TORUS-LItE National Weather Service High Resolution Radiosonde Data

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1.0 Data Set Description

High vertical resolution radiosonde data from National Weather Service radiosonde stations within and near the TORUS-LItE (Targeted Observation by Radars and UAS of Supercells - Left-flank Intensive Experiment) domain. High resolution (1 second vertical levels) are included from 20 stations.

Data Version: 1.0

Data Status: Final

Time Period: 21 May to 16 June 2023

Physical Location: 20 point locations within 29.375 to 48.206N and 93.402 to 108.477W

Data Frequency: Soundings were typically every 12 hours at 00 and 12 UTC and occasional special releases primarily at 18 UTC.

Vertical Resolution: 1 second (~5m) or mandatory/significant level

Data Source: NOAA/National Weather Service

Data Restrictions: None

Soundings Included: KABQ (48), KABR (48), KAMA (51), KBIS (48), KDDC (49), KDVN (48), KEPZ (48), KEWX (46), KFWD (50), KGGW (49), KLBF (49), KMAF (49), KMPX (48), KOAX (48), KOUN (57), KRIW (48), KSGF (48), KTOP (46), KUNR (48). A total of 926 soundings are included in the dataset.

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, 2022, and 2023 (TORUS-LItE) 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 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 mobile radars and lidars as well as mobile mesonets and Unmanned Aircraft Systems (UAS). 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

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.

KEWX used Vaisala RS41/AUTOSONDE radiosondes with a Humicap capacitance humidity sensor with active de-icing method.

KDDC, KFWD, KOUN, and KTOP used Vaisala RS41 radiosondes (DigiCORA MW41) with a Humicap capacitance humidity sensor with active de-icing method.

KEPZ used Vaisala RS92-NGP/Intermet IMS-2000 radiosondes with a twin alternatively-heated humicap capacitance humidity sensor

KDNR did not transmit any radiosonde data during the TORUS-LItE campaign.

2.2 Station Locations

Site ID	WMO ID	WBAN	Site Name	State	Latitude	Longitude	Elevation (m)
KABQ	72365	23050	Albuquerque	NM	35.038	-106.623	1619

KABR	72659	14929	Aberdeen	SD	45.455	-98.414	398
KAMA	72363	23047	Amarillo	TX	35.233	-101.709	1095
KBIS	72764	24011	Bismarck	ND	46.772	-100.762	506
KDDC	72451	13985	Dodge City	KS	37.762	-99.969	790
KDVN	74455	94982	Davenport	IA	41.613	-90.580	230
KEPZ	72364	03020	El Paso	TX	31.873	-106.697	1254
KEWX	72261	22010	Del Rio	TX	29.375	-100.918	314
KFWD	72249	03990	Fort Worth	TX	32.835	-97.298	195
KGGW	72768	94008	Glasgow	MT	48.206	-106.627	693
KLBF	72562	24023	North Platte	NE	41.134	-100.700	849
KMAF	72265	23023	Midland	TX	31.943	-102.190	874
KMPX	72649	94983	Chanhassen	MN	44.849	-93.564	290
KOAX	72558	94980	Omaha	NE	41.320	-96.366	351
KOUN	72357	03948	Norman	OK	35.230	-97.470	362
KRIW	72672	24061	Riverton	WY	43.065	-108.477	1699
KSGF	72440	13995	Springfield	MO	37.236	-93.402	391
KTOP	72456	13996	Topeka	KA	39.070	-95.620	268
KUNR	72662	94043	Rapid City	SD	44.073	-103.210	1029

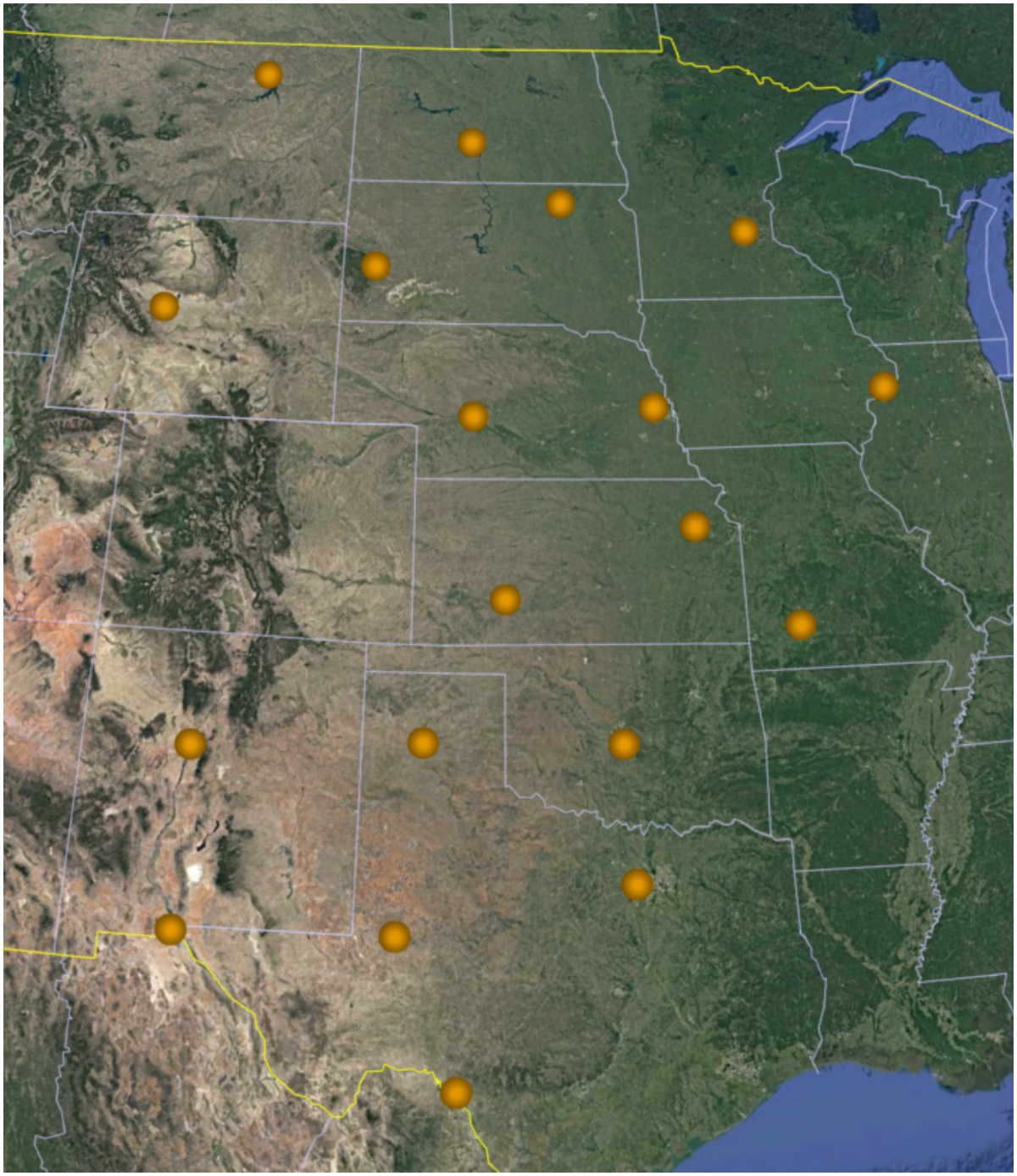

Figure 1. Map of TORUS-LItE NWS radiosonde locations.

3.0 Data Collection and Processing

3.1 Data Collection

Data were collected via the Global Telecommunications System. These data were in the WMO GTS BUFR radiosonde standard format.

3.2 Data Processing

The BUFR data were decoded using the ECMWF ECCODES software package.

All data were converted to the EOL Sounding Composite (ESC) format using EOL software. 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. ESC is further described in section 4.0.

3.3 Quality Control Processing

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	< -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

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: NWS_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	ºC	999.0
4	5	5.1	Dew Point Temperature	ºC	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

KDDC 16 June at 0001 UTC - no data above 644mb

KFWD 1 June at 2302 UTC - no data above 558mb

KGGW 9 June at 1100 UTC - no data above 603mb

KOAX 13 June 2305 UTC - no data above 255mb

KOUN 12 June at 1106 UTC - no data above 636mb

KOUN 15 June 2044 UTC - no data above 381mb

KRIW 1 June 2321 UTC - no data above 374mb

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.