The 2015 University of Nebraska DOW Education and Outreach (UNDEO-2015) Project

Final Report

1. Introduction

The 2015 **U**niversity of **N**ebraska **D**OW **E**ducation and **O**utreach (UNDEO-2015) project was a 14-day educational deployment of a Doppler on Wheels mobile radar conducted in the spring of 2015 and based out of the University of Nebraska-Lincoln. The principal objectives of UNDEO-2015 were as follows:

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-2015 students in *Radar Meteorology* deployed DOW-6 1) near Columbus, NE where data on multicellular deep convection were collected, 2) near Lincoln, NE where data on rural and urban boundary layers were collected, and 3) near Harper, KS were data on a supercell were collected. The DOW was also exhibited to 20 undergraduate students in *Severe and Hazardous Weather,* to ~40 high school students attending the state FFA convention, to ~200 members of the general public attending the 15th annual Central Plains Severe Weather Symposium, and to ~20 undergraduate students enrolled in *The Dynamic Planet: Hazards in the Environment* (a geography course offered at the University of Nebraska at Kearney) along with ~80 members of the general public who attended a showing of *Twister* at "The World Theater" in Kearney, NE The complete schedule of activities that occurred as part of UNDEO-2015 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-2015 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 Alycia Gilliland (staff member of 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 DOW training.
4. Developed an experiment design to use the DOW to collect data necessary for their proposed research projects
5. Executed their experiments in one of the three IOPs conducted during UNDEO-2015
6. Analyzed the data collected and synthesized their results into final term papers

Table 1 UNDEO-2015 activities. Education activities in blue and outreach activities in red.

12 March	Student project abstracts and work plans due
19 March	Student abstract presentations to the class
29 March	DOW arrived on campus
30-31 March	DOW operation training
1 April	IOP near Columbus, NE
4-5 April	DOW lab exercise
5 April	IOP near Lincoln, NE
7 April	Exhibition of DOW to undergraduate students in *Severe and Hazardous Weather*
8 April	IOP near Harper, KS
10 April	Exhibition of DOW to high school students attending the state FFA convention
11 April	Exhibition of DOW at 15th Central Plains Severe Weather Symposium
13 April	DOW leaves campus
13 April	Exhibition of DOW in Kearney, NE at showing of *Twister* at the World Theater
4 May	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 early April 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 all projects 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 2015 student project topics follows:

- Favorable Areas for Storm Redevelopment along the Gust Front of a Multicellular System
- Wind Shear and Beam Angle Effects on Doppler Velocity Spectrum Width
- Depolarization Signatures in Thunderstorm Anvils Associated with Lightning Activity
- Strength of the Storm as Dependent on the ZDR Column above the Freezing Layer
- Assessment of Correlation Coefficient Potential for Determining Updraft Strength
- Dissipation of a Misocyclone on an Outflow Boundary
- A Comparison of WSR-88D and DOW6 Resolution Using Lemon Criteria
- Mobile Doppler Analysis of Topographic and Urban Influences on Boundary Layer Convection in Lincoln, Nebraska
- Attenuation Correction with Dual-Frequency and Dual-Polarization Approach Using X-Band Doppler on Wheels Radar

After receiving feedback on their abstracts, students presented their projects to the class in 5-minute oral presentations. Dr. Houston then developed deployment and scanning strategies that would yield data that could best satisfy every project objective. These strategies were disseminated to the class for feedback and adjustments were made based on student feedback.

DOW-6 arrived on campus on 29 March and the training for DOW operations commenced on Monday the 30th. The training was administered by Alycia Gilliand, 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-2015 (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-2015.

IOP-1	1 April	North of Columbus, NE	Multicellular complex Gust front
IOP-2	5 April	Northwest of Lincoln, NE	Urban vs. rural boundary layer
IOP-3	8 April	Near Harper, KS	Supercell

IOP-1 (Figure 1-3) took place in east central Nebraska, north of Columbus and focused on a multicellular complex and associated gust front (Figure 2). Approximately 1.25 hrs of continuous data were collected during this IOP-1 which was characterized by robust deep convection (Figure 2). In-situ near-surface observations of temperature, moisture, pressure, and wind were also collected by a CSWR tornado pod deployed near the radar.

IOP-2 took place in the Lincoln, NE area and focused data collection on rural vs. urban planetary boundary layers. IOP-3 was executed the second week of UNDEO-2015 in south-central KS near the town of Harper. Data were collected on a dissipating supercell.

DOW-6 was exhibited to 20 non-major undergraduate students enrolled in the William H. Thompson section of *Severe and Hazardous Weather,* a general education course reserved for students participating in the William H. Thompson (WHT) Scholars Learning Community. WHT sections feature a restricted enrollment and are open only to 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. DOW-6 was also exhibited to WHT scholars enrolled in the University of Nebraska – Kearney's offering of *The Dynamic Planet: Hazards in the Environment* as part of a showing of the movie Twister at "The World Theater" in Kearney, NE.

Figure 1. Students and DOW-6 during IOP-1 near Columbus, NE.

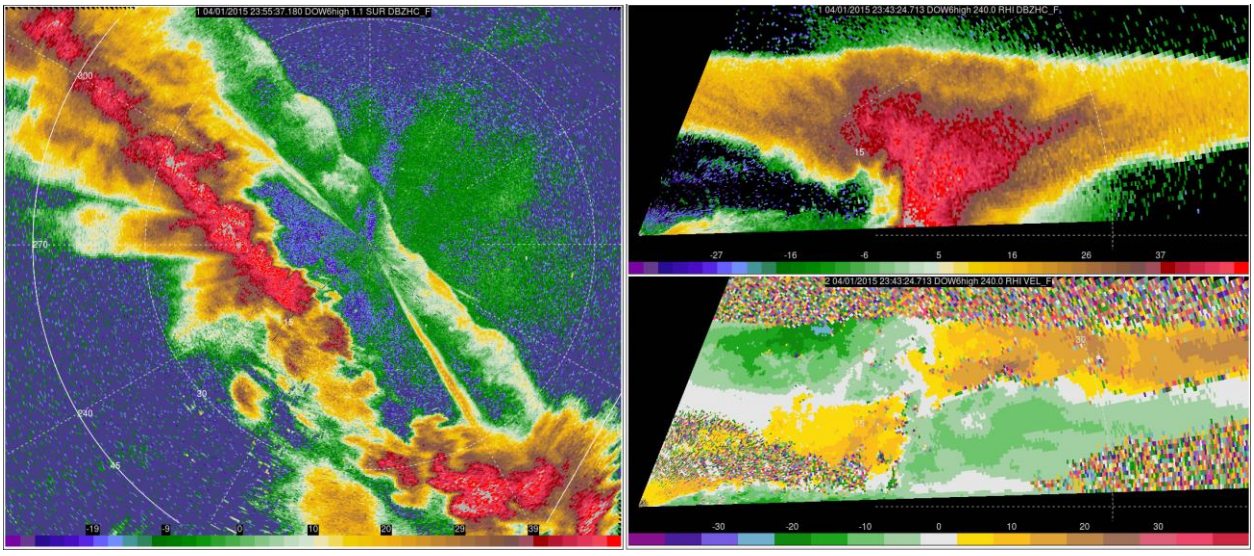

Figure 2. Examples of the DOW data collected during IOP-1. The PPI in the left panel illustrates the multicellular deep convection and associated gust front. RHIs of radar reflectivity (top) and radial velocity (bottom) appear in the right panels.

3. Outreach

The outreach component of UNDEO-2015 principally targeted high school students and the general public. The exhibition of DOW-6 to high school students involved participation in the state convention of FFA (Future Farmers of America; Figure 3a). DOW-6 was exhibited outside the Pinnacle Bank Arena for 3 hours during FFA activities. DOW-6 was also exhibited to a general audience primarily composed of members of the greater-Lincoln community during the 15th annual Central Plains Severe Weather Symposium (Figure 3b). Finally, DOW-6 was featured in a showing of *Twister* at "The World Theater" in Kearney. Approximately 80 members of the local community attended the showing and subsequent Q&A held by Dr. Houston.

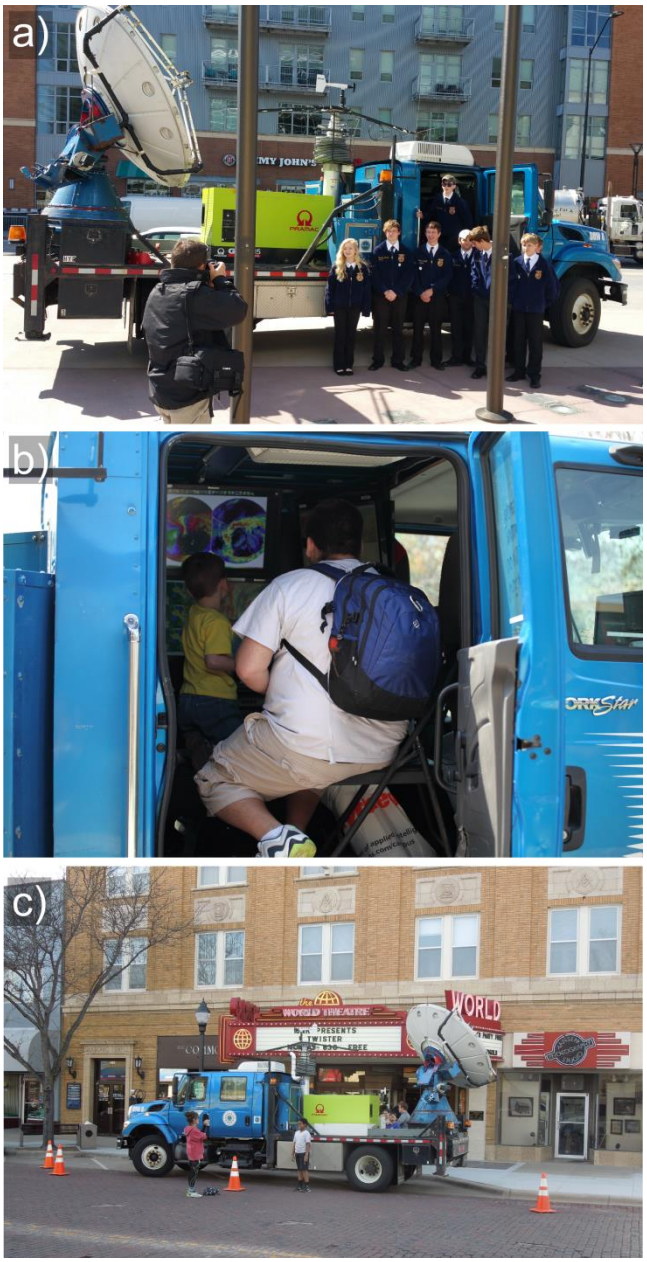

Figure 3. Outreach activities associated with UNDEO-2015: a) state FFA convention, b) 15th annual Central Plains Severe Weather Symposium, and c) showing of Twister *at* The World Theater *in Kearney, NE.*

4. Assessment of Student Learning

The success of UNDEO-2015 and identification of opportunities for improvement were assessed using the following vehicles:

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

Student learning was also measured through standard assessment tools ("lab" exercise, final exam, term paper, etc.) The "lab" exercise used appears in Table 4.

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5. Lessons learned

- Field deployment flexibility is demanded even when the operational area extends through much of the Central Plains. The primary field deployment for UNDEO-2015, originally scheduled for the weekend of 4 April, was scrapped for lack of storms in the operational area. Instead, 2 mid-week field deployments (IOP-1 and IOP-3) were executed during the 2-week educational deployment.

- While the exhibitions were generally effective at engaging with non-major undergraduates, high school students, and the general public, these need to be complemented with events for which the DOW is the focus and not merely ancillary.
- Based on survey results from UNDEO-3 (2013), the PI made a more deliberate effort to ensure that more students had the opportunity to operate the radar during the field deployments. While probably not statistically meaningful, students rated "the level of involvement of students in the actual data collection during the field deployments" 0.38 points closer to ideal in UNDEO-2015 than in UNDEO-3.

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

1.	How would you rate the length of the on-campus deployment of the DOW?	Too short	1 2 3 4 5 **2.67**	Too long
2.	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 **4.00**	Very effective
3.	How would you rate the overall helpfulness of Alycia Gilliland both prior to and during the field deployments of the DOW?	Not helpful	1 2 3 4 5 **4.78**	Very helpful
4.	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 **2.56**	Too much
5.	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 **2.78**	Too much
6.	How would you rate the benefit of the DOW **research project** to your understanding of radar meteorology?	No benefit	1 2 3 4 5 **4.56**	Very beneficial
7.	How would you rate the overall benefit of the DOW **activities** to your understanding of radar meteorology?	No benefit	1 2 3 4 5 **4.56**	Very beneficial
8.	How would you rate the overall benefit of the DOW activities to your **career goals**?	No benefit	1 2 3 4 5 **4.39**	Very beneficial
9.	How would you rate your overall enjoyment of the activities associated with the DOW visit?	No enjoyment	1 2 3 4 5 **4.83**	Very enjoyable

Table 4. DOW "lab" exercise

METR 463/863 DOW Exercise

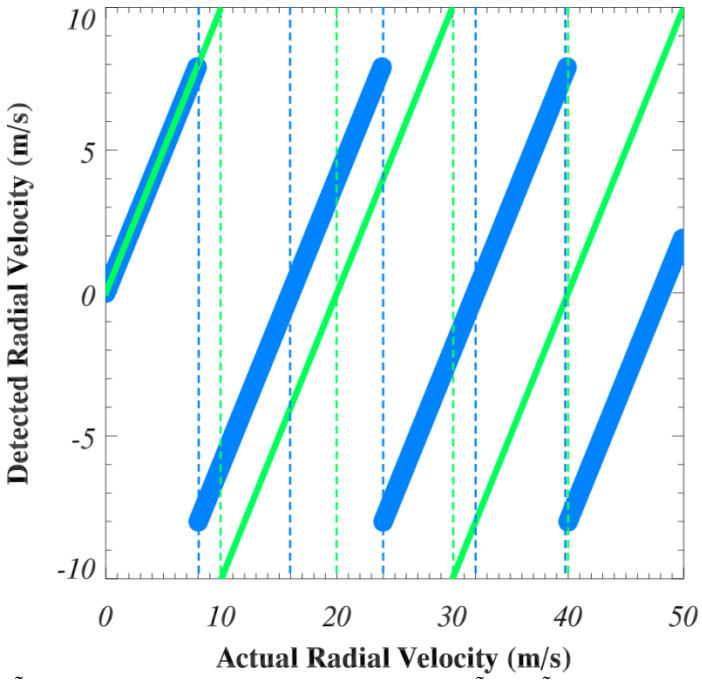
Turn in completed assignments via Blackboard. **Only single-document files will be accepted (images, analysis, discussion, etc. must be in a single document).**

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

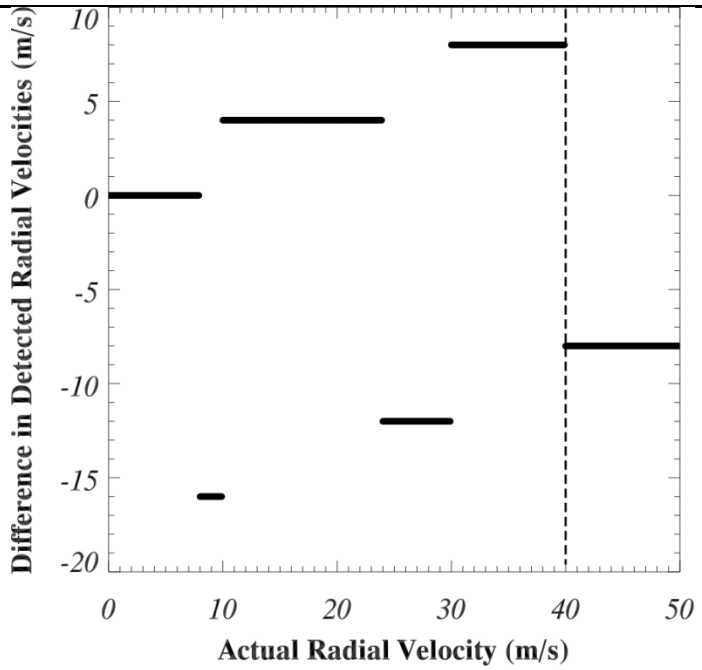
Background on staggered PRFs

A staggered PRF is used to mitigate the Doppler dilemma. It is a transmission protocol in which two PRFs are used and results in a higher Nyquist velocity than would be possible with either of the individual PRFs.

The staggered-PRF approach is based on the principle that a given actual radial velocity will produce a known difference in detected velocities from two PRFs. For example, if $PRF_1 = 1000$ Hz and $PRF_2 = 1250$ Hz, then $V_{max1} = 8$ m/s and $V_{max2} = 10$ m/s and the relationship between $\tilde{V}_{R1}$, $\tilde{V}_{R2}$, and V_R would look like this:



(blue is $\tilde{V}_{R1}$; green is $\tilde{V}_{R2}$; broken lines are the folds) and $\tilde{V}_{R1} - \tilde{V}_{R2}$ looks like this:



The value of $\tilde{V}_{R1} - \tilde{V}_{R2}$ points to a unique range of V_R values and therefore the number of folds that have occurred. It can be shown that $\tilde{V}_{R1} - \tilde{V}_{R2}$ cannot discriminate the sign of V_R beyond a V_R in which the ratio of the number of folds at the smaller PRF (n_1) to the number of folds at the larger PRF (n_2) is given by

$$\frac{n_1}{n_2} = \frac{PRF_2}{PRF_1}$$

In other words, the modified Nyquist velocity for staggered PRF is given by

$$V_{max\,S} = \frac{\lambda}{4\left(PRF_1^{-1} - PRF_2^{-1}\right)}$$

1. Fill in the missing elements in the following table
[Note that R_{max} is based on the larger PRF of stagger.]

Config file	Pulse duration (ns)	PRF (Hz)	Rmax (km)	Vmax (m/s)	Pulse length (m)
dowdrx.400.2500.4_5.60m	400	2000/2500			
dowdrx.800.1250.4_5.120m	800	1000/1250			

2. Beamwidth

A. The beamwidth of the DOW is approximately 0.9°. 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?

3. Clear-air sensitivity to pulse duration

Data collection

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 practical (qualitative) impact of clear-air sensitivity to pulse duration.

Using the dowdrx.400.2500.4_5.60m configuration, find the elevation angle that yields a PPI of radar reflectivity factor with a nominal amount of ground clutter and returns above the noise level out to the farthest range possible. For this same elevation angle, collect a sweep using the dowdrx.800.1250.4_5.120m configuration.

Analysis

Using Solo3 or IDV to visualize the data, discuss any differences that you might see in the resolution and noisiness of the reflectivity field. Provide theoretical justification for any differences that you might see. **Turn in representative images from these data to support your analysis.**

4. Impact of rotation rate on clear-air return

Data collection

Using the dowdrx.800.1250.4_5.120m configuration, run a few sweeps for each of the following rotation rates

- 10°/s
- 30°/s
- 50°/s

Analysis

Using Solo3 or IDV to visualize the data, discuss any differences that you might see in the resolution and noisiness of the reflectivity field. Provide theoretical justification for any differences that you might see. **Turn in representative images from these data to support your analysis.**