The 2015 Lyndon State College Doppler on Wheels Education Project

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1. Summary

Lyndon State College (LSC) with support from the Center for Severe Weather Research (CSWR) completed training, educational outreach, and five field deployment with DOW7 in late January and early February, 2015. This ended up being a very active winter period, and there were serendipitous field deployments lead by CSWR staff immediately before and after DOW7's visit to Lyndon State to sample major east coast winter storms.

The principle educational objectives were focused on students in the junior-level Remote Sensing and Analysis and Forecasting courses. The intended learning outcomes were for the students to:

- be able to develop skillful localized weather forecasts around critical forecast parameters for planning DOW deployments,
- to scout, plan, and execute a DOW deployment strategy to sample local mesoscale phenomena,
- to operate the radar and control its scanning strategies as appropriate to the situation, and
- become more comfortable working in a team environment to accomplish a common goal under stressful situations.

There were a number of individuals who learned about the DOW and got the opportunity to see this awesome remote sensing platform. These included all of the ATM majors (approximately 100), a special event with regional high school science teachers (20), and visits to four schools, with approximately 325 student between grades K-12.

The overall project was a great success, and a great way to engage our students in learning and keep enthusiasm high during an otherwise cold winter period.

2. Deployments

There were a total of five deployments during an active weather pattern from January 29 - Feb 10 (Table 1). The weather was cold during the deployment period, with air temperatures generally ranging from -20F to +20F (Figure 1). As a consequence, the majority of the sampled

hydrometeors were dry snowfall. There was some light freezing drizzle mixed during two of the IOPs when insufficient ice nuclei were present. The weather was particularly active during this period, with over 20" of snowfall, including at least some measurable snowfall in the greater Lyndon State College area on every day (Figure 2).

IOP #	Date (Year = 2015)	Location	Sampled
1	January 29 - 30	Pudding Hill, Lyndon, VT	Stratiform warm frontal dry snow
2	February 2	East Warren, VT	Orographically blocked upslope dry snow within stratiform snowfall
3	February 5	Westmore, VT	Flow channeling with Willoughby Gap in post coldfrontal regime
4	February 8	Craftsbury, VT	Warm frontal dry snowfall, Kingdom Community Wind farm effects in low-level easterly flow field, light PL, FZDZ
5	February 9	Pudding Hill, Lyndon, VT	Very light mixed precipitation: SN, FZDZ

Table 1. Intensive observing periods (IOPs).

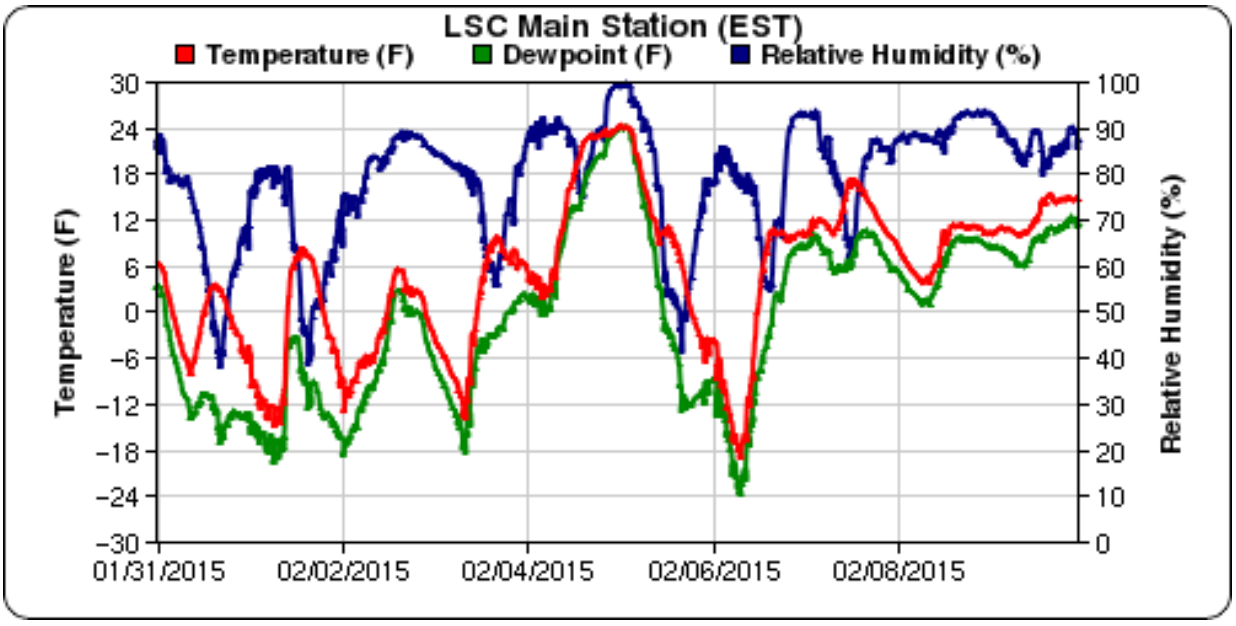

Figure 1. Lyndon State College temperature, Dewpoint, and relative humidity from Jan 31 – Feb 9, 2015. Courtesy University of Utah, http://mesowest.utah.edu

Stations:

VT-CL-1
Sheffield 2.8 NNW
Lat: 44.636769
Lon: -72.143257

* indicates Multi-Day Accumulation Report

Station VT-CL-1

Date	Precip in.	Snowfall in.	Core Precip in.	Total Snow Depth in.	Total SWE in.
01/30/2015	0.19	2.8	NA	19.0	NA
01/31/2015	0.20	2.9	NA	21.0	NA
02/01/2015	0.01	0.1	NA	20.0	NA
02/02/2015	0.03	0.3	NA	20.0	NA
02/03/2015	0.35	5.7	NA	25.0	NA
02/04/2015	0.02	0.4	NA	24.5	NA
02/05/2015	0.15	2.8	NA	25.0	NA
02/06/2015	0.01	0.3	NA	24.0	NA
02/07/2015	0.10	2.8	NA	26.5	NA
02/08/2015	0.08	1.8	NA	26.0	NA
02/09/2015	0.29	3.0	NA	27.5	NA
02/10/2015	0.02	0.2	NA	26.5	NA
Totals :	**1.45 in.**	**23.1 in.**	**0.00 in.**	--	--

Figure 2. Observed precipitation and snowfall near Lyndon State College during the DOW IOPs. Data: http://www.cocorahs.org/

IOP 1 Overview:

IOP 1 was conducted on night of January 29th into the morning of the 30th at the "go to" location on Pudding Hill Road, only 4 miles north-northeast of Lyndon State College (Figure 3). This is at an elevation of 1200', which places it on a local ridgeline, with good open perspectives in all directions. This event involved a widespread stratiform (warm frontal) snowfall event, with a total accumulation of 2-3" of dry (15:1) snow-to-liquid ratio snow. The intent was to capture any temporal or spatial variability within the widespread precipitation shield related to local terrain influences.

Surface winds were very light and there was high static stability, and a fairly deep dendritic growth zone, resulting in little apparent terrain modulation of the widespread precipitation shield. Reflectivities were relatively uniform and a veering wind profile was noted (Figure 4).

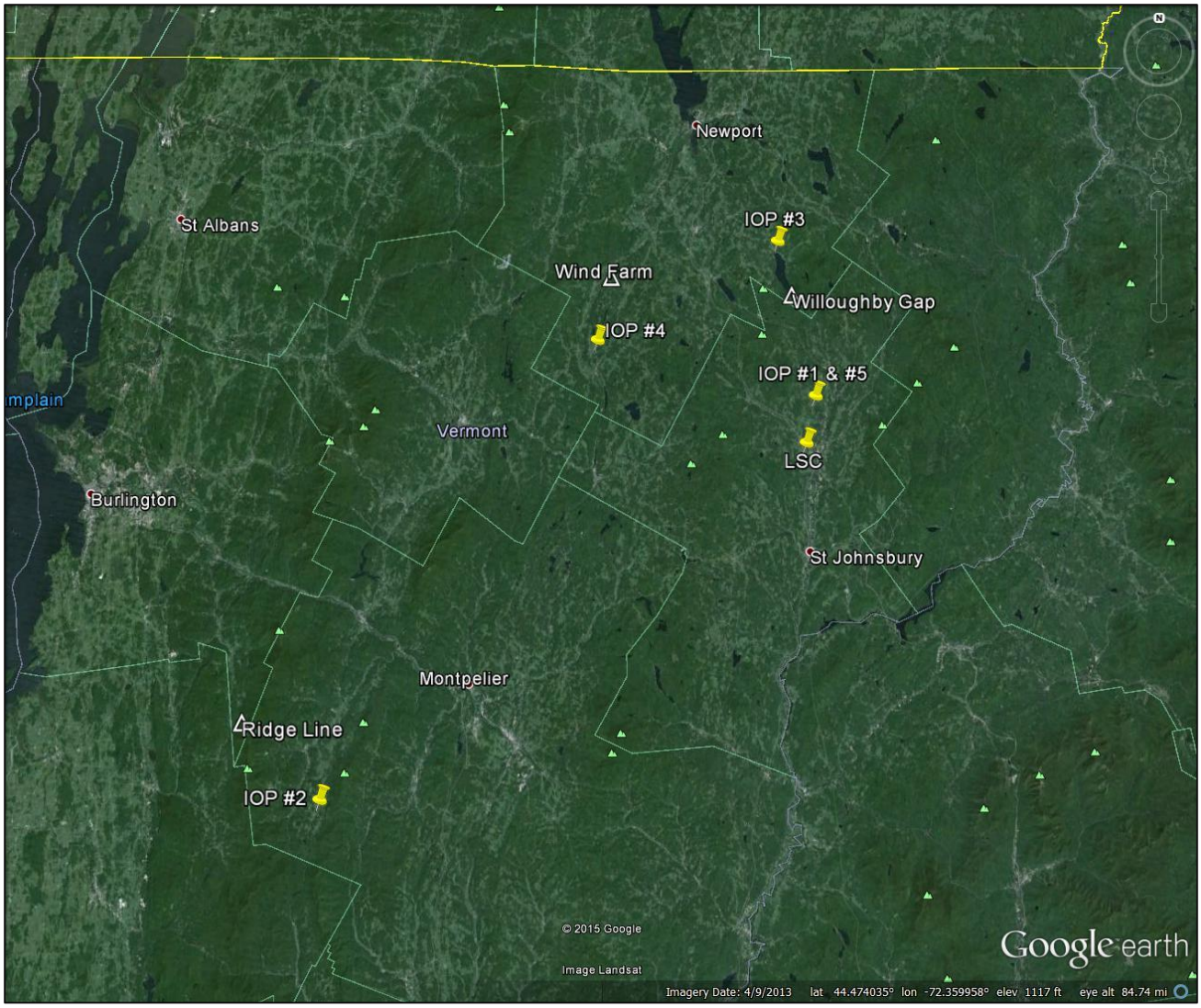

Figure 3. IOP locations and relevant features.

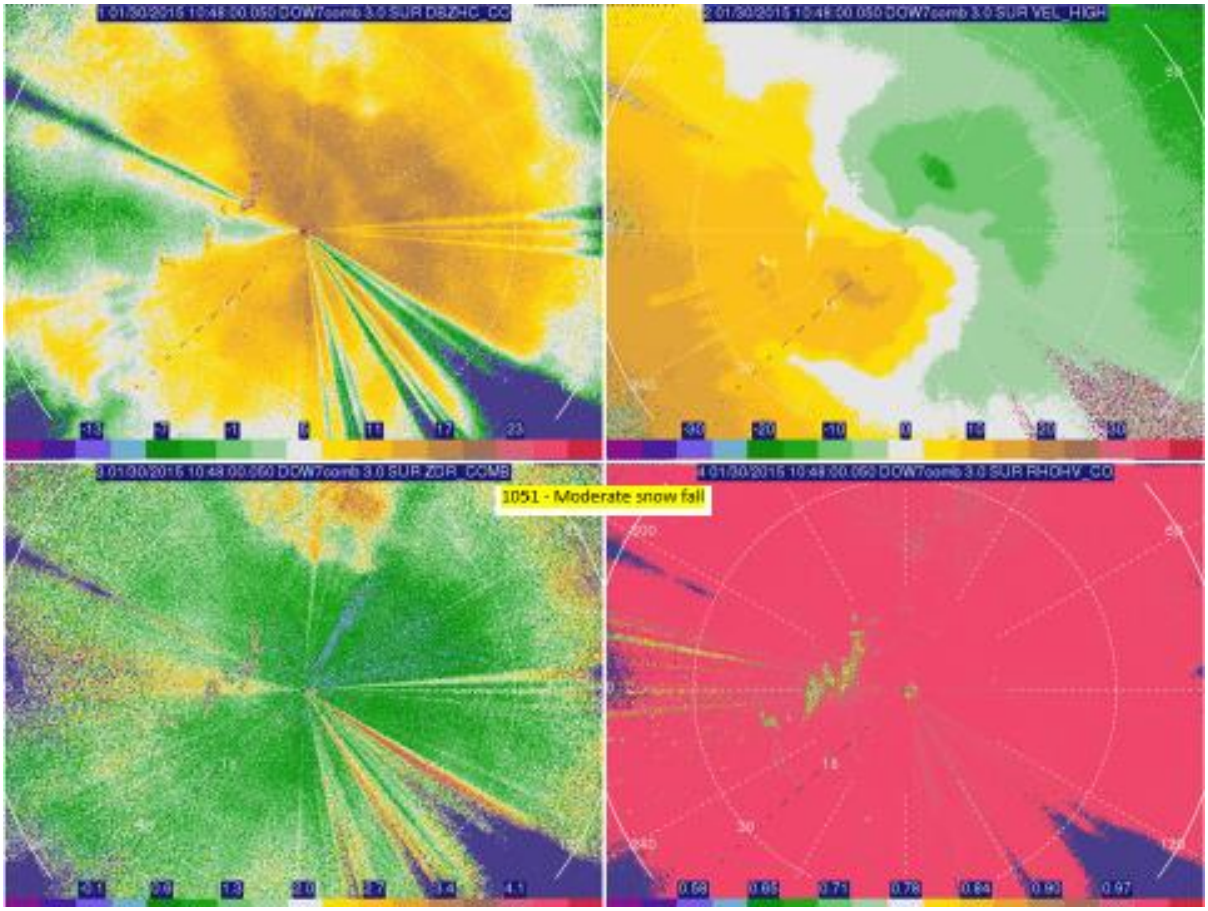

Figure 4. DOW7 observed 3.0 degree PPI reflectivity (top left), velocity (top right), differential reflectivity (lower left) and correlation coefficient (lower right) at 10:58 UTC Jan 30, 2015. Range rings are 15 km.

IOP 2 Overview

IOP 2 was conducted primarily during the daytime near East Warren, VT. The principle intent was to determine if there was flow blocking and resultant upstream precipitation enhancement in areas well upstream of the Green Mountain Crest, which was approximately 10 km to the west. This case featured high Froude number flow resulting from relatively weak cross barrier flow and high static stability. Unfortunately, it appeared that the flow below crest level was too weak to produce significant upslope precipitation on the eastern side of the Green Mountain Crest. Radar data from the DOW was inconclusive owing to the difficulty in getting a good siting location; however, observed snowfall amounts showed a narrow ribbon of 8-12” of storm total snowfall in the vicinity of the DOW (Figure 5). This was the only IOP that the students didn’t analyze in detail due to problems with citing the DOW.

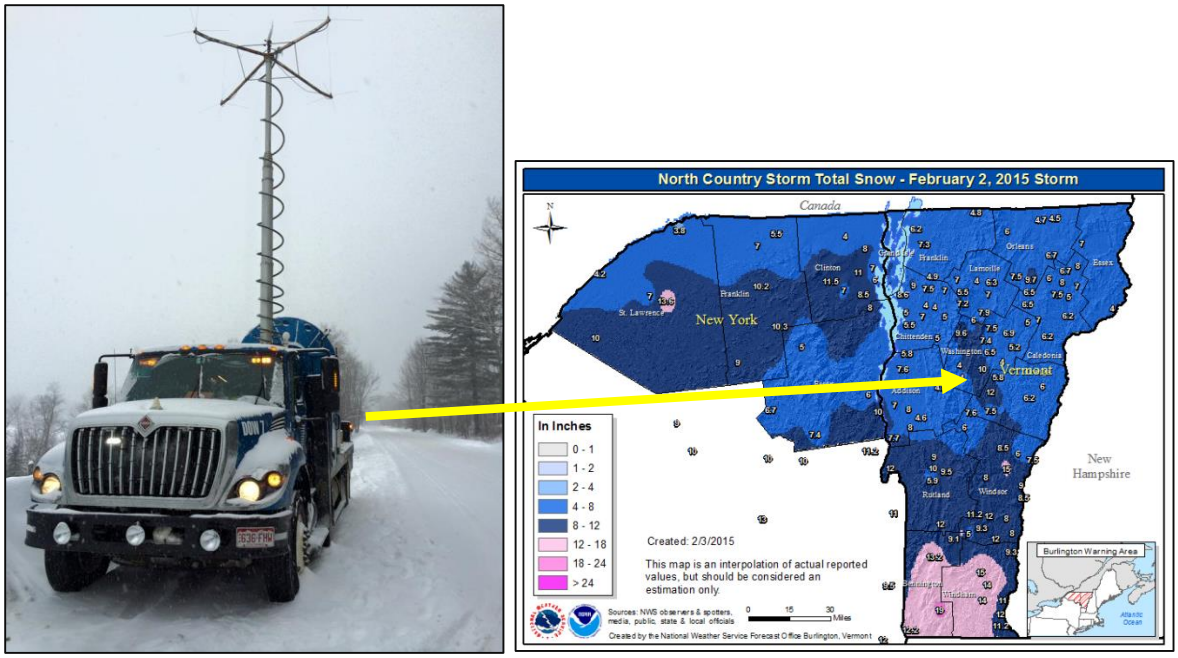

Figure 5. DOW configuration during IOP 2 (left), and NWS BTV observed storm snowfall (right) with DOW location shown by the yellow arrow.

IOP 3 Overview

The intent of IOP 3was to sample flow modifications produced by a unique local terrain feature near Lake Willoughby. Lake Willoughby is a 5-mile long lake oriented from south to north, and is the deepest in Vermont (over 400'). Its southern confluence has dramatic cliffs rising on either side, creating a localized gap in the topography, approximately 1500' above lake level and a half mile across. It is well known anecdotally that the wind turns and accelerates through Willoughby Gap. Our intent was to see if we could sample flow modification by this gap. Such flow modification has never been documented here using remote sensing.

IOP 3 was conducted during the early morning hours of Feb 5, from midnight to 6:00AM. During this window, a cold front passed, and a strong backing wind profile was seen (not shown). POD data confirms fropa with rising pressures and dropping temperatures (Figure 6). Approximately 2-3" of dry snow (around 20:1 snow-to-liquid ratio) fell overnight. Surface wind speeds at the south end of the Lake reached 7 m/s, while they were 0-2 m/s at the DOW's position on the north side of the lake.

The scanning strategy involved RHI scans along the long-axis of the lake to sample the light snow showers in the postfrontal environment. Results from the DOW velocity data appear to show the northwesterly flow increasing to 5-10 m/s through the gap (Figure 7).

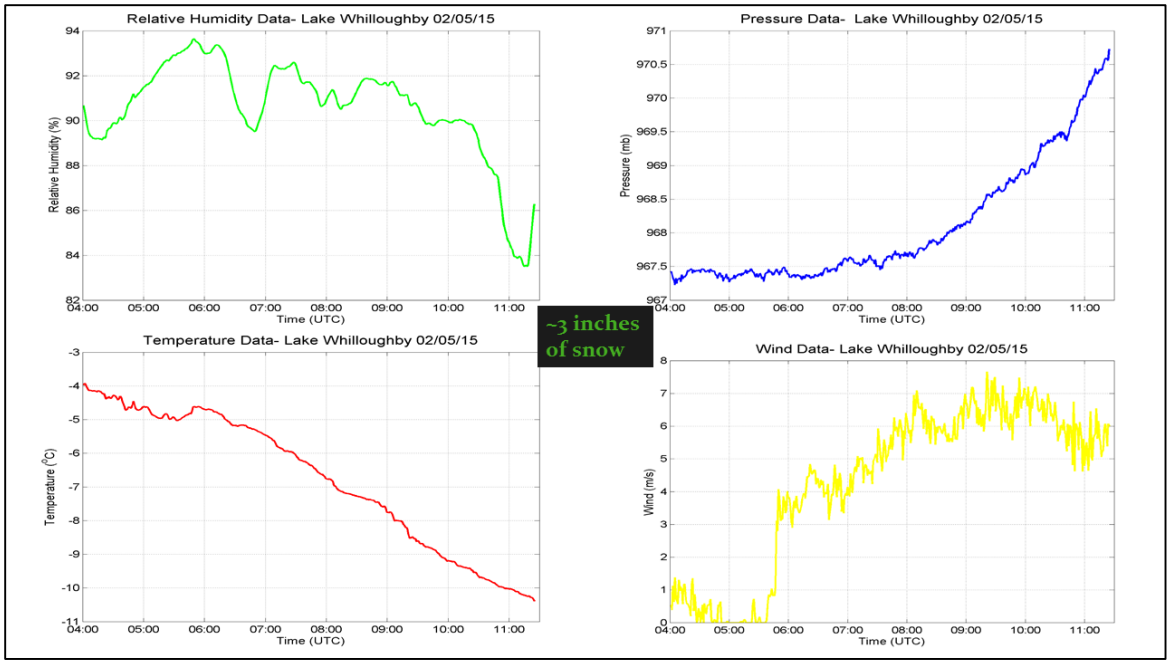

Figure 6. POD Time series from IOP3. POD was positioned at the south beach of Lake Willoughby, approximately 100' from shore.

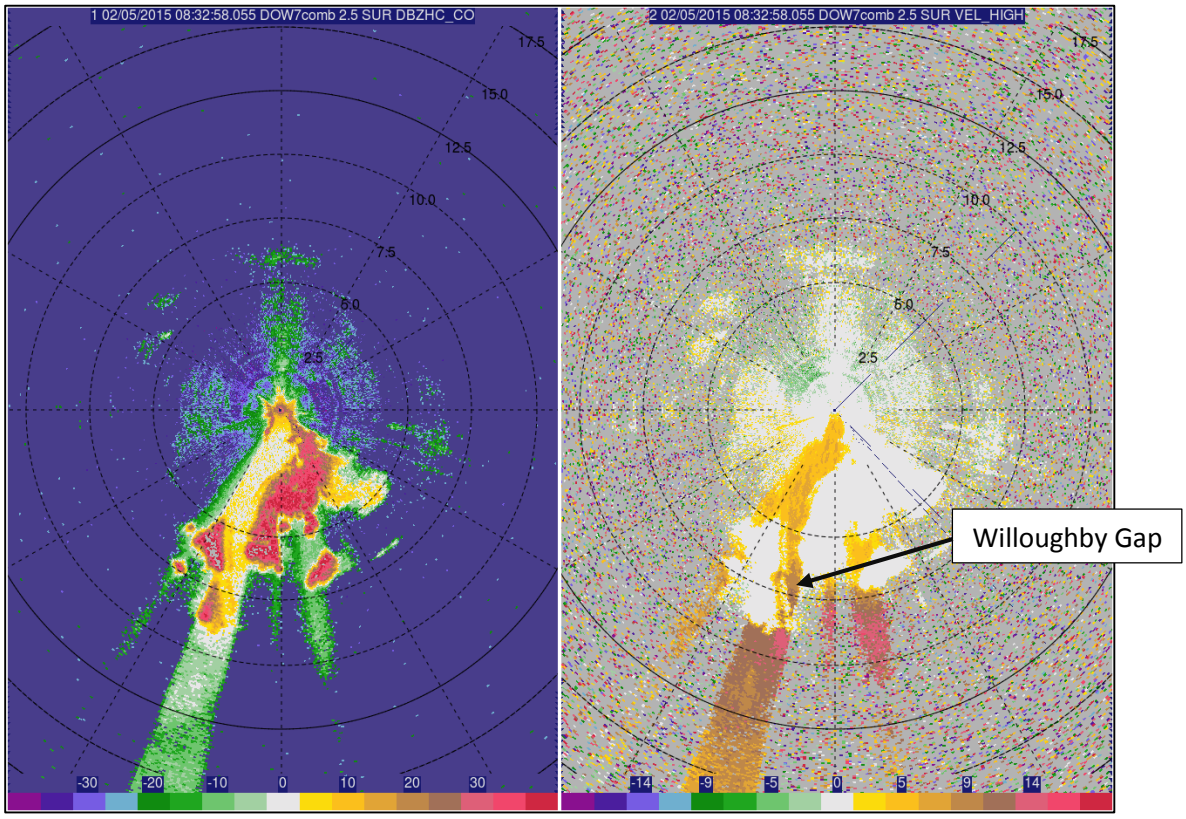

Figure 7. DOW 2.5 degree reflectivity (left) and velocity (right) at 08:32 UTC Feb 5. Up is 340 degrees. Range rings every 2.5 km.

IOP 4 Overview

The principle intent of IOP 4 was to sample how, if at all, Vermont's largest wind farm, Kingdom Community Wind (http://www.greenmountainpower.com/innovative/wind/) may influence downstream flow. The forecast was similar to IOP 2, with a dry warm frontal snowfall in high static stability and light low-level easterly flow. We were able to deploy less than 10 km to the nearest of the 21 turbines.

The flow at the hub height of the turbines was generally from the southeast around 7 m/s through the IOP (provided by Green Mountain Power). DOW data showed increased turbulence at and above the turbines (Figure 8), and decreased flow downstream.

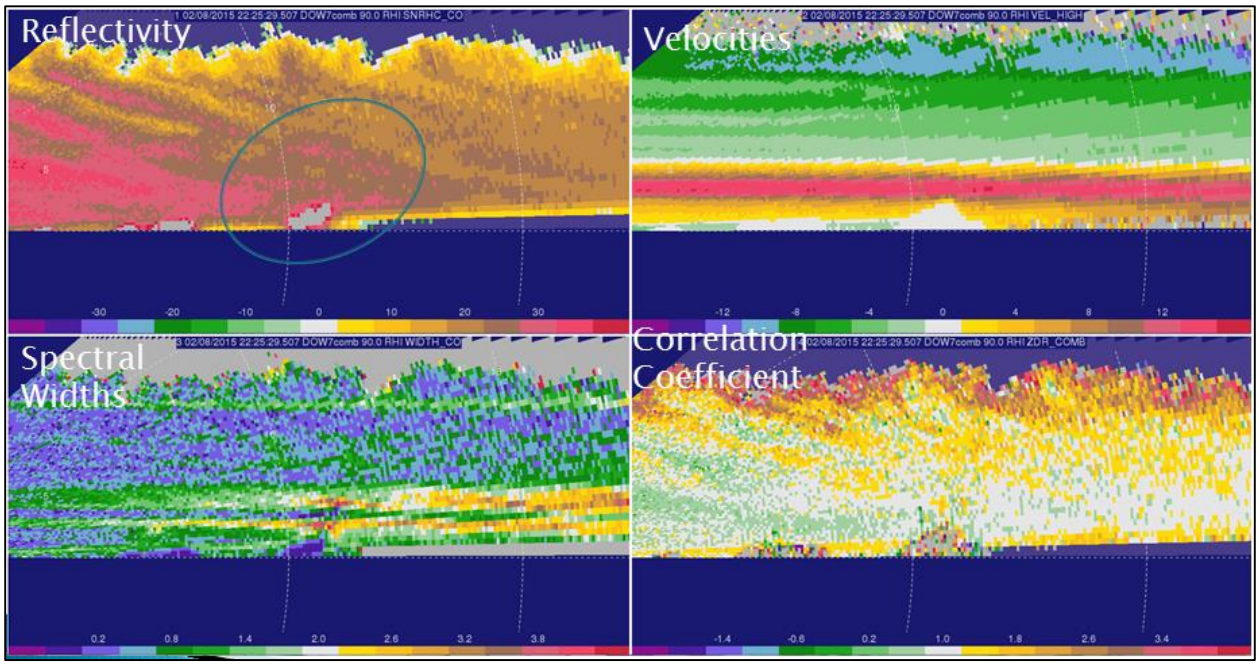

Figure 8. DOW RHI scan along 345 degrees at 22:25 UTC. Wind farm is centered in the circle the top left circle.

There was an unexpected light mix of sleet and freezing drizzle in the middle and end of this event. Differential reflectivity showed higher values to the northwest of the DOW position (Figure 9). The observation log supported the occurrence of sleet mixing in with snow during this timeframe.

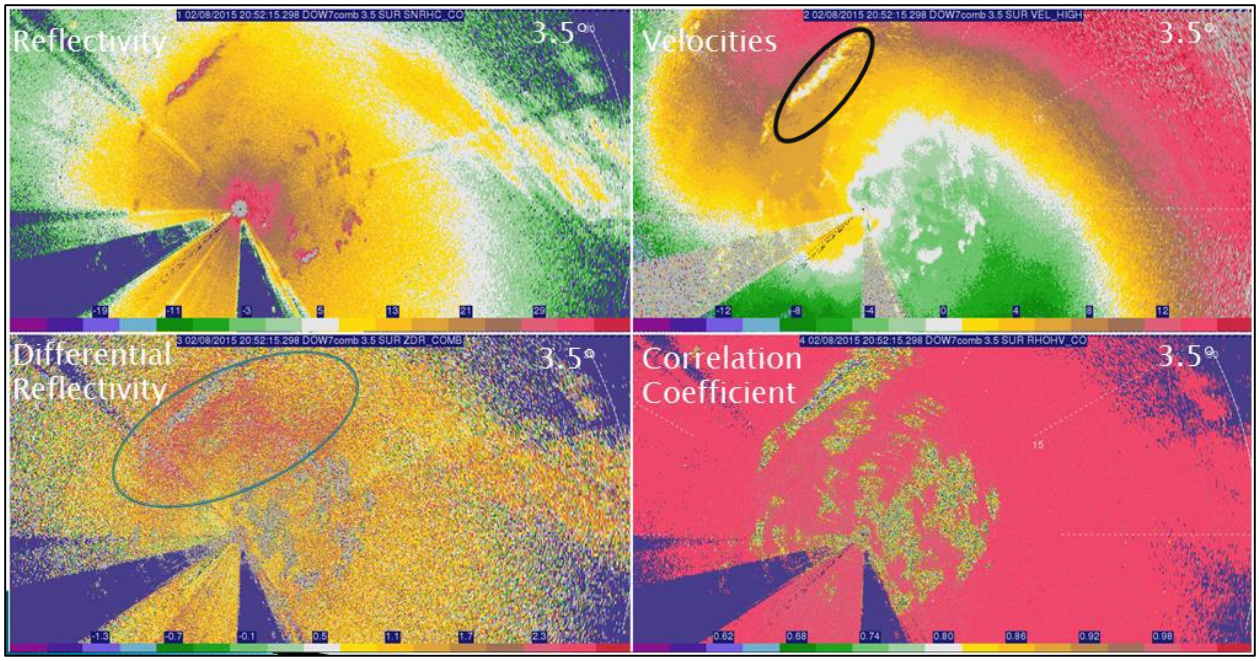

Figure 9. DOW PPI scan at 20:52 UTC. Kingdom Community Wind farm is circled in the top right panel, approximately 7 km from DOW position.

IOP 5 Overview

Persistent light snow showers and freezing drizzle continued the day after IOP 4, and the students decided to go back to the default location near the college. This was more an exercise in getting more people time operating the DOW, as there was little to no accumulating precipitation during the period and light flow limiting any orographic influences.

3. Student Work and Assessment

Lyndon State College Atmospheric Science students were placed in charge of all major DOW field operations details. The primary group was the 15 students enrolled in the junior-level Remote Sensing course, but seniors were also asked if they wanted to play a role.

There was a 3-person time responsible for helping to plan deployments and scheduling who would go out to each location. The primary means of student-to-student communication ended up being a closed Facebook Group (https://www.facebook.com/groups/926123397412243/). This ended up being productive, as anyone was able to weigh in the conversation, and it was a good place to keep an open record of project communication, activities, etc. Email was the primary student-faculty-CSWR staff communication mean.

Juniors in the Analysis and Forecasting class were responsible for issuing a day-ahead weather forecast focused on key attributes around field deployment. This was considered a major

homework assignment. Students in Remote Sensing were required to write up and present a case study from one of the DOW deployments, as one of their major assignment grades. They used SOLO to visualize the DOW data.

Final decision making for field deployment was complex, and was usually a multi-part conversation between faculty and students, but at the end of the day these decisions resided with the students.

From an instructor's point of view, this project was a great success. Logistically, it was more to manage than expected. There was a last-minute departmental personnel change that resulted in Nolan Atkins moving to a Dean position at the college three days before the semester started and myself assuming these responsibilities. The key to being successful was to incorporate as much course work as possible into the learning opportunities the DOW presented. There were many fruitful classroom and virtual conversations debating the merits of field deployment locations, the type of meteorological features to try to sample, interpreting the forecast, and the fundamentals of Doppler radar operations. The best part was seeing the smiles and all the "that's cool, wows" from both our students and the K-12 students we reached.

Our students were thrilled to have the DOW. Their enthusiasm and engagement in the different parts of the process was strong, although they sometimes backed away from the difficult parts of the project and sometimes struggled with good communication and thinking through all aspects of a deployment. There was only one student who did not pass Remote Sensing (due to missing work), so learning about radar using the DOW certainly played a major role in this outcome.

4. Educational Outreach

The DOW visited four schools (two public, two private) over an intensive two-day period. We were lucky that the weather was quiet during the pre-arranged visit dates of February 11th and 12th. All of these visits were secured through existing relationships the Lyndon ATM department has with local schools by myself. Rachel and I visited the St. Johnsbury School (Figure 11), one of the largest K-8 schools in the area, 10 miles south of Lyndon. Most of the grades five through eight classes got inside tours of the DOW (approximately 125 students). Later that afternoon, Rachel did a presentation at Blue Mountain Union High School, 20 miles south of Lyndon, where 50 seventh and eighth grade students listened to a general presentation and then toured the DOW.

The next day included a visit to the St. Paul's School, in Barton, Vermont, approximately 20 miles north of Lyndon (Figure 10). St. Paul's is a K-8 school, and every single student from the school (about 100 total) sat inside the DOW and got an outside tour (Rachel Humphrey and I conducted the tours). Our second visit this day was to the Thaddeus Stevens School, just down the hill from the College. The fourth through eighth graders (50 total) listened to a presentation by Rachel and then did tours with the help from Lyndon senior, Sarah Murphy.

We also organized a workshop for regional science teachers participating in the SWAC (Satellite Weather and Climate project (http://www.uvm.edu/~swac/). We hosted 20 high school science teachers from northern Vermont for an hour-long presentation by Rachel Humphrey, and then

went for a tour inside the DOW. This ended with an informal lunch with Rachel, myself, and the science teachers continuing the discussions around all the cool science the DOWs have conducted.

Figure 10. St. Paul's school students and their teacher checking out the DOW on February 12, 2015.

Figure 11. St. Johnsbury School students inside the DOW on February 11, 2015.

5. Lessons Learned

Lyndon has been fortunate to host the DOW multiple times over the last five winters. Despite this experience, when it comes to field work, few things go as planned. This was also the first time for many of our students working with the DOW. There were a number of lessons that we learned from this experience.

One of the biggest shortfalls was the lack of a formal scouting team to check possible deployment locations ahead of time. This was done on somewhat of an ad hoc basis (ok, who can go?), or via Google Earth. There is simply no substitute for checking out a location and doing it during the daytime. For example, the location for IOP 2 was only scouted with Google Earth. The pull off that was going to be used was plowed in with snow, so an alternate less-than-ideal location needed to be found nearby.

We operated at a lot during the nighttime and during inclement weather. There were several instances where students operated personal vehicles not suited for conditions. Designating drivers with 4WD/AWD and/or securing a small college van with snow tires would be a good solution. Also, ensuring our students are prepared appropriately for the conditions if they get stranded or need to walk in deep snow (several students pulled the POD over a soft 7' snow bank in jeans). Each team should travel with a snow shovel and basic provisions. Cold weather operations slow everything down, it's fine to not be in a hurry.

There are a lot of decisions that need to be made, many involving multiple parts. Managing and helping to facilitate the decision making process takes a lot of effort. Timely and transparent communication are necessary for successful planning and execution. There needs to be redundant communication with phone, email, and/or messaging (text/Facebook), with communication channels established ahead of any operations with the field teams and CSWR crew. There were a few instances of communication break downs because of cell phone dead zones and not having pre-determined plans in place. It's challenging being dynamic to the weather, yet needing concrete planning.

One of the hardest parts of the project was getting steadfast student support. The "fun" parts of the project were easy to get students involved in. However, at the end of the day, most assumed that someone else like the faculty may coordinate or make important decisions. If we did this again, we would hold students more accountable to the gritty planning details. The lack of enthusiasm toward the end of the project was disappointing; it seemed like they had their taste and wanted to move on, and not continue to try to do neat science.

Finally, the most important lesson we learned was to treat the CSWR staff and its staff well. Rachel and Traeger were awesome; without their patience, hard work, positive attitude, and knowledge we could not have executed this project. Everyone on the CSWR team was supportive and understanding. We hope to be able to host the DOW again in the future.

Figure 12. DOW7 and its deployment locations/conditions.


Figure 13. Lyndon State College students and the author's son during IOP 3.