PSU-DROPS:

Penn State University – Dual-pol Radar for Outreach and Precipitation Studies

Final Report

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0. Summary

The polarimetric Doppler on Wheels 7 (DOW7) visited Penn State University's University Park campus from 29 September—10 October 2014 for the Penn State University Dual-pol Radar for Outreach and Precipitation Studies (PSU-DROPS) project. PSU-DROPS was made possible by an Educational Deployment grant sponsored by the National Science Foundation. During PSU-DROPS, students from the Mesoscale Meteorology (METEO 414; 9 students) and Radar Meteorology (METEO 434; 17 students) courses received training on radar operation, designed their own scanning strategies, and went into the field to execute their scanning strategies during precipitation events. Additionally, DOW7 was part of numerous outreach efforts at local schools and community events.

1. Introduction

The nationwide upgrade of the Weather Surveillance Radar 1988-Doppler (WSR-88D) network to dual-polarization capabilities has added a wealth of new information for use by operational and research meteorologists. The complexity of these new data necessitates a solid understanding of the fundamentals of radar technology, mesoscale meteorology, and cloud physics. The meteorology department at Penn State University (PSU) already has an outstanding Mesoscale Meteorology course (METEO 414), taught by two of the leading researchers in the field (Dr. Yvette Richardson and Dr. Paul Markowski). After a several-year hiatus, the Radar Meteorology course was re-introduced and re-vamped this year, taught by Dr. Matthew Kumjian (METEO 434). The new course has a strong emphasis on dual-polarization principles and applications. Together, METEO 414 and 434 strive to arm PSU graduates with the knowledge and skills needed to have successful careers in the public, private, or academic sectors.

Previously, two DOW radars (DOW2 and DOW3) participated in the Pennsylvania Area Mobile Radar Experiment (PAMREX, Richardson et al. 2007), funded by the PSU College of Earth and Mineral Sciences in collaboration with the Center for Severe Weather Research (CSWR). The goal of PAMREX was to collect dual-Doppler data in mesoscale phenomena during the fall semester, with analyses carried out during the spring semester. The experiment was very successful, resulting in a BAMS article (Richardson et al. 2007) and a student-led conference paper and poster at the 5th Annual AMS Student Conference (Chipriano et al. 2006). Student reviews indicated a high level of perceived benefit and enthusiasm for the experiment and associated courses.

These previous successes and the timing of the new radar course served as the impetus for Drs. Kumjian and Richardson to host another visit from one of CSWR's DOWs. This project, called "PSU Dual-pol Radar for Outreach and Precipitation Studies" (PSU-DROPS), took place from 29 September—10 October 2014. PSU-DROPS differs from PAMREX by focusing more on the new dual-polarization capability of the DOW radars. The focus on dual-polarization interpretation is appropriate given the probability our students will use similar data from the newly upgraded WSR-88D network in their careers. The 2014 PSU-DROPS project, including outreach, educational, and data collection activities, was an enormous success, as detailed below.

2. Education and Deployments

PSU-DROPS was designed for students enrolled in Mesoscale Meteorology (METEO 414; 8 students) and Radar Meteorology (METEO 434; 17 students) at PSU. Leading up to the arrival of DOW7, students in both classes learned the fundamentals of radar technology and about different types of scanning strategies (e.g., plan-position indicator or PPI scans, range-height indicator or RHI scans, tradeoffs associated with setting the pulse repetition time, etc.). Students were tasked with designing an experimental scanning strategy technique for use during their deployments.

Upon the arrival of DOW7, students broke into smaller groups and received training sessions from Mr. Traeger Meyer (CSWR) on how to operate the radar. The training sessions were held on PSU's University Park campus near the building that houses the meteorology department. Students were encouraged to take notes and pictures during the training session.

In preparation for the deployments, students in both classes filled out an online "Doodle Poll" to indicate their availability for 2-hour shifts throughout the week. Drs. Richardson and Kumjian used this poll to assign shifts to the students up to about 2 days in advance, based on forecasts of precipitation in central Pennsylvania. Students were assigned shifts and instructions via email, with updates leading up to the deployment itself.

Fig. 1: Photograph of students in the 5:00 – 7:00 pm group during IOP2. From left to right: Zhiyuan Jiang, Ashley Ellis, Helen Guza, and Emily Huang.

Students deployed for 2-hour shifts in teams of about 4-5. Figure 1 is a photograph from one of the deployments, courtesy of Ashley Ellis. (It turns out that such "selfies" were common during deployments, as students were actively sharing their experiences on social media.) During their deployments, the students had to work as a team to implement a scanning strategy that targeted the specific type of meteorological phenomenon of interest. Though Mr. Meyer and Drs. Richardson and Kumjian provided some guidance and suggestions, the ultimate decisions were left to the students. In this way, the students were able to see the consequences of their scanning decisions first hand.

There were three intensive observation periods (IOPs) during PSU-DROPS: 30 September 2014 (from 18:45—00:00 UTC on 1 October); 3 October 2014 (from about 20:00—04:22 UTC on 4 October); and 6 October 2014 (about 23:50—04:15 UTC on 7 October). The students' deployment schedule is provided in Table 1. These corresponded to the first three precipitation events encountered during the PSU-DROPS deployment period. Unfortunately, the radar antenna jammed during the third IOP, and thus an additional precipitation event later in Week 2 was not sampled. For each deployment,

DOW7 was located on the PSU Agricultural Research site about 10.2 km southwest of campus (Fig. 2; precise location is at 40.7214° N, 77.9371° W). This site afforded clear views to the north through southwest, relatively free from blockage within the valley.

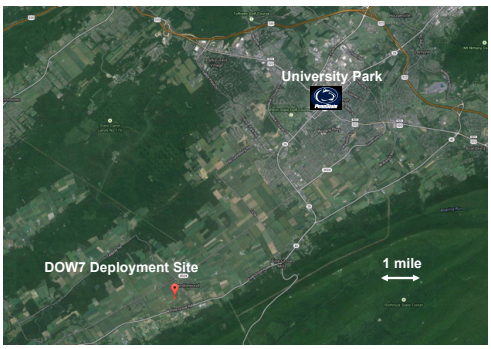

Fig. 2: Map of the DOW7 deployment site (red pin) and vicinity, with the PSU University Park campus indicated by the logo. Note the scale in the bottom right. Map is courtesy of Google.

IOP1 sampled a series of convective storms as they moved through central Pennsylvania in association with a front (Fig. 3). Some of the storms were marginally severe, with reports of accumulations of small hail about ~16 km northeast of State College. This dataset includes such features as three-body scattering signatures (TBSSs), differential reflectivity (Z_{DR}) columns, depolarization streaks, large amounts of attenuation and differential attenuation, the development of a Z_{DR} arc associated with the rapid intensification of the low-level vortex, etc. An RHI scan through the convective storm is shown in Fig. 4, constructed by a graduate student (R. Schrom) in the METEO 434 class. A PPI of the same case at a different time is shown in Fig. 5, including annotations pointing out features of interest that were discussed in class.

IOP1 (Tuesday 30 September 2014)	
2:00 pm – 4:00 pm EST	Brian Adams, Eli Dennis, Brad Guay, and Stephen Hopkins
4:00 pm – 6:00 pm EST	Brittany Recker, Anna Schneider, Matt Flournoy, and Lee Dunnavan
6:00 pm – 8:00 pm EST	Dana Tobin, Alex Sokolowsky, Robert Schrom
IOP2 (Friday, 3 October 2014)	
3:00 pm – 5:00 pm EST	Bob Mayo, Ben Luton, Bryant Sell
5:00 pm – 7:00 pm EST	Emily Huang, Zhiyuan Jiang, Helen Guza, and Ashley Ellis
7:00 pm – 9:00 pm EST	Stefano DiPietro, Jillian Bohenek, Eric Wendoloski, Giovanni Jimenez
9:00 pm – 11:00 pm EST	Branden Katona, Matt Brothers, and Daniel Eipper
IOP3 (Monday, 6 October 2014)	
8:00 – 10:00 pm EST	Brad Guay, Eli Dennis, Stephen Hopkins, and Eric Donten
10:00 pm – 12:00 am EST	Brittany Recker, Anna Schneider, Matt Flournoy, and Lee Dunnavan

Table 1: Schedule of deployments for the first three IOPs.

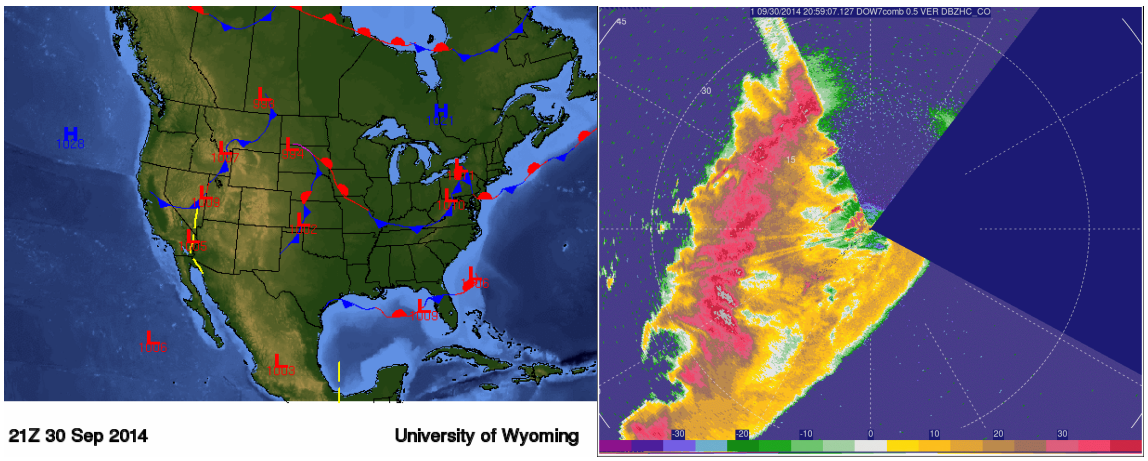

Fig. 3. Surface map near the time of IOP1 (left) and reflectivity factor at horizontal polarization (Z_H) from DOW7 (right).

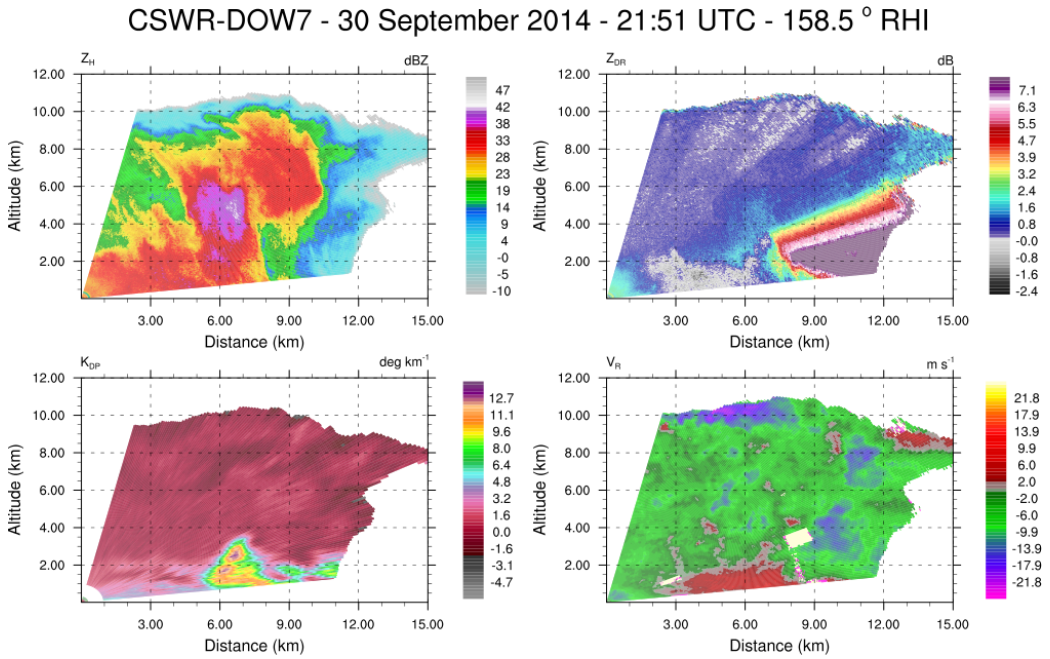

Fig. 4: RHI taken through the convective storm on 30 September 2014, at 2151 UTC. Fields shown are Z_H (top left), Z_{DR} x -1 (top right), specific differential phase (K_{DP}; bottom left), and Doppler velocity (V_r; bottom right). Figure provided by METEO 434 student Robert Schrom.

The second two IOPs offered less convective weather, as the precipitation was more widespread and weaker. However, the students were able to see examples of fascinating microphysical structure in these events associated with the pristine ice crystals (Fig. 6), the melting layer (Fig. 7), convective generating cells (Fig. 7), and even a textbook example of raindrop size sorting within a rain shaft embedded in vertical shear (Fig. 8; compare to Fig. 6 in Kumjian and Ryzhkov 2012).

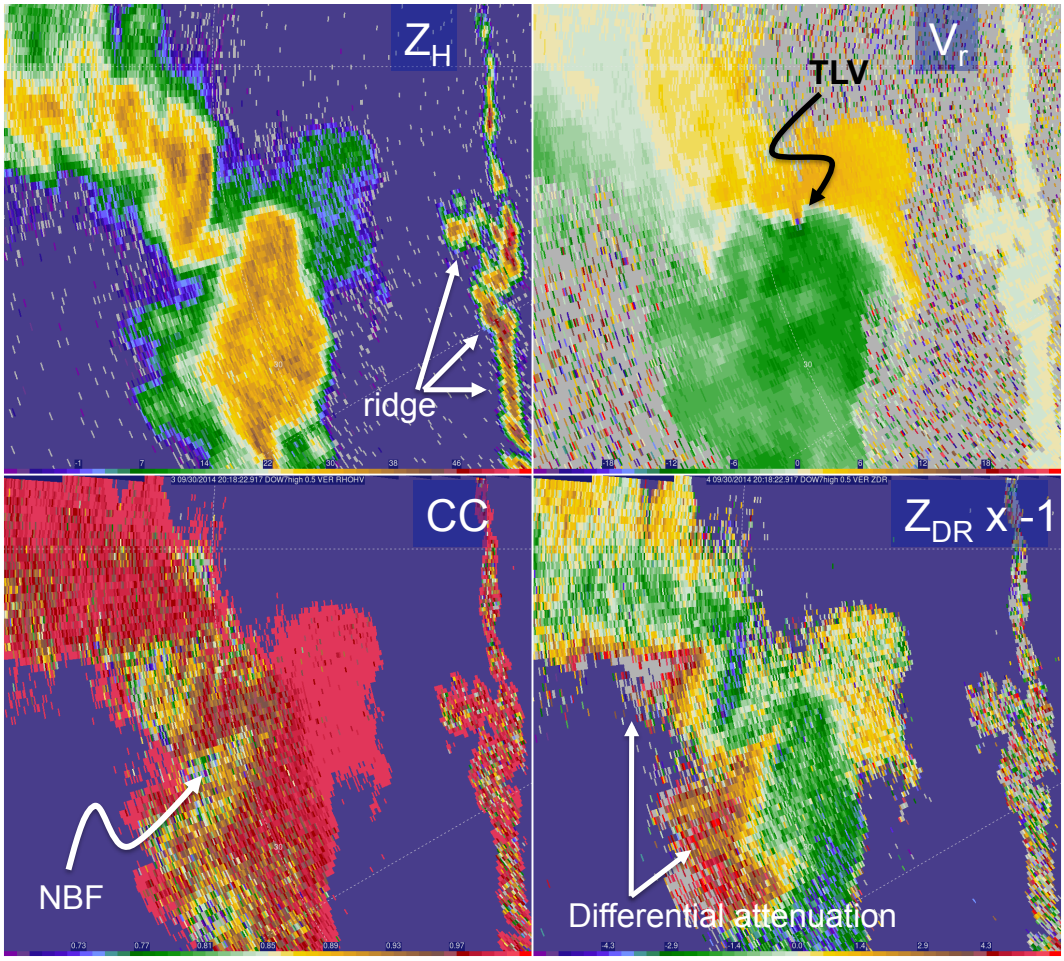

Fig. 5: Annotated screencapture from SOLO3 showing Z_H (top left), V_r (top right), correlation coefficient CC (lower left), and Z_{DR} x -1 (bottom right). Features of interest shown in class are the ridge, the tornado-like vortex (TLV), nonuniform beam filling (NBF) induced biases in CC, and differential attenuation in Z_{DR}.

Throughout the period of PSU-DROPS (and continuing to the present), examples of DOW7 data the students collected were used as examples in both classes. In METEO 414, students learned to use SOLO3 to peruse the data, and examined a small-scale, intense cyclonic vortex signature observed during the first IOP (Fig. 5). They also evaluated the low-level wind profile. The same data were shown in METEO 434, during the weekly radar discussion (in which students provide examples from the WSR-88D radar network for a brief presentation at the start of class). Notable polarimetric signatures and artifacts including biases in correlation coefficient (CC) owing to nonuniform beam filling, depolarization streaks in Z_{DR}, aliasing of Φ_{DP}, and differential attenuation were also discussed so far in METEO 434. An upcoming class will feature a TBSS in Z_H that was observed during IOP1. Much more of the data will be used in the classes to show examples of mesoscale and dual-polarization applications in upcoming lectures, such as Z_{DR} columns, dendritic growth zones, the melting layer, Kelvin-Helmholtz waves, topographic waves, etc.

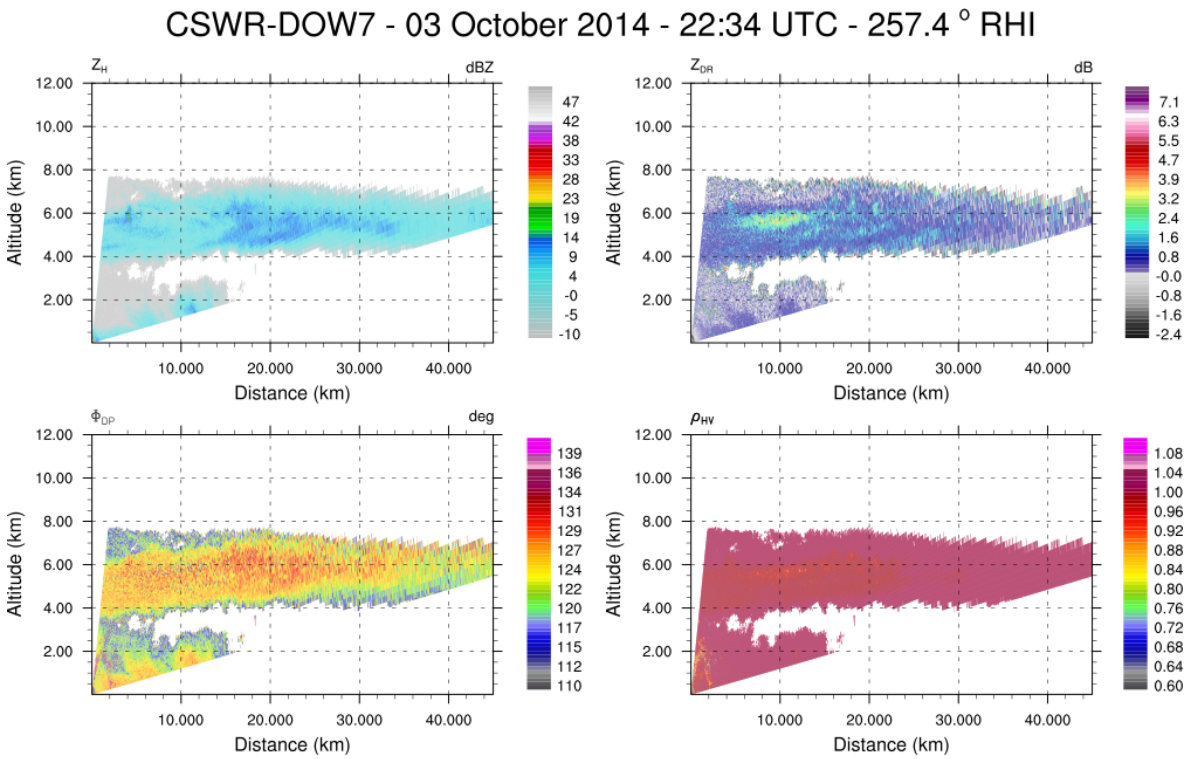

Fig. 6: RHIs of Z_H (top left), Z_{DR} (top right), differential phase shift Φ_{DP} (bottom left), and CC (bottom right) from 3 October 2014 at about 2234 UTC. The enhancements of Z_{DR}, reduction in CC, and increase in Φ_{DP} indicate pristine ice crystals in this cloud. Courtesy of Robert Schrom.

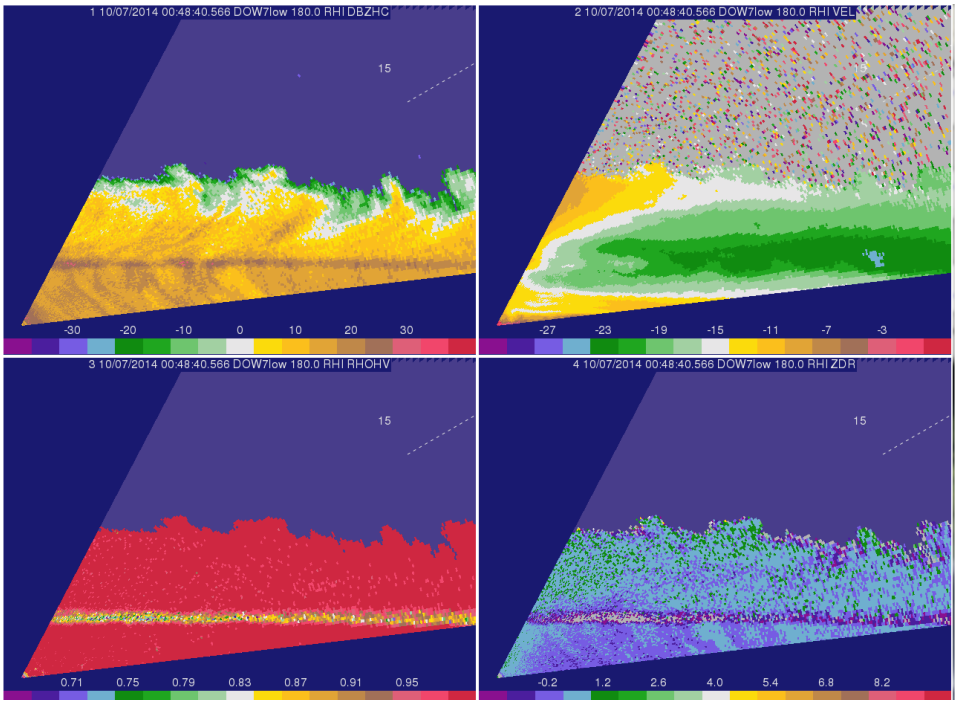

Figure 7: RHIs of Z_H (top left), V_r (top right), CC (bottom left), and Z_{DR} (bottom right) at about 00:48 UTC 7 October 2014. Evident near the top of the echo are convective generating cells. The melting layer bright band is also clearly visible in the middle of the echo, as are the sheared fallstreaks. Courtesy of Daniel Eipper, graduate student in METEO 434.

As part of their METEO 414 and 434 class, students will be analyzing the data they collected during the DOW7 deployments. The focus in METEO 434 will be on analyzing the dual-polarization signatures to better understand the microphysical structure and ongoing microphysical processes in the storms. In METEO 414, they will focus on the kinematic and mesoscale structure and evolution of the storms. After learning to peruse the data with SOLO3, students have already turned in a research prospectus describing the topic they want to explore for their final paper and presentation. In the coming weeks, the students will perform a quantitative analysis of the data to explore their chosen topic, ultimately culminating in an AMS conference-style paper and presentation. Some of the top student presentations may be encouraged to submit their studies to the upcoming AMS Radar Conference, availability of funding permitting.

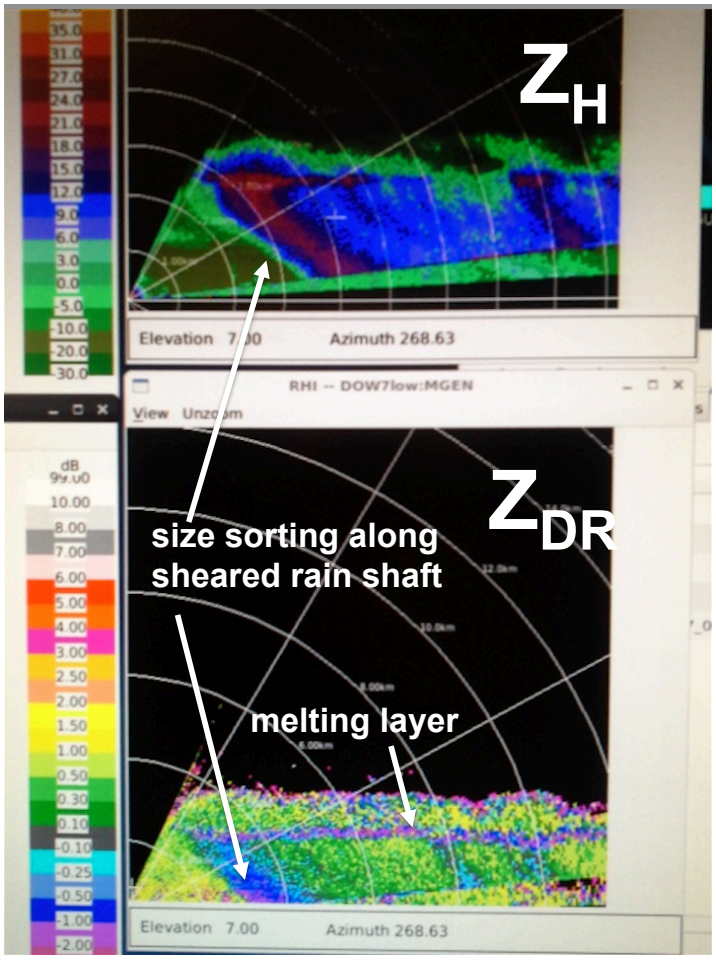

Fig. 8: Cell phone camera photograph of the real-time display screen from DOW IOP3, showing an RHI of Z_H (top) and Z_{DR} (bottom). The example clearly shows the melting layer bright band, as well as size sorting in the sheared rain shaft at closer ranges. Courtesy of Brittany Recker, graduate student in METEO 434.

3. Outreach Activities

PSU-DROPS featured a vibrant outreach program during the two weeks DOW7 was at University Park. This included community events, visits to local K-12 schools, tours for PSU classes, a visit to the local Boy Scout troop, and local media coverage. They are detailed below in each subsection. A total of ***nearly 800 people directly experienced the DOW*** by visiting inside the cab or discussing the tornado pod. A larger number of people interacted directly with PSU faculty and students at the outreach events and/or indirectly through the media coverage.

a. PSU Storm Chase Team and PSUBAMS Tour

The first outreach event occurred the first evening of PSU-DROPS. Members of the PSU Storm Chase Team and the PSU Branch of the American Meteorological Society (PSUBAMS) received a tour of the DOW and learned how it is used to study a variety of high-impact weather events (Fig. 9). The original seminar scheduled for Dr. Wurman was canceled owing to unforeseen travel problems caused by a fire at Chicago's airport. Nonetheless, the event attracted a large turnout of students and was documented on social media outlets (Fig. 10). About **50-60 students** participated in the evening's activity.

Fig. 9: Photograph of some PSU Storm Chase and PSUBAMS students in front of the DOW. Courtesy of Jillian Bohenek.

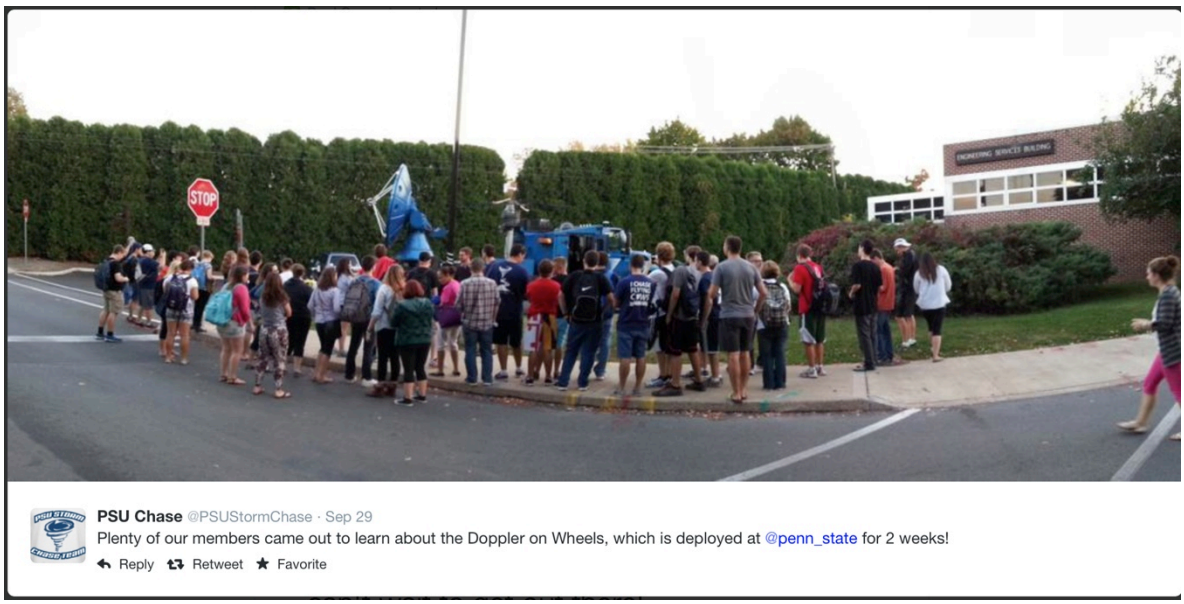

Fig. 10: Screenshot of the PSU Chase Team tweet about the DOW7 visit. A large number of students are gathered in front of the DOW.

b. Mount Nittany Middle School

The first community outreach event was on the second day (Tuesday, 30 September 2014) at Mount Nittany Middle School, located a few miles south of State College (Fig. 11). The event took place between about 9:45 am—1:00 pm EST, during which a total of about **250 middle-school students** visited each of four Science Stations associated with the DOW7. Individual "teams" of students, having 40-50 students, participated for about 25 minutes, with five teams total over the course of the visit.

Fig. 11: Photographs from the Mount Nittany Middle School outreach activity, showing several of the Science Stations. Pictured in the upper left is Dr. Richardson showing students examples of DOW7 data used in research; at right is Dr. Jim Marquis answering questions about the tornado pod.

Students in each team were divided into groups of about 8-10 and rotated through four Science Stations, which each lasted about 5 minutes. The four Science Stations were as follows:

(i) Inside the DOW7 cab, Mr. Meyer showed data examples and explained how we use radar to look at precipitation and storms. The students were able to see the controls and computer screens, and even saw a video of a tornado sampled by the DOW7 during VORTEX2.

Fig. 12: Prop representing a large raindrop used to explain particle oblateness and the basic concepts of dual-polarization to the community.

(ii) Outside of DOW7, in front of the rotating antenna (which was not transmitting!), Dr. Kumjian talked about how the radar works and explained the basic premise of polarimetry, using a prop in the shape of a very large raindrop (Fig. 12) to explain raindrop oblateness. (Nearly every group thought raindrops were "teardrop" shaped.) He described how the radar can be used to "see" different types of precipitation.

(iii) By the CSWR "tornado pod," where PSU graduate students Dana Tobin and Alicia Klees and PSU Research Scientist Dr. Jim Marquis explained the different instruments and what they measure. They also talked about how these pods are placed in the path of oncoming tornadoes and why such measurements are needed so close to the ground.

(iv) At a table next to the pod, where Dr. Richardson showed examples of DOW data being used in scientific research. She showed examples of dual-Doppler analyses of a tornadic supercell sampled by DOW7 during VORTEX2, and explained how the data help us understand what makes tornadoes.

c. State College Downtown Fall Festival: DOW on Display

PSU-DROPS leveraged a popular family activity that occurs annually in downtown State College, known locally as the Fall Festival. This event took place on Saturday, 4 October 2014, from 10:00 am—3:00 pm. The DOW was parked downtown amidst the other family activities, food vendors, games, etc. DOW7 was extremely popular, with over **200 children and parents** getting a chance to sit inside the cab. This does not include the many more who did not go inside the truck but still learned about the DOW7, tornado pod, and PSU Meteorology Department outside by talking with Drs. Richardson and Kumjian and several PSU undergraduate students who were volunteering for the event. Photographs from the event are shown in Fig. (13) below.

Fig. 13: Montage of photographs from the DOW on Display Fall Festival event on 4 October 2014. Photos courtesy of John Balogh (State College citizen), Ashley Ellis (METEO 434 student), and Jillian Bohenek (METEO 434 student).

d. Houserville Elementary School Fall Festival

A day after the Downtown Fall Festival, the Houserville/Lemont Elementary Schools held their own Fall Festival for families of students at the school. The event took place on Sunday 5 October 2014 from 3:30 pm—7:00 pm. Despite the cold and windy weather, **over 100 students** (Fig. 14) and parents braved the brisk conditions to venture into the parking lot and climb inside the DOW7 cab.

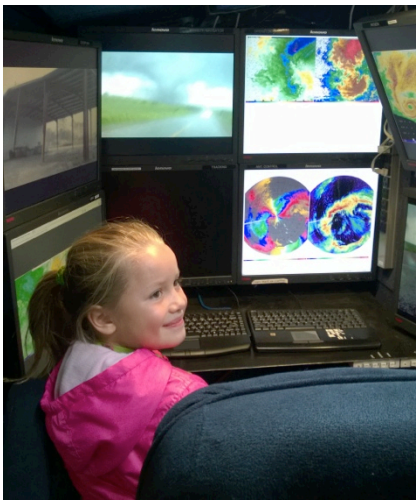

Fig. 14: An elementary school student sits in the operator's chair of DOW7, viewing data and a video of a tornado sampled during VORTEX2.

e. Boy Scout Troop 367

On Tuesday, 7 October 2014 from 7:30 pm—8:30 pm, DOW7 visited a local Boy Scout troop in Lemont. There were two stations set up for the Scouts and their parents: the tornado pod and the DOW. In total, about **10-15 scouts and parents** were present and learned about the radar and tornadoes at the two stations. Drs. Kumjian and Richardson answered questions and talked about the atmospheric sciences with the scouts as part of their "Weather" merit badge. In addition, PSU research scientist and Eagle Scout Dr. Jim Marquis wore his uniform and talked with the scouts

Fig. 15: Eagle Scout and research scientist Dr. Jim Marquis explains the tornado pod to members of the Lemont Boy Scout Troop 367. The DOW7 visit helped them complete a merit badge.

about being a scout and a scientist (Fig. 15). After the troop meeting was adjourned, many of the parents stayed after to continue to ask questions about the field of meteorology and the radar.

f. PSU Class Tours

In addition to the METEO 414 and 434 classes that participated in the data collection efforts with DOW7, tours were provided to a number of other classes offered by the PSU Department of Meteorology. Like some of the outreach activities, larger classes were split into groups to see different stations, including the tornado pod, outside the radar, and inside the cab. PSU graduate students aided Mr. Meyer and Drs. Richardson and Kumjian with the tours. In the case of upper-division classes, tour discussions focused on how radar data could be relevant to that course's particular area of meteorology. For example, the EE/METEO 477 course is an electrical engineering course, so Dr. Kumjian and Mr. Meyer gave more technical descriptions of the electronics and hardware in the tornado pod and in the DOW. In total, **166 students** went on these tours, as summarized in Table 2.

Monday, 29 September 2014	
METEO 436: Radiation and Climate	20
Wednesday, 1 October 2014	
METEO 411: Synoptic Meteorology	23
EE / METEO 477: Remote Sensing	12
Thursday, 2 October 2014	
METEO 300: Fundamentals of Atmospheric Science	46
Friday, 3 October 2014	
METEO 201: Introduction to Weather Analysis	47
Thursday, 9 October 2014	
METEO 440W: Principles of Atmospheric Measurements	18
TOTAL	**166**

Table 2: List of classes participating in the tours of DOW7 and the number of students who experienced tour in each class.

g. Local Media Coverage

To reach a broader audience in Pennsylvania, Drs. Richardson and Kumjian invited local media to participate in covering the outreach and educational activities and/or in doing special-interest segments for their broadcasts. Two regional TV broadcast channels did stories covering the class tours on PSU's University Park campus (WGAL, based in Harrisburg; WTAJ, based in Altoona). Drs. Kumjian and Richardson and several undergraduate and graduate students were interviewed as part of these stories, which were broadcast on their evening news segments and are accessible online:

WTAJ News (Altoona)
http://www.wearecentralpa.com/story/d/story/getting-a-firsthand-look-at-storm-chasing/95148/zd2CezQip06UFmGZPyKOSA

WGAL News (Harrisburg)
http://www.wgal.com/news/firsthand-look-at-lifesaving-weather-equipment/29532458

In addition, the Centre Daily Times newspaper ran a story in their "Focus on Research" section of the paper, which is also accessible online:

Centre Daily Times:
http://www.centredaily.com/2014/10/26/4422295_up-close-and-personal-doppler.html?sp=/99/188/&rh=1

The PSU Meteorology Department students create and produce a show called *Weather or Not* on local public access television (WPSU), which airs weekly. METEO 434 undergraduate student Jillian Bohenek (a double major in Meteorology and Broadcasting) produced a feature story on the DOW7 visit that aired in their weekly *Weather or Not* special during PSU-DROPS. It is archived on YouTube and available at the following link:

https://www.youtube.com/watch?v=aW7WNIrjJNo&feature=youtu.be

Finally, a science blog did a long-form video piece on the DOW, including a more technical description of how the radar works and the types of signals it receives. This science blog is geared toward a more technical crowd. The video and blog can be found at this link:

http://www.johnrleeman.com/2014/10/14/doppler-on-wheels-a-tour-of-a-mobile-radar/

Together, these various media outlets reached a far greater potential population than could realistically see/experience a DOW tour in person. The media stories help reinforce the importance of science, and radar and mesoscale meteorology in particular.

4. Success of PSU-DROPS

a. Instructors' Perspective

Drs. Kumjian and Richardson are extremely pleased with the outcomes of PSU-DROPS, from an educational, outreach, and data collection perspective. Despite the radar antenna problems that cut the deployments short during week 2, the data that were collected in the first three IOPs are among some of the best quality they have seen. The outreach activities were a resounding success, as explained above. The enthusiasm of kids, parents, and teachers at each spot made it a real pleasure to participate in, despite the occasionally long and somewhat cold hours! From an educational perspective, there is nothing that can compare to allowing students to experience first-hand the thrills, frustrations, and feeling of accomplishment that accompanies designing and executing an experiment and analyzing the resulting data.

It is important to note that the CSWR technician Traeger Meyer played a huge role in the successful implementation of PSU-DROPS. Without his dedication, enthusiasm, and good spirit through what must have been a tiring two weeks, they wouldn't have been able to pull off such successes. Mr. Meyer should be commended for his outstanding work and his universal admiration from the students and members of our community.

b. Students' Perspective

Throughout the duration of the project, we received very positive feedback and enthusiasm from the students about their experiences with DOW7 and Mr. Meyer. Some of this is readily seen in the interviews with students in some of the news media interviews accessible above. In addition to their positive reflection during interviews, students have emailed their instructors to express their gratitude and appreciation. For example, the following is an excerpt from an email from Matt Flournoy, a student in METEO 434 to Dr. Kumjian:

> Hi Dr. Kumjian,
>
> Just wanted to say thank you for setting this all up! Working with the DOW was phenomenal.

Others took to social media outlets such as Twitter:

Fig. 16: Screenshot of a METEO 414 student Brad Guay's tweet about learning how to use the DOW.

Still others took to other electronic media formats, including two blog posts by METEO 434 student Ashley Ellis, accessible online at the following links:

http://stormtrackwx.blogspot.com/2014/10/a-quick-update-on-dow-visit-today-was.html

http://stormtrackwx.blogspot.com/2014/10/psudrops-community-outreach-program.html

Examples from Ms. Ellis' blog posts are shown below:

> All in all we had such a fantastic experience on our first official DOW deployment and I was lucky to be paired with a group of enthusiastic people. Dr. Kumjian stopped by to spend some time with us, and so did the new Meteorology department head, David Stensrud, and his wife. There is so much to take away from this experience and we here at Penn State are so lucky to have the opportunity to have hands on experience with the DOW for the next week.

After her experience volunteering with an outreach activity, Ashley writes:

> All-in-all the day was very successful and I felt that the Meteorology department here at Penn State received a lot of positive publicity. It was a lot of fun to be able to teach young and old about the cool

> things we do here in the department, and about how cool this science really is. I was interviewed quickly by a classmate on how I felt about the DOW visit and that was exciting as well! This has been a fantastic week so far!

Taken together, this small sampling of unanimously positive feedback we've received strongly suggests it was a very positive educational experience for the students.

5. Lessons Learned and Closing Remarks

Overall, the PSU-DROPS experiment was a great opportunity for the students in our classes, as well as students across the meteorology department and many members of the State College community. The ability to have an exceptional DOW technician on-site made this project much more manageable for instructors than the previous PAMREX project. We also made better use of enthusiastic student volunteers for the outreach events. We were lucky to have three IOP-worthy precipitation events in the first week of the project and great weather for the tours, allowing us to accomplish our goals within a fairly tight schedule. We are grateful to NSF for providing the educational deployment opportunity.

Fig. 17: Drs. Kumjian and Richardson pose next to DOW7 as students inside prepared for operations during IOP1.

PSU-DROPS:
Penn State University Dual-pol Radar for Outreach and Precipitation Studies

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University Park, PA

For the purposes of education and outreach, the Department of Meteorology at Penn State University (PSU) is requesting a 2-week deployment of one of the dual-polarization Doppler on Wheels (DOW) radars operated by the Center for Severe Weather Research as part of the NSF Lower Atmospheric Observing Facilities. The deployment will be at our University Park campus and at nearby sites from 29 September 2014 through 10 October 2014, though these dates are flexible. The DOW radar and the data it collects will be used for undergraduate and graduate student education as part of our classroom instruction of *Radar Meteorology* (METEO 434) and *Mesoscale Meteorology* (METEO 414) courses. Student-collected data will also be used for projects in these courses. In addition, the DOW radar will be used for outreach, including tours and demonstrations for the university community and State College area K-12 schools. Instructors in at least seven other courses (METEO 003: *Introductory Meteorology*, METEO 005: *Severe and Unusual Weather*, METEO 201: *Introduction to Weather Analysis*, METEO 436: *Radiation and Climate*, METEO 440W: *Principles of Atmospheric Measurements*, METEO 473: *Application of Computers to Meteorology*, and EE/Meteo 477: *Fundamentals of Remote Sensing Systems*) plan to have their students tour the DOW radar during its visit.

Two DOW radars (DOW2 and DOW3) previously participated in the Pennsylvania Area Mobile Radar Experiment (PAMREX, Richardson et al. 2007), funded by the PSU College of Earth and Mineral Sciences in collaboration with the Center for Severe Weather Research. The goal of PAMREX was to collect dual-Doppler data in mesoscale phenomena during the fall semester, with analyses carried out during the spring semester. The experiment was very successful, resulting in a BAMS article (Richardson et al. 2007) and a student-led conference paper and poster at the 5th Annual AMS Student Conference (Chipriano et al. 2006). Student reviews indicated a high level of perceived benefit and enthusiasm for the experiment and associated courses. The current proposed experiment differs from PAMREX by focusing more on the new dual-polarization capability of the DOW radars, although target-of-opportunity dual-Doppler data may be collected with the nearby KCCX WSR-88D radar (e.g., Figure 1). We feel the focus on dual-polarization interpretation is appropriate given the probability our students will use similar data from the newly upgraded WSR-88D network in their careers. Dr. Kumjian is a leading expert in the interpretation of dual-polarization radar data while Dr. Richardson is an expert in dual-Doppler synthesis, ensuring we have the knowledge base to fully exploit the datasets we collect.

The benefits of the proposed DOW radar deployment will be achieved through the successful completion of the following main objectives:

1. Benefit to Education: *Provide undergraduate and graduate students with hands-on experience in planning and executing radar deployments, and in working with and analyzing experimental radar data*.

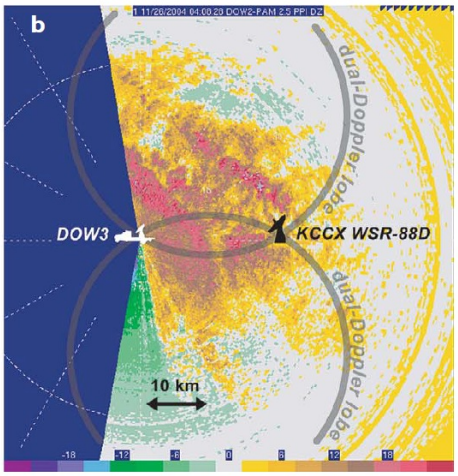

Fig. 1. Lake-effect snow bands on 26 November 2004 as seen by DOW3 at 0408 UTC. The locations of the dual-Doppler lobes between DOW3 and the KCCX WSR-88D radar are overlaid.

The local availability of the DOW radar will provide an invaluable experience for students in the *Radar Meteorology* and *Mesoscale Meteorology* courses at Penn State. After a several year absence, the newly resurrected *Radar Meteorology* course is generating excitement among graduate and undergraduate students. This course will provide students with the fundamentals of what radar is, how it works, and what it tells us about mesoscale meteorological phenomena. In particular, the meaning and interpretation of dual-polarization observations will be a key focus in METEO 434. Having direct access to a polarimetric radar is an outstanding opportunity to reinforce theoretical concepts taught in the classroom with hands-on practice. Students will see first-hand how the radar works, learn how to specify and execute various scanning strategies, and will see in real time the data they are collecting and the impact of their choices for pulse repetition time, pulse length, dwell time, etc. on the quality of the measurements. Further, the data they collect will be recorded for use in a project due at the end of the semester. This project will provide them with the valuable experience of working with and analyzing *unique* experimental radar data that *they themselves collected*. By the end of the course, students will understand how to interpret dual-polarization observations, including identification of different hydrometeor types and important signatures such as those related to microphysical processes (aggregation and melting of snow, collisional breakup and coalescence of raindrops, etc.) and kinematic features (updrafts, downdrafts, wind shear, etc.).

Students in the mesoscale course, METEO 414, which is a co-requisite for METEO 434, will have the chance to observe mesoscale phenomena and analyze the data as part of the laboratory section of the course. Figure 2 shows the climatological number of days with rainfall of at least 0.1" from Sep 20 to Oct 10 since 1894. On average, roughly ¼ of the days met this criterion, and *there were no null years*. Roughly ⅓ of the days had at least a trace of precipitation (not shown), sufficient for the type of study proposed herein. During this time of year, a variety of mesoscale meteorological phenomena can be expected. These include cold frontal rainbands, orographic clouds, and other synoptic-scale stratiform precipitation events with

embedded mesoscale features. In the unlikely event of an anomalous drought and sunny skies, we may target biological scatterers such as insects and birds in the boundary layer.

Any of these phenomena can be targeted for DOW observations, given appropriate scanning strategies. Students will be able to gain valuable experience in optimizing the radar scanning strategies depending on the target of the day. For example, PPI scans with more rapid updates may be desirable in convective storms, whereas slow RHI scans in stratiform rain will produce high-quality dual-polarization measurements amenable to microphysical studies. Students in the mesoscale course will focus on interpreting the morphology of these phenomena, while students in the radar course will focus on interpreting the dual-polarization data and its microphysical implications. Collaboration between the two courses will result in a holistic view of each phenomenon, blending together knowledge of the microphysical and kinematic structures present. This will allow students to have a first-hand look at the important connections and feedbacks between microphysics, thermodynamics, and kinematics in mesoscale phenomena. Such consilience of areas typically treated independently in our field will benefit students pursuing a wide range of careers in meteorology and the atmospheric sciences.

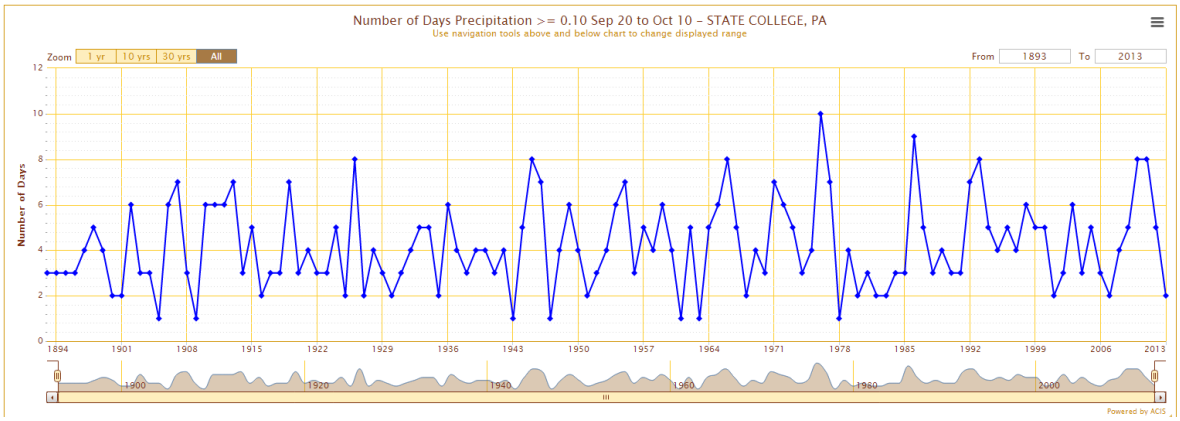

Figure 2. Number of days having precipitation greater than or equal to 0.1" between September 20 and October 10 in State College. (courtesy Paul Knight, Pennsylvania State Climatologist)

2. Benefit to STEM Outreach: *Teach and inspire members of the broader university and State College communities with the excitement of science and technology*.

The DOW radars are one of the most visually iconic symbols of meteorology, in part because of their appearance on numerous television shows and documentaries. We propose to have a "DOW on Display" day on the PSU campus on a weekend where the wider Penn State community, the public, and media may come to see the radar and ask questions about how it works and what it tells us about clouds,

precipitation, and storms. Both Drs. Richardson and Kumjian will be on site to help provide the tours and can answer questions from the visitors.

In addition, we propose several efforts that will make use of the DOW to promote STEM education and to encourage young students to consider careers in science and technology. This includes bringing a DOW to a State College area K-12 school. We will also coordinate with local Boy and Girl Scout troops to arrange a tour. Further, State College also has its very own children's science museum, Discovery Space. The PSU meteorology department has an active working relationship with the Discovery Space, which has an ongoing exhibit about weather. We plan on working with the Discovery Space staff to possibly set up an exhibit on a non-operations day.

To reach a wider audience than just the State College area, we propose two broader outreach activities. First, the PSU-produced television program *Weather World* that airs on the Central Pennsylvania PBS station (WPSU) as well as the Pennsylvania Cable Network (PCN). *Weather World* will have a feature story on the DOW radars, reaching viewers across Pennsylvania. WPSU will advertise the "DOW on Display" day on its community calendar.

Finally, students in the non-majors courses *Introductory Meteorology* and *Severe and Unusual Weather* will tour the DOWs as part of their course instruction, bringing to life an instrument whose data they are likely to see on television throughout their lives. Several other courses within the major (mentioned in the introduction) will offer tours as well, allowing a large number of undergraduate students to see and learn about the DOW.