Supercell Radar Signatures

OBJECTIVES

1. The student will understand how to use WxScope to access current and archived radar data.
2. The student will understand the reflectivity values frequently associated with hail and heavy rain.
3. The student will understand reflectivity patterns associated with hook echoes and tornadic circulations.
4. The student will understand the fundamentals of supercell storm motion.
5. Given a series of Doppler images from a supercell, the student will be able to identify the hook echo, presence of hail, heavy rain, and tornadic circulation.
6. The student will be able to predict storm locations relative to current radar images.
7. The student will be able to compare predictions to actual storm locations to determine if the storm moved as expected, moved right or left of predicted path.

PREREQUISITES

Basic understanding of WeatherScope.
Completion of Understanding Weather Radar lecture in the OCS EarthStorm series

MATERIALS

Computer
WxScope software
Archived radar data

VOCABULARY

Hook echo: A pendant-shaped echo usually toward the right rear of the echo on a radar screen that indicates the presence of a mesocyclone and possible presence of a tornado.
Radar: An electronic instrument used to detect objects (such as precipitation) by their ability to reflect and scatter microwaves back to a receiver.
Reflectivity: A measure of the fraction of radiation reflected by a given surface; defined as a ratio of the radiant energy reflected to the total that is incident upon a surface. Generally "reflectivity" is used in place of the phrase "radar reflectivity factor" or "equivalent radar reflectivity factor."
Supercell: A large, long-lived (up to several hours) cell consisting of one quasi-steady updraft-downdraft couplet that is generally capable or producing the most sever weather (tornadoes, high winds, and giant hail).
Tornado vortex signature (TVS): The radar "signature" of a vortex indicative of a tornado or tornadic circulation. A small-scale anomalous region of high shear associated with a tornado.
Doppler radar: A radar that determines the velocity of falling precipitation either toward or away from the radar unit by taking into account the Doppler shift.
Doppler shift: The change in the frequency of waves that occurs when the emitter or the observers is moving toward or away from the other.

I. Accessing radar data using WxScope

WeatherScope (or WxScope) software makes accessing and viewing weather data simple. Throughout the lab, you will be accessing archived radar data via WeatherScope. *The reader should download the WeatherScope software from this website* http://climate.ok.gov . While WxScope does not yet have complete radar data archives, you will be accessing specific times that are available. More specifically, you will be studying the reflectivity and velocity signatures associated with the May 3, 1999 tornadoes and thunderstorms as well as tracking the storms.

Application 1.1

1. Using WxScope, select the region of interest by choosing Product, New, Shape. From the pull down menu, select a state and click OK. *(More than one state may be displayed. Recall from the WxScope tutorial that ↑ Zooms in and ↓ Zooms out)*

2. To display radar in the desired regions, choose Product, New, Radar. From the pull down menu, choose the radar site. *(use the default Base Reflectivity I radar product)* By default the radar data shown will be current.
3. To display archived radar data, double-click on the date display in the legend.
4. Choose the desired date and the duration of data desired.
5. To view a time series of data in specific intervals, choose the interval steps desired.
6. From the Window pull-down menu, select Show Animator. To animate the images, select the Play button. To view the images individually, select the advance button to the right of the play button.

   *Example: To display radar images from the May 3, 1999 from 4:00 pm to 8:00 pm in 15 minute intervals, select **Date:** 05/03/1999 4:00:00PM **Duration:** 4 Hours After Date **Interval:** Step By 15 Minutes*

II. Vertical Structure of a Supercell

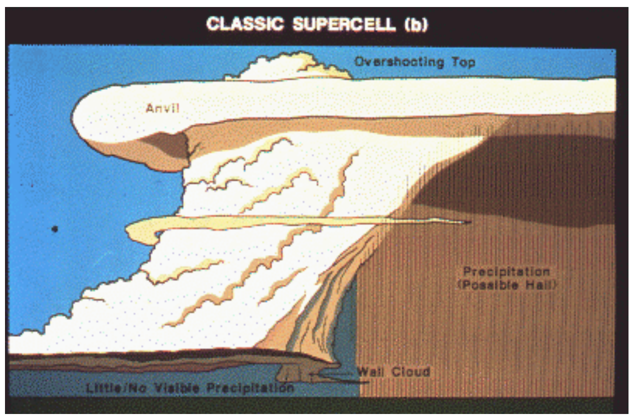


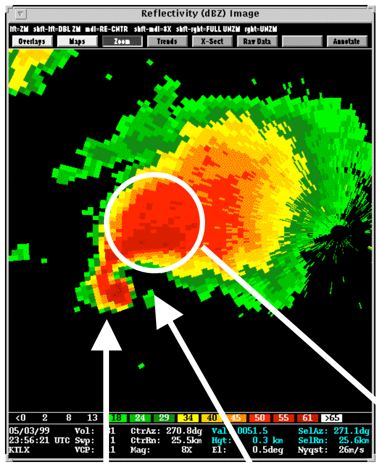
Figure 1: Supercell Structure (Church et al., The Tornado, 1993)

The schematic in Figure 1 is a vertical cross section of a supercell thunderstorm. As moist air rises in the front of the storm, an updraft forms. When air in the updraft cannot rise anymore it acts similar to water coming from a hose and hitting a wall; it spreads out both toward the front and rear of the storm. Strong winds aloft may cause the updraft to tilt towards the rear of the storm. In the above schematic, a rainy forward-flank downdraft is oriented toward the front of the storm while the rear-flank downdraft is towards the rear. Upper-level winds behind the supercell feeding air into the storm compose the rear inflow jet and reinforce the rear-flank downdraft. With a supercell, the updraft and downdraft are separate and structured in such a way to sustain the supercell for hours. The rainy forward-flank downdraft is associated with heavy rain. This corresponds to the broad region of reflectivity values toward the front of the supercell as seen on radar (discussed more in the following section). In strong updrafts, if an ice nucleus forms, precipitation will freeze around the nucleus and hail can form. Hail generally occurs in the same region as heavy precipitation, near the updraft of the storm. Suspended hail particles fall when their weight can no longer be supported by the updraft. Enhanced areas of reflectivity within regions of reflectivity associated with rain indicate the possibility of hail.

III. Reflectivity Structures of a Supercell

Supercells often can be identified by viewing Doppler radar images. A classic supercell has several distinctive characteristics on radar including the **hook echo**, **areas of enhanced reflectivity**, and a **bounded weak echo region**.

A low-level hook is often present on the right rear side of the storm. The hook is formed by the interaction of the downdrafts with the updraft. In this region, the winds are cyclonic (counter-clockwise) and draw the precipitation into a cyclonic spiral. The hook surrounds a clear "notch" in the echo is caused by precipitation-free, warm, moist air flowing into the storm- the updraft. This is notch is referred to as a weak echo region. Recall from lecture that the dark purple and red regions of the image represent the strongest reflectivities associated with strong rainfall and/or hail.



Enhanced Reflectivity

Figure 2: Hook Echo and Bounded Weak Echo
From http://www.crh.noaa.gov/lmk/soo/docu/supercell.htm

Application 3.1

1. Access radar data for May 3, 1999 at 7:00 pm using WxScope.
   a. Use NEXRAD Level III data; base reflectivity I; OK-Oklahoma City radar.
2. What distinct radar signatures do you note?
3. Of the three main cells, focus on the southeastern cell. Identify the region where likelihood for tornado development is the greatest (hook echo)
4. Identify the bounded weak echo region.
5. In the same cell, where is the heaviest precipitation occurring?
6. Given the reflectivity values, where is hail most likely to occur?

IV. Doppler Radar: Target Velocities

Recall from lecture that Doppler radar can also sense target velocities, or the speed at which a target is moving horizontally toward or away from the radar. Mesocyclones and tornadic circulations have distinct velocity patterns that produce distinct radar signatures. Cyclonic rotation (counter-clockwise) (below left) is represented by Doppler radar velocity image (below right):

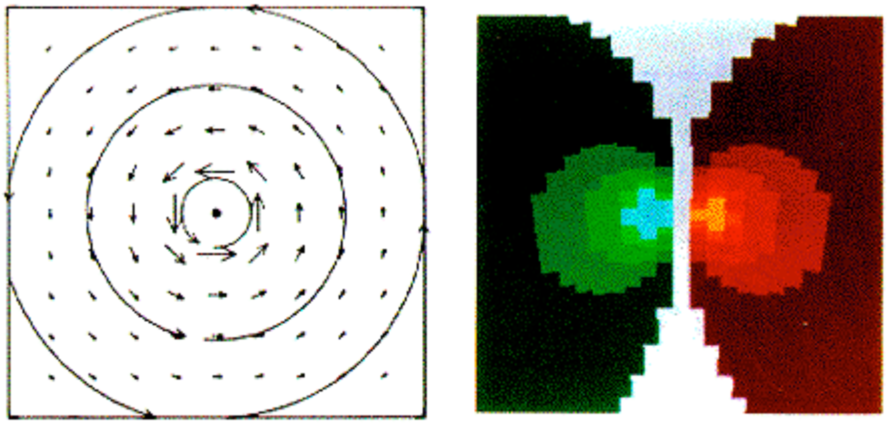


Figure 3: Left: Rotational winds within a vortex. Right: Doppler velocity pattern. From http://ww2010.atmos.uiuc.edu/(Gl)/wwhlpr/tvs.rxml?hret=/indexlist.rxml

In tornado velocity signatures, adjacent regions will have sharply different velocities, typically with one inbound (green- toward the radar) and one outbound (red- away from the radar). In the radar velocity image below, note the highlighted region. The winds blowing toward the radar (green) are in close proximity to those blowing away from the radar (red). A pair questions to motivate scientific inquiry are: (a) What type of circulation is associated with this signature, cyclonic (counter-clockwise) or anticyclonic (clockwise)? and (b) What atmospheric phenomena is associated with this type of signature?

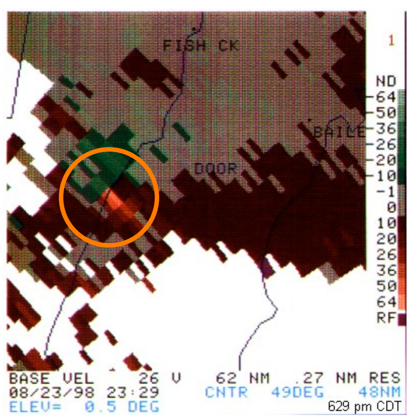


Figure 4: Example of Doppler velocity pattern from a WSR-88D. From http://www.crh.noaa.gov/grb/indexphp.php?page=events/082398

The area of variable velocities above is considered a **Tornado Vortex Signature (TVS)**. A TVS indicates cyclonic motion (counter-clockwise) and is associated with favorable conditions for tornado development. The presence of a low-level TVS suggests that a tornado may be occurring or may soon develop.

Application:

Activity 4.1

The following images show the reflectivity and velocity, respectively, for a storm in Texas in 1995.

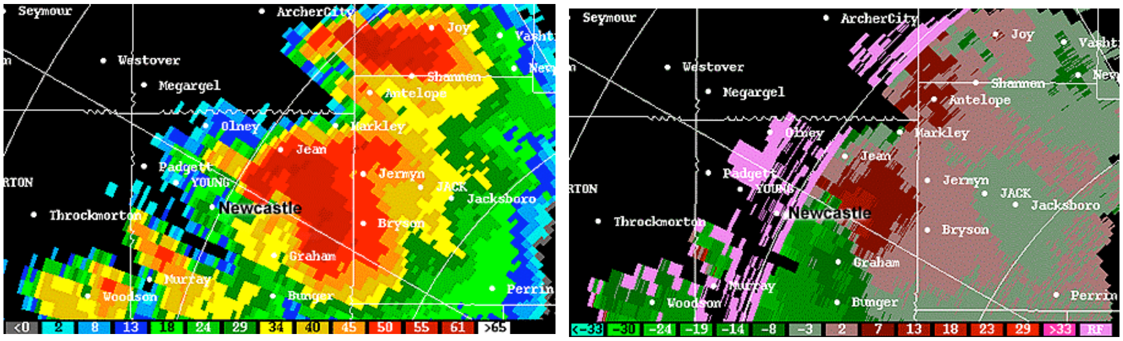


Figure 5: Reflectivity (left) and velocity (right) imagery. From
http://ww2010.atmos.uiuc.edu/(Gh)/guides/rs/rad/appl/trndo.rxml

1. Locate the hook echo in the reflectivity image.
2. What do you notice about the velocity patterns in the second image with respect to the hook echo location?
3. What atmospheric phenomena might occur near Newcastle?

Activity 4.2

1. Using WxScope, from the Product pull-down menu, select New → Radar…
2. Select NEXRAD Level III data for the site OK-Oklahoma City radar. Select Product: Base Velocity I and Opacity 100%.
3. Click on the date in the upper-left corner. View the velocity data for May 3, 1999 at 7:00pm, as in the Supercell application.

At first it may be difficult to see a Tornado vortex signature. In order to better identify the TVS, overlay the radar for May 3:

4. From the Product menu select New → Radar. Select NEXRAD Level III radar at the OK-Oklahoma City site using the Product Base Reflectivity I. Set the Opacity to 50%.
5. In the legend, right-click KTLX-BVEL1 and select Properties. Change the Opactity to 50%.
6. Zoom in on the hook echo region of the Southeastern cell discussed in the previous section. What do you notice about the Velocity signature in this region?

V. Storm Forecasts

Doppler radar can be used to locate thunderstorms and determine their intensity. Radar is very effective in tracking storms. During the May 3 tornado outbreak, Meteorologists relied on Doppler radar data to track the storm paths and to predict where the storms would be (spatial) and when they would be there (temporal).

Application

Activity 5.1

1. Access the Base Reflectivity I data for the OK-Oklahoma City radar. Use the default Opacity and NEXRAD Level III data.
2. In the legend, double-click the date and select May 3, 1999. Select images from 4:00 pm to 6:00 pm in 15 minute intervals.
3. Choose Window → Show Animator. Advance through the sequence of images.
4. What is the direction of propagation (storm motion)? What do you notice about the easternmost cell at 4:45 pm compared to 5:00 pm.

5. Where do you expect the cells to be at 6:30 pm? At 7:00 pm?
6. Verify your forecasted storm motion by changing the time interval of data shown. In the legend, double-click the date and change the duration to 4 hours. Advance to the 6:30 pm and 7:30 pm images and compare the cell locations to your predictions.
7. How do you know that the following sequence of images is not complete? (note the difference in the distance the cells progress from image 1 to 2 compared to progression from 2 to 3 as well as the number of cells)

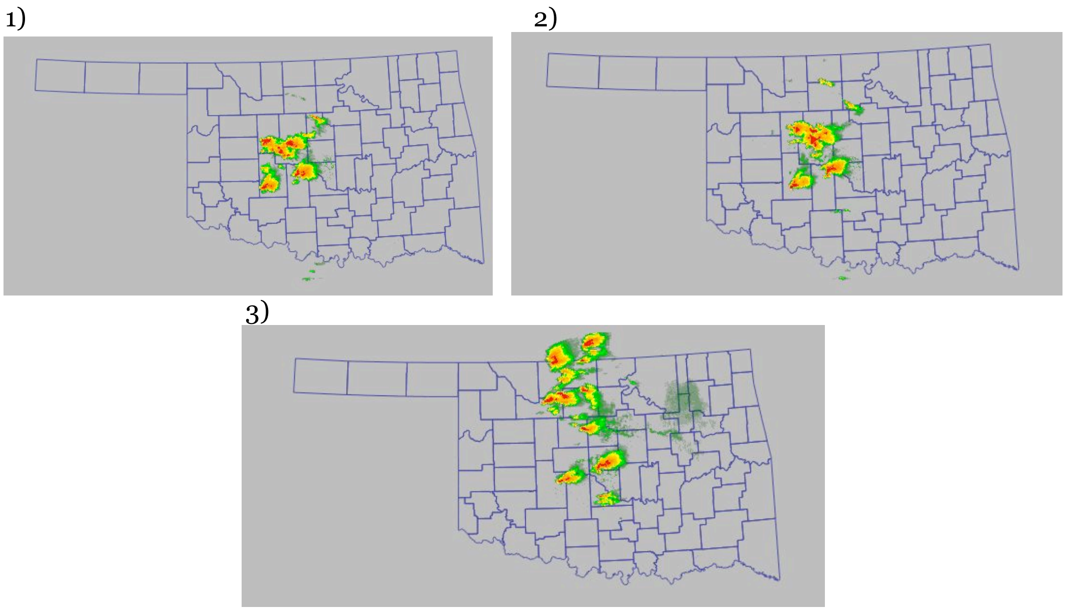


Figure 6: Weather Scope Displays of Radar Reflectivity Data, May 3, 1999.

So how do meteorologists predict storm motion? As mentioned, meteorologists use radar to predict storm motion by assessing the location of storms and their propagation speed. In addition, they take into consideration atmospheric conditions ahead of the storms. Forecast models attempt to predict weather using the following premise: If you can describe the current state of the atmosphere, and if you can mathematically represent all the interactions that occur in the atmosphere, then you should be able to predict the future state of the environment. Forecast models have dramatically improved over the years, due to tremendous leaps forward in both computer technology and forecast methods. Forecast models coupled with current radar data help meteorologists predict storm motion.

Activity 5.1

1. Examine the following two radar images (figures 7 and 8). The first display is the reflectivity at 6:45 pm on May 3, 1999. The second is the velocity display at 6:45 pm on May 3, 1999.
2. By the radar signature and the velocity display, what type of warning would you issue for the county highlighted in the third image (see figure 9)? Why?
3. Where might you forecast the heaviest rain? Hail?

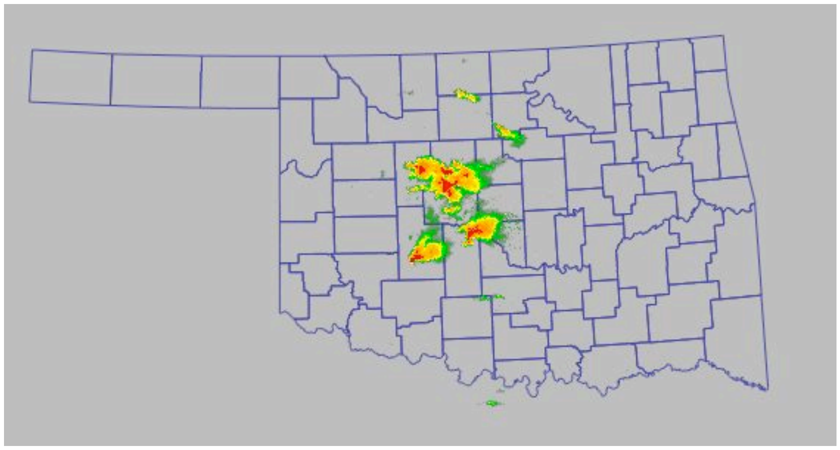


Figure 7: Reflectivity Image May 3, 1999 at 6:45pm

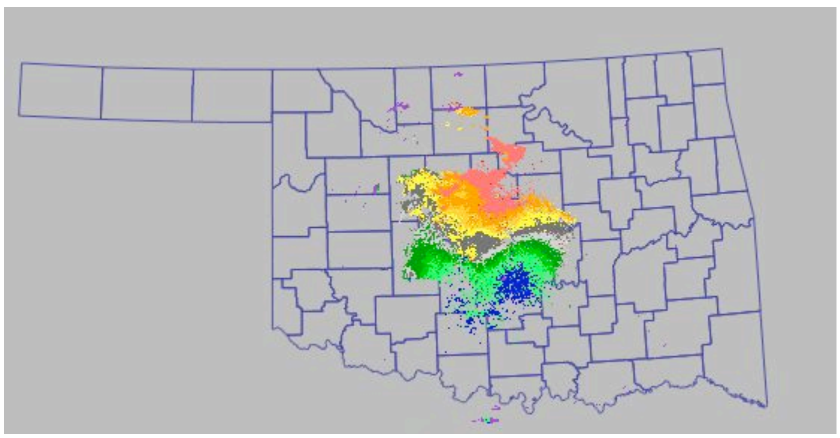


Figure 8: Velocity Image May 3, 1999 at 6:45pm

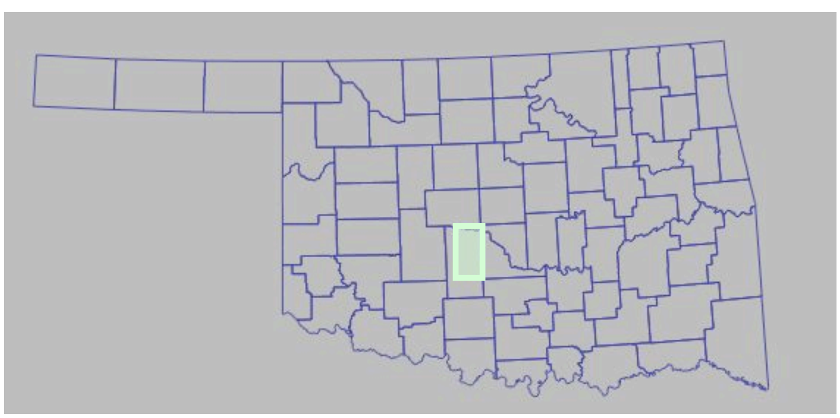


Figure 9: Region of Potential Warning

Verification is the process by which meteorologists determine the accuracy of a forecast. To see how your forecast compared to the actual events, study the following image (see figure 10). Figure 10 shows the tornado tracks for the May 3 tornadoes. Did you correctly issue a tornado warning for Grady County during the previous exercise?

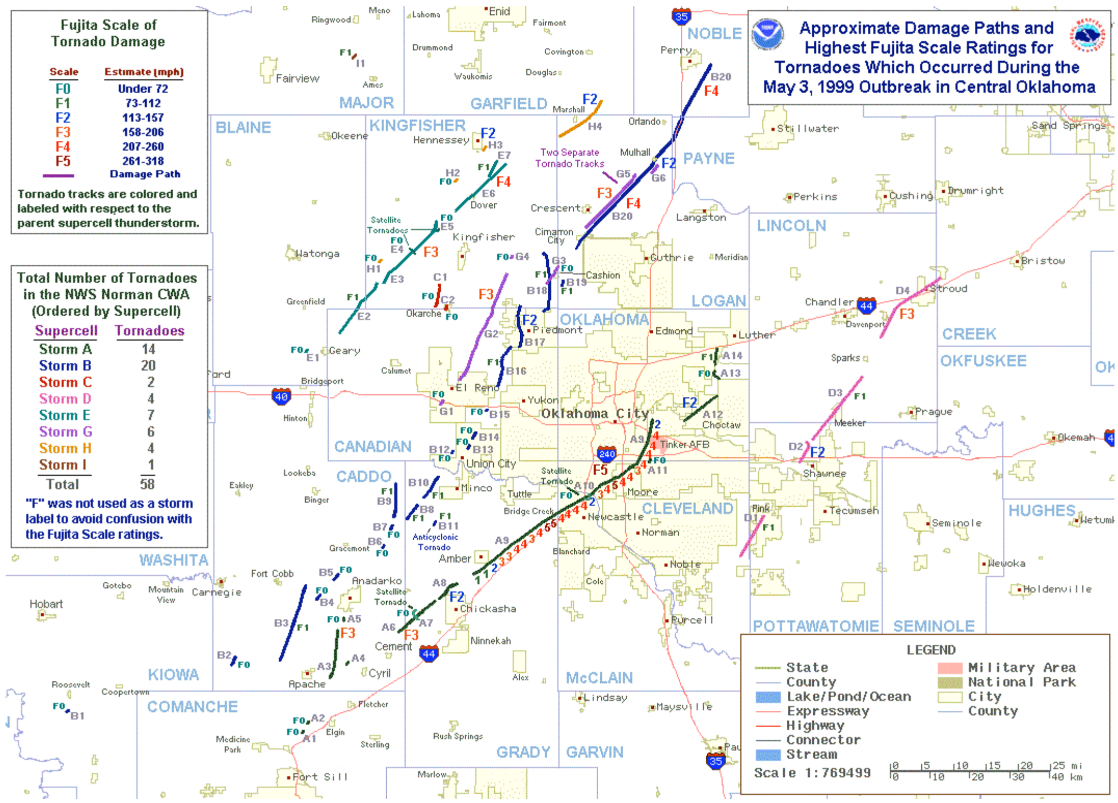


Figure 10: Tornado Damage Paths for the May, 1999 storm.