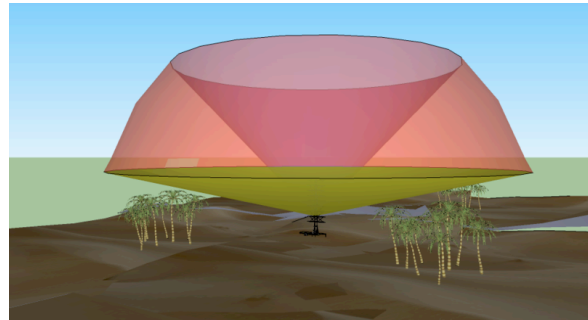


Current Weather Studies
7C:

WEATHER RADAR: Reflectivity and Velocity Modes

1. As directed by your instructor, complete this activity with its associated images.
2. Reference: Chapter 7 in the *Weather Studies* textbook. Complete the Investigations in the *Weather Studies Investigations Manual* as directed by your instructor.

The image to the right shows the volume scanned by the radar after multiple elevation angle scans. The base level is 0.5 degrees of elevation. After each scanning rotation, the antenna elevation is changed for the next scan. This process is repeated for many angles until all of air around the radar is scanned out to the maximum range. A full scan takes between 5 and 10 minutes.



There are two main modes of operation for the Weather Service's Weather Surveillance Radar (WSR) 88D radars: Clear Air Mode and Precipitation Mode. Within these modes, forecasters can vary the number of elevation tilts and rotation speeds of the radar.

Clear Air Mode is the most sensitive mode and is used when there is no rain within the range of the radar. The rotation rate is slowest and permits greater sampling of the atmosphere. This mode is often used when there is snow falling because snow does not reflect radar energy very well.

Precipitation Mode is used when precipitation is occurring. This mode does not have to be as sensitive since there are plenty of targets for the radar signal to hit. Scans in this mode go higher into the atmosphere because meteorologists want to see more of the vertical structure of the storm. Full scans are faster...important during severe weather events because rapid updates on storm development and progress are critical.

National Weather Service (NWS) Radar Image Types

Reflectivity Images

There are two types of images in this category: **Base (or ½° elevation) Reflectivity** and **Composite Reflectivity**.

Recall that radar works by bouncing radio waves off particles (rain, snow, hail, insects, birds, etc) in the air. The amount of energy that returns back to the radar is called "reflectivity" and is represented by the variable "Z". Reflectivities can be weak to strong and are measured on a decibel (logarithmic) scale where the units are dBZ, or decibels of

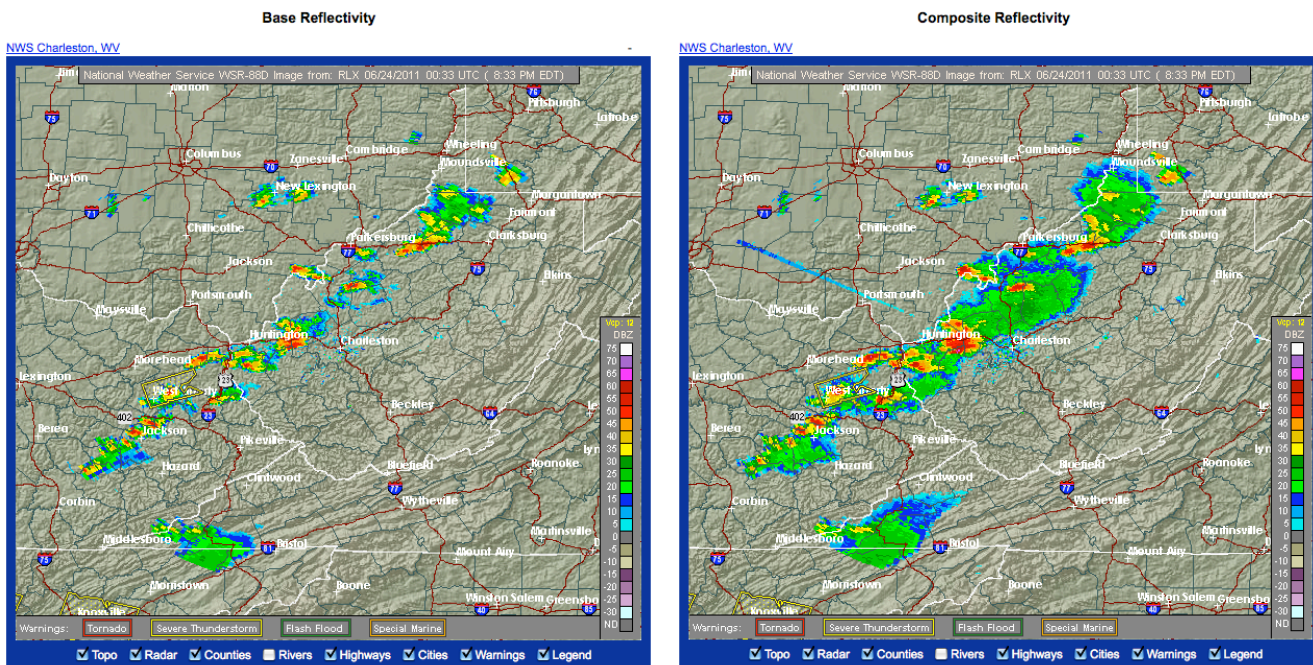
Z. The higher the dBZ, the stronger the return to the radar (larger targets or greater number of targets that the beam is hitting). On the radar images, you will see a scale with colored squares and associated dBZ values. The *rough* association between colors/dBZ and precipitation is as follows:

- 10 dBZ (green) - Very light rain or light snow
- 20 dBZ (green) - Light rain or moderate to heavy snow
- 30 dBZ (yellow) - Moderate rain or sleet showers
- 40 dBZ (orange) - Moderate to heavy rain or sleet showers
- 50 dBZ (red) - Heavy thunderstorms
- 60 dBZ (pink) - Intense to severe thunderstorms with hail

If you see values <5 dBZ, the radar is operating in clear air mode, indicating that it is likely NOT raining in the area. Such low values indicate dust or insects in the air rather than precipitation.

Base Reflectivity is one of the basic quantities that a Doppler radar measures. It corresponds to the amount of radiation that is scattered or reflected back to the radar by whatever targets are located in the radar beam at a given location. The sample is taken from the lowest elevation slice at an elevation of $\frac{1}{2}^\circ$. The targets can be forms of precipitation (snow, rain, hail, cloud drops, ice particles) or other targets (dust, smoke, birds, airplanes, insects). The colors on the Base Reflectivity product correspond to the intensity of the radiation that was received by the radar antenna from a given location.

Composite Reflectivity shows the highest echo intensity or reflectivity in a vertical column (for an entire volume scan). It is used to show the highest reflectivity in all echoes and helps determine the 3-D structure of a thunderstorm.



The images above show the differences between the two types of reflectivity images. Notice the larger areas of yellow and red (higher reflectivities indicating heavier precipitation) on the composite view. This shows that there is heavy rain or embedded hail higher in the thunderstorms as opposed to near the base (although there is heavy precipitation in the lowest sample (base view)).

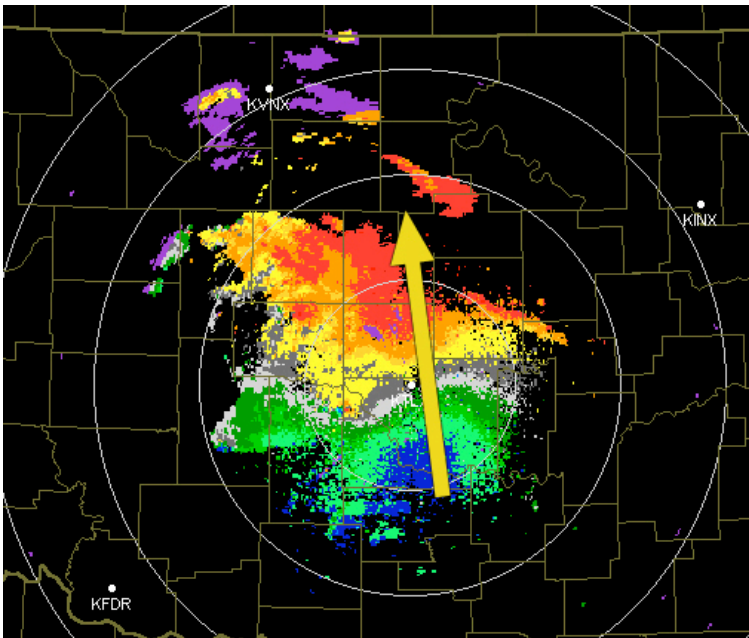
Velocity Images

The real benefit of the 88D Doppler radar is its ability to detect motion...in essence, its ability to “see the wind”. The radar can only “see” movement either directly toward or away from the radar. This is called radial velocity as it is the component of the target’s motion that is along the direction of the radar beam. You saw this in the exercise you completed in the *Weather Studies Investigations Manual*.

In these images, **green (cool tones)** colors indicate wind moving **toward the radar** while **red (warm tones)** colors show wind **moving away**. You need to know where the radar is located for proper interpretation.

There are two types of images in this category: **Base Velocity** and **Storm Relative Motion**.

Base Velocity Image shows **winds moving away** from the radar with **red (warm) colors** and winds **moving toward** the radar in **greens (cool colors)**. The transition zone between incoming and outgoing winds is shown by a gray tone between the two. **Purple** color shows “**range folded**” areas where the radar is **unable to determine the wind velocity**.



The radar’s location is the small white dot to the left of the yellow arrow. The yellow arrow indicates the basic wind field in this region, however, the actual wind direction varies depending on the distance from the radar. Closest to the radar, the beam is close to the surface and winds are modified by friction. As distance from the radar increases, the beam is ‘looking’ higher into the sky above the friction layer.

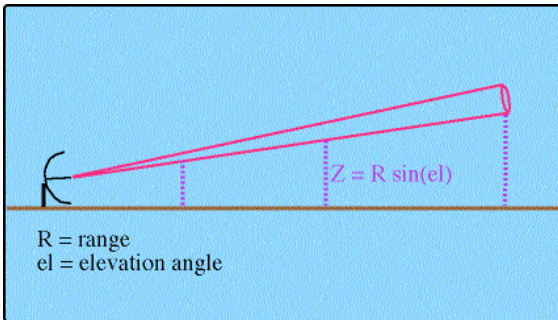
Storm Relative Motion is computed by subtracting the motion of the storms from the overall wind field giving a picture of the wind as if the storms were stationary. This image is useful for finding small-scale circulations such as the mesocyclone / tornadoes, where strong inbound wind is situated next to strong outbound winds.



In the example below left, we see two rotational signatures (mesocyclones) from the 1998 Central Florida Tornado Outbreak. The two mesocyclones have pink arrows pointing to them. The red areas show outbound winds (radar is to the right...off of the image) and the green tones adjacent to the red show air moving inbound to the radar. The regions between these two zones in both cases show the tornado locations. Remember that the radar isn't looking at ground level, so it can't actually see the tornado itself. It is seeing the

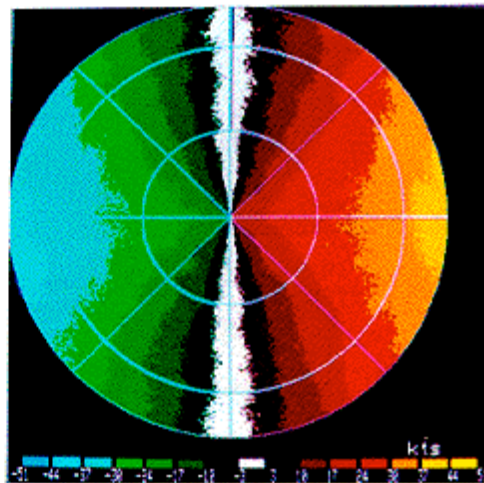
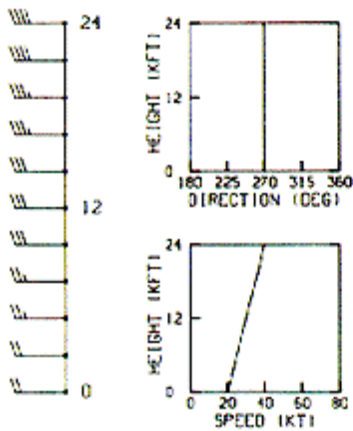
rotation higher up in the storm.

Beam Location above Ground



When interpreting velocities, remember that the beam height above ground increases at larger ranges...therefore, at larger distances you are not looking at surface flow anymore. (Don't worry about the question in the image...you won't have to do any calculations.)

The images below show the Doppler wind velocity display in the case of speed shear (winds increasing with height into the atmosphere). We see that in the wind speed indicators on the far left side. Winds of 20 knots are nearest the ground with winds increasing to 40 knots aloft (24,000'). The graph in the upper center shows that the wind direction is from 270° (from the west) at all levels and the graph below it shows the increase in wind speed with height. Look at the colored Doppler display. Blue/green



shows inbound flow, red/orange/yellow is outbound. The radar location is in the center of the image. The white area shows 'zero' wind. The scale at the bottom shows values increasing as one moves away from the center of the scale. Example: going from dark green to light

green to blue, winds are increasing in velocity in the inbound direction (from west here). The values increase as we move away from the radar in the outbound direction as well. This is not saying that as we move away from the radar, winds are stronger at the surface. Remember that the beam is looking further up into the atmosphere as distance increases. Since winds are increasing as we move higher into the atmosphere, this display makes sense.

Image 1 is the Base Reflectivity display from the Minneapolis, MN (MPX) radar on 29 October 1995. The multi-colored area that surrounds the radar location (black dot) shows “ground clutter” and is not precipitation. Precipitation is occurring to the north, northeast, and southwest through southeast of the Twin Cities (Minneapolis/St. Paul).

1. Reading the text on the right side of the image under “Base Reflectivity” and “MPX”, what mode was the radar being operated in: _____
2. At what elevation was the radar beam operating at for this image? _____ degrees
3. What is the maximum reflectivity of the precipitation (not in the “clutter”) in this image? _____ dBZ. Give the value at the upper end of the color range you see for your answer. (Note: Ignore the “Max dBZ = 43” you see under the colored scale...this maximum value is somewhere in the clutter around the radar.)
4. Given the date of 29 October and the geographic location of Minnesota (at 45° north latitude), what is the likely form of the precipitation in the area of the highest reflectivities that you noted in question #1 (e.g., light rain, heavy rain, light snow, heavy snow, hail, etc.) _____

Image 2 is an example of the Doppler velocity pattern on 03 May 1999 from Oklahoma City, OK (KTLX). Recall from Investigations 7B (Doppler Radar and Applications) that the 0-Doppler wind speed boundary is the lighter shade between the warm and cool tones. In Image 2, it is white in color.

Draw a short straight-line segment through the grey radar site dot out to roughly the first range line (teal colored line – 10 nautical miles (nm)) to show the position of 0 Doppler wind speed near the radar site.

5. Based on what you learned in question 19 of Investigation 7B: Applications, what would be the general low-level wind direction in this region? Winds are from the _____. Draw a short arrow showing the direction of airflow in this region.

Next, go out to the 3rd range line (30 nautical miles from radar). Draw a straight-line segment connecting the white area (0-Doppler wind speed) on one side of the radar site (at a distance of 30 nm) to the white area on the other side of the radar site also at 30 nm.

6. Draw two arrows (one on each side of the radar site near 30 nm distance) indicating the wind flow direction at this higher height in the atmosphere. (Remember that as the radar beams travels outward from the radar site, the beam is looking higher into the atmosphere.) What is the wind direction? _____

Finally, go out to the 5th range line (50 nm distance). Draw a straight-line segment connecting the middle of the white area on one side of the radar site (at 50 nm distance) to the white area on the other side of the radar site also at 50 nm.

7. Draw two arrows (one on each side of the radar site near 50 nm distance) indicating the wind flow direction at this higher height in the atmosphere. What is the wind direction at this higher height? _____

As we go up into the atmosphere, if the winds are changing direction, we give terms to indicate whether the changes are in a clockwise or counterclockwise direction with height. If winds are changing direction in a clockwise direction (e.g., coming from SE and then W as we move higher in the atmosphere), this is called a **veering wind**. Veering winds are associated with warm air advection and lifting. If the winds turn counterclockwise with height, they are said to be **backing**. A backing wind is associated with cold air advection and sinking.

8. In the example from 03 May 1999, are the winds veering or backing with height?

9. Is warm air advection or cold air advection taking place? _____

The following table shows the basic relationship between rainfall rate and radar reflectivity. This is based on the work of the Oklahoma Climatological Survey. Use **Image 3** and answer the following questions. **Image 3** is a zoomed in view of the Composite

Rain Rate vs. Reflectivity

Reflectivity (dBZ)	Rain Rate (inch/hour)
15	.01
20	.02
25	.04
30	.09
35	.21
40	.48
45	1.10
50	2.50
55	5.68
60	12.93

Rain generally falls with reflectivities beginning at 20 dBZ. Echoes above 55 dBZ usually contain large hail.

Reflectivity image from the Birmingham, AL radar on Sunday, July 10, 2011 at 5pm local time.

10. What is the maximum reflectivity value of the precipitation on this image? _____ dBZ
11. According to the bullet items near the top of page 2 of this exercise, what precipitation type/event is associated with this color/reflectivity value?

12. Using the Rain Rate vs. Reflectivity table to the left, what is the rain rate in inches per hour corresponding to the darkest red tone on the scale? _____ in/hr (Note: this rain rate and accumulated precipitation would be noted if

the storms cells were stationary...which they rarely are).

13. Is it likely that this cell contains hail? Yes or no _____

Images 4 and 5 (together) are the Reflectivity and Storm Relative Motion images for 23 May 2008 near Quinter, KS at 6:26 p.m. The city of Quinter is just right of center in each image.

14. What is the highest radar reflectivity (range) in the storm echoes located between the cities of Park and Quinter? between _____ dBZ. Reflectivities this high suggest that the precipitation is characteristic of *[(light rain) (moderate rain) (heavy/intense to severe thunderstorms)]*.

The bright red curled extension you see between Park and Quinter (south-southwest of the larger red area) is often apparent in tornadic thunderstorms. This radar ‘signature’ is called a “hook echo” and indicates precipitation being wrapped around a circulation in the cloud. This would suggest that there is the possibility of tornadic activity in this region. To confirm this, the radar operator can examine the storm relative radial velocity (shown in Image 5).

From our earlier discussion on pages 3 and 4 regarding Storm Relative Motion, we saw that rotation within the cloud can possibly be identified by locating warm color/cool color couplets on the velocity display. These couplets are also called tornado vortex signatures (TVS). Examine Image 5 in the region between Park and Quinter. The radar site itself is off the screen to the left (WNW direction).

15. Draw a short arrow away from the radar site over the color representing motion away from the radar and then draw a short arrow towards the radar over its appropriate color. The pattern of your arrows suggests a *[(clockwise) (counterclockwise)]* circulation within the cloud. This *[(is) (is not)]* indicative of a mesocyclone / tornadic circulation within this thunderstorm.