The 2017 University of Nebraska DOW Education and Outreach (UNDEO-2017) Project

Final Report

1. Introduction

The 2017 **U**niversity of **N**ebraska **D**OW **E**ducation and **O**utreach (UNDEO-2017) project was a 14-day educational deployment of a Doppler on Wheels mobile radar conducted in the spring of 2017 and based out of the University of Nebraska-Lincoln. The principal objectives of UNDEO-2017 were as follows:

1. Provide undergraduate and graduate students in *Radar Meteorology* an opportunity to use a sophisticated research radar to collect data for micro research projects;
2. Promote general understanding of weather radars and their application amongst non-major undergraduates;
3. Improve scientific literacy of non-major undergraduates by proving opportunities to learn about the scientific method and see examples of its application;
4. Exhibit a valuable NSF-supported facility to a broad audience of current and future scientists, members of the general public, and K-12 students.

During UNDEO-2017 the 9 students in *Radar Meteorology* deployed DOW-8 1) near Brady, TX where data on a tornadic supercell were collected and 2) in western IA near the Eclipse Wind Farm. The DOW was also exhibited to 735 K-12 students, ~120 preschoolers, ~70 undergraduate students in the general-education *Weather and Climate* course, and ~60 members of the general public. The complete schedule of activities that occurred as part of UNDEO-2017 is listed in Table 1.

2. Education goals and activities

The primary 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*. The primary focus of the proposed project was on the 9 students enrolled in *Radar Meteorology*, a course for upper-level undergraduate majors and graduate students in the University of Nebraska–Lincoln (UNL) Meteorology-Climatology program of the Department of Earth and Atmospheric Sciences. UNDEO-2017 achieved the primary education goal through the following. Students in *Radar Meteorology*,

1. Identified a question that could be answered with data collected by the DOW during the project.
2. Developed an experiment design using the DOW to collect data necessary for his/her (their) research project.
3. Crafted an abstract that described the questions and hypotheses and proposed the experiment design to address them.
4. Presented their proposed projects to the class.
5. Were trained by Alycia Gilliland (CSWR) to operate the DOW.
6. Completed a “lab” exercise that used the DOW to explore fundamental concepts in radar theory.
7. Operated the DOW during the primary field deployment near Brady, TX on 1 April.
8. Processed and analyzed the data collected

9. Presented a brief description of their use of the scientific method to students in the general-education *Weather and Climate* course.
10. Synthesized their results into final term papers.

Table 1. Calendar of events occurring during UNDEO-2017.

			March 1	2	3	4
5	6	7 Abstracts due	8	9	10 Abstracts rtrn'd. w/ feedback	11
12	13	14 Abstract presentations	15	16	17	18
19	20	21	22	23	24	25
26 DOW arrives	27 Student training	28 Student training	29 DOW exercise	30 LPS outreach	31 LPS outreach	April 1 Data collection in TX
2 Data collection in TX	3	4	5	6 METR 100 DOW exhibition	7	8 Exhibition at State Museum Data collection in IA
9 DOW leaves	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25 Presentations to METR-100.	26	27 METR-100 in-class exercise	28	29
30	May 1	2	3	4 Term papers due	5	6

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. 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 for students to complete the work in the short time following the IOPs. The list of the 2017 student project topics follows:

- Thunderstorm Outflow Boundary and Density Current Sensitivity to a Mobile Doppler Radar Vertical VAD Profile

- Characteristics of the Gust Front Nose
- Velocity Structures in Cold Pool Heads
- Impact of Proposed Cottonwood Wind I Project on WSR-88D Radar Products: An Observational Study
- Verification of Thunderstorm Outflow Structure Modeling using X-band Radar and Surface Observations

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 and adjustments were made based on student feedback.

DOW-8 arrived on campus on 26 March and the training for DOW operations commenced on Monday the 27^{th}. 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.

Two IOPs took place during UNDEO-2017 (Table 2). Radar operations during the deployments were performed by the students working in shifts.

Table 2. Intensive operation periods during UNDEO-2017.

IOP-1	1 April	Northwest of Brady, TX	Supercell Gust front
IOP-2	8 April	Near Adair, IA	Wind farm

IOP-1 (Figure 1) took place northwest of Brady, TX (~50 mi east of San Angelo, TX) and focused on a supercell and attendant gust front. The IOP consisted of two deployments both of which used shallow surveillance sweeps, large angle surveillance sweeps for VAD calculations, and RHIs. The first deployment was in the path of the supercell and involved ~30 min of data collection. The second deployment was south of the supercell and involved 74 min of data collection. In-situ near-surface observations of temperature, moisture, pressure, and wind were also collected by one of UNL's Integrated Mesonet and Tracker (IMeT) vehicles.

IOP-2 took place the following week near the Eclipse Wind Farm in Guthrie County, IA. Three deployments were executed and involved sector scans across the wind farm.

A second goal of the education component of UNDEO-2017 was to enhance understanding of weather radars amongst non-major undergraduate students enrolled in the University's *Weather and Climate* course, a general-education course in the Meteorology-Climatology program. This was achieved through the development and administration of mini-lecture and in-class-exercise that …basic knowledge of weather radars and highlights two concepts: ground clutter vs. clear-air returns and the differences between mobile research radar and surveillance radars. Both the mini-lecture and in-class-exercise utilized visualizations of data collected during UNDEO-2017.

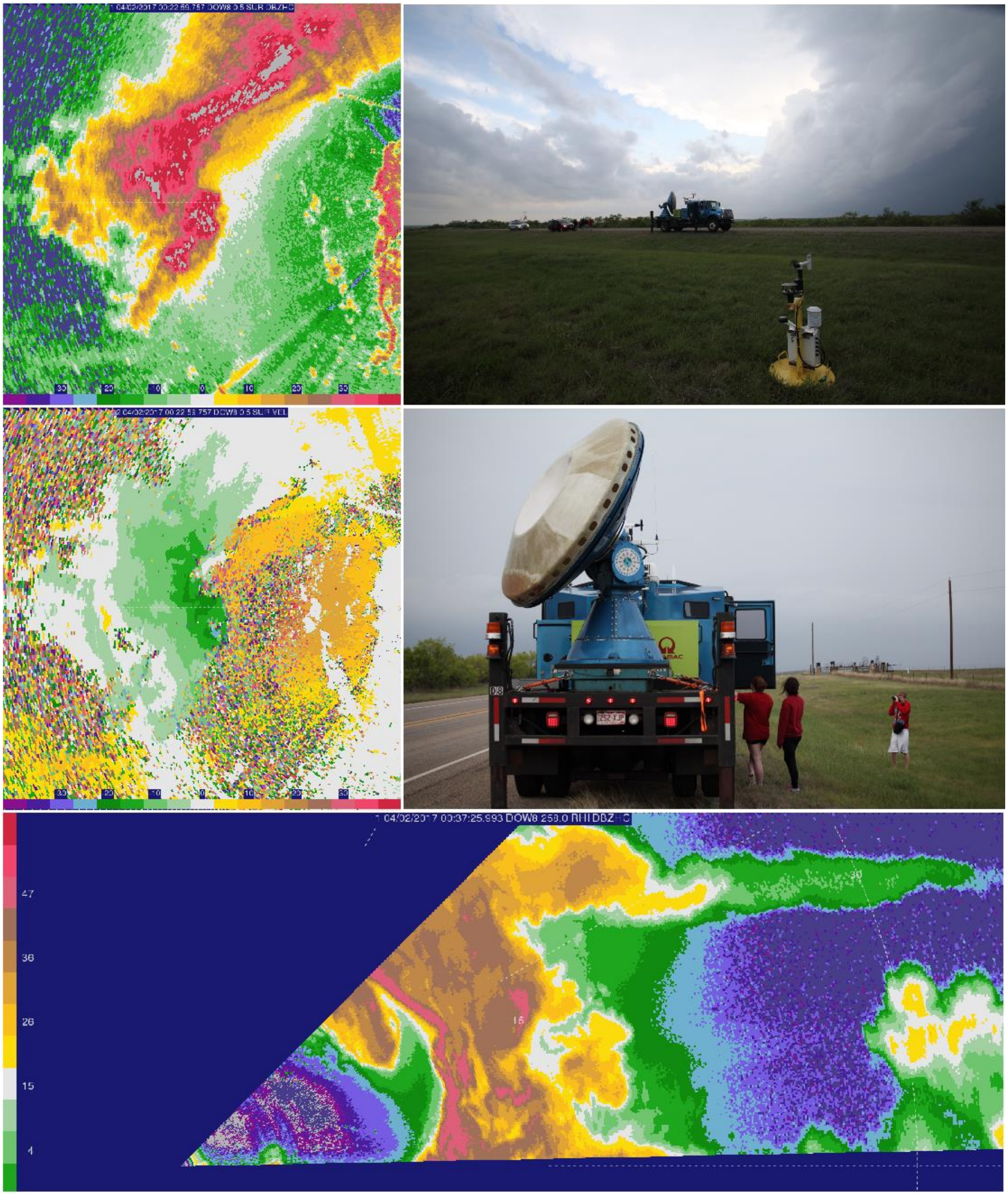


Figure 1. Images of data collected and photos from the 1 April deployment near Brady, TX.

The third goal for the education component was to promote the scientific literacy of non-major undergraduate students enrolled in *Weather and Climate* while piloting a program that will be expanded to general-education meteorology courses at local colleges including Doane University and Nebraska Wesleyan University in future UNDEO projects. Improved scientific literacy was facilitated through exposure to the methods adopted by *Radar Meteorology* students in executing their micro research projects. Each *Radar Meteorology* student/group was tasked to present a 5-minute general-education-level talk to the *Weather and Climate* students. They were allotted two content slides: in the first slide, students were asked to demonstrate how they used their experiment to test their hypothesis; in the second slide the students were asked to teach a basic concept in radar meteorology that incorporates results from, or techniques used in, their micro research project.

To maximize the engagement of the *Weather and Climate* students during the presentations, they were asked to vote for the micro research project that did the best job of connecting experiment design to hypotheses. The *Radar Meteorology* student with the winning project received 1 bonus point on his final project grade.

3. Outreach

The goals of the outreach component of UNDEO-2017 were to 1) demonstrate NSF investments in basic science and support for facilities like the DOWs, 2) engage with K-12 students to initiate or fuel interest in STEM, and 3) contribute to increasing public scientific literacy.

Figure 2. Outreach to preschoolers at the University of Nebraska Children's Center (top) and to students in Weather and Climate *(bottom).*

DOW-6 reached 735 K-12 students in the Lincoln Public School (LPS) system via six separate exhibitions at three elementary schools and two high schools (Table 3). DOW-6 was also exhibited to ~120 preschoolers at the UNL Children's Center (Figure 2) and to ~70 undergraduate students in *Weather and Climate* (Figure 2). DOW-6 also figured prominently in an outreach event designed by the PI and associated with the Nebraska State Museum's *Investigate: Second Saturday Science Lab*. This exhibition reached over 100 members of the general public, ~60 of whom had direct interaction with the DOW.

4. Assessment of Student Learning

The success of UNDEO-2017 and identification of opportunities for improvement were assessed using the following vehicles:

- <u>Anonymous survey of *Radar Meteorology* students</u>

  Students were asked to evaluate how well the learning objectives were met. The survey and average results are included in Table 4. A summary of average responses over the last five UNDEOs is included in Figure 3 and Figure 4.

- Graded assessments in *Radar Meteorology*
  The "lab" exercise used appears in Table 5.
- Anonymous survey of *Weather and Climate* students who participated in the active learning exercise and observed student presentations
  Students were asked to evaluate how well the student presentations and in-class exercise improved their understanding of the scientific method and basic concepts related to weather radar. They were also asked for suggestions to improve the effectiveness of this component. The survey, average results, and suggestions are included in Table 6.

Table 3. Summary of K-12 outreach.

	Thursday March 30	Friday March 31
9:00	Saratoga Elementary	Saratoga Elementary
9:30	48	34
10:00		
10:30		Science Focus HS
11:00	North Star HS	86
11:30	29	
12:00		
12:30		
13:00	Calvert Elementary	Kloefkorn Elementary
13:30	68	470
14:00		
14:30		
15:00		

5. Lessons learned

- Based on the longitudinal data presented in Figure 3 and Figure 4 it appears the training (questions 2 and 3) and the "overall enjoyment" were rated markedly worse in 2017 than in previous years. I do not believe this to be an actionable finding, but it bears watching for future UNDEOs.

- The outreach to LPS was much easier with the new Science Curriculum Specialist (James Blake) who facilitated contact with numerous teachers/schools in the system.

- Overall, the *Weather and Climate* students found the new educational component to be effective. It appears that the student presentations were more effective at improving understanding of basic concepts related to weather radars than improving understanding of the scientific method. Based on student comments, it would likely benefit the *Weather and Climate* students to receive a quick review of the scientific method prior to the presentations.

- Several *Weather and Climate* students noted the less than ideal timing of the educational component. First, the suggestion was made that the educational component should be administered closer to the class lecture dealing with weather radars. Second, its occurrence during "dead week" (the week prior to finals), agitated several folks who argued that this time should have been dedicated to reviewing for the final. Positioning the component nearer to lectures on weather radars might be difficult if the data collected during an active UNDEO are to be used. However, given that this is not essential, some flexibility is certainly possible. Similarly, administering this component before "dead week" should be possible.

Table 4. Summary of the survey given to Radar Meteorology students (9 respondents). 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 **3.00**	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 **3.33**	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 **3.89**	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 **3.28**	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 **4.44**	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 **3.44**	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 **3.78**	Very enjoyable

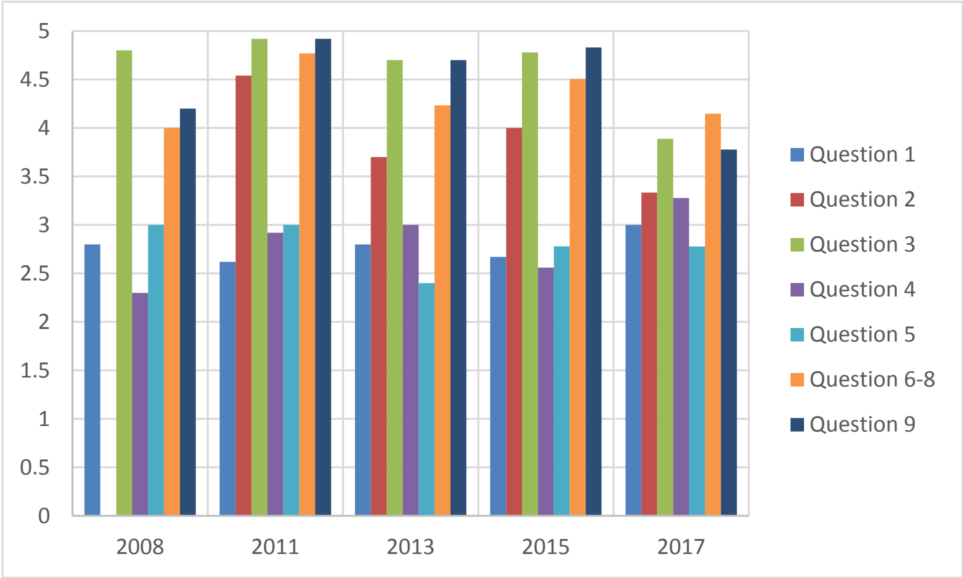


Figure 3. Summary of average responses over the five UNDEO projects (refer to Table 4 for question text).

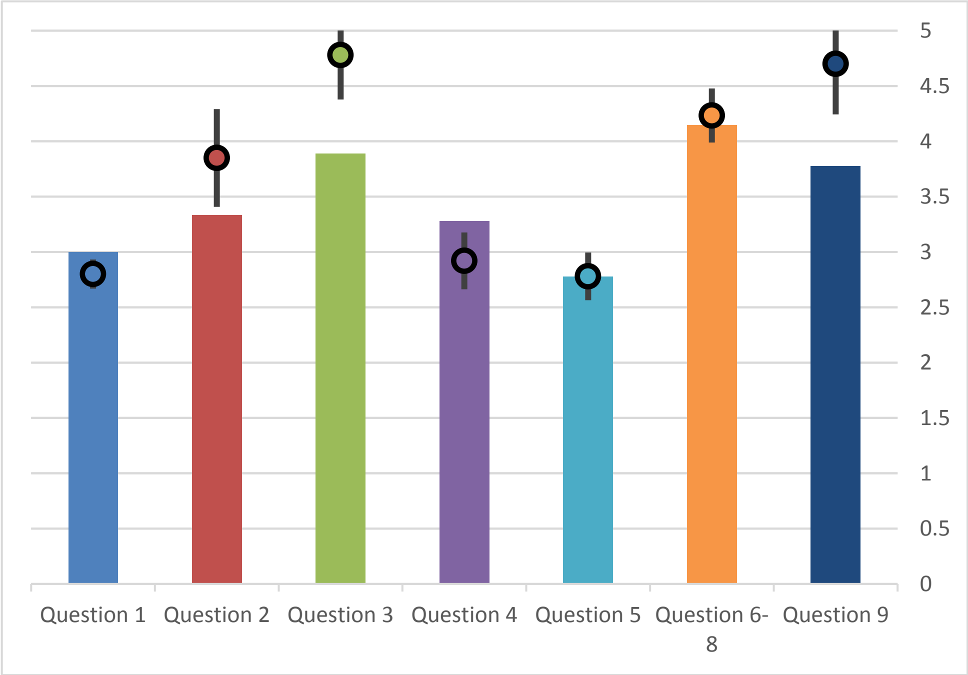


Figure 4. Scores for each question asked in the 2017 survey (bars; refer to Table 4 for the question text) relative to the median (circles) and standard deviation (whiskers) across all years.

Table 5. DOW "lab" exercise

METR 463/863 DOW Exercise

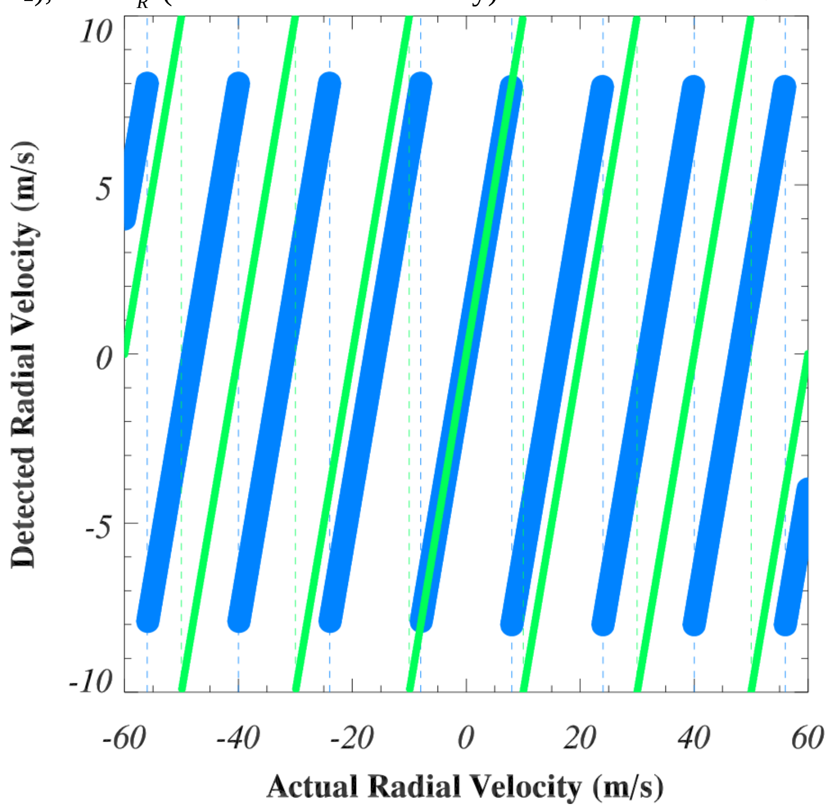
Turn in completed assignments via Canvas. **Only single-document files will be accepted (images, analysis, discussion, etc. must be in a single document).**

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

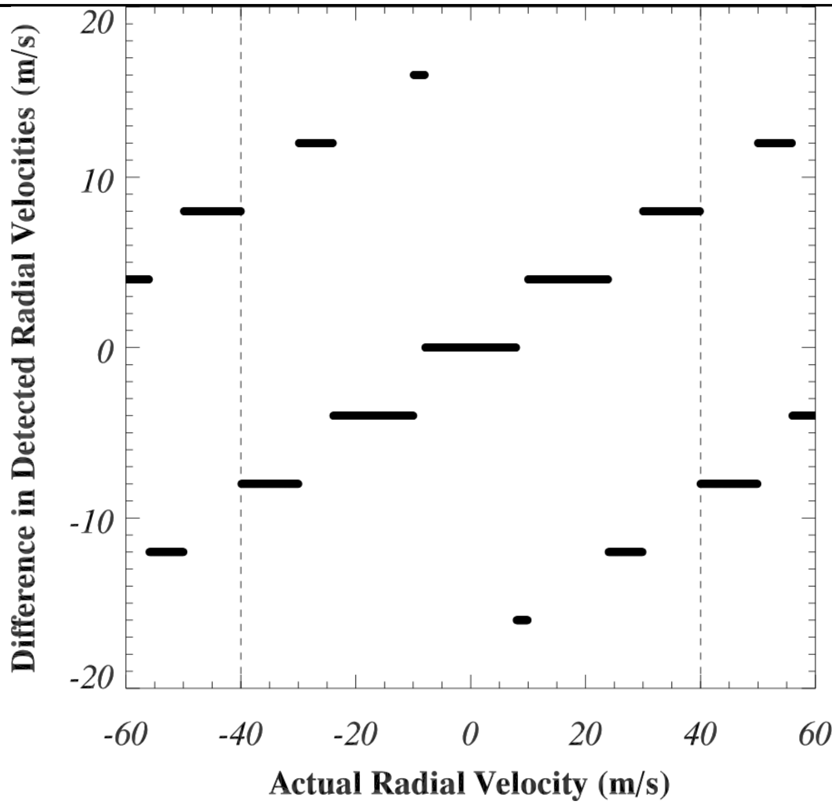
Background on staggered PRFs

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 between two PRFs. For example, if $PRF_1 = 1000$ Hz and $PRF_2 = 1250$ Hz, then $V_{\max 1} = 8$ m/s and $V_{\max 2} = 10$ m/s and the relationship between $\tilde{V}_{R1}$ (the detected radial velocity for PRF1), $\tilde{V}_{R2}$ (the detected radial velocity for PRF2), and V_R (the actual radial velocity) 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. As apparent above, $\tilde{V}_{R1} - \tilde{V}_{R2}$ cannot discriminate the sign of V_R beyond a V_R in which the ratio of $n_1 = V_R / V_{\max 1}$ to $n_2 = V_R / V_{\max 2}$ equals PRF_2 / PRF_1. In other words, the modified Nyquist velocity for staggered PRF is given by

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

Typically the PRF ratio is set to either 2-3, 3-4, or 4-5. While the Nyquist velocity increases with increasing ratio, signal quality generally "degrades".

1. Fill in the missing elements in the following table

[Note that R_{max} is based on the larger PRF of the stagger.]

Pulse duration (ns)	PRF (Hz)	Rmax (km)	Vmax (m/s)	Pulse length (m)
500	2000*			
500	1500/2000			
833	1000/1250			
1000	1000			
1000	800/1000			

* If a single PRF is listed, it is an unstaggered configuration

2. Quality for different stagger ratios

Data collection

Using the dowdrx.1000.1000.1_1.150m (PRF=1000) 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.1000.1000.4_5.150m (PRF=800/1000) configuration.

Analysis

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

3. 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?

4. 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.1000.1000.1_1.150m 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.333.1000.1_1.150m 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.**

5. Impact of rotation rate on clear-air return

Data collection

Using the dowdrx.833.1250.4_5.125m 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.**

Table 6. Summary of the surveys given to Weather and Climate *students (54 respondents). Bold values are the average scores received.*

1. Overall, how well did the presentations from the Radar Meteorology students on Tuesday improve your understanding of the scientific method?	No improvement	1 2 3 4 5 **3.50**	Significant improvement
2. Overall, how well did the presentations from the Radar Meteorology students on Tuesday improve your understanding of basic concepts related to weather radars?	No improvement	1 2 3 4 5 **4.02**	Significant improvement
3. How well did today's in-class exercise improve your understanding of basic concepts related to weather radars?	No improvement	1 2 3 4 5 **4.19**	Significant improvement

4. Do you have any suggestions on how the presentations and/or the in-class exercise could be administered differently so as to improve their effectiveness?
   - It was helpful. I don't have any recommendations
   - Good to learn new stuff before the end of the semester
   - Having slightly more fleshed out presentations might be helpful for demonstrating the scientific method
   - Do the presentations closer to when we learn about radars in lecture
   - Nope, it was very good overall and very well thought through
   - Have the students present after they have looked at the data and made their conclusions.
   - During dead week, in class review would be more helpful, maybe do this at another time
   - Getting people/students involved was a great idea and having others talk amongst each other to sprout new ideas is a great way to engage students who don't seem interested
   - Group work is great because it forces you to think
   - Having it at a different time, not dead week when our class should be reviewing for the final

- I was really interested in the biological effects and wish I could've studied that more
- Maybe have handouts for people to take notes/fill-out
- Relate the information to things we see on the Weather Channel
- Try to do a better introduction of what each group is going to talk about in their presentations.
- I liked the section overall, well done!
- Have a more decisive definition of what part of the scientific method is and to look out for.
- Talk more about things we don't know like I had no idea that birds and bugs had a significant effect on radar
- This was super fun. Please keep doing it
- More hands-on activities associated with the learning segment.
- Enjoyed the concepts greatly.
- Great job
- Clarify the definitions of the weather processes you present, maybe in visual definitions.
- Presentation was thorough in explaining the concepts, no way of changing presentation.
- Maybe encourage a little more discussion with the presentations, like we did in the exercise.
- Make it more clear as to what the different colors in the velocity radar represent.
- I thought this was going to be a review period for the final exam.
- Use time for the final review instead of this.
- Maybe add videos to the slides of research
- They did very well.
- It was dope yo, keep it up