FARM PERiLS 2022

Dataset User Guide

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FARM PERiLS 2022 DOW and COW Radar Data:

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FARM PERiLS 2022 Mesonet, Pod, Sounding, and Disdrometer Data:

Wurman, J., & Kosiba, K. (2022). *Flexible Array of Radars and Mesonets, non-Radar data, PERILS* [Data set]. Flexible Array of Radars and Mesonets, University of Illinois. https://doi.org/10.48514/962K-9866

Contents

1 Introduction

This User Guide provides information regarding the data collected by the Flexible Array of Radars and Mesonets (FARM) facility during the Propagation, Evolution and Rotation in Linear Storms (PERiLS) project during the 2022 Field Phase.

Table 1 provides a summary of the data collected by FARM facility instrumentation for each intensive observational period (IOP). See the NCAR/EOL PERiLS Field Catalog for more information on IOP timing and mission type:

http://catalog.eol.ucar.edu/perils_2022

Table 1: Available FARM data for the PERiLS 2022 IOPs.

Date:	**3/22/22**	**3/30/22**	**4/5/22**	**4/13/22**
IOP:	**1**	**2**	**3**	**4**
DOW6				🟩
DOW7	🟩	🟩	🟩	🟩
DOW8	🟩	🟩	🟩	
COW1	🟩	🟩	🟩	🟩
SCOUT1 Mobile Mesonet	🟩	🟩	🟩	🟩
SCOUT2 Mobile Mesonet	🟩	🟩	🟩	🟩
SCOUT3 Mobile Mesonet	🟩	🟩	🟩	🟩
SONDE1 Soundings	4	7	4	5
SONDE2 Soundings	5	8	5	5
SONDE3 Soundings	6	7	3	4
SONDE4 Soundings	6	7	3	4
SONDE5 Soundings	10	7	4	4
PODs	13	13	12	12
Disdrometers	3	3	3	3

2 Requesting Data Access

The FARM PERiLS 2022 dataset is hosted on a publicly accessible SFTP server as part of the FARM permanent archive. The dataset is separated into a radar and non-radar component.

The preferred method for accessing the datasets is through manual FTP:

Dataset:	Radar	Non-Radar
Preferred Protocol:	SFTP (port 22)	SFTP (port 22)
Host:	96.78.13.107	96.78.13.107
Username:	perilsradarpi	perilsnonradarpi
Password:	E-mail for password	E-mail for password

It is recommended that an independent FTP client such as FileZilla be used to download the dataset. FileZilla is a free FTP client and is available at https://filezilla-project.org/.

The dataset also can be accessed via two separate DOI links, separated into radar and non-radar archives. See the citations below. These DOI links will point your chosen FTP client to the host server with the correct username, but omits the password. Depending on your FTP client settings, it will either prompt you to enter the password before trying to connect or will fail to connect. If it fails, use the manual FTP setup with the correct password before trying to connect.

Please email the Data Manager, Josh Aikins (jaikins@illinois.edu), CC-ing Josh Wurman (jwurman@illinois.edu) and Karen Kosiba (kakosiba@illinois.edu) for the password.

Citation (Radar):

Wurman, J., & Kosiba, K. (2022). Flexible Array of Radars and Mesonets, Radar Data, PERILS (Version 1) [Data set]. Flexible Array of Radars and Mesonets, University of Illinois. https://doi.org/10.48514/JBJZ-KF06

Citation (Non-Radar):

Wurman, J., & Kosiba, K. (2022). Flexible Array of Radars and Mesonets, non-Radar data, PERILS [Data set]. Flexible Array of Radars and Mesonets, University of Illinois. https://doi.org/10.48514/962K-9866

3 Data Organizational Hierarchy

Radar Data

The FARM PERiLS 2022 radar dataset is contained beneath the top-level directory "2022_PERiLS_radar_QC" at the FTP access point. From there, the data are organized by IOP, where date and IOP number both are provided. The naming convention is "(YYYYMMDD)_IOP##," for example: "20220322_IOP01." The next lower set of directories is organized according to Radar Name. During PERiLS, the radars were DOW6, DOW7, DOW8, and COW1. Table 2 describes each of the possible sub-directories available beneath the vehicle/team directory, with references to the section of this User Guide where the relevant information concerning that data type may be found. Radar datasets are further segregated into "high" and "low" frequency directories for the radars operating in dual-frequency mode (See Section 4).

Table 2: Organizational hierarchy of the 2022 PERiLS radar dataset.

Directory Tree		**Section**	**Notes**
IOP → Radar Name →	radar → dorade	4	*dorade files only*
IOP → Radar Name →	radar → cfradial_netcdf	4	*cfradial files only*
IOP → Radar Name →	logs	5	
IOP → Radar Name →	inclinometer	5	
IOP → Radar Name →	media	5	*Select photos/videos*

Non-Radar Data

The FARM PERiLS 2022 non-radar dataset is contained beneath the top-level directory "2022_PERiLS_non-radar_QC" at the FTP access point. From there, the data are organized similarly to the radar dataset by IOP and then vehicle/team. During PERiLS, this included mobile mesonets SCOUT1, SCOUT2, and SCOUT3 as well as mobile sounding teams SONDE1, SONDE2, SONDE3, SONDE4, and SONDE5. DOW radars instrumented with mast-mounted weather instruments (DOW6, DOW7, and DOW8) are also included. Table 3 describes each of the possible sub-directories available beneath the vehicle/team directory, with references to the section of this User Guide where the relevant information concerning that data type may be found.

Table 3: Organizational hierarchy of the 2022 PERiLS non-radar dataset.

Directory Tree		**Section**	**Notes**
IOP → Vehicle/Team →	sounding	6	
IOP → Vehicle/Team →	mesonet	7	
IOP → Vehicle/Team →	pod	8	
IOP → Vehicle/Team →	disdrometer	9	
IOP → Vehicle/Team →	logs	5	
IOP → Vehicle/Team →	media	5	*Select photos/videos*

README files for radar, sounding, mobile mesonet, and pod/disdrometer deployments are available within each vehicle/team directory. These files contain detailed information relevant to each deployment, such as the scan strategy used (radar), number of files (radar), start and stop times of the data (radar & non-radar), navigational information such as latitude and longitude of deployment, altitude, and heading (radar & non-radar). Additional notes are contained in operator logs, but the README document should be used for the main source of accurate/verified deployment information. The README is also the source for important information regarding quality control, including issues and errors regarding the dataset or issues that arose during the deployment.

For the PERiLS 2022 datasets, additional documentation has been provided relating to the processing of the data. This includes spreadsheets with information on the verification of quality control corrections, including radar ZDR corrections and sounding surface initial conditions. Presentations that explain the quality control process have also been uploaded to each respective dataset. The programs and parameter files used to translate raw radar time series have also been shared in the radar dataset, which includes backups of the LROSE-core software developed by NCAR. Animated loops showing all FARM PERiLS assets with overlaid radar data have been created using the GURU2 software for all IOPs (GURU-Loops). Quicklook plots of raw mesonet and pod data have also been provided in the non-radar dataset. These additional documents and plots are meant to aid in reproducing the quality-controlled datasets, if desired. They have been placed on the same directory level as the IOP directories and may contain additional README files with more information.

4 Radars

The FARM PERiLS 2022 radar dataset is provided in both the Doppler Radar Data Exchange format (DORADE) and CfRadial formats. Solo3 and other perusal programs can be used to view, edit, and process the data. Solo3 can be downloaded at:

https://www.eol.ucar.edu/software/solo3

For PERiLS 2022, DOW7 and COW1 radars have independent data sets from “high” and “low” frequencies. Data from either or both frequencies can be used for analysis, or combined to reduce error. Sometimes data from one frequency is higher quality or less subject to interference. This type of information is detailed in the READMEs.

The FARM PERiLS 2022 radar dataset has undergone an extensive quality control, detailed here. In the next sub-section, a brief overview of the DOW and COW mobile weather radars is given, followed by a description of their PERiLS configuration. Next, the quality control process is discussed, followed by a brief overview of the available products, clutter filter, and known issues during the project.

4.1 Mobile Weather Radars

The Flexible Array of Radars and Mesonets (FARM) mobile and deployable weather radars are part of the National Science Foundation (NSF) Community Instruments and Facilities (CIF) program.

A full technical summary of the FARM instrumentation operated during PERiLS can be found in Wurman et al. (2021).

The DOW6 radar employed a temporary spare transmitter during PERiLS. This transmitter radiated with a maximum power of 70 kW at a single frequency (low).

4.2 PERiLS 2022 Configurations

During PERiLS 2022, the transmit/processing and antenna scan strategies for the FARM radars were optimized to sample convection. A list of the main transmit/processing configurations for all FARM radars is given in Table 4.

Table 4: PERiLS 2022 main radar transmit/processing configurations.

	DOW6	DOW7	DOW8	COW1
Pulse Length	500 ns	500 ns	500 ns	500 ns
Gate Length	75 m	75 m	75 m	75 m
Number of Gates	1000	1000	984	1181
PRF	1666.7 Hz / 1250 Hz	1666.7 Hz / 1250 Hz	2000 Hz / 1333 Hz	1666.7 Hz / 1250 Hz
Stagger	3/4	3/4	2/3	3/4
Max Range	75 km	75 km	73.8 km	88.6 km
Nyquist Velocity	39.9 m/s (low)	39.4 m/s (high) 40.1 m/s (low)	31.7 m/s	67.5 m/s (high) 69.4 m/s (low)
Mode	Fast-45	Fast-45	Single-Pol	Fast-45
Beam Indexing	0.5° (SUR)	0.5° (SUR)	0.5° (SUR)	0.5° (SUR)

DOW8 occasionally was used to get high-resolution radar data near the leading edge of quasi-linear convective systems (QLCS) when tornadic circulations were present. This meant changing the radar transmit configuration to a short pulse/high PRF setup. These secondary transmit/processing configurations for DOW8 are detailed in Table 5.

Table 5: PERiLS 2022 secondary radar transmit/processing configurations.

	DOW8	DOW8	DOW8
Pulse Length	167 ns	167 ns	167 ns
Gate Length	25 m	25 m	25 m
Number of Gates	1751	1451	1151
PRF	3333 Hz / 2222 Hz	4000 Hz / 3000 Hz	5000 Hz / 3333 Hz
Stagger	2/3	3/4	2/3
Max Range	43.8 km	36.3 km	28.8 km
Nyquist Velocity	52.9 m/s	95.2 m/s	79.3 m/s
Mode	Single-Pol	Single-Pol	Single-Pol
Beam Indexing	0.5° (SUR)	0.5° (SUR)	0.5° (SUR)

The PERiLS 2022 scan strategy included the use of surveillance scans (azimuthally-rotating). These scans are indicated in the filename (called the sweep file) with the abbreviation SUR. The fixed angle of the scan (the angle in the filename and header) is the median of antenna elevations for every ray in the file. It is not necessarily the exact position of every ray since there is often some degree of error, and because also at some point the antenna must transition to the next scan. In the SUR scans provided in this dataset, it should be representative of at least the majority of rays, unless otherwise noted. Regardless, care should be taken when analyzing radar data to check that the antenna is positioned at the intended elevation.

Vertical ("bird bath" or VER) scans are also provided in this dataset, which contain radar data while pointing nearly vertically (89° elevation) and rotating azimuthally for at least 360 degrees. These VER scans are typically provided as-is, and may or may not include transition data. Additionally, VER scans are not indexed to an exact azimuthal resolution and instead the resolution varies.

FARM radars complete a programmed set of scans in a given period of time called a sync cycle. The amount of time it takes to complete a list of scans may be less than the sync, in which case the radar simply waits at the end of its scan queue for the sync to pass before starting again. The beginning of the cycle starts at the next sync interval in UTC time, determined by GPS. In this way, all radars in the field operating at the same sync interval start their assigned list of scans at the same time, which helps line up the radar data in time, a useful technique for creating dual-Doppler analyses. Throughout PERiLS, with the exception of DOW8, FARM radars operated in a sync interval of 10 minutes.

The antenna scan strategy used for PERiLS 2022 consisted of full volumetric sampling (SUR scans) at moderate speed antenna rotation rates to capture several full volumes over each 10-minute sync period. VER scans were programmed at the end of each sync cycle for ZDR calibration (see section 4.6). A list of possible antenna scan modes for all FARM radars is given below in Table 6.

Table 6: PERiLS 2022 antenna scan strategies used for each radar.

Radar(s)	Scan ID	Rotation Rate	Sync	Elevation Angles	Azimuth Angles
COW1	PERILS.1	28 deg/s	10 min	0.5° - 5.1° SUR (x7) 0.5° - 14° SUR (x9) 0.5° - 5.1° SUR (x14) 0.5° - 14° SUR (x9) 89° VER (x1)	0° - 360°
COW1	PERILS.1.Slow	12 deg/s	10 min	0.5° - 2.6° SUR (x20)	0° - 360°
COW1	PERILS.2	20 deg/s	10 min	0.5° - 3.4° SUR (x5) 0.5° - 8° SUR (x7) 0.5° - 3.4° SUR (x10) 0.5° - 8° SUR (x7) 89° VER (x1)	0° - 360°
COW1	PERILS.3.SUR	10 deg/s	N/A	1.2° SUR (x20)	0° - 360°
DOW6	SDS + SDVP + Sync	31 deg/s	10 min	0.5° - 7° SUR (x9) 0.5° - 14° SUR (x9) 0.5° - 7° SUR (x18) 0.5° - 14° SUR (x9) 89° VER (x1)	0° - 360°
DOW7	S3 + SDBR + Sync	31 deg/s	10 min	0.5° - 7° SUR (x9) 0.5° - 14° SUR (x9) 0.5° - 7° SUR (x18) 0.5° - 14° SUR (x9) 89° VER (x1)	0° - 360°
DOW8	??	50 deg/s	N/A	0.5°, 1°, 1.5°, 2° SUR	0° - 360°
DOW8	??	50 deg/s	N/A	1° SUR	0° - 360°
DOW8	??	40 deg/s	N/A	1°, 1.7°, 2.4° SUR	0° - 360°

4.3 Radar Variables

A listing and description of all possible radar variables provided in each DORADE/CfRadial file is given in Table 7. Some fields are appended with "_F" to indicate their status as a clutter filtered product. More details on the clutter filter are provided in Section 4.4.

Table 7: Radar variables available in quality-controlled radar data for PERiLS 2022.

Fields	Long Name (Units)
DBMHC	Received power, horizontal channel, co-polar (dBm)
DBMVC	Received power, vertical channel, co-polar (dBm)
DBZHC	Equivalent reflectivity factor, horizontal channel, co-polar (dBZ)
DBZHCC	Offset-corrected equivalent reflectivity factor, horizontal channel, co-polar (dBZ) (see Section 4.7)
DBZVC	Equivalent reflectivity factor, vertical channel, co-polar (dBZ)
NCP	Normalized coherent power (unitless)
RHOHV	Correlation coefficient (unitless)
PHIDP	Differential phase shift (deg)
KDP	Specific differential phase (deg/km)
SNRHC	Signal-to-noise ratio, horizontal channel, co-polar (dB)
SNRVC	Signal-to-noise ratio, vertical channel, co-polar (dB)
TRIP_FLA	Second trip detection (values > 3 indicate second trip)
VEL	Doppler velocity (m/s)
VL	Doppler velocity, long pulse (m/s)
VS	Doppler velocity, short pulse (m/s)
WIDTH	Spectrum width (m/s)
ZDRC	Offset-corrected differential reflectivity (dB) (see Section 4.6)
ZDRM	Measured differential reflectivity with no correction (dB)

4.4 Clutter Filtering

Selected fields in the DOW dataset have been chosen for additional clutter filtering. These fields are appended with “_F” to indicate their status as a clutter filtered product. In all cases, the original non-filtered field is also provided.

A simple notch clutter filter is used with notch width set at ± 1 m/s. For each individual gate that is processed, a fast Fourier transform (FFT) algorithm is used to process raw I & Q (in phase and quadrature) time series data into a velocity spectrum of returned power. A fuzzy logic algorithm determines gates that are likely contaminated with clutter. For these gates, typically the spectrum is largely dominated by near 0 m/s returns. Those gates that pass the detection are processed through the clutter filter, which removes and then interpolates across a notch centered on 0 m/s at the parameterized width. The power and velocity are then determined from the spectrum normally (Hubbert et al. 2009).

Figure 1 shows an example of the clutter filtering applied to the radar dataset. The left panel shows the unfiltered velocity product at a range of 0-4 km from DOW7 during a selected deployment. The right panel shows the filtered velocity product in the same scan. While the filter removes the vast majority of ground clutter, a small portion of it remains. It also tends to eliminate much of the 0 m/s isodop, an unfortunate side effect of the notch removal and interpolation process. The clutter filter cannot unfold velocities beyond the Nyquist limit.

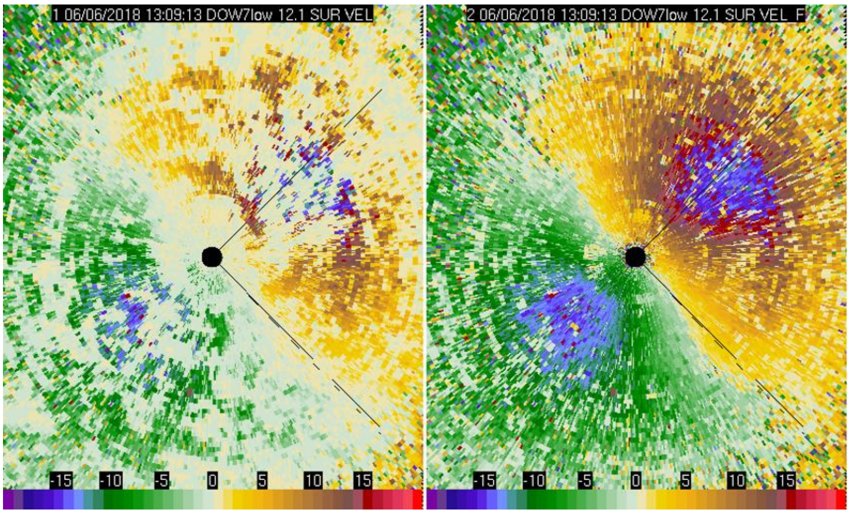


Figure 1: (Left) Unfiltered Doppler velocity product. (Right) Clutter filtered Doppler velocity product.

4.5 Navigation/Geo-referencing

All DOW radar data provided with this release have been carefully navigated to the precise geographic position of the radar deployment site and rotated according to the calculated heading of the vehicle so that zero degrees points north. These adjustments are made in post-processing, during translation of the raw time series data into DORADE files.

Latitude and longitude were initially collected and saved in the radar data using Spectracom GPS receivers installed in the radars. Deployment site latitude and longitude values typically were recorded in the field logs using the Garmin GPS observations from the weather mesonet, which are mounted on the front dash of the DOW radar trucks. Since COW1 does not have a weather mesonet, a highly accurate GPS position was determined using a handheld GPS at the beginning of each IOP. These field values are then verified using Google Earth imagery and site photos taken by operators and students.

Altitude was retrieved using Google Earth and verified with a point query estimate from the USGS 3DEP national elevation dataset (link). Note that these altitude values refer to the ground altitude at each site. We have left it up to the user to decide whether an antenna height above ground level should be added to this altitude value. Typically, 3 m is added for DOW radars and 4 m is added for the COW1 radar.

Solar scans (in which the antenna is made to point directly at the sun) were conducted at the beginning or end of each IOP, if possible. Solar scans were used to calculate the vehicle heading. During the solar scan, a sharp spike in received power is observed when the antenna is pointed at the sun (Figure 2). The azimuth at which the sun was observed by the antenna is then compared to the expected true solar azimuth angles at that time and location. The NOAA Solar Calculator website (link) was used to calculate the expected azimuth and elevation angle of the sun at the times of the solar scans. The difference (expected azimuth – observed azimuth) is the vehicle heading.

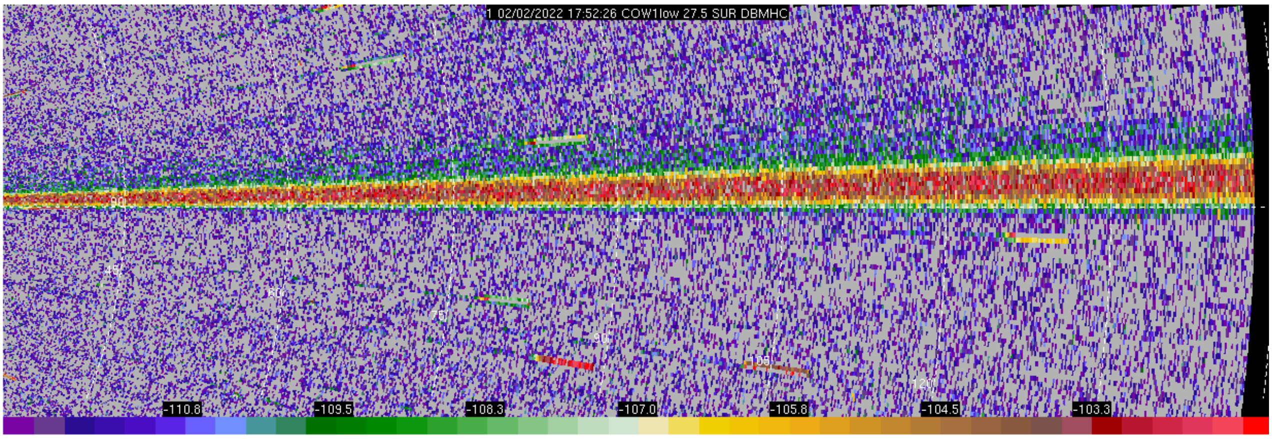


Figure 2: A solar spike observed in the horizontal power field (DBMHC) by the COW1 radar.

The headings obtained using solar scans later were refined by comparing ground clutter targets (cell towers, water towers, etc.) in radar scans to their true location using Google Earth imagery. Tall objects like cell towers typically show up as a high-power radar return. Figure 3 shows an example of a cell tower clutter target. The center of this target is assumed to be the range gate with the strongest reflectivity, although large reflective targets many times show up across gates more than 1 degree azimuthally and across several gates in range. Multiple radar sweeps are investigated to make sure the target does not move over time. Targets that disappear later in an IOP generally were not used for the clutter target analysis. Once a target is found, the range and true azimuth (relative to North) of the target from the radar is measured using the Google Earth measure tool. The heading of the truck can then be calculated as the true azimuth of the target minus the radar-observed azimuth of the target. Additionally, any range gate offset can be calculated by subtracting the true range of the target from the radar minus the radar-observed range. This is called a range-to-first-gate (RTFG) correction and it makes sure targets appear at the correct range from the radar. Refer to Section 4.6 for more details.

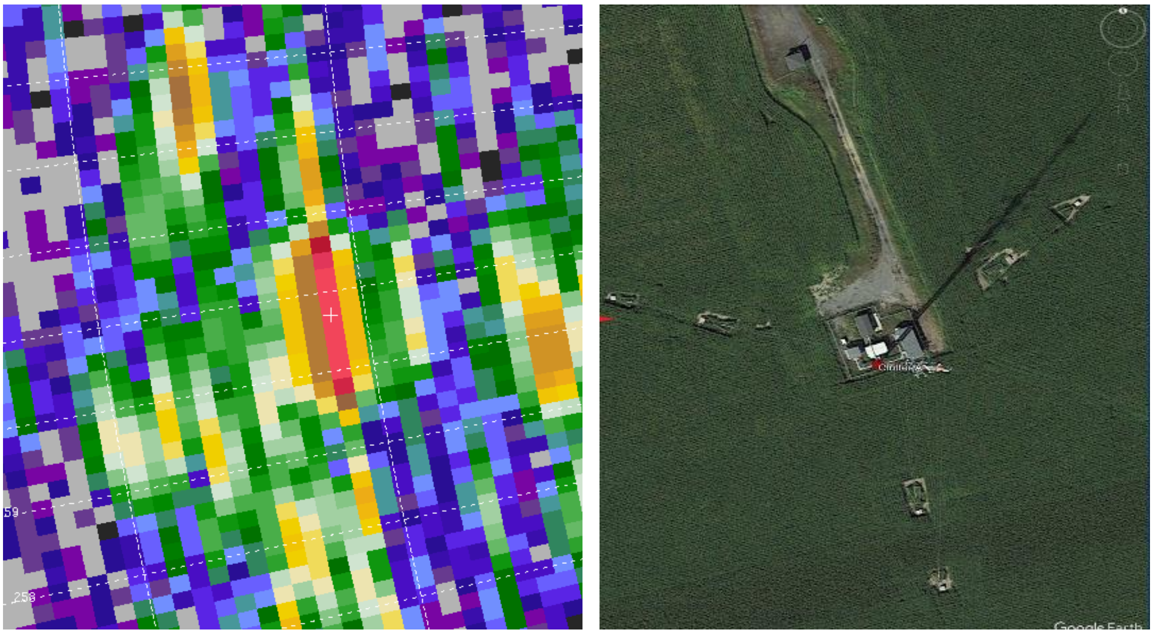
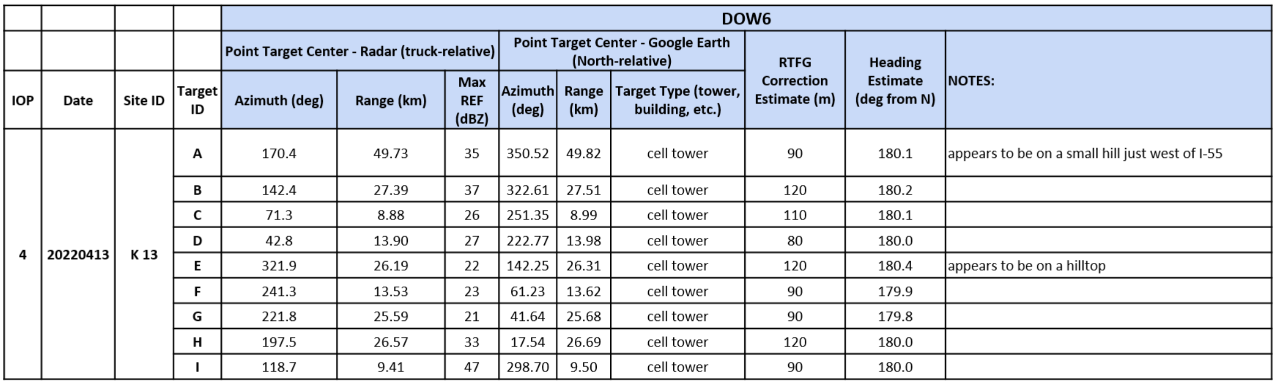


Figure 3: (Left) Radar reflectivity (DBZHC) of a cell tower clutter target (Right) observed by the COW1 radar 1.0° elevation SUR scan.

At least 3 clutter targets are required to calculate a reasonable heading and RTFG correction, with each target preferably in a different azimuthal quadrant. Figure 4 shows a screenshot of a typical point clutter analysis. For PERiLS 2022, typically 6 to 9+ clutter targets were used to calculate highly accurate headings and RTFG corrections.



				DOW6								
				Point Target Center - Radar (truck-relative)			Point Target Center - Google Earth (North-relative)			RTFG Correction Estimate (m)	Heading Estimate (deg from N)	NOTES:
IOP	Date	Site ID	Target ID	Azimuth (deg)	Range (km)	Max REF (dBZ)	Azimuth (deg)	Range (km)	Target Type (tower, building, etc.)			
4	20220413	K 13	A	170.4	49.73	35	350.52	49.82	cell tower	90	180.1	appears to be on a small hill just west of I-55
			B	142.4	27.39	37	322.61	27.51	cell tower	120	180.2	
			C	71.3	8.88	26	251.35	8.99	cell tower	110	180.1	
			D	42.8	13.90	27	222.77	13.98	cell tower	80	180.0	
			E	321.9	26.19	22	142.25	26.31	cell tower	120	180.4	appears to be on a hilltop
			F	241.3	13.53	23	61.23	13.62	cell tower	90	179.9	
			G	221.8	25.59	21	41.64	25.68	cell tower	90	179.8	
			H	197.5	26.57	33	17.54	26.69	cell tower	120	180.0	
			I	118.7	9.41	47	298.70	9.50	cell tower	90	180.0	

Figure 4: Point Clutter analysis spreadsheet results for DOW6 during PERiLS IOP04.

4.6 Quality Control Overview

The radar dataset provided with this release has undergone an extensive quality control process. The DORADE files generated during this process were translated from the raw I & Q (in phase and quadrature) time series data collected during deployments. Upon request, the time series data can be made available to the PIs. During the translation process, the dataset was navigated (latitude/longitude and altitude values were applied), oriented to north, and indexed at 0.5 degrees in azimuth for surveillance scans. Indexing at other resolutions can be applied upon request.

The delineation between SUR scans was manually chosen to occur at an azimuth centered within the antenna transition from one elevation angle to the next. This period of transition, typically lasting 10-20 degrees for slower antenna rates and shorter elevation transitions, is automatically set to begin in FARM radars at truck-relative 350 degrees azimuth. Since FARM radar data are oriented to be north-relative, the transition period should begin at about truck heading minus ~ 10 degrees. The delineation between SUR scans for PERiLS was chosen to be aligned with the truck heading (0° azimuth truck-relative). This means there will be transition data both at the beginning and end of each SUR sweep. For transitions between SUR scans with large differences in elevation angles, the transition data can encompass 30°+ in azimuth. These transition data have been retained in the dataset to allow the user to decide where to cut out data based on their targeted analysis.

After a final translation is run on the data, the first step is to apply range-to-first-gate (RTFG) corrections. These corrections were applied directly to the DORADE sweep files using the soloii software. The RTFG corrections, calculated using clutter target analysis (section 4.5), may vary by pulse width, so a unique value was found for each radar and for each pulse width. A correction value was then applied according to radar and pulse width for each IOP. Table 8 shows the correct RTFG values applied to each radar for PERiLS 2022.

Table 8: Corrected range-to-first-gate values for each radar and pulse used during PERiLS 2022.

Radar	RTFG	Pulse Width
DOW6	140 m	500 ns
DOW7	165 m	500 ns
DOW8	-62.5 m	500 ns
DOW8	-77.5 m	167 ns
COW1	87.5 m	500 ns

Adjustments were then applied to measured differential reflectivity (ZDRM) to account for system offsets resulting from equipment temperature anomalies, system biases, or other receiver/transmitter errors. The offset is found from measuring the median ZDRM in vertical (VER) scans conducted every 10-minute sync period. When there were clouds or precipitation overhead of the radar and VER scans were present, we accepted an error of +/- 0.2 dB in this calculation, which is within the literature-suggested accuracy for practical use of dual-polarization radar data (Gorgucci et al. 1999). The scalar offset value is subtracted from ZDRM and placed in a new field called ZDRC (ZDR, Corrected).

In an idealized scenario, vertically falling hydrometeors should have a differential reflectivity value of approximately 0 dB when viewed at vertical incidence and averaged over a full 360-degree azimuthal rotation. For each 10-minute period in which VER scans were both available and contained reliable data (had hydrometeors overhead), FARM quality control staff calculated the median value of ZDRM in power returns within the linear region of the receiver (-60 dBm to -90 dBm). Often, an annulus around the radar center was also removed, as this region is generally over-saturated. The size of the annulus was determined from each VER scan and varied by radar and frequency. This filtering was intended to calibrate ZDRM on reliable meteorological radar returns rather than clutter or low power clouds. A level of confidence was then given to each VER scan ZDRM offset, determined by the availability of these moderate power returns and its deviation from temporally adjacent offsets. The calculated ZDRM offsets were then plotted and a best-fit line was created to track with changing offsets over each IOP for each radar and frequency. This best fit line generally was meant to keep the measured offsets within +/- 0.2 dB. This best fit line offset is what was used to correct the ZDRM field in PERiLS 2022 sweep data, rather than applying the measured ZDRM offset to each 10-minute volume. This allowed us to estimate offsets across periods when VER scan ZDRM offsets could not be calculated, although there is less confidence in the offset during these times. The ZDRM measured 10-minute offsets and the best fit offset corrections applied to the data may be found at the bottom of the README documents for each IOP and each radar vehicle. Figure 4 shows an example of measured ZDRM offsets for COW1 during IOP05, and Figure 5 shows the measured ZDRM offsets with the best fit line of applied ZDRM offset corrections for COW1 high frequency data for IOP05. Plots for each IOP/radar/frequency are provided in the README documents.

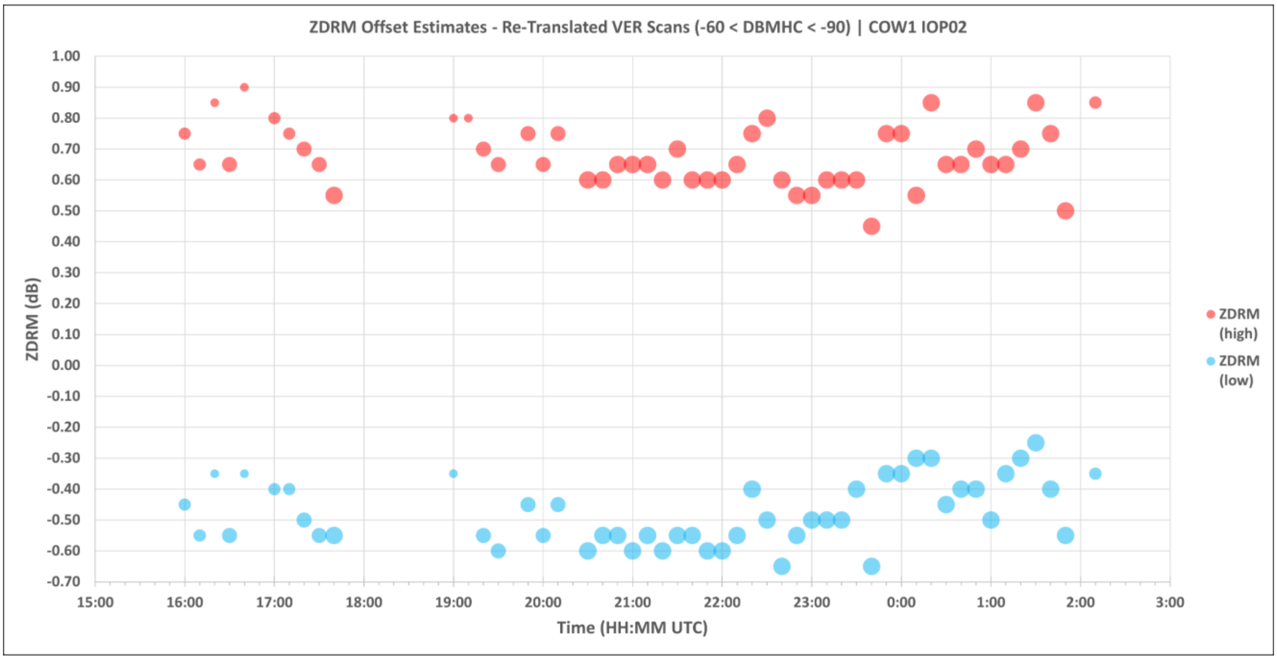


Figure 5: Measured COW1 ZDRM offsets from VER scans during IOP02 on 30-31 March 2022. Red (blue) bubbles represent the high (low) frequency channel. The size of the bubbles represents the confidence in the offset value, where larger bubbles denote larger confidence.

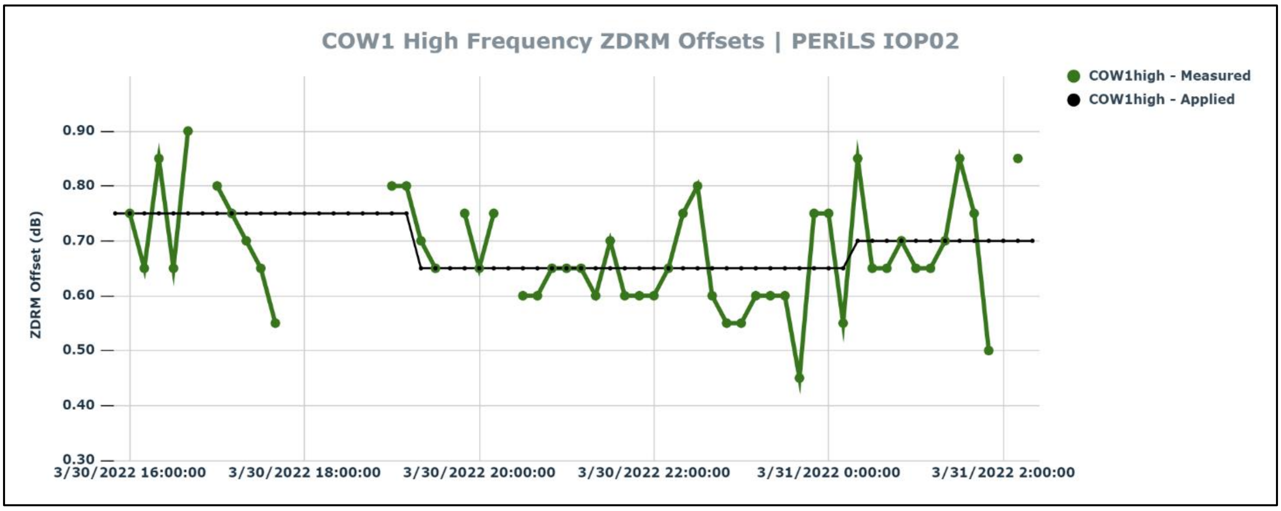


Figure 6: Measured (green) and applied (black) ZDRM offsets for COW1 high frequency channel data during PERiLS 2022 IOP02.

An offset-corrected horizontal reflectivity field (DBZHCC) is available in the FARM PERiLS 2022 dataset. This field is equivalent to the raw horizontal co-polar reflectivity field (DBZHC) with IOP-specific offsets subtracted. These offsets were derived for each IOP from the average difference between each FARM radar reflectivity field (DBZHC) and a nearby WSR-88D reflectivity field (REF).

To compute these reflectivity (DBZ) offsets, a co-located region in a set of radar scans at a similar altitude and time is compared in soloii when a precipitation feature of moderate 20-30 dBZ reflectivity was located within it. A DBZ offset for the horizontal channel for each radar and each frequency was calculated by determining the difference between the average WSR-88D reflectivity centered within the co-located region and the reflectivity observed by each FARM radar in the same region. Finding these co-located regions typically requires different elevation angles for different radars, and generally a co-located region is satisfied if it falls within +/- 300 m in altitude of the other radars. Bright band contamination was avoided when finding these co-located regions. Figure 6 shows one intercomparison time from PERiLS 2022 IOP01 with each reflectivity field corrected to match the KGWX WSR-88D radar. Several of these intercomparisons were found for each radar and each IOP so that an average could be computed for each IOP. Table 9 shows the final DBZ offsets calculated for each radar and each IOP during PERiLS 2022.

Table 9: Reflectivity offsets for each radar frequency and IOP during PERiLS 2022.

	COW1		**DOW7**		**DOW6**	**DOW8**	
IOP	**High**	**Low**	**High**	**Low**	**Low**	**500 ns**	**167 ns**
1	0.0 dB	-4.5 dB	-6.5 dB	-6.5 dB		-6.5 dB	-17.0 dB
2	-1.5 dB	-5.0 dB	-10.0 dB	-8.0 dB		-12.5 dB	-19.5 dB
3	+0.5 dB	-3.5 dB	-7.0 dB	-5.5 dB		-25.5 dB	-25.5 dB
4	-3.0 dB	-3.5 dB	-7.0 dB	-5.5 dB	-2.5 dB		

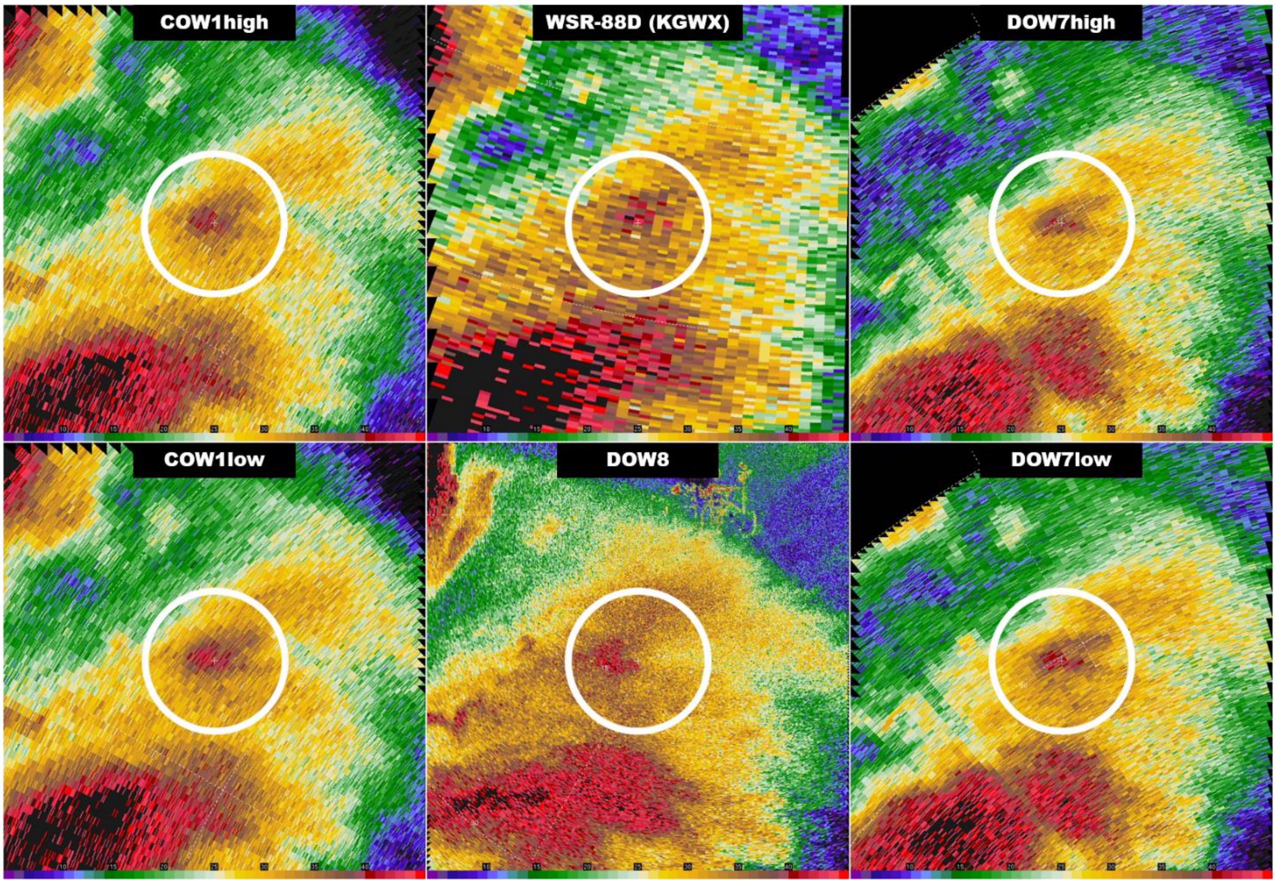


Figure 7: Offset-corrected reflectivity (DBZHCC) for each FARM radar and KGWX WSR-88D reflectivity (REF) centered on a location where each scan transects a similar level of the atmosphere around 20:02 UTC 22 March 2022 during PERiLS IOP01.

Following the corrections of RTFG, ZDR, and DBZ, the dataset was carefully and thoroughly perused by FARM quality control staff for issues and errors. Radar sweep files containing unreliable radar data or mainly transitional scan data were removed from the final dataset. Due to errors and issues that occurred in the field, some scans may have missing, empty or bad data sectors. We have made a best effort to note as many of these as possible in the README documents, but care should be taken regardless when analyzing all radar datasets. When a correctable issue was found, the data was re-translated with the issue corrected, and the process was begun again. Other issues relating to radar operation that were not correctable were noted in the README file that accompanies each deployment. These READMEs are the definitive source for issues and information relating specifically to each deployment and should be reviewed before analysis is undertaken on any part of the dataset.

Finally, once all edits are complete on the DORADE sweep files, all sweeps are converted to cfradial netcdf format using the RadxConvert command. Both the DORADE and cfradial netcdf versions of the dataset are provided.

4.7 Known Issues

The following sub-sections describe some data-collection impacting issues that occurred during PERiLS 2022. Other issues not noted here are in the READMEs for specific deployments.

4.7.1 Operational Status

DOW6: DOW6 was only used during IOP04.

DOW7: DOW7 frequently suffered from severe attenuation in heavy rain due to its smaller wavelength radar pulse (X-band). Additional attenuation correction algorithms can be applied to power/reflectivity products to further correct for attenuation.

DOW8: DOW8 was largely used to document tornado-scale circulations at the leading edge of convective systems as a smaller pulse was used to give higher resolution.

DOW8 did not collect data during IOP04 due to a power issue.

The unique antenna configuration of DOW8 (Cassegrain antenna) requires the use of a radome for operations. However, radome wetting caused severe attenuation during most IOPs when heavy rain was observed at the deployment site. This exacerbated the attenuation already present due to the smaller wavelength pulse (X-band). DOW8 velocity products should mainly be used for analysis as power/reflectivity products (even corrected products) are not reliable because of this frequent severe attenuation from heavy rain.

COW1: During PERiLS 2022, COW1 experienced some issues wherein phase products (VEL, WIDTH, TRIP_FLA, NCP), would have missing data sectors. The issue tends to affect the Low frequency more, but can affect both. This typically occurs near the beginning of each IOP as the frequency is tuned manually. It also occurred when the transmit frequency drifted from its nominal value prior to operator adjustments.

During PERiLS 2022 the high frequency COW1 radar data suffered from some minor interference, inferred to originate with nearby cellular network transmitters. This created some radial sectors of unreliable data in power, reflectivity, WIDTH, PHIDP, RHOHV, SNRHC, SNRVC, and ZDR fields. The low frequency COW1 radar data contain less interference but were still affected. This interference has not been removed from the dataset.

A solar scan calibration prior to the PERiLS project identified a +0.6 degree elevation angle offset, meaning raw elevation angles recorded in the radar data were 0.6 degrees higher than the actual pointing angle of the antenna. This elevation offset has been corrected in the final COW1 quality-controlled radar dataset.

4.7.2 Notes on Equivalent Radar Reflectivity and Differential Reflectivity Measurements

Radar Reflectivity (DBZHCC):

Assumed Accuracy: ± 1 dB

Differential Reflectivity (ZDRC):

Assumed Accuracy: ± 0.2 dB

The Two Watches Problem:

When examining the reflectivity or differential reflectivity fields from just one calibrated radar, one is tempted to assume these measurements, if appearing reasonable, are correct. Once more measurements from additional radars are available, differences due to the limits of calibration accuracy, scattering effects/assumptions, and observing geometry become apparent.

Among the three X-band DOW systems, there are four different X-band operating frequencies. The dual-pol, dual-frequency DOW7 radar provides contemporaneous, independent radar measurements at two different frequencies, separated by 150 MHz. Fields from the same radar platform will not be identical. Differences in the reflectivity and differential reflectivity fields between the multiple operating frequencies may be attributed to scattering effects, system efforts, or random variation. At higher reflectivity values, non-Rayleigh scattering is more likely than for longer wavelength radars, and, in clear air, irregular large scatterers (e.g., bugs) also violate the Rayleigh scattering assumption. Between radar platforms, differences in radar volume geometry, beam filling, intervening precipitation, etc. also contribute to differences in the moments calculations. Additionally, resonance effects may occur for certain hydrometeor sizes.

Similar to the dual-pol, dual-frequency X-band DOW7, the dual-pol, dual-frequency COW1 radar operates at two different independent C-band frequencies, separated by 150 MHz. Although less impacted by non-Rayleigh scattering and attenuation, resonance effects are more pronounced for certain hydrometeor sizes.

If reflectivity and differential reflectivity fields are associated with the maximum assumed error, and of opposite sign, reflectivity fields can be 2 dB different from one another and differential reflectivity fields can be 0.4 dB different from one another.

5 Ancillary Data

Logs

Digital copies of the deployment logs are provided in IOP → Vehicle → logs. Deployment logs contain a variety of metadata recorded by the vehicle crew, including the date, names of crew, data collection start and stop times, radar receiver configurations used, radar scan strategies used, and 30-minute radar transmitter frequency logs. Radar operators were asked to keep a 30-minute log of weather observations as well. These are appended to the 30-minute transmitter log. SCOUT vehicle logs contain POD and Disdrometer deployment information and transect start/stop locations and times. SONDE vehicle logs contain sounding deployment information, including failed launches and issues encountered while attempting launches.

The deployment logs are provided as-is, as recorded by operators and may contain errors and unverified information. At times, the data manager in the field corrected known erroneous values/notes soon after an IOP. Regardless, in all cases the README should be regarded as the definitive source for information regarding the deployment.

Inclinometer

FARM radars measure the tilt of their antenna pedestal using inclinometer devices along four points (front, rear, left, right). The raw inclinometer measurements have been provided in IOP → Vehicle → inclinometer as text files. These measurements have also been plotted for visual reference. These plots are provided in the “inclinometer” sub-folder as well. Typically radar operators keep the radars level throughout the IOP, adjusting only when an inclinometer measurement reaches or exceeds 2 tenths of a degree. Inclinometer data are used to detect time periods when the radar was out of level and thus may require corrections to elevation angles. Refer to the README documents for more information.

Media

Photographs and videos taken by crew members of each vehicle/team have been provided in IOP → Vehicle → media. This includes a) site photos that can be used to verify vehicle headings, nearby blockage targets, and surface conditions, b) photos of handheld GPS screens with deployment location information for PODs, disdrometers, and vehicles, and c) bubble level pictures used to verify radar vehicles are level. Additional instrument, computer screen, or weather photos may be included.

6 Soundings

The FARM PERiLS 2022 sounding dataset has undergone an extensive multi-level quality control by FARM staff prior to delivery. The steps undertaken during this process, as well as a description of the provided dataset are detailed here. The dataset is available in the IOP → Vehicle/Team → soundings directory tree of the FARM PERiLS 2022 non-radar dataset. From there, the data is separated by quality control level. In this way, the final choice of quality control level is given to the user. README documents specifically for sounding data are provided due to the extensive procedures involved in radiosonde launch and product quality control. These READMEs document issues and information on individual launches as well as notes concerning the quality control. They should be reviewed before an analysis is undertaken on the dataset.

6.1 Radiosonde Instrumentation

A total of 108 radiosondes were successfully launched by the FARM facility during the PERiLS 2022 field data collection period.

GRAW type DFM-09 radiosondes were used throughout the project, attached to Kaymont 150 gram balloons. The sondes measure temperature and humidity directly. Wind speed and direction are calculated from GPS measurements. An initial surface pressure value entered by the user is used to fit a pressure function to the sounding data because the DFM-09 sondes do not directly measure pressure.

GRAW type GS-U groundstation receivers attached to laptops with GRAWMET software installed were used to collect data. GRAW radiosondes and groundstations transmit/receive data using UHF frequencies between 400-406 MHz. GRAWMET version 5.14.10.3 was used on Windows 10 field laptops throughout the project.

Radiosondes were launched from mobile deployment sites within the IOP domain by five mobile sounding teams. Soundings often were launched at regular intervals, typically one hour, but this interval occasionally was shortened to 30 minutes near the leading edge of or immediately following the passage of a convective line. Balloons carrying the sounding package were filled with enough Helium to target ascent rates of ~ 5 m/s.

Initial surface conditions were entered manually prior to launch. Temperature and relative humidity were obtained either from the radiosonde itself or from a handheld Kestrel 5500 Weather Meter; pressure and wind speed/direction were obtained using the handheld Kestrel 5500 Weather Meter; launch latitude, longitude, and altitude were entered using a handheld Garmin GPS unit.

Throughout the sounding ascent, the raw sensor and GPS data table is monitored in the GRAWMET software to ensure good data is being received from the radiosonde. Once a balloon burst is detected (GPS altitude decreasing rapidly) or communication with the sonde is lost for a time period longer than 5 minutes, the sounding is manually terminated in the GRAWMET software.

6.2 Quality Control Overview

The sounding dataset provided with this release has undergone an extensive quality control process. The steps outlined here roughly follow those laid out in Ciesielski et al. (2012) with a few modifications. The process is divided into three levels, as shown in Figure 8 below.

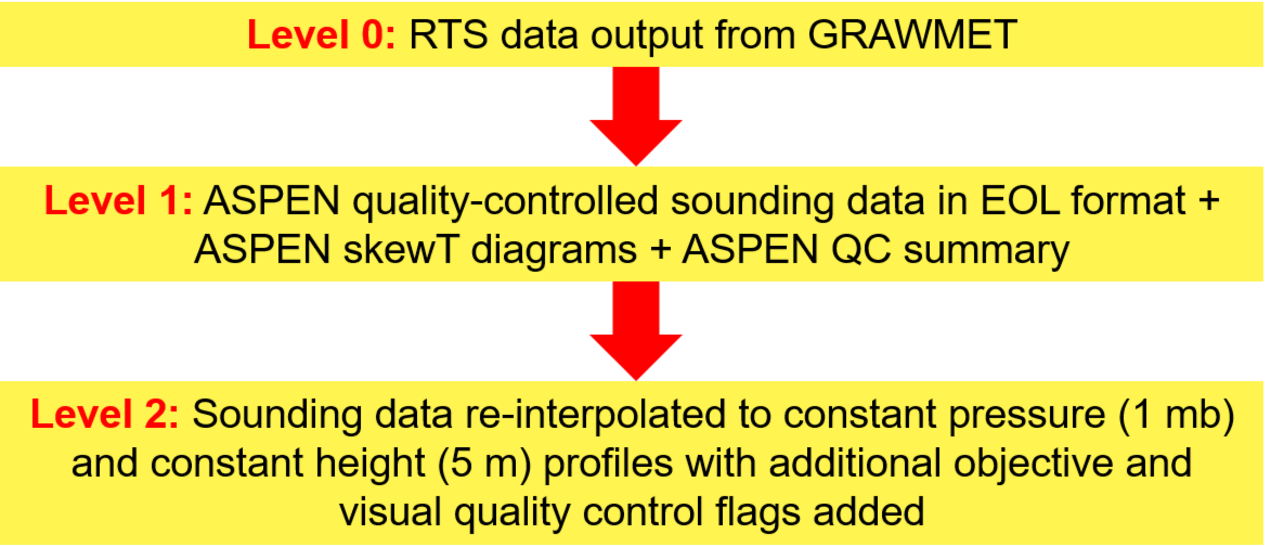


Figure 8: Sounding quality control flow diagram documenting the three main processing levels.

LEVEL 0: The RTS file is produced by GRAWMET and exported by the user. For a formal description of the file, please refer to Section 6.3. GRAWMET begins by removing outliers and empty records from the time series dataset and then interpolates to a uniform time series (1 second resolution). For large data gaps, GRAWMET interpolates across the gap regardless of its size. Meteorological variables not directly measured (such as pressure, wind speed and wind direction) are calculated from the measured variables as the time series is processed. This includes fitting a pressure function to the data based on the user-input surface pressure and GPS altitude. A formal launch time in terms of elapsed time since radiosonde initialization is automatically detected by GRAWMET but may be adjusted slightly by the user. Time series data occurring prior to the launch time is omitted from the RTS file, and the elapsed time is reset to zero. Ground values of temperature, relative humidity, pressure, wind speed and direction input by the user at the time of radiosonde initialization are substituted in place of the measured values at launch time and scaled to their measured values within the first 1-2 minutes after launch.

The RTS file provided with this dataset was re-generated in the GRAWMET software from the raw time series records and updated ground values verified during the quality control phase following the project.

For each sounding, FARM staff adjusted the launch time manually. The record immediately prior to the first large positive change in GPS altitude in the time series data was taken as the time of launch. README files provided with the dataset include a record of the manually selected launch times.

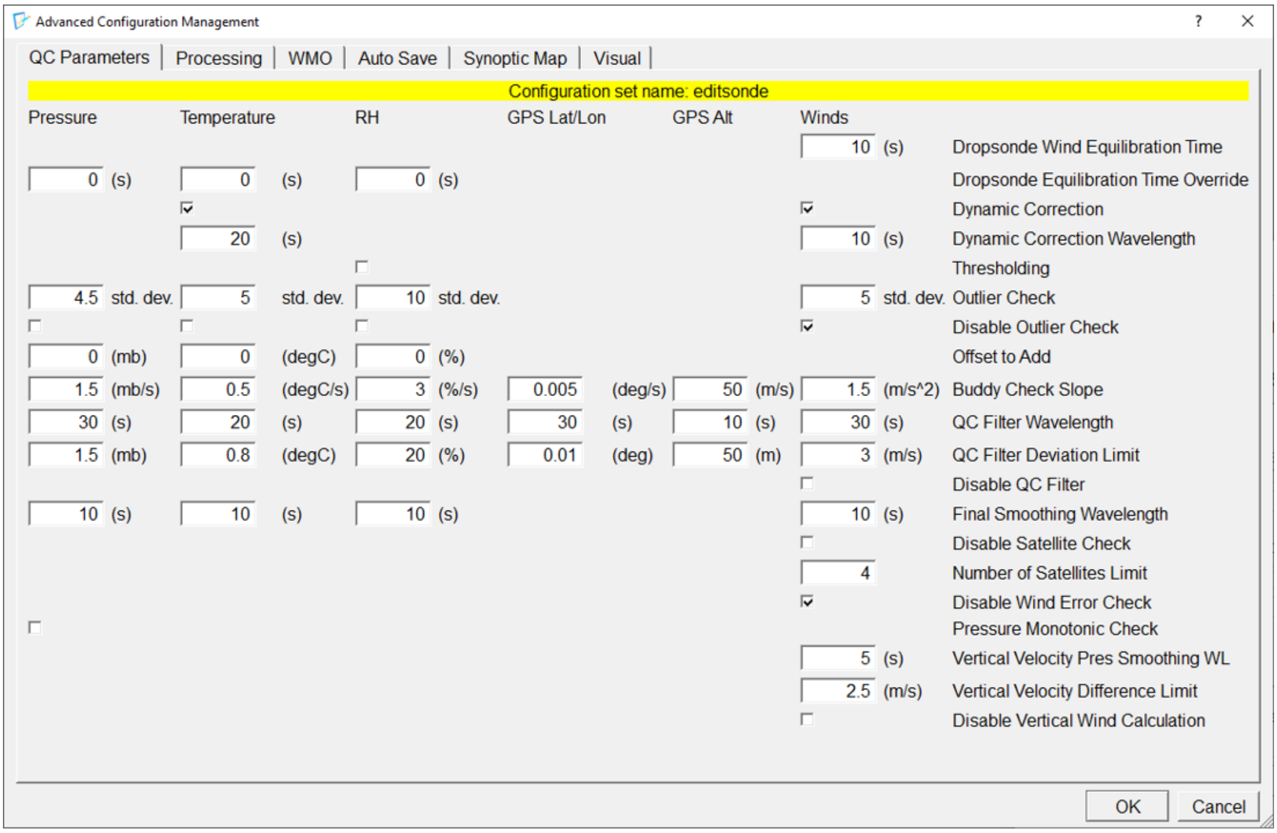
The original ground values of temperature, relative humidity, wind speed/direction, and pressure were also updated with verified values for each sounding by FARM staff. Ground values were verified with the FARM mesonet instrument array (mobile mesonets, DOWs, and PODs) and the closest ASOS weather station at the time of each launch. Initial values of latitude and longitude were also cross-checked with radiosonde measured GPS values at the time of launch and updated if necessary. Finally, launch altitude was verified with radiosonde measured GPS altitude at the time of launch as well as the USGS 1/3 arc-second 3DEP elevation point query service (https://ned.usgs.gov/epqs/).

LEVEL 1: Following the regeneration of the Level 0 RTS sounding data files with GRAWMET, the dataset was subjected to a rigorous set of quality control checks using the NCAR ASPEN (Atmospheric Sounding Processing Environment) software version 3.4.7. ASPEN is a collection of automated, systematic upsonde/dropsonde quality control algorithms built into a user-friendly software environment. A total of 23 separate quality control procedures are completed in a specific order. These include hard limit checks on individual variables, outlier removal, low pass filters, data smoothing, a monotonic pressure check, temperature dynamic adjustment, and a vertical velocity calculation. For a complete list of the quality control algorithms used, please see the ASPEN online documentation (Martin and Suhr 2021).

Prior to ASPEN processing, the raw Level 0 RTS data was first converted to CSV format using a custom Python script. The CSV file was then manually edited to remove descent data in cases where GRAWMET did not adequately detect balloon burst and radiosonde descent. The CSV data file also has erroneous/null data values re-formatted so that ASPEN can properly process missing data. Any manual edits to the CSV file are documented in the sounding README documents.

Following the RTS-to-CSV conversion and editing, each sounding was processed individually with ASPEN. Many of the quality control checks and procedures performed in ASPEN require that a number of user-defined parameters be set prior to dataset processing. Although any of these parameters may be changed by the user at will, we chose to use the default upsonde parameters recommended by ASPEN support for the entirety of the quality control process. A screenshot of the quality control parameters used to process the FARM PERiLS 2022 sounding dataset is shown in Figure 9.

At the conclusion of ASPEN processing, a tabulated summary of sounding quality control statistics is presented to the user. We have provided these summaries in PDF format, as well as the output EOL file that contains the quality-controlled sounding data. Additionally, a snapshot skewT diagram produced in ASPEN is also provided. These skewT diagrams are intended only as a snapshot, so the user may visualize the data at a glance. They are not intended to be published.



Configuration set name: editsonde

Pressure	Temperature	RH	GPS Lat/Lon	GPS Alt	Winds	
					10 (s)	Dropsonde Wind Equilibration Time
0 (s)	0 (s)	0 (s)				Dropsonde Equilibration Time Override
	☑				☑	Dynamic Correction
	20 (s)				10 (s)	Dynamic Correction Wavelength
		☐				Thresholding
4.5 std. dev.	5 std. dev.	10 std. dev.			5 std. dev.	Outlier Check
☐	☐	☐			☑	Disable Outlier Check
0 (mb)	0 (degC)	0 (%)				Offset to Add
1.5 (mb/s)	0.5 (degC/s)	3 (%/s)	0.005 (deg/s)	50 (m/s)	1.5 (m/s^2)	Buddy Check Slope
30 (s)	20 (s)	20 (s)	30 (s)	10 (s)	30 (s)	QC Filter Wavelength
1.5 (mb)	0.8 (degC)	20 (%)	0.01 (deg)	50 (m)	3 (m/s)	QC Filter Deviation Limit
					☐	Disable QC Filter
10 (s)	10 (s)	10 (s)			10 (s)	Final Smoothing Wavelength
					☐	Disable Satellite Check
					4	Number of Satellites Limit
					☑	Disable Wind Error Check
☐						Pressure Monotonic Check
					5 (s)	Vertical Velocity Pres Smoothing WL
					2.5 (m/s)	Vertical Velocity Difference Limit
					☐	Disable Vertical Wind Calculation

Figure 9: ASPEN quality control parameters for upsondes used to process the FARM PERiLS 2022 sounding dataset.

LEVEL 2: The next step in the quality control process is to generate a high-resolution interpolated dataset at uniform vertical levels. Two files are generated through this process, one interpolated at uniform 1 hPa pressure levels, and the other at uniform 5 meter geopotential height levels. Following the interpolation, a pair of additional objective quality control checks are performed on each of the major variables, and flags are assigned to the data. The procedure for the quality control checks follows the approach of Loehrer et al. (1996), utilized in Ciesielski et al. (2012). Quality control checks are performed for each record of pressure, height, temperature, dewpoint temperature, and winds. The meaning of the quality control flags assigned by these checks are given in Table 10.

The first of the two quality control tests is a gross limit check. For each record the standard deviation is calculated. Entries that are 4σ from the mean are omitted (assigned a value of -999) and the quality control flag for that value is set to 9. On a second pass, entries that are greater than 6σ from the mean are given a quality control flag of 4 for "objectively bad". Entries that are 3σ-6σ from the mean are given a quality control flag of 2 for "objectively questionable".

The second of the quality control tests are three vertical consistency checks. Hydrostatic checks ensure that as pressure decreases, height increases and vice versa. Records that fail to meet this criterion are given a flag of 4 for "objectively bad". A second check tests for unnaturally strong adiabatic layers. If the change in temperature with height is greater than -30°/km between one level and the next, a flag of 4 is assigned. If the change in temperature with height is between -30°/km and -15°/km between one level and the next, a flag of 2 is assigned. Finally, the surface dewpoint gradient is measured. If the change between the dewpoint at the surface and the next level is greater than 6°, a flag of 4 is assigned. If the change is between 3° and 6°, a flag of 2 is assigned.

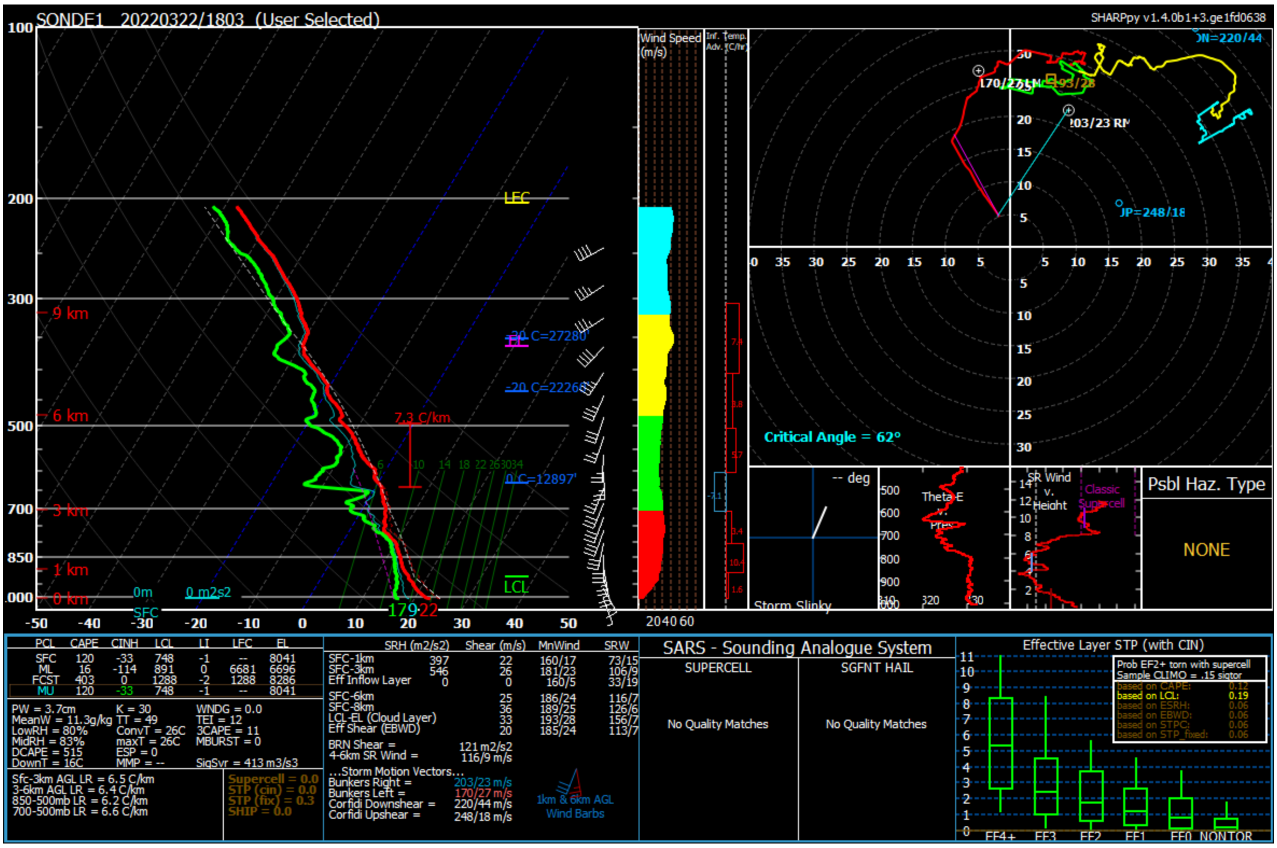
Table 10: Level 2 quality control flags and their description.

Flag	Description
1	good
2	objectively questionable
3	visibly questionable
4	objectively bad
5	visibly bad
6	interpolated
7	estimated
8	unchecked
9	omitted/missing

The final step in the quality control process is a visual perusal of the dataset. The flags 3 and 5 (for "visually questionable" and "visually bad") are added here. Where issues are found, they are noted in the README and flags are added to the appropriate column. The sounding is reprocessed if the issue can be resolved. Notably, if a large data gap resulted in a long interpolation at level 0, a flag of 3 is assigned. Typically, during these periods, GPS altitude is not interpolated across the gap by GRAWMET and is instead left empty.

For the FARM PERiLS 2022 sounding dataset, the final level 2 quality-control flagged sounding data was converted to SPC format with objectively and visually bad (flagged 4 and 5) data removed. This format is easily ingested into the SHARPpy sounding visualization software. SHARPpy plots of SPC sounding data were then generated using SHARPpy version 1.4.0b1. These plots are provided in the Level 2 dataset and include calculations of standard sounding parameters. See Figure 10 for an example SHARPpy plot. More information on the SHARPpy processing can be found online:

http://sharp.weather.ou.edu/dev/



PCL	CAPE	CINH	LCL	LI	LFC	EL
SFC	120	-33	748	-1	--	8041
ML	16	-114	891	0	6681	6696
FCST	403	0	1288	-2	1288	8286
MU	120	-33	748	-1	--	8041

PW = 3.7cm
MeanW = 11.3g/kg
LowRH = 80%
MidRH = 83%
DCAPE = 515
DownT = 16C
K = 30
TT = 49
ConvT = 26C
maxT = 26C
ESP = 0
MMP = --
WNDG = 0.0
TEI = 12
3CAPE = 11
MBURST = 0
SigSvr = 413 m3/s3

Sfc-3km AGL LR = 6.5 C/km
3-6km AGL LR = 6.4 C/km
850-500mb LR = 6.2 C/km
700-500mb LR = 6.6 C/km

Supercell = 0.0
STP (cin) = 0.0
STP (fix) = 0.3
SHIP = 0.0

	SRH (m2/s2)	Shear (m/s)	MnWind	SRW
SFC-1km	397	22	160/17	73/15
SFC-3km	546	26	181/23	106/9
Eff Inflow Layer	0	0	160/5	33/19
SFC-6km		25	186/24	116/7
SFC-8km		36	189/25	126/6
LCL-EL (Cloud Layer)		33	193/28	156/7
Eff Shear (EBWD)		20	185/24	113/7

BRN Shear = 121 m2/s2
4-6km SR Wind = 116/9 m/s

...Storm Motion Vectors...
Bunkers Right = 203/23 m/s
Bunkers Left = 170/27 m/s
Corfidi Downshear = 220/44 m/s
Corfidi Upshear = 248/18 m/s

SARS - Sounding Analogue System

SUPERCELL	SGFNT HAIL
No Quality Matches	No Quality Matches

Prob EF2+ torn with supercell
Sample CLIMO = .15 sigtor

based on CAPE:	0.12
based on LCL:	0.19
based on ESRH:	0.06
based on EBWD:	0.06
based on STPC:	0.06
based on STP_fixed:	0.06

Figure 10: A SHARPpy plot of Level 2 quality-controlled sounding data from the SONDE1 vehicle launched at 18:03:37 UTC on 22 March 2022 during PERiLS IOP01.

6.3 Description of the Dataset

Here we list the detailed formatting and data descriptions for each of the data files provided at each quality-control processing level.

LEVEL 0:	RTS raw sounding data file from GRAWMET
Extension:	*.txt
File type:	Tab-separated Text
Header lines:	1

Table 11: RTS data file parameter descriptions.

Column	Variable	Units
1	Elapsed Time	seconds
2	Pressure	millibar
3	Temperature	Celsius
4	Relative Humidity	%
5	Geopotential Height	meters
6	Dewpoint Temperature	Celsius
7	Refractivity Index	unitless
8	Gradient Refractivity Index (unused)	unitless
9	Modified Refractivity Index	unitless
10	Speed of Sound	m/s
11	Air Density	g/m^3
12	Vapor Pressure	millibar
13	Potential Temperature	Celsius
14	Virtual Temperature	Celsius
15	Specific Humidity	g/kg
16	UTC Time	seconds since start of day
17	Wind Speed	m/s
18	Wind Direction	degrees from North
22	Longitude	degrees East
23	Latitude	degrees North
24	Geometric (GPS) Height	meters

LEVEL 1:	Quality-controlled EOL output sounding data file from ASPEN, skewT plot, and a quality-control summary document
Extension:	*.eol, *.png, *.pdf
File type:	Tab-separated Text, PNG image, PDF document
Header lines:	14, N/A, N/A

Table 12: EOL data file parameter descriptions.

Column	Variable	Units
1	Elapsed Time	seconds
2	UTC Hours	hours
3	UTC Minute	minutes
4	UTC Second	seconds
5	Pressure	millibar
6	Temperature	Celsius
7	Dewpoint Temperature	Celsius
8	Relative Humidity	%
9	Wind U-component	m/s
10	Wind V-component	m/s
11	Wind Speed	m/s
12	Wind Direction	degrees from North
13	Ascent Rate	m/s
14	Geopotential Height	meters
15	Longitude	degrees East
16	Latitude	degrees North
17	GPS Height (unused)	meters

LEVEL 2: Height(Hgt)/Pressure(Prs)-interpolated sounding data files, SPC data files, SHARPpy plot

Extension: none, *.txt, *.png

File type: Tab-separated Text, Comma-separated Text, PNG image

Header lines: 4, 6, N/A

Table 13: Level 2 Hgt/Prs data file parameter description.

Column	Variable	Units
1	Pressure	millibar
2	Geopotential Height	meters
3	Temperature	Celsius
4	Dewpoint Temperature	Celsius
5	Wind Direction	degrees from North
6	Wind Speed	m/s
7	QC Flag – Pressure	unitless (Table 10)
8	QC Flag – Geopotential Height	unitless (Table 10
9	QC Flag – Temperature	unitless (Table 10)
10	QC Flag – Dewpoint	unitless (Table 10)
11	QC Flag – Winds	unitless (Table 10)
12	Longitude	degrees East
13	Latitude	degrees North

Table 14: Level 2 SPC data file parameter description.

Column	Variable	Units
1	Pressure	millibar
2	Geopotential Height	meters
3	Temperature	Celsius
4	Dewpoint Temperature	Celsius
5	Wind Direction	degrees from North
6	Wind Speed	m/s

7 Vehicle Weather Instruments

Each vehicle in the FARM fleet (with the current exception of COW1) is equipped with a comprehensive suite of meteorological instrumentation for in situ data collection. Weather instrument arrays are mounted to pneumatically raisable masts on each of the three DOW radars and to rigid masts on each of three "Mobile Mesonets," also called "SCOUT" vehicles.

For vehicle mast-mounted weather instrumentation arrays specifically, the dataset is available in the IOP → Vehicle/Team → mesonet directory tree, which is discussed here. This dataset has undergone extensive quality control by FARM staff prior to delivery. The steps undertaken during this process, as well as a description of the provided dataset are detailed here.

7.1 Deployment Procedures and Instrumentation

Instruments are mounted to masts attached to each vehicle in the FARM fleet (with the current exception of COW1). On the DOWs, the mast is fully extendable to 17 meters, and can be lowered or raised at will. As part of standard procedure, the mast is fully raised for each DOW deployment, though for safety, the mast is lowered when lightning is observed nearby. For SCOUTs, instruments are affixed to a cross-braced metal pole attached at the front end of the vehicle. The instrument package is elevated 4 meters from the ground atop the mast and cannot be lowered or raised. Figure 11 shows an example of a DOW mast fully extended and a SCOUT rigid mast. Table 15 summarizes the instruments used and their measurements.

Figure 11: (left) DOW6 with its pneumatic mast fully extended and (right) SCOUT1 with its rigid mast. Mesonet instrumentation are mounted on the tops of each mast.

Table 15: DOW & Mobile mesonet in situ measurements and associated instrument specifications.

Measurement	Model Number	Sampling Frequency	Location
Temperature & Relative Humidity	Rotronic HC2A-S3	1 Hz (up to 10 Hz)	Mast
Pressure	Vaisala PTB110	1 Hz	Vehicle Cabin
Wind Speed & Direction	R.M. Young 05103 Wind Monitor	1 Hz	Mast
GPS	Garmin 16X-HVS	1 Hz	Vehicle Cabin

At the very top of each mast is mounted an RM Young Wind Monitor (model #05103) anemometer. These instruments are typically mounted to the mast with an offset from forward-facing due to a wind direction data collection hole from 350-0 degrees anemometer-relative. A common issue due to the necessity of wiring past the rotation bearing, wind directions within this range are recorded as either 350 or 0 degrees. By offsetting the device from vehicle-forward, wind direction data is accurately corrected when the vehicle is in motion and the blade is mostly pointed toward the forward end of the vehicle. The anemometer offset is not accounted for in the raw product, but is accounted for in the quality-controlled product. Please note that for DOWs, when the mast is lowered the pattern of wind turbulence around the dish (especially when it's spinning) can interfere with measurements.

Rotronic temperature/relative humidity sensors (model #HC2A-S3) are housed in rear-ventilated J-tubes on DOWs, and aspirated U-tubes on SCOUTs. Please note that for DOWs, when the mast is lowered and the generator is running, heat from exhaust may interfere with measurements.

Pressure and GPS measurements are collected from each vehicle's interior cabin rather than being exposed to the harsh atmospheric elements on the mast. Vaisala PTB110 pressure sensors (model #CS106) are mounted on a wooden wall panel inside the operator cabin in DOWs and under the rear seat in SCOUTs. Garmin GPS devices (model #GPS16X-HVS) are mounted on the front dashboard of each vehicle. Campbell Scientific CR1000 Dataloggers mounted inside the vehicle cabins provide real-time 1-Hz monitoring and long-term data collection and storage for all instruments in the array.

For PERiLS 2022, SCOUTs conducted transects across features of interest. Operators do their best to maintain a constant speed during these transects. Wind components related to vehicle motion will later be removed from the direct wind observations during the transect to get the true wind. Transects were typically driven after deploying pods (see section 8).

For DOWs, data collection begins when the generator is turned on and ends when it is turned off. The vehicle is usually on-site by this point, so no mobile data is typically collected. Occasionally, DOWs may shift sites during a deployment in which case the generator is left on and mobile data during the move is retained in the dataset. All DOW deployments were stationary for PERiLS 2022.

7.2 Quality Control Overview

The dataset provided with this release has undergone an extensive quality control process. The dataset is divided into two levels; level 0 is the raw dataset collected from the datalogger trimmed to a vehicle's deployment time and level 1 is the quality-controlled product. A special folder for plots of the quality-controlled product is also provided.

LEVEL 0: The raw dataset from the datalogger trimmed to the time period of interest is provided here. In the case of the DOWs, the time period of interest was the times in which the radar was deployed and stationary. In the case of the SCOUTs, the time period of interest includes all data from the power on of the datalogger and instruments prior to departing for the IOP through when data was collected after the IOP deployment. Although not all of these SCOUT mesonet wind data are correctable to true wind measurements (vehicle heading not always available), the data have been retained to allow the user to decide what data is useful. Please be aware that after the datalogger and instruments are first turned on, up to a full minute is typically required for the GPS to acquire a satellite fix and correct the datalogger time, so for this period GPS and time values are not available (NAN) or unreliable. However, this startup period was frequently removed in the trimmed data files.

LEVEL 1: The quality-controlled mesonet product is provided here. The FARM facility provides these data as an Excel document, which is described below. Select data from the Excel document is also exported to a CSV text file with a modified header.

The Excel document is the primary file for the quality control. It contains the true wind in 1-sec, 3-sec, and 1-minute values, as well as plots of the data. The source dataset for the Excel document is the level 0 text file. It was first imported into columns A-S on the first sheet. Wind speeds/direction from the anemometer in the source dataset are raw observations and do not contain any heading offset or anemometer corrections, or any corrections related to vehicle motion. The remaining columns are mostly dedicated to obtaining the true wind speeds/directions, where "true" is defined as the wind incident on the anemometer relative to a north-origin georeference.

Column U is a place to override the heading of the vehicle if known. For stationary deployments, GPS heading can become inaccurate if the vehicle does not move for an extended period of time, or is simply zeroed if the instrument is turned on while the vehicle is motionless. For DOWs, the heading of the vehicle was replaced for the entirety of the stationary deployment with the value obtained from the radar quality control. For SCOUTs, vehicle heading was only overridden when reliable notes or photos were available to document the heading of the vehicle while stationary. Otherwise, winds are only reliably correctable while moving.

The anemometer offset is defined as the value the anemometer would have if the blade was pointed straight ahead of the vehicle. This value was obtained before and after the project by physically pointing the blade forward and checking the reading. Additionally, driving data during the project was also analyzed to estimate the anemometer offset. While driving at fast speeds and along a route that returns to the original location (out and back), it is assumed that the anemometer will generally face directly forward (parallel with the vehicle motion). The anemometer offset can then be calculated by taking the median blade direction when vehicle speed exceeds a moderate speed (10-20 m/s).

A project-wide pressure offset value was determined for each mesonet instrument by intercomparing all mobile mesonet and pod pressure measurements when co-located in a pre-IOP location (typically a hotel parking lot). These offsets appear to be instrument-specific and stable over the entire project. These offsets are entered into cell AG1 of the

Excel spreadsheet. The offset-corrected pressures are then calculated in column AU.

7.3 Description of the Dataset

Raw (level 0) and quality-controlled (level 1) data are provided with this dataset. Plots of the data are also provided for reference to the user in the “plots” sub-folder. Available time series plots include temperature/relative humidity, pressure, and 1-second and 1-minute wind speed/direction. Here we list each of the files provided at each level and describe their contents.

LEVEL 0:	Raw data output from the datalogger trimmed to deployment time
Extension:	*.dat
File type:	Comma-separated Text
Header lines:	3

Table 16: Raw mobile mesonet data column descriptions.

Column	Variable	Units
1	UTC Date and Time String	“YYYY-MM-DD hh:mm:ss”
2	Record Number	num
3	Last Clock Sync	milliseconds
4	Number of Clock Syncs	num
5	Temperature	Celsius
6	Relative Humidity	%
7	Blade Wind Speed	m/s
8	Blade Wind Direction	degrees
9	Pressure	hPa
10	Latitude (degrees only)	degrees N
11	Latitude (minutes only)	minutes N
12	Longitude (degrees only)	degrees E
13	Longitude (minutes only)	minutes E
14	Altitude	meters MSL
15	GPS Speed	knots
16	GPS Heading	degrees
17	GPS Dilution of Precision	meters
18	GPS Fix Quality	num (0 = invalid, 1 = GPS, 2 = differential GPS, 6 = estimated)
19	GPS Number of Satellites	num

LEVEL 1:	Quality controlled products
Extensions:	*.xlsx, *.csv
File types:	Microsoft Excel document, Comma-separated Values Text File
Header lines:	5, 7
Notes:	Plots provided in Excel document, second sheet, and “plots” sub-directory

Table 17: Quality-controlled Excel document header input and data column descriptions.

Header Input Cell	**Description**
X1	Stationary threshold for vehicle speed (kt)
AB1	Blade anemometer offset (degrees)
AG1	Pressure offset (hPa)

Column(s)	**Description**
A – S	Level 0 raw data
U – V	Heading override (degrees relative to North)
W	Stationary flag (0 = no, 1 = yes)
X	Transect flag (0 = no, 1 = yes)
Z	True Wind Direction corrected for vehicle heading & anemometer offset (degrees from North)
AA	Vehicle speed (m/s)
AB – AC	U- and V-components of observed wind (m/s)
AD – AE	U- and V-components of vehicle motion (m/s)
AF – AG	U- and V-components of true wind (m/s)
AH – AI	Latitude and Longitude (decimal degrees)
AJ – AL	1-second true wind speed (m/s, kt) and direction (deg)
AM – AP	3-second centered average true wind speed (m/s) and direction (deg)
AQ – AT	1-minute centered average true wind speed (m/s) and direction (deg)
AU	Offset-corrected Pressure (hPa)

Table 18: Quality-controlled CSV data file header and data column descriptions.

Header Row	Description	Units
1	Platform (vehicle ID)	text
2	Project name	text
3	IOP number	text
4	Anemometer offset	degrees
5	Pressure offset	hPa
6	Column headers	text
7	Column units	text

Column	Description	Units
1	UTC Date and Time String	YYYY-MM-DD hh:mm:ss
2	Temperature	Celsius
3	Relative Humidity	%
4	Pressure	hPa
5	1-sec Blade Wind Speed (observed)	m/s
6	1-sec Blade Wind Direction (observed)	degrees
7	Latitude	decimal degrees
8	Longitude	decimal degrees
9	Platform Speed	m/s
10	Platform Heading	degrees from North
11	Stationary flag	0 = no, 1 = yes
12	Transect flag	0 = no, 1 = yes
13	1-sec Blade Wind Speed (true)	m/s
14	1-sec Blade Wind Direction (true)	degrees from North
15	3-sec Blade Wind Speed (true)	m/s
16	3-sec Blade Wind Direction (true)	degrees from North
17	1-min Blade Wind Speed (true)	m/s
18	1-min Blade Wind Direction (true)	degrees from North
19	Offset-corrected pressure	hPa

8 Pods

In addition to vehicle mast-mounted weather instrument arrays, the FARM facility operated 13 deployable weather stations called “pods” (Figure 12) for PERiLS 2022. Together with the vehicle mast-mounted instruments these comprise the FARM facility Mesonet, a quickly-deployable network of in situ weather instruments that measure temperature, relative humidity, pressure and wind speed/direction.

The pod dataset is available in the IOP → Vehicle/Team → pod directory tree. This dataset has undergone extensive quality control by FARM staff prior to delivery. The steps undertaken during this process, as well as a description of the provided dataset are detailed in this section. README documents for pod data are combined with disdrometers and are available for each vehicle/team. They contain both deployment notes and quality control issues identified after the project, and they should be reviewed before an analysis is undertaken on the dataset.

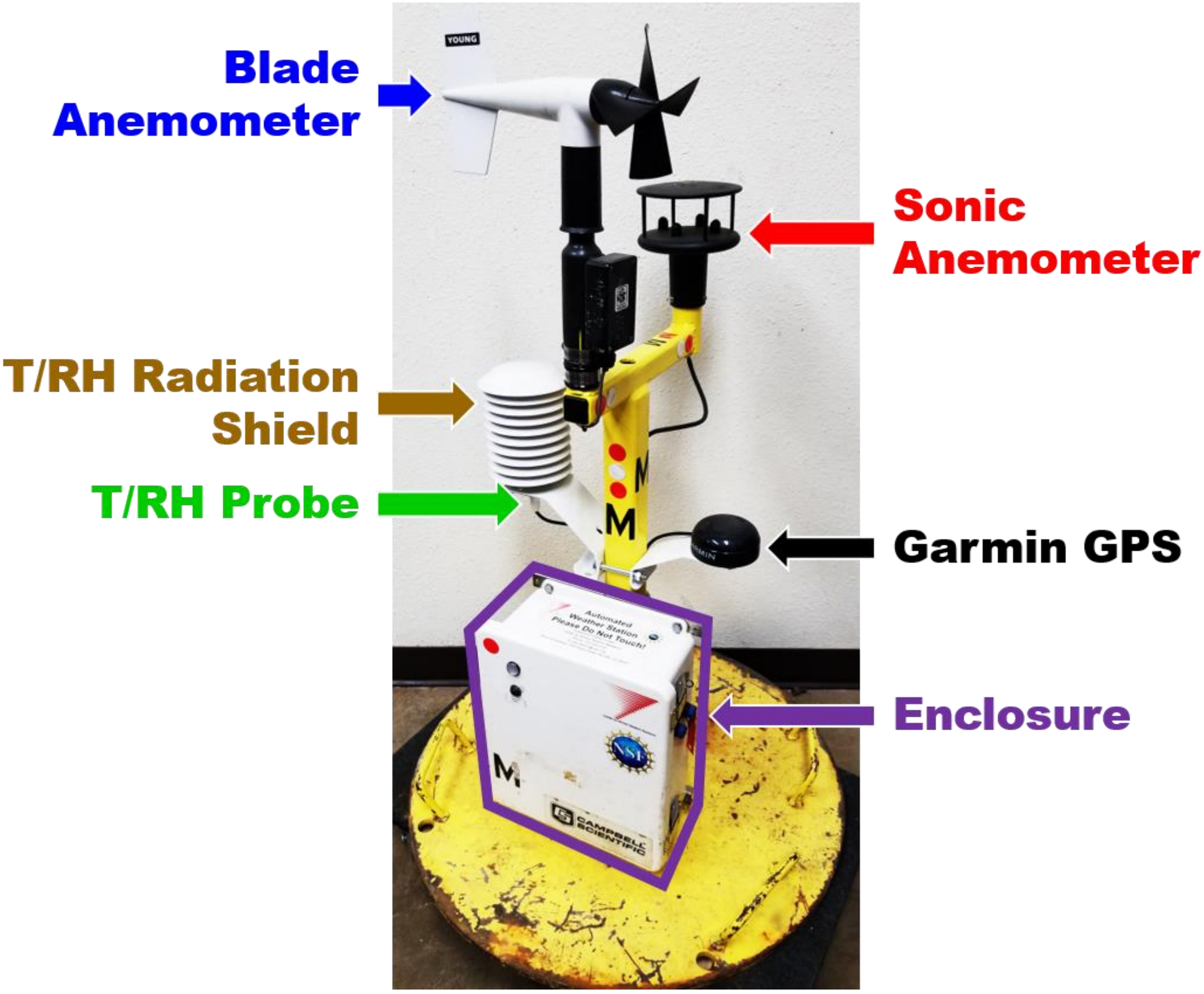


Figure 12: FARM quickly-deployable “pod” with weather instrumentation and components identified. A pressure sensor, battery, and datalogger is encompassed in the enclosure.

8.1 Deployment Procedures and Instrumentation

Originally designed for tornado intercepts, each pod is rugged, quickly-deployable and bottom-heavy, with a large array of weather instruments for ground level observations (Figure 12). The basic apparatus is a large, heavy steel disk at the bottom with a short, half-meter vertically-oriented pole welded at the center. The large disk lays flush with the ground to minimize lifting from high winds. Table 19 describes the instruments installed on each pod.

Table 19: Pod mesonet in situ measurements and associated instrument specifications.

Measurement	Model Number	Sampling Frequency	Height of Observation (AGL)
Temperature & Relative Humidity	Rotronic HC2A-S3 + R.M. Young 41003-5 10-Plate Solar Radiation Shield	1 Hz (up to 10 Hz)	24 - 26 in (0.61 - 0.66 m)
Pressure	Vaisala PTB110	1 Hz	12 in (0.30 m)
Wind Speed & Direction	R.M. Young 04101 Wind Monitor Jr (blade anemometer)	1 Hz	40 in (1.02 m)
	Gill WindSonic 75 (sonic anemometer)	1 Hz (up to 4 Hz)	34 in (0.86 m)
GPS	Garmin 16X-HVS	1 Hz	19 - 21 in (0.48 - 0.53 m)

Each FARM pod is equipped with both blade and sonic anemometers. Like vehicle mast-mounted blade anemometers, these devices also have an azimuth offset from forward-facing. For orienting pods, a North arrow on the cross-bar is used to align the anemometers to a forward-facing direction. When deployed, the heading of this North arrow is documented. The blade anemometer has a measurement dead zone from 350-0 degrees azimuth anemometer-relative, where wind directions within this range are recorded as either 350 or 0 degrees, but the sonic anemometer does not have this dead zone.

At the base of each FARM pod, a waterproof Campbell Scientific enclosure attached to the pole houses a pressure sensor, Campbell Scientific CR1000 datalogger, and a battery. Data from each instrument is collected by the datalogger every 1 second when power is applied from the battery.

A total of 13 pods were available for deployment during PERiLS 2022, which were divided across the three SCOUT mobile mesonet vehicles. Deployment locations for pods were decided by project PIs and disseminated to SCOUT crews at the start of each IOP. Typically deployments consisted of an equal 1-5 km spacing along a paved road. Deployment of pods at their respective locations was the first priority for SCOUT mobile mesonet teams before embarking on transects. Pods were retrieved by SCOUT teams after the IOP was complete. Pods would never be placed directly in the road, only on flat ground off to the sides. An attempt was made to make the pod as level as possible by using available rocks/sticks/dirt/sand at each site. Pods were placed in areas with as little blockage from trees, bushes, or buildings as possible, though some blockage was unavoidable. Teams would sometimes align the pod so that the North arrow on the cross-bar faced north using a compass (compass-aligned). Alternatively, the cross-bar was aligned parallel to the road (road-aligned). Team members verified pod deployment locations and orientations by taking pictures with nearby obstacles and roads visible in the background. Team members were asked to take pictures of their handheld GPS devices with the pod visible in the background to document accurate locations quickly.

8.2 Quality Control Overview

The pod dataset is divided into two levels; level 0 is the raw dataset collected from the datalogger trimmed to the deployment period, and level 1 is the quality-controlled product. A special folder for plots of the quality-controlled product is also provided. Pictures taken during the deployment are also available in the “media” folder.

LEVEL 0: The raw data format from the datalogger is provided here, except the data has been cropped to the time period of interest. For pods, the datalogger and instrumentation are powered on before the SCOUT vehicle leaves home base, so much of the data is of little use until the pod is removed from the vehicle and placed on the ground (aka deployed). Therefore, all of the data collected when the pod is in the vehicle was cropped from the level 0 dataset. This leaves only pod data for when the pod was stationary and deployed during the IOP.

LEVEL 1: The quality-controlled pod data product is provided here as an Excel document, which is described below, and a CSV file that is simply a text version of Excel document.

The Excel document is the primary file for the quality-controlled pod dataset. It contains the true wind in 1-sec, 3-sec, and 1-minute values, as well as plots of all the data. The source dataset for the Excel document is the level 0 text file. It was first imported into columns A-Y on the first sheet. Wind speeds/direction from either anemometer in the source dataset are raw observations and do not contain any heading offset or anemometer corrections. The remaining columns are mostly dedicated to obtaining the true wind speeds/directions, where “true” is defined as the wind incident on the anemometer relative a north-origin georeference.

Since pods are stationary throughout their deployment, the heading of the pod is described by a single scalar value rather than a changing value dependent on a vehicle motion. Pod headings are verified by FARM staff using pictures taken during deployments, deployment notes, and Google Earth. The value of both the heading and the blade anemometer offset is provided as a header value in the Excel spreadsheet. Please note that only the blade anemometer azimuth offset is provided, and that only the blade wind data is corrected here. The sonic anemometer azimuth offset may be provided upon request, but it typically is aligned with the pod north arrow on the cross-bar due to being mechanically fixed that way when designed (no rotating parts like the blade anemometer base). In some cases, the pod heading may not be verified due to lack of pictures, which creates low confidence. For these cases, please refer to the pod READMEs for each IOP deployment and team.

Anemometer offsets were obtained before, after, and during the project by physically pointing the blade parallel to the cross-bar and recording the reading. This allows both a comparison with the expected 90-degree azimuth and 270-degree azimuth. The difference between the observed azimuth and the expected azimuth is the offset magnitude. Measurements at the expected 90-degree azimuth or 270-degree azimuth are used due to the dead zone between 350 – 0 degrees azimuth for RM Young blade anemometers.

A project-wide pressure offset value was determined for each mesonet instrument by intercomparing all mobile mesonet and pod pressure measurements when co-located in a pre-IOP location (typically a hotel parking lot). These offsets appear to be instrument-specific and stable over the entire project. These offsets are entered into cell AF1 of the Excel spreadsheet. The offset-corrected pressures are then calculated in column AQ.

8.3 Description of the Dataset

Raw (level 0) and quality controlled (level 1) data is provided with this dataset. Plots of the data are also provided for reference to the user in the sub-folder named “plots.” These include temperature/relative humidity, pressure, and wind speed/direction time series plots in 1-second and 1-minute intervals. Pictures from pod deployments are provided in the “media” sub-folder. Here we list each of the files provided at each level and describe their contents.

LEVEL 0:	Raw data output from the datalogger, cropped to stationary deployment
Extension:	*.csv
File type:	Comma-separated Values Text
Header lines:	4

Table 20: Raw pod data file parameter description.

Column	Variable	Units
1	UTC Date and Time String	“YYYY-MM-DD hh:mm:ss”
2	Record Number	num
3	Battery Volts	volts
4	Last Clock Sync	milliseconds
5	Number of Clock Syncs	num
6	Temperature	Celsius
7	Relative Humidity	%
8	Blade Wind Speed	m/s
9	Blade Wind Direction	degrees
10	Sonic Wind Speed	m/s
11	Sonic Wind Direction	degrees
12	Pressure	hPa
13	Latitude (degrees only)	degrees N
14	Latitude (minutes only)	minutes N
15	Longitude (degrees only)	degrees E
16	Longitude (minutes only)	minutes E
17	Altitude	meters MSL
18	GPS Speed	knots
19	GPS Heading	degrees
20	GPS Magnetic Variation	degrees
21	GPS Fix Quality	num (0 = invalid, 1 = GPS, 2 = differential GPS, 6 = estimated)
22	GPS Number of Satellites	num
23	GPS PPS Time	microsecond
24	GPS Ready	num
25	GPS Dilution of Precision	meters

LEVEL 1:	Quality controlled products
Extensions:	*.xlsx, *.csv
File types:	Microsoft Excel document, Comma-separated Values
Header lines:	5, 8
Notes:	Plots provided in Excel document, second sheet

Table 21: Quality-controlled pod data Excel document parameter description.

Header Input Cell	Description
AC1	Blade anemometer offset (degrees)
AC2	Pod deployment heading (degrees from North)
AF1	Pressure offset (hPa)

Column(s)	Description
A – Y	Level 0 raw data
AA	True Wind Direction corrected for anemometer offset & pod heading (degrees from North)
AB – AC	U- and V-components of true wind (m/s)
AD – AE	Latitude and Longitude (decimal degrees)
AF – AH	1-second true wind speed (m/s, kt) and direction (deg)
AI – AL	3-second centered average true wind speed (m/s) and direction (deg)
AM – AP	1-minute centered average true wind speed (m/s) and direction (deg)
AQ	Offset-corrected Pressure (hPa)

Table 22: Quality-controlled pod CSV data file header and data column descriptions.

Header Row	Description	Units
1	Platform (pod letter)	text
2	Project name	text
3	IOP date and number	text
4	Anemometer offset	degrees
5	Pressure offset	hPa
6	Pod heading	degrees from North
7	Column headers	text
8	Column units	text

Column	Description	Units
1	UTC Date and Time String	YYYY-MM-DD hh:mm:ss
2	Temperature	Celsius
3	Relative Humidity	%
4	Pressure	hPa
5	1-sec Blade Wind Speed (observed)	m/s
6	1-sec Blade Wind Direction (observed)	degrees
7	1-sec Sonic Wind Speed (observed)	m/s
8	1-sec Sonic Wind Direction (observed)	degrees
9	Latitude	decimal degrees
10	Longitude	decimal degrees
11	1-sec Blade Wind Speed (true)	m/s
12	1-sec Blade Wind Direction (true)	degrees from North
13	3-sec Blade Wind Speed (true)	m/s
14	3-sec Blade Wind Direction (true)	degrees from North
15	1-min Blade Wind Speed (true)	m/s
16	1-min Blade Wind Direction (true)	degrees from North
17	Offset-corrected pressure	hPa

9 Disdrometers

The FARM PERiLS 2022 disdrometer dataset consists of 10-second temporal resolution hydrometeor size and fall velocity data and calculated integral rain parameters from three OTT Parsivel^2 laser-optical disdrometers. This section summarizes the disdrometer instrumentation, deployment procedures, and dataset format.

The disdrometer dataset is available in the IOP → Vehicle/Team → disdrometer directory tree. The dataset has undergone a conversion to a more easily-ingestible data format, but has otherwise not been extensively quality-controlled. README files for disdrometer data are combined with pod README documents for individual vehicles/teams. They contain both deployment and quality control notes, and should be reviewed before an analysis is undertaken on the dataset.

9.1 Disdrometer Deployment Procedures and Instrumentation

Three OTT Parsivel^2 laser-optical disdrometers were deployed during PERiLS 2022. These disdrometers were each mounted on custom metal bases similar to the pedestals used for pods (Figure 13). On each base was mounted a waterproof Pelican case containing a 12V battery and Windows laptop for data collection. A summary of the disdrometers used and their measurement heights is provided in Table 23.

Figure 13: A FARM Parsivel2 disdrometer instrument deployed in a grass field (left) and on a SCOUT truck bed showing the battery and laptop installed within the Pelican case (right).

The OTT Parsivel^2 disdrometer communicates directly with the Windows laptop via a COM port and the manufacturer-supplied ASDO software. Data measured by the disdrometer was polled every 10 seconds and written to an ATM4-formatted text file on the Windows laptop. More technical information about the OTT Parsivel^2 disdrometer and the software can be found on the OTT manufacturer website:

https://www.otthydromet.com/en/p-ott-parsivel-laser-present-weather-sensor/70.210.002.3.0

Table 23: FARM disdrometers used for PERiLS 2022.

Disdrometer Name	Manufacture Date	Firmware Version	Measurement Height (m AGL)
FARM_P2S02	2016	2.11.2	1.04
FARM_P2S03	2016	2.11.2	1.04
FARM_P2S04	2016	2.11.2	1.04

The FARM facility disdrometers were deployed during PERiLS 2022 by mobile mesonet (SCOUT) vehicle teams. Typically, disdrometers were co-located with pods, providing contemporaneous surface observations of state variables (temperature, relative humidity, pressure, and wind speed/direction). Similar to pods, two crew members lifted the disdrometer base and placed it on level ground away from the road. Crew members then connected the battery and enabled data recording on the laptop before carefully closing the Pelican case. The disdrometer deployment locations (latitude, longitude) and its co-located pod are provided in the pod README documents for each SCOUT vehicle.

9.2 Data Format

The OTT Parsivel^2 disdrometer measures the diameter and fall velocity of individual hydrometeors across 32 diameter (D_i) and 32 velocity bins (V_j). These diameter and velocity bin classes are detailed in Table 24 and Table 25, respectively. Note that diameter classes 1 and 2 are beyond the limits of the OTT Parsivel^2 measurement and will contain no particle counts in the raw particle count spectrum and are not used in calculating integral rain parameters (shaded red). Figure 14 shows the diameter and velocity bins as well as a zoomed-in view of the first 10 diameter and velocity bins with their respective indices as used in the disdrometer CSV dataset for reference.

The raw data computed by the OTT Parsivel^2 disdrometer is formatted as an ATM4 text file, which writes out the data every 10 seconds as a block of rows numbered 01: through 98: with each row containing one variable or array. However, because this format is difficult to process, FARM staff have re-formatted the raw disdrometer data into CSV formatted text files. This format is similar to the pod and vehicle weather instrument datasets in which each row of data represents one record in time with each variable separated by a comma, thus each column represents the same variable in each row of data.

The CSV data format is described in Table 26, which includes variable names, units, and data format (string, integer, floating-point number) for each comma-separated column. The data format for floating-point numbers also specifies the number of significant figures output by the Parsivel^2 disdrometer. Note that all data in this CSV-formatted dataset contains raw measurement values and calculated integral rain parameters directly from the OTT Parsivel^2 disdrometer unit. These data have not been re-processed in any way, only re-formatted to the CSV text file format. Also note that data after column 22 contains array data rather than scalar variables. The log of Spectral Number Density data consists of a 32-element vector that takes up columns 23 through 54. Similarly, mean particle velocity data consists of a 32-element vector that takes up columns 55 through 86. The raw particle count spectrum consists of a 32x32 element 2-dimensional array that takes up columns 87 through 1110. The raw particle count spectrum was split up to list each diameter bin count first, then index up one in the velocity bin and repeat.

Table 24: Parsivel^2 disdrometer diameter bin classes.

Class	**Min Diameter (mm)**	**Mid Diameter (mm)**	**Max Diameter (mm)**	**Bin Width (mm)**
1	0.0	0.0625	0.125	0.125
2	0.125	0.1875	0.25	0.125
3	0.25	0.3125	0.375	0.125
4	0.375	0.4375	0.5	0.125
5	0.5	0.5625	0.625	0.125
6	0.625	0.6875	0.75	0.125
7	0.75	0.8125	0.875	0.125
8	0.875	0.9375	1.0	0.125
9	1.0	1.0625	1.125	0.125
10	1.125	1.1875	1.25	0.125
11	1.25	1.375	1.5	0.25
12	1.5	1.625	1.75	0.25
13	1.75	1.875	2.0	0.25
14	2.0	2.125	2.25	0.25
15	2.25	2.375	2.5	0.25
16	2.5	2.75	3.0	0.5
17	3.0	3.25	3.5	0.5
18	3.5	3.75	4.0	0.5
19	4.0	4.25	4.5	0.5
20	4.5	4.75	5.0	0.5
21	5.0	5.5	6.0	1.0
22	6.0	6.5	7.0	1.0
23	7.0	7.5	8.0	1.0
24	8.0	8.5	9.0	1.0
25	9.0	9.5	10.0	1.0
26	10.0	11.0	12.0	2.0
27	12.0	13.0	14.0	2.0
28	14.0	15.0	16.0	2.0
29	16.0	17.0	18.0	2.0
30	18.0	19.0	20.0	2.0
31	20.0	21.5	23.0	3.0
32	23.0	24.5	26.0	3.0

Table 25: Parsivel^2 disdrometer velocity bin classes.

Class	Min Velocity (m/s)	Mid Velocity (m/s)	Max Velocity (m/s)	Bin Width (m/s)
1	0.0	0.05	0.1	0.1
2	0.1	0.15	0.2	0.1
3	0.2	0.25	0.3	0.1
4	0.3	0.35	0.4	0.1
5	0.4	0.45	0.5	0.1
6	0.5	0.55	0.6	0.1
7	0.6	0.65	0.7	0.1
8	0.7	0.75	0.8	0.1
9	0.8	0.85	0.9	0.1
10	0.9	0.95	1.0	0.1
11	1.0	1.1	1.2	0.2
12	1.2	1.3	1.4	0.2
13	1.4	1.5	1.6	0.2
14	1.6	1.7	1.8	0.2
15	1.8	1.9	2.0	0.2
16	2.0	2.2	2.4	0.4
17	2.4	2.6	2.8	0.4
18	2.8	3.0	3.2	0.4
19	3.2	3.4	3.6	0.4
20	3.6	3.8	4.0	0.4
21	4.0	4.4	4.8	0.8
22	4.8	5.2	5.6	0.8
23	5.6	6.0	6.4	0.8
24	6.4	6.8	7.2	0.8
25	7.2	7.6	8.0	0.8
26	8.0	8.8	9.6	1.6
27	9.6	10.4	11.2	1.6
28	11.2	12.0	12.8	1.6
29	12.8	13.6	14.4	1.6
30	14.4	15.2	16.0	1.6
31	16.0	17.6	19.2	3.2
32	19.2	20.8	22.4	3.2

Table 26: Disdrometer re-formatted CSV data file parameter description.

Column(s)	Variable	Unit	Format
1	Date + Time	"YYYY-MM-DD hh:mi:ss UTC"	string
2	Station Name	"FARM_P2S0x"	string
3	Station Number	"S0x"	string
4	Rain Rate	mm/h	float [0.000]
5	Rain Accumulation	mm	float [0.00]
6	Weather Code, SYNOP W_aW_a Table 4680	(see Table 4680)	integer [00]
7	Weather Code, SYNOP ww Table 4677	(see Table 4677)	integer 00]
8	Weather Code, METAR/SPECI w'w' Table 4678	(see Table 4678)	string
9	Weather Code, NWS	(see NWS Table)	string
10	Radar Reflectivity (Z)	dBZ	float [0.000]
11	MOR Visibility	meters	integer
12	Sample Interval (t)	seconds	integer
13	Laser Amplitude	unitless	integer
14	Total # of Detected Particles	count	integer
15	Temperature in Sensor	Celsius	integer
16	Sensor Serial Number	"xxxxxx"	string
17	Firmware IOP version	"x.xx.x"	string
18	Firmware DSP version	"x.xx.x"	string
19	Heating Current	Amps	float [0.00]
20	Power Supply Voltage	Volts	float [0.0]
21	Sensor Status	0 = OK 1 = Screen dirty, but measurements still possible 2 = Screen dirty, no usable measurements 3 = Laser damaged	integer
22	Kinetic Energy Flux (E_k)	$\mathrm{J/m^2h}$	float [0.000]
23-54	Log10 of Spectral # Density $\log_{10}(N(D_i))$	$\log_{10}\left(\frac{1}{m^3 mm}\right)$	float [0.000] $N(D_1), \ldots, N(D_{32})$
55-86	Mean Particle Velocity $\bar{V}(D_i)$	m/s	float [0.000] $\bar{V}(D_1), \ldots, \bar{V}(D_{32})$
87-1110	Raw Particle Count Spectrum $n(D_i, V_j)$	count	integer $n(D_1, V_1), \ldots, n(D_{32}, V_1),$ $n(D_1, V_2), \ldots, n(D_{32}, V_2), \ldots$

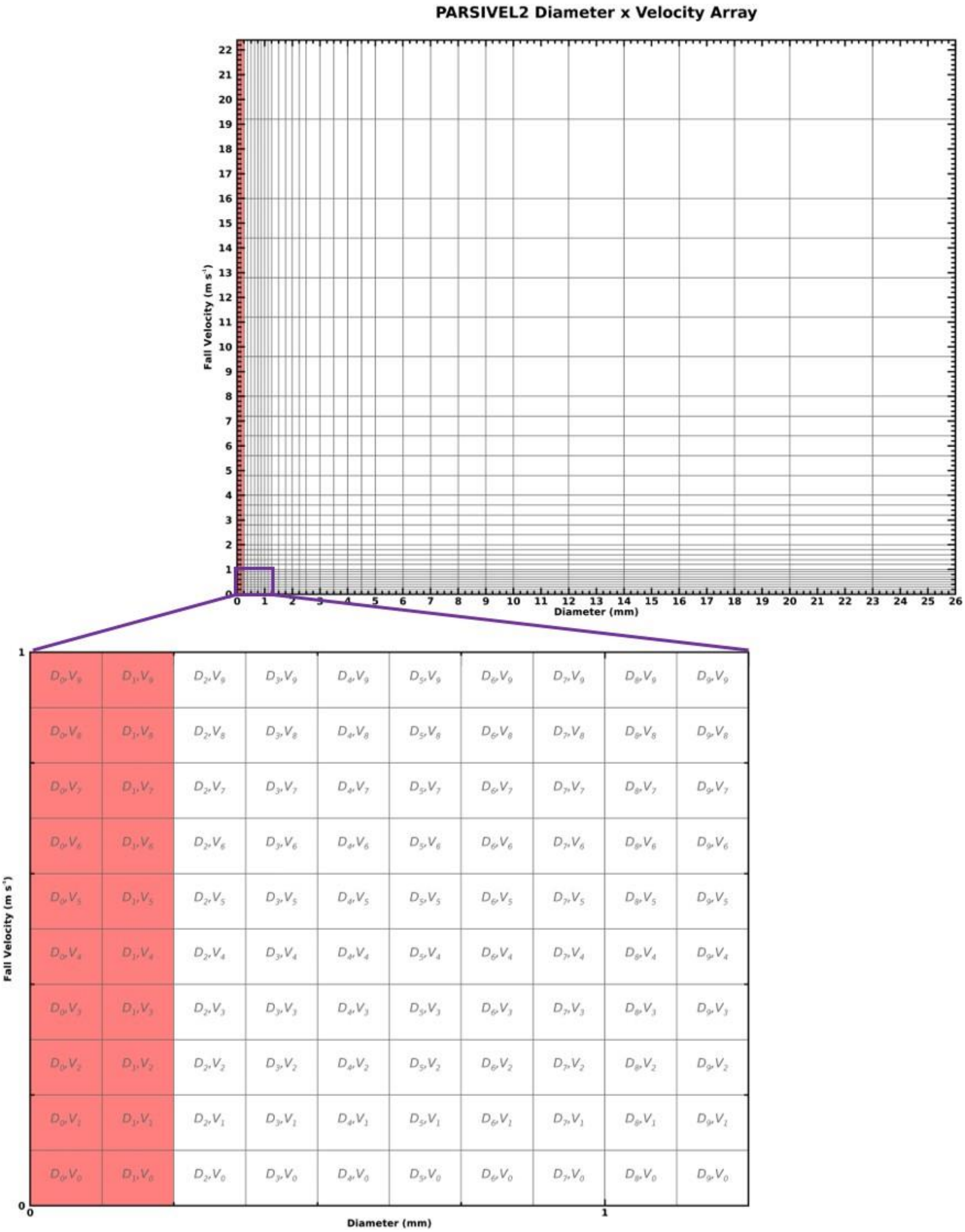


Figure 14: A plot of the Parsivel^2 diameter x velocity observational matrix with a zoomed- in view of the first 10 diameter and velocity bins with their respective diameter bin (D_i) and velocity bin (V_j) indices. The red shaded bins represent the first two diameter bins that are below the measurement limits of the Parsivel^2 and will contain no data.

Below are definitions of variables and formula for some variables calculated by the OTT Parsivel^2 disdrometer internal software (Kurt Nemeth, OTT Hydromet, 2014).

D_i = mean particle diameter (mm) of diameter class i

Δn_i = number of particles in diameter class i

ΔD_i = width of diameter class i (mm)

A = measurement area of Parsivel^2 laser sheet (m^2) = 180 mm × 30 mm = 0.054 m^2

t = measurement sample time interval (s)

c = number of diameter bin classes to integrate over (1-32)

$$Spectral\ Number\ Density = N(D_i) = \frac{\Delta n_i}{A \cdot t \cdot \bar{V}(D_i) \cdot \Delta D_i} \qquad [m^{-3} mm^{-1}] \quad (1)$$

$$Rain\ Rate = 0.0036 \cdot \frac{\pi}{6} \cdot \frac{1}{A \cdot t} \cdot \sum_{i=1}^{c} \Delta n_i \cdot D_i^3 \qquad [mm\ h^{-1}] \quad (2)$$

$$Equivalent\ Reflectivity = Z_e = \frac{1}{A \cdot t} \cdot \sum_{i=1}^{c} \frac{\Delta n_i \cdot D_i^6}{\bar{V}(D_i)} \qquad [mm^6 m^{-3}] \quad (3)$$

$$Radar\ Reflectivity = Z = 10 \cdot \log_{10}(Z_e) \qquad [dBZ] \quad (4)$$

$$Kinetic\ Energy\ Flux = E_k = 0.0003 \cdot \frac{\pi}{A \cdot t} \cdot \sum_{i=1}^{c} \Delta n_i \cdot \bar{V}^2(D_i) \cdot D_i^3 \qquad [Jm^{-2} h^{-1}] \quad (5)$$

The Parsivel^2 disdrometer classifies precipitation type and outputs these classifications based on four different precipitation coding definitions. These four classification system tables are 1) SYNOP $w_a w_a$ Table 4680, 2) SYNOP ww Table 4677, 3) NWS, and 4) METAR/SPECI w'w' Table 4678. These precipitation classification codes are broken down by precipitation type, intensity, and equivalent rain rate. Table 27 documents the precipitation classification codes for the two SYNOP tables and Table 28 documents the NWS and METAR/SPECI w'w' Table 4678 classification codes.

Table 27: Precipitation classification codes according to SYNOP tables.

Precipitation Type	**Intensity**	**Rain Rate (mm h^{-1})**	**SYNOP w_aw_a Table 4680**	**SYNOP ww Table 4677**
No Precipitation	---	---	00	00
Drizzle	Light	< 0.1	51	51
	Moderate	≥ 0.1, < 0.5	52	53
	Heavy	≥ 0.5	53	55
Drizzle with Rain	Light	< 2.5	57	58
	Moderate	≥ 2.5, < 10.0	58	59
	Heavy	≥ 10.0	58	59
Rain	Light	< 2.5	61	61
	Moderate	≥ 2.5, < 10.0	62	63
	Heavy	≥ 10.0	63	65
Rain, Drizzle, with Snow	Light	< 2.5	67	68
	Moderate	≥ 2.5, < 10.0	68	69
	Heavy	≥ 10.0	68	69
Snow	Light	< 1.0	71	71
	Moderate	≥ 1.0, < 4.0	72	73
	Heavy	≥ 4.0	73	75
Snow Grains	---	> 0	77	77
Soft Hail	Light	< 1.0	87	87
	Moderate/Heavy	≥ 1.0	88	88
Hail	Light	< 2.5	89	89
	Moderate/Heavy	≥ 2.5	89	90

Table 28: Precipitation classification codes according to NWS and METAR/SPECI w'w' Table 4678.

Precipitation Type	**Intensity**	**Rain Rate (mm h^{-1})**	**NWS**	**METAR/SPECI w'w' Table 4678**
No Precipitation	---	---	C	NP
Drizzle	Light	≤ 0.25	L-	-DZ
	Moderate	> 0.25, < 0.5	L	DZ
	Heavy	≥ 0.5	L+	+DZ
Drizzle with Rain	Light	≤ 2.5	RL-	-RADZ
	Moderate	> 2.5, < 7.6	RL	RADZ
	Heavy	≥ 7.6	RL+	+RADZ
Rain	Light	≤ 2.5	R-	-RA
	Moderate	> 2.5, < 7.6	R	RA
	Heavy	≥ 7.6	R+	+RA
Rain, Drizzle, with Snow	Light	≤ 2.5	RLS-	-RASN
	Moderate	> 2.5, < 7.6	RLS	RASN
	Heavy	≥ 7.6	RLS+	+RASN
Snow	Light	≤ 1.25	S-	-SN
	Moderate	> 1.25, < 2.5	S	SN
	Heavy	≥ 2.5	S+	+SN
Snow Grains	Light	≤ 1.25	SG	-SG
	Moderate	> 1.25, < 2.5	SG	SG
	Heavy	≥ 2.5	SG	+SG
Soft Hail	Light	≤ 1.25	SP	-GS
	Moderate	> 1.25, < 2.5	SP	GS
	Heavy	≥ 2.5	SP	+GS
Hail	---	> 0	A	GR

10 Questions or Comments

For any questions or comments regarding the quality of the dataset, or for any other inquiries, please email the Data Manager, Josh Aikins, at jaikins@illinois.edu, CCing Karen Kosiba (kakosiba@illinois.edu) and Josh Wurman (jwurman@illinois.edu).

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