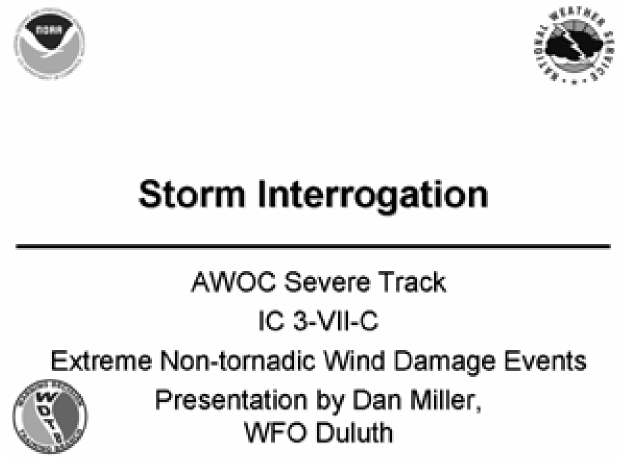
1. Storm Interrogation

Instructor Notes:

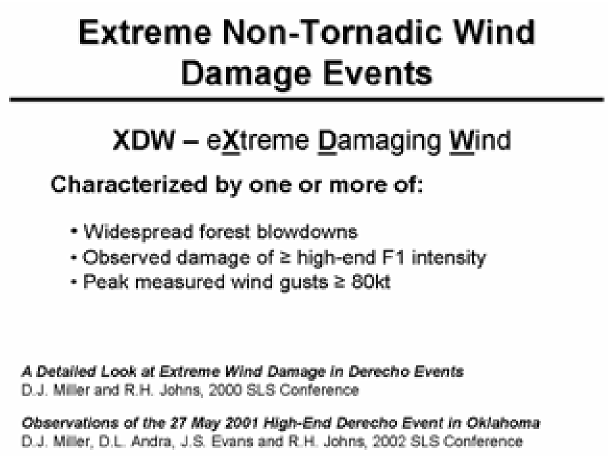
Student Notes:



2. Extreme Non-Tornadic Wind Damage Events

Instructor Notes: Study of Extreme Non-Tornadic Wind Damage Events, or XDW events, began about 5 years ago and was motivated initially by a simple desire to document an event on 1 July 1997 in central Minnesota. After looking at that event in detail, and with level 2 WSR-88D data, it became apparent that the conceptual model of high-end non-tornadic wind events needed scrutiny, because many of these events do not fit well into the bow echo conceptual model very well when high resolution radar data is examined. The initial phase of the study was focused on derecho producing MCSs that resulted in exceptionally severe non-tornadic winds and/or wind damage. It should be emphasized that considerable effort was made to distinguish these events from “ordinary” derecho events, in that these events are a sub-set of derecho events, characterized by widespread forest blowdowns or wind damage areas that include observed damage of high-end F1 or greater intensity and/or peak measured wind gusts roughly 80 knots or greater. Two SLS conference papers has been published to date on this topic, and those publications are listed at the bottom of this slide. Additional motivation for study of similar events was generated by examination of the 1 July 1997 case, which is summarized on the next slide.

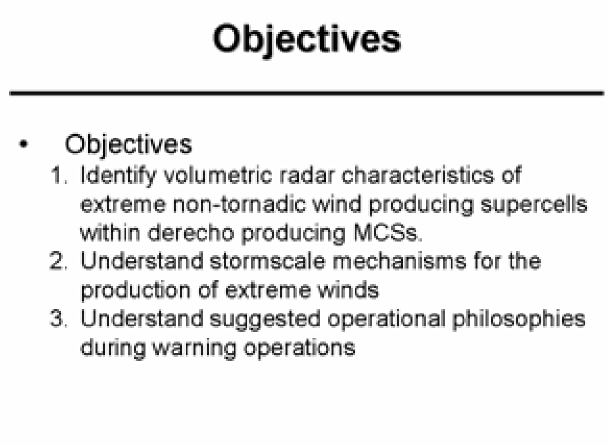
Student Notes:



3. Lesson 26: Extreme Non-Tornadic Wind Damage Events

Instructor Notes: Objectives Identify volumetric radar characteristics of extreme non-tornadic wind producing supercells within derecho producing MCSs. Understand storm-scale mechanisms for the production of extreme winds Understand suggested operational philosophies during warning operations

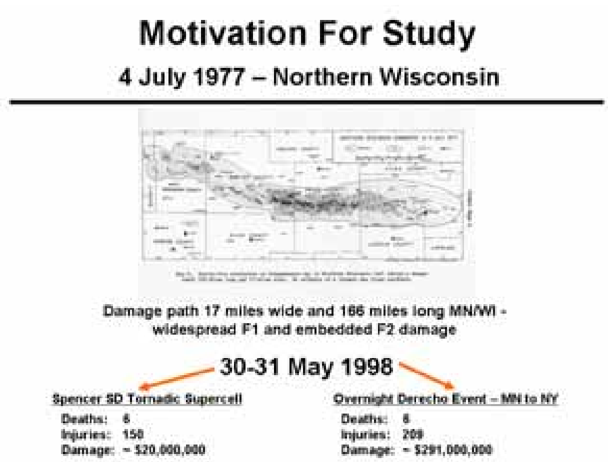
Student Notes:



4. Motivation For Study

Instructor Notes: Additional motivations for further study are numerous. First, these events are the non-tornadic equivalent to tornado outbreaks, and although a qualitative study has not been done to date, it is quite likely that a disproportionate amount of the injuries, deaths, and damage from non-tornadic winds each year are due to XDW events. Second, many XDW events produce widespread damage areas that include considerable areas of equivalent F1 damage, and some include quite sizeable areas of F2 equivalent damage. The figure at the top of this slide (from one of Dr. Fujita's publications) is an extreme example from 4 July 1977. The damage path is 166 miles long, and up to 17 miles wide, extending across parts of 6 counties in northern Wisconsin, and includes widespread F1 damage (in the dark gray shading), and considerable areas of F2 damage (in the black shading.) Winds in this event were estimated at 100-120 mph winds with gusts up to 135 mph. One eyewitness account from this event stated that the intense wind continued for 20 minutes and was accompanied by large hail. Third, many XDW events produce just as much, if not more, dollars in damages than tornadoes, and injury/deaths can be comparable. For example, a major severe weather outbreak occurred on 30-31 May 1998 from the northern plains states eastward into much of the Great Lakes region. An F4 tornado struck the tiny town of Spencer, SD during the afternoon of the 30th, killing 6, injuring 150, causing $20 million in damage, and destroying over half of the town. Consequently, media converged on the town and provided several days of coverage. 6 years later, many remember the Spencer, SD tornado. However, what most DO NOT remember about this event is the very intense derecho event occurred during the overnight hours following the Spencer, SD tornado. This XDW event from the evening of the 30th, through the morning of the 31st, affected areas from central Minnesota, eastward across Wisconsin, Lake Michigan, Lower Michigan, extreme northern Ohio, Lake Erie, and far western New York State, resulting in 6 fatalities, 209 injuries, and $291 million in damage. The winds also resulted in a 4 foot seiche on Lake Michigan, that was the primary factor in the sinking of a ship in port on the eastern shore of the lake. It is only a matter of time before an event like this affects a major metro area, perhaps during rush hour, that could result in event greater loss of life and property. There is much improvement that can be done with respect to forecasting and warning for these events, and increased situation awareness to these events is the primary goal of this module.

Student Notes:



5. Extreme Non-Tornadic Wind Damage Events

Instructor Notes: To drive home the point, this slide shows a now somewhat-famous video taken during an XDW event in the Pakwash forest of northwest Ontario, Canada on 18 July 1991. Incidentally, this video was taken on the edge of a large forest blowdown area. Damage in the center of the blowdown path was described as considerably more severe than at the location where the video was taken. The entire video is about 15 minute long, and shows three separate pulses of extreme winds, within a period of sustained winds ~50-60 mph. There was no hail in this video, but in some XDW events, particularly ones that involve supercells, the intense wind can be accompanied by golfball to baseball size hail. As an interesting aside, note the time stamp on the video (which is accurate) – 1051 AM CDT.

Student Notes:

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6. What Convective Elements Are Associated with XDW Events?

Instructor Notes: In investigating XDW events, it quickly became obvious that the best way to look at them was to define an XDW event, and then work backward to the radar data and 4-D storm structure evolution. So, what storm-scale convective elements are associated with XDW events? Many (most?) of these events are produced by forward propagating MCSs, and therefore are, by definition, part of a derecho event. As one might expect according to the widely held conceptual model (from Johns and Hirt, 1987, and many other papers) some events are produced by serial or progressive bow echoes. However, some of the forward propagating MCSs involved exhibit very complex 4-D reflectivity/velocity structure evolution, and involve circulations on the storm-scale. For the purpose of this presentation, we will focus on the MCSs that contain embedded supercell storm structures. A summary of events that have been studied in full or in part are listed on the slide.

Student Notes:

What Convective Elements Are Associated with XDW Events?

Non-Supercell (Serial or Progressive Bow Echo)
15 July 1995 – Upstate New York
30-31 May 1998 – Minnesota to New York

Hybrid (Line Mesovortex/Supercell structure)
30-31 May 1998 – Minnesota to New York
4 July 1999 – Northern Minnesota
22 July 2003 – Western Tennessee (Memphis event)
4 March 2004 – Texas/Oklahoma

Supercell (MCS with embedded supercells)
3-4 May 1989 Texas/Oklahoma
1 July 1997 – Central Minnesota
29 June 1998 – Central Iowa
27 May 2001 – Oklahoma
26 August 2002 – Western Kansas

7. 27 May 2001 - Oklahoma

Instructor Notes: The first case example we will look at occurred on 27 May 2001 in Oklahoma. This slide and the next provide a brief overview of the larger-scale environment that supported this MCS. The thermodynamic profile was characterized by very strong instability (surface-based CAPE approaching 5000 j/kg), and rich tropical moisture in the low levels (surface dewpoints in the low 70s F.) Also of note is the relatively low LCL height at 858 mb, which is roughly 2,500 meters agl.

Student Notes:

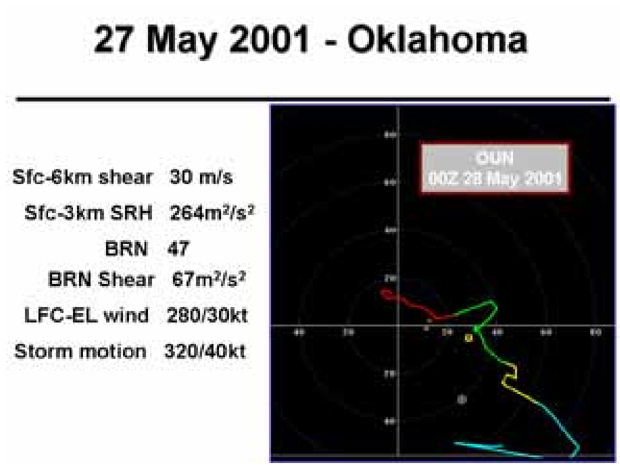
27 May 2001 - Oklahoma

SBCAPE 4874 j/kg
MLCAPE 3279 j/kg
CIN 0 j/kg
LI -11
WBZ 11653 ft
700-500 LR 7.6 deg/km
LCL 858 mb

8. 27 May 2001 - Oklahoma

Instructor Notes: The wind shear profile, when viewed in combination with the thermodynamic profile as seen on the previous slide, reveals an environment that would easily support supercell thunderstorms, with surface to 6 km wind shear of 60 kts (30 m/s), and BRN shear of 67 m2/s2.

Student Notes:



9. 27 May 2001– Oklahoma

Instructor Notes: This XDW event was produced by a forward propagating MCS that evolved from several discrete supercells over southwest Kansas. The annotated areas on the radar loop are corridors of XDW that were produced by this MCS (corridors were derived from a combination of Oklahoma mesonet peak winds, damage reports, and damage surveys conducted by local emergency managers.) Radar data viewed at this scale, suggests that this was a rapidly moving and large-scale bow echo. However, if one studies the loop carefully, individual storm elements can be identified, that coincide with the corridors of XDW. These elements are supercells embedded within the MCSs, and we will examine the storm structure in detail on the next several slides.

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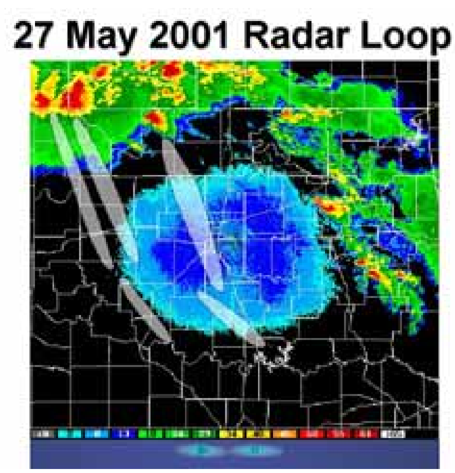
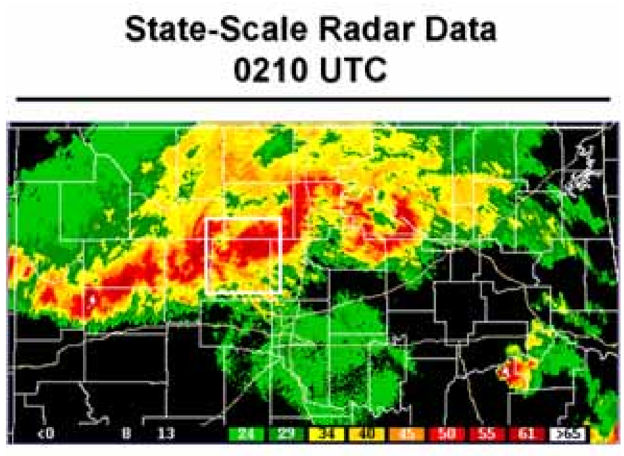


10. State-Scale Radar Data

Instructor Notes: The image on this slide is a state-scale reflectivity image from the central Oklahoma Twin Lakes WSR-88D (KTLX) at 0210 UTC 28 May 2001. Again, viewed at this scale, the MCS at first glance appears to be a large-scale bow echo. However, on the next slide we will zoom in on the area within the white square.

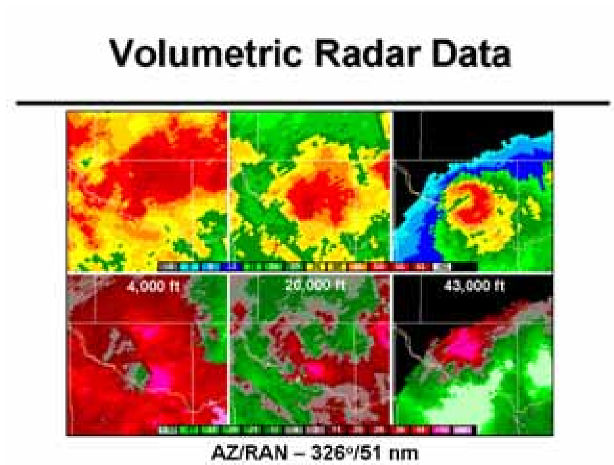
Student Notes:



11. Volumetric Radar Data

Instructor Notes: Here is the volumetric reflectivity/velocity data from the white box on the previous slide at 0210 UTC. Reflectivity (top) and velocity (bottom) data are shown at roughly 4,000 ft agl (left), 20,000 ft agl (center) and 43,000 ft agl (right), which should provide a representative view of the storm at low, mid and high levels, respectively. The reflectivity core is strong and very deep, with 55+ dBz echo evident up to at least 43,000 ft, with significant mid and upper level overhang to the inflow (south) side of the storm. A rather large and high reflectivity hook echo is also evident in the low levels. Velocity data at low levels clearly indicates a cyclonically convergent mesocyclone that is displaced slightly to the lower reflectivities on the inflow flank. In the mid levels, a strong mesocyclone is evident (although there are velocity dealiasing errors in the radial inflow velocities), that is co-located with the high reflectivity core. At high levels, strong anti-cyclonic divergence is indicated near the storm summit. The combination of these reflectivity and velocity signatures is exceptionally consistent with the conceptual model of radar-observed supercell storm structure, and indicates a mature (likely Hp-type) supercell embedded within the MCS. The location just on the upshear flank of the low-level mesocyclone was directly associated with a long-tracked XDW corridor.

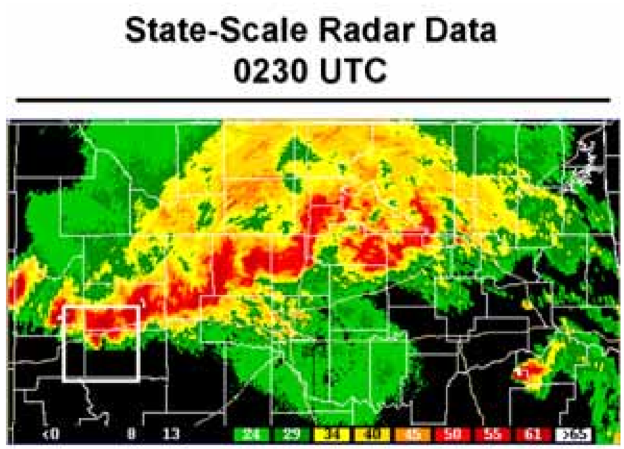
Student Notes:



12. State-Scale Radar Data

Instructor Notes: At 0230 UTC, we will zoom in and examine an area farther to the west in the quasi-linear MCS. On the next slide, we will look at volumetric reflectivity data from the area highlighted in the white box.

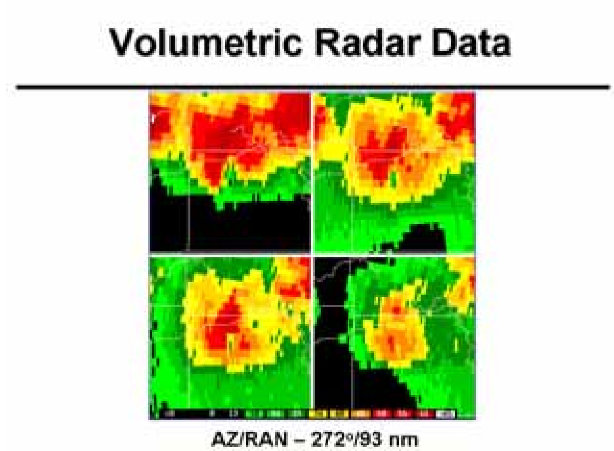
Student Notes:



13. Volumetric Radar Data

Instructor Notes: Radial velocity data at this location was range-folded. However, the volumetric reflectivity data reveals a lot. We are somewhat limited in sampling the lower levels of the storm at a range of 93 miles, but at 10,000 ft agl, an notch on the inflow side and a well-defined hook echo are clearly evident. At 20,000 and 30,000 ft agl, a very well-defined bounded weak echo region is present, with the storm summit and highest reflectivities at 40,000 ft agl displaced to the inflow side, directly above the inflow notch at low levels. This feature was present for over 30 minutes, and again is clear evidence of a mature, intense and long-lived supercell updraft. This embedded supercell was responsible for another long corridor of XDW over western Oklahoma.

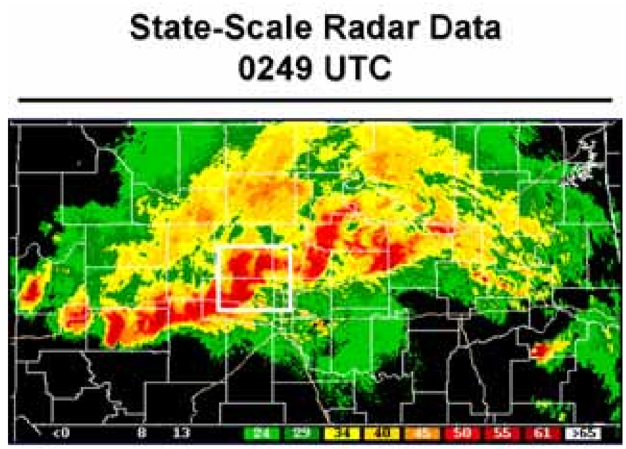
Student Notes:



14. State-Scale Radar Data

Instructor Notes: Finally, at 0249 UTC, we will zoom in and examine a storm in the MCS immediately to the west of the storm we examined in slides 8 and 9. On the next slide, we will look at volumetric reflectivity data from the area highlighted in the white box.

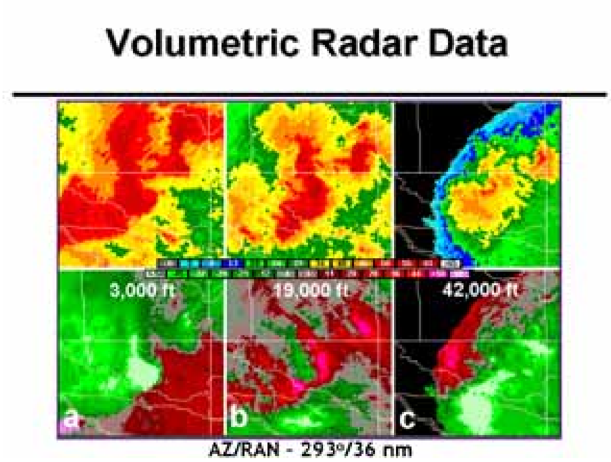
Student Notes:



15. Volumetric Radar Data

Instructor Notes: This slide shows volumetric reflectivity/velocity data from the third storm embedded within the MCS at 0249 UTC. This storm was located immediately to the west of the storm that we looked at in slides 8 and 9 at 0210 UTC. Again, reflectivity (top) and velocity (bottom) data are shown at roughly 3,000 ft agl (left), 19,000 ft agl (center) and 42,000 ft agl (right). Very similar signatures are evident. The reflectivity core is strong and very deep, (although the highest reflectivities are a bit more shallow than the 0210 UTC storm we looked at) with 50+ dBz echo evident at 42,000 ft, with significant mid and upper level overhang to the inflow (southeast) side of the storm. A rather large and high reflectivity hook echo is once again clearly evident at 3,000 ft agl. Velocity data at low levels clearly indicates a strong and unbalanced cyclonically convergent mesocyclone coincident with the low level reflectivity hook. The velocity image at 3,000 ft agl above is radial base velocity, and raw data sampling revealed nearly 100 kt inbound velocities at 3,000 ft agl. In mid levels, a mesocyclone is evident, co-located with the high reflectivity core. At high levels, strong anti-cyclonic divergence is indicated near the storm summit. Again, clear indication of a mature (HP-type) supercell embedded within the MCS. As with the other two storms we have looked at, locations just on the upshear flank of the low-level mesocyclone (underneath the location of strong inbound radial velocities) experienced XDW. This storm was responsible for considerable F2 structural damage in the city of El Reno, including taking the roof off of a hospital and city hall.

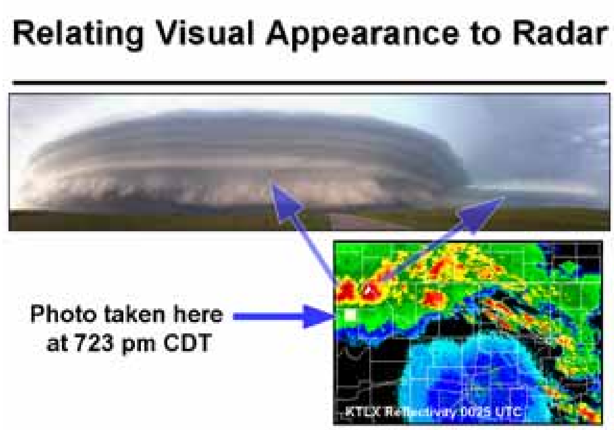
Student Notes:



16. Relating Visual Appearance to Radar

Instructor Notes: Here is a photograph of the storm complex as it appeared in northwest Oklahoma, just before 730 PM local time (0030 UTC.) At this time, the MCS was still in the process of transitioning from discrete supercells, to a quasi-linear MCS with embedded supercells, but a common gust front and strong surface cold pool had already become established. The photo shows two distinct HP type supercell storms, linked by a common gust front. For comparison, the location of the photo is annotated on the lowest cut reflectivity image in the lower right, with the two arrows pointing to the two storms from their respective radar echoes.

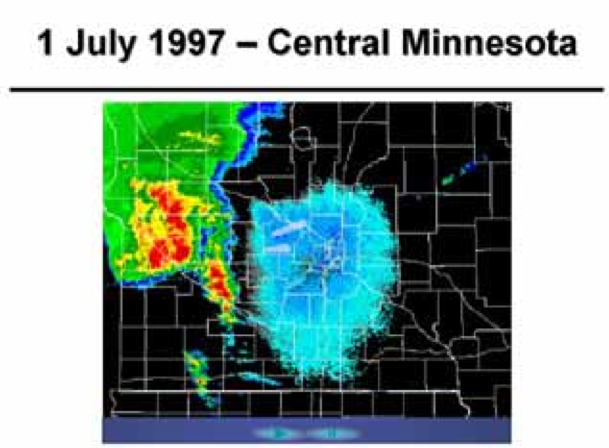
Student Notes:



17. 1 July 1997 – Central Minnesota

Instructor Notes: It is also useful to provide an example from another part of the country. This is a 0.5 degree reflectivity loop of the 1 July 1997 MCS that produced an XDW event. The XDW areas are annotated in white on top of the radar loop. Much as in the Oklahoma case we just looked at, the MCS is quasi-linear, and at state-scale appears much as a large-scale bow echo.

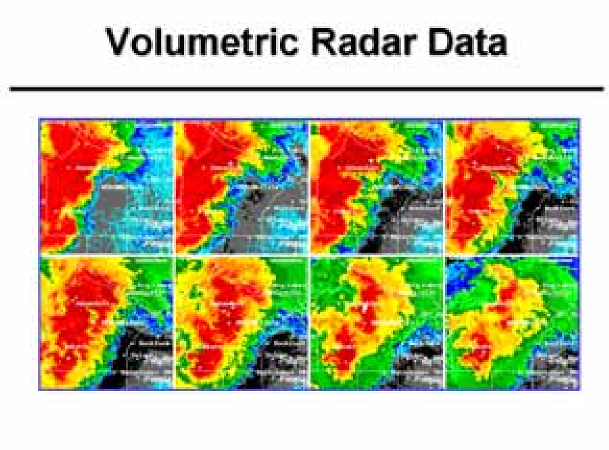
Student Notes:



18. 1 July 1997 – Central Minnesota

Instructor Notes: This slide is an enlarged view of the volumetric radar data, zoomed in on Wright County, Minnesota at the time two corridors of XDW were in progress. Nearly identical volumetric reflectivity and velocity signatures are again clearly apparent, with the location of the XDW events placed just on the upshear flank of the low level mesocyclone, coincident with the precipitation filled rear-flank downdraft portion of the HP supercell.

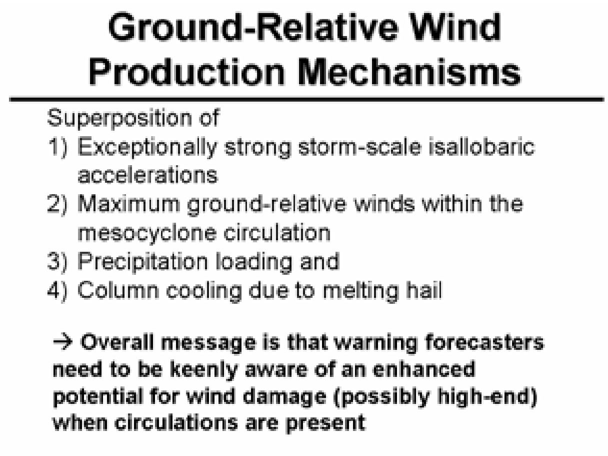
Student Notes:



19. Ground-Relative Wind Production Mechanisms

Instructor Notes: So, why do XDW events seem to have a favored storm-relative location of occurrence? Primarily because of the juxtaposition of exceptionally strong storm-scale isallobaric wind accelerations near the surface, the ground relative winds in the near-surface mesocyclone circulation, and precipitation loading and column cooling from hail melt. The primary point is that these events appear to be much more complicated than a simple "downburst," with a significant contribution to the extreme ground-relative wind speeds coming from storm-scale dynamic forcing.

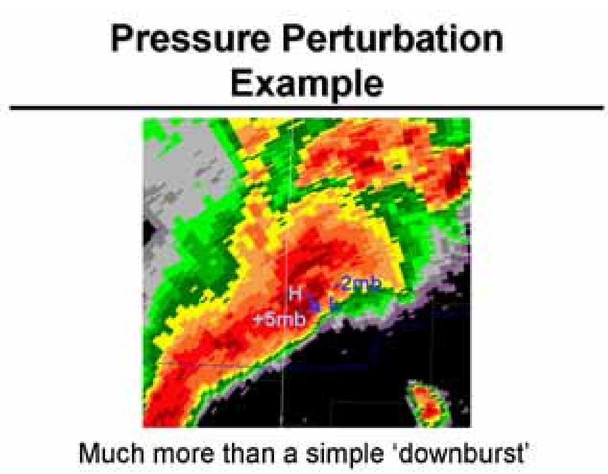
Student Notes:



20. Ground-Relative Wind Production Mechanisms

Instructor Notes: Meteograms from several XDW events indicate that a 5-10 mb pressure perturbation exists between the low under the updraft, and the high underneath the downdraft and cold precipitation core, and radar data suggests that separation of these storm-scale features was generally on the order of 5 to 10 miles. Most of the MCSs examined had forward propagation speeds of greater than 35 kts, and it follows that a very intense storm-scale isallobaric wind acceleration is likely a very strong contributor to the intense wind speeds.

Student Notes:



21. Ground-Relative Wind Production Mechanisms

Instructor Notes: This annotated velocity image simply shows where this area of the storm is located in the velocity imagery.

Student Notes:

Location of XDW

Most likely area for XDW is on up-shear flank of low-level mesocyclone and in the precip-filled RFD area

22. Unique? Characteristics of XDW Events

Instructor Notes: Much more research needs to be done, including obtaining data from new cases as they occur, to ascertain whether these XDW characteristics are generally the case with all XDW events. However, these characteristics were common in most cases examined thus far.

Student Notes:

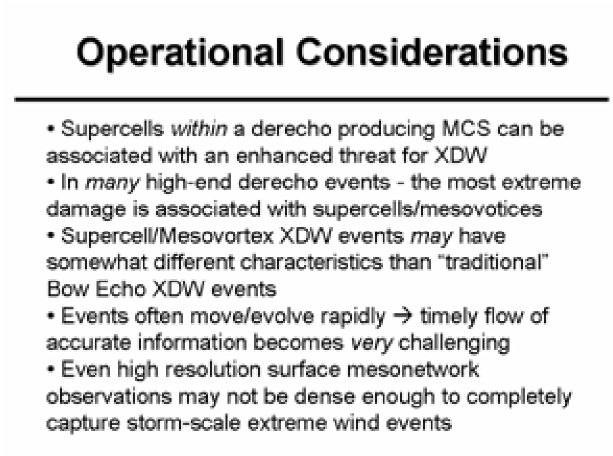
Unique? Characteristics of XDW Events

1) Quite long in duration at any one location along the path (10-20 minutes - or longer in extreme supercell/mesovortex events vs. a few minutes or less for bow echoes)
2) Very tight damage gradients along the periphery of XDW area
3) Supercell events have a much higher probability of being accompanied by large hail (> 4cm)

23. Operational Considerations

Instructor Notes: The bullets presented here generally need little additional explanation. All are important things to remember when working an XDW event operationally. AWIPS and other operational procedures should be optimized to maintain maximum situation awareness during the event.

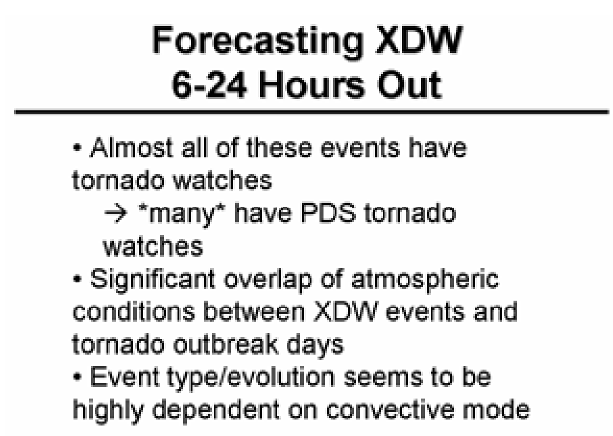
Student Notes:



24. Forecasting 6-24 Hours

Instructor Notes: A few brief comments about forecasting these events. It should be emphasized that a qualitative study of environmental parameters has not been completed yet, primarily because the dataset is still too small for results to be statistically significant. With addition of additional cases as they occur, hopefully the dataset will reach a critical mass soon. With that said, there are a few general points about forecasting these events that can be stated from anecdotal and observational evidence. First, the fact that most of these events occur in tornado watches, and many in PDS tornado watches, seems to suggest that there is a significant overlap in the large-scale environmental conditions that support both XDW events and significant tornado events (strong instability, strong surface-6 km shear, strong surface-1 km shear, low LCL/LFC heights, etc.) It seems as though event type is highly dependent on convective mode (discrete supercells vs. MCS development.)

Student Notes:



25. Tips for AWIPS D2D Display

Instructor Notes: Here are a few tips for AWIPS procedures and conveying information to users in warnings, statements and graphical products.

Student Notes: