The University of Illinois DOW Education, Research and Outreach (UIDOW) 2016 Project

Final Report to the National Science Foundation

submitted by

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1. Introduction

Figure 1 Professors Hence and Rauber with the students of ATMS 410 on the first day of the DOW deployment.

The University of Illinois at Urbana-Champaign was awarded a 21-day educational deployment of a Doppler on Wheels (DOW), a National Science Foundation (NSF) facility managed by the Center for Severe Weather Research (CSWR) for a usage period from 24 February – 16 March 2016. This time period allowed for the enhancement of classroom instruction in ATMS 410 (Radar Remote Sensing, enrollment 14), as well as ATMS 314

(Mesoscale Dynamics, enrollment 26) and ATMS 306 (Cloud Physics, enrollment 10). PI Deanna Hence is the instructor for ATMS 410. In addition to the enrichment of these three classes, we intend to use the data collected for undergraduate capstone research projects in Fall 2016. During the DOW's time at UIUC, we engaged in outreach and contributed to the education of our campus community, our local community college, and the general public. The many components of this educational deployment resulted in a department-wide engagement of both undergraduate and graduate students that was an enriching experience for those within and without the designated classes directly involved. This final report summarizes the activities and outcomes that we accomplished during this deployment.

2. Deployments and Class Procedures

2.1. Overview and Scheduling

Table 1 shows the scheduling for the students of ATMS 410 as well as the 8 scientists (6 professors, 2 experienced graduate students) that contributed to the deployments. Each student in ATMS 410 was able to deploy with the radar at least twice, and additional students not in ATMS 410 were included as space and time allowed. In addition to these deployments, the radar was reserved for the use of ATMS 314, where students accompanied Professor Trapp in groups of 3-4. The DOW was reserved for the use of ATMS 306 for one class period, with a focus on how radar retrievals can be used to characterize cloud physics and microphysical retrievals. In addition, ATMS 304 (Radiative Transfer-Remote Sensing) also reserved the radar for a class period to discuss how the principles of radiative transfer apply to active remote sensing. Because of overlap between the classes, some students were able to interact with the radar on multiple occasions with different contexts, which allowed them to see how these principles they were learning in the disparate classes applied to radar remote sensing. Professor Frame and a graduate student coordinated providing us with weather forecasts throughout the deployment, to notify us of potential opportunistic data collection days.

Table 2 outlines the weather sampled with each of the DOW deployments. Professors Hence and Rauber performed site surveys to identify several of the sites prior to the arrival of the DOW, although further sites were identified during the course of the deployment. The DOW time at UIUC was bookended by two examples of severe weather: a blizzard that reached full intensity during the first full day of the DOW being at the university; and an outbreak of severe convection across central Illinois on the final day. In between these extreme events, the students examined frontal passages with associated precipitation, regions of stratiform precipitation, thick lightly precipitating cloud layers, scattered convection that underwent a convective-stratiform transition, and a relatively frequent occurrence of clear air days. In addition, we were able to sample in the parking lot near the Atmospheric Science building to do a cross-calibration of the department's new MRR on the same day as our campus community outreach day. This activity provided valuable data that can be cross-analyzed and used for future research, but also enabled many students on and off of our campus to witness data collection from two radars in real-time.

2.2. Highlights

2.2.1. 22 February 2016 – Blizzard hits first full day

Figure 2 Professor Rauber explaining the external components of the DOW to the students.

The first full day with the radar was reserved for an introduction to the radar and the deployment for ATMS 410, and what a start! As a data collection opportunity and in partnership with researchers from the UI Energy Farms, the radar deployed to a pre-determined research field southeast of campus. The radar performed PPI and RHI scans as Professors Rauber introduced the students to the internal and external components of the radar in strong winds and blowing snow. Students were shuttled back and forth to the radar (only a few miles from the department) during the course of the deployment.

2.2.2. Clear air and non-precipitating cloud studies

We used the several instances of clear weather days to put students in the operation seat for the radar to teach the students various calibration and clutter identification techniques. Given that this was the most frequent weather occurrence, almost every student was given opportunity to perform site surveys, map ground clutter, test various scan strategies, and examine other non-meteorological returns such as those from trains, planes, power lines, and sun spikes. When the opportunity arose, students also examined cirrus cloud generating cells, haze, and thick low-level cloud layers using a variety of scan strategies and experimenting with the effects of using different pulse repetition frequencies. In their final projects, all ATMS 410 students will be required to use the data from clear air retrieval days to identify and investigate strong sources of ground clutter.

Figure 3 The DOW parked at the SOY-FACE farm south of campus.

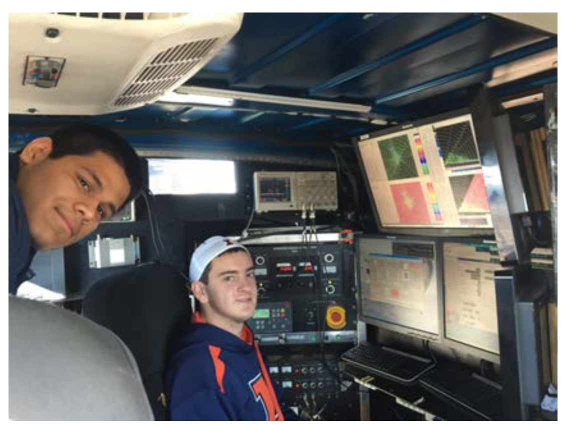

Figure 4 Students examining clear air returns.

2.2.3. Light to Moderate Precipitation Cases

Figure 5 Professor Frame with students sampling a tornadic supercell.

On days where precipitation was present, students were able to examine the particle and velocity characteristics of the precipitation in real-time and were given the opportunity to alter the scan strategies. The students were encouraged to examine both the horizontal and vertical distribution of precipitation targets and think about how the different parameters and settings of the radar impacted their ability to retrieve useful information. In one case of a cold frontal passage, the students were able to witness the transition from rainfall to snow and the wind shift in real time via the velocity and dual-polarization parameters. During a different deployment, during which we shuttled numerous students back and for, the students examined the transition of scattered convection into stratiform precipitation.

2.2.4. 15 March 2016 – Severe convection near Springfield, IL

One of the most exciting and rewarding days was the final day of the deployment, which not only was an excellent data collection day but also showed everyone the power that social media can have in science. When forecasts indicated that Central Illinois was primed for severe convection, Professor Frame coordinated with both graduate and undergraduate students to collect data near the Springfield area. Through Professor Frame's active use of Twitter, an opportunity for collaboration arose when students from Purdue University notified him that they were in the same area collecting data of their own. Professor Frame and students from both universities were able to coordinate a joint operation and were able to successfully capture the tornado that touched down in the region.

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Firefighters search through a damaged structure that was possibly hit by a tornado at 6320 West Iles Ave. on Tuesday, March 15, 2016, in Springfield, Ill. Justin L. Fowler/The State Journal-Register

Steven Spearie
Correspondent

Posted Mar. 26, 2016 at 10:10 PM

The convergence of some of the Midwest's preeminent storm experts from the University of Illinois and Purdue University on the Springfield area last week to observe an EF-1 tornado that touched down two miles west of Curran was "opportunistic," said one of the faculty members.

Students and professors from the two institutions joined forces March 15 in and around Springfield collecting data that they hope may ultimately improve tornado

Figure 6 Newspaper article discussing the DOW's trip to Springfield and the coordination with student from Purdue.

3. Classroom Educational Objectives

3.1. Classroom instruction enhancement for ATMS 410, ATMS 314, and ATM 306

ATMS 410 is a comprehensive radar meteorology course that covers the basic principles of conventional, Doppler, and polarization radar. In addition, the class covers precipitation measurement and microphysical interpretation of radar data, Doppler processing techniques such as VAD analysis, dual-Doppler analysis, and wind profiling for a variety of ground-based, airborne, and spaceborne platforms. One fundamental problem is that the class lacks direct access to a radar facility where students can see the components, learn how they work together, and operate themselves to test various sampling strategies. Access to the DOW allowed for students to see the impacts, in real time, of the various "trade-offs" that Professor Hence discussed repeatedly in class. This included visualizing the Doppler Dilemma through visualizing the relationship between the maximum unambiguous range, the Nyquist velocity, and the PRF, watching how high winds aloft led to velocity folding , brightband identification, reflectivity in ice vs. rain, etc. The students are working with and learning Solo3 to interact with the data. Students in ATMS 314 and 306 also had the opportunity to apply these principles to the topics specific to their courses

3.2. Assessment

The primary tool for assessment for the students in ATMS 410 is a final project, included in this report, where they are asked to perform several types of analysis of the individual cases collected by the DOW. The students are asked to examine both clear air and precipitation cases, and are required to provide information on the situational awareness of the case (location, conditions, etc), discussion of the meteorology involved, and perform the requested analysis. The students will be expected to present their results to the class at the end of the quarter in a short presentation.

3.3. Field deployment experience

Especially for students still too junior to have yet participated in field activities, several students reported being excited to witness the weather they had been studying in class in action. Graduate students with field experience from PECAN (Choate, who is also TA for ATMS 410, and Stechman) were given the opportunity to pass their knowledge gained from extensive experience with the DOW to these younger students. Through this experience, the students also got a taste for some of the hard realities of field research: some were frustrated by deploying on clear weather days; many were surprised by the challenges of attempting to collect data in tough conditions, despite efforts to inform them on what to expect (One student said "This is why I study warm weather convection!" on the day of the blizzard). Most, however, seemed thrilled to be receiving hands-on experience.

3.4. Data collection for undergraduate capstone research

We were highly fortunate to collect data in a wide variety of spring weather phenomena, which will provide an ample dataset for student analysis. Seniors are strongly encouraged to take a capstone research experience (ATMS 492), for which they receive 4 credit hours. We intend to use the DOW data to provide recent observational cases for the students to study.

4. Outreach Activities

4.1. Campus and Community College Outreach

Figure 7 A class visit from Parkland Community College.

We held two outreach events: one geared towards our campus community and visits from Parkland Community College, and one later in the week for the community. Given that the DOW visit corresponded with National Severe Weather Awareness Week, as well as the first tests of the local tornado sirens of the season, Professor Hence coordinated with two graduate students (one active in emergency management research, the other active in K-12 outreach and education) as well as the UIUC Student Chapter of the American Meteorological Society (SCAMS) to organize the events around severe weather awareness and hazard preparation.

The campus outreach event was held in the DOW's parking space next to Atmospheric Sciences, which we had rented from the university for the duration of the campaign. The campus event was advertised to all of the Office of Inclusion and Intercultural Relations cultural houses, science and engineering-focused registered student organizations, as well as to faculty and staff through the various campus newsletters and publications (Inside Illinois, Eweek, etc). A press release was also sent to the Daily Illini (student newspaper).

Unfortunately, likely due to cold, wet weather attendance was low, but as planned three classes (ranging from 10-20 students per class) from Parkland Community College's Weather 101 class came for tours of the DOW, as well as a scattering of other students throughout the open house period of the day. A science journalism student interviewed Professors Rauber, Frame, and Hence as well as covered the two events as one of her class projects, which was put on YouTube as well as on the local student television station. In these ways, we contributed to the education of a variety of students in our collegiate community.

Figure 8 A science journalism student doing her class project on the DOW. Available at https://www.youtube.com/watch?v=gm9ZuvUhv2g

4.2. Community Engagement

Although it was still a bit cold and windy, the severe weather preparedness community event met with greater success. The Illinois

Figure 9 Local news coverage of the severe weather preparedness event. Available at: http://www.illinoishomepage.net/news/local-news/wheeled-doppler-raising-weather-awareness

Exchange advertised the event as part of their own severe weather preparedness community outreach. The department issued press releases to Channel 3 WCIA, the News-Gazette (local newspaper), and WILL (local NPR station). WCIA interviewed Professor Rauber and notified the community of the event. Local schools were notified of the event and flyers were distributed for children to take home. The event was held in a highly visible, well-trafficked parking lot on the south side of campus, close to the athletic fields and campus arboretum.

In addition to giving tours of the DOW, we were able to have a representative from the American Red Cross available to give community members informational pamphlets and coloring books for children. We also had two informational posters; one poster explained the meanings of watches and warnings in relation to typical Illinois hazardous weather phenomena, while the other had examples of a variety of emergency preparedness kits for adults, children, and pets. Professor Hence contributed her home emergency kits as hands-on visual examples. All told, the event reached 50-60 people over a 4 hour period and reached a range of children, with some visitors being as young as 3-6 years old.

5. Lessons Learned

As has been experienced previously with UIDOW, we discovered that having enough activities to keep students engaged on clear air days is a challenge. Although making sure the students take the reins and get the experience of setting up and operating the radar themselves is important overall, this is even more so critical on clear air days.

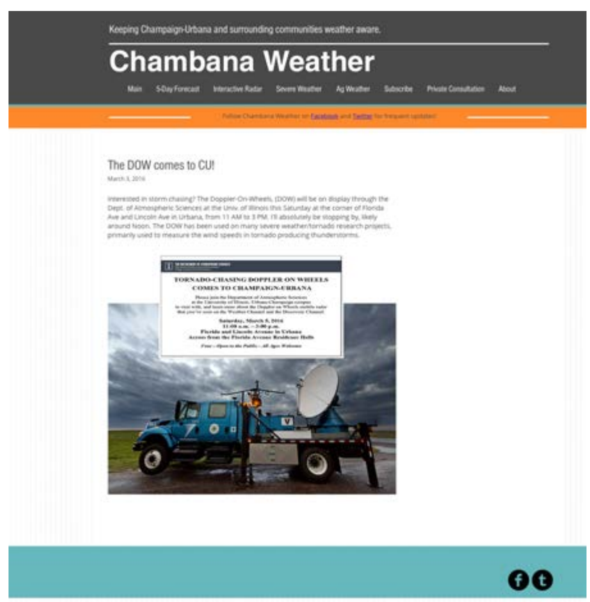

Figure 10 Local severe weather interest blog advertising our community outreach event.

In general, although our undergraduate students are typically drawn to our program out of an interest in severe weather, we need to make sure to stress more clearly that all weather data collection is important, and not just the "exciting" part. An introduction to some of the tedium that is data collection better introduces them for the challenges of doing this in the future. Having the support of the operator to help make the student experience on "boring" days as engaging (or as close to as can be managed) as those with precipitation will be very helpful on future deployments. In particular, having students do manual solar calibration and other activities can be very educational.

We got a first taste of coordinating with other colleges and universities in the area for educational and data collection opportunities with the DOW, and this is something we will explore more in future deployments.

Finally, we learned the hard way that corn fields, even ones presumed frozen, are not good for DOW hydraulic feet.

Figure 11 Professor Hence, various students, and a representative from the American Red Cross interacting with members of the public.

Table 1: Student and Faculty deployment schedule during UIDOW 2016.

Name: DAY	DATE	TIME	Hence	Choate	Rauber	Trapp	Frame	Nesbitt	Lasher-Trapp	Stechman	Bareda	Brown	Chehak	Chen	CrowleyFarenga	Erwin	Grande	Greene	Hunzinger	Janiszeski	Steckler	Taylor	Thayer	White
W	24-Feb-16	8am-2pm																						
W	24-Feb-16	2pm-8pm																						
Th	25-Feb-16	8am-2pm																						
Th	25-Feb-16	2pm-8pm																						
F	26-Feb-16	8am-2pm																						
F	26-Feb-16	2pm-8pm																						
Sa	27-Feb-16	8am-2pm																						
Sa	27-Feb-16	2pm-8pm																						
Su	28-Feb-16	8am-2pm																						
Su	28-Feb-16	2pm-8pm																						
M	29-Feb-16	8am-2pm																						
M	29-Feb-16	2pm-8pm																						
Tu	1-Mar-16	8am-2pm																						
Tu	1-Mar-16	2pm-8pm																						
W	2-Mar-16	8am-2pm																						
W	2-Mar-16	2pm-8pm																						
Th	3-Mar-16	8am-2pm																						
Th	3-Mar-16	2pm-8pm																						
F	4-Mar-16	8am-2pm																						
F	4-Mar-16	2pm-8pm																						
Sa	5-Mar-16	8am-2pm																						
Sa	5-Mar-16	2pm-8pm																						
Su	6-Mar-16	8am-2pm																						
Su	6-Mar-16	2pm-8pm																						
M	7-Mar-16	8am-2pm																						
M	7-Mar-16	2pm-8pm																						
Tu	8-Mar-16	8am-2pm																						
Tu	8-Mar-16	2pm-8pm																						
W	9-Mar-16	8am-2pm																						
W	9-Mar-16	2pm-8pm																						
Th	10-Mar-16	8am-2pm																						
Th	10-Mar-16	2pm-8pm																						
F	11-Mar-16	8am-3pm																						
F	11-Mar-16	3pm-8pm																						
Sa	12-Mar-16	8am-2pm																						
Sa	12-Mar-16	2pm-8pm																						
Su	13-Mar-16	8am-2pm																						
Su	13-Mar-16	2pm-8pm																						
M	14-Mar-16	8am-2pm																						
M	14-Mar-16	2pm-8pm																						
Tu	15-Mar-16	8am-2pm																						
Tu	15-Mar-16	2pm-8pm																						

ATMS 410 Shifts
Cloud Physics
Mesoscale
Instructors
Outreach
Radiation
Opportunistic Data Collection
DOW Not used/Unavailable

Table 2: Missions during UIDOW 2016

DAY	DATE	TIME	Latitude	Longitude	Orientation	Mission Weather	Scientist
W	24-Feb-16	8am-2pm				Class Introduction; Blizzard	Hence, Rauber
W	24-Feb-16	2pm-8pm					
Th	25-Feb-16	8am-2pm				No Mission	
Th	25-Feb-16	2pm-8pm					
F	26-Feb-16	8am-2pm					
F	26-Feb-16	2pm-8pm					
Sa	27-Feb-16	8am-2pm					
Sa	27-Feb-16	2pm-8pm				Ground Clutter Mapping	Rauber
Su	28-Feb-16	8am-2pm				No Mission	
Su	28-Feb-16	2pm-8pm				Frontal Passage with Precipitation	Frame
M	29-Feb-16	8am-2pm				Clear Air: PRF testing, elevation and RHI scans	Trapp
M	29-Feb-16	2pm-8pm				Clear Air	Nesbitt
Tu	1-Mar-16	8am-2pm				Frontal Passage with Precipitation	Hence
Tu	1-Mar-16	2pm-8pm				No data collection – Generator Failure at Site	Choate
W	2-Mar-16	8am-2pm				Radiation Class Demo	DiGirolamo
W	2-Mar-16	2pm-8pm				Mission Cancelled	
Th	3-Mar-16	8am-3pm			South	Parkland Community College Tours, Campus Open House, MRR/DOW calibration tests	Hence, Rauber, Nesbitt
F	4-Mar-16	8am-2pm				Clear Air, Clutter Mapping, Site Survey	Trapp
F	4-Mar-16	2pm-8pm				Clear Air, Clutter Mapping, Site Survey	Hence
Sa	5-Mar-16	11am-3pm				Community Engagement Day	Hence, Rauber
Su	6-Mar-16	8am-2pm				No Mission	
Su	6-Mar-16	2pm-8pm				Clear air, cirrus generating cells, sun spikes	Rauber
M	7-Mar-16	8am-2pm				Clear air	Trapp
M	7-Mar-16	2pm-8pm				Clear air, cirrus generating cells, sun spikes	Stechman

Tu	8-Mar-16	8am-2pm				No Mission: DOW Generator Maintenance	
Tu	8-Mar-16	2pm-8pm					
W	9-Mar-16	8am-2pm				convection, convective-stratiform transition, gust front	Hence
W	9-Mar-16	2pm-8pm				No Mission	
Th	10-Mar-16	8am-2pm				Distant showers	Choate
Th	10-Mar-16	2pm-8pm				No Mission	
F	11-Mar-16	8am-3pm				Cloud Physics Class, Computer Failure	Lasher-Trapp
F	11-Mar-16	3pm-8pm				Mission Cancelled	Stechman
Sa	12-Mar-16	8am-2pm				Very weak precipitation	Nesbitt
Sa	12-Mar-16	2pm-8pm				Weakly precipitating cloud layers	Hence
Su	13-Mar-16	8am-2pm				Stratiform precipitation	Frame
Su	13-Mar-16	2pm-8pm				Stratiform precipitation	Rauber
M	14-Mar-16	8am-2pm				Mission Canceled	
M	14-Mar-16	2pm-8pm				Stratiform precipitation	Nesbitt
Tu	15-Mar-16	8am-2pm				No Mission	
Tu	15-Mar-16	2pm-8pm				Severe deep convection, Tornado	
W	16-Mar-16	8am-2pm				No Mission - DOW Departed	

ATMS 410: Radar Remote Sensing
FINAL PROJECT

ASSIGNED: April 6, 2016
Due: May 2, 2016

During our class, the DOW collected data on both days with precipitation and without. Using Solo3, Google Earth, and whatever else you find useful, you will use both clear air and precipitation scans of the DOW to identify key features of your particular cases. Place all images that I request that you either obtain or create in your report with the indicated annotations. *Make sure that you show your work so that I can understand your process.* **Report all units in SI.**

Your assignment:

A. Clear Air Case

Examine your clear air case in Solo3.

a. Write a brief summary of the details of your case. This should include the location of the radar (give the latitude/longitude as well as location information, such as "2 km north of the intersection of Neil St and Shale Road"), the time of data collection, and any notable features within the vicinity of the radar (the pictures of the site, which are in your case folder, and Google Earth may be useful in determining this).
b. Plot the radar data in solo3 during a time you have a 360 degree PPI sweep. Make a screen shot of a representative PPI sweep, at the lowest elevation angle, of the reflectivity and radial velocity. In each image, include range rings every 2 km.
c. Using arrows and figure annotations, indicate 5 significant and distinct regions of ground clutter in the images on both the reflectivity and velocity images.
d. Obtain and include a Google Earth image that is centered on the location of the truck at the time of your case. Label the location of the truck within the image.
e. Using your favorite image editing software (Illustrator, Powerpoint, etc), overlay a copy of the reflectivity image (with transparency) onto the Google Earth map and align the features. Remember that the solo3 images and azimuths are **truck relative!** One recommended way to align the image is to use the distance measuring tool in Google Earth along with the range rings from the radar to align the distances. (I was able to use PowerPoint to do this overlay successfully)
    i. On the overlaid image, identify your five significant regions of ground clutter.
    ii. Capture and include close-up Google Earth satellite images of the 5 sources of ground clutter and include a physical description of each source.

f. **<u>Using your ground clutter map,</u>** determine the heading of the truck relative to true north. Make sure to show your work as to how you determined this. Indicate this heading on your map overlay. And then, check your value against the compass heading given in the log.

B. Precipitation Case

Examine your precipitation case in Solo3.

a. Write a summary of what happened during the event. This should include: what your precipitation event was (in terms of type of precipitation); the precipitation's general movement relative to meteorological coordinates; any significant changes that occur to the precipitation over the timeframe of your case; what, if anything, the event was associated with (such as a frontal passage); and any other information that can help me understand the event you are analyzing. Also include the location of the radar, the time of data collection, and any notable features within the vicinity of the radar.
b. RHI Analysis:
    i. Select an RHI that has precipitation within its field of view at least up to 10-15 km away from the radar. Using the truck heading (from the compass heading in the log is fine), convert the truck-relative azimuth of the RHI to an azimuth angle relative to true north. Indicate the truck location, heading, and azimuth angle of the RHI on a Google Earth map.
    ii. In solo3, plot range rings on this RHI at least every 1 km. Use this RHI to estimate the cloud top height at this time.
    iii. Using the radial velocities at 10 km and your favorite programming language (Matlab, Python, etc), plot a vertical profile of the radial velocities from the surface up to the cloud top. Make sure to label your graph appropriately in terms of heights, magnitudes, and units.
    iv. Obtain the Lincoln sounding closest in time to your case:
        1. Go to <u>http://weather.uwyo.edu/upperair/sounding.html</u>.
        2. Put in your date and the time closest to your case from the dropdown menu.
        3. Select "Text:List" under "Type of Plot"
        4. Click on ILK on the map. Another window should pop up with a text version of the radiosonde data.

v. Using the wind direction and speed from the sounding (caution: the wind speeds are in knots!), as well as your radial velocity profile and the true north azimuth of your RHI, calculate the amount that the wind velocities from the Lincoln sounding project into the measured radial velocity for every level of the sounding up to the cloud top. Show your technique for this calculation. Report this amount in meters per second.

c. PPI Velocity Analysis:
   i. Draw rings at 5 km intervals from radar on a representative PPI sweep of radial velocity. Using the maxima -> minima technique discussed in class, estimate the wind speed and direction at each 5 km interval. Show your work on the image. Tip: Use a high enough elevation angle that you have a full precipitation field around the radar with minimal blockage. If you cannot get both a maxima and a minima in the velocity because the precipitation field is not full enough, estimate. Using the data widget in solo3, also report the height of the beam at each distance interval.
   ii. Using this analysis, describe the winds of your case. Are they changing direction or speed at a given elevation? Are there any discontinuities in the wind field? Are the winds significantly changing speed or direction with height?

d. Brightband Analysis:
   i. Indicate during what times you have evidence of brightbanding in your case
      1. Make representative images during a time you have a brightband of your reflectivity, rhohv, and zdr PPI sweeps. Indicate on your images the location of the brightband. Provide the altitude of the top of the brightband. By analyzing your PPI scans, indicate how far the particles fell before they fully melted. Tip: When you plot the rhohv, try setting the color scale to plot from 0.8-1.0. For the ZDR, set the scale from -2.0 to 2.0. This will help you actually see the data! It will also likely be helpful to use higher elevation scans.

Oral Presentation:

Using your favorite presentation software (Powerpoint, keynote, Illustrator, etc.), create an oral presentation summarizing the highlights of the results of each portion of your analysis. You and your partner will have a total of 5 minutes; this timing will be strictly enforced. Each partner must present for equal amounts of time. We will allow two minutes for questions.

Email your presentation to me and Jessie (dhence@illinois.edu; choate2@illinois.edu) by 8 am CDT on the due date (May 2nd, 2016). We will run the presentations from my laptop to facilitate transitions.