FARM LEE Dataset
User Guide

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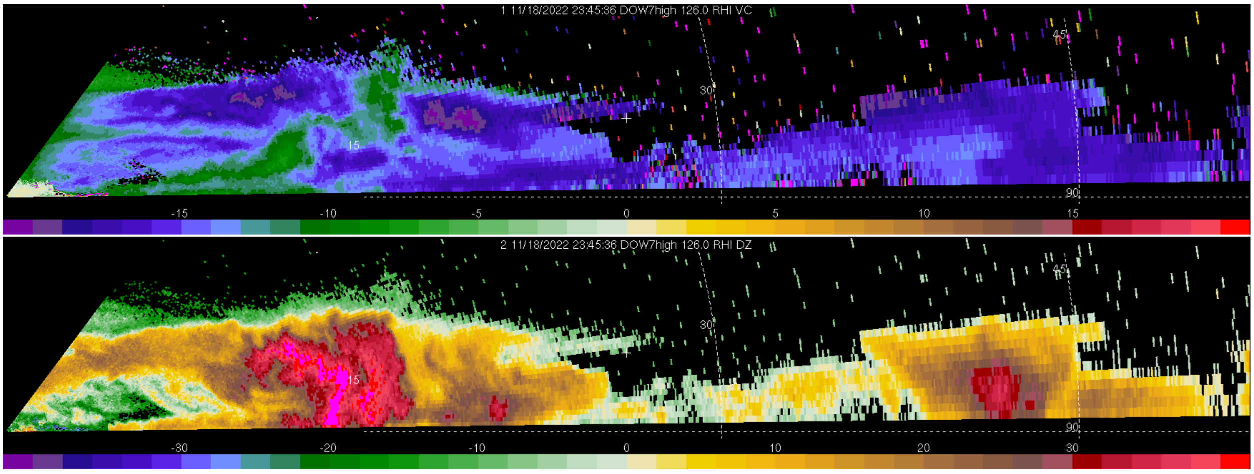

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1 Introduction

The dataset provided with this release is from the Doppler On Wheels (DOW) mobile radar (DOW7) deployed by the Flexible Array of Radars and Mesonets (FARM) facility during the Lake Effect Electrification (LEE) project that took place between November 2022 and February 2023. Table 1 provides a summary of each intensive observational period (IOP) during the LEE field data collection period. See the NCAR/EOL LEE Field Catalog for more information on IOP timing and mission type:

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

The purpose of this User Guide is to provide users a broad overview of the available data, including its organizational structure and the processes used during quality control. Section 2 describes the process for requesting LEE data from the FARM facility. Section 3 describes the organizational hierarchy of the data within the FTP top-level directory. Sections thereafter are organized according to each data type.

Table 1: Data availability by FARM radar for LEE IOPs. All times are UTC.

IOP	Date(s)	DOW7
1	13 November 2022	09:35 (11/13) – 15:58 (11/13)
2	18-19 November 2022	18:58 (11/18) – 16:31 (11/19)
3	20 November 2022	10:48 (11/20) – 22:35 (11/20)
4	17-18 December 2022	23:16 (12/17) – 15:03 (12/18)
5	19 December 2022	11:32 (12/19) – 17:31 (12/19)
6	24 January 2023	15:56 (01/24) – 21:31 (01/24)
7	27 January 2023	05:16 (01/27) – 07:21 (01/27)
8	28 January 2023	14:41 (01/28) – 17:21 (01/28)
9	31 January 2023	05:19 (01/31) – 10:01 (01/31)
10*	1-2 February 2023	10:54 (02/01) – 00:04 (02/02)
11	2-3 February 2023	22:10 (02/02) – 03:29 (02/03)

*Includes three separate deployments.

2 Requesting Data Access

The FARM LEE dataset consists of quality-controlled DOW7 radar data, as well as mast-mounted mesonet data.

The FARM LEE dataset is hosted on a publicly accessible FTP/SFTP server as part of the FARM permanent data archive. The dataset is accessible using the following DOI:

https://doi.org/10.48514/8NK8-NE59

Citation:

Wurman, J., & Kosiba, K. (2023). *LEE FARM DOW data* (Version 1) [Data set]. Flexible Array of Radars and Mesonets (FARM). https://doi.org/10.48514/8NK8-NE59

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

The dataset can also be accessed manually by SFTP as follows:

Preferred Protocol: SFTP (port 22)
Host: 96.78.13.107
Username: leepi
Password: e-mail for password

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

3 Data Organizational Hierarchy

The FARM LEE dataset is contained beneath the top-level directory “LEE_2022-2023_QC” at the FTP access point. From there, the data are organized into mesonet and radar datasets. Entering either the “mesonet” or “radar” sub-directory, you will see the dataset is further broken down into individual deployments, or intensive observational periods (IOPs), where date and IOP number are both provided. The naming convention is “YYYYMMDD_IOP##”, for example: “20221113_IOP01”. The next lower set of directories is organized according to vehicle. During LEE, this included only radar DOW7. Table 2 describes each of the possible sub-directories, 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, since DOW7 operated in dual-frequency mode during LEE (See Section 4).

README files for individual deployments are available within each vehicle directory for the radar dataset. These files contain detailed information relevant to each deployment, such as the scan strategy used, number of files, start and stop times of the data, navigational information such as latitude and longitude of deployment, altitude, and heading. Much of this information is also available in the contemporaneously created operator logs, but these operator logs may contain inaccurate information. The README is the primary source for verified information, including issues and errors regarding the dataset found during quality control.

Table 2: Organizational hierarchy of the LEE dataset.

Directory Tree		**Section**	**Notes**
radar → IOP → Vehicle →	dorade	4	*dorade files only*
radar → IOP → Vehicle →	cfradial_netcdf	4	*cfradial files only*
radar → IOP → Vehicle →	logs	5	
mesonet → IOP → Vehicle →		6	includes a “plots” sub-directory

4 Radars

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

https://github.com/NCAR/lrose-solo3

For LEE, the DOW7 radar has independent datasets 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 information is detailed in the READMEs. The final radar product is stored in “high” and “low” directories within the radar → IOP → Vehicle → dorade/cfradial_netcdf directory tree.

4.1 The FARM Mobile and Deployable 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 LEE can be found in Wurman et al. (2021).

4.2 LEE Configurations

During LEE, the radar transmit, processing, and antenna scan strategies were optimized to sample mixed/frozen hydrometeors within lake-effect bands. In general, a moderately long pulse length/PRF configuration with stagger was used to balance resolution and maximum range, and limit Doppler velocity folding. The same operating/processing configuration was used for the entire project. Table 3 details this operating/processing configuration used during LEE.

Table 3: LEE operating/processing radar configurations.

	DOW7
Pulse Length	500 ns
Gate Length	75 m
Number of Gates	781
PRF	1666.7 Hz / 2500 Hz
Stagger	2/3
Max Range	59 km
Nyquist Velocity	39.4 m/s (high) 40.1 m/s (low)
Mode	Fast-45
Beam Indexing	0.5° (SUR) 0.2° (RHI)

The LEE project scan strategy included the use of surveillance scans (azimuthally-rotating). These type of scans are indicated in the scan 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. Most analysis programs will use the azimuth and elevation angles of individual beams since individual beams, especially during scan transitions, may not be pointing at the fixed angle used in the naming convention.

Range-height indicator (RHI) scans are also provided as part of the FARM LEE dataset. These scans transect vertically at a user-set azimuth angle, alternating between upward-scanning (low elevation to high elevation) and downward-scanning (high elevation to low elevation) RHIs. For LEE, RHI sweeps generally cover 0° to 50° elevation angles.

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

The antenna scan strategy used for LEE included a mix of surveillance (SUR) scans and multiple vertical atmospheric slices (RHI scans) with moderate speed antenna rotation rates to capture lake-effect band mesoscale features within a ~5 minute temporal resolution. VER scans were programmed at the beginning of each scan cycle for ZDR calibration (see section 4.6). A single SUR scan elevation angle was chosen based on the deployment site to scan just above most beam blockage (trees, buildings, terrain). For some deployments during LEE, a special clutter scan strategy (Surv in Table 4) was used to identify which SUR elevation angle is least blocked and help with clutter target alignment (see section 4.5). RHI scans were programmed for azimuths that lined up approximately with the upwind and/or downwind sectors of the lake-effect band. When limited downwind band structure was available, sometimes cross-band RHI scans were performed, which were roughly aligned perpendicular to the lake-effect band axis. A list of possible antenna scan modes for the DOW7 radar is given below in Table 4.

For LEE, the DOW7 radar was not programmed with a set sync cycle. This means the radar did not stop and wait for a synced start time after running through its scan strategy. Instead, the radar simply just started the next scan strategy once finished with the previous one. This means scan strategies (or radar volumes) will not start exactly on each :00, :05, :10, etc. after the hour, like it would with a 5-minute sync period. For LEE, the DOW7 scan strategies took just under 5 minutes to complete and may change slightly with different target angles.

Table 4: LEE DOW7 antenna scan strategies.

Scan ID	**Rotation Rate**	**Sync**	**Elevation Angles**	**Azimuth Angles***
RHI-All-LEE + Combo-LEE	25 deg/s (SUR/VER) 7 deg/s (RHI)	none	89° VER (x2), 1.0° - 3.0° SUR (x2)	A-20°, A-10°, A, A+10°, B-20°, B-10°, B, B+10°, … RHI (x24)
RHI-1-LEE + Combo-LEE	25 deg/s (SUR/VER) 7 deg/s (RHI)	none	89° VER (x2), 1.0° - 3.0° SUR (x2)	A-20°, A-10°, A, A+10°, … RHI (x24)
Surv	20 deg/s (SUR)	none	0.5°, 0.5°, 1.0°, 1.5°, 2.0°, 2.5°, 3.0° SUR	no RHI

*RHI angles A and B were provided by the PIs each IOP and represent the target upwind and downwind azimuth angles of the lake-effect band. Multiple azimuth angles were programmed to bracket the target azimuths and account for uncertainty in radar headings.

4.3 Radar Variables

A listing and description of all possible radar variables provided in each DORADE/CfRadial file is given in Table 5. Some fields are appended with "_ F" to indicate their status as a clutter filtered product. Please see Section 4.4 for more details.

Table 5: Radar variables available in quality-controlled radar data for LEE.

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)
KDP	Specific differential phase (deg/km)
NCP	Normalized coherent power (unitless)
PHIDP	Differential phase shift (deg)
RHOHV	Correlation coefficient (unitless)
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 radar dataset have been chosen for additional clutter filtering. These fields (DBZHC, DBZVC, VEL) 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. A typical clutter-contaminated example is shown. The left panels show the unfiltered reflectivity and Doppler velocity products at a range of 0-9 km from DOW7 during LEE IOP02. The right panels show the filtered reflectivity and velocity products in the same scan. Note that while the filter removes the vast majority of ground clutter, small portions of clutter remain. It also tends to remove power (lower reflectivity) from occasional gates near the 0 m/s isodop, an unfortunate side effect of the notch removal and interpolation process. Furthermore, it cannot unfold velocities beyond the Nyquist limit. However, Figure 1 shows that the clutter filtered products are greatly improved both in clear air and precipitation regions close to the radar.

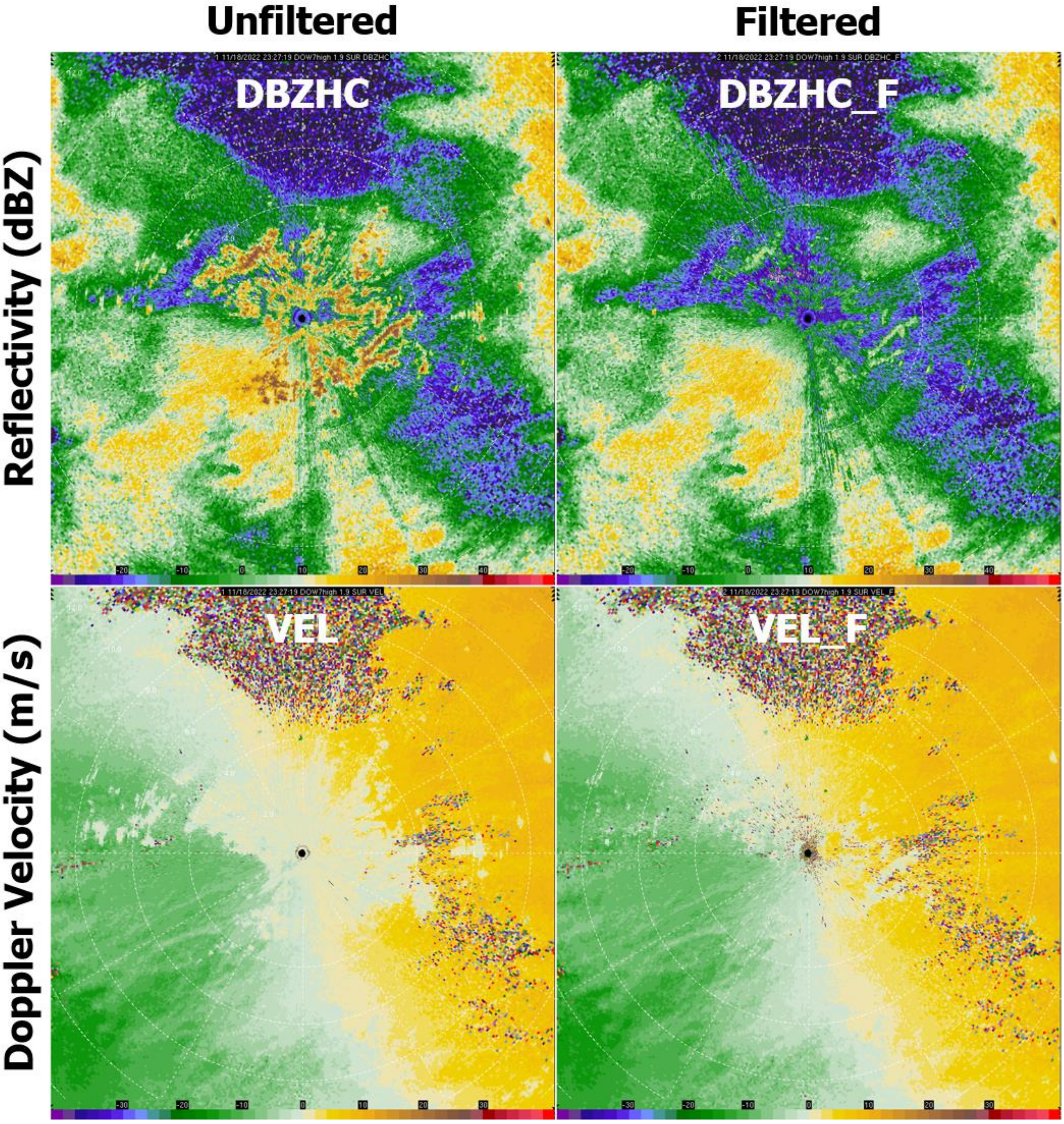

Figure 1: (Left) Unfiltered reflectivity and Doppler velocity products. (Right) Clutter filtered products. Data are from DOW7 high frequency during LEE IOP02.

4.5 Navigation/Geo-referencing

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 azimuth points true north. These adjustments are made in post-processing, during translation of the raw time series data into DORADE sweep files.

Latitude and longitude were initially collected and saved in the radar data using Spectracom GPS receivers installed in the vehicles themselves. Deployment site latitude and longitude values were typically recorded in the field logs using GPS observations from either the mast-mounted mesonet or a hand-held Garmin Mini GPS unit. These field values are then verified using Google Earth imagery and site photos taken by operators.

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 and are not adjusted for the antenna elevation above the ground (typically about 3 m for DOW7).

Solar scans (in which the antenna is made to point directly at the sun and the radar is not transmitting) were conducted at the beginning or end of each IOP, if possible. Several LEE IOPs occurred overnight and therefor did not allow for solar scans. 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.

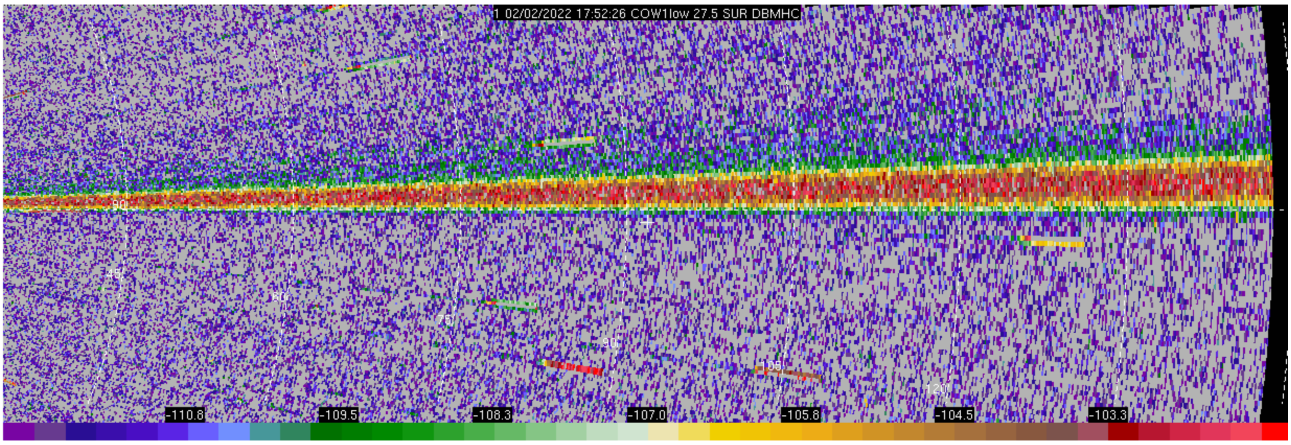

Figure 2: A solar spike observed in the horizontal power field (DBMHC) by a FARM DOW radar.

The headings obtained using solar scans were later 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 cluster of cell tower clutter targets during LEE. The center of each 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 shift over time. Targets that disappear later in an IOP are generally not used for the clutter target analysis. Clusters of discrete cell tower targets, like shown in Figure 3, add to the confidence that the target seen on Google Earth is in fact the target observed on radar. 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.

Generally, azimuths are navigated to within 0.2 degrees, which is << the beamwidth of the radars, and range is navigated to within 35 m, which is approximately half a radar range gate length.

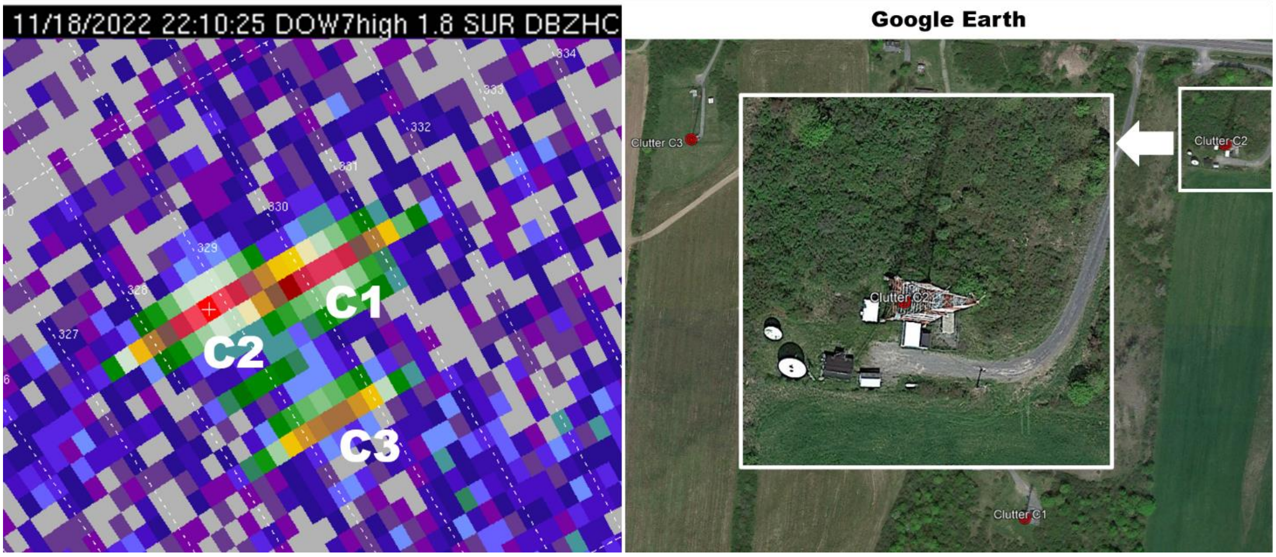

Figure 3: (Left) Radar reflectivity (DBZHC) of (Right) cell tower clutter targets denoted C1, C2, & C3 observed by the DOW7 radar 1.8° elevation SUR scan on 18 November 2022.

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 and 0.2 degrees in elevation for RHI 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 LEE 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) typically varies by pulse width, so a unique value was found for each radar and each possible pulse. A correction value was then applied to each time range of consistent pulse widths for every radar and every IOP. During LEE the same pulse width was used throughout the project, so RTFG corrections were calculated for all IOPs and then averaged to get one reliable RTFG correction. Table 6 shows the correct DOW7 RTFG value applied for LEE.

Table 6: Corrected range-to-first-gate value for DOW7 calculated from all LEE IOPs.

Radar	RTFG
DOW7	155 m

Adjustments were then applied to differential reflectivity (ZDR) to account for system offsets resulting from equipment temperature anomalies, system biases, or other receiver/transmitter errors. ZDRM is the raw differential reflectivity field calculated during translation from the time series. When adjusted, a scalar offset value is subtracted from ZDRM and placed in a new field called ZDRC (ZDR, Corrected). The offset is found from measuring the median ZDRM in vertical (VER) scans conducted every scan strategy, which was every ~5 minutes during LEE. When there are clouds or precipitation overhead of the radar and VER scans are present, we accept 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).

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 5-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 within moderate power returns (-55 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 ZDR on reliable meteorological radar returns rather than clutter or low power clouds. A level of confidence was 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 LEE sweep data, rather than applying the measured ZDRM offset to each 5-minute volume. This allowed us to estimate offsets across periods when VER scan ZDRM offsets could not be calculated, although we cannot promise ZDR is corrected to within +/- 0.2 dB during these times. The ZDRM offset corrections applied to each 5-minute volume period 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 DOW7 during IOP05, and Figure 5 shows the measured ZDRM offsets with the best fit line of applied ZDRM offset corrections for DOW7 high frequency data for IOP05. Plots like that shown in Figure 5 are also in each radar README document.

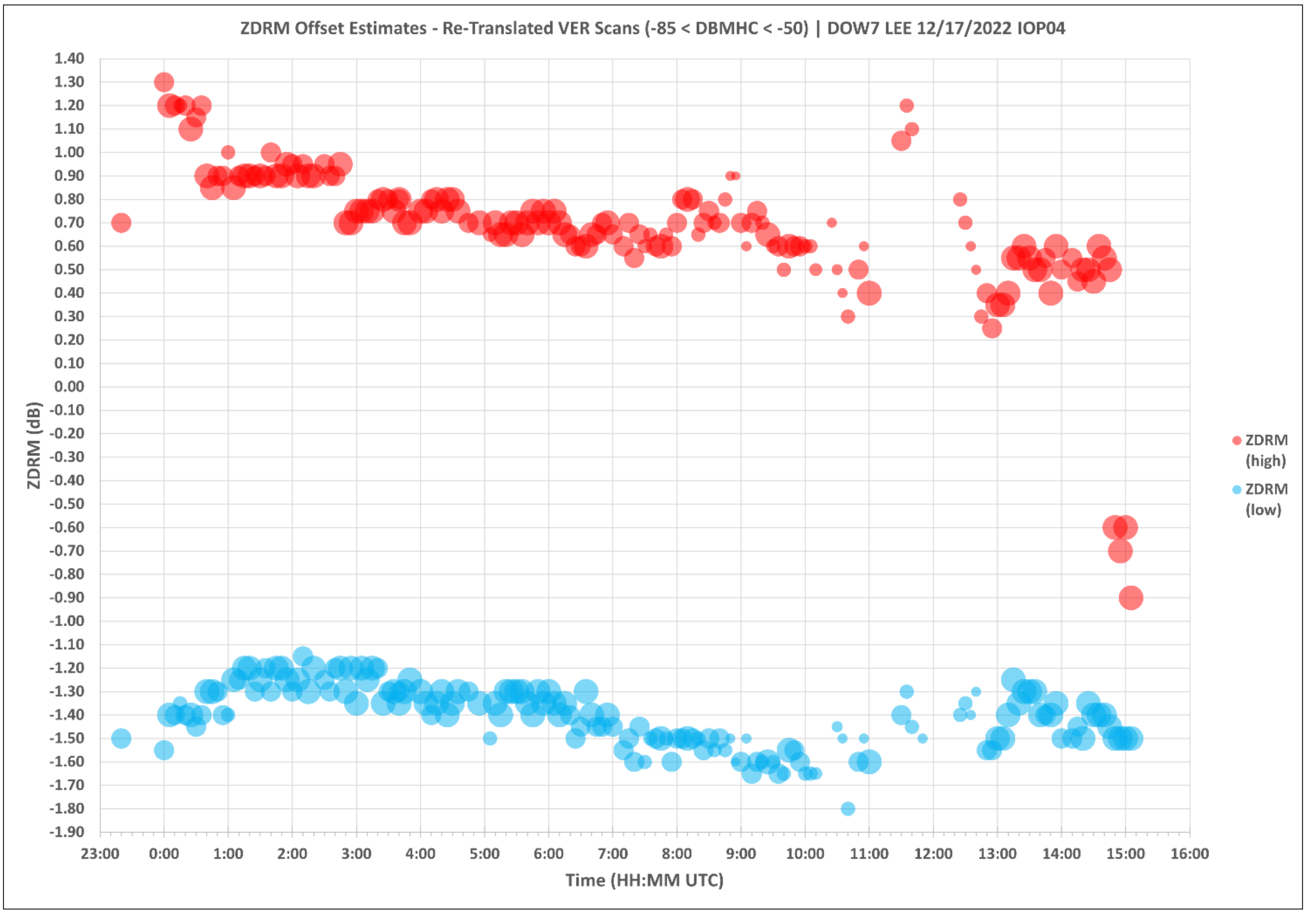

Figure 4: Measured DOW7 ZDRM offsets from VER scans during LEE IOP04 on 17 December 2022. Red bubbles represent the high frequency channel and blue bubbles represent the low frequency channel. The size of the bubbles represents the confidence in the offset value, where larger bubbles denote larger confidence.

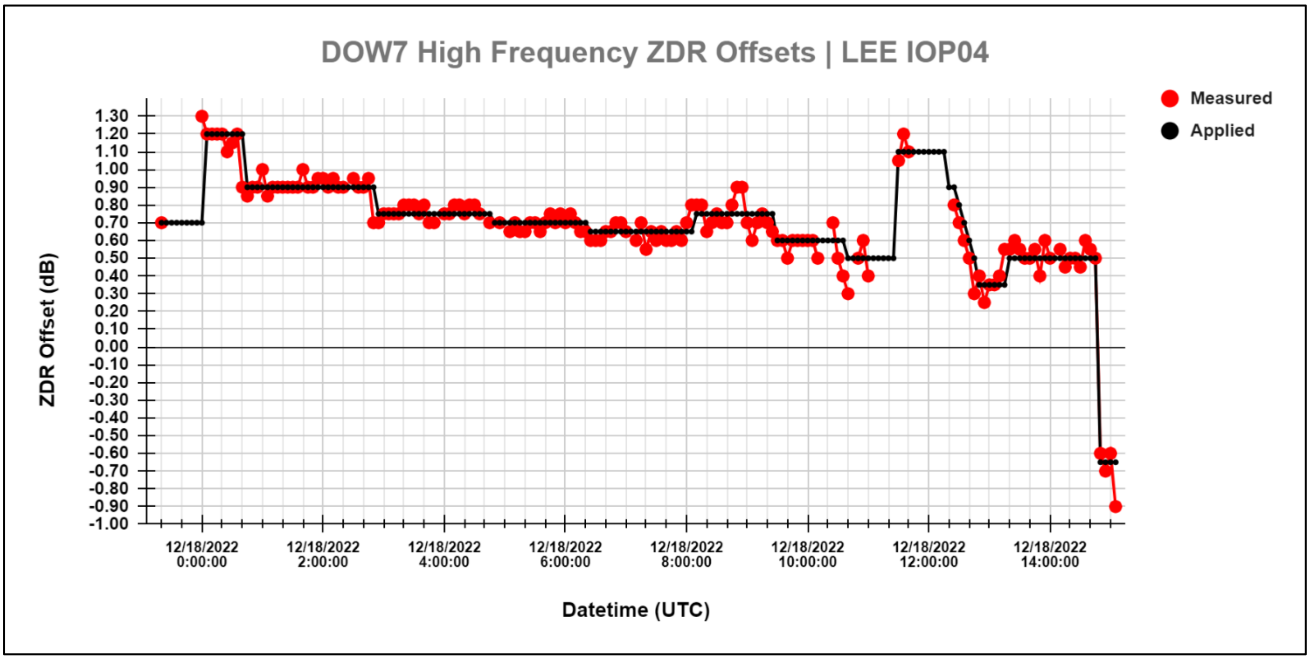

Figure 5: Measured (red) and applied (black) ZDRM offsets for DOW7 high frequency radar data from LEE IOP04.

An offset-corrected horizontal reflectivity field (DBZHCC) is available in the FARM LEE dataset. This field is equivalent to the raw reflectivity field (DBZHC) with IOP-specific offsets applied. 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). For LEE, the Montague, NY NEXRAD radar (KTYX) was used as the WSR-88D comparison.

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 each radar and 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 radar(s). Bright band contamination was avoided when finding these co-located regions. Several of these intercomparisons were found for each IOP so that an average could be computed for each IOP. Table 7 shows the final DBZ offsets calculated and applied for each IOP during LEE.

Table 7: Reflectivity offsets for each radar frequency and IOP during LEE.

	DOW7	
IOP	**High**	**Low**
1	-4.5 dB	-3.5 dB
2	-7.0 dB	-6.0 dB
3	-5.5 dB	-5.5 dB
4	-6.5 dB	-6.0 dB
5	-6.0 dB	-5.5 dB
6	-6.0 dB	-5.5 dB
7	-6.5 dB	-6.0 dB
8	-7.5 dB	-7.0 dB
9	-5.0 dB	-5.0 dB
10	-6.0 dB	-6.0 dB
11	-8.0 dB	-8.0 dB

Following the corrections of RTFG, ZDR, and reflectivity, 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 radar 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 sections describe some data-collection impacting issues that occurred during LEE. Other issues not noted here are in the READMEs for specific deployments.

4.7.1 Field Operations Issues

During LEE, DOW7 RHI scanning suffered from intermittent antenna watchdog error failures. This meant troubleshooting and manually starting/stopping of the antenna during some IOPs. When the antenna scan strategy was stopped, this reset the volume numbers in the sweep files, so volume numbers do not continuously increase throughout many IOPs.

Occasionally, heavy snowfall at the radar site necessitated a manual stop of the antenna so that snow can be cleared. This temporarily stopped data collection during some IOPs and should be denoted in the radar READMEs.

4.7.2 Radar Calibration/Sensitivity Issues

Inspection of recent DOW7 radar calibrations revealed that the high frequency horizontal and vertical polarization channels have a non-linear difference in sensitivities as a function of power. This means the system ZDR offset changes as a function of returned power, rather than staying consistent across all powers. The largest changes in system ZDR offset (up to 1 dB different) occur between powers of -90 and -60 dBm, which is roughly the moderate power range used for ZDR offset corrections applied to the data (see section 4.6). That means the ZDR offsets calculated for DOW7 high frequency data do not accurately correct the ZDRM field across all powers. This can be seen as a gradient in the corrected ZDR field (ZDRC) from higher power/reflectivity regions to lower power/reflectivity regions. This is most noticeable as you approach cloud tops, which tend to have a higher ZDR value than higher power regions below. Based on the ZDR calibration technique used to correct the LEE DOW7 radar data (section 4.6), this additional ZDR error has not been corrected in the released dataset. Therefor, the DOW7 high frequency ZDRC product accuracy is actually +/- 1.0 dB.

Fortunately, the DOW7 low frequency dataset does not appear to have this system ZDR offset issue. The user should use the DOW7 low frequency corrected ZDR product (ZDR) if performing analysis that requires highly accurate ZDR values as the DOW7 low frequency ZDRC field has an accuracy of +/- 0.2 dB when precipitation is present over the radar.

4.7.3 Notes on Equivalent Radar Reflectivity and Differential Reflectivity Measurements

Radar Reflectivity (DBZHCC, DBZVCD):

Accuracy after quality control about: ± 1 dB

Differential Reflectivity (ZDRC):

Accuracy after quality control: ± 0.2 dB (low frequency), ± 1.0 dB (high frequency)

Segal's Law: The Two Watches Problem:

When examining the reflectivity or differential reflectivity fields from just one calibrated radar, (or, any measurement from any single instrument) 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 two X-band FARM DOW systems, there are three 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 exactly 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.

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 Logs

Digital copies of the deployment logs are provided in radar → 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, receiver configuration files used, 30-minute transmitter frequency logs, scan strategies used, and even notes on notable weather observations. Radar operators were asked to keep a 30-minute log of weather observations. These are appended to the 30-minute transmitter log. A general overview of the weather event can also be found in the “Weather Observations” cell just above the “General Deployment Notes” cell.

The deployment logs are provided as-is in Excel spreadsheet (.xlsx) and PDF formats, as recorded by operators and may contain errors and unverified information. In all cases, the README should be regarded as the definitive source for information regarding the deployment.

6 Vehicle Weather Instruments

Each X-band DOW radar in the FARM fleet is equipped with a comprehensive suite of meteorological instrumentation for in situ data collection. Weather instrument arrays are mounted to pneumatically raisable masts.

For vehicle mast-mounted weather instrumentation arrays specifically, the dataset is available in the mesonet→IOP→Vehicle directory tree, which is discussed here. For LEE, this dataset has undergone basic 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.

6.1 Deployment Procedures and Instrumentation

Weather instrumentation arrays are mounted to masts attached to each vehicle in the FARM fleet (with the current exception of COW1). For DOW7, 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 radar deployment, though for safety, the mast is lowered when lightning is observed nearby or when icing is expected. During LEE, the mast was only raised for four IOPs, largely due to some deployment sites being located under power lines.

At the very top of each mast is mounted an RM Young Wind Monitor (model #05103) blade 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 DOW masts. Please note that for DOWs, when the mast is lowered and the generator is running, heat from exhaust may interfere with measurements. Additionally, random spikes in temperature/relative humidity can be observed when the radar is transmitting.

Vaisala PTB110 pressure sensors (model #CS106) are mounted not on the masts but inside the DOW cabins, which provide highly sensitive station pressure measurements.

Garmin GPS devices (model #GPS16X-HVS) are positioned on the dashboard of each vehicle, which provide highly-accurate geo-position information.

Campbell Scientific CR1000 Dataloggers mounted inside the DOW cabins provide real-time monitoring and long-term data collection and storage for all devices in the array. Data is stored directly to the datalogger and is typically collected every 1 second on a Windows computer when the LoggerNet software is running. At the end of an IOP, a separate data file is generated with only data from the specified IOP time period.

DOW deployments are typically stationary or a stationary/mobile hybrid. Data collection only 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. However, weather instrument data was trimmed to only stationary DOW deployments for this LEE dataset.

6.2 Quality Control Overview

The mesonet dataset provided with this release has undergone a basic quality control process. The dataset is divided into two levels; level 0 is the raw dataset collected from the datalogger with no modification, level 1 is the quality-controlled product.

LEVEL 0: The raw dataset from the datalogger with no modification is provided here (*_All.dat), along with a secondary copy of this raw data cropped to the time period of interest (*_Trimmed.dat). In the case of DOW weather instruments, the time period of interest was the times in which the radar was deployed and stationary. It is possible that data collection did not start until after the DOW radar truck was deployed and leveled as the weather instruments start up when the generator is powered on. 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, so for this period GPS values are not available (NAN).

LEVEL 1: The quality-controlled product is provided here. The FARM facility provides these data as an Excel spreadsheet (*QC.xlsx), which is described below, as well as a CSV text file (*QC.csv) containing all the data found in the Excel spreadsheet.

The Excel spreadsheet 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 all the data. The source dataset for the Excel spreadsheet is the level 0 trimmed text file (*Trimmed.dat). 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 necessary. When the field is populated, it is duplicated in column V, otherwise the value from the GPS vehicle heading in column P is used. 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 DOW weather instruments, the heading of the vehicle was replaced for the entirety of the stationary deployment with the value obtained from the radar quality control.

Columns W and X are boolean values that indicate whether the vehicle is stationary or if running a transect, respectively. To indicate a stationary interval, the vehicle speed indicated by GPS was thresholded below 0.5 m/s.

Columns Z through AG are where the true wind is calculated. First, in column Z, the wind direction corrected for vehicle heading and anemometer offset is calculated. The formula for calculating the number is the observed wind direction from column H, minus the anemometer offset taken from cell “AB1”, plus the vehicle heading from column V. 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).

In column AA the vehicle speed from column O is converted to m/s from knots. In columns AB through AC, the wind speed from column G and wind direction from column Z are converted to U- and V-components and multiplied by -1. In columns AD through AE the vehicle speed from column AA and direction from column V are also converted to U- and V-coordinates. In columns AF through AG, the U- and V- components of the vehicle motion and the negative of the wind are added together to resolve the true geolocated wind speed and direction incident on the anemometer. In columns AJ through AL, the U- and V-components of the true wind are converted back to 1-second wind speed and direction. In columns AM through AT, the true wind in U- and V-coordinates is center-averaged in 3-second and 1-minute values and is converted back to wind speed and direction.

Column AU provides a corrected station pressure, which is calculated by adding a pressure offset in cell AG1 to the pressure measurements in column I. For LEE, DOW7 pressure offset was 0 mb as no other FARM instrumentation was available to intercompare.

6.3 Description of the Dataset

As stated in the previous section, raw (level 0) and quality controlled (level 1) data is provided with this dataset. Plots of the data are also provided in the level 1 EXCEL spreadsheet and have been exported to a “plots” sub-folder for quick viewing. Here we list each of the files provided at each level and describe their contents.

LEVEL 0: Raw data output from the datalogger + cropped raw data to deployment times

Extension: *.dat

File type: Comma-separated Text

Header lines: 4

Table 8: Raw output file parameter description.

Column	**Variable**	**Units**
1	UTC Time string	”YYYY-MM-DD hh:mm:ss”
2	Record Number	num
3	Last Clock Sync	milliseconds
4	Num Clock Syncs	num
5	Temperature	°C
6	Relative Humidity	%
7	Blade Wind Speed	m/s
8	Blade Wind Direction	deg
9	Pressure	hPa
10	Latitude (degrees only)	deg
11	Latitude (minutes only)	deg minutes
12	Longitude (degrees only)	deg
13	Longitude (minutes only)	deg minutes
14	Altitude MSL	m
15	GPS Speed	knots
16	GPS Heading	deg
17	GPS Dilution of Precision	m
18	GPS Fix Quality	num
19	GPS Number of Satellites	num

LEVEL 1:	Quality controlled products
Extensions:	*.xlsx, *.csv
File types:	Microsoft Excel document, CSV text file
Header lines:	5, 7
Notes:	Plots provided in Excel spreadsheet, second sheet

Table 9: Level 1 Excel spreadsheet file parameter description.

Headers	**Description**
X1	Stationary threshold (knots)
AB1	Anemometer offset (deg)
AG1	Pressure offset (mb)

Columns	**Description**
A-S	Level 0 dataset
U-V	Vehicle heading override
W	Stationary vehicle flag (1 = yes, 0 = no)
X	Transecting vehicle flag (1 = yes, 0 = no)
Z	Wind direction corrected for vehicle heading & anemometer offset
AA	Vehicle speed converted to m/s
AB-AC	U- and V-components of observed wind
AD-AE	U- and V-components of vehicle motion
AF-AG	U- and V-components of true wind
AH-AI	Latitude/Longitude converted to decimal degrees
AJ-AL	1-second wind speed/direction
AM-AP	3-second wind speed/direction & U- and V- components
AQ-AT	1-minute wind speed/direction & U- and V-components
AU	Corrected station pressure (mb)

Table 10: Level 1 CSV data file parameter description.

Column	Variable Name	Units	Description
1	Time	YYYY-MM-DD hh:mm:ss UTC	Measurement time in UTC
2	Temperature	°C	Air temperature
3	Relative_Humidity	%	Relative Humidity
4	Pressure	hPa	Station pressure
5	Bld_Wnd_Spd_Obs	m/s	Observed raw blade anemometer wind speed
6	Bld_Wnd_Dir_Obs	deg	Observed raw blade anemometer wind direction
7	Latitude	decimal degrees	GPS latitude
8	Longitude	decimal degrees	GPS longitude
9	Veh_Spd	m/s	Vehicle speed
10	Veh_Heading_Corr	deg	Vehicle heading correction
11	Stationary	Boolean (1 = yes, 0 = no)	Stationary flag, 1 when vehicle not moving
12	Transect	Boolean (1 = yes, 0 = no)	Transect flag, 1 when vehicle moving
13	Bld_Wnd_Spd_Corr	m/s	Corrected 1-sec blade anemometer wind speed
14	Bld_Wnd_Dir_Corr	deg	Corrected 1-sec blade anemometer wind direction, relative to true north
15	3-sec_Bld_Wnd_Spd_Corr	m/s	Corrected 3-sec blade anemometer wind speed
16	3-sec_Bld_Wnd_Dir_Corr	deg	Corrected 3-sec blade anemometer wind direction, relative to true north
17	1-min_Bld_Wnd_Spd_Corr	m/s	Corrected 1-min blade anemometer wind speed
18	1-min_Bld_Wnd_Dir_Corr	deg	Corrected 1-min blade anemometer wind direction, relative to true north
19	Corr_Pressure	hPa	Corrected station pressure

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