



# Enhanced Storm Investigation

National Weather Service  
Milwaukee/Sullivan, WI

[www.weather.gov/milwaukee](http://www.weather.gov/milwaukee)



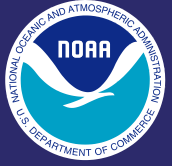
[www.facebook.com/US.NationalWeatherService.Milwaukee.gov](https://www.facebook.com/US.NationalWeatherService.Milwaukee.gov)



[twitter.com/NWSMKX](https://twitter.com/NWSMKX)

**“We’re going to die, we’re going to die” screaming heard on Oklahoma Highway Patrol radio before they were killed. Tim Samaras was found strapped in the car. Other victims were discovered 1/2 mile east and 1/2 mile west of the car.**



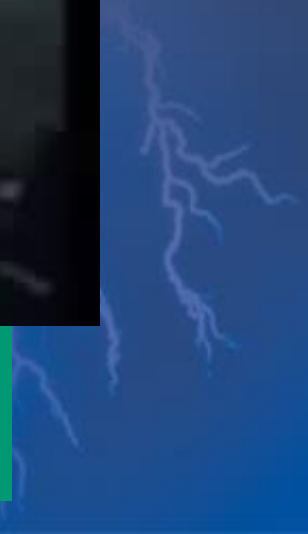


# Personal Safety



Video

This was a weak tornado – what about a strong or violent tornado?







# Convection Basics



- Moisture
- Instability
- Lift
- Wind Shear (for severe storms)





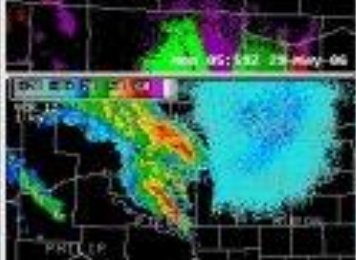
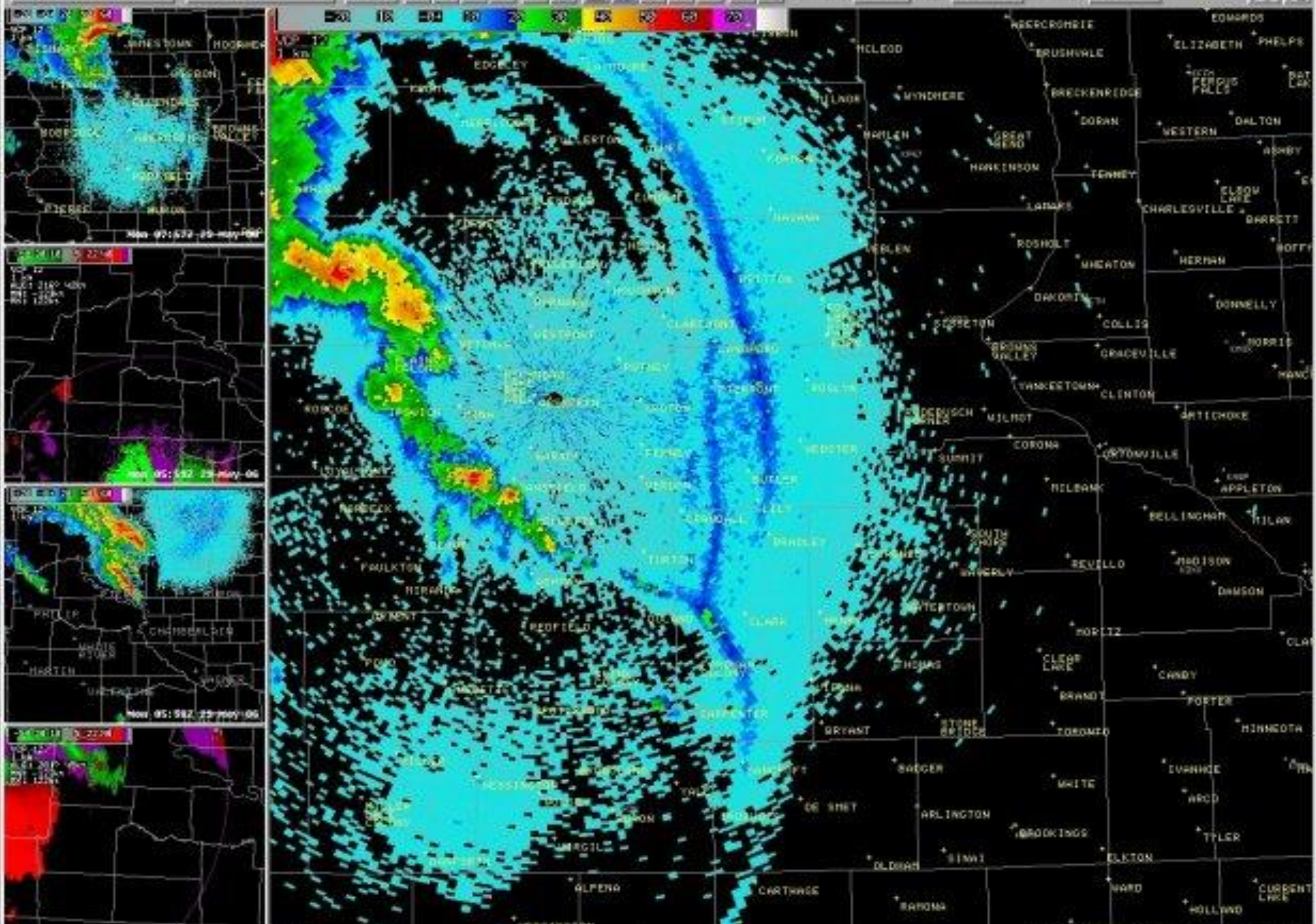
# “Triggering” Mechanisms



- **Starts the convection**
  - *Low pressure systems/Jet ‘s*
  - *Air mass boundaries, Fronts*
  - *Sea/Lake Breeze*
  - *Thunderstorm ‘outflow boundaries’*
  - *Orographic lift*







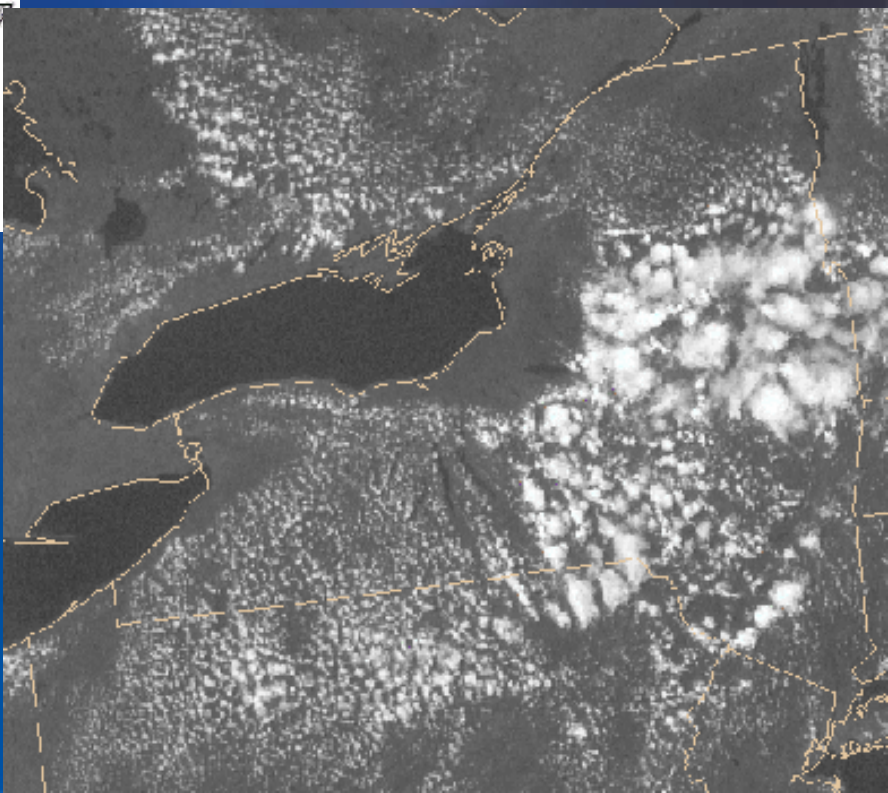
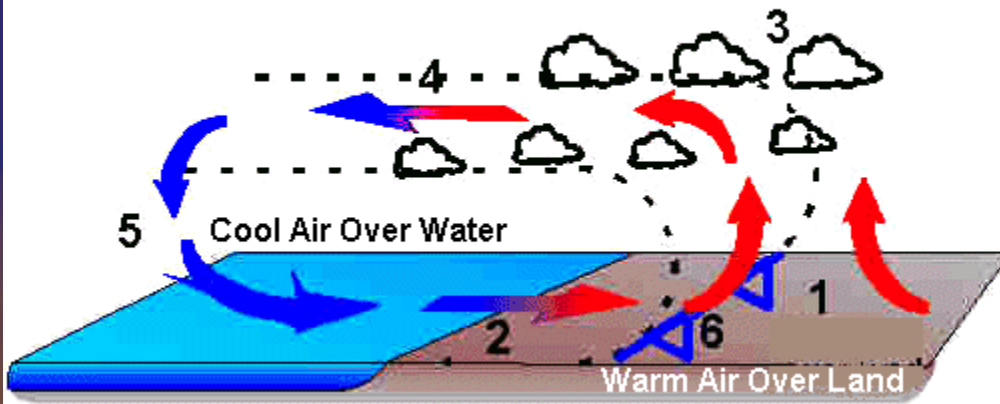




# Lake Breeze

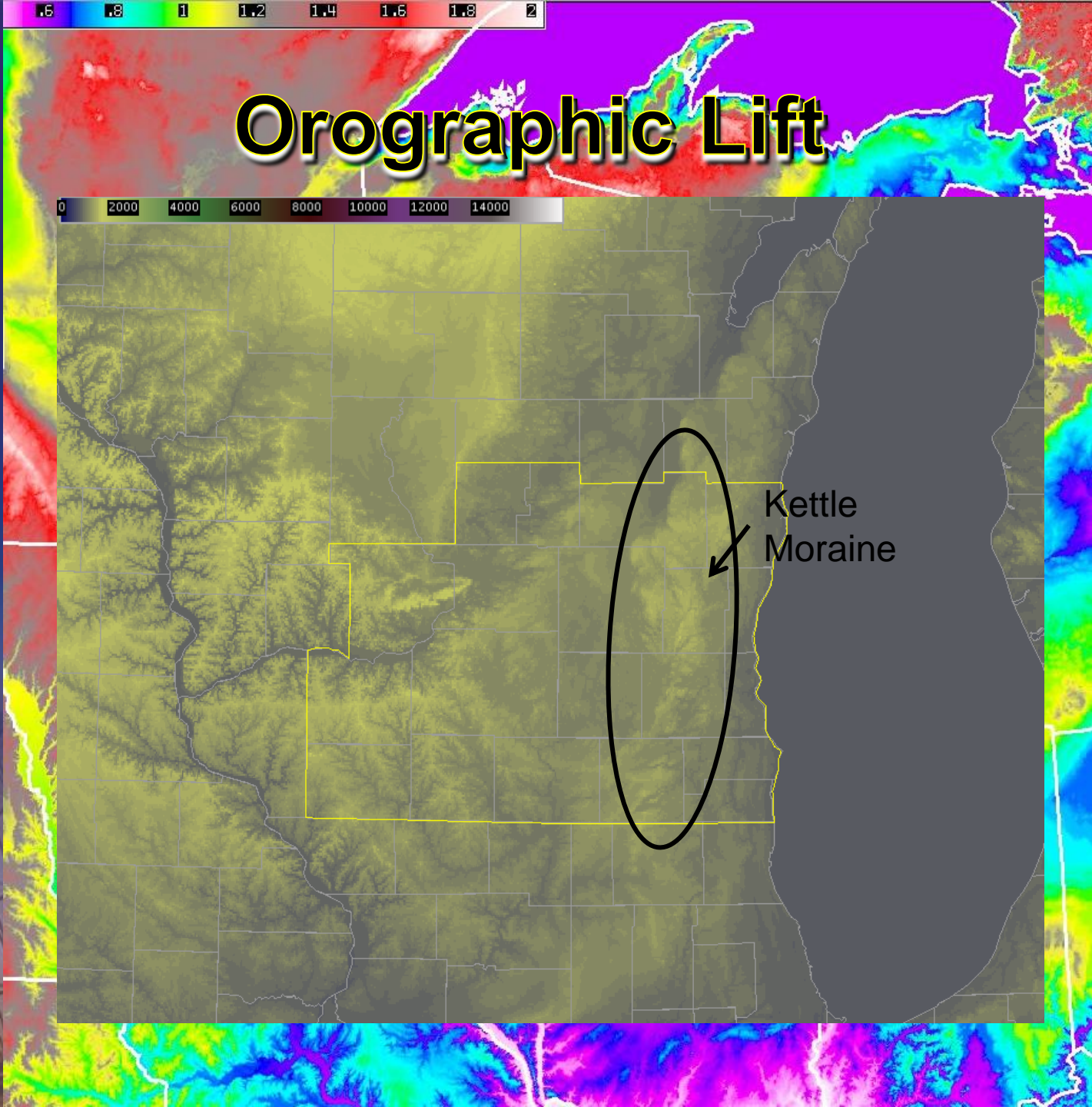


## Sea Breeze Circulation





# Orographic Lift



Kettle  
Moraine





# June 30, 2011



**Video**

# Four Types of Thunderstorms

Single  
Cell

Multicell  
Cluster

Multicell  
Line

Supercell

Weak updraft  
(non-severe  
or severe)

Moderate  
updraft (non-  
severe  
or severe)

Moderate  
updraft (non-  
severe  
or severe)

Intense updraft  
(Always severe)

**Mesocyclone -  
Rotating updraft**

*Slight threat*

*Moderate  
threat*

*Moderate  
threat*

*High threat*







# Single Cell Storms



**May produce brief severe weather**

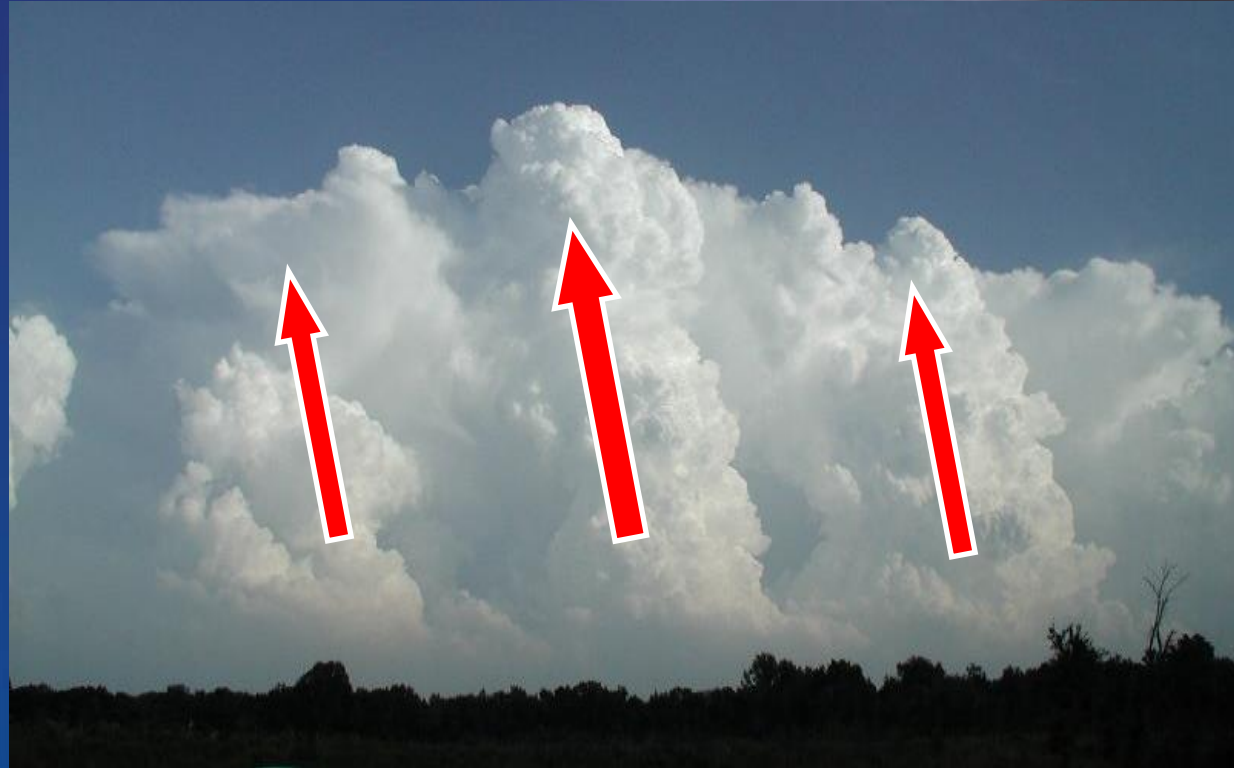


# Multi-Cell Thunderstorms



Ordinary, non-organized storms with low severe threat

Each cell lasts 20-30 minutes, but a cluster can last for hours



Heavy rain is the main problem

Strong winds, small hail and weak tornadoes are possible





# Multi-Cell Thunderstorms



Ordinary, non-organized storms with low severe threat





# Multi-Cell (Squall) Line



- Leading edge of squall line usually marked by shelf cloud
- Do not report shelf clouds

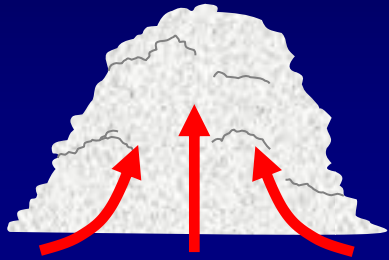


- What to expect
  - *Strong and possibly damaging wind*
  - *Heavy rain/hail*

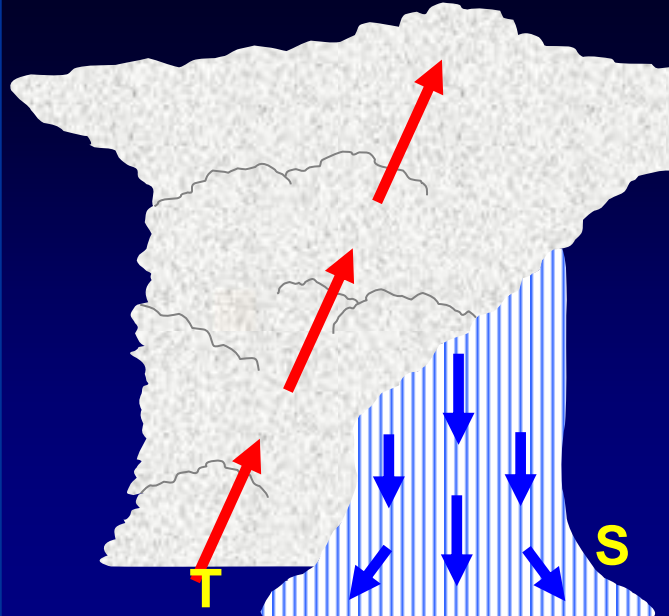




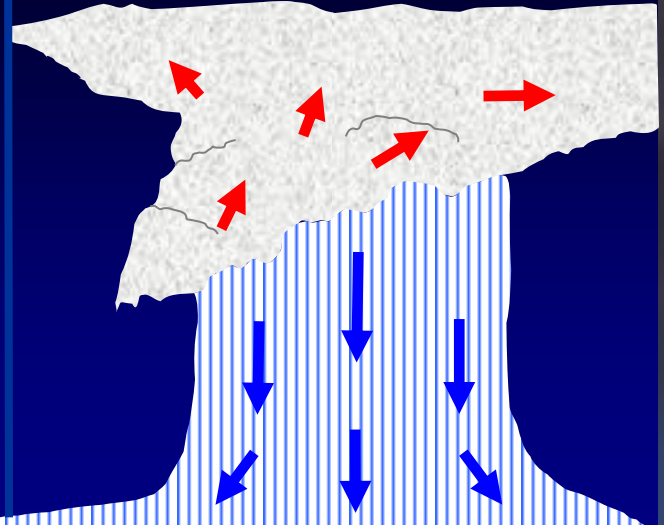
# Thunderstorm Life Cycle



Cumulus Stage



Mature Stage

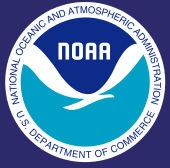


Dissipation Stage



©2001 Chris Kridler skydiary.com





# Downburst Winds!



shelf cloud







# Downburst Winds!



Vic



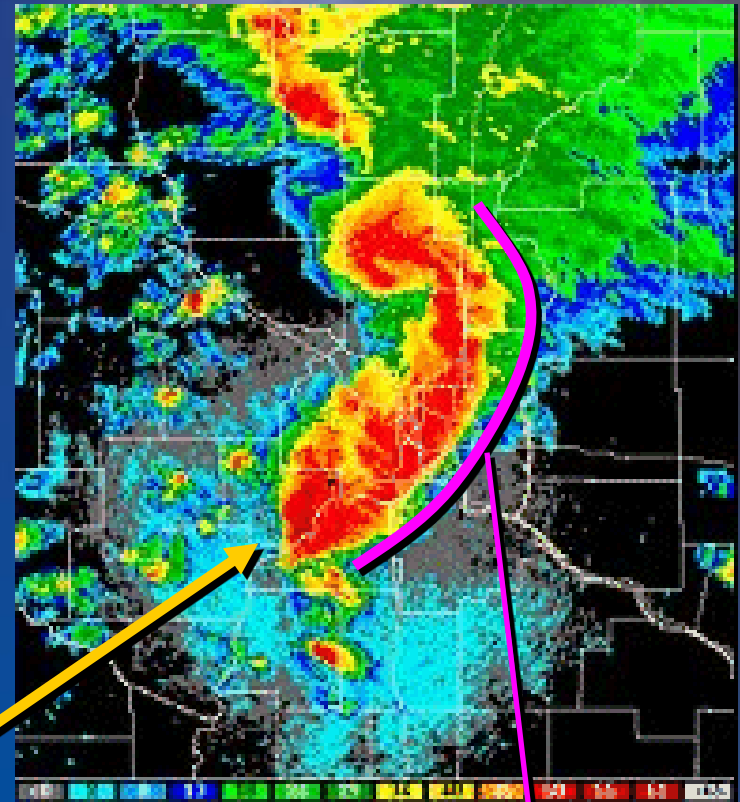
# Squall Line - Bow Echo



This shelf cloud is ahead of bow echo on right



Storm moving left to right (W-E)

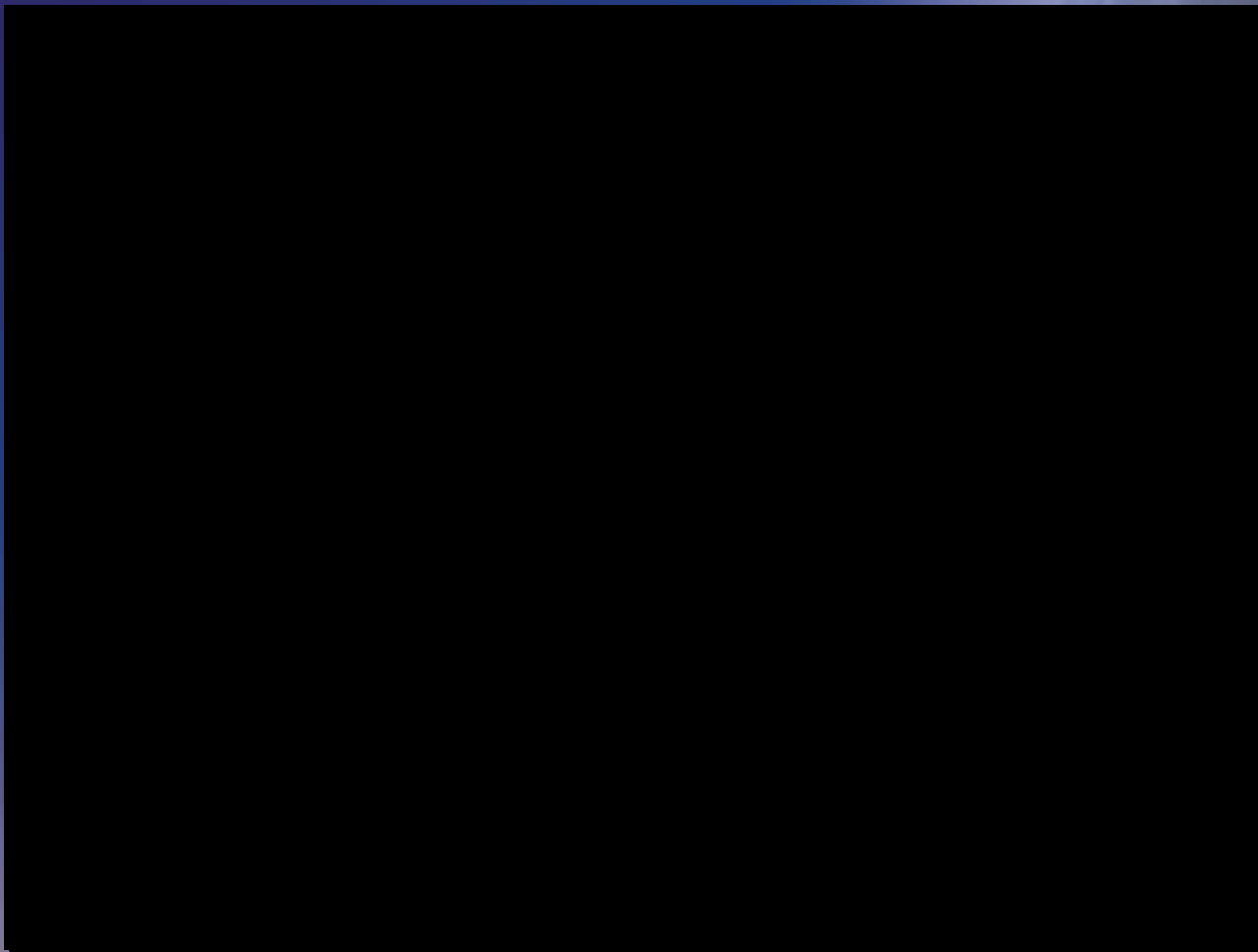


Well-developed shelf cloud is found on front side of line

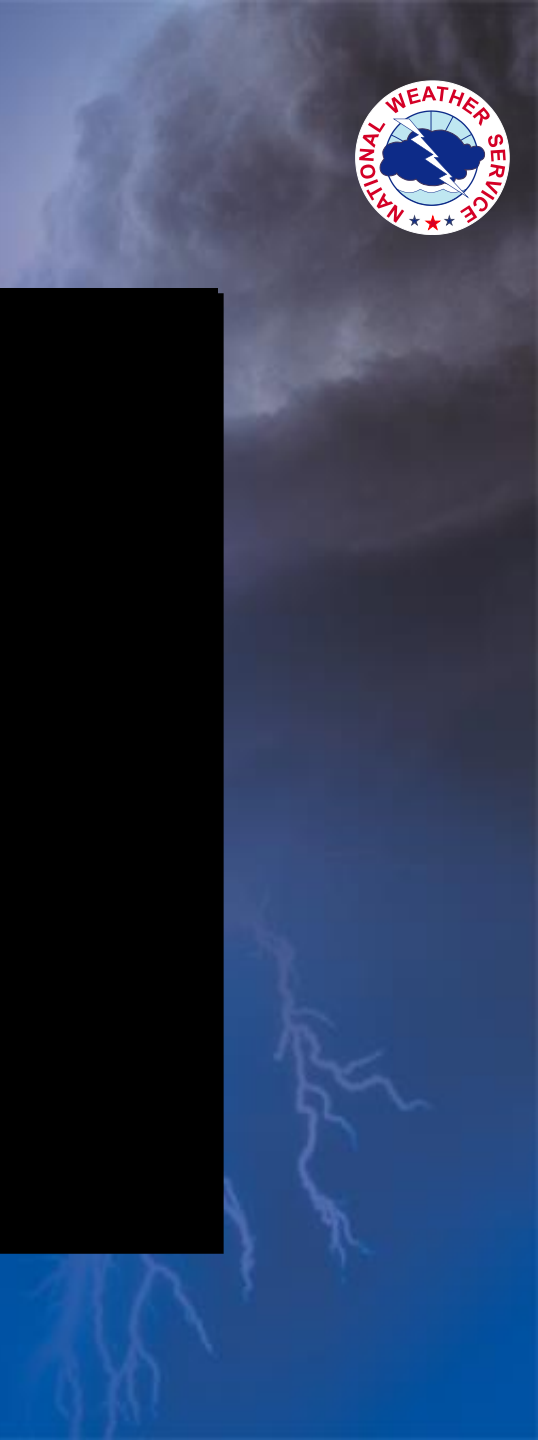


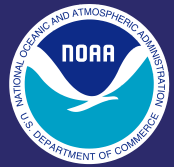


# Shelf Cloud

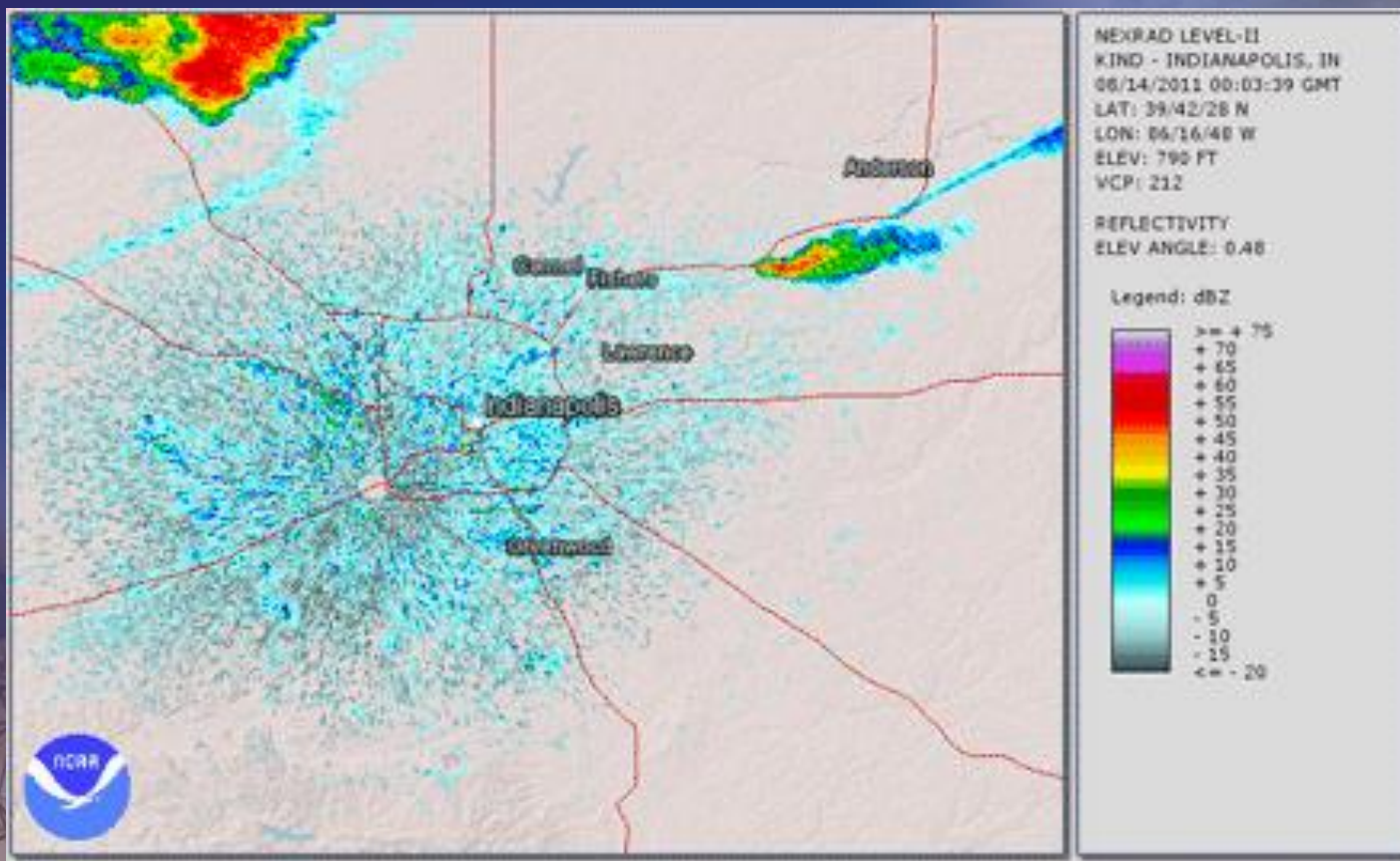


Video



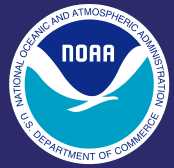


# August 13, 2011 Indiana State Fair



Stage collapsed at an outdoor concert  
7 Fatalities, 43 injured, Estimated Wind Gusts 70 mph





# Hail Shaft



# Storm Strength Clues

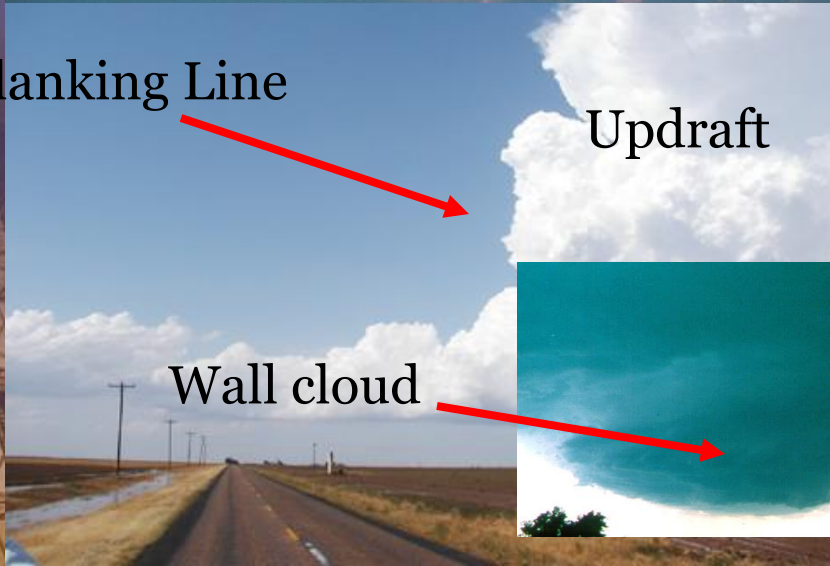


Overshooting Top

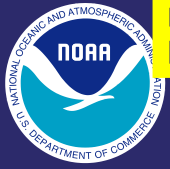
Flanking Line

Updraft

Wall cloud







# Evaluating the Surroundings



2004 Bruce Sherbon

A thick, crisp anvil (knuckles) is another sign of a strong updraft

Hard-crisp appearance is indication of a rapidly, intensifying storm!



# Supercell Thunderstorm



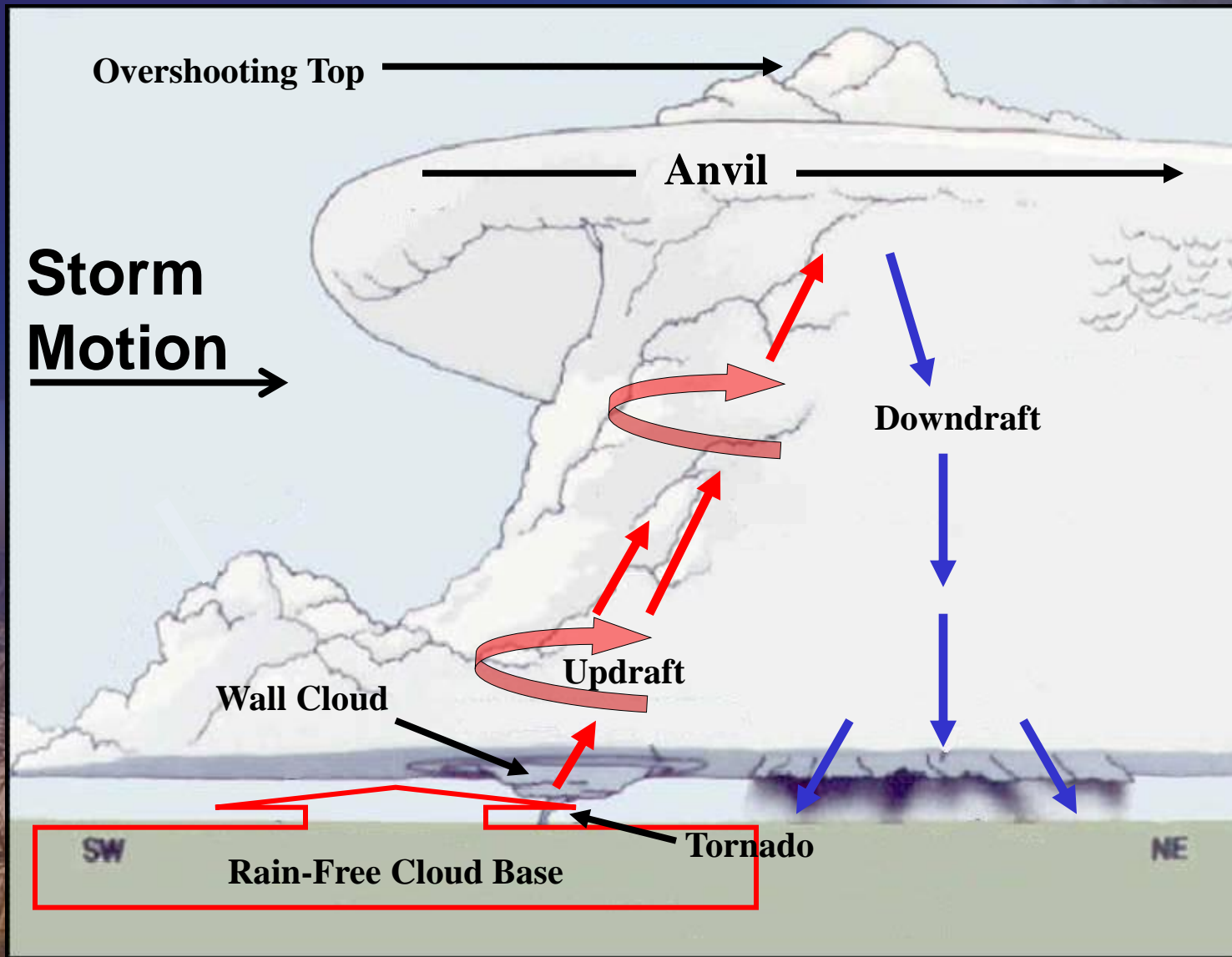
- Contains a rotating updraft called a mesocyclone
- Only about 10% of radar-detected meso's are associated with a tornado
- Produce large hail, high winds, and strong to violent tornadoes
- Can last for several hours

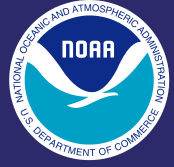






# Supercell Structure





# Rotation in Updraft Tower



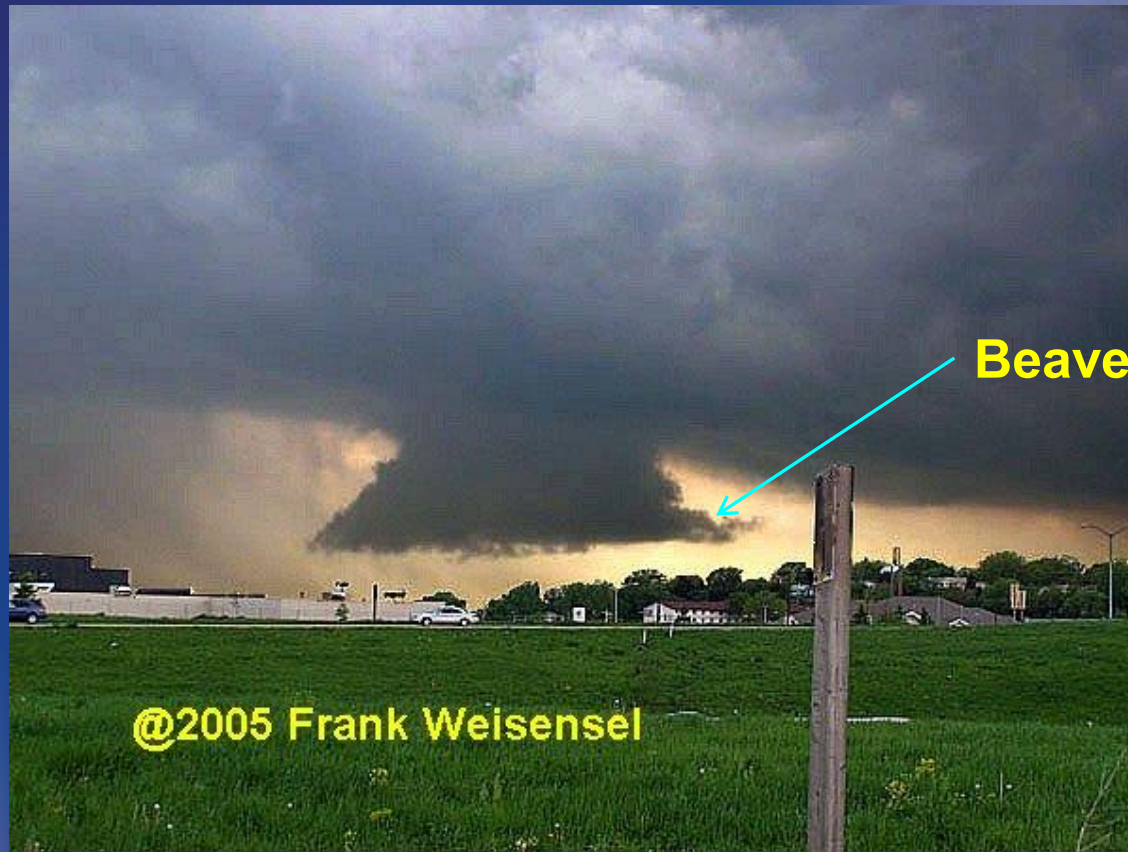
**Spiral bands and cork-screw look**





# Rotating Wall Clouds

An isolated lowering of the rain-free base, rotating on a vertical axis



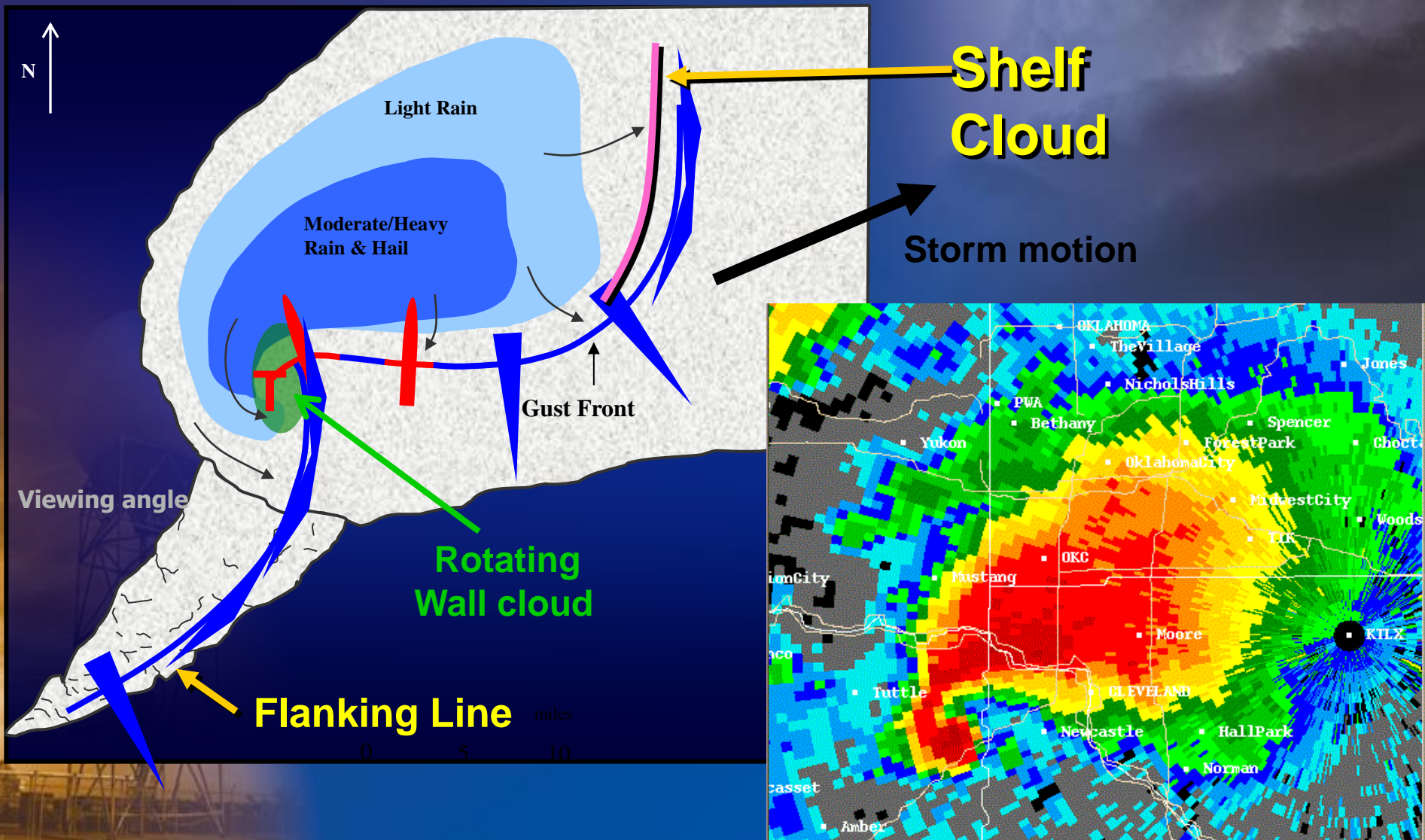
@2005 Frank Weisensel

A good number of, but not all, tornadoes develop underneath or near a rotating wall cloud



# Tornadic Supercell Thunderstorm

## top-down view

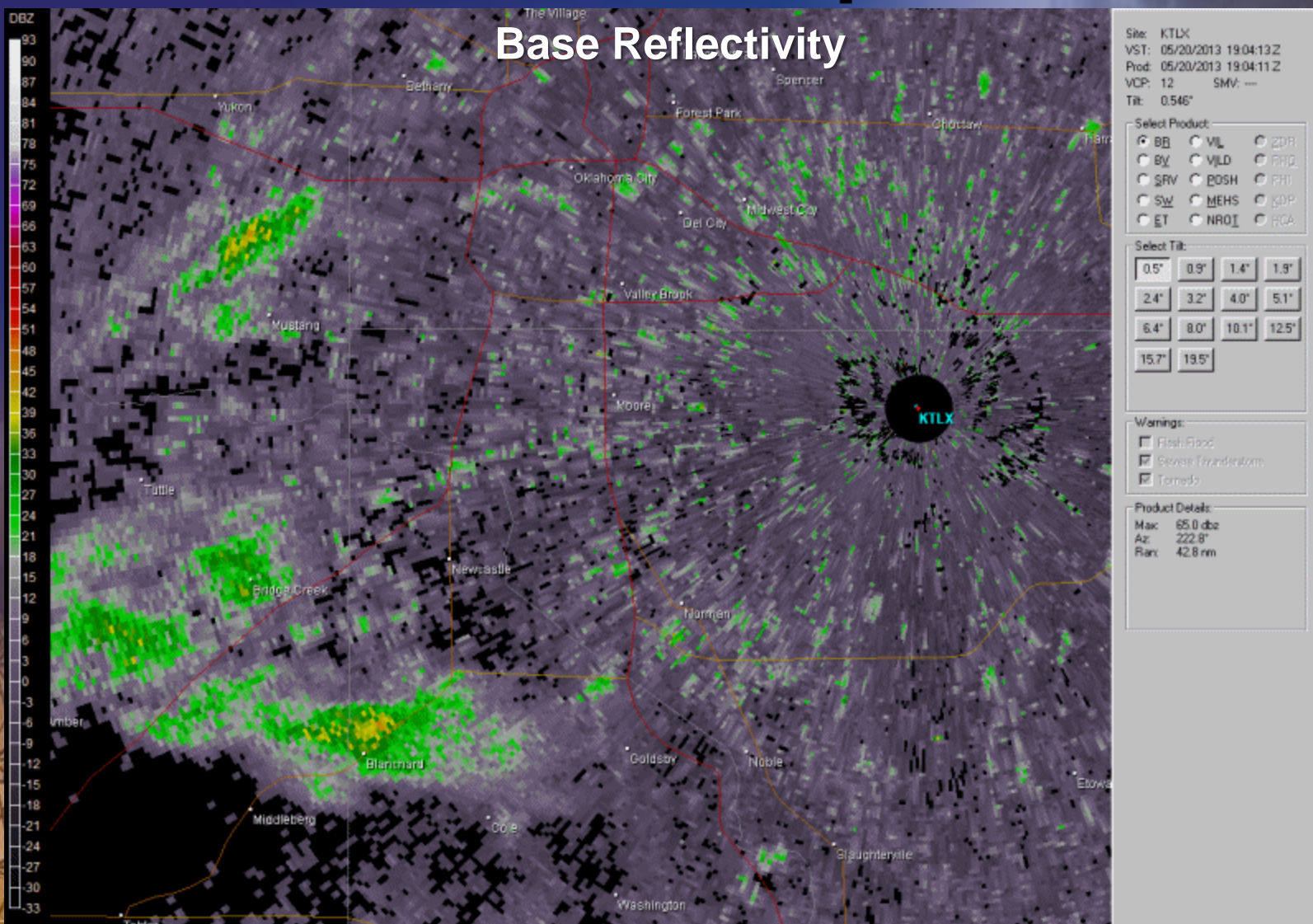






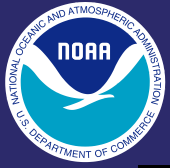
# Radar Loops

## Base Reflectivity

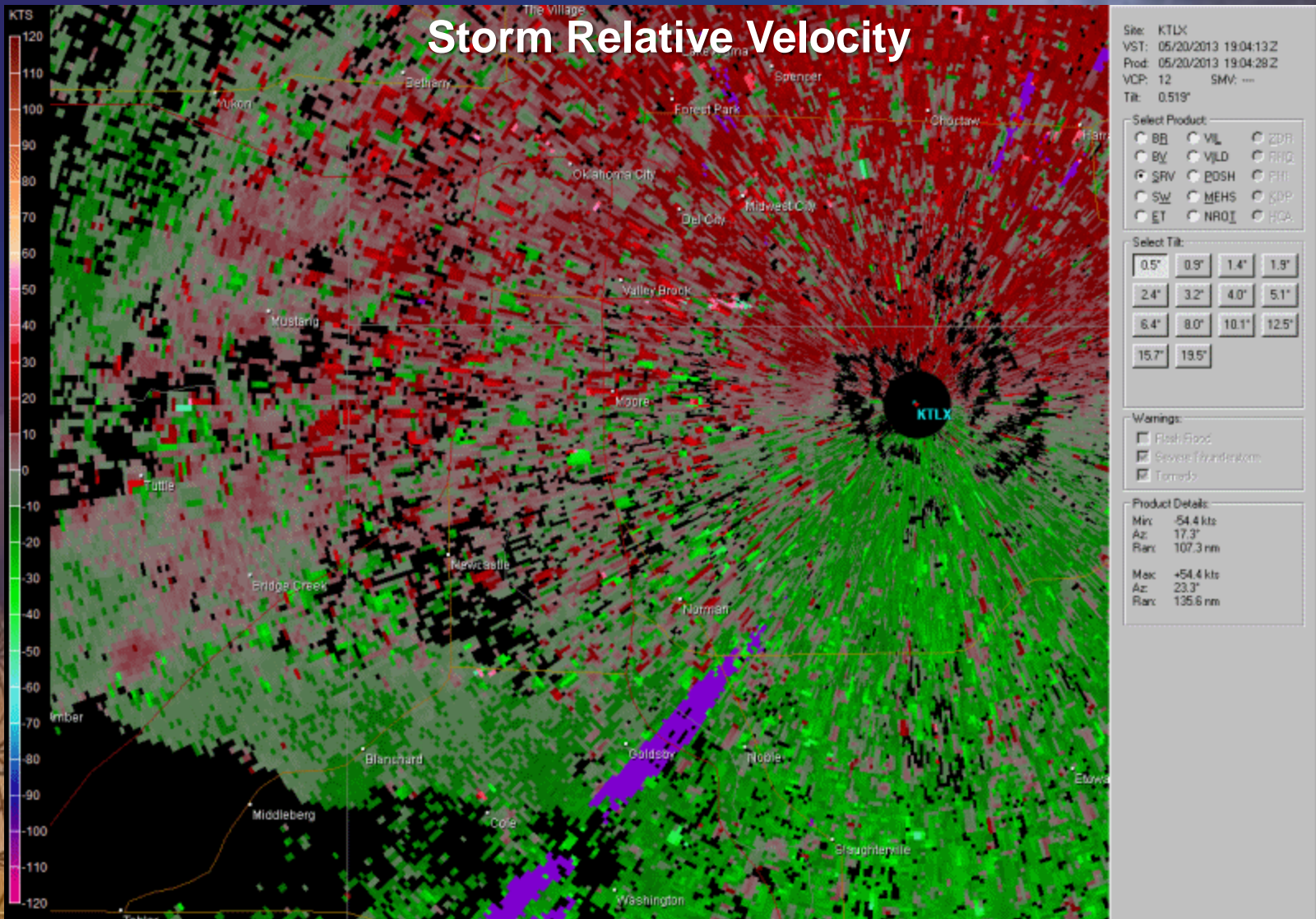


May 20, 2013 Moore, OK





# Radar Loops



May 20, 2013 Moore, OK



# Tornado



Lone Tree, IA May 15, 1998

5:39:03 PM

©1998 Brian Jewett





# Ratings & Types of Tornadoes



- **Enhanced Fujita Scale (EF 0 to EF 5)**
- **Classic, Wedge, and Rope**
- **Injuries & fatalities can occur with each type.**
- **NWS does NOT need to know what type of tornado you are observing.**





# Enhanced Fujita Scale



## Rating Tornadoes

EF 0	65-85 mph
EF 1	86-110 mph
EF 2	111-135 mph
EF 3	136-165 mph
EF 4	166-200 mph
EF 5	Over 200 mph

## Relative Frequency

**53.5% (weak)**

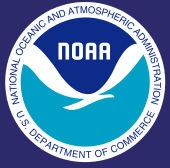
**31.6% (weak)**

**10.7% (strong)**

**3.4% (strong)**

**0.75% (violent)**

**<0.1% (violent)**

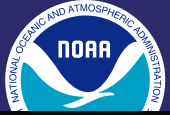


# “Classic” Tornado



Near Central City, IA, Apr 26, 2009

# Wedge Tornado



TwisterChasers.com

©2010 - Shannon Lupton

NSSL Photo

©2003 D. Lewison www.facethewind.com

They look wider than the distance from the ground to the cloud base





# Rope Tornado



NSSL Photo



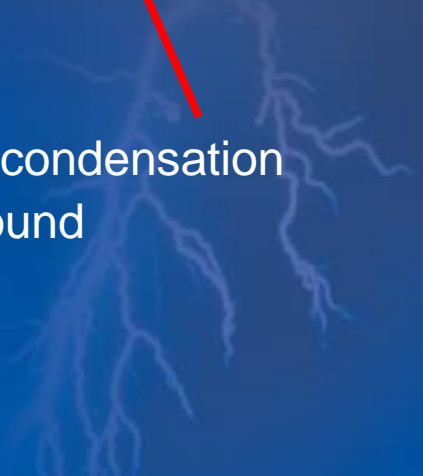
© 1999 Roger Edwards



Tornado – note extent of condensation funnel; debris-spray at ground



Tornadoes – note extent of condensation funnel; debris-spray at ground



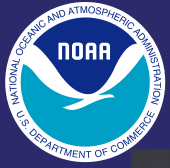


# Tornado



**Note – condensation funnel not touching ground**  
**Video**





# Wisconsin Tornadoes



April 21, 1974 near Oshkosh

Copyright 1974, 1998 Rusty Kapela



April 27, 1984 near Wales (Waukesha Co.)



July 18, 1996 approaching Oakfield (Fond du Lac Co.)

Copyright 1996 Don Lloyd



August 18, 2005 in Stoughton (Dane Co.)



# Wisconsin Tornado Stats

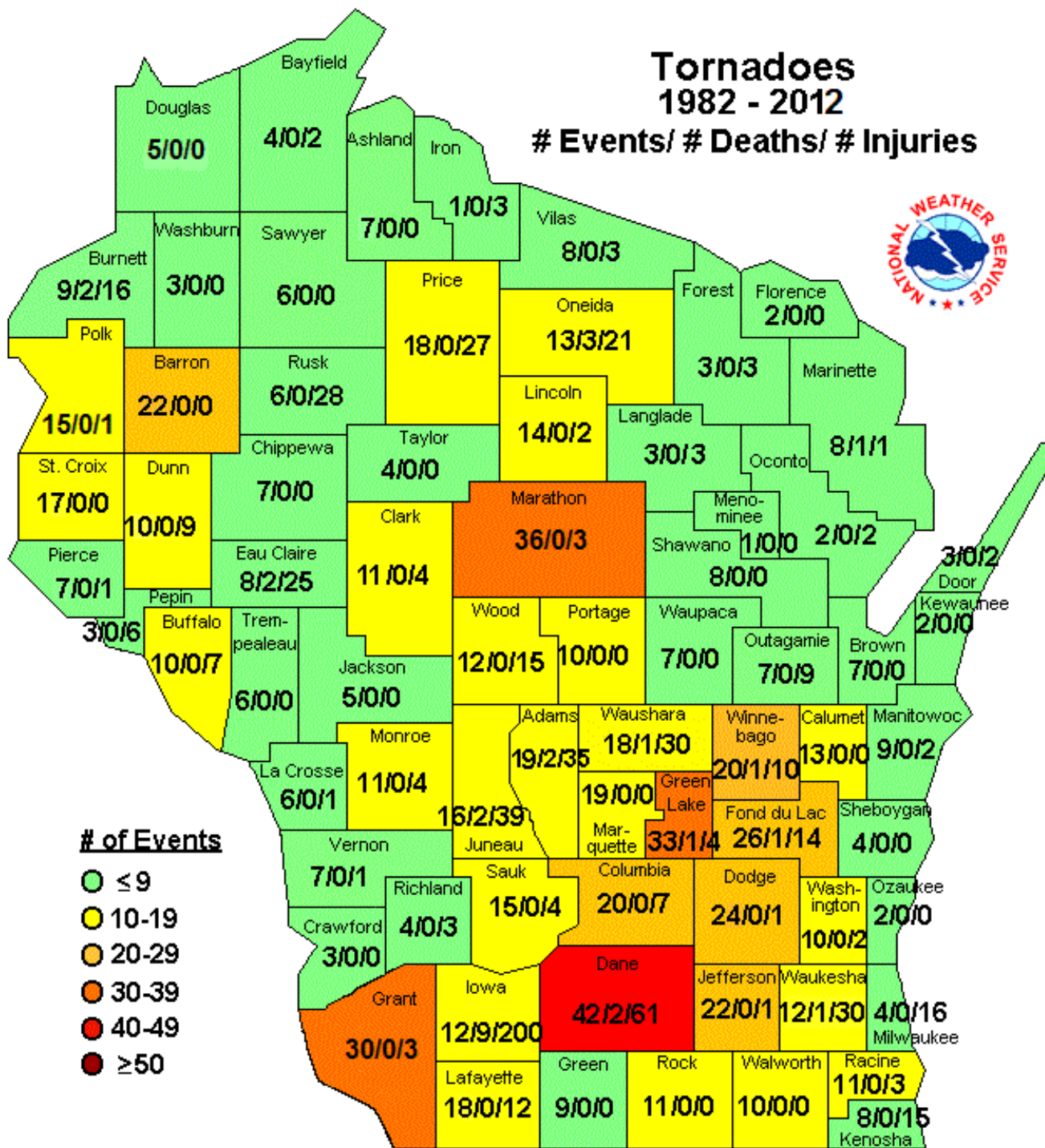


- Most tornadoes spin up between 3 pm and 9 pm, with 6-7 pm being the busiest.
- Most tornadoes occur between April and September, with June being the peak month.
- Tornadoes generally move southwest to northeast, but west to east, and northwest to southeast movements are quite possible.

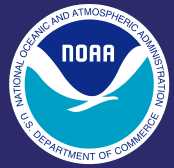


# Tornadoes 1982 - 2012

## # Events/ # Deaths/ # Injuries







# Wisconsin Tornadoes 1950-2011

Credit: Doug Norgord, Geographic Techniques





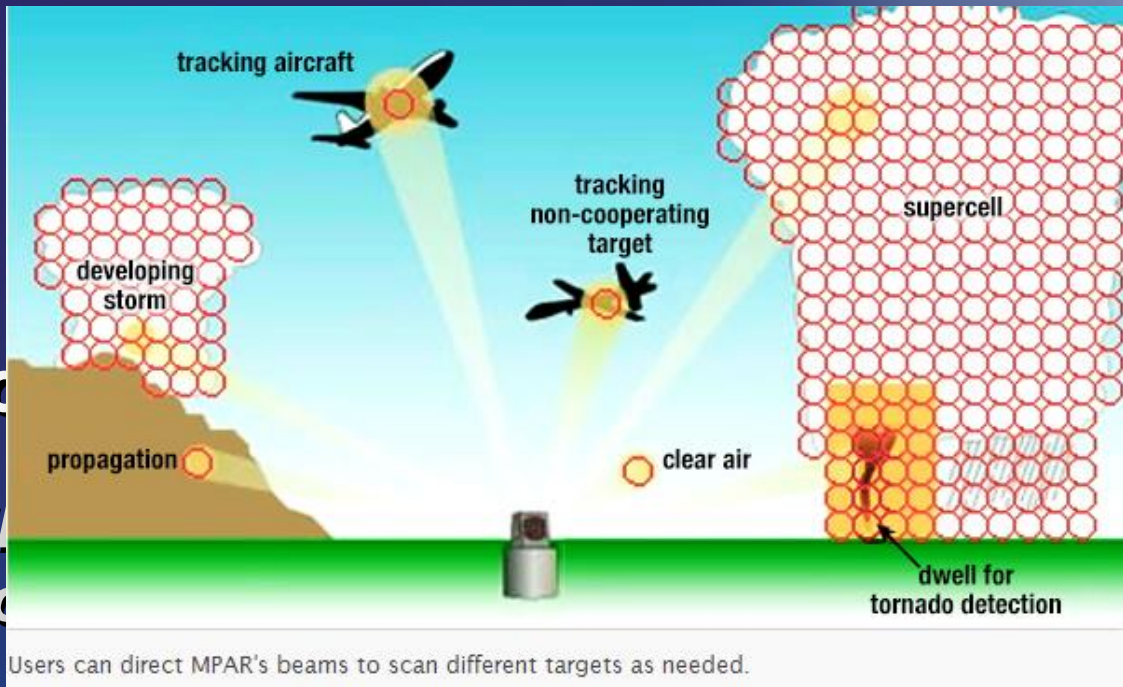
# New Technology on Horizon



- **Phased Array Radar**
- **Warn-on-Forecasts**







- **Nation**

- **Mitigation**
- **protection**

(VIRT)

to  
threats

- **Flat panel antenna**
- **Scans sky in less than 1 minute**
- **Possible cost-effective replacement for aging weather and aircraft tracking radars**

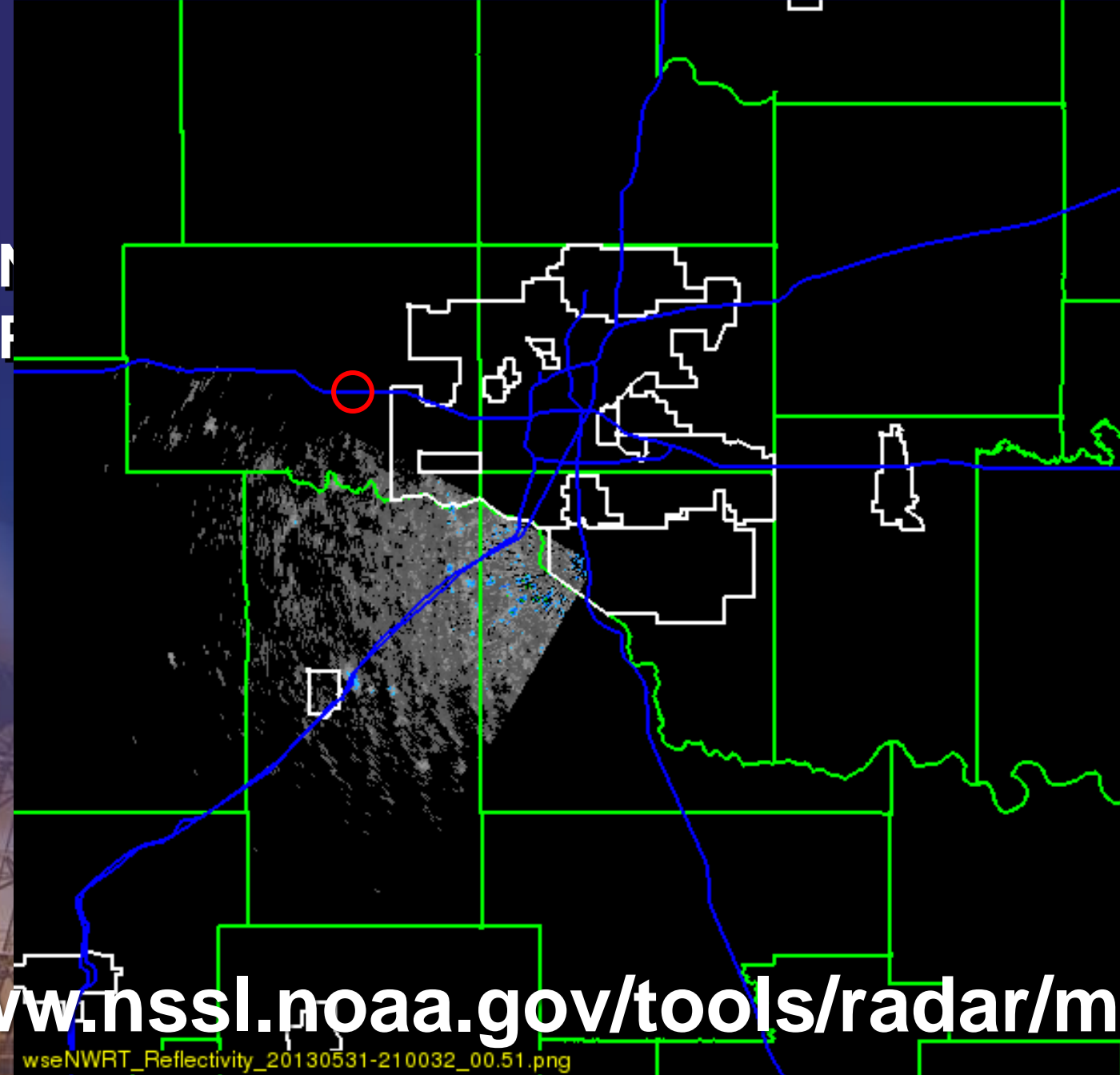
[www.nssl.noaa.gov/tools/radar/mpar](http://www.nssl.noaa.gov/tools/radar/mpar)







na MD <10 10-20 20-30 30-40 40-50 50-60 60-70 <75 75+ dBZ



[www.nssl.noaa.gov/tools/radar/mpar](http://www.nssl.noaa.gov/tools/radar/mpar)

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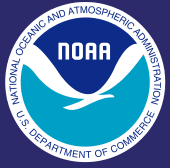


# Warn-on-Forecast

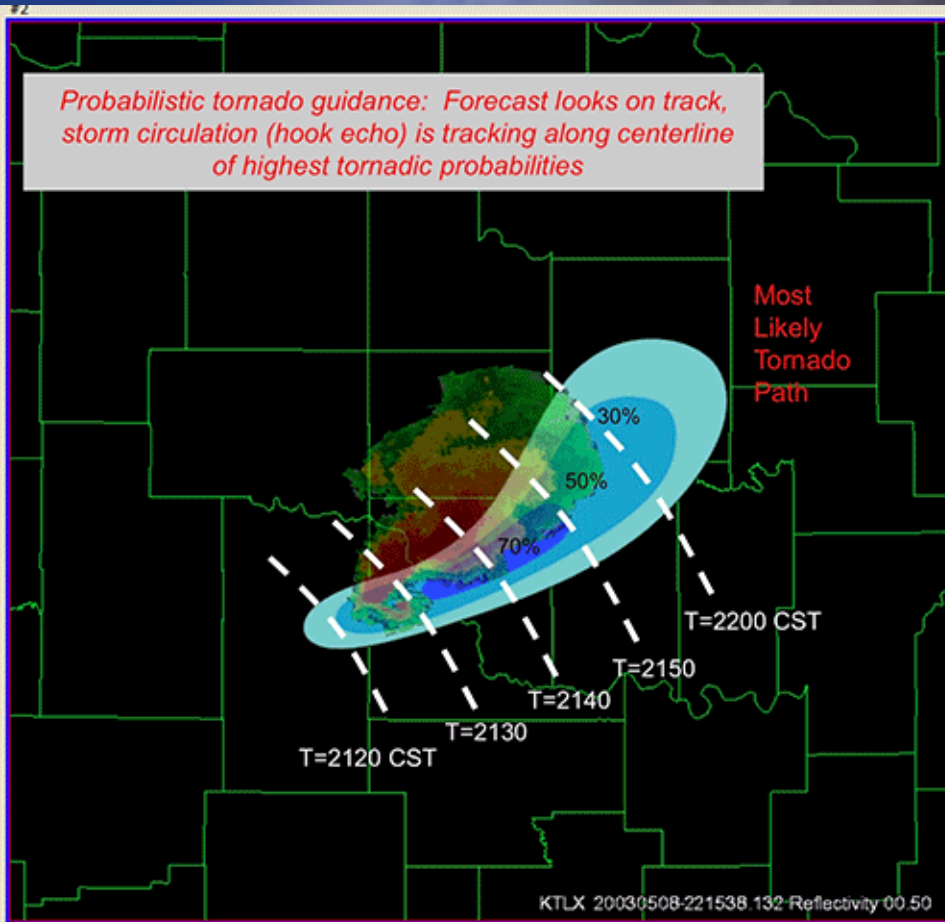
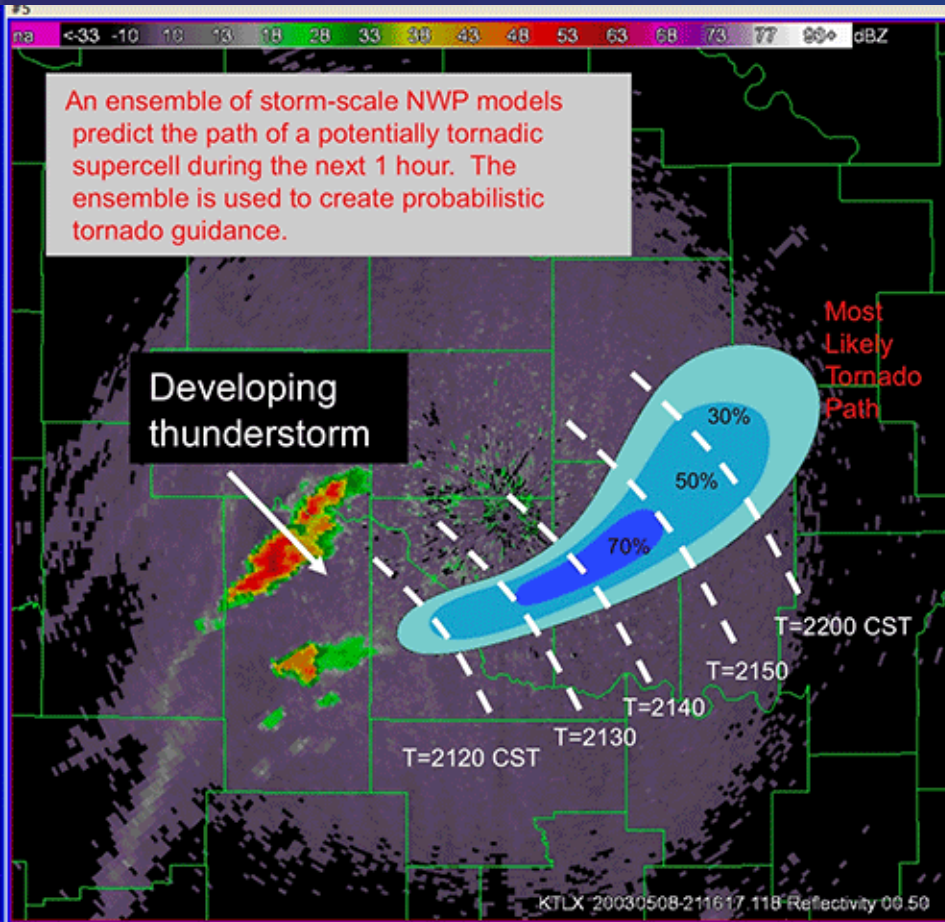


- **Currently, warning process based upon warn-on-detection approach**
- **Reaching a plateau in lead time**
- **Ensemble of storm-scale numerical weather prediction models**
- **Probabilistic hazard guidance**

[www.nssl.noaa.gov/projects/wof](http://www.nssl.noaa.gov/projects/wof)



# Warn-on-Forecast







# The End



# Questions?

