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A comprehensive and quality-controlled field sounding dataset in the Southeast United States

Matthew D. Flournoy^{1,2}, Lauren E. Pounds^{2,3,1}, Anthony W. Lyza^{1,2}, Rachel L. Miller^{3,1}, and Michael C. Coniglio^{1,2}

¹NOAA/OAR/National Severe Storms Laboratory, Norman, OK

²School of Meteorology, University of Oklahoma, Norman, OK

³Cooperative Institute for Severe and High-Impact Weather Research and Operations, University of Oklahoma, Norman, OK



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1. Abstract

Multiple field campaigns occurred in the Southeast United States (hereafter referred to as “the SE”) from 2016–2023 in an effort to better understand thunderstorm, tornado, and environmental evolution during regional severe weather events. These were the first of their kind in the SE since the original VORTEX (Verification of the Origins of Rotation in Tornadoes Experiment; Rasmussen et al. 1994) field project pioneered large-scale observing campaigns targeted at tornadoes in the modern era. Observing platforms in these SE campaigns were myriad and included ballooning, radars, lidars, mesonets, etc. This report summarizes efforts to collect, quality control, and synthesize all ballooning observations (from both radiosonde and windsonde platforms) during many of the intensive observational periods (IOPs) in these campaigns. In total, 2475 soundings across 39 events are catalogued. Analysis of a dataset of this size and diversity can address many outstanding questions related to SE severe environments. The dataset is publicly available at <https://data.nssl.noaa.gov/thredds/catalog/WRDD/VORTEX-USA-Sounding-Dataset/catalog.html>.

2. Background and motivation

The 26–28 April 2011 Super Outbreak of tornadoes across the SE devastated numerous communities, resulting in 318 fatalities, thousands of injuries, and several billion dollars in property damage (Knupp et al. 2014, Lyza et al. 2022a). In response to the 2011 Super Outbreak and the questions regarding tornado behavior and vulnerability across the SE that were highlighted by the event, Congress authorized the Verification of the Origins of Rotation in Tornadoes Experiment - Southeast (VORTEX-SE) program in FY2015. Through FY2025, this program has led to a staggering [173 different studies](#) covering topics such as the characteristics and behavior of tornadic storms and their attendant environments, the role of terrain on severe storm and tornado behavior and frequency, interactions between tornadoes and the natural and built environments, improvements to tornado-intensity estimation, societal response to tornado forecasts and hazards, individual and NWS partner decision making, forecast communication, and societal vulnerability, among many others.

Field observations have been a critical component of the VORTEX-SE program since its inception. The [first VORTEX-SE field campaign](#) was held from 1 March–1 May 2016, centered on northwestern and north-central Alabama. Field operations expanded to include northeastern Alabama in the [Spring 2017 field campaign](#) (8 March–8 May) to focus on studying the role of terrain on severe storm and tornado behavior. The [Spring 2018 field campaign](#) (1 March–30 April) was scaled down in focus to serve as a risk-reduction exercise for future mobile and airborne radar data collection efforts in the SE, but it was expanded in area to include northern Louisiana as another operations domain. The [Meso18-19 field campaign](#) (1 November 2018–30 April 2019) shifted focus to collect observations for improved understanding the predictability of



SE severe storms at multiple spatiotemporal scales, from meso- α (200–2000 km) to meso- γ (2–20 km) spatial scales and from minutes to up to 48 h in advance of a tornadic thunderstorm. The efforts of Meso18-19 were continued at the meso- β (20–200 km) and meso- γ (2–20 km) scales in the 2019–2020 cold season (1 November 2019–30 April 2020) across northern Alabama, northeastern Mississippi, and Middle Tennessee. These initial efforts culminated in the large-scale [Propagation, Evolution, and Rotation in Linear Storms \(PERiLS\) field campaign](#), which ran from 1 March–30 April 2022 and 8 February–8 May 2023 and is detailed in Kosiba et al. (2024).

Numerous platforms have been involved in data collection efforts as part of the above-listed VORTEX-SE field campaigns, including fixed and mobile radars, mobile and deployable mesonets, mobile and deployable profiling systems, aircraft, and disdrometers. One of the most prolific data sources collected across VORTEX-SE field programs has been radiosonde data, which have been extensively collected in every single field campaign listed above. This report details the acquisition, quality control, and synthesis of 2497 soundings collected during 39 IOPs in VORTEX-SE, Meso18–19, and PERiLS that featured severe convection in the domain.

To improve forecasts, environmental profiles have long been studied to understand storm-environment relationships using both rawinsonde observations (e.g., Showalter and Fulks 1943, Fawbush and Miller 1954, Kerr and Darkow 1996, Rasmussen and Blanchard 1998, Potvin et al. 2010, Coniglio and Parker 2020) and model analysis profiles (e.g., Thompson et al. 2003, Nowotarski and Jensen 2013, Coffey et al. 2019, Coffey et al. 2020). The latter exist over far more locations and times than routine rawinsonde observations and therefore provide a convenient data source for these studies. However, there are deficiencies in these analyses that may negatively impact our ability to understand, and ultimately predict, severe weather (Taszarek et al. 2021, Coniglio and Jewell 2022, Coniglio and Thompson 2024, Coffey et al. 2025). While direct observations are preferred, the drawback is that rawinsondes taken in the “Goldilocks zone” surrounding a storm—close enough to represent the environment in which the storm forms and matures, but far enough to not sample the storm influences themselves—are relatively scarce and have largely been collected over the Great Plains. That changed with VORTEX-SE. The rawinsonde dataset presented here represents the culmination of eight years of these collaborative efforts—between 11 different institutions—to better understand the typical environments of tornadic storms in the SE. This dataset is currently being used to produce a climatology of tornado environments in the SE, to evaluate model analysis profiles in the SE, and to drive model simulations of SE storms to better understand their processes. We expect that other studies that use this dataset will emerge once it is published.

3. Field campaign IOPs in the Southeast from 2016–2023

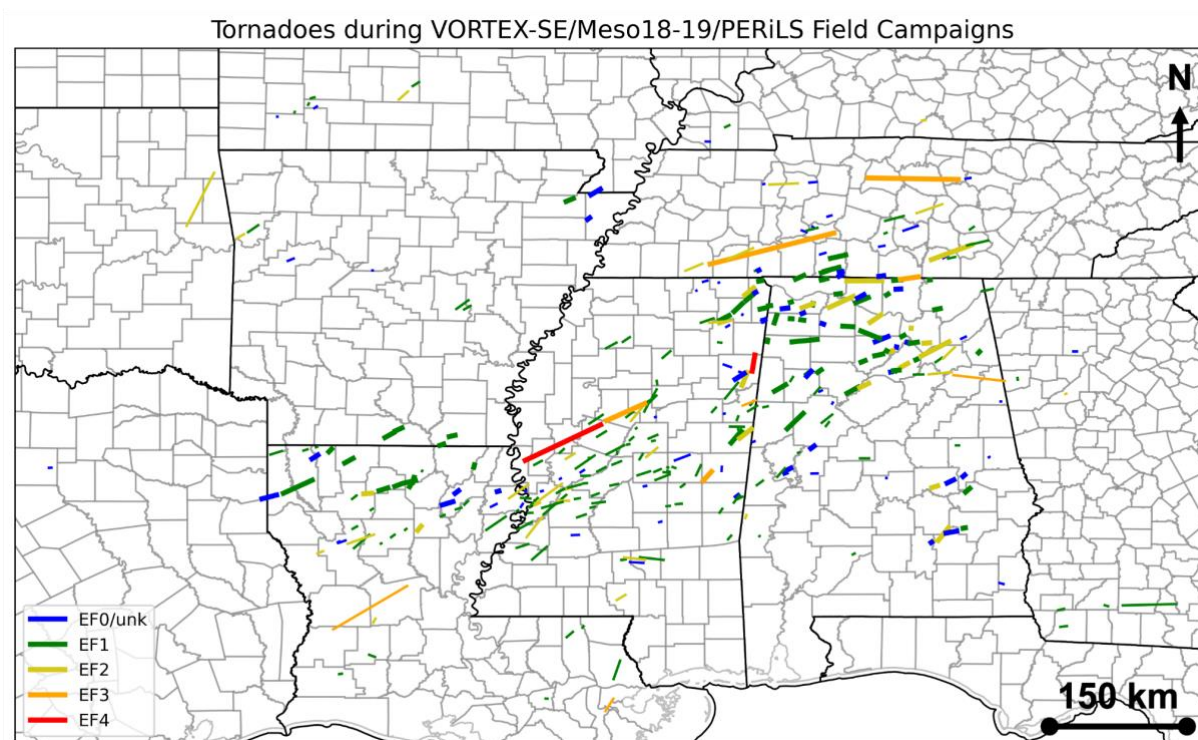


Figure 1: Map of the 326 tornadoes that occurred within 100 km and 90 min of a sounding during any of the VORTEX-SE, Meso18–19, and PERiLS IOPs. Tracks are colored by maximum EF-Scale rating. Bolded tracks highlight the 117 tornadoes that occurred within a focused observational network as part of one of the field campaign IOPs.

This sounding database is derived from multiple field campaigns from 2016–2023, including VORTEX-SE (2016–2018, 2020), Meso18–19 (2018–2019), and the PERiLS (2022–2023) campaign. The operations domains for VORTEX-SE and Meso18–19 were centered on Huntsville, Alabama, and included the north-central portion of Alabama and the surrounding vicinity. PERiLS featured multiple subdomains across this same region, central Alabama, and the Mississippi Delta extending from central Louisiana northward to southern Illinois. While observing tornadoes and their parent storms (across various convective modes) were a primary goal—particularly for VORTEX-SE—both tornadic and nontornadic storms and their local environments were sampled. Figure 1 shows the 326 tornadoes¹ that occurred within 100 km and 90 min of a sounding launch during the three field campaigns, and Table 1 summarizes the 39 IOPs that are included in the sounding dataset.

¹ These tracks and intensities are consistent with Storm Data except for the EF4 tornado in Monroe County, Mississippi. This is officially recorded as an EF2, but Lyza et al. (2022b) documented tree damage consistent with 3-s gusts exceeding 170 mph (EF4).



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Table 1: Project, IOP, date range (UTC), and the number of soundings launched for the events included in this dataset.

Project	IOP	Date Range (UTC)	No. Soundings
VORTEX-SE 2016	3	31 March – 1 April 2016	54
VORTEX-SE 2016	4b	29–30 April 2016	16
VORTEX-SE 2016	4c	30 April 2016	39
VORTEX-SE 2017	1a	25 March 2017	34
VORTEX-SE 2017	1b	27–28 March 2017	87
VORTEX-SE 2017	3b	5 April 2017	102
VORTEX-SE 2017	4a	26–27 April 2017	22
VORTEX-SE 2017	4c	30 April – 1 May 2017	78
VORTEX-SE 2018	1	19–20 March 2018	40
VORTEX-SE 2018	2a	28–29 March 2018	26
VORTEX-SE 2018	3	3–4 April 2018	33
VORTEX-SE 2018	4	6–7 April 2018	45
VORTEX-SE 2018	5	13–14 April 2018	48
Meso18–19	1	3–6 November 2018	105
Meso18–19	2	1–2 December 2018	104
Meso18–19	3	6–7 February 2019	108
Meso18–19	5	23–24 February 2019	109
Meso18–19	6	3 March 2019	36
Meso18–19	7	9–10 March 2019	105
Meso18–19	8	12–14 April 2019	135
Meso18–19	9	18–19 April 2019	89
VORTEX-SE 2020	1	16–17 December 2019	38
VORTEX-SE 2020	2	29–30 December 2019	18
VORTEX-SE 2020	3	10–11 January 2020	47
VORTEX-SE 2020	4	5–6 February 2020	54
VORTEX-SE 2020	5	12 February 2020	40
VORTEX-SE 2020	6	3–4 March 2020	42
VORTEX-SE 2020	7	24 March 2020	23
VORTEX-SE 2020	8	28–29 March 2020	42
VORTEX-SE 2020	9	8–9 April 2020	37
VORTEX-SE 2020	10	12 April 2020	48
VORTEX-SE 2020	11	23 April 2020	26
PERiLS 2022	1	22 March 2022	87
PERiLS 2022	2	30–31 March 2022	98
PERiLS 2022	3	5 April 2022	61
PERiLS 2022	4	13 April 2022	70
PERiLS 2023	1	16–17 February 2023	99
PERiLS 2023	3	24–25 March 2023	98
PERiLS 2023	4	31 March – 1 April 2023	153

Total: 2497

A total of 2497 quality-controlled soundings across the 39 IOPs are synthesized in this dataset. Figure 2 shows sounding counts for each IOP as well as a cumulative sum through the 2016–2023 period. Sounding locations are shown in Figure 3 (soundings within 15 km of each other are grouped together for clarity). The quality control and synthesis processes to produce this dataset are the primary focus of this report and are described in more detail below.

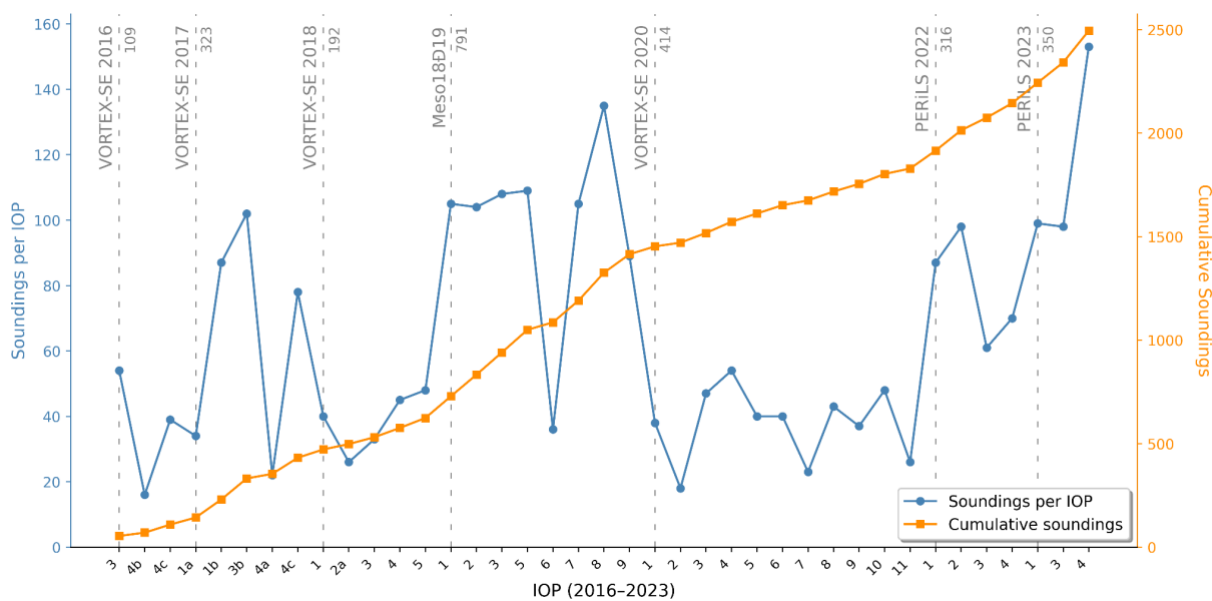


Figure 2: Timeseries of the number of soundings launched during each IOP (blue, left y axis) and the cumulative number of soundings launched during all IOPs (orange, right y axis). The x axis is labeled by project-specific IOP number, and the start of each project is indicated with a dashed gray line. The number of soundings launched during each project is provided.

4. Sounding acquisition, quality control, and synthesis

a. Collecting sounding data

Sounding platforms from several institutions and National Weather Service (NWS) sites were used for this dataset. Soundings from research and academic institutions were collected from the National Center for Atmospheric Research (NCAR) Earth Observing Laboratory (EOL) archive. NWS soundings—at native 1-s resolution—were included during select campaigns when they were launched within 100 km of a thunderstorm within the IOP domain. The VORTEX-SE campaigns from 2016–2018 included a NWS sounding feed on EOL, and NWS soundings during the 2020 campaign were obtained from the University of Wyoming sounding archive.

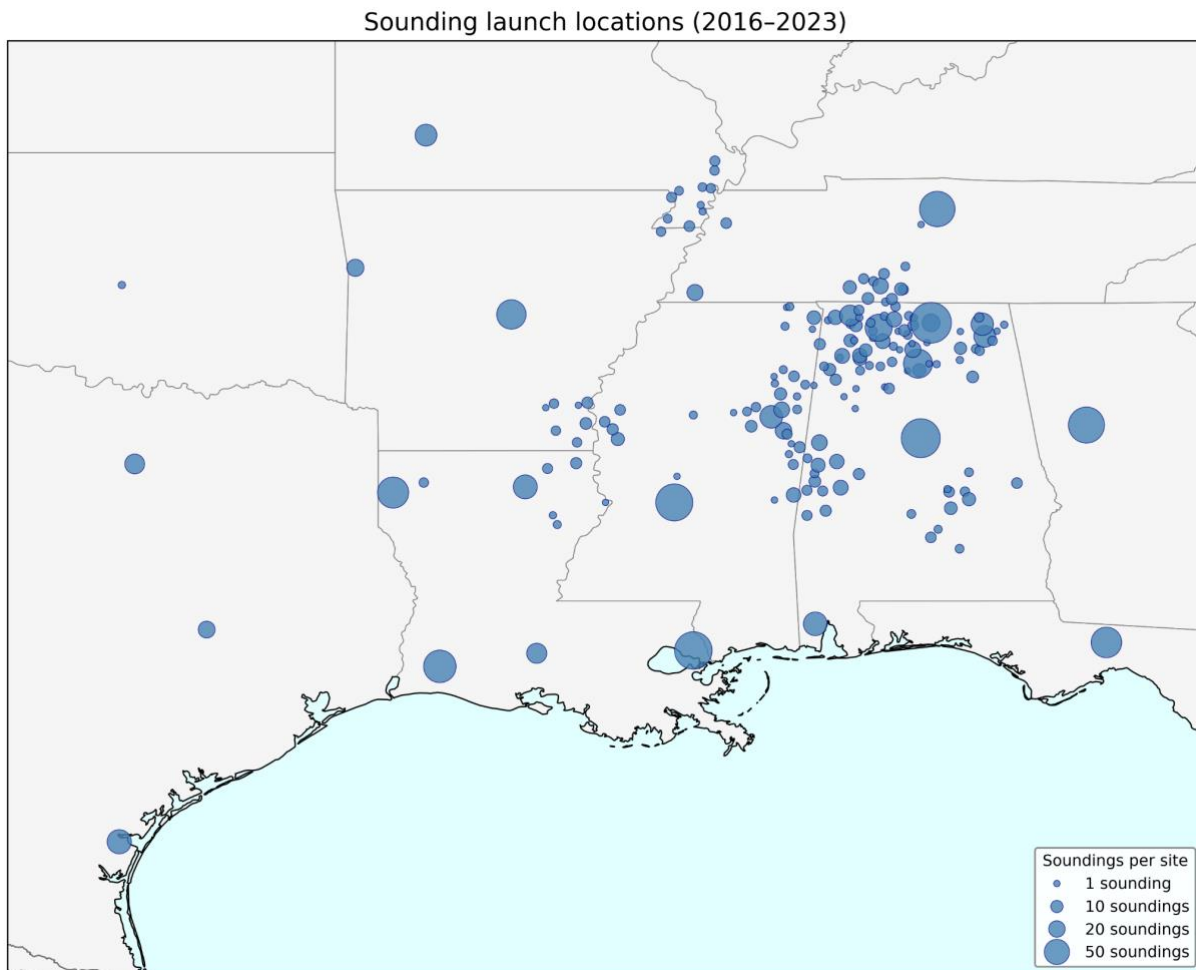


Figure 3: Map of all sounding locations during the 2016–2023 field campaigns. For clarity, soundings launched within 15 km of each other are binned into the same circles.

b. Objective quality control process

Manual quality control of each individual sounding was not feasible due to the thousands of soundings included in this dataset. Rather, extensive examination of the soundings yielded a few thresholds of select attributes that were used to automatically mask undesired values. These thresholds included removing:

- temperature observations below 20 m when the lapse rate exceeded 15 C km^{-1} ,
- temperature observations in ascending layers that featured a) relative humidity decreasing below 90% and b) a local 50-m lapse rate greater than 9 C km^{-1} (to address cloud-radiative effects),



- temperature and dewpoint observations where the dewpoint exceeded the temperature,
- all observations after a rolling 5-point average of vertical velocity (if provided or calculatable) exceeded 15 m s^{-1} ,
- all observations in layers featuring negative ascent rates or increasing pressure, and
- all winds above 10 km (as in Coniglio and Parker 2020).

c. Windsonde compositing

Due to the nature of windsonde missions consisting of closely launched windsondes from the same location, the majority of the windsonde profiles were composited so that similar profiles were not overrepresented in environmental composites. The end result of this compositing process is shown in the Figure 4 schematic illustrating how 226 windsondes were organized into 34 composite profiles. The compositing was a manual, subjective process that used a general time frame of 30 minutes and/or environmental evolution to determine the individual profiles forming a composite. For example, on 31 March 2023 the NSSL windsondes were split into composites based on changes in temperature and dewpoint profiles as well as wind shifts in low levels. The PSU windsondes were split about every 30 minutes due to the large number of windsondes launched during that IOP. On 24 March 2023, the PSU windsondes were split into four composites over a 1-h period due to the temperature and dewpoints profiles cooling and moistening. A larger time frame for compositing would have averaged out these environmental modifications as convection approached. During the 2022 deployments, NSSL had two windsonde crews launching at similar times from different locations, so composites were constructed based on both time and launch location.

d. Synthesis of all sounding formats

Dozens of institutions contributed to the collaborative SE field campaign effort from 2016–2023. The relative sounding contributions from various entities are shown in Figure 5. Routine and special soundings launched at NWS sites are shown in shades of blue and comprise 39% of the dataset. Other federal entities included the National Oceanic and Atmospheric Administration (NOAA) National Severe Storms Laboratory (NSSL) and Atmospheric Turbulence and Diffusion Division (ATDD). The academic institutions involved in sounding collection include the following, in order of number of soundings launched:

- University of Alabama-Huntsville (UAH),
- University of Louisiana-Monroe (ULM),
- Flexible Array of Radars and Mesonets (FARM; affiliated with the Univ. of Illinois and UAH),
- Mississippi State University (MSU),
- University of South Alabama (USA),
- Purdue University,

- Colorado State University (CSU),
- Texas Tech University (TTU),
- Texas A&M University (TAMU),
- The Pennsylvania State University (PSU), and
- Stony Brook University (SBU).

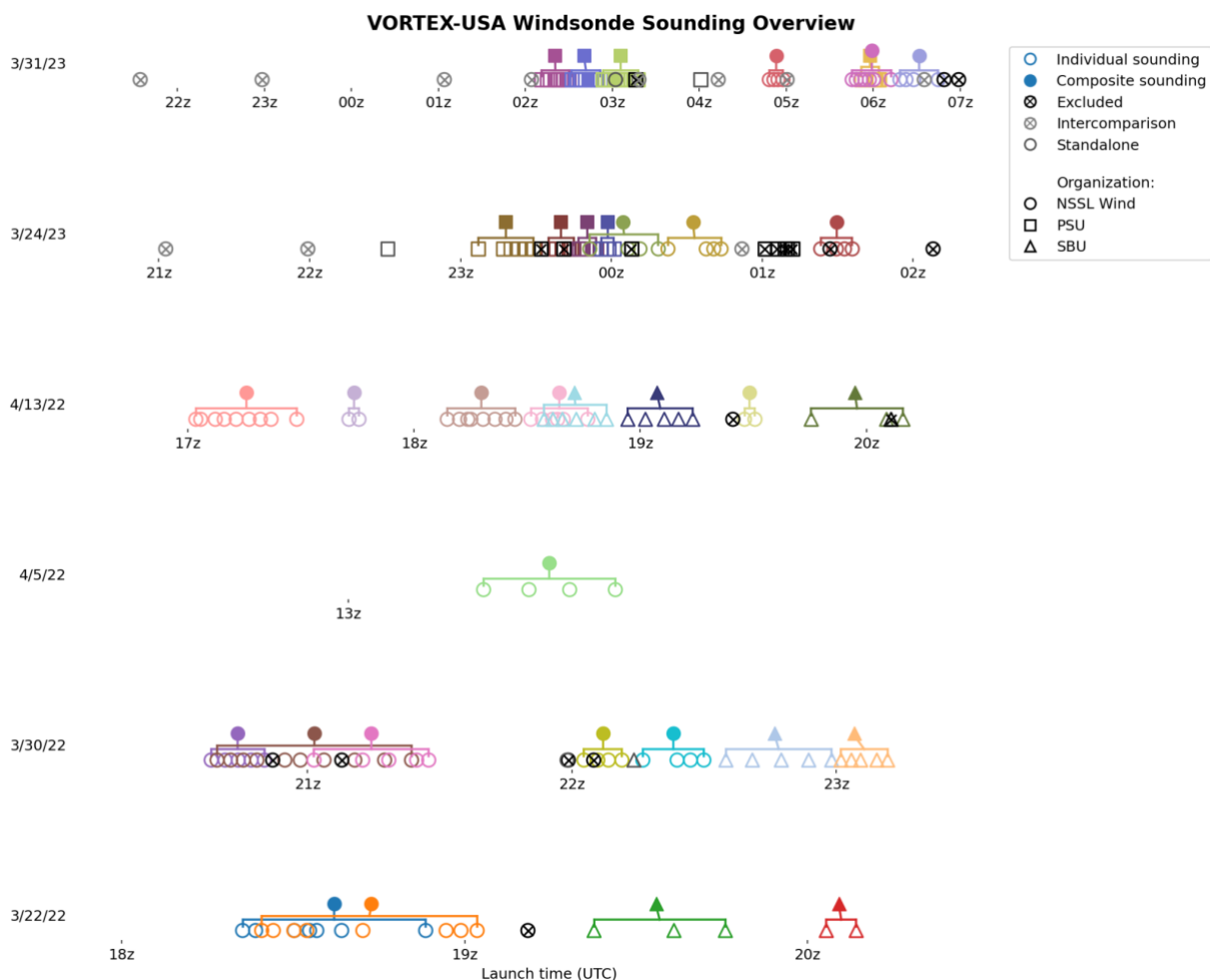


Figure 4: Schematic of all windsondes launched during IOPs 1–4 in PERiLS 2022 and IOPs 3 and 4 in PERiLS 2023. Each row represents a different convective event (with different x axis limits). Open polygons represent individual sounding launch times that contributed to a composite sounding, indicated by a bracket and filled polygon of the same color. Simultaneous composites from different institutions were composited at different spatial locations. Black Xs indicate soundings that were excluded due to data quality issues, and gray ones represent those that were launched simultaneously with a radiosonde. Gray open circles indicate windsondes that were launched “on their own” and thus treated as a standalone sounding.

In all, 11 academic entities and three government organizations (NWS, NSSL, ATDD)—including 13 NWS offices—contributed to this collaborative sounding effort. Consequently,

myriad (12, to be exact) sounding formats were used (Fig. 6, described further in Pounds et al. 2026). The formats here follow the nomenclature of Pounds et al. (2026), who refer to each format by an identification number. The identification numbers are not necessarily correlated to the sample sizes, and “Format 6” was skipped because the soundings that were originally tagged as “Format 6” were later available at higher resolution in a different format. 61% of the soundings featured Formats 1 or 2, but the remaining 39% used any of 10 other formats (Fig. 6). The format for each sounding was manually recorded to facilitate synthesized analysis.

Lastly, the soundings were collected by instruments from several different manufacturers, including 17 models in total from the GRAW, Lockheed Martin (LM) Sippican, Vaisala, Sparv Embedded (Windsond), and iMet manufacturers. An overview schematic documenting the manufacturers, brands, and institutions and projects that used each radiosonde type is provided in Fig. 7. Some known biases exist (e.g., a dry bias in Vaisala RS80 profiles—not used in these field campaigns—per Wang et al. 2002) but intercomparison studies are limited (e.g., Diedrichsen et al. 2025). Given the large number of soundings in this dataset and uncertainties regarding biases for many of the brands, we do not apply any bias correction.

5. Summary and potential applications

This report describes the construction of a quality-controlled dataset of radiosonde and windsonde observations from field campaigns in the SE. These collaborative observing efforts included 11 entities from around the country and yielded 2497 soundings from 2016–2023. Given the required quality control and inclusion of several different sounding formats, synthesizing this dataset was complex and time consuming (an effort accomplished by the second author as part of her dissertation research). The steps taken to quality control soundings, synthesize different formats, and composite windsondes were described above. The end result is a novel, large, accessible sounding dataset in SE convective environments.

Ongoing efforts by our group that use this dataset include: establishing baseline composites of tornadic and nontornadic environments across different convective modes (Pounds et al. 2026), comparing observed environments to modeled ones, similar to Coniglio et al. (2022), examining environmental characteristics of varying tornado behaviors (Miller et al. 2024), simulating near-inflow modification across a range of background environments (Flournoy et al. 2026) and supercell characteristics in the composite tornadic and nontornadic environments, and developing a storm motion estimate for quasi-linear convective system mesovortices (similar to the Bunkers et al. 2020 supercell estimates).

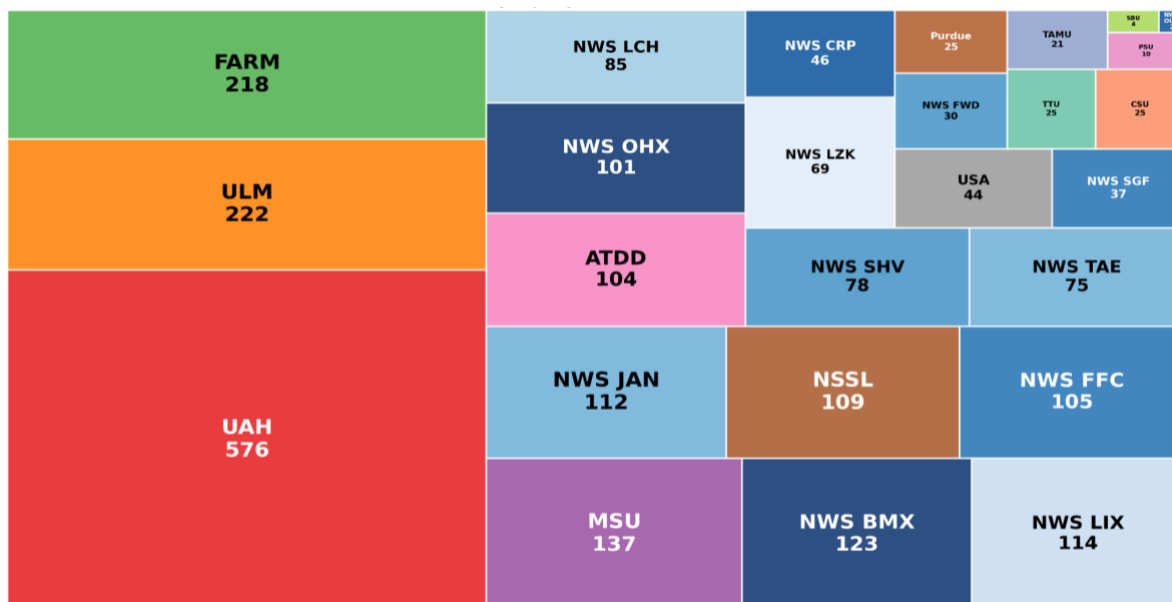


Figure 5: Treemap of all organizations that launched soundings during the 2016–2023 field campaigns. Sample sizes for each bin are shown. NWS sites are various shades of blue. The three smallest boxes represent PSU (10), SBU (4), and NWS OUN (2).

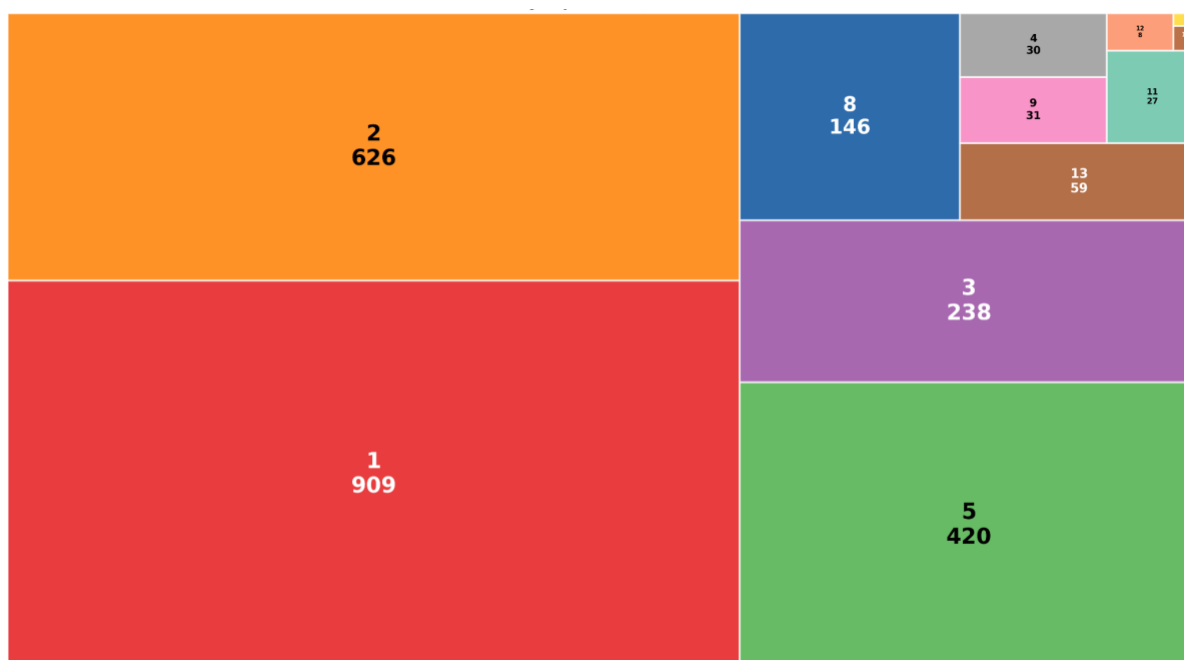


Figure 6: Treemap of all sounding formats used during the 2016–2023 field campaigns. Each numeric label refers to a different format referenced in Pounds et al. 2026. Sample sizes for each bin are shown below the format identifier. The three smallest boxes represent formats 7 (1), 10 (2), and 12 (8). The colors in this figure are not necessarily correlated to those in Fig. 5.

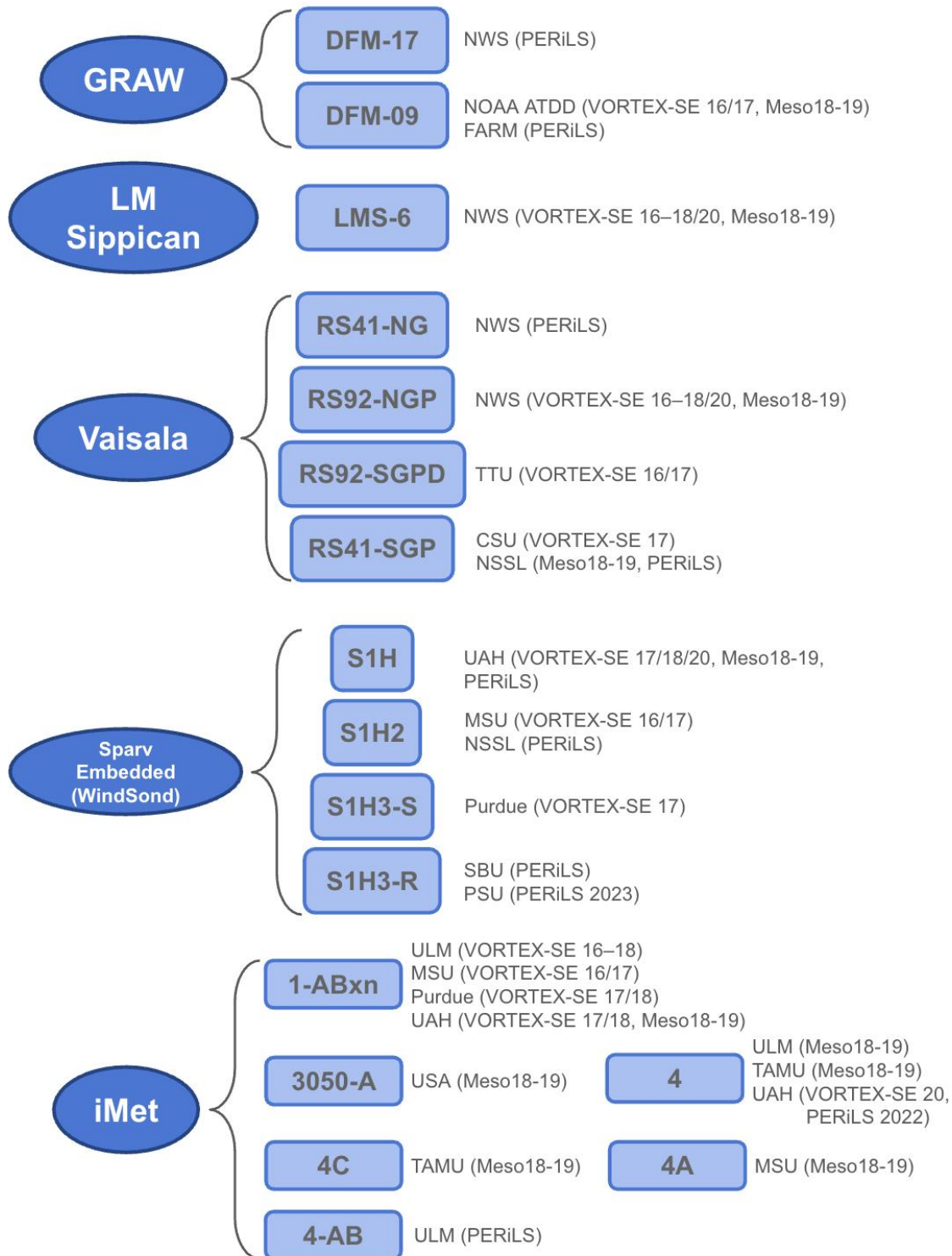


Figure 7: Flowchart of radiosonde manufacturers and brands. The manufacturers are circled on the left and brands are boxed. The institutions that used each sonde type are listed along with the project in which the sonde was used. Institutes may be listed multiple times.



Further applications of this dataset are myriad. Observations of the background environment and quasi-linear convective system orientation could be examined with respect to along-line variability in mesovortex production, including the development of line-embedded supercells.

Examining environmental trends leading up to and/or during severe weather events could yield new knowledge or parameters useful for real-time forecasting. The very-high-temporal resolution windsounde deployments could be used to investigate the sometimes-rapid environmental evolution that occurs ahead of storm complexes (e.g., Diedrichsen et al. 2024). This is an inexhaustive list of the sorts of studies that are possible with this dataset. We encourage community members to use this dataset for these or other purposes, and are excited for the resulting applications to better understand and predict hazardous convection in the SE.

6. Acknowledgements

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