FINAL REPORT
Northern Autumn Plains Echo Patterns (NAPEP)
St. Cloud, MN (St. Cloud State University)
2-18 October 2010

Professor Gregory D. Nastrom
Department of Earth and Atmospheric Sciences
21 December 2010

Narrative of the Proposed Project:

Observations from the DOW will be used primarily by the 18 undergraduate meteorology majors registered in EAS 468, Radar and Satellite Meteorology. Some of the topics to be studied include warm and cold frontal structure including vertical and horizontal wind shear layers, evolution of the bright band during stratiform rain episodes, changes in polarimetric quantities in relation to frontal boundaries, and evolution of the boundary layer during clear-air episodes, among other possible topics.

St. Cloud State operates an instrumented 500-foot tower located near campus. Vertical profiles from the tower can be used to augment the DOW data for some of the studies mentioned above. Also, there is a meso-network of 6 surface stations in the St. Cloud area, within about a 10 km diameter, which can be used for some studies.

Summary of the Completed Project:

The DOW arrived at St. Cloud State University (SCSU) on Friday, 1 October 2010. Mr. Justin Walker, a trainer from Center for Severe Weather Research (CSWR), conducted training sessions on basic DOW start-up and data collection procedures for 17 students and 2 faculty on Saturday-Monday, October 2-4, in 2- or 3-hour sessions with 2 or 3 persons trained each session as shown in this grid:

	Saturday	Sunday	Monday
0830-1200	Mark Katie Greg	Leandro Barry Adrian	
1200-1530	Erin Dan	Alana Zach Allison	(1100-1300) Juan Rande David
1530-1830	Ryan Alyssa Kyle	Jennifer Kirstin	

On Monday afternoon Mr. Walker conducted an hour-long classroon training session on SOLOii applications. This was followed by a 2-hour open laboratory session where students could practice SOLOii using data files furnished by CSWR.

On Tuesday Mr. Walker and Dr. Greg Nastrom, the local PI for NAPEP, conducted numerous site surveys in the St. Cloud area to identify suitable sites to deploy the DOW for hands-on training and anticipating actual storm observations. In the early afternoon Mr. Walker conducted a second laboratory session on SOLOii.

Dr. Josh Wurman arrived on Tuesday evening. On Wednesday he gave lectures to the Introductory Meteorology class (45 students) and the Radar and Satellite Meteorology class (17 students). He also gave an auditorium lecture open to the general public (Atch. 1) that was attended by about 200 people. In all cases his lectures were followed by active question and answer periods. Comments from attendees were very favorable.

On Thursday, 7 October, the DOW was taken off-campus for a practice deployment. Mr. Walker supervised the students (about 11 participated, the others had classes or other conflicts) as they leveled the truck, initialized the electronics, and collected samples of data. The skies were clear that day, but the fairly brisk boundary layer winds produced longitudinal rolls that could be identified. Mr. Walker showed them how to combine PPI scans with RHI scans to analyze the longitudinal rolls. One of the students later used these observations in her class project report, as discussed more below.

A reporter from Minnesota Public Radio accompanied us on the deployment. She made several recordings of interviews with students, Mr. Walker, and Dr. Nastrom. Her report aired on MPR on 11 October; a copy of the on-line version of her report is included here (Atch. 2).

On Friday, 8 October, Mr. Walker returned to Colorado. Skies remained clear [we note here that there were no actual storms at St. Cloud during the entire period of the DOW visit; it was one of the longest rain free, in fact nearly cloud free, periods in recent history, Atch. 3]. Despite the continuing clear skies, a team of students drove the DOW off-campus on Tuesday, 12 October, to practice deployment procedures and data gathering. However, due to a software problem with the DOW they were not able to initialize the system. After many hours on the phone with CSWR and their contractors it was determined that the problem could not be solved by long-distance. Mr. Walker returned to SCSU on Thursday, 14 October, and by Friday afternoon had the problem fixed (it turned out to be a problem with the antenna control software).

On Sunday, 17 October, a weak system passed over central Minnesota, although well south of SCSU. A team of students drove the DOW about 50 miles south and made observations of the light rain event. The data was analyzed extensively at SCSU and used for class project reports. This was the final opportunity the students had to use the DOW because it left SCSU on October 19th.

Two examples of class project reports are included here. The first, by Erin Walter, is of the longitudinal rolls seen in the clear air on October 7th. The project reports included both a brief written report and an oral report. Ms. Walter's written report is in Atach. 4 and the powerpoint slides she used for her oral report are in Atch. 5. The second example, by Mr. Barry Windschitl, is of the precipitation event observed on October 17th. The slides used for his oral report, which focused primarily on the bright band they analyzed, are in Atch. 6.

Summary

The DOW at SCSU was an overall success. While events were not as anticipated and the weather was not ideal, the educational experiences were excellent for several reasons. First, the students learned that field experiments in meteorology must adapt to the weather conditions available during the time frame of the experiment. Second, they learned that field equipment does not always work as expected (it must be noted that the CSWR staff responded quickly and effectively to solve the problem we encountered, they are to be commended for their actions). Third, the students obtained hands-on experience as they operated the DOW themselves; this was an opportunity not often available to undergraduates. Finally, despite less than ideal weather conditions the students were able to make meaningful observations, analyze their data, and draw conclusions regarding what they saw. This sequence of events is the essence of the scientific method and at the core of effective education.

The NAPEP experience brings out the importance of having alternate plan(s) when the reality of weather or equipment makes an otherwise excellent plan impossible to execute. Future field program should always include contingency plans.

Atch. 1

WEDNESDAY, OCTOBER 6, 2010

2:00 P.M.

BROWN HALL AUDITORIUM

DR. JOSHUA WURMAN

THE DOPPLER ON WHEELS

Dr. Wurman received his doctorate from Massachusetts Institute of Technology and now serves as President of the Center for Severe Weather Research. Dr. Wurman is a meteorology researcher and technology innovator expert on tornadoes, hurricanes, and radar. Dr. Wurman developed the Doppler on Wheels (DOW), a mobile Doppler Radar, used to get "up close and personal" with severe weather events. His talk will highlight unique developments in severe weather research associated with the DOW. Dr. Wurman's visit to SCSU marks the beginning of a two-week deployment of the DOW at SCSU to study autumn storms in the northern plains.

Sponsored by The College of Science and Engineering's Department of Earth and Atmospheric Sciences and The National Weather Association St. Cloud Chapter.

MPRnews

St. Cloud State meteorology students get unique training chance

by Ambar Espinoza, Minnesota Public Radio
October 11, 2010

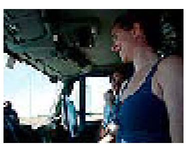
St. Cloud, Minn. — For budding weather forecasters, it doesn't get any better than this -- spending three weeks with a "Doppler on Wheels" radar unit. Meteorology students at St. Cloud State University are getting a rare opportunity to play with this high-tech, storm-chasing toy.

The Doppler on Wheels looks like a semi truck, with a satellite dish mounted on the back where a trailer would normally be found. The dish is actually a huge radar antenna.

The antenna has to be stationed just right, and that explains the adjustable metal legs on the four corners of the truck, which raise it up and down and stabilize it. As it sits parked unevenly along a Sherburne County road, a meteorology student volunteers to level the truck, so its readings are accurate.

"That way we get good quality data," said Justin Walker, a radar technician with the Center for Severe Weather Research, the company that developed the Doppler on Wheels.

The radar uses electromagnetic waves to identify the range, altitude, direction and speed of objects, including storms.



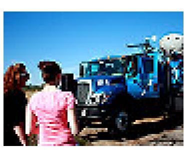
Leveling the Doppler

Walker says severe weather researchers station the mobile Doppler within about a mile of a storm to get high-resolution data. As a storm or tornado passes near the Doppler, researchers can also get a time series of what's happening, kind of like a movie.

Walker has been training the St. Cloud State students how to operate the mobile Doppler system and collect and analyze data. So he stands by to guide them through their first radar scans.

"[The radar] allows us to see lots of small things, like insects and dust," said Walker. "They set up a scan so they can actually look at things that are invisible to the naked eye, so you can actually see what's going on in the lowest part of the atmosphere."

Walker says existing stationery radar systems only collect good data when storms get close to it. So the idea behind developing Doppler on Wheels was to take the radar to the storm.



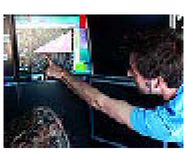
Students

The Center for Severe Weather research makes the nearly $1 million mobile radar available to small universities that don't have their own radar facilities. The National Science Foundation sponsors this project, so schools don't have to pay anything.

The Doppler on Wheels visited two universities last year for the first time. And this school year, it's visiting St. Cloud State and four other schools.

Greg Nastrom, a professor of earth and atmospheric sciences at St. Cloud State, submitted a proposal requesting the Doppler on Wheels. The intention was to look at autumn storms over northern plains.

"There haven't been any, as you can tell," Nastrom said.



Unfortunately for these would-be stormchasers, the Doppler is here during rare burst of beautiful, and calm, weather. But the students are still making the most of it. They're out in the outskirts of Sherburne County to look at the clear air.

"We're going to look at bugs and things like that that fly with the air, that move with the air," said Nastrom, "so we can, for example, look at the wind profile at different altitudes as a substitute project."

Good weather challenges SCSU class

By Ben Katzner
bkatzner@stcloudtimes.com

The good news for St. Cloud State University professor Greg Nastrom and his radar and satellite meteorology class was that during the past two weeks, they were able to get an in-depth look at how much hard work studying the weather can be.

Students were given the rare opportunity to use groundbreaking technology that allowed them more access to the storms and inclement weather they signed up to study in the class.

The bad news was that during the past two weeks, the area has seen some of the nicest fall weather in recent memory. Temperatures were in the 70s and high 60s last week.

So what's a storm chaser to do?

"We had to go to plan B," said Leandro Ribeiro, a junior at St. Cloud State. "That's kind of a bummer, but there's nothing you can do about it. Mother Nature needs to cooperate."

"Plan B" was to hope for the best, gather as much information as they could, and turn those facts into a well-researched statement when it's all said and done.

The machine that Nastrom's class is using is called Doppler on Wheels, or DOW. It was created by Center for Severe Weather Research President Joshua Wurman. The DOW is a mobile radar system that does close-range observation of different natural phenomena.

"(That) means we can take it to where the interesting weather is, we don't have to wait for interesting weather to come to us," said Wurman, who received a doctorate in meteorology from the Massachusetts Institute of Technology and was on the 2007 season of the Discovery Channel's television series "Storm Chasers."

"If you're able to drive to different states, you can collect more data," he said.

St. Cloud State got the DOW through a program supported by the National Science Foundation, which allows universities around the country to request use of the machine. Schools are asked to develop a proposal

See RADAR, 4A ▶

FROM PAGE 3A

Radar

that explains how they would use the DOW. If the proposal is considered possible by Wurman and his colleagues at the National Weather Service, the DOW is given on a short-term basis to the school that requests it. Nastrom submitted a proposal for use of the DOW last winter. The machine arrived Oct. 2, and Nastrom and his students will have their project complete by Tuesday.

"This is a unique opportunity," Nastrom said.

Wurman said the DOW has allowed his team to study different kinds of weather around the world, including 20-25 tornadoes this year alone. Nastrom and his students would be happy with a few rain drops at this point.

"It would have been great to have it last month," Ribeiro said. "With the nice weather, there isn't really a lot to see."

The original goal of allowing St. Cloud State to use the DOW was so it could assist in the study of autumn storms on the northern plains. Now, Nastrom's class is collecting information on topics that range from wind patterns to how things such as insects can affect the information they gather.

Despite not being able to chase down storms, the DOW still should be a great learning experience for the class, Wurman said.

"I think hands-on experience with cutting-edge technology makes for a broader, more intense learning experience," he said. "Students get to get in the radar, throw all the switches ... It's better even than a lab."

Nastrom agreed that while his class' experiment may have lacked some excitement, being able to get students' hands on state of the art technology will help them in the future.

There's a least one undisputed fact that he can take away from the experience, he said. His class is dedicated.

"For undergraduate students, to get them to give up a free weekend is very hard," Nastrom joked. "They were very excited."

Atch.3

The Detection of Clear Air Turbulence with DOW Data:

By Erin Walter (Dec. 8, 2010) EAS 468

The Doppler on Wheels (DOW) is a governmentally funded project directed by Dr. Josh Wurman. The project consists of three DOWs. Dr. Wurman constructed the DOW in order to gather data at a close range to severe weather by driving a mobile Doppler near the site of interest. The DOWs are used to map detailed resolutions of tornado winds and also to study hurricane wind streaks. The DOWs were constructed to measure significantly large winds, roughly 300 mph, allowing researchers to understand the development and movement of serve storms. The presence of DOW 6, October 2-19 2010, gave our Radar and Satellite Meteorology class the opportunity to see and experiment with the radar images of the region directly surrounding our deployment location. Due to the lack of precipitation during its visit, we were able to study and understand the significance of scanning in clear air.

Radar scans in clear air can still illustrate wind speed and direction as well as any disturbances aloft. Clear air images typically consist of "ground clutter" (buildings, trees, bushes or other solid objects) surrounding the radar because the beam width is low and near the ground closest to the radar. The ground clutter pixels have a radial velocity of about zero, allowing the observer to distinguish the difference between the noise on the ground versus collectable data in the air. As the range of the beam extends, the beam reaches higher points in the atmosphere because of the curvature of the earth and the secondary effect, called refraction. The images aloft in clear air may have very little reflectivity because of the absence of clouds and moisture. However, the airborne dust, bugs and atmospheric particles that flow with the wind are picked up by the radar, making good indicators of wind direction and any turbulence aloft. Disturbances occurring in upper layers of the atmosphere, such as clear air turbulence (CAT), are difficult to predict. CAT is formed by instabilities due to vertical wind shear. As the vertical wind shear increases, eddies are produced when the flow becomes unstable. These eddies are most frequently seen in jet streams where wind shears are the strongest. Forecasting the wind speed in eddies can be difficult because of their chaotic motion, but the atmospheric particles allow the radar to measure the location and direction of eddies forming aloft. Winds that change speed and direction in a sinusoidal pattern, by rising and falling along axes parallel to the mean wind, are called longitudinal rolls. Longitudinal rolls are recognizable on the reflectivity, power, and velocity scans as the air particles and bugs flow with the undulating wind speeds.

For our deployment on October 7th, 2010 around 1800 UTC, we were scanning in clear skies and observed the formation of longitudinal rolls. The velocity image showed an increase of wind speed as altitude increased, which indicates that shearing winds were present. The change in wind speed with height allowed the vertical shearing to create clear air turbulence aloft. The reflectivity, normalized power, and velocity images we captured showed a distinct separation between the shifting wind directions in the longitudinal rolls because of the airborne bugs and atmospheric particles following the wind patterns. There were no clouds present that day which made the values on the reflectivity and power images very low, but the disturbances were still distinguishable on all images.

After collecting the data, it is important to edit the images to remove any areas of ground clutter, second trip echoes or folding. The Soloii program allowed us to "clean up" our data collected during the surveillance scan. One particular image, on the surveillance scan with a 2° tilt at 18:40:42 UTC, showed a very nice representation of clear air turbulence aloft that was located about 30 km south of the DOW's deployment location and roughly 1050 m above the surface. In many cases, including this one, there is ground clutter within a 10 to 15 km radius surrounding the radar which can be removed by comparing the velocity image to the normalized power (NCP) image from the same scan. On the normalized power image, values that are under 0.3 are typically considered noise or second trip echoes. By using the widget tool, the NCP values at any point on the image are readily available and on this image the values of power within 10 km of the DOW were mostly negative and less than 0.3. There were a few sections across the scan that had patches of noise and second trip echoes that stretched outside of the 10 to 15 km radius of the radar, but each of these portions can be removed by using the same editing tool. The tool used is referred to as "thresholding." By thresholding velocity on NCP below 0.3, Soloii will remove every section on the velocity image that has a power less than 0.3. This tool removes much of the noise from the velocity image, but there are additional threshold parameters, like absolute velocity and reflectivity, that can be used to clean up the data even more, giving a clearer picture of the wind direction and speed. There is also a tool called "forced unfolding," which removes any folding on the radar scan. However, the wind speed this day was fairly low and we did not experience any folding. It is important to understand that editing the images using Soloii can have diverse results because the thresholding restrictions the observer editing the data chooses for deleting ground clutter can differ slightly from person to person.

Once the ground clutter was removed, the wind direction, wind speed and location of the clear air turbulence were easily distinguishable. There were longitudinal rolls just south of the DOW's deployment location showing wind flowing towards and away from the radar as the bugs and particles followed the rolling clear air turbulence. Also, the velocity scan showed light southwesterly winds near the surface with increasing wind speed with height. The data from the DOW corroborates with the results from the 1800Z surface analysis which showed a high pressure system just south of Minnesota indicating an anticyclonic circulation system providing southwesterly winds over St. Cloud, clear skies over St. Cloud, and light winds at the surface. The MPX sounding from that evening at 00Z also showed increasing wind speeds with height, confirming the DOW clear air scans. The national radar image from 1800Z on October 7^{th} did not show any echoes over Minnesota. Therefore, having the DOW added information that is usually not readily available.

References:

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6. National Weather Service Hydrometeorological Prediction Center. HPC's Surface Analysis Archive. 1 Mar. 2007. Nov. 2010 <http://www.hpc.ncep.noaa.gov/html/sfc_archive.shtml>.

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DOW Deployment October 7th, 2010: A study of clear air scans

Erin Walter

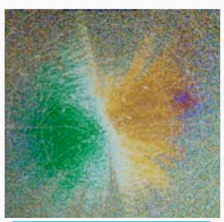
DOW History:

DOW 6 scanning a developing supercell in Kansas, 2009, provided by Ryan McGinnis, "The Big Storm Picture: Scanning." http://bigstormpicture.blogspot.com/2009/07/scanning.html

- DOW (Doppler On Wheels)
- Governmentally funded project with CSWR, directed by Dr. Josh Wurman
  - Consists of 3 DOWs
  - X-band radar
- Collects data of severe weather at a close range
  - Tornadoes
  - Hurricane wind streaks

Radar Imagery in Clear Air

- Noise on radar scans
  - Typically within a 10-15 km radius
- Detection of wind speed and direction
  - Bugs, airborne dust, atmospheric particles
- Clear Air Turbulence (CAT)
  - Longitudinal Rolls
  - Eddies



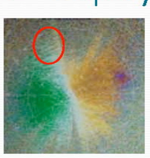
Surveillance Velocity Scan with 2° tilt

Why is this important?

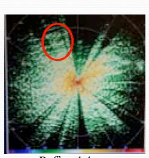
- Aviation hazards
  - Formation of eddies, downbursts and surges of energy due to turbulence can potentially injure the plane's passengers by:
    - Affecting the plane's landing or take off
    - Plane can veer off course
    - Rapid drop can cause the plane to lose control

October 7th Deployment

- Surveillance scan with a 2° tilt at 18:40:42 UTC
- Increasing wind speeds with height in clear air
  - Vertical shearing
- Longitudinal rolls found about 30 km south of DOW's deployment location, about 1050 m from the surface.



Velocity scan

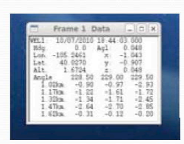


Reflectivity

Normalized Power

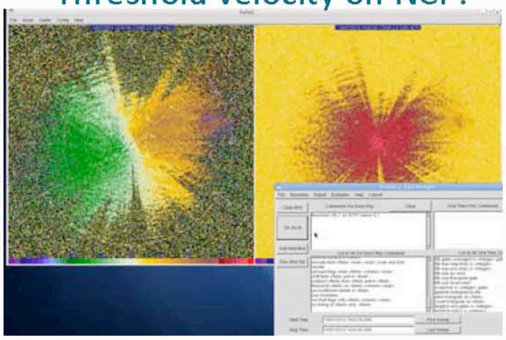
Editing Data

- Soloii Program
- Velocity versus Normalized Power (NCP)
  - Widget values of noise and second trip echoes are less than 0.3
- Other thresholding parameters:
  - Velocity versus Absolute Velocity
  - Velocity versus Reflectivity
- Before editing data make copies of original scans!!!
  - Ex: Copy VEL to VEL1



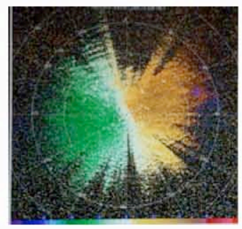
Widget data on NCP over second trip echo

Threshold velocity on NCP:

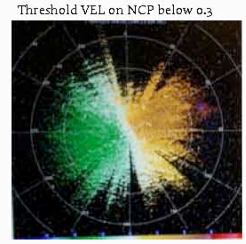


Threshold Velocity on NCP Continued…

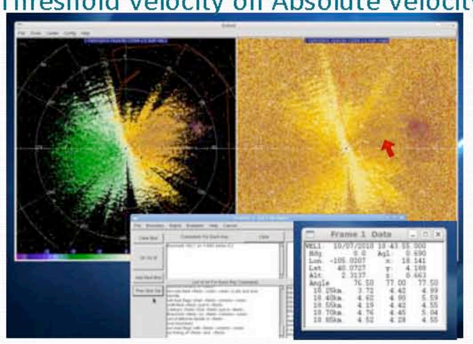
Threshold VEL on NCP below 0.2



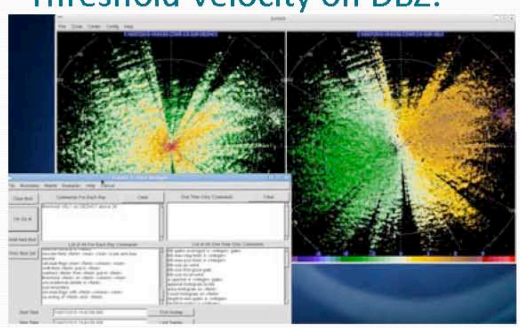
Threshold VEL on NCP below 0.3



Threshold Velocity on Absolute Velocity



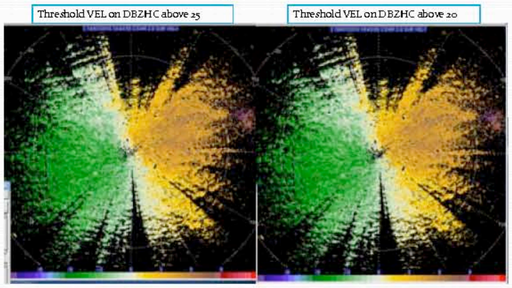
Threshold Velocity on DBZ:



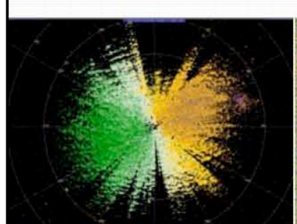
Threshold Velocity on DBZ Continued…

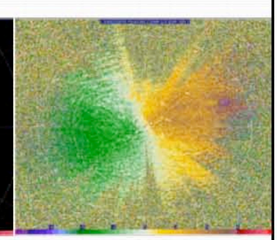
Threshold VEL on DBZHC above 25

Threshold VEL on DBZHC above 20

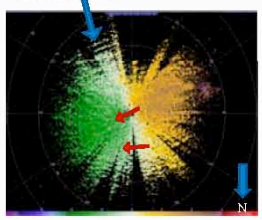


Revised vs. Original Velocity Scan:





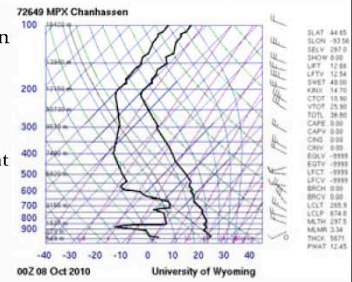
Conclusions:



- Wind Direction
  - The colors on the velocity scan were reversed for the DOW data collected during St. Cloud's entire deployment
  - There were southwesterly winds near the surface with a slight shift in wind direction with height towards westerly winds aloft
- Longitudinal Rolls
  - Due to vertical shearing

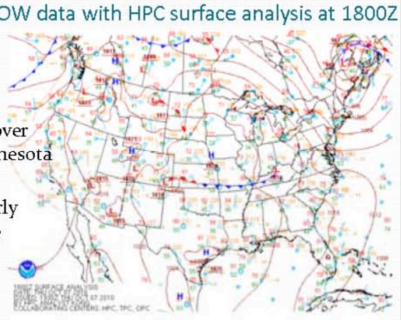
Comparing DOW data with MPX sounding at 00Z

- DOW velocity scan correlates with MPX sounding at 00Z
  - Increasing wind speed with height
  - Change in wind direction



Comparing DOW data with HPC surface analysis at 1800Z

- Clear skies over central Minnesota
- Light Southwesterly winds at the surface



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7. University of Wyoming Department of Atmospheric Sciences. Atmospheric Soundings. 2010. Nov. 2010 <http://weather.uwyo.edu/upperair/sounding.html>.

Questions?

DOW DEPLOYMENT: OCTOBER 17TH, 2010.

A brief analysis of data collected near the cities of Luxemburg, MN and Hutchinson, MN.

Barry J. Windschitl,
Student, St. Cloud State University

The DOW Truck

- DOW- Doppler On Wheels
- X- Band Radar (3cm) (DOWs 6, 7)
- The first DOW truck, DOW 1, was initially deployed in 1995 by Dr. Josh Wurman.
- Developed as a means to get scans in the lowest levels of storms, where stationary radars often couldn't.

The DOW Truck

- There have been 7 DOWs made: DOWs 6, 7, and Rapid Scan DOW 5 are still in service.
- Also has been used to scan other phenomena, such as hurricanes and wild fires, and just clear air scans.
- During the off season, they are loaned out to many universities and colleges.
  - Hands- on Experience for student
  - Used in class projects: Northern Autumn Plains Echo Patters (NAPEP)

Deployment: Oct 17, 2010

- Two Deployments:
  - One in the morning, one in the late afternoon/ evening.
- The Plan: Go out at 4:30 to do scans, especially if precipitation was expected/ ongoing.
- It was decided to go south of St Cloud on Highway 15.
- First site was just south of Luxemburg, MN. No precipitation was reaching the ground, so it was decided that we should head further south.

The Final Deployment Site

- About 5 miles north-northwest of Hutchinson, MN.
- Light Precipitation was occuring by this time.
- Set up facing south over a relatively flat farm field.
- We were scanning at this location for about one half hour.

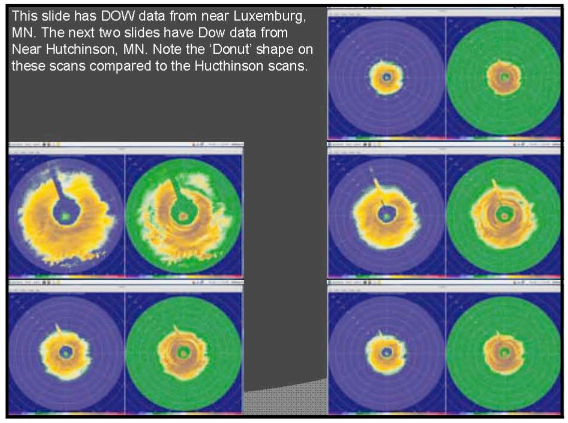
Data Analysis

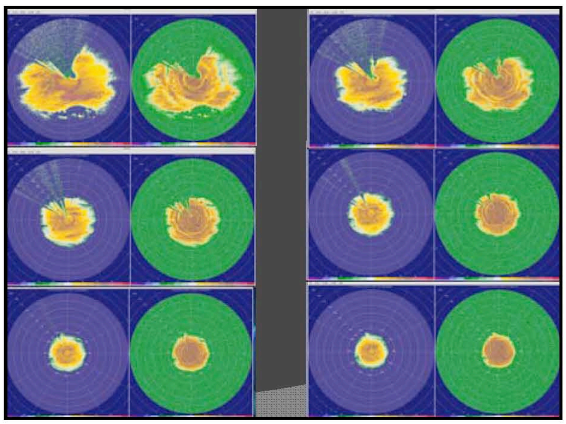
- Notice the difference between the two deployment areas.
  - The scans from near Luxemburg, where precip wasn't yet hitting the ground, do show a precip layer aloft.
  - Contrast with the scans from near Hutchinson, where precip was hitting the ground.

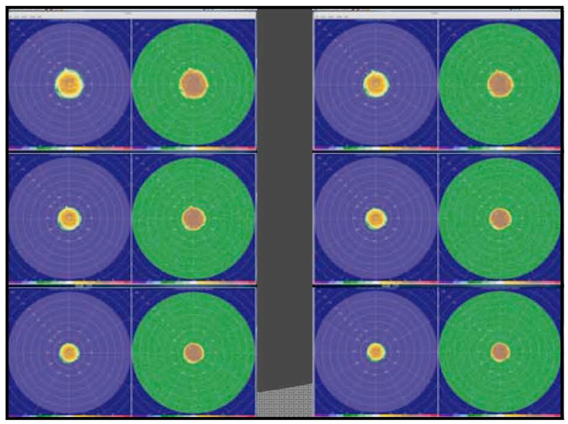
Data Analysis (Cont'd)

- Notice in the scans from near Hutchinson that there is a small band of higher reflectivity. This is very likely the bright band, given the temperature at ground level was only in the low 40s. But how can one be sure?
  - First, we will look at the DOW data, then measure the approximate height of the apparent bright band. Then that height can be compared to archived data from that day and location, specifically, data for the freezing line at that time.

This slide has DOW data from near Luxemburg, MN. The next two slides have Dow data from Near Hutchinson, MN. Note the 'Donut' shape on these scans compared to the Hucthinson scans.







Ascertaining the elevation of the possible bright band.

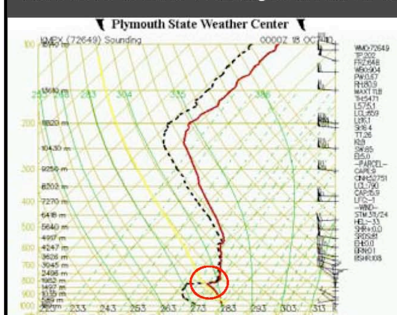
- Simple Trigonometry reveals….

One can simply use the elevation angle of a given scan and the range of the bright band to find the elevation.

Height= (range) *tan(elev. angle)

- After taking as accurate of measurements as possible (a little difficult using a computer screen and ruler), the bright band appears to be centered at approximately 1550- 1600 meters above ground level. This is a very rough estimate given the possiblity of measurement errors. We can now check this by consulting archived data from that time frame.

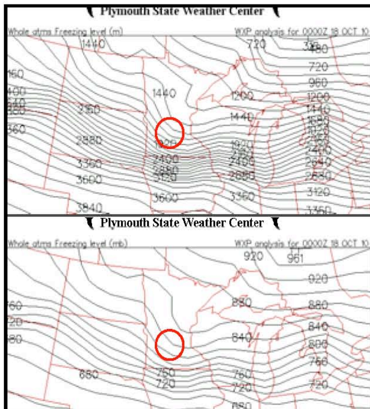
The 00z 10-18-2010 sounding from KMPX/ Chanhassen, MN.



This sounding does have a dry slot at the surface, but should work as a reference for where the Bright Band was estimated to be.

On the skew-t, the temperature line crosses the 0 degree isotherm at about 1497 meters and approaches it again at 1982 meters.

Within the ball park, but not quite a match.



Another, probably better, way to check the estimate is to look at the freezing level data from that day. Here it is laid out in terms of both hieght (meters) and pressure (mb).

The height chart shows the freezing level at approximately 1680 meters, which corresponds to a pressure height of approximately 830 mb on the pressure chart.

This is only about 80 meters off from the postiion of the suspected bright band.

Conclusion: Bright Band!

- It looks like a bright band does show up in the scans. The various data doesn't match up exactly, but is close enough that the difference can be chalked up to the small errors that can crop up in (estimated) measurements.
  - We can also look at the fact that the ring of higher reflectivity is relatively consistent throughout the run of scans.
  - With more time, other data could be consulted to corroborate the current data and assumptions.

Thank you for your time. Questions?