Third University of Nebraska DOW Education and Outreach (UNDEO-3)

Final Report

1. Introduction

The third **U**niversity of **N**ebraska **D**OW **E**ducation and **O**utreach (UNDEO-3) project was conducted in the spring of 2013. UNDEO (in 2008), UNDEO-2 (in 2011), and UNDEO-3 were supported as "educational deployments" of the NSF Lower Atmospheric Observing Facilities. This support enabled a 14-day deployment of a Center for Severe Weather Research Doppler on Wheels (DOW) mobile radar to meet the following two principal objectives:

1. *Education*: To provide undergraduate and graduate students enrolled in *Radar Meteorology* an opportunity to use a sophisticated research radar to collect data for student research projects
2. *Outreach*: To exhibit a valuable platform in the NSF deployment pool to a broad audience of current and future scientists, members of the general public, and K-12 students.

During UNDEO-3 students in *Radar Meteorology* deployed DOW-6 1) near Lawton, OK where data on an isolated supercell were collected, 2) near the Gray County wind farm of southwest KS, and 3) near Lincoln for supplemental data collection. The DOW was also exhibited to students in 2 sections of *Severe and Hazardous Weather*, to ~80 high school students at Burke High School (a designated aeronautics and space career specialty school) and Omaha North High School (a science, technology, engineering, and math magnet), to high school students attending the state FFA convention, to attendees of the 12th annual Central Plains Severe Weather Symposium, and to local girl scouts and cub scouts. The complete schedule of activities that occurred as part of UNDEO-3 is listed in Table 1.

2. Education goals and activities

The main goal of the education component of this project was to *significantly advance student understanding of weather radar theory and applications through the operation of a cutting-edge research radar and analysis of the data collected*. UNDEO-3 achieved this goal through the following: Students in *Radar Meteorology*,

1. Developed research projects that would use data collected by the DOW during IOPs
2. Were trained by Ab Pfeiffer (radar technician for the Center for Severe Weather Research - CSWR) to operate the DOW
3. Completed a "lab" exercise that used the DOW for a guided exploration of fundamental concepts in radar theory and for practice applying operating instructions learned in the previous training.
4. Developed an experiment design to use the DOW to collect data necessary for their proposed research projects
5. Executed the experiment in one of the three IOPs conducted during UNDEO-3
6. Analyzed the data collected and synthesized their results into final term papers

Table 1 UNDEO-3 activities. Education activities in blue and outreach activities in red.

7 March	Student project abstracts due
14 March	IOP planning meeting.
23 March	DOW arrived on campus
25-26 March	DOW operation training
26 March	Karen Kosiba gives presentation on research involving data collected by the DOWs to ~30 students from *Radar Meteorology* and *Atmospheric Thermodynamics*
27 March	DOW lab exercise
28 March	Presentations by Rachel Humphrey to 2 sections of *Severe and Hazardous Weather*
29 March	Depart for Oklahoma
30 March	Intensive operations period (IOP) near Lawton, OK
31 March	IOP near Gray County wind farm near Dodge City, KS
1 April	Return to Lincoln
3 April	Exhibition of DOW to Burke High School honors earth science and honors physics classes Exhibition of DOW to Omaha North High School Science Club
4 April	Exhibition of DOW to Burke High School aircraft and rocketry class
5 April	Supplemental data collection near Lincoln Exhibition of DOW to high school students attending the state FFA convention
6 April	Exhibition of DOW at 12th Central Plains Severe Weather Symposium Exhibition of DOW to local girl scouts and cub scouts
10 April	DOW leaves campus
29 April	Student term papers due

Individual graduate students and undergraduates in small groups were tasked with developing research projects that dealt with questions/hypotheses related to airmass boundaries and/or thunderstorms; meteorological phenomena that are ubiquitous in the central and southern plains in late March and therefore are likely to be targetable during the proposed field deployments. Students were given the freedom to determine the specific focus of their project but were vetted by Dr. Houston in his review of their project abstracts, submitted 2 weeks prior to the DOW's arrival on campus. Research topics were generally focused on basic concepts in radar meteorology. This simplicity was necessary in order for students to complete the work in ~1 month's time following the IOPs. The list of the 2013 student project topics follows:

- Discrimination of Bird and Insect Radar Echoes in Clear Air Using the DOW
- Effects of Wind Farms on Downstream Mesoscale Wind Fields
- Spatiotemporal sensitivity of the Z-R relationship applied to a supercell observed with S-band and X-band radars
- A Comparison of Low Level Radial Velocities in a Severe Thunderstorm to Surface Wind Data Using Mobile Doppler Radar
- Comparison of DOW6 and WSR-88D Doppler derived vertical motion in clear-air mode
- Comparison of Deep Convection on GOES East Imagery to High Resolution Radar Data
- Derived Vertical Wind Profiles around a Wind Farm Using the Velocity-Azimuth Display Technique
- Cold Pool Depth Detection Using Radar Analysis with the aid of the Propagation Speed Equation
- Structure of Outflow Surges
- Pseudo Dual Doppler Horizontal Wind Field Estimates Using Single Doppler Technique

- A Study of a Thunderstorm Gust Front Using a Mobile X-Band Radar
- Comparison of the Representation of the Lawton, Oklahoma Thunderstorm between the WSR-88D Radar and the Doppler on Wheels Radar

Following abstract submission and review, the students met as a group with Dr. Houston to devise a deployment and scanning strategy that would yield data that could best satisfy every project objective. This planning meeting was not only a logistical necessity but also 1) gave students a sense of the challenges involved in executing a collaborative field project and 2) reinforced the cooperative nature of the overall endeavor.

DOW 6 arrived on campus on 23 March and the training for DOW operations commenced on Monday the 25th. The training was administered by Ab Pfeiffer, CSWR Technician. Every student in *Radar Meteorology* was trained to operate the radar. The training covered basic DOW operation including powering up the radar; scheduling, configuring, and visualizing radar scans; and powering down the radar.

Three IOPs took place during UNDEO-3 (Table 2). Radar operations during the deployments were performed by the students working in shifts. The cooperative nature of such an activity had the ancillary benefit of fostering teamwork amongst the students.

Table 2. Intensive operation periods during UNDEO-3.

IOP-1	30 March	23:56-01:17Z	15 km southwest of Lawton, OK	Supercell Gust front
IOP-2	31 March	22:41-00:15Z 01:03-02:04Z 02:38-03:43Z	8 km southeast of Montezuma, KS 15 km north of Montezuma, KS 15 km northeast of Montezuma, KS	Wind farm wake
IOP-3	5 April	22:23-23:29Z	15 km west of Lincoln, NE	Biological scatterers

IOP-1 (Figure 1) took place in southwest OK near Lawton and was concentrated on a slow-moving supercell and associated gust front (Figure 2). In-situ near-surface observations of temperature, moisture, pressure, and wind were also collected by a CSWR tornado pod deployed 4 km east-northeast of the DOW. The radar data collected during IOP-1 were used in 8 of the 12 student projects.

Through a guest lecture administered by Dr. Karen Kosiba (CSWR scientist), UNDEO-3 also offered students in *Radar Meteorology* as well as students in *Atmospheric Thermodynamics* the opportunity to learn how the DOW mobile radars have been used to conduct atmospheric science. Additionally, Rachel Humphrey administered guest lecturers for 2 sections of *Severe and Hazardous Weather* (Figure 3), a general education course with a typical enrollment of ~150 students. One of these sections has been designated a component of the William H. Thompson (WHT) Scholars Learning Community. These sections feature a restricted enrollment (~30 students) and are open only to WHT scholars: students who have been awarded a Susan T. Buffett Foundation scholarship which is eligible to low-income students who have graduated from Nebraska high schools and exhibit strong academic potential.

Figure 1. Students and DOW-6 during IOP-1 near Lawton, OK.

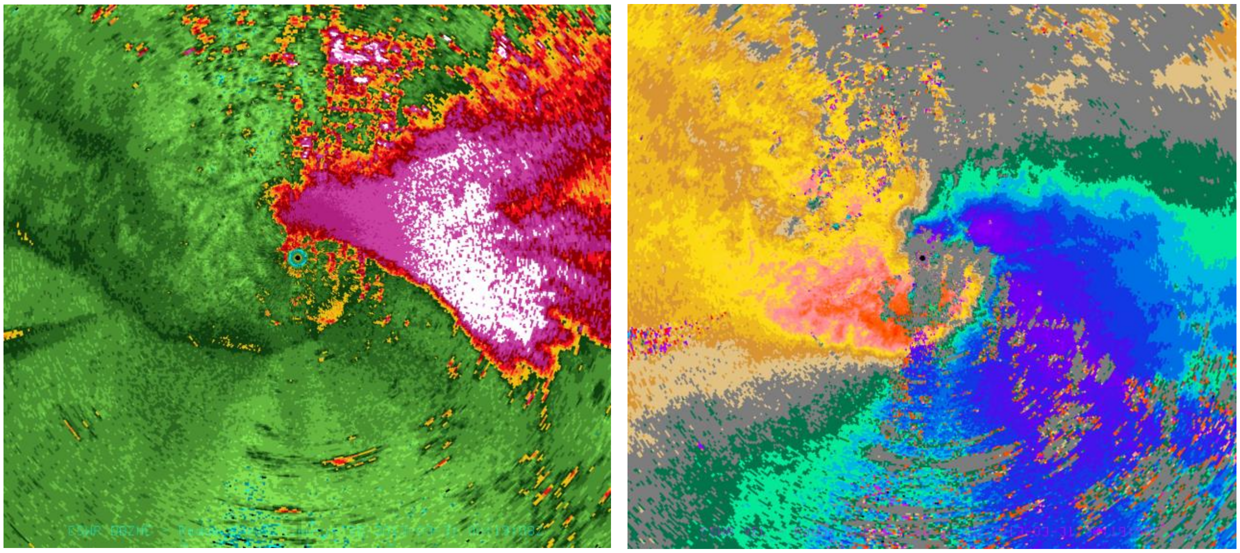

Figure 2. Examples of the DOW data collected during IOP-1 on 30 March 2013. Left panel is radar reflectivity and the right panel is radial velocity.

Figure 3. Guest lecture by Rachel Humphrey in the William H. Thompson section (top) and large lecture section (bottom) of "Severe and Hazardous Weather".

3. Outreach

The outreach component of UNDEO-3 targeted three demographics: 1) high school students, particularly those who have exhibited an aptitude for science, technology, engineering, and math, 2) K-6 students, and 3) the general public. The exhibition of DOW-6 to high school students involved 2 visits to Burke High School in Omaha, NE, a visit to Omaha North High School, and participation in the state convention of FFA (Future Farmers of America). Each high school visit featured 1) a presentation by Ab Pfeiffer that provided a basic explanation of how radars work, why radars are used for atmospheric science, and examples of how the DOW mobile radars have been used to investigate a range of atmospheric phenomena, 2) a Q&A administered by Adam Houston and Ab Pfeiffer, and 3) an exhibition of DOW-6 to the students.

Burke High School has been designated an aeronautics and space career specialty school. Presentations were given to Ms. Vaughn's honors earth science and honors physics classes in the first trip to Burke (Figure 4) and Ms. Stover's aircraft and rocketry class in the second trip. Omaha North High School is a science, technology, engineering, and math magnet. A presentation was given to the school's science club.

High school students were also the focus of an exhibition of DOW-6 at the state FFA convention. K-6 students were the focus of an exhibition of the DOW to several girl scouts and cub scouts troops on 6 April. Finally, a general audience primarily composed of members of the greater-Lincoln community was the focus of the exhibition of DOW-6 at the 12th annual Central Plains Severe Weather Symposium.

Figure 4. Outreach event at Burke High School (Omaha, NE)..

4. Assessment of Student Learning

The success of UNDEO-3 and identification of opportunities for improvement were assessed using the following vehicles:

- <u>Anonymous survey of the students</u>
  Students were asked to evaluate how well the learning objectives were met. The survey and average results are included in Table 3.
- <u>Graded assessment in *Radar Meteorology*</u>

Student learning was also measured through standard assessment tools ("lab" exercise, final exam, term paper, etc.) The "lab" exercise used appears in

Table 4.

5. Lessons learned

- UNDEO-3 was further proof that deployments should not be restricted to the immediate vicinity of the host institution unless research projects are not a component of the project or project foci are much more tightly constrained.
- The number of outreach events executed as part of UNDEO-3 was just about at the limit of what is possible when the first week of the educational deployment is reserved for educational activities.
- As reflected in Table 3, students found the DOW training to be effective but it appears that there is room for improvement. Given the limited time available, it is difficult to reserve more training time unless more than 14 days are reserved for the on-campus deployment.
- Based on the survey, it also appears that there is room for improvement when it comes to distributing the operation of the radar amongst the students during the IOPs. This is certainly possible and in future UNDEOs, the PI intends to be more deliberate about rotating students through the DOW during operations.

Table 3. Summary of the student survey. Bold values are the average scores received.

1.	How would you rate the value of Dr. Karen Kosiba's presentation?	Very low	1 2 3 4 5 **4.13**	Very high
2.	How would you rate the length of the on-campus deployment of the DOW?	Too short	1 2 3 4 5 **2.88**	Too long
3.	How would you rate the overall effectiveness of the DOW training, including the DOW exercise, in preparing you to operate the DOW with some assistance?	Not effective	1 2 3 4 5 **3.75**	Very effective
4.	How would you rate the overall helpfulness of Ab Pfeifer both prior to and during the field deployments of the DOW?	Not helpful	1 2 3 4 5 **4.63**	Very helpful
5.	How would you rate the level of involvement of students in the strategic planning of the deployments for data collection?	Too little	1 2 3 4 5 **3.00**	Too much
6.	How would you rate the level of involvement of students in the actual data collection during the field deployments?	Too little	1 2 3 4 5 **2.38**	Too much
7.	How would you rate the benefit of the	No benefit	1 2 3 4 5	Very beneficial

	DOW research project to your understanding of radar meteorology?		**4.38**	
8.	How would you rate the overall benefit of the DOW activities to your understanding of radar meteorology?	No benefit	1 2 3 4 5 **4.38**	Very beneficial
9.	How would you rate the overall benefit of the DOW activities to your career goals?	No benefit	1 2 3 4 5 **4.13**	Very beneficial
10.	How would you rate your overall enjoyment of the activities associated with the DOW visit?	No enjoyment	1 2 3 4 5 **4.63**	Very enjoyable

Table 4. DOW "lab" exercise

METR 463/863 DOW Exercise

Assigned:

Due:

For each question requiring DOW data collection, **capture images** from the Hiq-Hi screen and **include these images in your completed assignment**

Config File	PRF (Hz)	Rmax (km)	Vmax (m/s)	Pulse Length (µs)
educFAR	800/1200	90	19.2	0.8
educCLOSE	2000/3000	30	47.9	0.4

Questions in blue can be answered before/after going to the DOW

1. Beamwidth [this question doesn't require data collected using the DOW]

   A. The beamwidth of the DOW is approximately 1°. Assuming a typical antenna efficiency for a circular, parabolic reflector that is 1.8 m in diameter, calculate the theoretical beamwidth of the DOW antenna system.

   B. How would the theoretical beamwidth change if the wavelength was 10 cm instead?

   C. How much closer to a target would the DOW need to be if sampling required a beam diameter of 10 m?

2. Clear-air sensitivity to pulse duration

   The sensitivity of the radar depends on the amount of power returned to the radar. As you determined in an earlier homework assignment, the returned power is very sensitive to the pulse duration. In this set of questions you will determine the theoretical impact of the pulse duration and also the practical (qualitative) impact.

   A. Assuming an antenna gain of 43.4 dB, a beamwidth of 1°, and a peak power of 45 kW, plot the minimum *theoretical* logarithmic reflectivity factor (defined based on the linear reflectivity factor $z \equiv \sum_{UnitVol} d^6$) as a function of range (consider a maximum range of 100 km) detected at an MDS of -108.4 dBm for the following pulse durations:

      i. 0.4 µs
      ii. 0.8 µs

   B. Discuss the implications of the results from part A in terms of radar sensitivity.

C. Using the educFAR configuration, find the elevation angle that yields a PPI of radar reflectivity factor with a nominal amount of ground clutter and a returns above the noise level out to range as close to Rmax as possible. For this same elevation angle, collect a sweep using the educCLOSE configuration. Making sure to zoom in so that individual bins are clearly visible, discuss any differences that you might see in the resolution and noisiness of the 2 reflectivity fields. Provide theoretical justification for any differences that you might see.