PurRad: Enhancing Radar Education at Purdue University using the Doppler on Wheels

Final Report to the National Science Foundation

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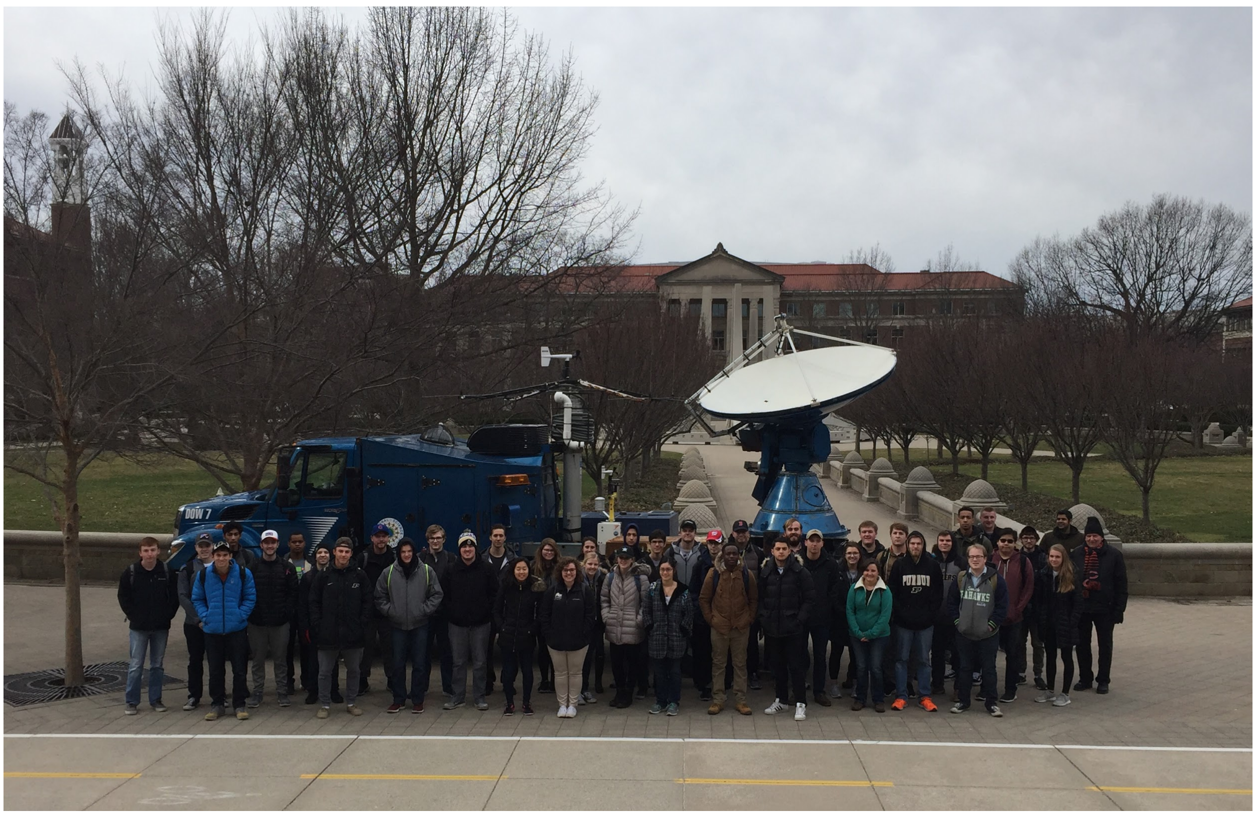

Fig. 1. Approximately 40 students enrolled in EAPS 13800: Thunderstorms and Tornadoes visit DOW 7 during an on-campus demonstration on 5 March 2018.

1. Summary

A Doppler on Wheels mobile radar (DOW 7) from the Center for Severe Weather Research (CSWR) visited Purdue University from 26 February to 17 March 2018 (Fig. 1). The primary purpose of this NSF-sponsored educational deployment, nicknamed PurRad (for "Purdue Radar"), was to enhance learning in Purdue's Radar Meteorology course (EAPS 52300), taught by the PI. Students in that course gained considerable experience designing and carrying out radar-based studies of precipitation microphysical processes during the region's winter-to-spring transition. More than 100 additional Purdue students came into contact with the DOW during the deployment, and more than 400 people from across the region experienced the DOW at a public demonstration in Lafayette, Indiana. The educational deployment also received favorable local media coverage.

2. Introduction

As discussed in the proposal for PurRad 2018, the ubiquity of dual-pol radar data makes it imperative that meteorology students spend considerable time learning complex and often subtle concepts of dual-pol radar design, operation, and data interpretation. In addition, as is the case with many physical sciences, meteorology instruction is enhanced by authentic research experiences, including the use of research-grade equipment (NRC 2000, 2017).

PurRad was designed to enhance college-level learning of radar meteorology. Purdue University offers EAPS 52300: Radar Meteorology as an elective every other spring semester to senior undergraduate and graduate atmospheric science students. Prior to the arrival of the DOW, the 2018 EAPS 52300 students learned about radar history, design, operating principles. In addition, the group took a field trip to the nearest NWS weather forecasting office in Indianapolis, Indiana, where they were able to visit and inspect the WSR-88D in person under the supervision of its chief technician. This WSR-88D field trip was designed to complement the DOW educational deployment. Students were asked to explain differences in the radar hardware (antenna, klystron vs. magnetron transmitter, waveguide size, etc.), data, and capabilities between the DOW and the WSR-88D.

3. Logistics

During this educational deployment, EAPS took advantage of its close relationship with the Purdue Agronomy department to obtain facilities and deployment sites for the DOW. When not in use, the DOW was housed in the phenomics tool development high bay of the Indiana Corn and Soybean Innovation Center (ICSC), a Purdue-owned agronomical research facility. This large indoor space was not in heavy demand during February and March, because this time period fell outside the region's growing season. Use of the high bay allowed CSWR staff to work on the DOW in a comfortable indoor environment during the cold Indiana weather (Fig. 2).

Fig. 2. DOW 7 sitting inside the ICSC high bay between deployments. Photo courtesy of Alycia Gilliland.

The ICSC is part of the Agronomy Center for Research and Education (ACRE), a Purdue field research station located about 4 miles from Purdue's main campus. The ACRE site proved a convenient test deployment site for the DOW, as it is located on 1,400+ acres (5.7 km^2) of relatively flat terrain. Nearby clutter targets like high-tension power lines and wind turbines provided opportunities to demonstrate concepts like ground clutter mapping and atmospheric refraction (Fig. 3). Unless otherwise noted, all atmospheric observations by the DOW during this educational deployment were conducted from ACRE.

Training deployments occurred at ACRE from 26 February through 6 March. During these training sessions, CSWR staff members instructed the PI, the four Radar Meteorology students, and one undergraduate independent study student on the operation of the DOW. In some instances, Intensive Observing Periods (IOPs) for the class experiments doubled as training deployments for the students.

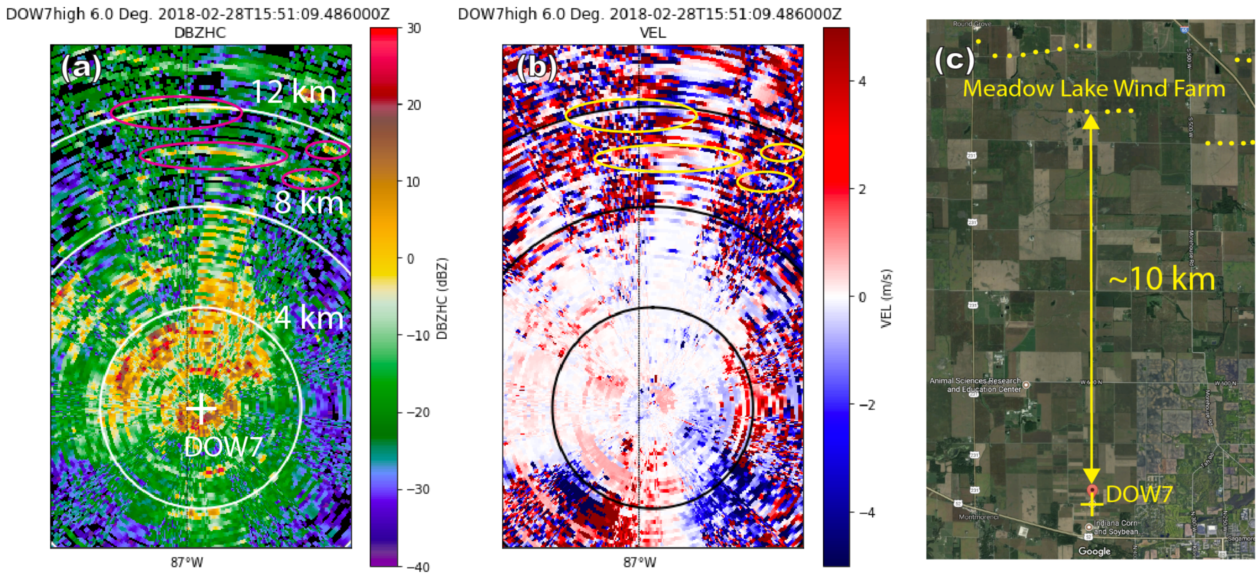

Fig. 3. (a) Reflectivity (in dBZ) and (b) Doppler radial velocity (in m s^{-1}) measured by DOW7 at 6.0° elevation during a clutter survey at ACRE on 28 February 2018. (c) Satellite imagery (courtesy Google Maps) of the same area, with the locations of wind turbines in the Meadow Lake Wind Farm plotted as yellow dots. Corresponding echoes are circled in magenta in panel (a) and yellow in panel (b).

4. University activities

a. EAPS 52300: Radar Meteorology

PurRad was timed to coincide with Indiana's winter-to-spring transition. A wide variety of weather, ranging from snow to tornadic storms, have historically been observed during this period. After reading and discussing Kumjian et al. (2013), four graduate students enrolled in Radar Meteorology identified three atmospheric phenomena to target for detailed case studies: (1) the polarimetric refreezing signature; (2) the melting layer signature; and (3) differential reflectivity (ZDR) columns in convective storms. The phenomena were selected to align with both the expected range of weather conditions and the individual students' interests. By focusing on three distinct atmospheric phenomena instead of one, the class proactively hedged against the failure to collect observations of one or more of the phenomena. As it turned out, owing to a lack of strongly convective storms in Indiana, no suitable observations of ZDR columns were collected. Accordingly, the students' DOw-based projects were focused primarily on identification of melting layers and refreezing signatures.

During the experiment design, it was noted that studies of all three of these phenomena would benefit from local observations of the 0 °C height. As Purdue University is located 230 km from the nearest operational National Weather Service upper-air sounding site (Springfield, Illinois; KILX), the students requested the use of a mobile sounding system to collect local atmospheric soundings during deployments. Prof. Michael Baldwin (EAPS) instructed the students on how to launch radiosondes. Owing to an equipment failure, sonde flights were only successful in one case.

The six EAPS 52300 participants (Fig. 4) and the CSWR staff members (A. Gilliland and M. Hanshaw, Fig. 5) developed a set of scanning strategies for each type of mission that involved surveillance scans (PPIs) from 4° to 20° for melting layer observations, 0.5° to 4° for refreezing signatures, and vertical scans (RHIs) for ZDR columns. Fortunately, the DOW scan scheduling software was versatile enough to handle combinations of the above with just a few mouse clicks.

The group monitored forecast model updates and designated Intensive Observing Periods (IOPs), during which the DOW was deployed with at least one student assisting in operation, logging, and curation of the data. Throughout the deployment, the PI, students, and CSWR staff communicated using the social media site GroupMe. Each day, the PI initiated a daily forecast discussion, soliciting input from the other participants. If an IOP was deemed necessary, the chat was used to coordinate deployment, crewing, and scanning strategies. A total of four IOPs were conducted (Table 1), along with a “0th” IOP (ground clutter survey) that occurred early in the deployment.

Following each IOP, A. Gilliland curated and converted all of the DOW data into DORADE format, collected all of the associated logs, mesonet data, and inclinometer data, and transmitted them to the PI. The PI then further converted the DOW data into Cf/Radial format, added sounding data to the archive when it was available, and posted it on Purdue servers for access by the students. Students analyzed these data using both Solo II (NCAR 2016) and Py-ART (Helmus and Collis 2016) software. As there were four registered students and four IOPs, one IOP was assigned to each students as a case study. Each student was tasked with producing quasi-vertical profiles (QVPs; Ryzhkov et al. 2016) and applying a hydrometeor classification algorithm to the raw DOW observations.

Fig. 4. Left to right, EAPS 52300 (Radar Meteorology) participants R. Tanamachi (instructor and PI), A. LaFleur, J. Chen, M. Sharma, P. Saunders, and undergraduate research assistant D. Dalman.

Table 1. Summary of the IOPs conducted during PurRad 2018.

IOP	**Date / Time**	**Mission**	**Conditions / comments**

0	28 February 2018, 1500 - 1600 UTC	Training, clutter survey	Distant light rain, otherwise quiescent conditions
1	1 March 2018, 1300 - 1800 UTC	Melting layer	Cold FROPA. Sonde data collected (3).
2	5 March 2018, 2200 UTC - 0230 UTC	Refreezing signature	Warm FROPA.
3	6 March 2018, 1900 - 2200 UTC	Refreezing signature	Graupel and snow.
4	17 March 2018, 0200 - 0900 UTC	Melting layer and refreezing signature	Warm FROPA and freezing rain.

1. IOP “0”, 28 February 2018

Ahead of an approaching trough, two light rain events affected Tippecanoe County, Indiana (in which Purdue is located). A thin cloud deck with virga was exiting the county to the southeast. Since no observations pertinent to the three working hypotheses were anticipated, IOP 0 was treated primarily a training deployment designed to familiarize the students with the DOW theory of operation.

Fig. 5. CSWR staff M. Hanshaw (left) and A. Gilliland (second from left), seated in the cab of DOW7, instruct the EAPS 52300 students on the operation of the radar.

The CSWR staff walked the students through the startup-to-shutdown procedure for DOW7 (Fig. 5), tasking students with choosing scanning strategies, logging the deployment, and performing a sun scan for subsequent azimuth correction. Light precipitation (virga) was detected at high elevations (not shown), and students observed echoes from ground clutter targets, such as buildings, transmission towers, and wind turbines (Fig. 3) close to the radar.

2. IOP 1, 1 March 2018

An approaching surface low pressure center passed over west central Indiana on 1 March 2018 (Fig. 6), bringing widespread precipitation and gusty surface winds to the ACRE site. Most of the precipitation was forecast to occur in the warm sector of the low, with little to no trailing precipitation behind the cold front. Accordingly, a melting layer IOP was declared. DOW7 deployed at the ACRE site from 1300 to 1800 UTC, recording increased backing winds, indicating cold air advection in association with the frontal passage (FROPA; Fig 7). The IOP ended when the precipitation shield exited the range of the DOW at 1800 UTC.

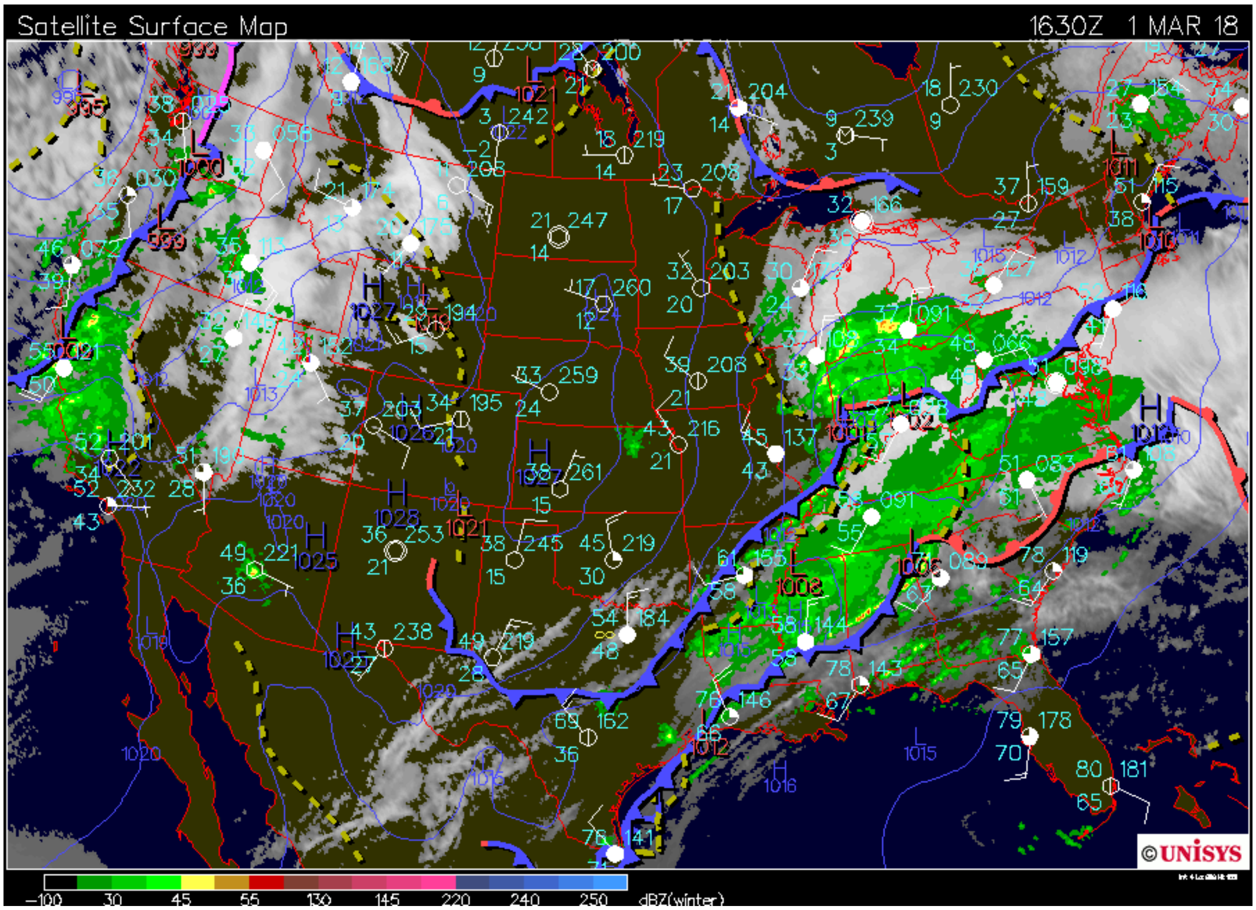

Fig. 6. Analyzed surface fronts and surface pressure extrema (in hPa) overlaid upon composite satellite (greyscale cloud cover) and WSR-88D reflectivity (filled color in dBZ). Surface observations are plotted with temperatures in deg F, pressure in hPa. All observations are valid at 1630 UTC, approximately halfway through IOP1. Image courtesy of Unisys.

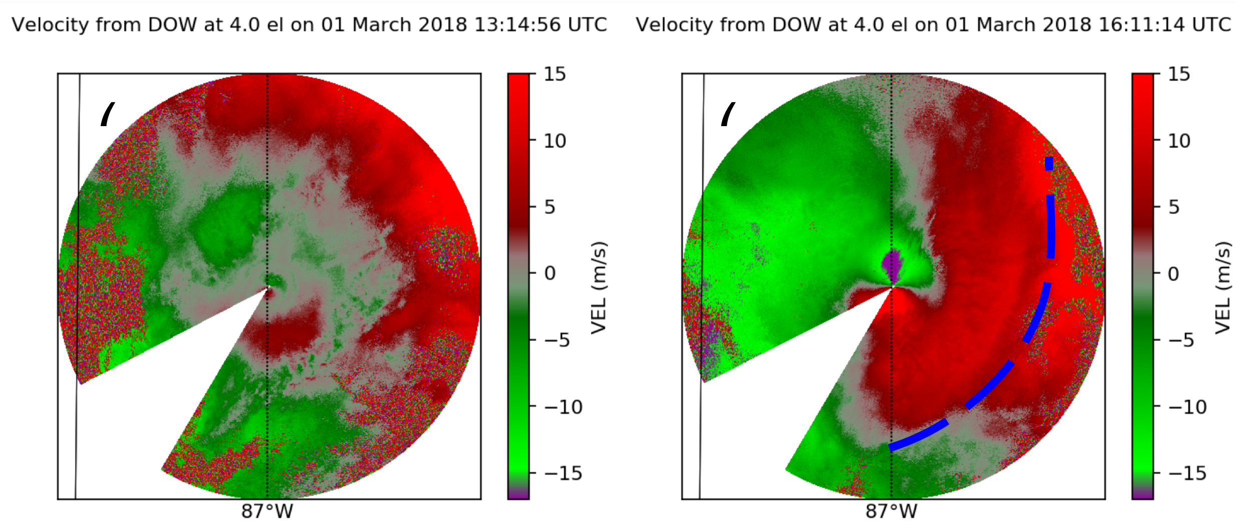

Fig. 7. DOW-measured Doppler radial velocity at (a) 1315 UTC on 1 March 2018, prior to the cold FROPA, and (b) at 1611 UTC, shortly after the FROPA. In panel (b), the leading edge of the cold air is annotated by a blue dashed line. The white sector denotes where the antenna was still changing elevation from the preceding scan.

While the DOW was deployed, other EAPS 52300 students launched three iMet radiosondes from Purdue campus, recording the boundary layer cooling during the cold frontal passage (Fig. 6). Interestingly, the top of the boundary layer appeared to warm back up slightly following the surface frontal passage, even as the surface temperatures cooled. As a result, the 0 °C level dipped from 2489 m MSL at 1403 UTC to 2074 m MSL at 1616 UTC, then rebounded to 2229 m MSL at 1742 UTC.

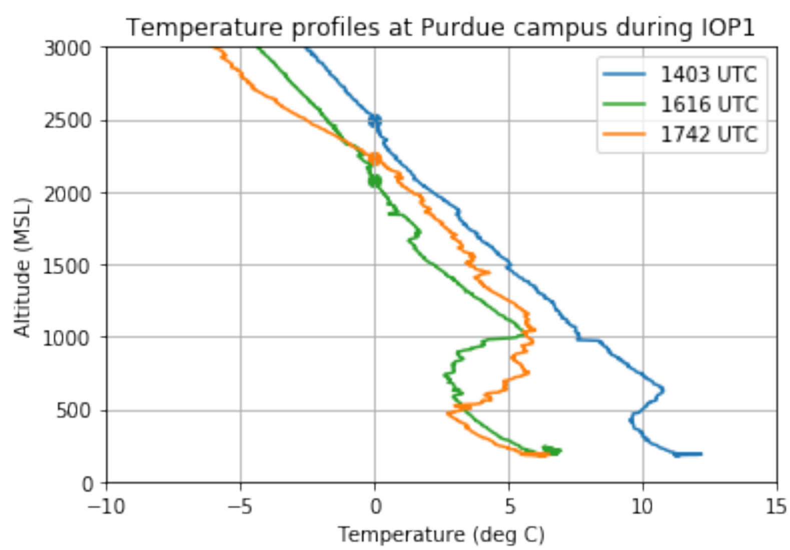

Fig. 6: Temperature profiles at Purdue campus, measured by radiosondes launched during IOP1. The height of the 0 °C level in each profile is marked by a large dot.

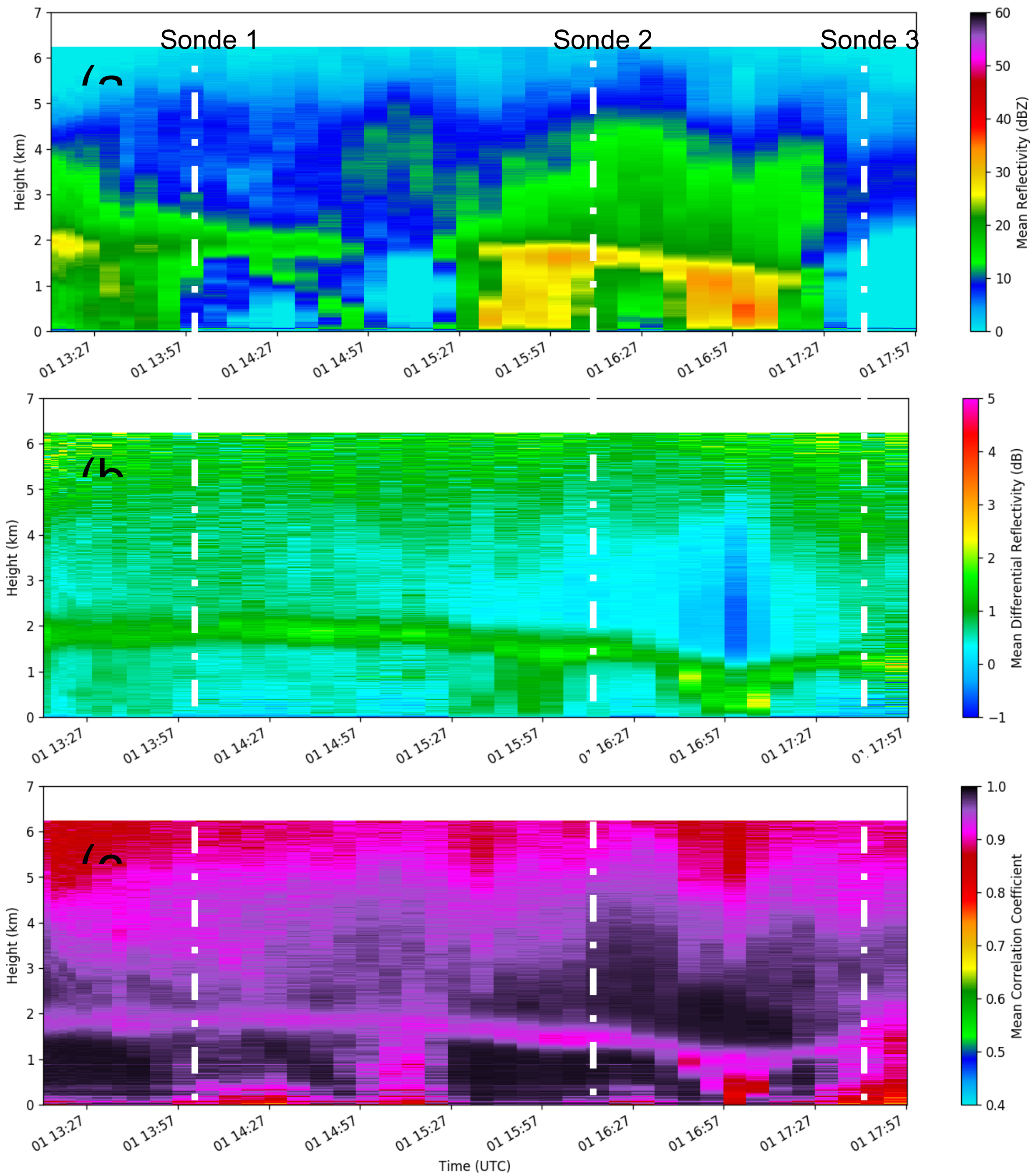

Fig. 7. QVPs of DOW7 observations of (a) reflectivity (in dBZ), (b) ZDR (in dB), and correlation coefficient (unitless) for IOP1. White, vertical dot-dash lines indicate the times of sonde launches from campus (Fig. 6). Images courtesy P. Saunders.

EAPS 52300 student P. Saunders performed QVP analyses of the DOW data for this IOP (Fig. 7). This analysis showed clearly that the melting layer descended toward the surface during the cold FROPA, before rebounding slightly just prior to the end of the IOP. This behavior matches what would be expected based upon the sounding temperature profiles (Fig. 6). An interval of enhanced differential attenuation above the melting layer was also noted at 1704 UTC (Fig. 7b), associated attenuation to the northeast of an area of relatively heavy, possibly convective precipitation northeast of the DOW (Fig. 8a). An RHI scan through this cell (not shown) showed a relatively shallow, weak ZDR column.

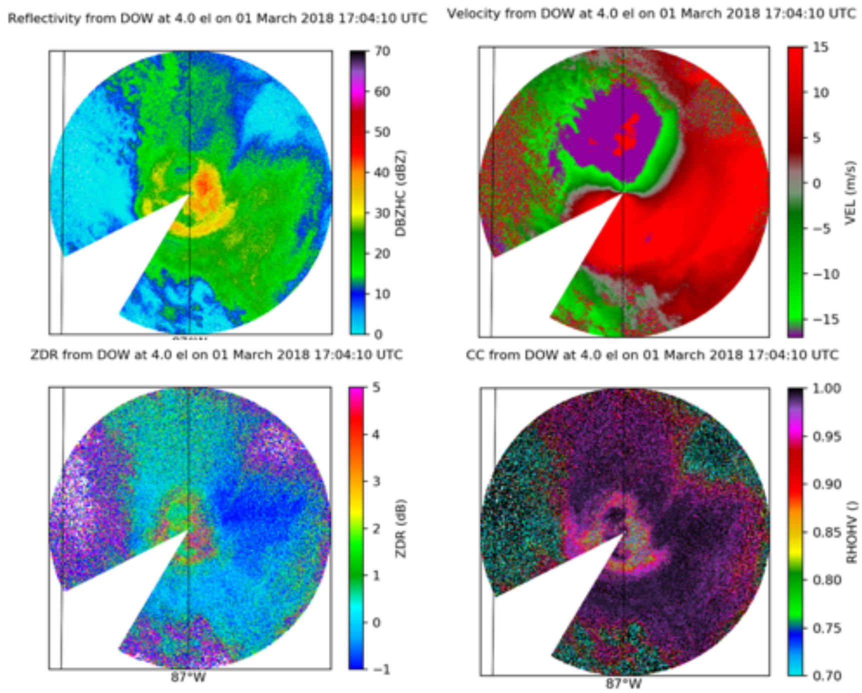

Fig. 8. (clockwise from top left) PPI displays of DOW7 reflectivity (in dBZ), Doppler velocity (in m s^{-1}), correlation coefficient (unitless), and ZDR (in dB) at an elevation angle of 4.0° at 1704 UTC.

The DOW7 polarimetric observations, including ZDR (e.g., Fig. 9a) and the temperature profile from the 1742 UTC radiosonde (Fig. 6) were ingested into the semi-supervised hydrometeor classification algorithm (SSHCA; Besic et al. 2016) contained in Py-ART. The ratio of gates classified as vertically aligned ice (VI) to dry snow (DS) seemed unrealistically high for the warm sector of an extratropical cyclone (Fig. 9b). Through azimuthal averaging of the near-vertically pointing “birdbath” scans (Gorgucci et al. 1999) collected with each volume (not shown), it was found that ZDR values recorded by the DOW’s “high” channel (9.5 GHz) were biased approximately 2.75 dB too low. ZDR values less than zero above the melting layer are commonly associated with vertically aligned ice. Applying a ZDR bias correction factor (Fig. 9c) resulted in a much more realistic ratio of vertically aligned ice to dry snow classified gates (Fig. 9d).

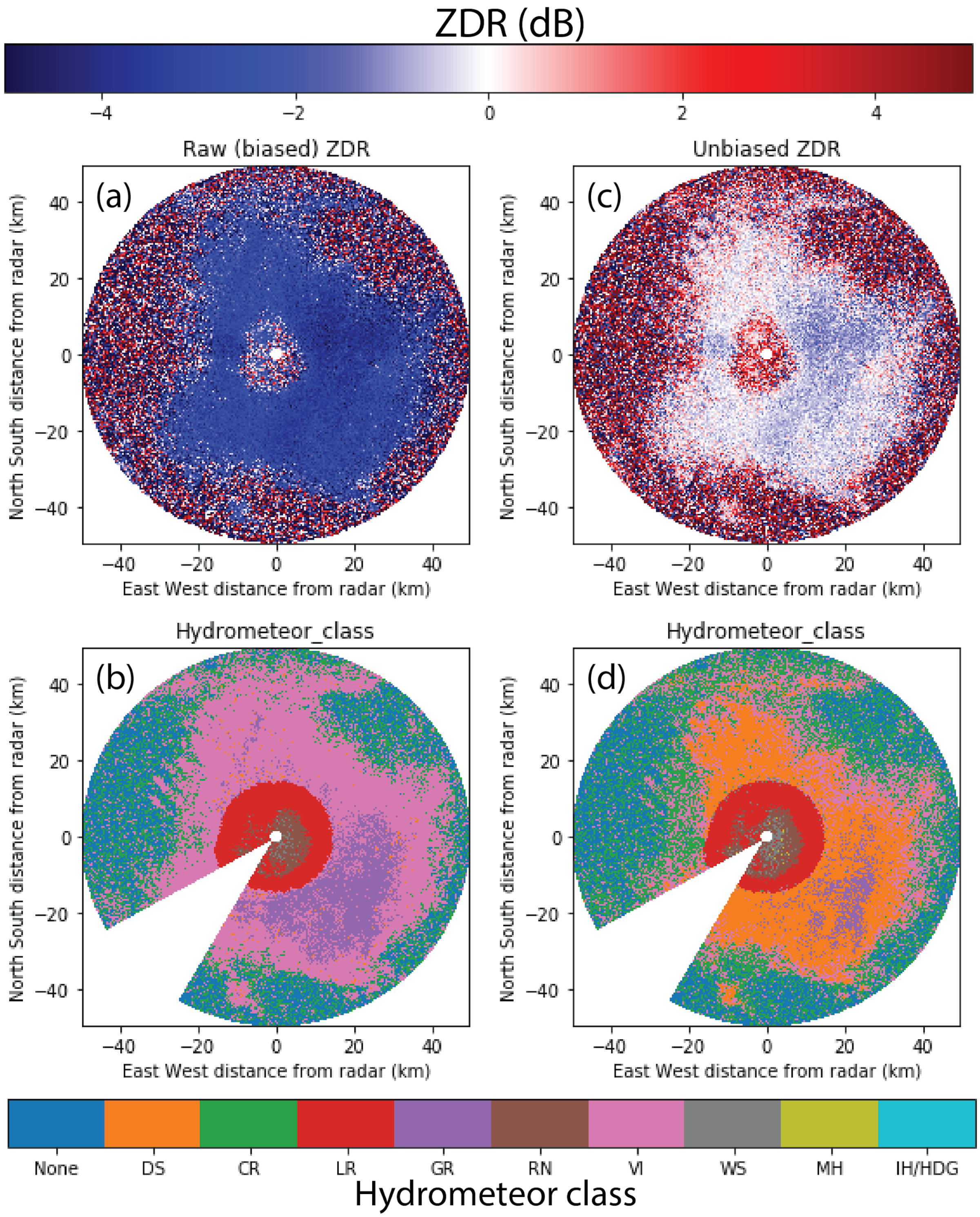

Fig. 9. (a) Raw ZDR (in dB) and (b) corresponding hydrometeor classifications based (in part) upon the ZDR measurements shown in (a), at an elevation angle of 7.0° at 1705 UTC. (c) ZDR (in dB) with bias removed by the Gorgucci et al. (1999) technique, and (d) the corresponding hydrometeor classifications following bias removal. Abbreviations on the hydrometeor class color bar are, respectively, dry snow, ice crystals, light rain, graupel, rain, vertically aligned ice, wet snow, melting hail, and ice hail / high density graupel.

3. IOP 2, 5 March 2018

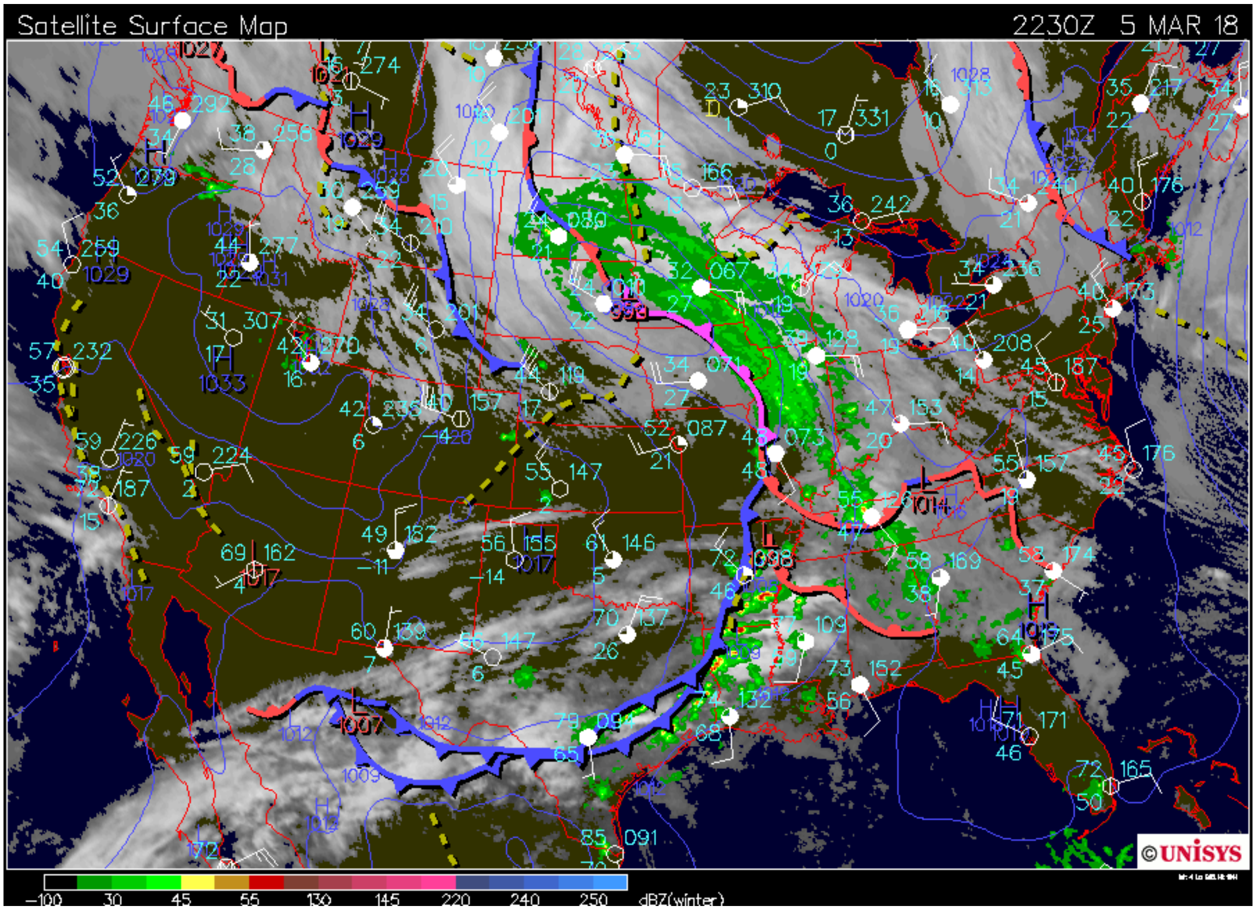

Fig. 10. As in Fig. 6, but for 2230 UTC on 5 March 2018, near the beginning of IOP2.

A cycloidally tracking low pivoted over Minnesota as it began to occlude (Fig. 10). The occluded front, trailing southeast from the surface pressure minimum, pushed northeastward through Indiana during the evening. The NAM and GFS forecast soundings for Lafayette, Indiana (not shown) both indicated the potential for mixed winter precipitation. A refreezing signature IOP was planned for that evening beginning at 2300 UTC.

As the precipitation bands along the occluded front approached Lafayette during the afternoon, some were observed to contain widely varying values of correlation coefficient (Fig. 11). The IOP start time was moved back to 2200 UTC in light of this development. The DOW deployed at ACRE with sleet falling on it, and it collected a nine-minute sequence of PPIs, RHIs, and birdbath scans through 0200 UTC. Unfortunately, no soundings could be launched during IOP2 (or any subsequent IOPs) owing to failure of the helium regulator during IOP1.

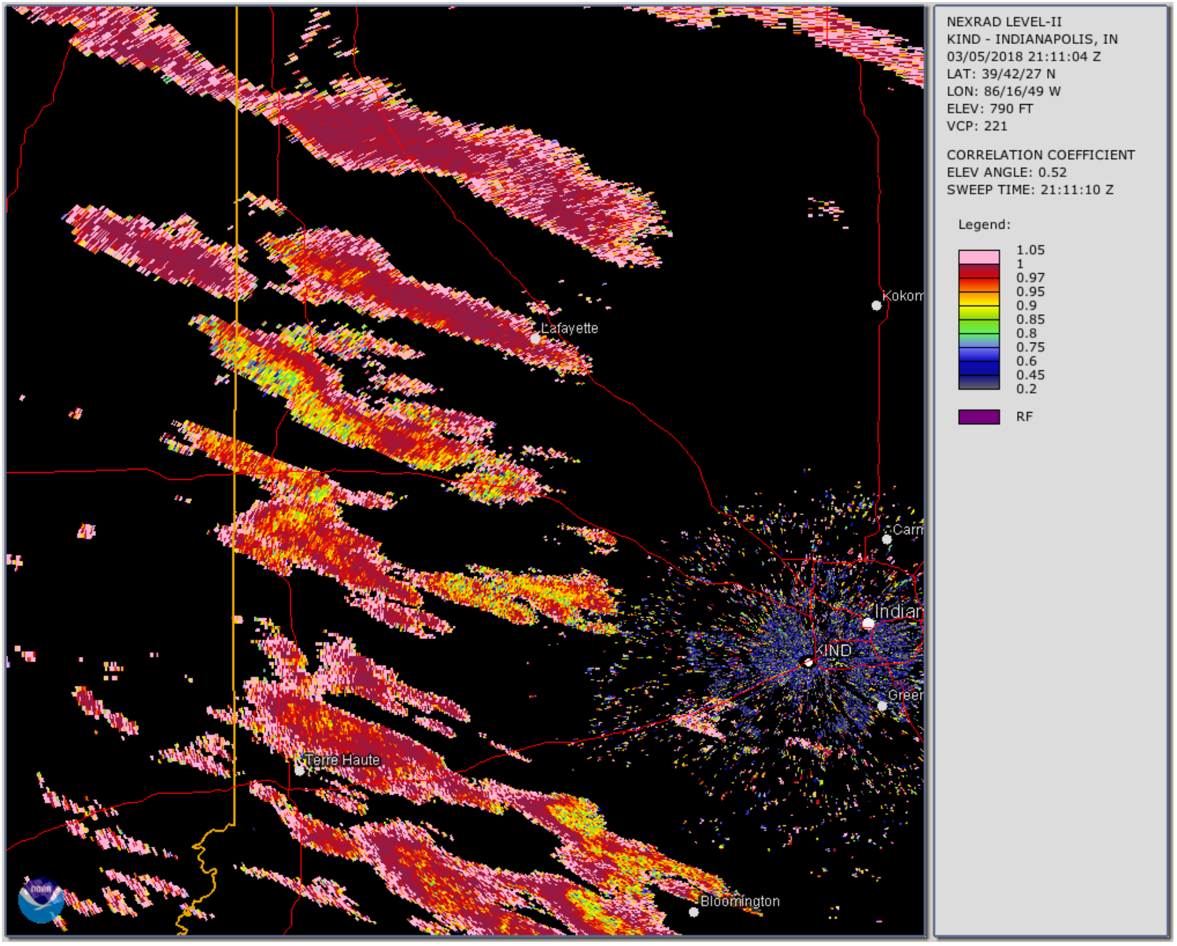

Fig. 11. Correlation coefficient at 2111 UTC over western Indiana, measured by the KIND WSR-88D radar at an elevation angle of 0.5°. The bands of precipitation depicted here moved toward the north-northeast.

EAPS 52300 student J. Chen was assigned to analyze IOP 2 DOW data. She found that her QVPs did not conclusively show a refreezing signature at a time one was noted in the log (2327 UTC). She hypothesized that the observed horizontal heterogeneity in the precipitation bands was masking the refreezing signature in the QVPs. Indeed, as the precipitation bands passed over the DOW at 2354 UTC (Fig. 13a), a localized signature partially consistent with refreezing (Kumjian et al. 2013), consisting of enhanced ZDR and slightly decreased correlation coefficient, was observed at low elevation angles to the DOW's immediate southwest (Fig. 13). The expected enhancement in KDP (Kumjian et al. 2013) was not observed (Fig. 13d). In summary, although sleet was observed at the DOW deployment site, inconclusive evidence for refreezing was found in the polarimetric measurements.

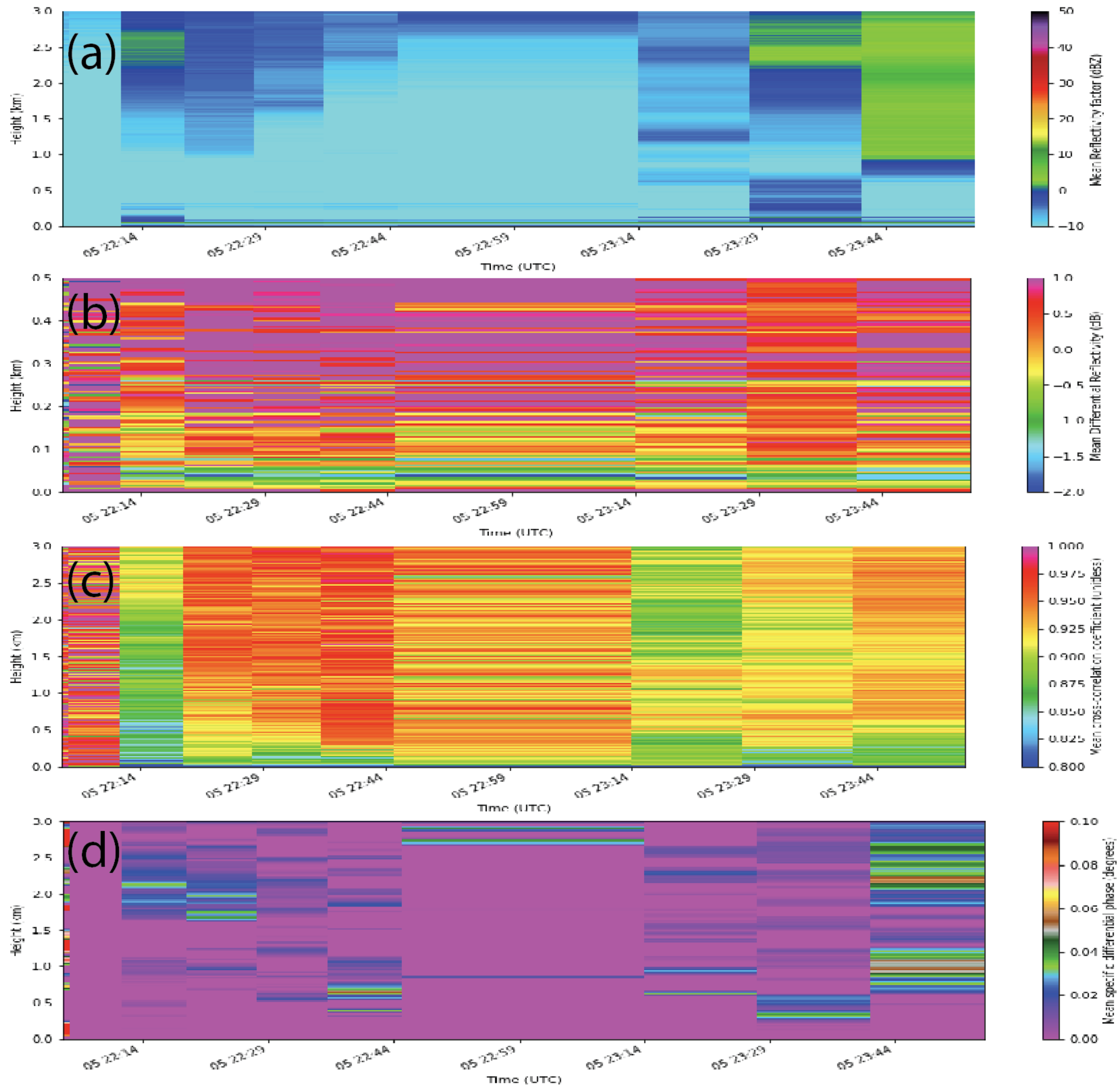

Fig. 12. QVPs of DOW7 observations of (a) reflectivity (in dBZ), (b) ZDR (in dB), (c) correlation coefficient (unitless), and (d) specific differential phase for a portion of IOP2. Image courtesy of J. Chen.

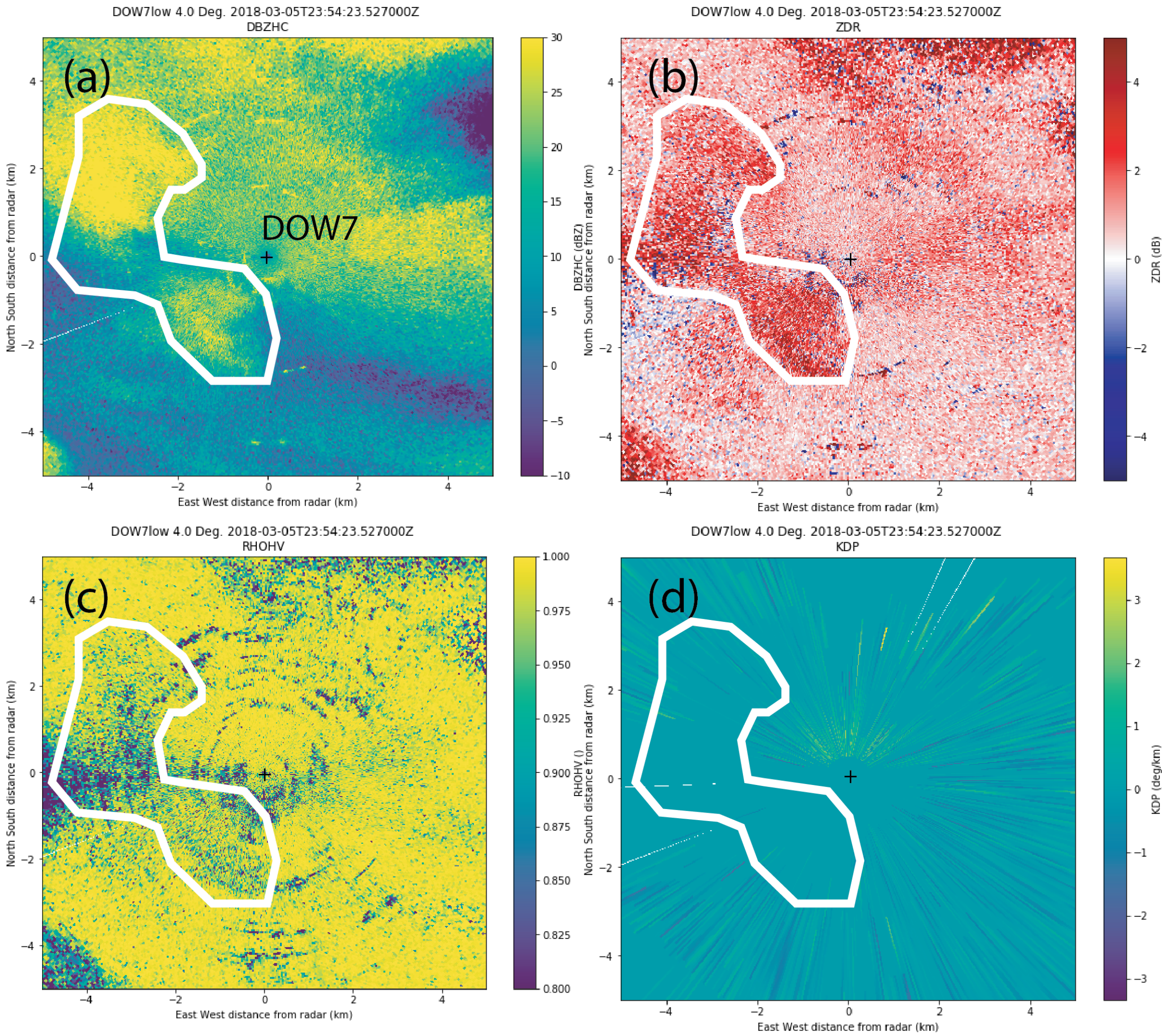

Fig. 13: PPI displays of DOW7 (a) reflectivity (in dBZ), (b) ZDR (in dB), (c) correlation coefficient (unitless), and (d) specific differential phase (in deg km^{-1}) at 2354 UTC on 5 March 2018 at an elevation angle of 4.0°. The view is confined to a 5 km x 5 km box centered on DOW7 (whose location is marked by a black cross). A possible refreezing signature is outlined in white.

IOP 3, 6 March 2018

As the elongated closed surface low from IOP 2 exited Minnesota and traversed Indiana from west to east (Fig. 14), a brief (three-hour) IOP was convened in response to a forecast rain-to-snow transition event. On the east side of the low, rain was expected, but practically none fell in the 12 hours preceding IOP 3 owing to dry deep-layer conditions behind the occluded front.

Graupel was observed in falling in Lafayette shortly before IOP 3 began at 1932 UTC, and snow was observed thereafter. The surface temperature recorded by the DOW pod (Fig. 15a) and by KLAF (not shown) never dropped below freezing, but instead oscillated between about 2 and 4 °C. Snow flakes can persist without melting at above-freezing temperatures when the relative humidity (which hovered around 80% for this deployment; Fig. 15b) is low (Matsuo and Sasyo 1981). Indeed, no melting layer was observed during this deployment, leading to its termination at 2230 UTC.

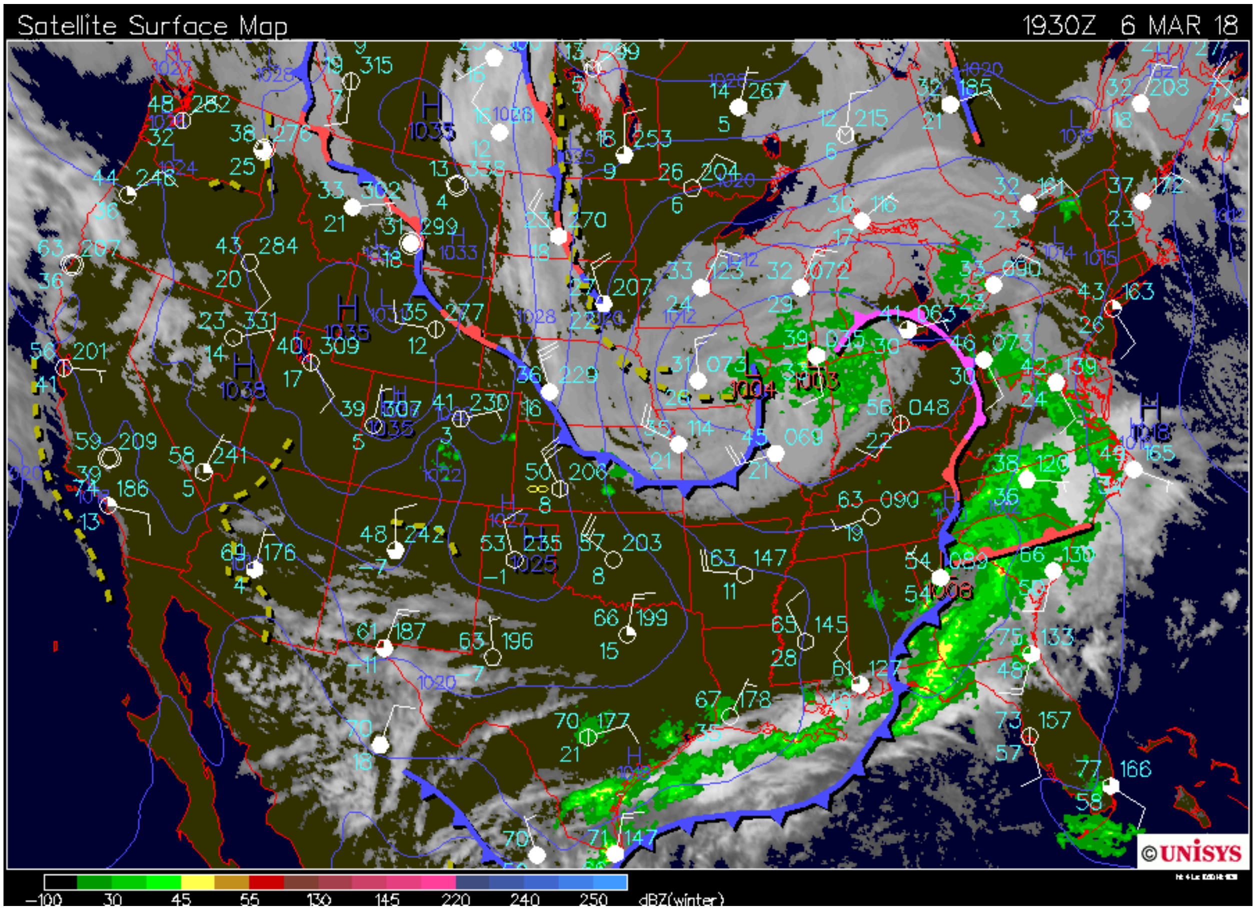

Fig. 14. As in Fig. 6, but at 1930 UTC on 6 March 2018, near the start of IOP 3.

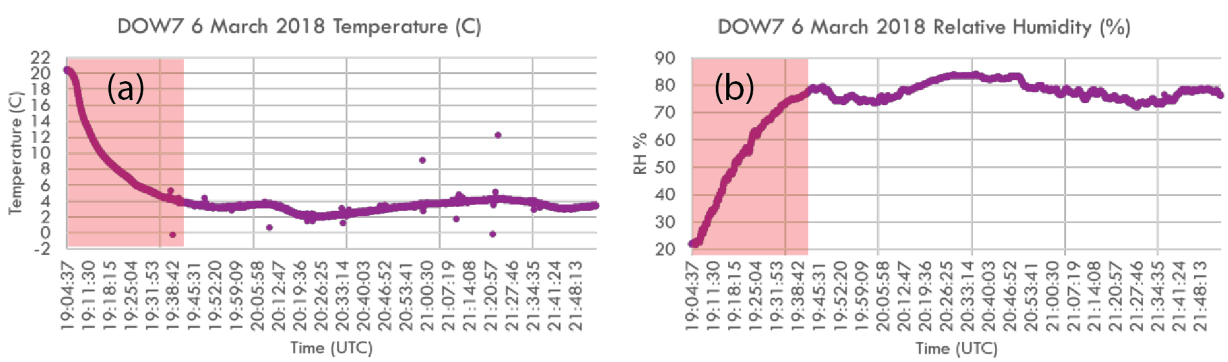

Fig. 15. Air temperature (in deg C) and relative humidity (in percent) observed by the DOW pod during IOP3. The red shaded area denotes when the DOW was still equilibrating to the outdoor conditions after departing the garage (Fig. 2) and are not representative of the environmental conditions at ACRE. Base image courtesy of A. LaFleur.

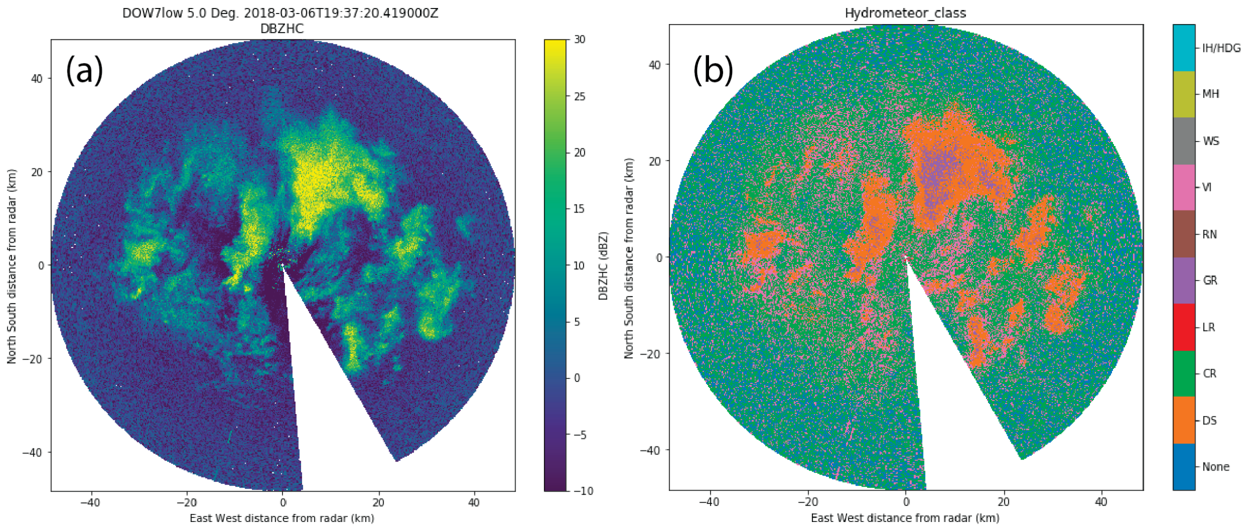

Fig. 16: (a) DOW low-frequency polarimetric observations of reflectivity (in dBZ). (b) As in Fig. 9d, but for HCA output generated from the polarimetric observations and the 0000 UTC 7 March KILX sounding.

EAPS 52300 graduate student A. LaFleur performed a hydrometeor classification on the DOW high-frequency data, but found (as in IOP1) that classification of vertically aligned ice was suspiciously high owing to ZDR bias of approximately -2.4 dB (not shown). The low-frequency DOW observations (Fig. 16a) exhibited minimal ZDR bias (< 0.2 dB; not shown). Because no soundings were available from Purdue for this deployment, the Lincoln, Illinois (KILX) synoptic sounding taken at 0000 UTC on 7 March 2018 was used in the semi-supervised HCA (Besic et al. 2016) instead (Fig. 16b). Precipitation cores containing mostly graupel (GR) were encircled by regions of dry snow (DS), which were themselves encircled by regions of ice crystals (CR). Very little vertically aligned ice (VI) was classified. Both graupel and dry snow were observed at the surface at ACRE.

IOP 4, 17 March 2018

Following 10 days of quiescent weather, the final IOP of PurRad 2018 occurred on 17 March, the last day of the educational deployment. As a surface low (Fig. 17) passed over southern Illinois, cold Canadian air spilled into Indiana from the north and northwest, dropping surface temperatures to 0 °C across the Lafayette area (Fig. 18). In the North American Mesoscale model, a broad warm nose (not shown), centered around 850 mb, was forecast to persist for several hours after the surface frontal passage. Because of this forecast sandwiching of a relatively warm layer of air between two sub-freezing layers within the precipitation band, a widespread and long-duration freezing rain event was forecast, with the probability of freezing rain greater than 0.1 inch at ACRE greater than 50% (Fig. 19). Based upon this forecast, IOP 4 was conducted overnight as a refreezing signature hunt. From 0200 to 0900 UTC, deep volumes (0.5 to 20°) were collected, interspersed with RHI scans perpendicular to precipitation motion and a sequence of five birdbath scans at the end of each volume. An additional RHI was collected over a disdrometer deployed at the PI's residence.

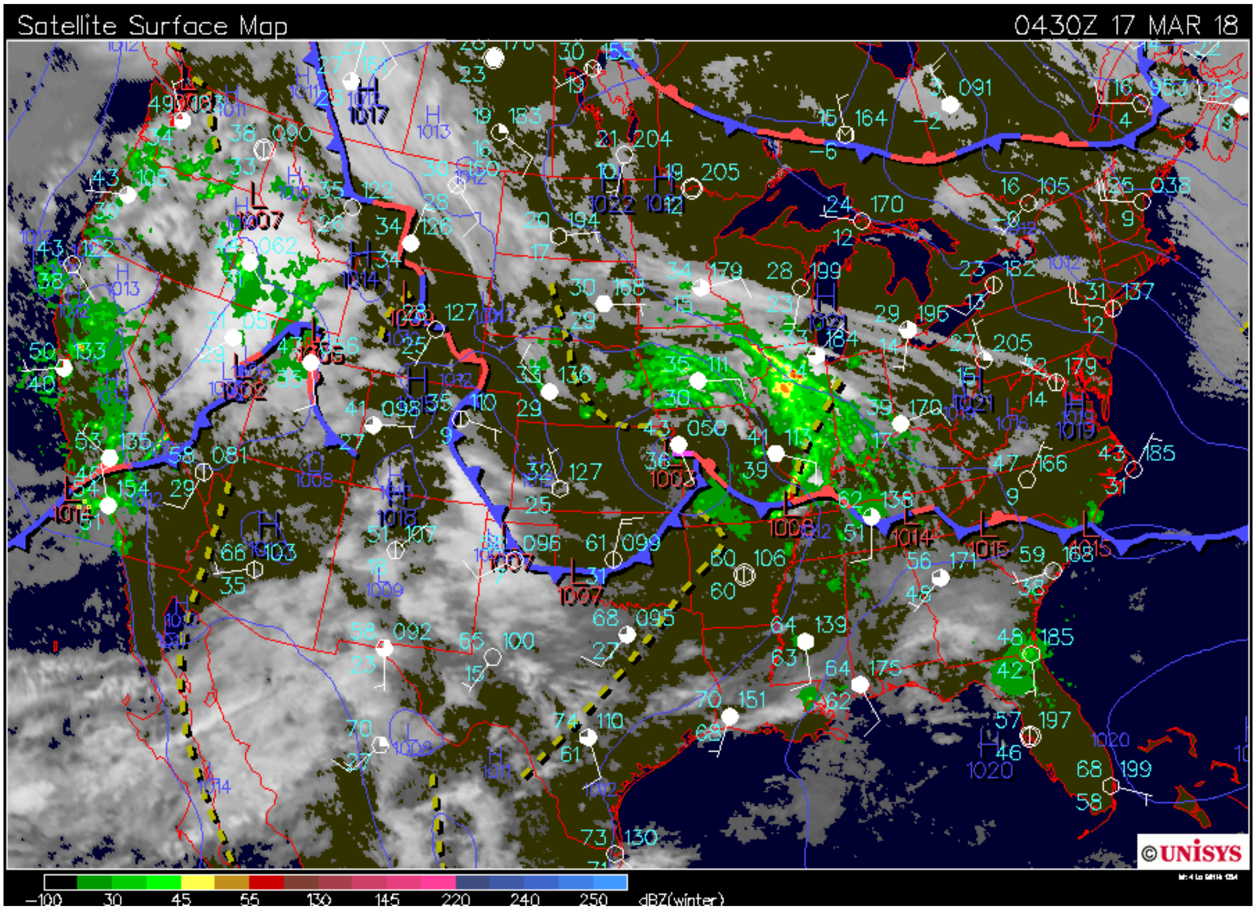

Fig. 17. As in Fig. 6, but at 0430 UTC on 17 March 2018, near the start of IOP 4.

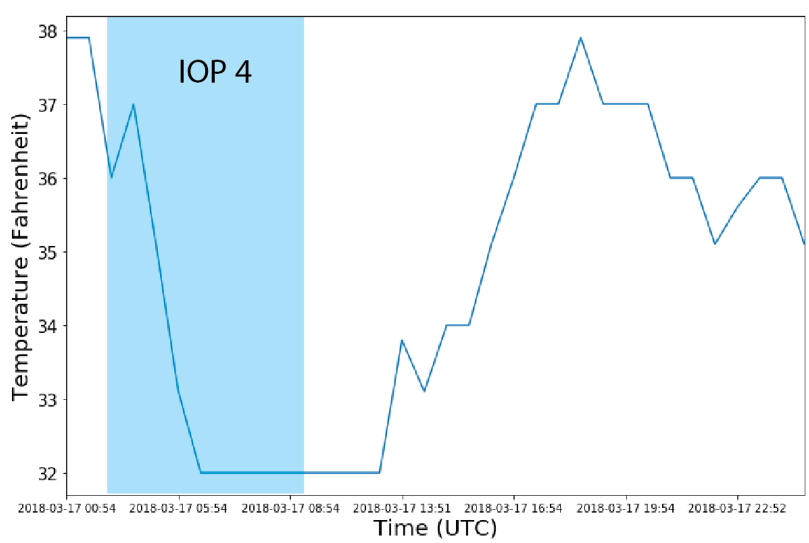

Fig. 18. Surface temperature (in °F) at the Lafayette, Indiana ASOS station on 17 March 2018. The period of IOP 4 (0200 - 0900 UTC) is shaded in light blue. Base image courtesy M. Sharma.

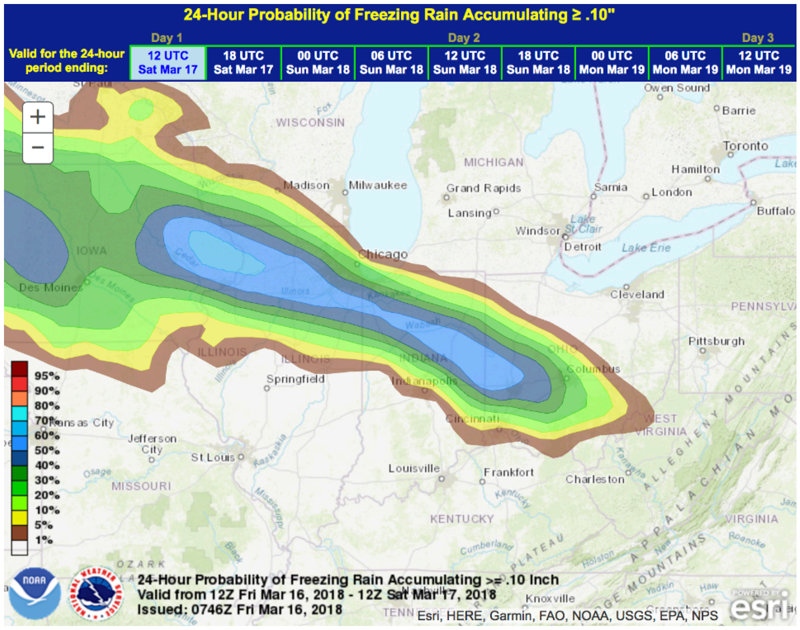

Fig. 18. Weather Prediction Center forecast of the probability of freezing rain accumulation in excess of 0.1 inches (2.5 mm) in the 24 hours preceding 1200 UTC on Saturday, 17 March 2018.

EAPS 52300 student M. Sharma generated QVPs from the 6° DOW PPIs (Fig. 19), revealing fluctuations of up to 500 m in the top and bottom heights of the melting layer over the ACRE site. Although ice glaze accumulated on the DOW and on the other instruments, no sleet was observed at ACRE, nor was a refreezing signature (Kumjian et al. 2013) conclusively identified in the QVPs. Attenuation and differential attenuation were observed above the melting layer during the heaviest precipitation at 0630 UTC (Fig. 19b).

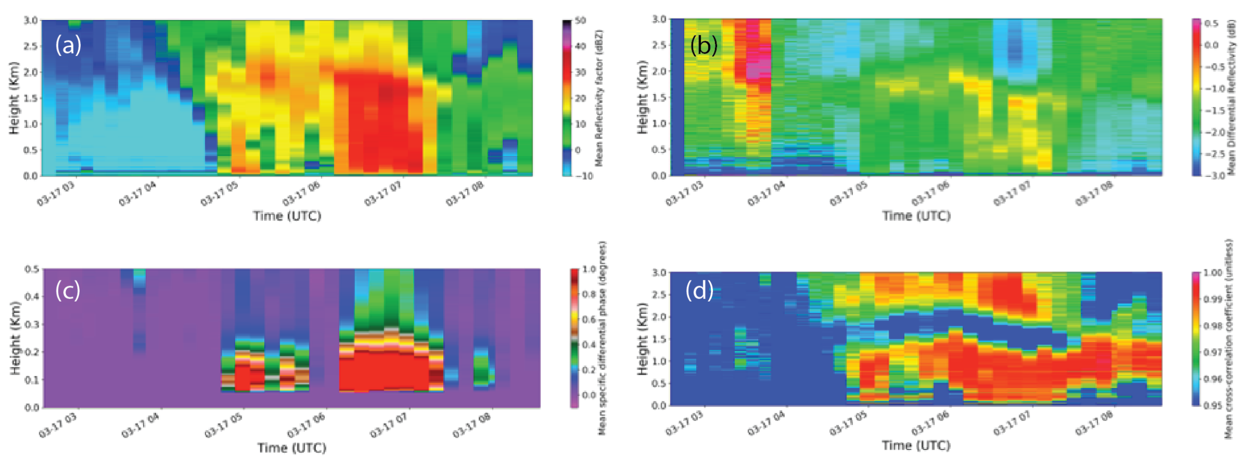

Fig. 19. QVPs of the DOW observations of (a) reflectivity (in dBZ), (b) ZDR (in dB), (c) specific differential phase (in deg km^{-1}), and (d) cross-correlation coefficient (unitless) over the ACRE site from 0230 UTC to 0850 UTC on 17 March 2018. Note that the height scale in panel (c) differs from that in the other three panels, in that it is confined to the lowest 500 m. Courtesy of M. Sharma.

b. DOW demonstration deployments on Purdue campus

The DOW was displayed on Purdue campus on 5, 6, and 7 March 2018. The DOW was parked in a high foot-traffic area near Purdue's iconic Engineering Mall (Figs. 1, 20), and attracted a great deal of attention from passersby.

Fig. 20. Purdue students inspect DOW 7 during its on-campus deployment on 5 March 2018. Photo courtesy of Logan Judy.

EAPS classes were invited to tour the DOW and ask questions of the CSWR staff and class participants. Classes that visited included EAPS 13800: Thunderstorms and Tornadoes (96 students, Fig. 1), EAPS 43100: Synoptic Laboratory I (50 students), EAPS 434: Weather Analysis and Forecasting (12 students), and EAPS 53200: Atmospheric Physics I (12 students). Numerous passersby also introduced themselves to the participants and asked questions. In total, **approximately 80 visitors toured DOW during the three on-campus deployments**. At least one-third were female, and five were from underrepresented minority groups.

c. Visit by Dr. Karen Kosiba

Dr. Karen Kosiba, an atmospheric scientist at CSWR and an alumna of Purdue University EAPS (Ph.D. 2009) visited the department on 26 and 27 February 2018. Dr. Kosiba is a well-known high level member of CSWR staff, with national recognition from her role on the Discovery Channel "Storm Chasers" television show. The visit was designed to allow Dr. Kosiba to reconnect with her former mentors and peers, and to inspire a new generation of students as a role model for women in STEM. During Dr. Kosiba's visit, for which the PI served as host, she had an informal lunch with six graduate students (Fig. 21a), and delivered a seminar entitled "**DOW discoveries: What we are learning about tornadoes, hurricanes and other high impact mesoscale phenomena**" to a mixed audience of about 25 faculty, graduate students, and undergraduate students (Fig. 21b). One class (EAPS 53200: Atmospheric Physics I) was specifically excused from lecture to attend Dr. Kosiba's seminar. Afterward, several female students approached and spoke to Dr. Kosiba individually (Fig. 21c). Dr. Kosiba also had individual meetings with several Purdue EAPS faculty and graduate students during her visit (e.g., Fig. 21d).

Fig. 21. Images from Dr. Karen Kosiba's visit to Purdue EAPS on 26 February 2018.

5. Outreach activities

Mr. Steven Smith, EAPS outreach coordinator, facilitated multiple public outreach events during this deployment, during which more than 500 people came in contact with the DOW. Unfortunately, owing to statewide mandatory standardized testing during Week 2 of the deployment and spring break during Week 3, no public schools accepted our offer of an on-site demonstration of the DOW. Instead, most of the public outreach effort was concentrated in a single, day-long event at a local science museum, described in the next section.

a. GLOBE Citizen Science Day at Imagination Station, Lafayette, Indiana

Mr. Smith, the regional representative of the Global Learning and Observations to Benefit the Environment (GLOBE) Program, arranged for a public demonstration of the DOW at Imagination Station, a science museum in Lafayette, Indiana targeting elementary school-age children. The DOW was the headlining attraction at a GLOBE-themed event entitled, "Disasters Happen: Are You Ready?" (Fig. 22). This event was promoted publicly on Imagination Station's social media accounts (link) and through flyers distributed in day care centers and public schools.

Fig. 22. Flyer / web graphic promoting the 10 March 2018 GLOBE "Disasters Happen" citizen science event. Note the headline billing of the DOW.

The DOW, situated in the parking lot at Imagination Station (Fig. 23), served as a first stop for many of the visitors arriving for the event. One CSWR staff member (A. Gilliland), an EAPS graduate student (D. Reano), and the PI allowed members of the public to climb inside the DOW (Figs. 24 and 25), answered their questions, and distributed DOW stickers and bookmarks. Imagination Station board president P. Cardella reported that **468 people attended "Disasters Happen,"** and the PI estimates at least 150 of these visitors climbed inside the DOW in groups of three to five. Many visitors arrived in family groups, with visitors ranging in age from infant to 87 years old. One family reported having driven more than 70 miles just to see the DOW.

Fig. 23. Visitors queue to climb inside the DOW during the “Disasters Happen” outreach event at Imagination Station in Lafayette, Indiana on 10 March 2018. Photo courtesy of Logan Judy.

Fig. 24. Keagan Howells, age 15, sits in the operator's seat of the DOW. Photo courtesy of Jefferson Howells.

Fig. 25. Three young children watch animated loops of DOW hurricane and tornado data inside the DOW. Photo courtesy of Logan Judy.

b. Media coverage

The EAPS department promoted the educational deployment and outreach events associated with it, including an internet news story (Fig. 26) and video interview with the PI. The PI and the EAPS department used their respective Twitter accounts (@tornatrix and @PurdueEAPS) to keep followers up to date on any scheduling changes to the demonstration times and locations.

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Doppler-on-Wheels to Bring Education, Outreach to EAPS

02-27-2018

Writer(s): Logan Judy

A Doppler-on-Wheels is coming to campus, and it is bringing an EAPS alumna with it.

An expert in severe storms research, Dr. Robin Tanamachi understands the importance of connecting students with real world instruments. One of the instruments that is necessary for instruction in atmospheric science is a Doppler-on-Wheels (DOW) mobile radar. Getting instruments in the hands of students can be difficult, but Dr. Tanamachi had an idea: An educational deployment from the National Science Foundation.

"I thought it would be good for students to have a live demonstration by an actual Doppler-on-wheels radar," she said. "Many of them have heard of it, so this deployment is meant to connect them to the instrument and see concepts we've learned in class, in real life."

Fig. 26. Screen shot of part of the EAPS news release announcing the educational deployment, the visit by Dr. Kosiba, and the "Disasters Happen" event. The full news release can be found at http://www.eaps.purdue.edu/news/articles/2018/dow.html.

A local TV news channel, WLFI-18 in West Lafayette, Indiana, broadcast a one-minute segment about the "Disasters Happen" event at Imagination station on 10 March 2018. The DOW can be seen prominently throughout the piece, and the transcript makes mention of the NSF-sponsored educational deployment.

c. Individual tours

The CSWR staff facilitated a private tour of the DOW for a high school student who contacted the PI saying he could not attend the Imagination Station event owing to college entrance examinations the same day. This student and a family member traveled across the state to meet with CSWR staff and one of the Radar Meteorology students on 3 March 2018. He expressed gratitude for the opportunity.

Concluding remarks

Overall, we regard this DOW educational deployment as a success, with approximately 100 Purdue students impacted, and more than 500 individual contacts with the DOW. The EAPS 52300 students all gained valuable hands-on experience designing and carrying out a scientific observing mission using the DOW, and analyzing the data afterward. Dr. Karen Kosiba's visit to EAPS made a clear positive impression on many female students. Students' reactions to the DOW were overwhelmingly positive. EAPS reaffirmed its close relationships with the Department of Agronomy and Imagination Station through this project. The PI, a junior faculty member at an R1 institution, gained valuable teaching experience and positive media exposure as a result of this deployment.

Written feedback from EAPS 52300 students:

- "The DOW7 tutorial is of great help for understanding and analyzing the radar observations, as we can be aware of the potential errors exhibit in the algorithms or scans. Through processing the data collected by DOW during the PurRad 2018 IoPs, I am getting familiar with the Python-based software for radar data. I learned the approaches to identify melting layer and refreezing features, and how to increase the accuracy of HCA. The radar class with DOW benefits my future research on Hurricane landfall where radar data could provide us insight information on hurricane wind fields." -- J. Chen, EAPS graduate student
- "Regarding my experience with DOW: I believe I was fortunate enough to have worked with DOW radar just when I am starting with my research on severe storms. A radar meteorology class would have been incomplete if I would not have got a chance to do hands-on work with actual radar and analyzing the data. The whole learning experience was enlightening and helped in grasping the intricate technical details related to radar operations. I am highly thankful to my instructor, Dr. Robin Tanamachi and the CSWR folks to have made this educational deployment possible." -- M. Sharma, EAPS graduate student
- "Since I have operated mobile radar before and have the experience, it may have impacted me a little less than somebody operating a mobile radar for the first time. However, working with the radar definitely helps to see how different scanning strategies allows us to see how it impacts observations in real time. It allows us to apply concepts that we learn in class out in the field which is extremely beneficial to those are learn best with hands-on activities." -- P. Saunders, EAPS graduate student

Lessons learned

- <u>Fast data turnaround:</u> It was extremely beneficial to have the IOP data turned around to the PI within about 24 hours of collection, as she was able to quickly integrate it into EAPS 52300 labs. The CSWR staff who accompanied the DOW were highly competent at quick deployment, as well as processing and organizing the data, which made the PI's job of incorporating it into lessons much easier. We strongly encourage NSF to provide support for CSWR staff members to accompany the DOW on each educational deployment to provide these services.

- Deployment timing: As mentioned in the outreach section, the timing of the deployment (early March) negatively impacted our ability to make local school visits, as it conflicted with Indiana standardized testing, as well as spring break at many primary and secondary schools. Any future repeats of the PurRad deployment will likely be requested 1-2 weeks later in the semester relative to spring break in order to avoid similar scheduling issues.
- Accessibility: During the “Disasters Happen” event, at least one physically disabled person was not able to climb into the DOW, and therefore missed out on part of the experience. At future public outreach events, it is suggested that accommodations be made (perhaps in the form of a temporary set of stairs or elevator) for those who may have difficulty physically getting into and out of the DOW.
- Assessment: Personal contacts and anecdotal written remarks were our principal metric for assessing this deployment. Future repeats of PurRad will incorporate more formal assessment to quantify knowledge gained and the educational impact of the deployment. Additional written feedback will also be gathered from Purdue students enrolled in EAPS courses other than Radar Meteorology.
- Soundings: It was highly beneficial to have coordinated local soundings from Purdue during each IOP, as the nearest operational sounding site is 230 km from Purdue and often not representative of conditions at Purdue. Representative soundings are critical to the accuracy of the hydrometeor classification algorithm, particularly in cases of phase change. The PI will work to ensure that the EAPS sounding equipment is functioning and available during future PurRad deployments, and that all students are appropriately trained on its safe operation.

Additional analysis of the PurRad IOPs is planned, and a manuscript about PurRad observations is currently in preparation for a refereed journal, with the PI as lead author and all four Radar Meteorology students as coauthors, enhancing their respective careers. The PI also plans to include her lessons learned from this deployment in several professional presentations. The PI plans to request another educational deployment when EAPS 52300 is taught again at Purdue University in Spring 2020.

Acknowledgments

The PI gratefully acknowledges the energetic assistance of CSWR staff members Alycia Gilliland and Maiana Hanshaw during this deployment. Ms. Gilliland, in particular, played a critical role in the success of our four IOPs, driving the DOW to the deployment site, leveling the truck, configuring the computer array, and instructing the students on the safe operation of the radar.

Purdue University’s College of Science and Spirit EMS sponsored the “Disasters Happen” event, providing free admission to the Imagination Station visitors. Steven Smith (EAPS) coordinated EAPS departmental participation. Phil Cardella organized the event and tracked the number of visitors.

We gratefully acknowledge James Beatty, ACRE superintendent, and Jason Burns, director of the ICSC, for allowing the DOW to park in the ICSC high bay during this educational deployment, and arranging access to the facility for the participants.

Logan Judy (EAPS) handled media outreach and supplied several of the photographs in this report. EAPS professors Ernie Agee, Mike Baldwin, Dan Dawson, Dan Chavas, and Harshvardan created activities for their respective classes that were centered on the DOW.

Many of the figures in this report were created using the open source software Py-ART (Helmus and Collis 2016). Scott Collis, Zach Sherman, Robert Jackson, and Mike Picel supported the EAPS 52300 participants in its use.

Last, but not least, we thank the students of Purdue for their enthusiastic participation in this educational deployment. Boiler up!

References

Besic, N., J. Figueras i Ventura, J. Grazioli, M. Gabella, U. Germann, and A. Berne, 2016: Hydrometeor classification through statistical clustering of polarimetric radar measurements: a semi-supervised approach. *Atmos. Meas. Tech.*, **9**, 4425-4445, doi:10.5194/amt-9-4425-2016.

Dixon, M., W.-C. Lee, B. Rilling, C. Burghart, and J. Van Andel, 2013: CfRadial Data File Format: Proposed CF-compliant netCDF Format for Moments Data for RADAR and LIDAR in Radial Coordinates. National Center for Atmospheric Research, Boulder, Colorado, 66 pp. https://ral.ucar.edu/projects/titan/docs/radial_formats/CfRadialDoc.pdf

Gorgucci, E., G. Scarchilli, and V. Chandrasekar, 1999: A procedure to calibrate multiparameter weather radar using properties of the rain medium. IEEE Trans. Geosci. Remote Sens., 37, 269-276, doi:10.1109/36.739161.

Helmus, J. J., and S. Collis, 2016: The Python ARM Radar Toolkit (Py-ART), a library for working with weather radar data in the Python programming language. *Journal of Open Research Software*, **4**, e25, doi:10.5334/jors.119.

Kumjian, M. R., 2013: Principles and applications of dual-polarization weather radar. Part II: Warm- and cold-season applications. *J. Operational Meteor.*, **1**, 243–264, doi:http://dx.doi.org/10.15191/nwajom.2013.0120.

Kumjian, M. R., A. V. Ryzhkov, H. D. Reeves, and T. J. Schuur, 2013: A dual-polarization radar signature of hydrometeor refreezing in winter storms. *J. Climate Appl. Meteor.*, **52,** 2549-2566, doi:10.1175/jamc-d-12-0311.1

Matsuo, T., and Y. Sasyo, 1981: Non-Melting Phenomena of Snowflakes Observed in Subsaturated Air below Freezing Level. *J. Meteor. Soc. Japan*, **59,** 26-32, doi:10.2151/jmsj1965.59.1_26.

National Center for Atmospheric Research, cited 2016: solo3. [Available online at https://www.eol.ucar.edu/software/solo3.]

National Research Council, 2000: How People Learn: Brain, Mind, Experience, and School: Expanded Edition. 2 ed. National Academies Press, 384 pp.

National Research Council, 2017: Undergraduate Research Experiences for STEM Students: Successes, Challenges, and Opportunities. National Academies Press, 279 pp.

Ryzhkov, A., P. Zhang, H. Reeves, M. Kumjian, T. Tschallener, S. Trömel, and C. Simmer, 2016: Quasi-vertical profiles—A new way to look at polarimetric radar data. *J. Atmos. Oceanic Technol.*, **33,** 551-562, doi:10.1175/JTECH-D-15-0020.1.