolution radiosonde data from research and operational sources during the Targeted Observation by Radars and UAS of Supercells 2022 (TORUS_2022) 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 (three platforms) and NOAA/NWS (20 sites).

Data Version: 1.0

Data Status: Final

Time Period: 16 May to 15 June 2022

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

Data Frequency: National Weather Service sites typically released twice daily at 00 and 12 UTC with occasional special soundings particularly at 18 UTC. The NSSL platforms released soundings during TORUS operations at schedules dependent on weather conditions.

Vertical Resolution: 1 second (~5m)

Data Sources: NOAA/NSSL and NOAA/NWS

Data Restrictions: Limited to TORUS investigators through 16 July 2023. 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 aimed to use the data collected to improve the

conceptual model of supercell thunderstorms (the parent storms of thwexe 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 2022 campaign additional instrumentation included a NOAA P-3 aircraft with a suite of radar and cloud physics instruments as well as mobile radars and lidars as well as mobile mesonets. Information on TORUS_2022 operations and Intensive Observation Periods (IOPs) can be found in the TORUS_2022 Field Catalog (https://catalog.eol.ucar.edu/torus_2022) 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

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

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

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

NWS KEPZ used Vaisala RS92-NGP/Intermet IMS-2000 / Twin alternatively-heated humicap capacitance sensor

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

NWS KDNR, KOUN, and KTOP utilized the Lockheed Martin Sippican LMS6 with the chip thermistor, external boom mounted capacitance relative humidity sensor, and derived pressure from GPS height.

2.2 Station Locations

Site ID	Source	Site Name	State	Latitude	Longitude	Elev (m)
NSSL_Far_Field	NSSL	Far Field		mobile	mobile	
NSSL_Lidar	NSSL	Lidar		mobile	mobile	
NSSL_Probe1	NSSL	Probe1		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
KDNR	NWS	Denver	CO	39.770	-104.880	1611
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

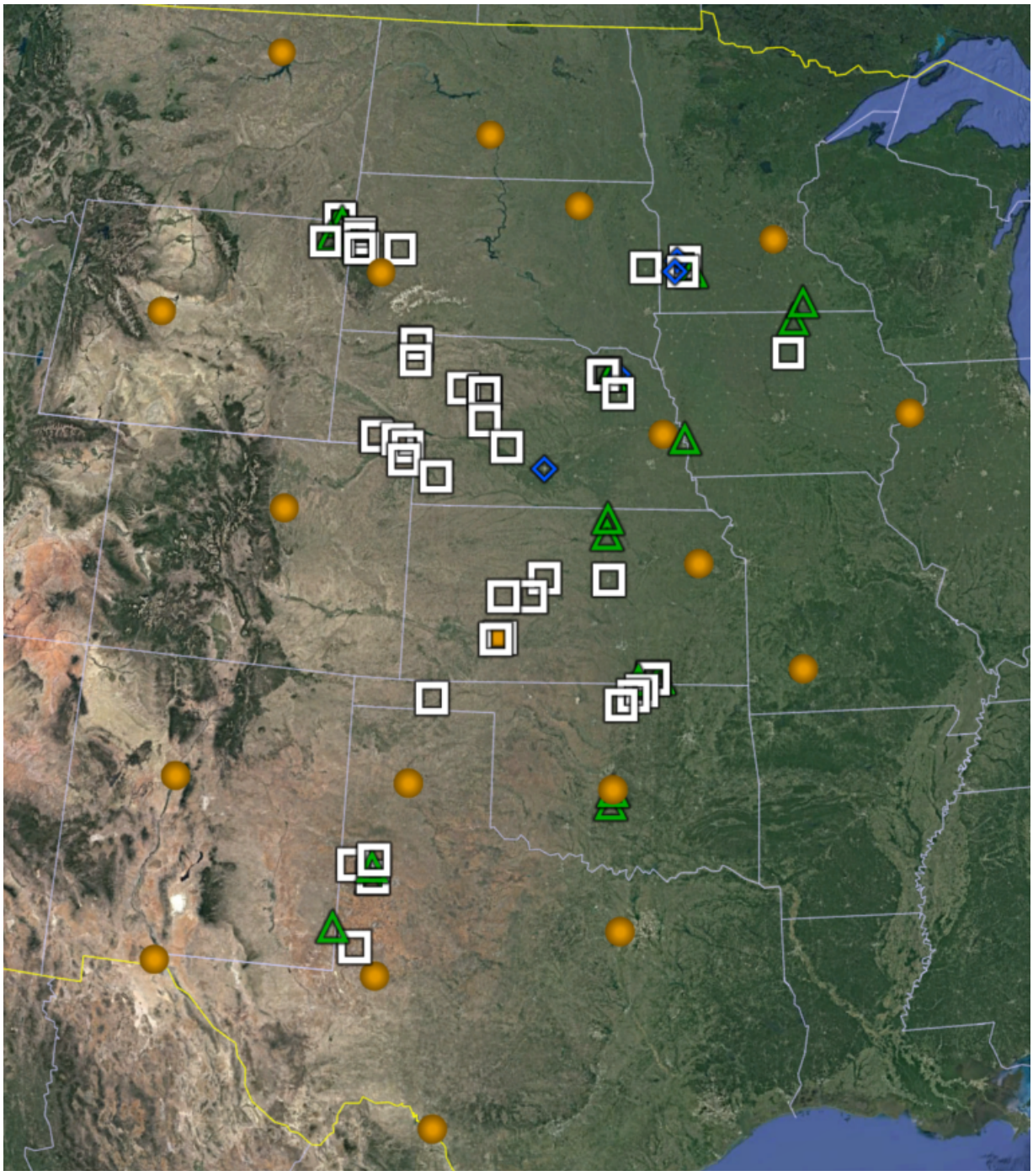

Figure 1. Map of TORUS_2022 radiosonde composite locations. Orange circles are NWS sites, the white squares are NSSL Far Field sites, the green triangles are NSSL Lidar sites, and the blue diamonds are NSSL Probe1 sites.

The NSSL Far Field, Lidar, and Probe1 sites operated only during TORUS_2022 IOP operations. Soundings were released at varying intervals depending on weather. A total of 71 soundings are included in the dataset with 48 from Far Field, 19 from Lidar, and 4 from Sedgwick.

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 1292 NWS soundings are included in the dataset, with 65 from KABQ, 65 from KABR, 64 from KAMA, 65 from KBIS, 63 from KDDC, 60 from KDNR, 73 from KDVN, 64 from KEPZ, 60 from KEWX, 64 from KFWD, 65 from KGGW, 69 from KLBF, 64 from KMAF, 68 from KMPX, 68 from KOAX, 60 from KOUN, 59 from KRIW, 64 from KSGF, 66 from KTOP, and 66 from KUNR.

3.0 Data Collection and Processing

3.1 Data Collection

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/10.26023/83ZC-M7FT-N20R

NWS Sites: https://doi.org/10.26023/7MCC-Q7G9-JT08

3.2 Data Processing

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/10.26023/83ZC-M7FT-N20R

NWS Sites: https://doi.org/10.26023/7MCC-Q7G9-JT08

3.3 Quality Control Processing

Each sounding underwent initial quality control processing by their respective radiosonde systems described above.

In addition to the quality control procedures conducted by the data source, each sounding was passed through a two-step quality control process. First a series of automated data quality checks were conducted including basic gross limit checks as well as rate of change checks as described in section 3.3.1. Second, each sounding was visually examined utilizing the NCAR/EOL XQC sounding QC software as described in section 3.3.2.

3.3.1 Automated Data Quality Checks

Each sounding in this dataset was passed through a set of automated data quality checks. This procedure includes both gross limit checks (section 3.3.1.1) on all parameters as well as rate-of-change checks (section 3.3.1.2) on temperature, pressure, and ascent rate. A version of these checks is described in Loehrer et al. (1996) and Loehrer et al. (1998).

3.3.1.1 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 were 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

3.3.1.2 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, RH	Q
	> 1mb/s or < -1mb/s > 2mb/s or < -2mb/s	P, T, RH	Q
		P, T, RH	B
Temperature	< -15ºC/km	P, T, RH	Q
	< -30ºC/km	P, T, RH	B
	> 50ºC/km	P, T, RH	Q
	> 100ºC/km	P, T, RH	B
Ascent Rate	> 3m/s or < -3m/s	P	Q
	> 5m/s or < -5m/s	P	B

3.3.2 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.

4.0 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: TORUS2022_HighRes_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

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