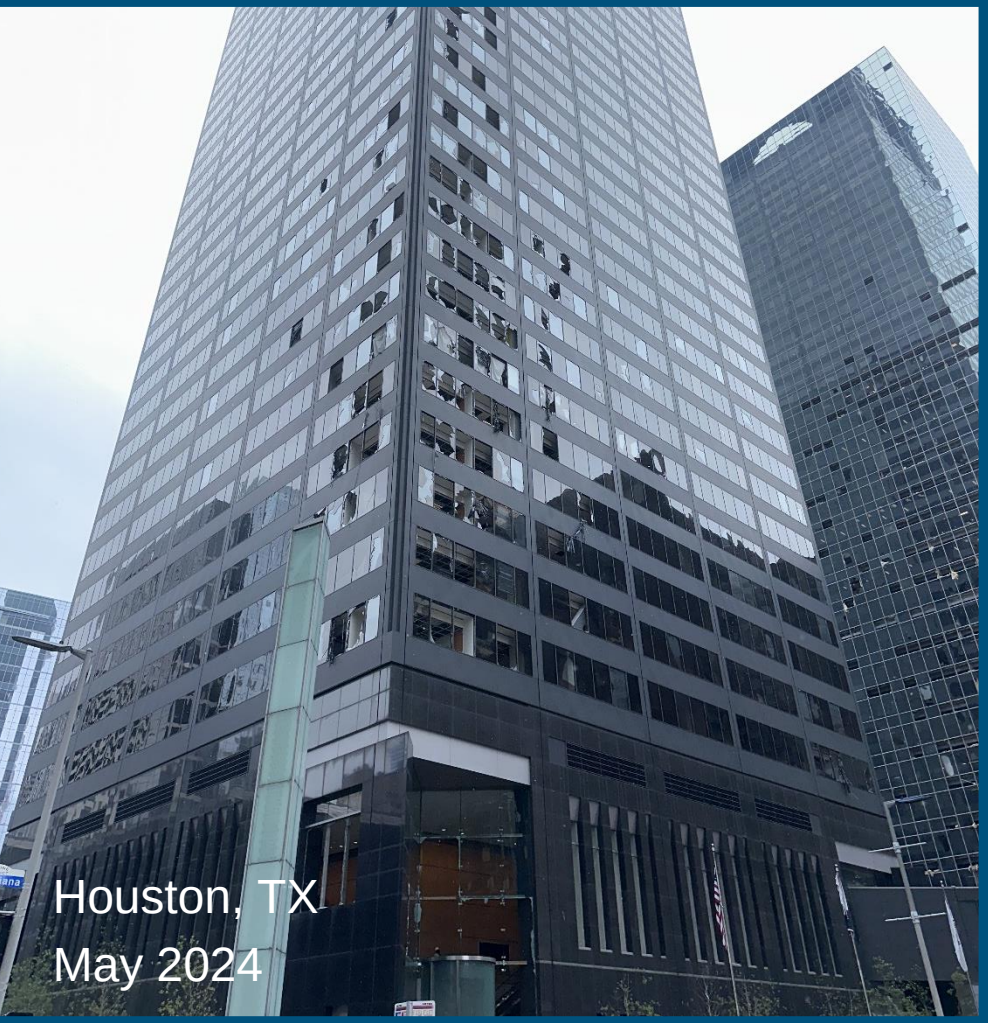
# Skywarn Weather Spotter Training

## National Weather Service – Houston/Galveston



Houston, TX
May 2024


Onalaska, TX
April 2020

# Your Instructors

## Tim Cady

- NWS Forecaster since 2019
- B.S., Saint Louis University
- M.S., University of Kansas
- Also lead the office heat and warning verification programs

## Cameron Self

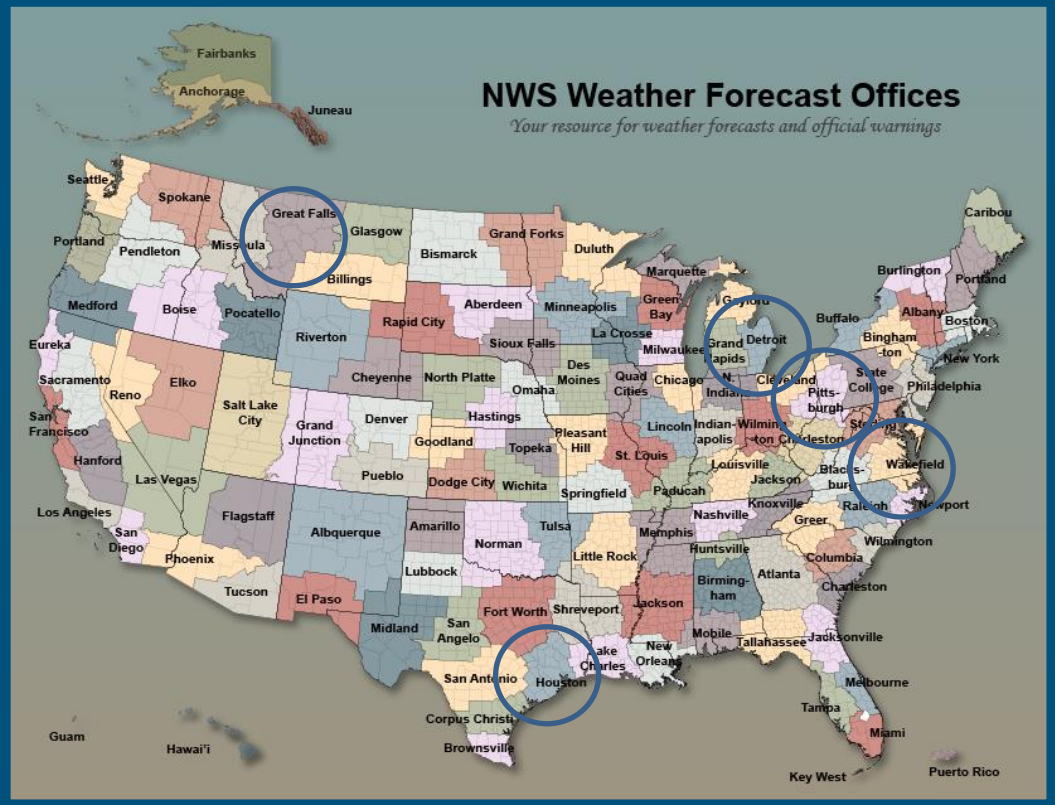
- NWS Forecaster since 2022
- B.S., College of Charleston
- M.S., UNC-Charlotte
- Climate and marine weather program leader

# NWS Houston/Galveston Weather Forecast Office

Issues forecasts and warnings for much of Southeast Texas

Mission: Provide weather, water and climate data, forecasts, warnings, and impact-based decision support services for the protection of life and property and enhancement of the national economy.

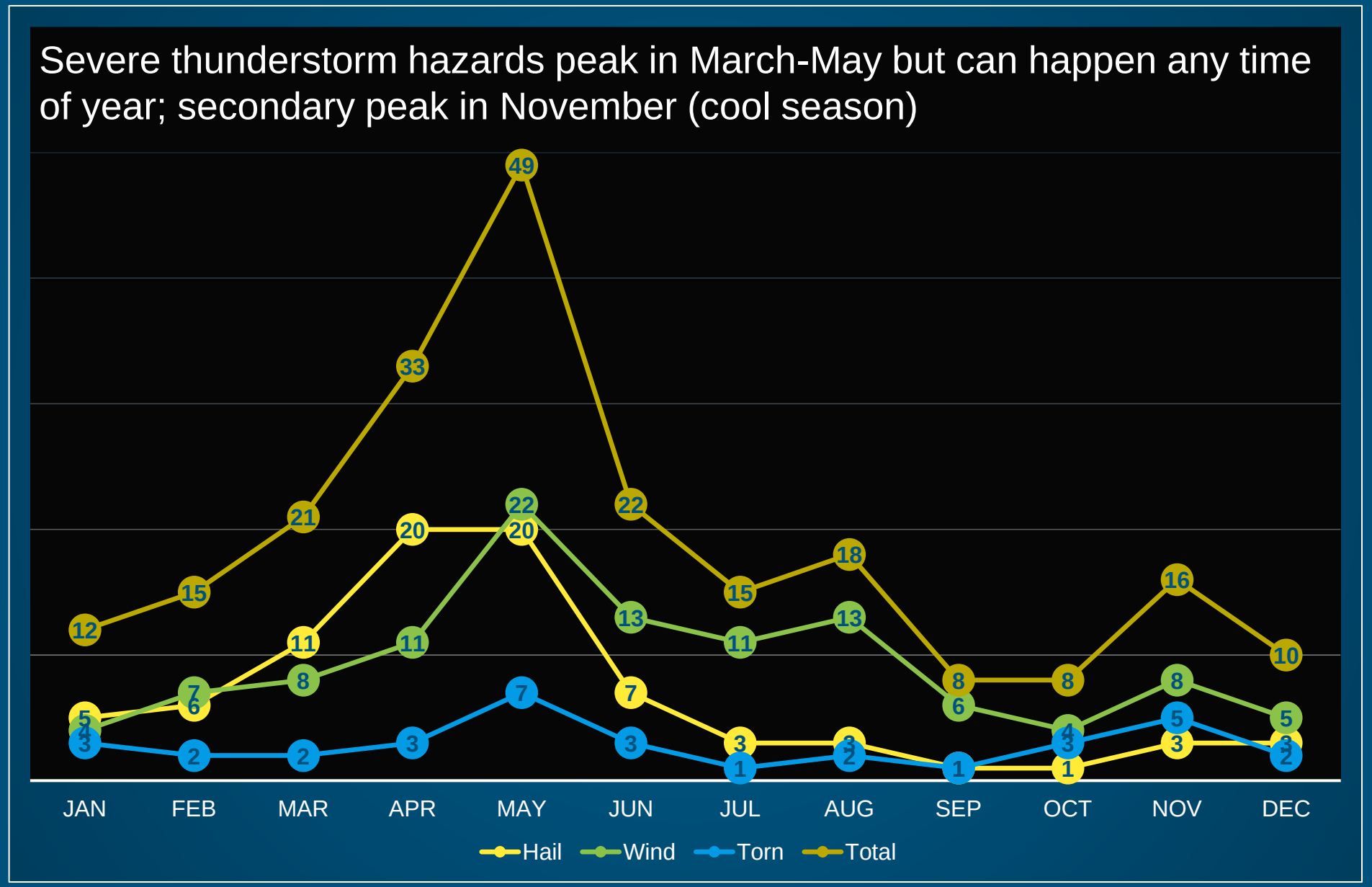
NWS is a federal agency, part of NOAA which is part of the Department of Commerce.





Forecasters briefing each other at shift change during Harvey

# Severe Weather Climatology for Southeast Texas



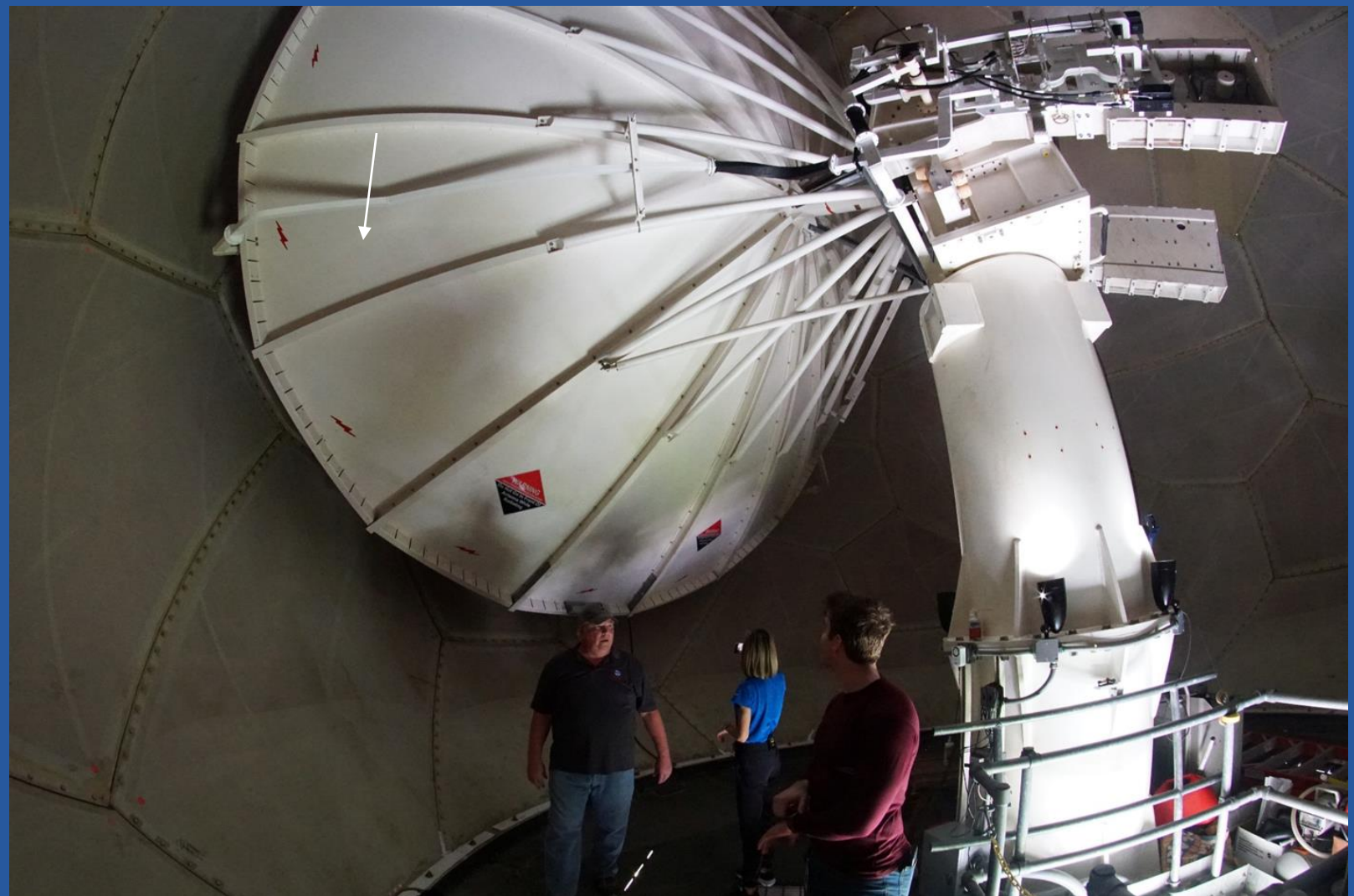
# Skywarn Spotters

- Spotters report severe weather when and where they see it; not asked to be chasers; best to spot from a safe location.
- Spotter reports essential for accurate and timely warnings.
- Spotter reports can and do save lives; may prompt a new warning, add credibility to an existing warning.
- Spotter information most useful real-time but still helpful after the fact. Please call, we are not too busy!

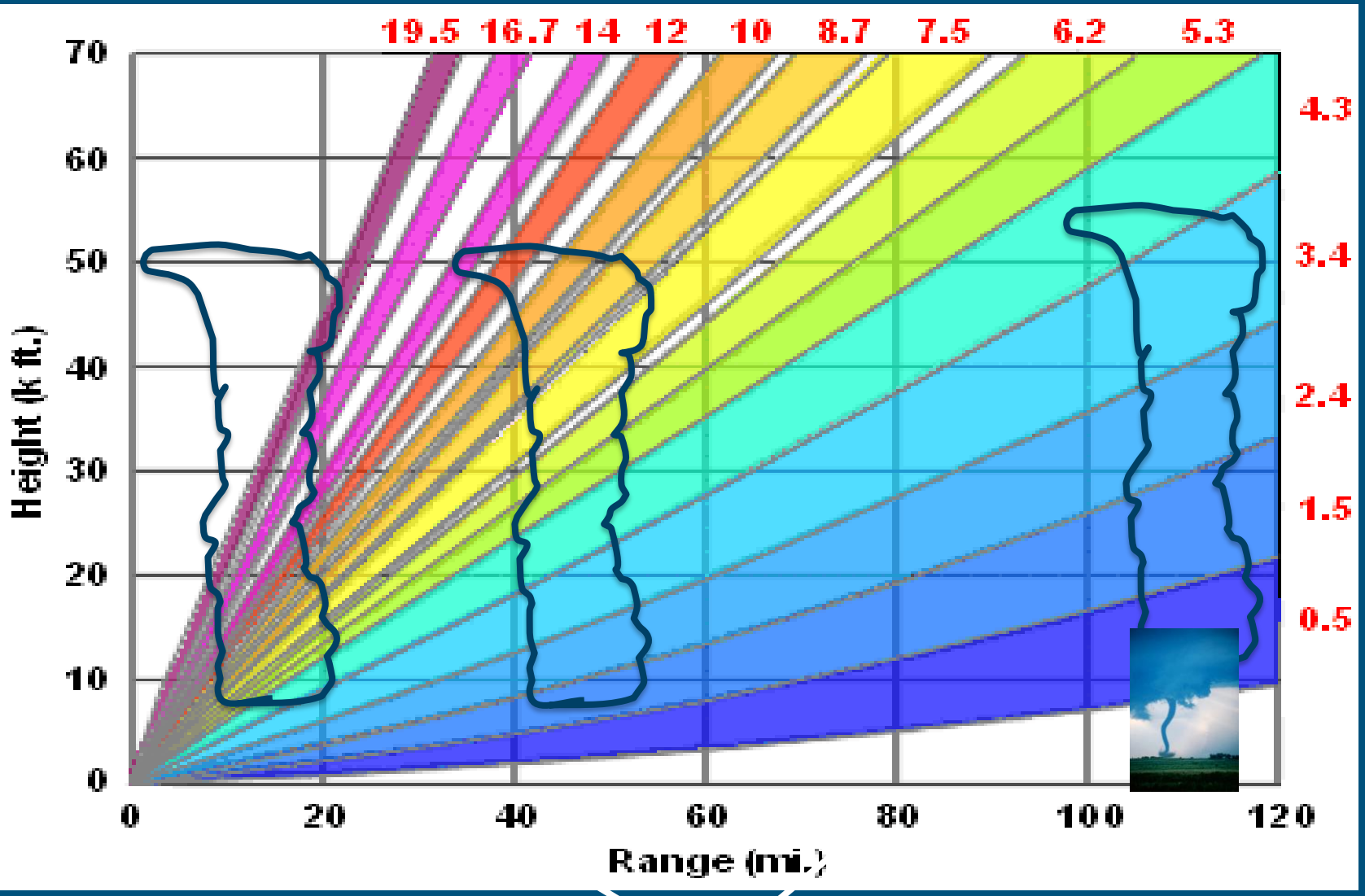

# Weather Radar

Radome made of rigid fiberglass

WSR-88D is the primary technology tool for evaluating storms, determine severity, making warning decisions



# Radar Limitations

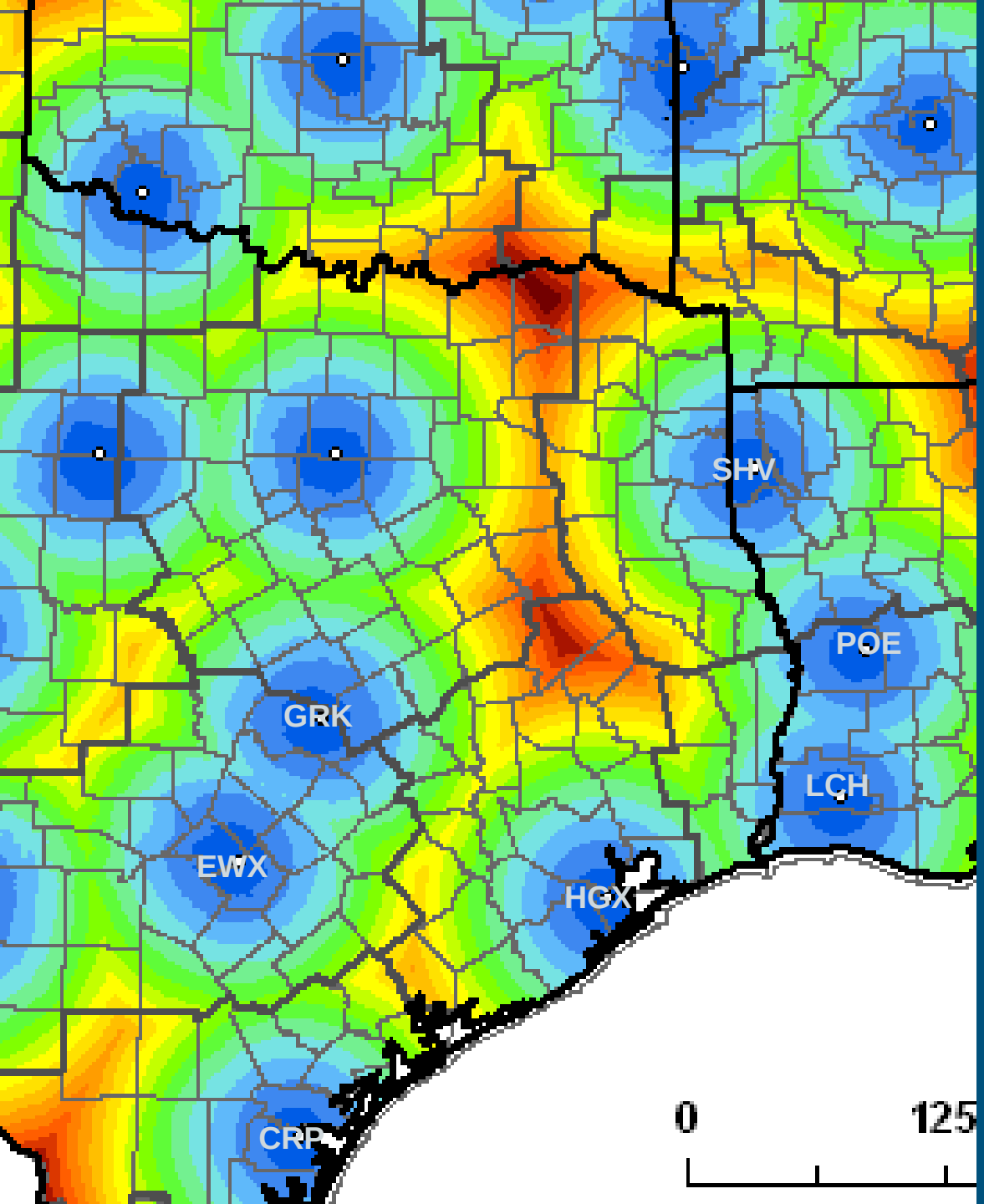



~ optimum range of detection

Storms may be too close or too far to be well sampled by the radar beam.

If too far, lowest cut (0.5 degrees above horizontal) may “overshoot” the storm, not seeing lower levels.

If storm is very close, mid to upper levels wont be sampled by the highest cut. It is in the “cone of silence”.




LEGEND

- NEXRAD Sites

0.5 Degree Beam Height (ft AGL)

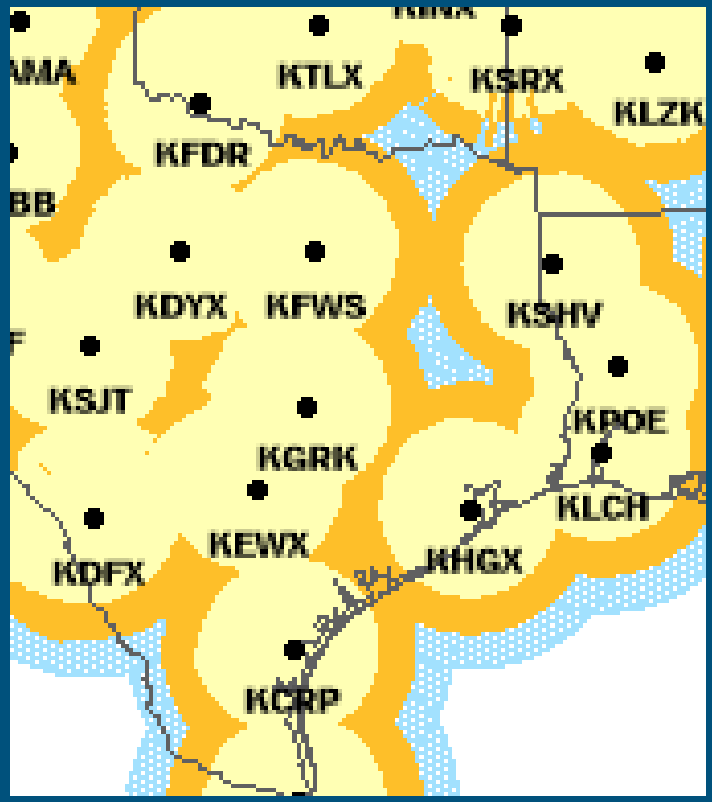
<VALUE>

- 0.363769531 - 1,000
- 1,000.000001 - 2,000
- 2,000.000001 - 3,000
- 3,000.000001 - 4,000
- 4,000.000001 - 5,000
- 5,000.000001 - 6,000
- 6,000.000001 - 7,000
- 7,000.000001 - 8,000
- 8,000.000001 - 9,000
- 9,000.000001 - 10,000
- 10,000.000001 - 11,000
- 11,000.000001 - 12,000
- 12,000.000001 - 13,000
- 13,000.000001 - 14,000
- 14,000.000001 - 15,000
- 15,000.000001 - 16,000
- 16,000.000001 - 30,000
- County Borders
- CWA Boundaries

Shows height of the lowest beam from any radar, a measure of the overshooting problem.

For College Station, GRK 4500 feet, HGX 11,000 feet AGL.

***Radar useful but we need spotters for ground truth!***



# What to Report

- **Hail** (including size)
- **Thunderstorm wind damage** to trees, structures; measured wind gusts 58 mph or higher
- **Tornadoes or waterspouts**
- **Flooding** (roads impassable, hazardous; streams, creeks out of banks)
- **Funnel clouds or wall clouds**
- **Storm damage** from any of the above or from lightning
- Weather related injuries, fatalities


# How to Report

Call NWS spotter line 1-800-846-1828
OR
Report via ham radio (call sign WX5HGX)

Can send follow up information (pictures, videos) to operations area email, Twitter or Facebook if you like:

- Email: sr-hgx.nws@noaa.gov
- Twitter: @NWSHouston
- Facebook: NWSHouston

More information on Ham radio frequencies here:

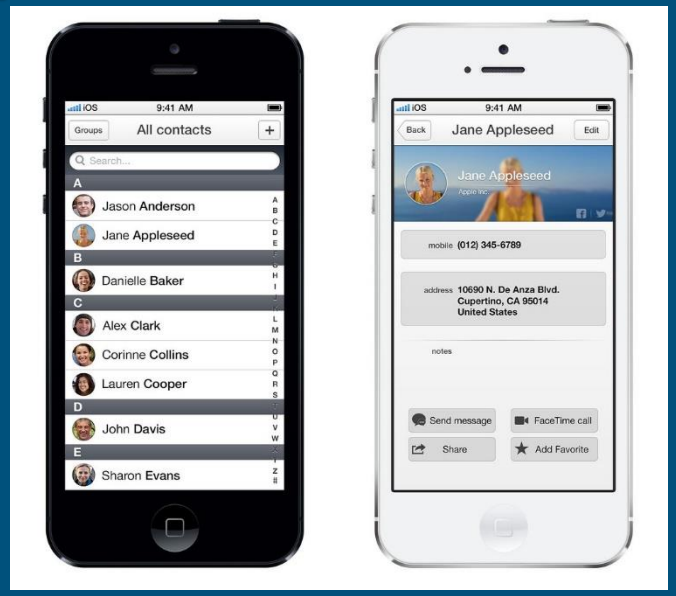
http://southcoastreflector.com/

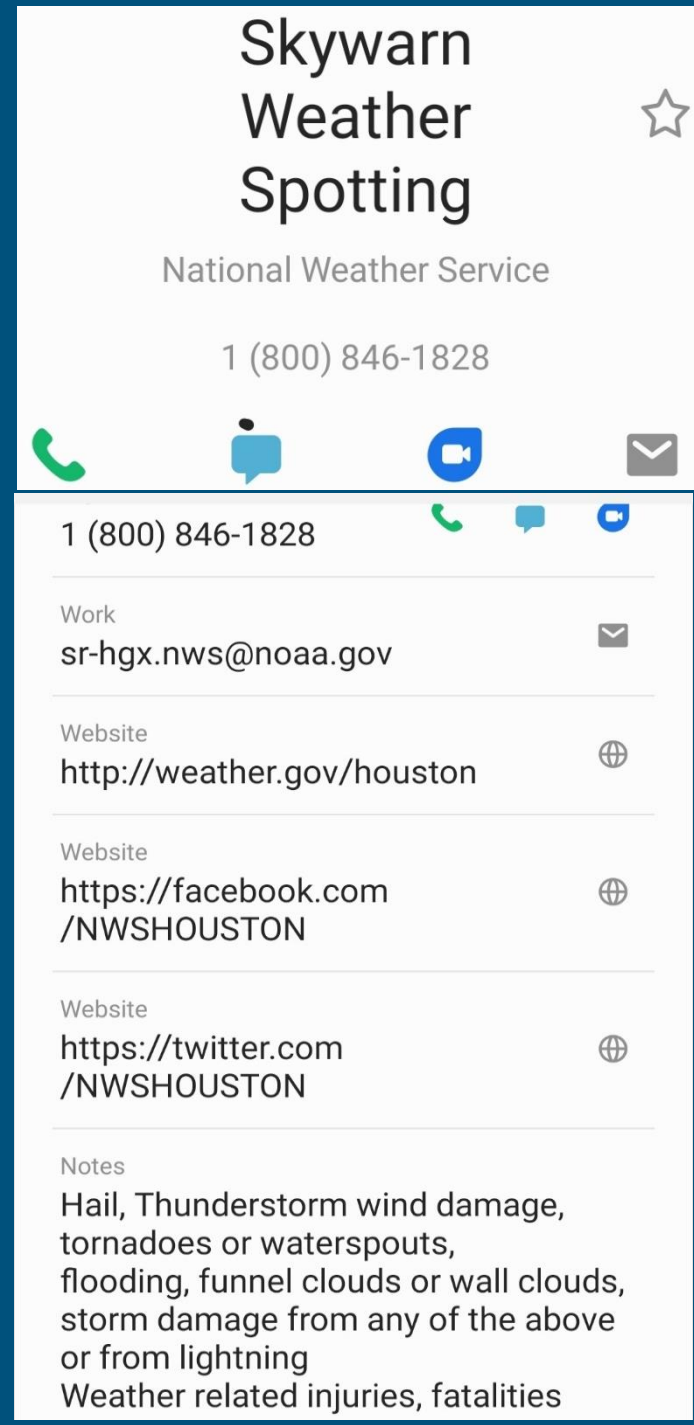
# Recommendation: Setup Skywarn as Contact on Your Smartphone

## 1-800-846-1828

You will be ready to report by phone and send quick follow up photo/video if you choose.

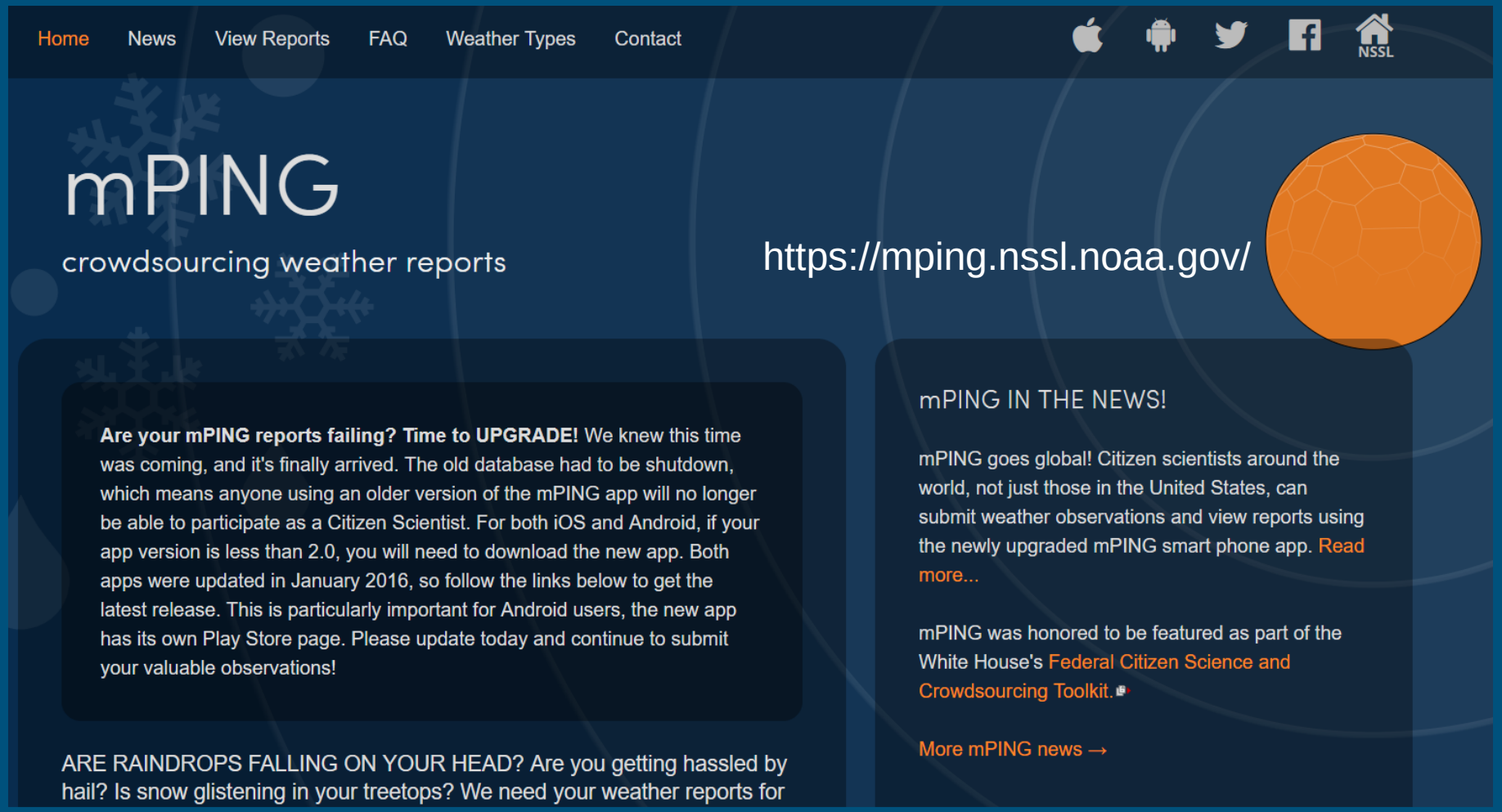
Call whatever you like. Skywarn, spotter. Phone number will ring NWS Houston ops 24/7, you will speak to a forecaster.

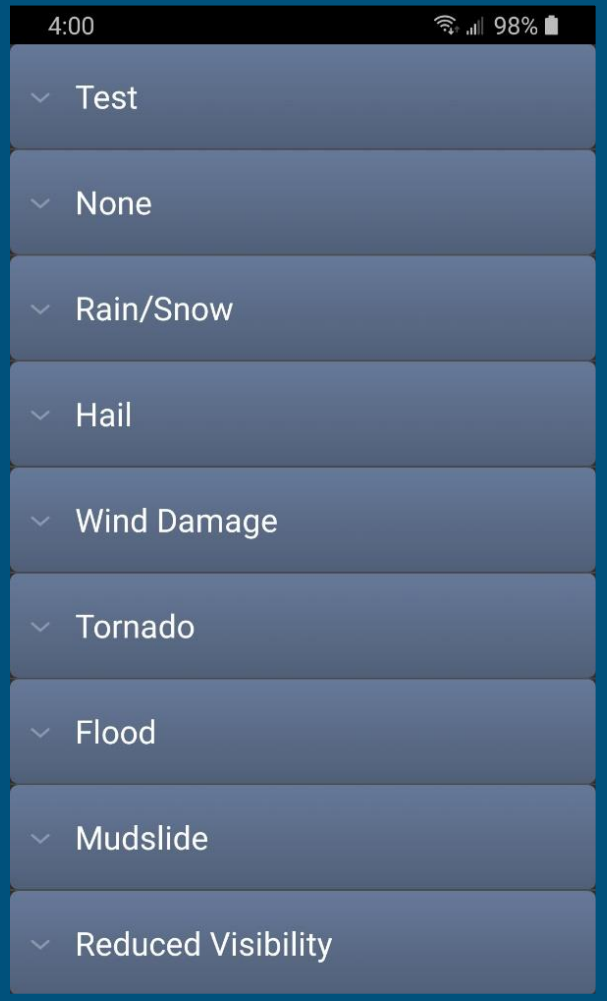


# Mobile Application mPing

This doesn't replace primary method of Skywarn reporting. Can take this additional step if you choose. Can pick this up from the app store. Developed by NOAA NSSL.



# Reporting Hail

Report size of hail including largest hail stones

When and where did hail occur?

Did hail damage crops, vehicles, structures?

Can measure with a ruler (after the storm)

Easiest to estimate relative to common object like a coin or a ball

**VIDEO: Severe hailstorm moves through Bryan/College Station**

Severe hail swept through Brazos County Thursday night. (KBTX)

By Max Crawford

*Published: Apr. 8, 2021 at 9:43 PM CDT | Updated: Apr. 8, 2021 at 11:56 PM CDT*

# Hail Size Chart

While the National Weather Service encourages the actual measurement of hail size, oftentimes, an object-to-size conversion can provide important information about hail that fall from thunderstorms. Below you will find a list of common objects used to describe the diameter of observed hail.

| | | | |
|---|---|---|---|
| 0.25 inches | Pea | 2.00 inches | Lime |
| 0.75 inches | Penny | 2.50 inches | Tennis Ball |
| 1.00 inches | Quarter | 2.75 inches | Baseball |
| 1.50 inches | Ping Pong Ball | 4.00 inches | Softball |
| 1.75 inches | Golf Ball | 4.50 inches | Grapefruit |

weather.gov

# Estimate Hail Size Using Common Objects or Measure

Hail >=1 inch diameter (quarter-sized) defined as large “severe” hail (warrants a severe thunderstorm warning

Photo courtesy of
WCM Todd Heitkamp
NWS Sioux Falls, SD

Record hailstone 8 inches, 2 lbs

# Thunderstorm Wind Damage

- Report damage caused by wind (Trees blown down, large limbs stripped off trees, damage to structures)
- Can report measured gusts if you have anemometer
- When and where did the damag



# Flooding

- High water covers road & starting to impact travel, or floods a structure
- Stream or bayou out of its banks
- Give location describe situation
  - How deep? Is water standing or flowing?
  - Is road impassable or closed due to high water?
- Six inches or more of flowing water can be hazardous

# What is a Tornado?

A narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground


weather.gov

# Funnel Cloud

- A funnel shaped cloud, rotating, that projects from the base of a thunderstorm cloud and often precedes the development of a tornado.
- Look for persistence, rotation, then for evidence circulation is on the ground (swirling debris, power flashes for example). If there is evidence, report tornado, if not funnel cloud.


# Tornado Look-Alikes

- Scud clouds, rain shafts the most common features mistaken for tornadoes.
- Look for rotation, debris associated with the feature. If not, its most likely on of these imposters.

Credit: Kaylor Frakes

Photo Credit: Beth Lauderdale

## Beware of Tornado Look-alikes

Scud clouds are perhaps the most common feature mistaken for tornadoes. They are low, ragged cloud fragments that can sometimes be located near the updraft region of the storm. However, **they lack organized, persistent rotation**. Here are a couple examples of scud clouds.


There are several other features, some associated with an actual storm and others that are not, that can also be mistaken for a tornado.

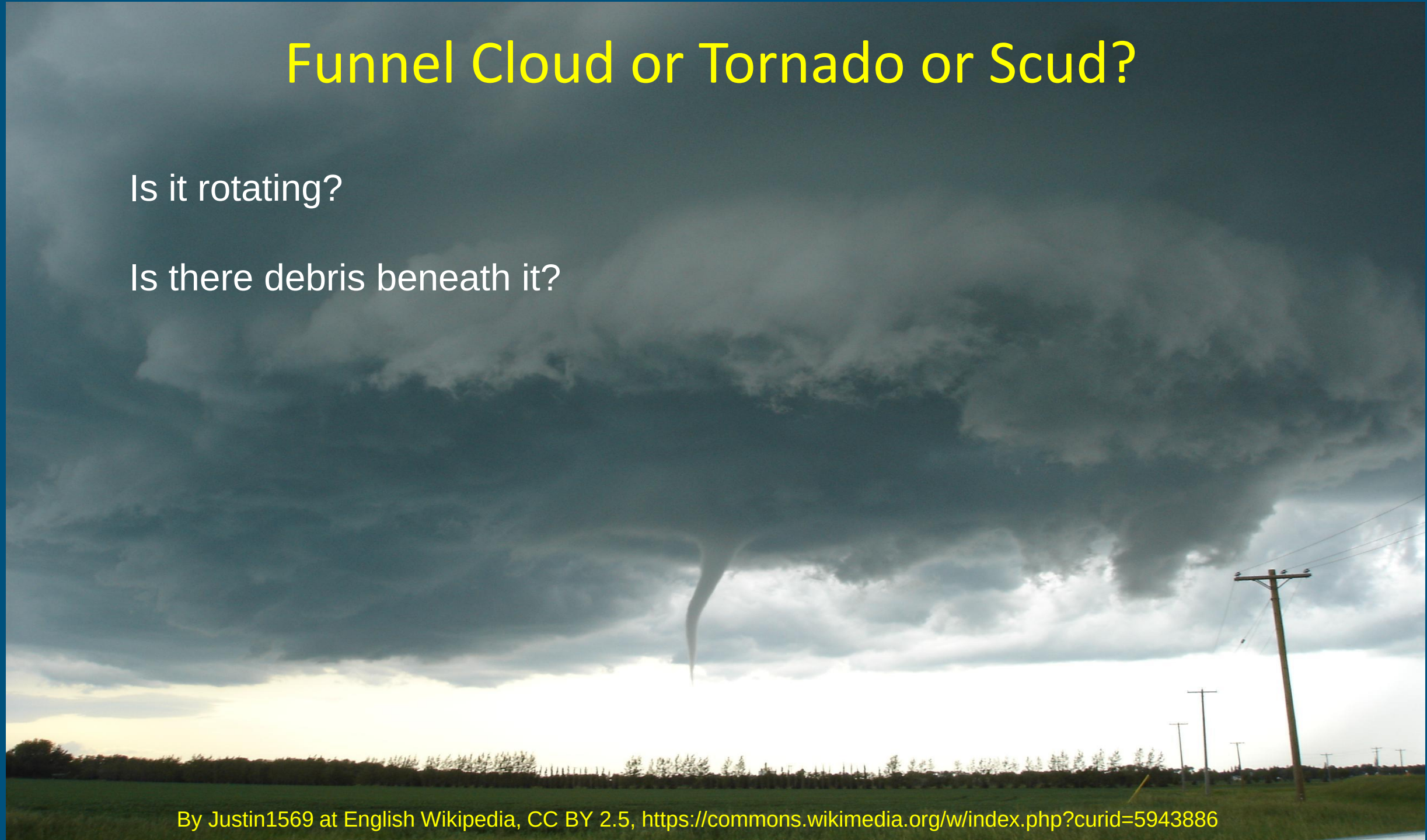

Rainshaft - also lacks organized rotation about a vertical axis


Upward directed shadow cast on a higher cloud deck by a low cloud eclipsing the setting sun.

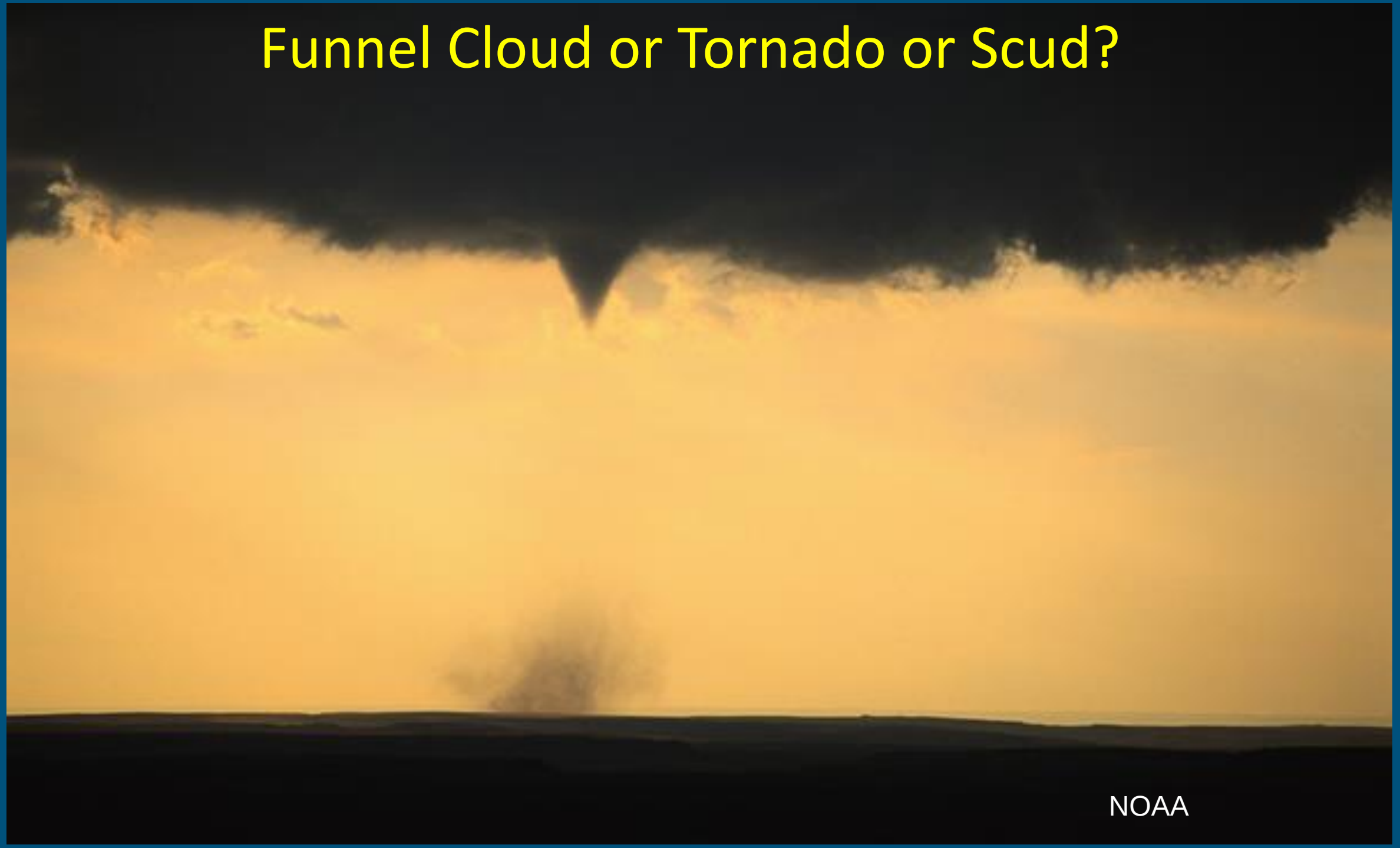
# Funnel Cloud or Tornado or Scud?

Is it rotating?

Is there debris beneath it?



# Funnel Cloud or Tornado or Scud?



# Waterspouts

Essentially tornadoes over water. Most not as strong as more typical tornadoes over land. Tornadic waterspouts generally associated with a severe thunderstorm. Can form over land and move over water. These are essentially same as cousins over land.

Photo Credit: Calvert Cliffs Nuclear Power Plant

Photo Credit: Sandro Puncet

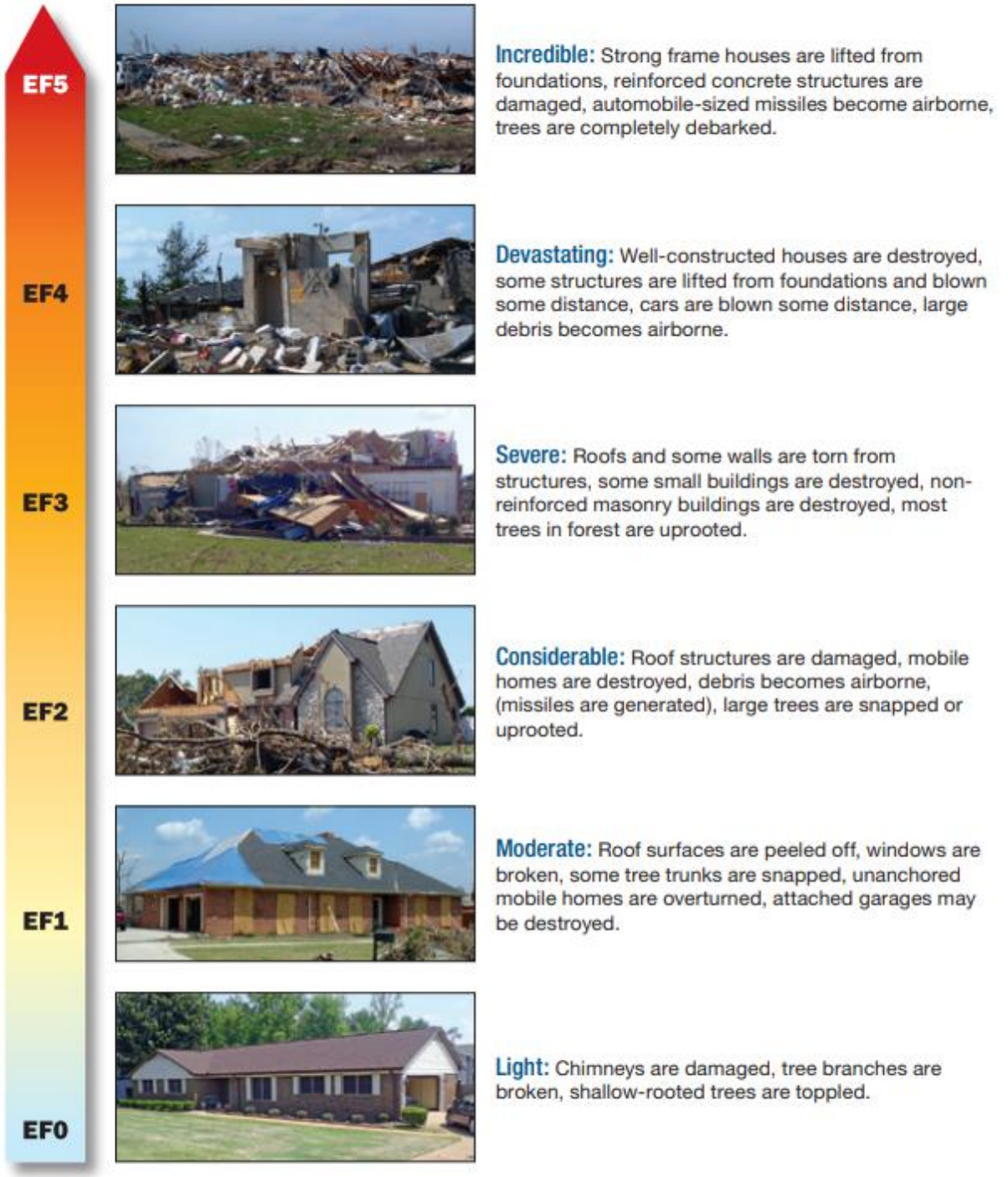
# Rating the Tornado Damage: Enhanced Fujita Scale

Tornado rated by the damage it causes; winds are estimated from that damage.

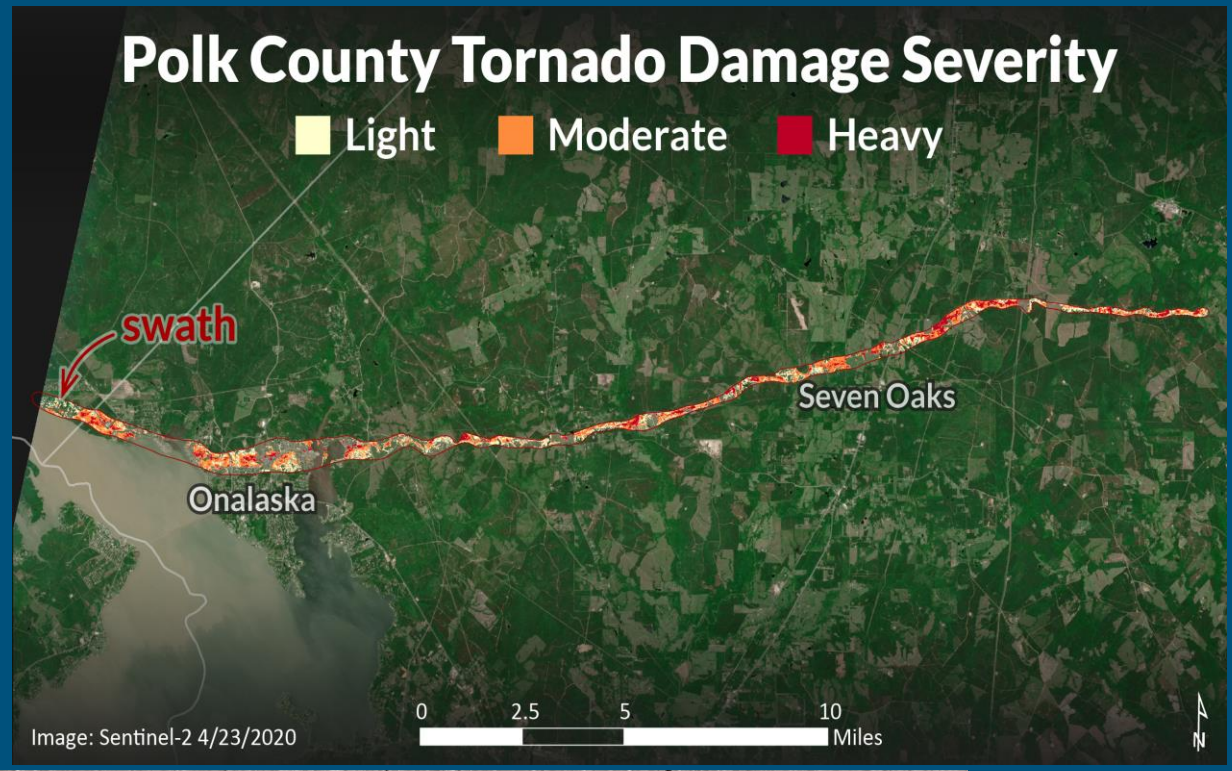
EF-Scale relates the observed damage to estimated 3-second average wind gusts.

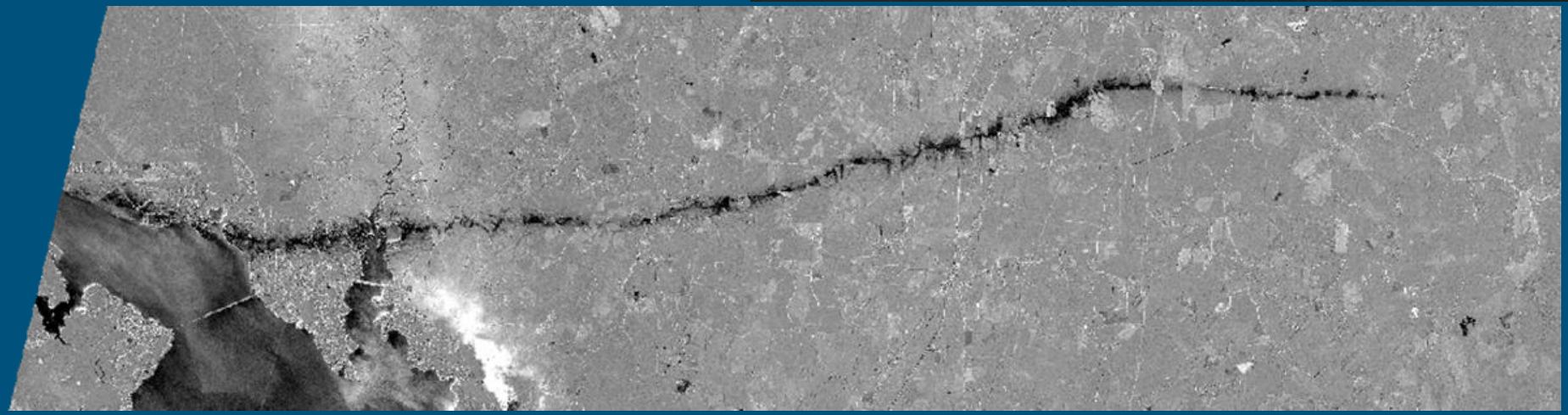
| EF Scale | EF Scale: 3-Second Gust (mph) |
|---|---|
| EF0 | 65–85 |
| EF1 | 86–110 |
| EF2 | 111–135 |
| EF3 | 136–165 |
| EF4 | 166–200 |
| EF5 | Over 200 |

https://www.fema.gov/media-library-data/20130726-1827-25045-7585/tornado_mat_app_e_508.pdf



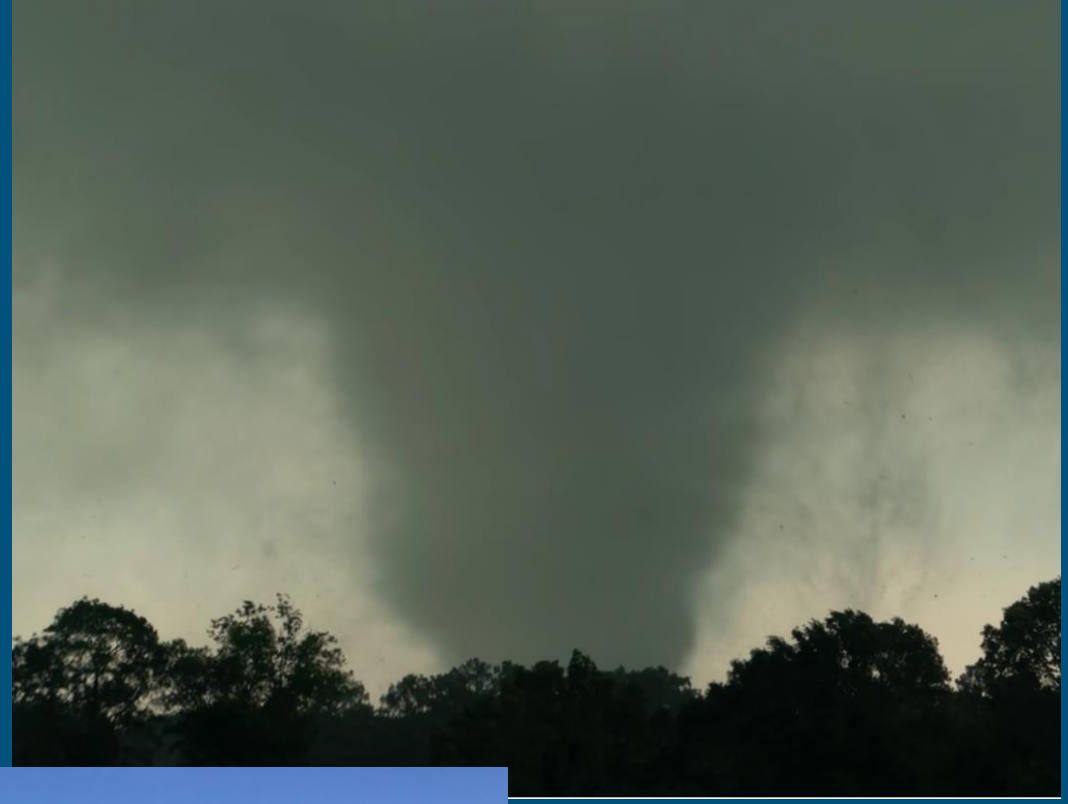
# Polk County EF3 Tornado, Onalaska, April 2020

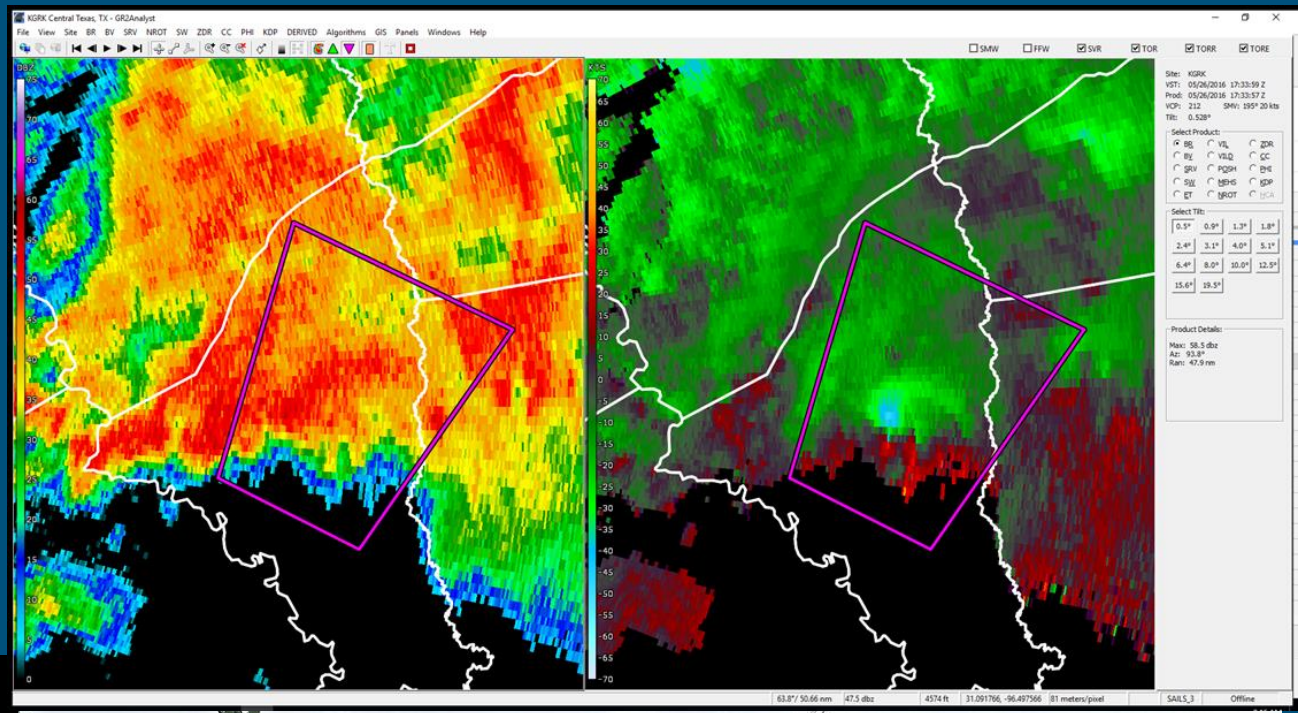
# EF-2/3 Onalaska

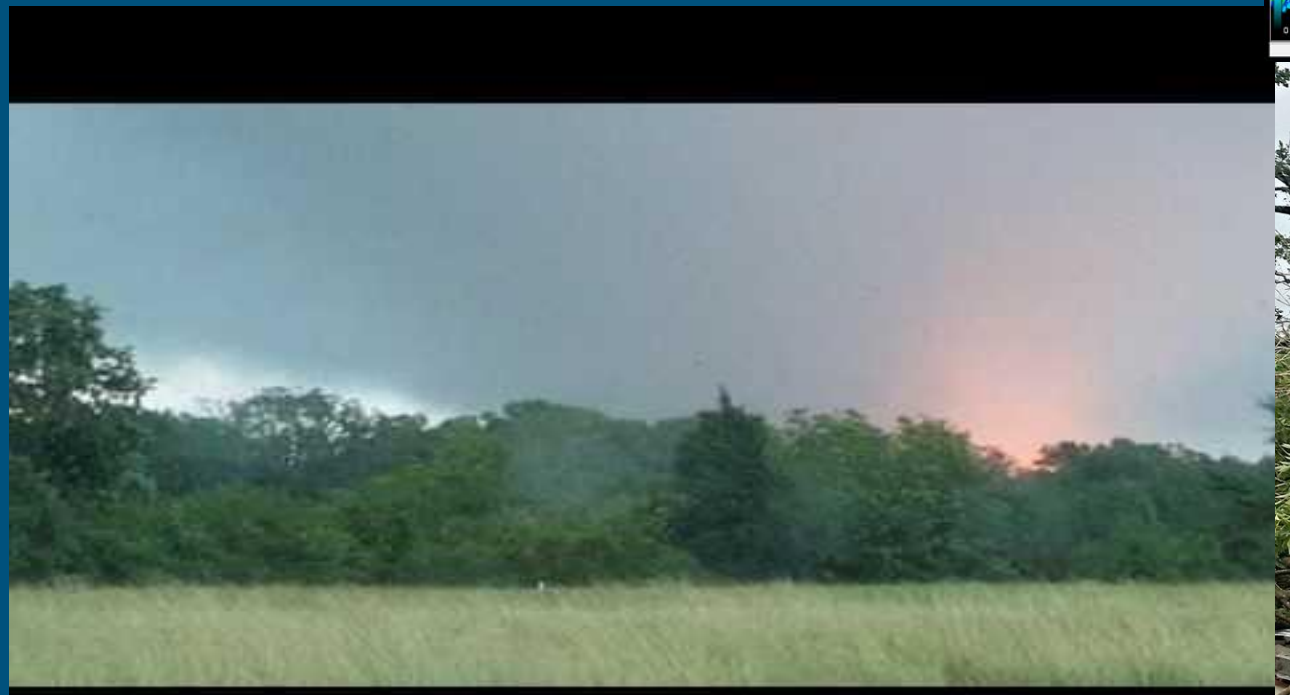
# West of Lovelady, EF3, April 2019



Photos Nikki Hathaway, Scott Overpeck, Dan Reilly

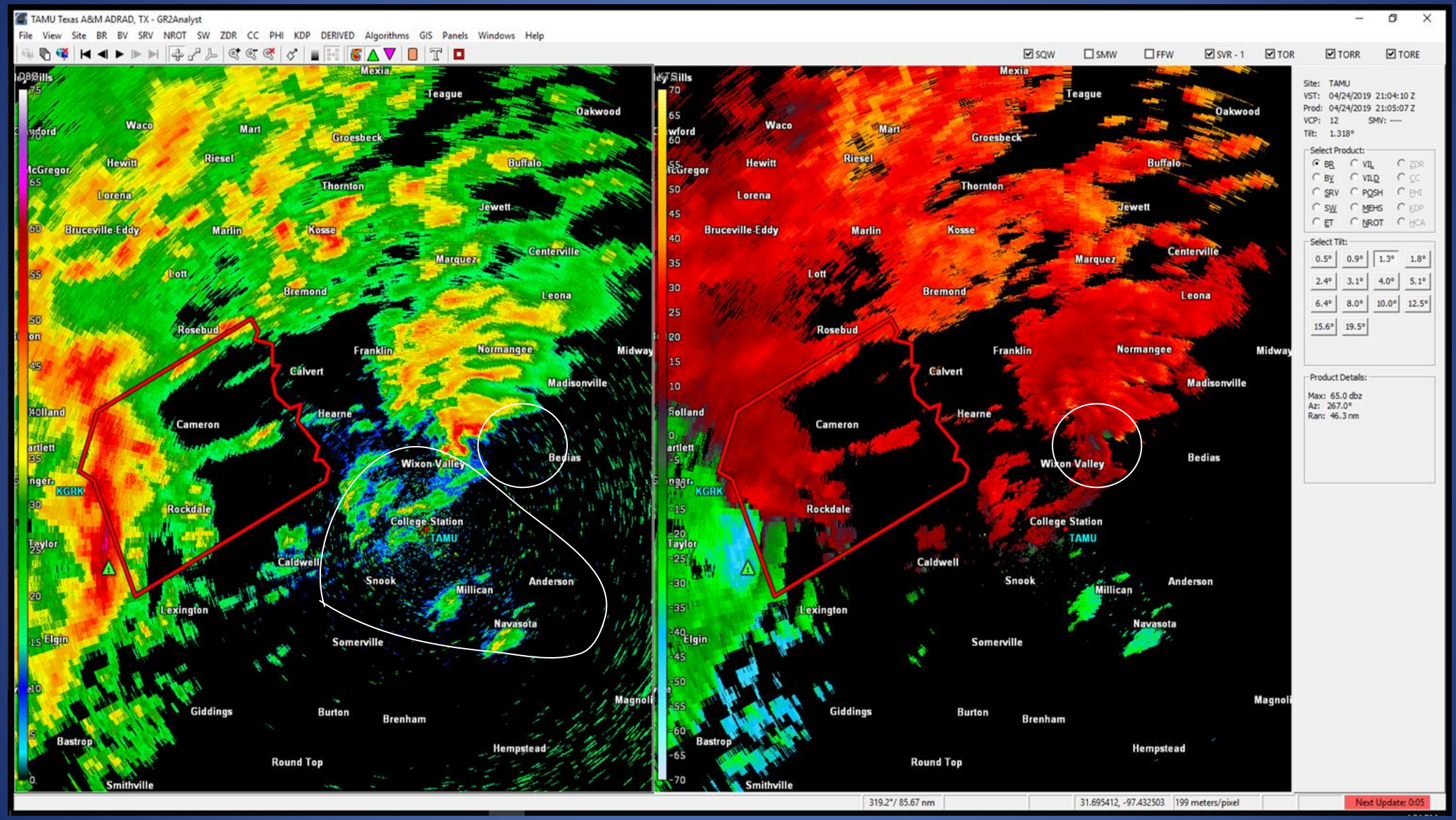
# Bryan/College Station (May 26, 2016)





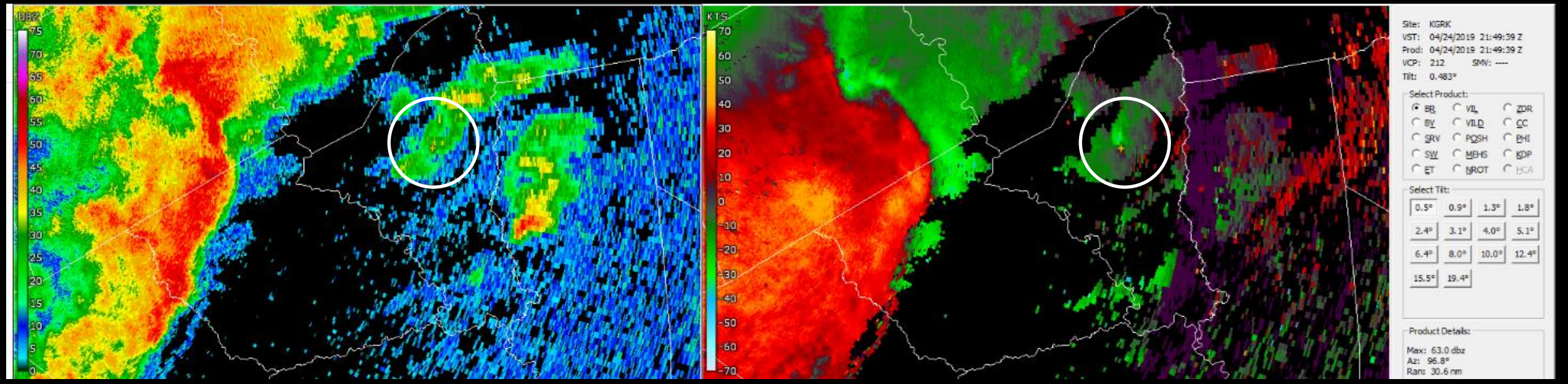
Note the Power Flashes

# April 29th, 2019




TAMU Radar 2104Z showing one obvious supercell NE of Wixon Valley, numerous other showers in warm sector to south; environment moderate CAPE very strong low level shear

# April 29th, 2019



# Southeast Harris, January 24th, 2023


Deer Park/Baytown


Deer Park

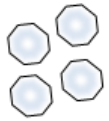

Pasadena


Deer Park

# Severe Weather Safety Considerations

- What is your vulnerability to each hazard? Are you inside, outside, in a sturdy structure?
- Do you have a way to receive forecasts, warnings, monitor the radar?
- What is your plan if severe weather were to strike? Identify adequate shelter areas etc.

## Understanding Severe Weather Hazards

| | |
|---|---|
| **Tornado**  | Tornadoes are violently rotating columns of air that can destroy buildings and cause significant injury or death<br>ACTION: Take shelter immediately in a sturdy structure |
| **Large Hail**  | Hail can damage vehicles, crops, buildings, and cause injuries<br>ACTION: Move indoors away from windows |
| **Strong Wind**  | Strong wind can knock over trees and damage buildings<br>ACTION: Move indoors away from windows |
| **Heavy Rain**  | Heavy rain can cause flash flooding<br>ACTION: Avoid rising creeks and water-covered roads |
| **Lightning**  | Lightning strikes can cause significant injury or death<br>ACTION: Move indoors if you hear thunder |

Weather-Ready Nation
National Oceanic and Atmospheric Administration

National Weather Service
weather.gov/tornado

# Outlook, Watch and Warning

*Outlook:* Look ahead at severe weather potential next 7 days. Convective outlook issued by Storm Prediction Center.

*Watch*: Heads up, be alert conditions favor the development of the hazard (such as a tornado); be ready to act. The ingredients are there.

*Warning*: Hazard has been spotted or detected on radar. Take action to protect yourself if you are in the warned area.

Types: Tornado, Severe Thunderstorm, Flash Flood, etc

# Watch, Warning, Advisory

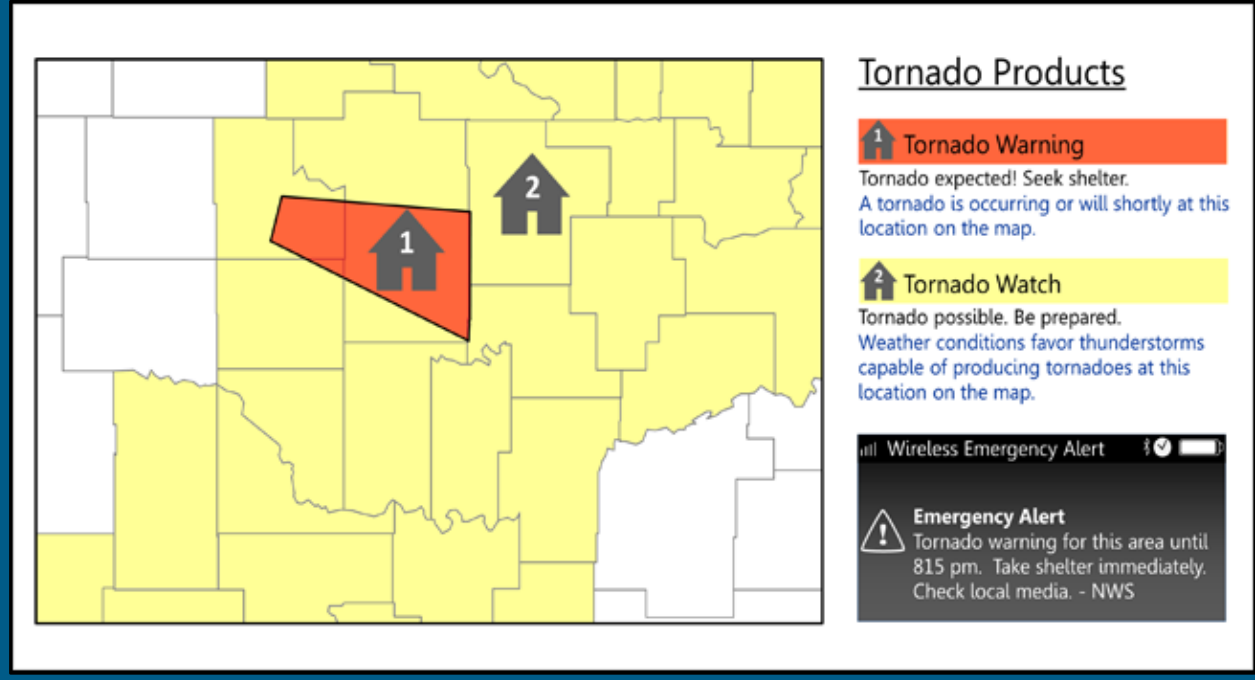
**Outlook:** Looking out several days, what are the areas of concern for a particular hazard.

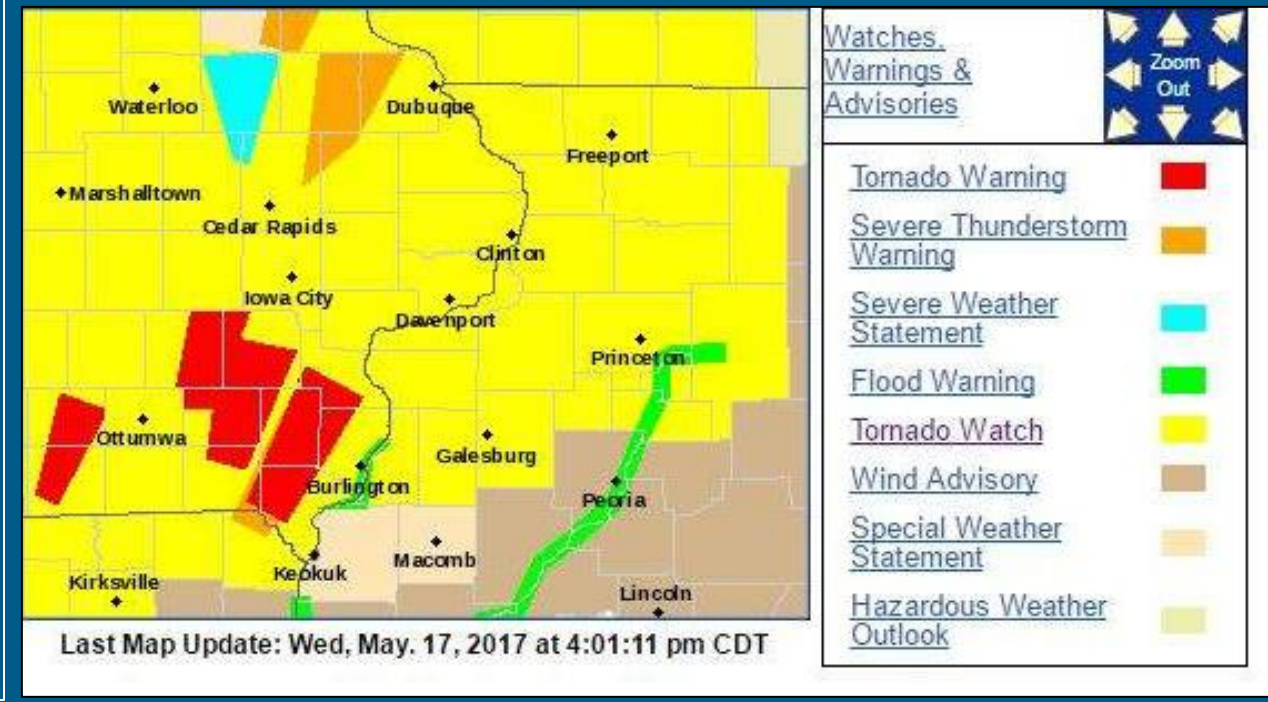
**Watch**: Heads up, be alert conditions favor the development of the hazard (such as a tornado); be ready to act. For thunderstorms/ tornadoes watches typically valid 6 hours or so.

**Warning**: Hazard has been spotted or detected on radar. Take action to protect yourself if you are in the warned area.

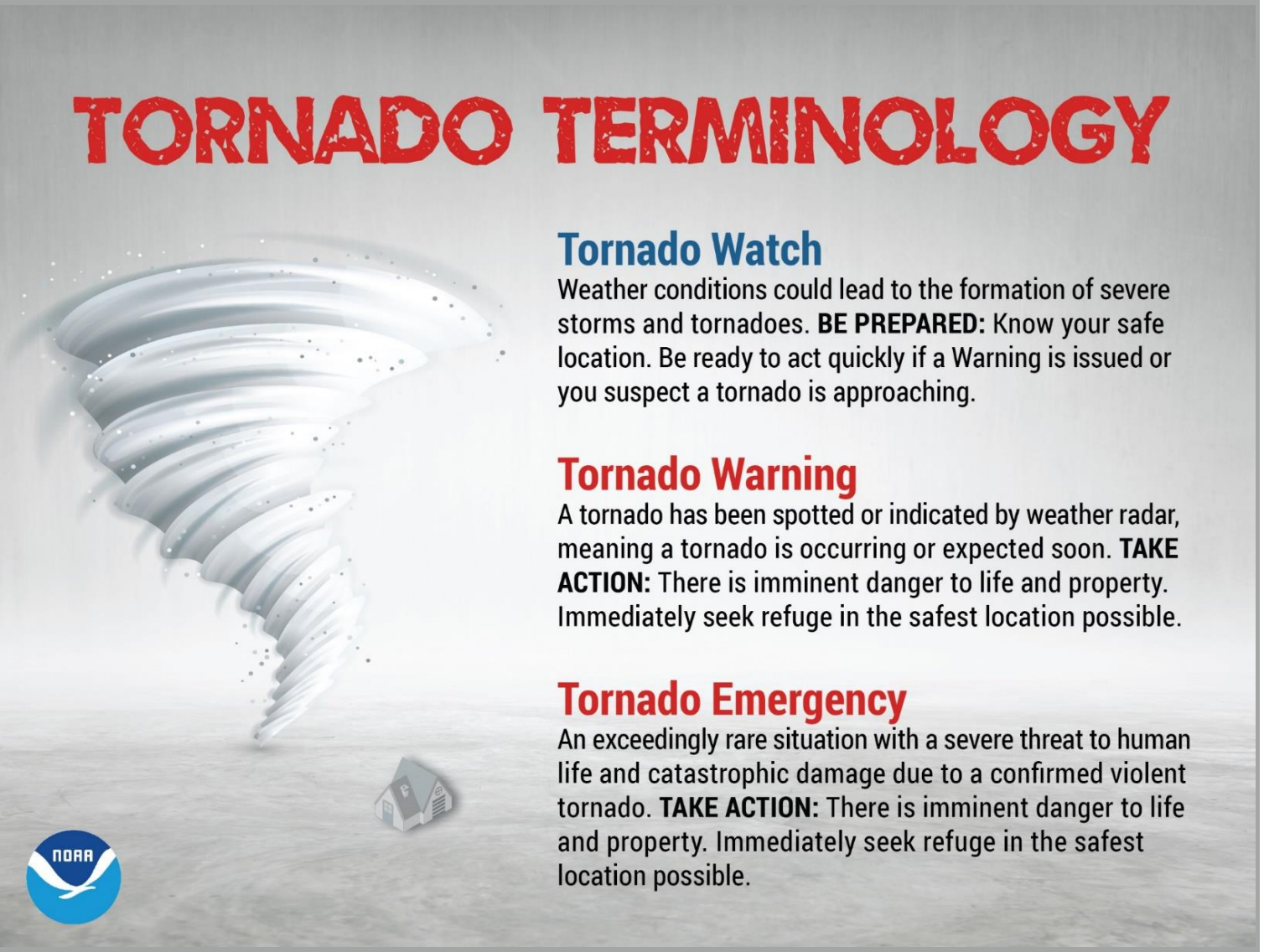
**Advisory:** Less severe than a warning but could still be life threatening.

Thunderstorm related: Tornado, Severe Thunderstorm, Flash Flood



# *Tornado Emergency a Rare, Special Type of Warning*




BULLETIN - EAS ACTIVATION REQUESTED
Tornado Warning
National Weather Service Houston/Galveston TX
224 PM CST Tue Jan 24 2023

...TORNADO EMERGENCY FOR PARTS OF SOUTH HARRIS...

The National Weather Service in League City has issued a

* Tornado Warning for...
  Northwestern Chambers County in southeastern Texas...
  South central Liberty County in southeastern Texas...
  Southeastern Harris County in southeastern Texas...

* Until 300 PM CST.

* At 223 PM CST, a confirmed large and destructive tornado was
  observed over northwestern Pasadena, moving northeast at 60 mph.

  TORNADO EMERGENCY for parts of SE TEXAS. This is a PARTICULARLY
DANGEROUS SITUATION. TAKE COVER NOW!

  HAZARD...Deadly tornado.

  SOURCE...Radar confirmed tornado.

  IMPACT...You are in a life-threatening situation. Flying debris
          may be deadly to those caught without shelter. Mobile
          homes will be destroyed. Considerable damage to homes,
          businesses, and vehicles is likely and complete
          destruction is possible.

* The tornado will be near...
  Morgan's Point and San Jacinto State Park around 230 PM CST.
  Baytown, Highlands and Channelview around 235 PM CST.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

To repeat, a large, extremely dangerous and potentially deadly tornado is on the ground. To protect your life, TAKE COVER NOW! Move to an interior room on the lowest floor of a sturdy building. Avoid windows. If in a mobile home, a vehicle or outdoors, move to the
closest substantial shelter and protect yourself from flying debris.

&&

LAT...LON 2960 9517 2967 9523 2998 9489 2992 9478
      2982 9475
TIME...MOT...LOC 2023Z 231DEG 51KT 2967 9514

TORNADO...OBSERVED
TORNADO DAMAGE THREAT...CATASTROPHIC
MAX HAIL SIZE...<.75 IN

$$

# Convective Outlooks from Storm Prediction Center

Black hatching means a 10% or higher probability for significant severe events within 25 miles of any point. "Significant" is defined as: tornadoes rated EF2 or greater, thunderstorm wind gusts of hurricane force (74 mph) or higher, or hail 2 inches or larger in diameter.

## Understanding Severe Thunderstorm Outlook Categories

| General Thunder | 1 Marginal (MRGL) | 2 Slight (SLGT) | 3 Enhanced (ENH) | 4 Moderate (MDT) | 5 High (HIGH) |
|---|---|---|---|---|---|
| Severe* Storms are not expected<br><br>Any thunderstorms could still produce gusty winds and small hail | **Severe storms will produce hail, damaging winds and/or possibly tornadoes** | **Severe storms will produce hail, damaging winds, and/or tornadoes** | **Several severe storms will produce very large hail, damaging winds, and/or tornadoes** | **Several severe storms will produce very large hail, damaging winds, and/or tornadoes** | **Many severe storms will produce tornadoes, damaging winds, and/or very large hail** |
| Similar to storms you see many times per year | Similar to storms you may see several times per year | Similar to storms you may see a few times per year | Similar to intense storms you may only see once or twice per year | Similar to intense storms you may only see once per year or less | Very intense storms you may only experience once or twice in a lifetime |

w w w . w e a t h e r . g o v

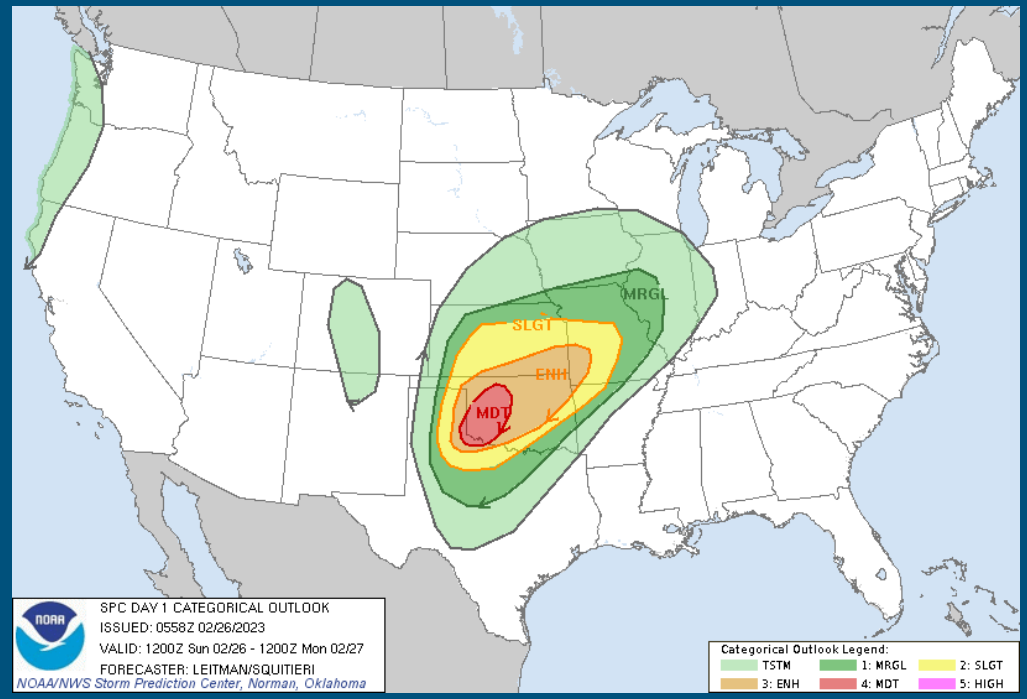
**Remember: Severe storms don't care which category they are in. Severe weather is a threat in ALL of the numbered categories mentioned above.**

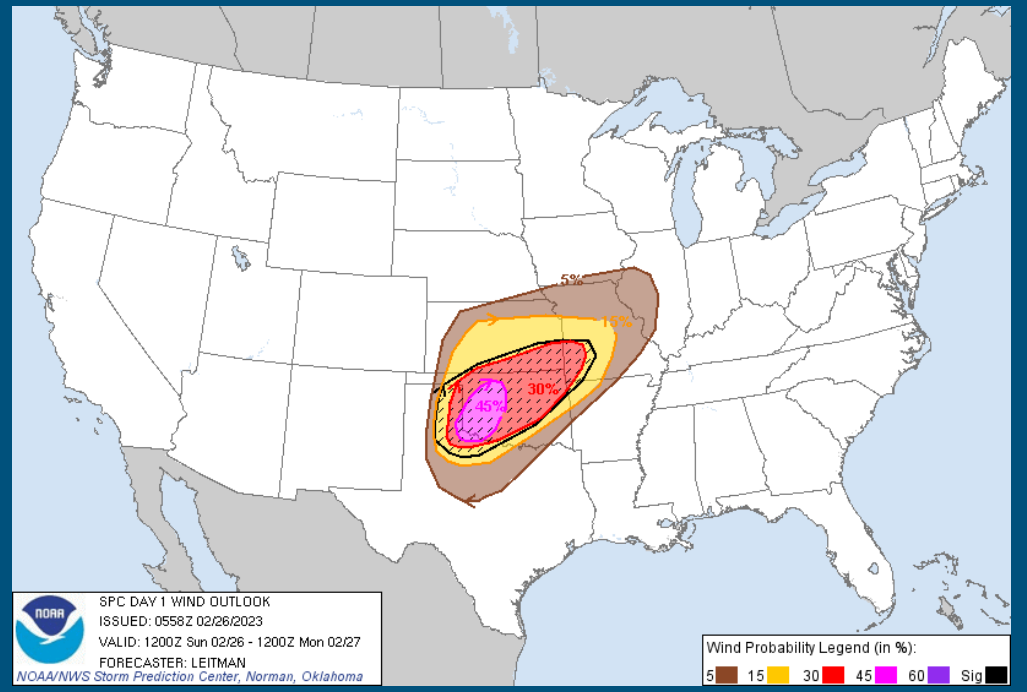
No Matter the Category, ALWAYS:
Keep a watch on changing conditions. Monitor trusted weather sources.
Ensure multiple ways of receiving weather warnings at ALL times day or night.
Have a plan! Be ready to take shelter immediately.
Be Weather-Ready! Things can go from bad to worse rapidly.

**All thunderstorm categories imply lightning and the potential for flooding.**

*NWS defines a severe thunderstorm as measured wind gusts of at least 58 mph, and/or hail of at least one inch in diameter, and/or a tornado.

Categories are tied to the probability of a severe weather event within 25 miles of your location.



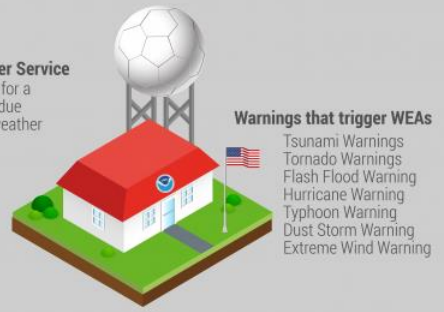



Do you have any favorite weather apps?

There are many good ones (some free) that will show the latest radar, warnings and alert you (via notification) if there is a warning for your area.

weather.gov/subscribe

# How You Receive
## Wireless Emergency Alerts (WEAs)



**National Weather Service**
Issues a warning for a specific location due to an imminent weather or water threat.

**Warnings that trigger WEAs**
Tsunami Warnings
Tornado Warnings
Flash Flood Warning
Hurricane Warning
Typhoon Warning
Dust Storm Warning
Extreme Wind Warning

**Integrated Public Alert and Warning System (IPAWS)**
The alerts from authenticated public safety officials, such as the NWS, are sent through FEMA's Integrated Public Alert and Warning System.


**Mobile Networks**
IPAWS pushes the alerts to over 100 participating wireless carriers.

**Your Mobile Device**
Cell towers push the alerts to mobile devices in the affected area.

**What WEAs Look Like**
The alerts appear like SMS text messages, but they are not. They are accompanied by a unique attention signal and vibration.


**Who Gets WEAs**
Alerts are broadcast only from cell towers whose coverage areas are closest to the threatened area. Phones that are locked on to cell towers broadcasting the WEA will receive the message.

www.nws.noaa.gov/com/weatherreadynation/wea.html

# Wireless Emergency Alerts


- Emergency messages sent by authorized government alerting authorities to your mobile device.
- Alerts can be sent to your mobile device without needing to download an app or subscribe to a service.
- Alert Types Include:
  - Extreme weather warnings
  - Local emergencies requiring evacuation or immediate action
  - AMBER Alerts
  - Presidential alerts during a National emergency

National Weather Service | Paducah, KY

*https://www.ready.gov/alerts*

# WEA Messages Originated by NWS

| | Warning Type | WEA Message |
|---|---|---|
| Extreme | Tsunami Warning | Tsunami danger on the coast. Go to high ground or move inland. Listen to local news. –NWS |
| | Tornado Warning | Tornado Warning in this area til hh:mm tzT. Take shelter now. Check local media. –NWS<br>*-- or --*<br>Tornado EMERGENCY til hh:mm tzT. Tornado spotted in this area. Find shelter now! -NWS |
| | Extreme Wind Warning | Extreme Wind Warning this area til hh:mm tzT ddd. Take shelter. –NWS |
| | Hurricane Warning | Hurricane Warning this area. Check local media and authorities. -NWS |
| | Typhoon Warning | Typhoon Warning this area til hh:mm tzT ddd. Check local media and authorities. -NWS |
| Severe | Storm Surge Warning** | NWS: Life-threatening storm surge danger. Check for possible evacuation orders. |
| | Flash Flood Warning | Flash Flood Warning this area til hh:mm tzT. Avoid flooded areas. Check local media. -NWS |
| | Dust Storm Warning | Dust Storm Warning til hh:mm tzT. Remember, Pull Aside, Stay Alive -NWS |

EXPIRED TORNADO WARNING

English | Spanish

SENT
03/21/2022 20:09:00

EXPIRES
03/21/2022 21:00:00

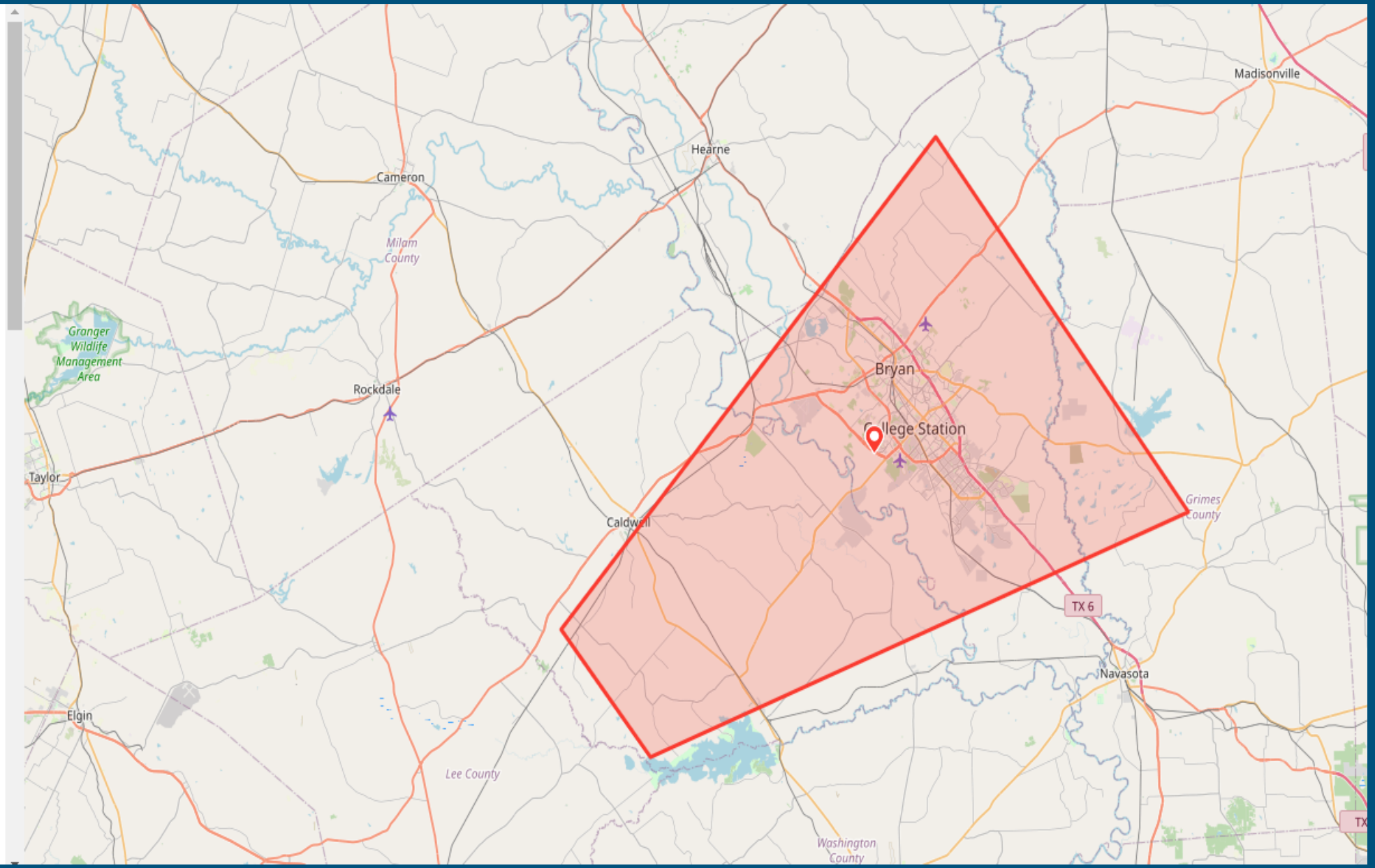
HEADLINE EN
Tornado Warning issued March 21 at 8:09PM CDT until March 21 at 9:00PM CDT by NWS Houston/Galveston TX

AREA
Brazos, TX; Burleson, TX; Grimes, TX

SENDER
NWS Houston/Galveston TX

WEA 360CH EN
National Weather Service: TORNADO WARNING in this area until 9:00 PM CDT. Take shelter now in a basement or an interior room on the lowest floor of a sturdy building. If you are outdoors, in a mobile home, or in a vehicle, move to the closest substantial shelter and protect yourself from flying debris. Check media.

WEA 90CH EN
NWS: TORNADO WARNING in this area til 9:00 PM CDT. Take shelter now. Check media.



# TORNADO SAFETY

## FOR YOUR HOME

- Move to the lowest level and to an interior room without windows, like a closet or bathroom.
- If you have a basement in your home, this is your best option.
- Cover your head and neck to protect yourself from falling debris.

For more information, visit:
***weather.gov/safety/tornado***

If there or a tornado warning or one is sighted, heard, head for an interior, windowless room on the lowest floor. Most often this will be a closet or bathroom.

For a school this may be an interior hallway.

Put as many walls between you and the outside as possible.

# TORNADO SAFETY

## FOR YOUR APARTMENT

- For an apartment or university dormitory, go to lowest possible floor and into central room.
- Crouch under an indoor stairwell or in an interior windowless hallway.
- Cover your head and neck to protect yourself from falling debris.

For more information, visit:
*weather.gov/safety/tornado*

Similar advice for multi-story buildings. Get to the interior of the building away from windows and to the lowest floor possible.

Interior stairwells can be a good option.

# TORNADO SAFETY

## FOR MOBILE HOMES

- If you are in a mobile home, it is NOT safe, and you MUST seek an alternative shelter.
- Make plans ahead of time to stay with friends or family who live in a sturdy building.
- Your last resort is to lie low and flat on your stomach with your hands over your head in a ditch or ravine.

For more information, visit:

**weather.gov/tornado**

Alvin, Oct 2015, EF0

Ratcliff, Apr 2019, EF2

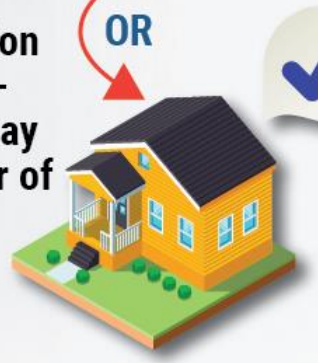
# TORNADOES AND ROAD SAFETY

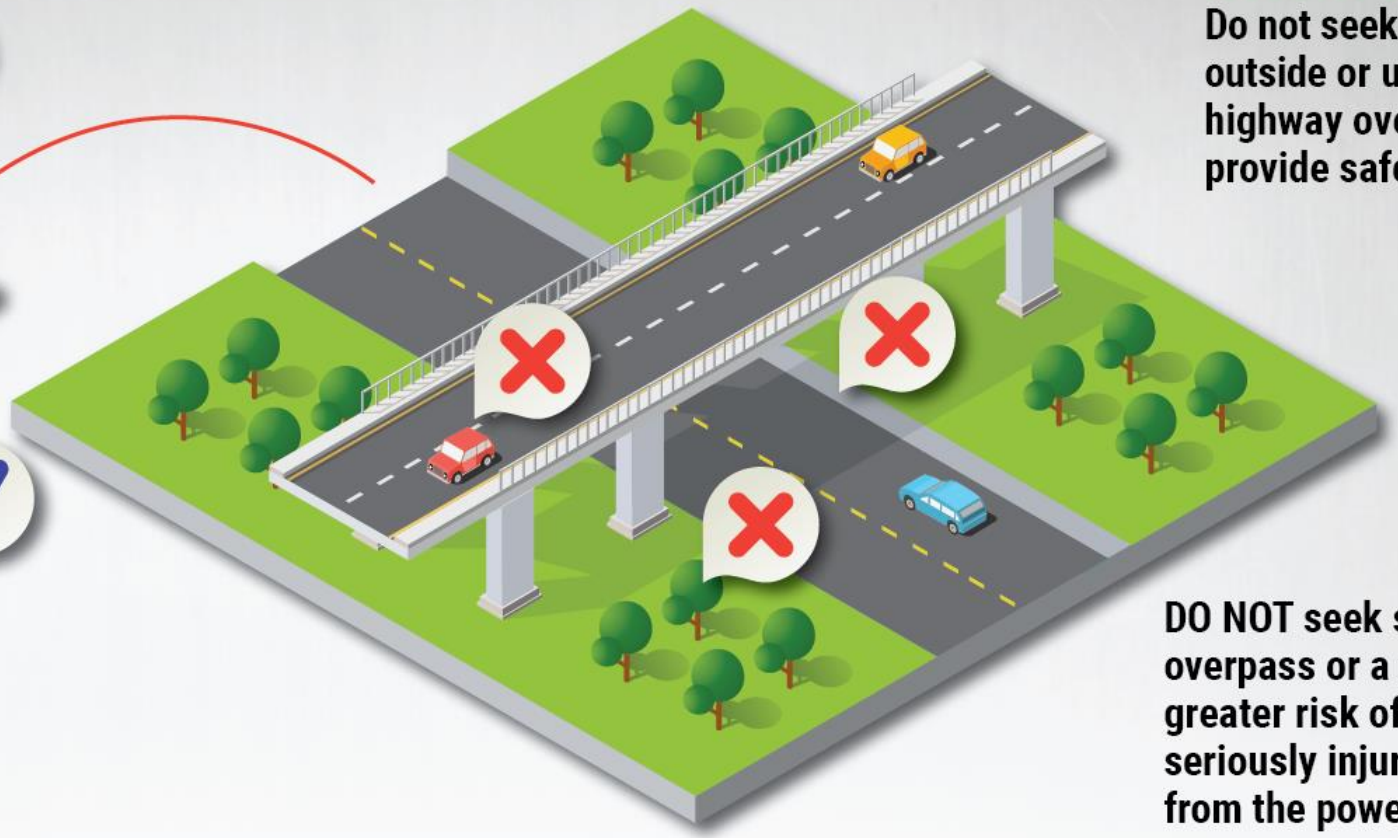
## WHAT TO DO

Get off the road. The best option is to drive to a designated shelter, basement or safe room.

OR

The next best option is a small, window-less room or hallway on the lowest floor of a sturdy building.





## WHAT NOT TO DO

Do not seek refuge in a vehicle, outside or under an overpass. A highway overpass does not provide safety from a tornado.

DO NOT seek shelter under an overpass or a tree. This puts you at greater risk of being killed or seriously injured by flying debris from the powerful tornadic winds.

# Hail Safety

## Staying Safe During a Hail Storm

### At Home

Head indoors immediately

If time allows, close all drapes, blinds, or shades to prevent broken glass from entering your home

Stay away from windows, skylights and head to a save location in your home

weather.gov/thunderstorm

### Driving

Stay in your vehicle

Slow down or pull over and stop in a safe location

Turn your back to windows or cover yourself with a blanket, coat, or spare clothing to protect from breaking glass

# STRAIGHT LINE WINDS

- ✓ Straight line winds can exceed 100 mph, and affect large areas.
- ✓ Strong winds can knock over semi-trucks, trees and powerlines.
- ✓ Stay indoors away from windows.
- ✓ Avoid trees, power lines, and objects that could blow around.
- ✓ If driving, slow down and keep two hands on the wheel.

# Lightning Safety: How Lightning Forms

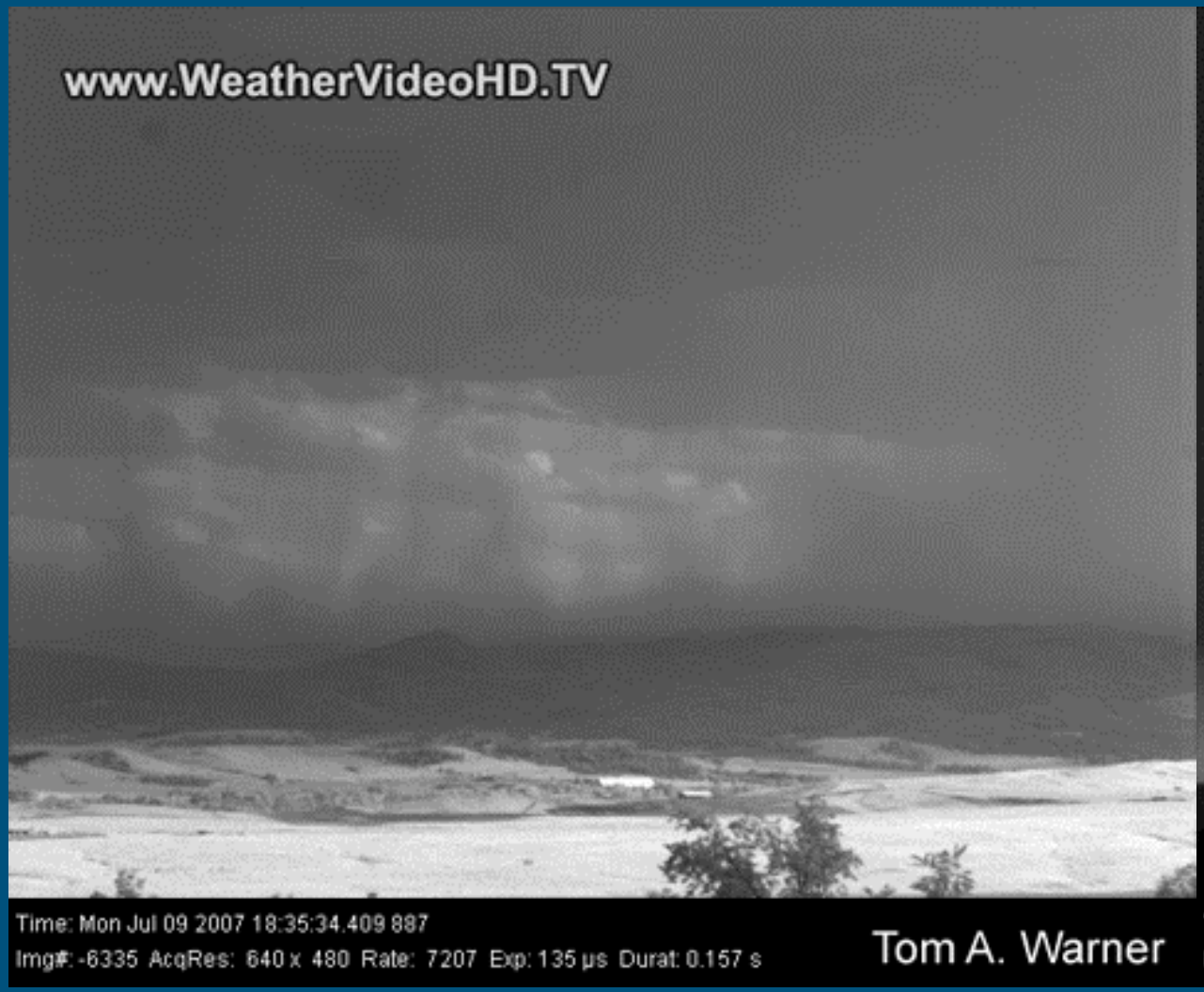

Charge separation in cloud


Stepped Leader

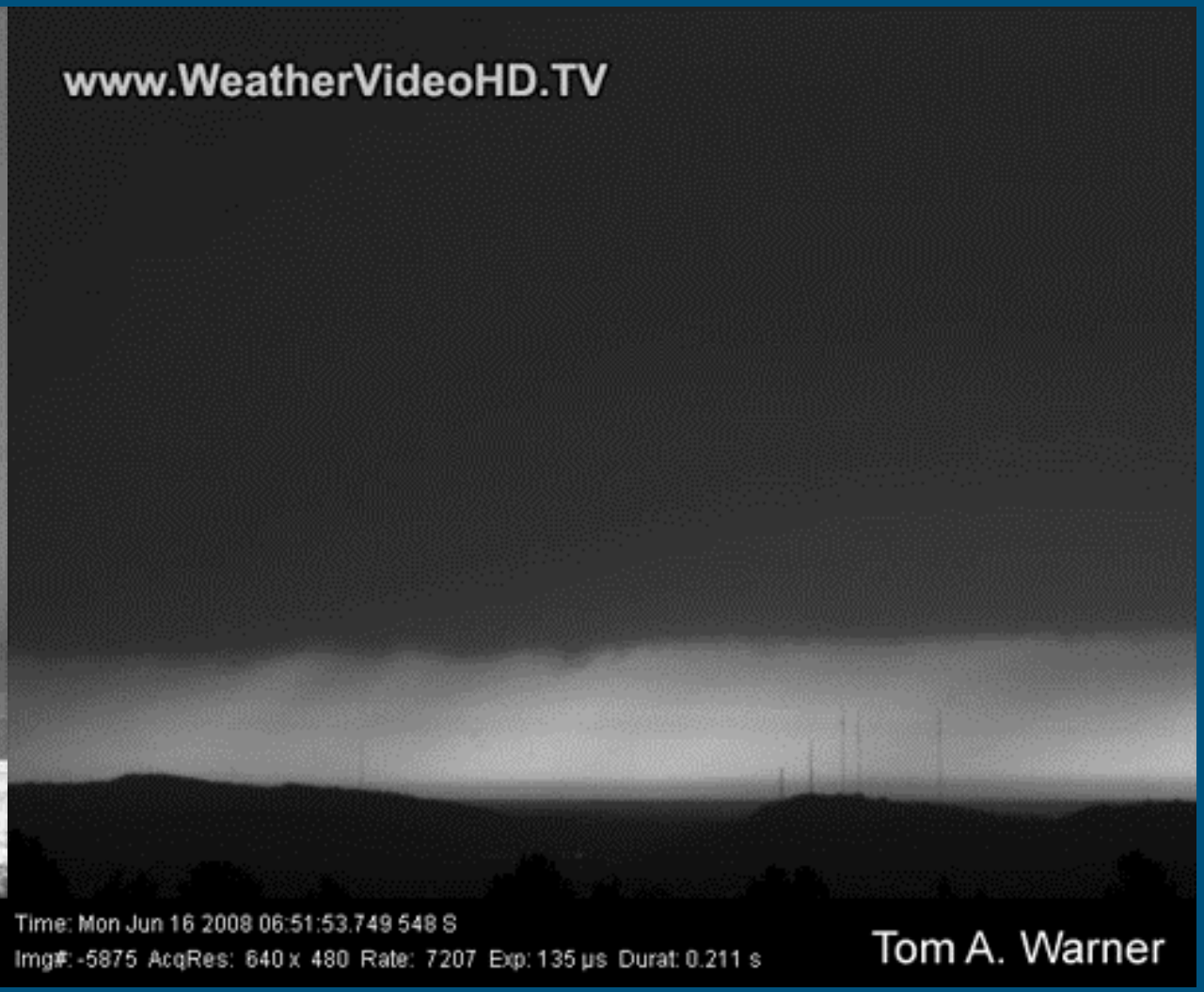

Return Streamer Connects, Visible Bolt

# Lightning in Super Slow Motion

Cloud to Ground




Ground to Cloud




# WHEN THUNDER ROARS GO INDOORS

## Lightning Fatalities For Outdoor Sports

- 40% SOCCER
- 27% GOLF
- 17% RUNNING
- 10% BASEBALL
- 3% FOOTBALL
- 3% OTHER

weather.gov/lightning

## step1

Leave the field immediately

## step2

Seek shelter in an enclosed building or car




***Wait 30 minutes after the last rumble of thunder to return outside***

# 3 SIMPLE STEPS FOR
# FLASH FLOOD SAFETY

During a flood, water levels and the rate at which the water is flowing can quickly change. Remain aware and monitor local radio and television.


weather.gov/flood

## 1 GET TO HIGHER GROUND

Get out of the areas subject to Flooding

## 2 DO NOT DRIVE INTO WATER

Do NOT drive or walk into flooded areas. It only takes 6" of water to knock you off your feet.

## 3 STAY INFORMED

Monitor local radar, television, weather radio, internet or social media for updates.


NEVER DRIVE
AROUND BARRICADES
ROAD
CLOSED
Most flood fatalities occur in vehicles
12 inches of fast-moving water can sweep a car off the road
NOAA
weather.gov/flood

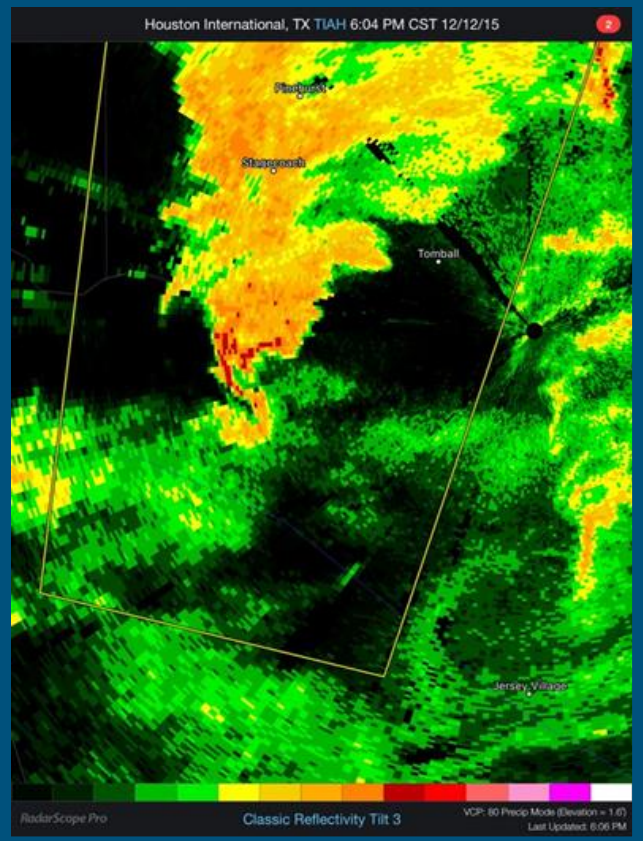
# Summary First Half of Training

- Skywarn spotters report severe weather to the NWS when they see it, typically by phone, ham radio and/or social media.
- Weather radar is very useful but spotter reports are critical for effective weather warnings.
- We talked about what to report and how to report it.
- Be safe! Don’t put yourself in danger to get a report; spot from safe location.

# Let’s take a 5-minute break!

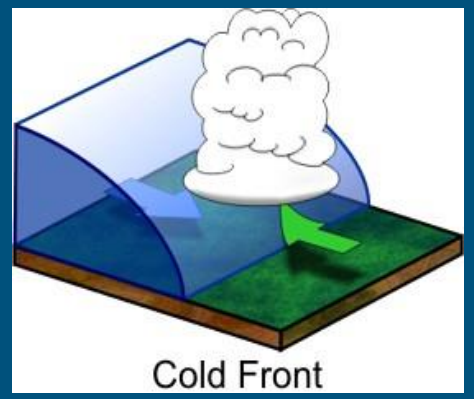
# How to Identify Severe Thunderstorms

- Thunderstorm types and hazards
- Cloud features and what they mean
- Examples: photos, videos, etc
- Basic radar signatures



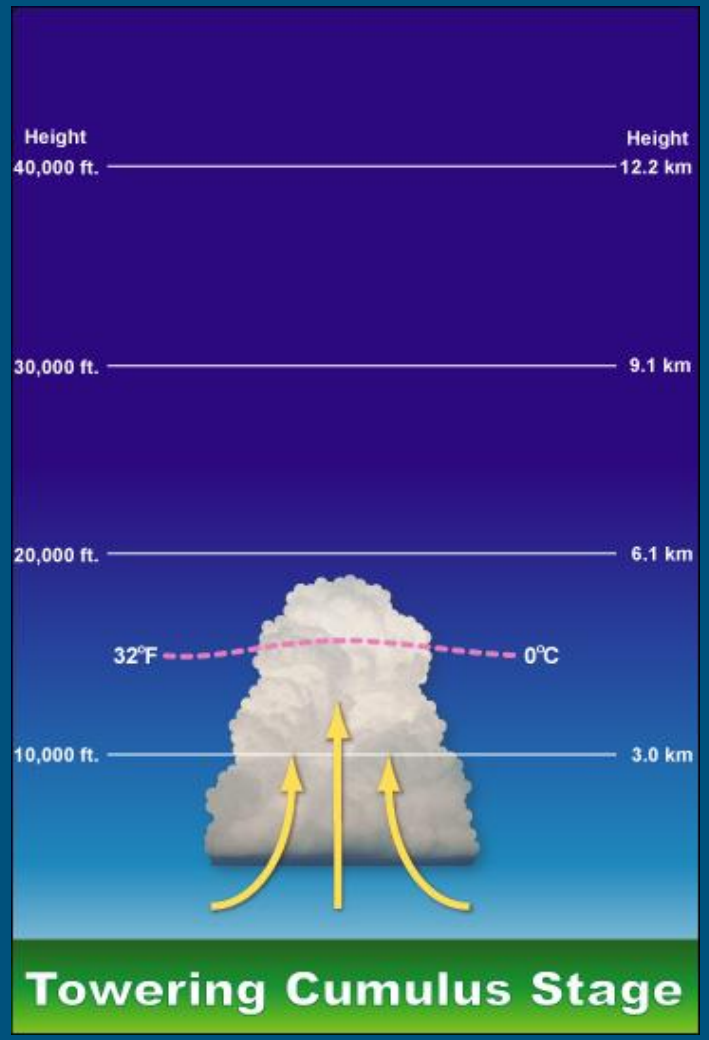
# Thunderstorm Ingredients

- **Moisture:** Often brought in by flow off the Gulf of Mexico
- **Instability:** Conditions favor strong rising currents of air due to buoyancy; less dense warm moist air below colder air
- **Something to lift the air:** Forcing mechanism to cause air to start to rise. Could be *a front, sea or bay breeze, outflow boundary, etc.*

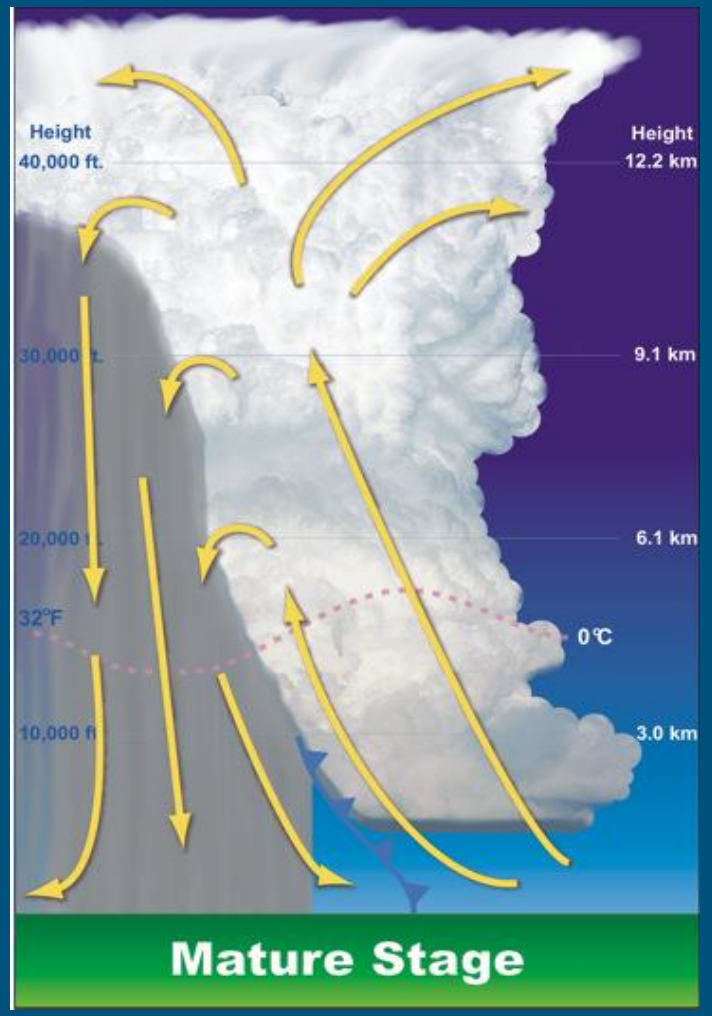



Images: NWS JetStream

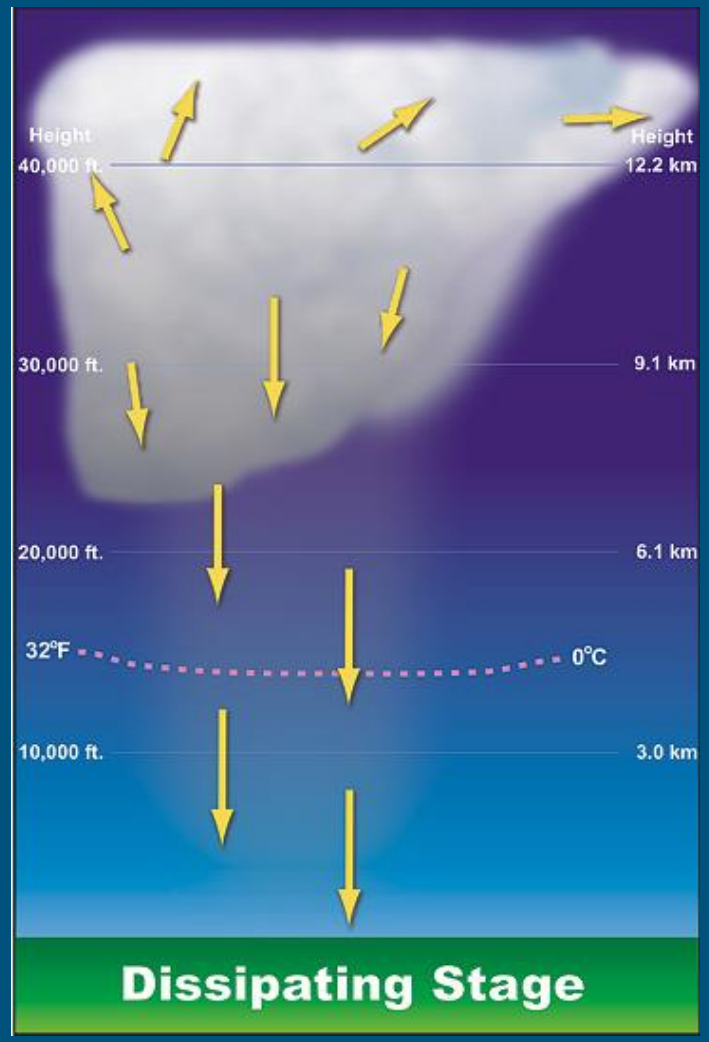
# Thunderstorm Life Cycle: Low Shear Case (Ordinary Cell)




Updraft of warm, moist air, building cumulus cloud.

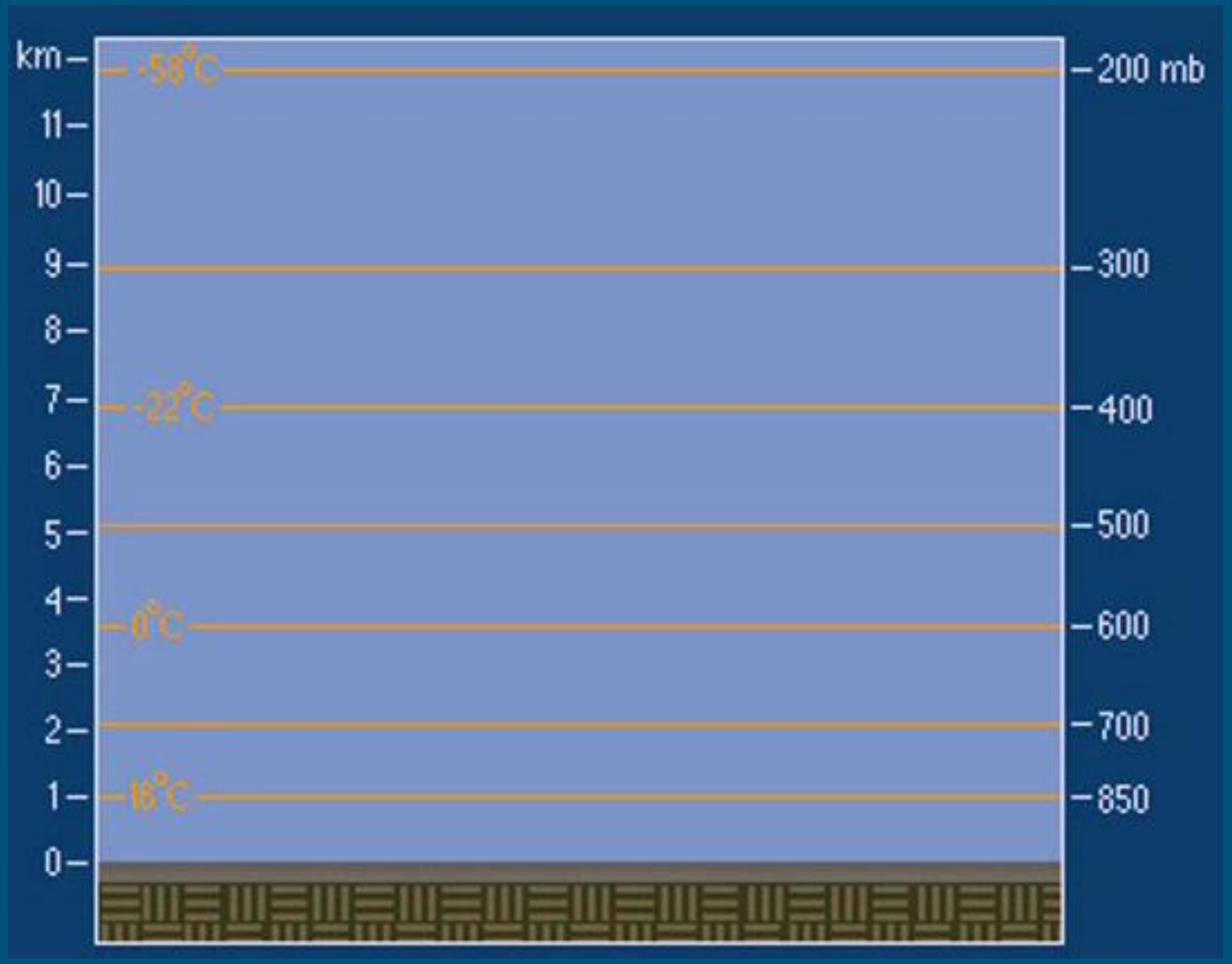



Updraft, rainy cold downdraft, cumulonimbus cloud.




Updraft, rainy cold downdraft, cumulonimbus cloud; downdraft from rain-cooled dense air cuts off supply of warm moist air, thunderstorm dissipates.

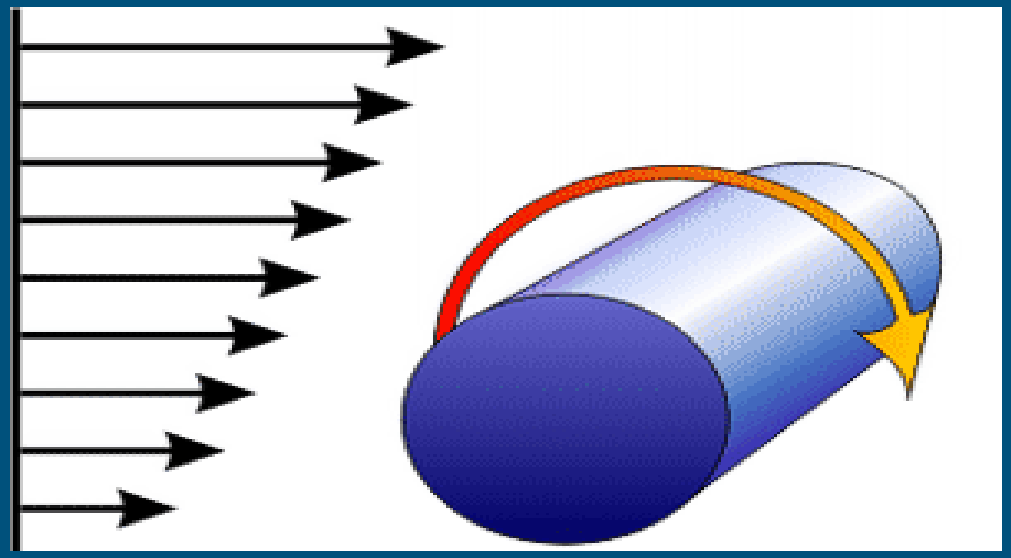
# Thunderstorm Life Cycle: Key Concepts, Terms

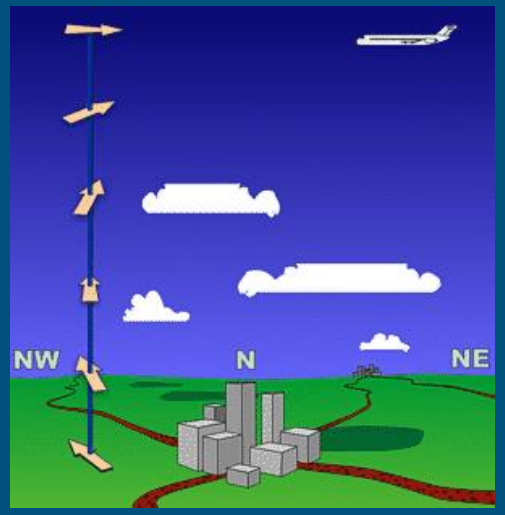



- Rising current or air or updraft; building cumulus cloud, raindrops form within cloud
- Raindrops fall out of cloud; rain cools the air and becomes more dense, downdraft forms (sinking current of air). Rain also pulls the air down via friction(“precipitation drag”);
- Rain-cooled air in downdraft hits the ground and spreads out; this is called outflow; leading edge is called a gust front or outflow boundary.

# Additional Ingredient for Severe Thunderstorms: Vertical Wind Shear

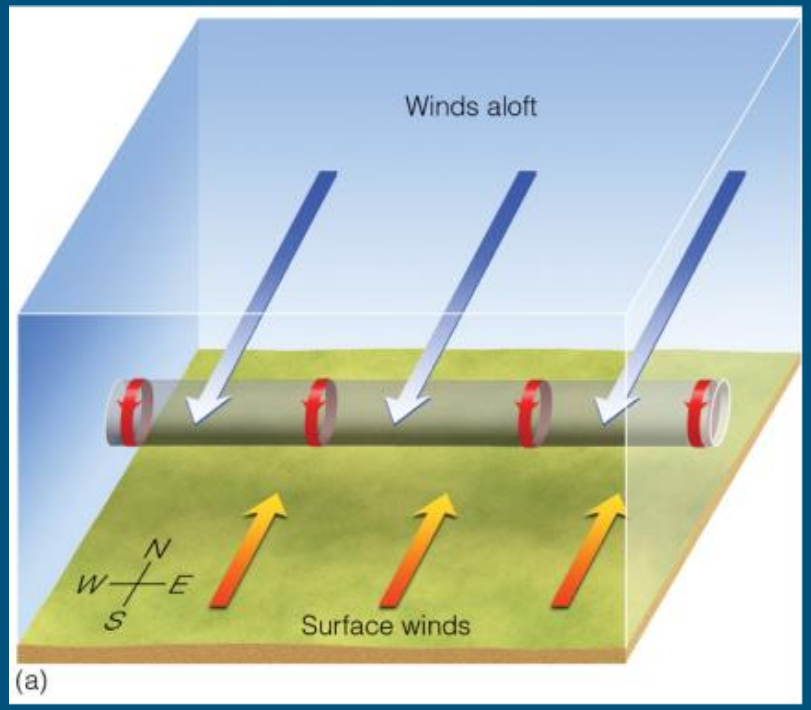
- Vertical wind shear
  - Change in wind speed and/or direction with height
  - Shear, instability and their ratio are important in determining storm type
- High shear and high instability combine to produce the most severe storms (supercells)

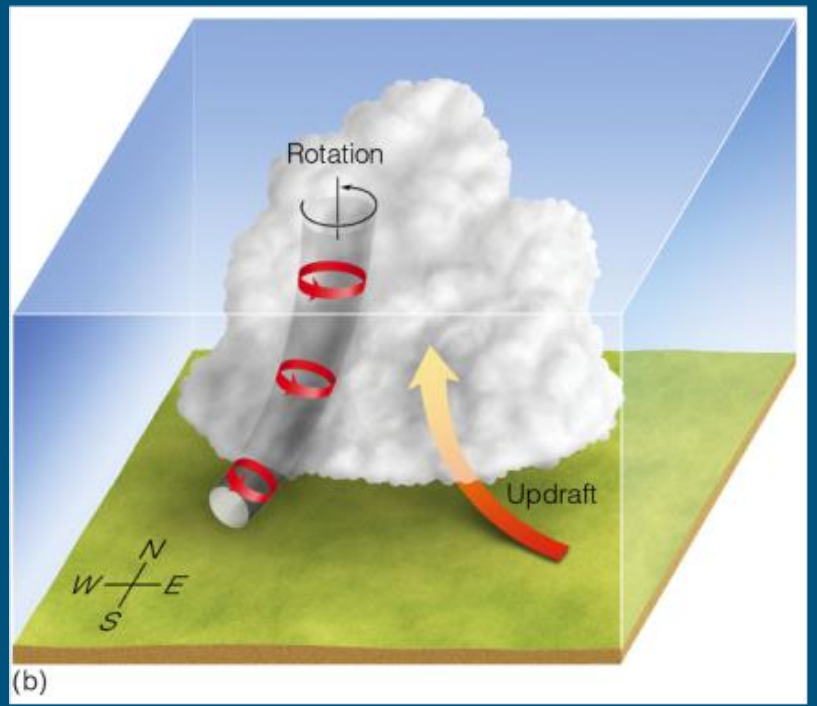


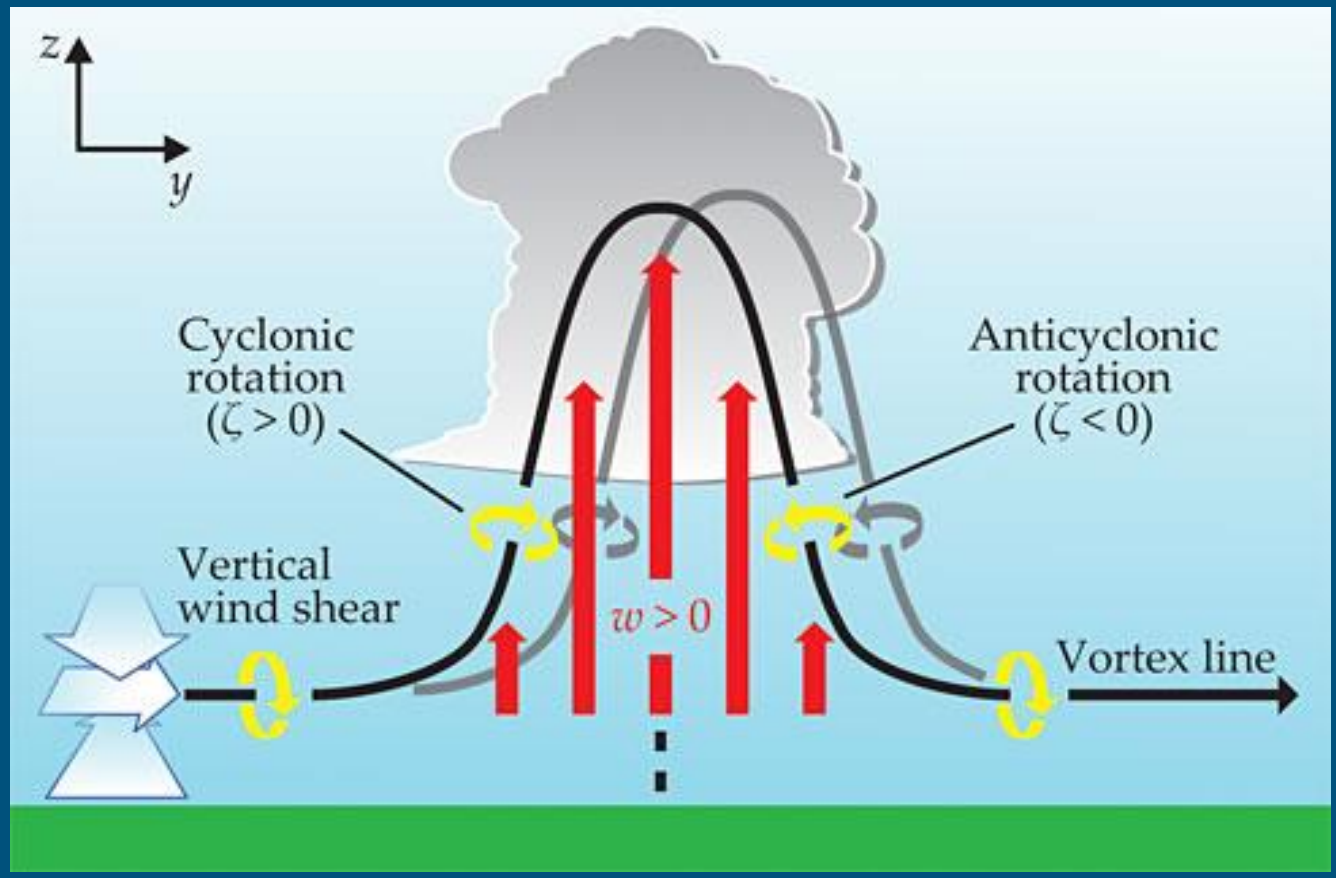


# Vertical Wind Shear→Horizontal Spin, Vortex Tubes

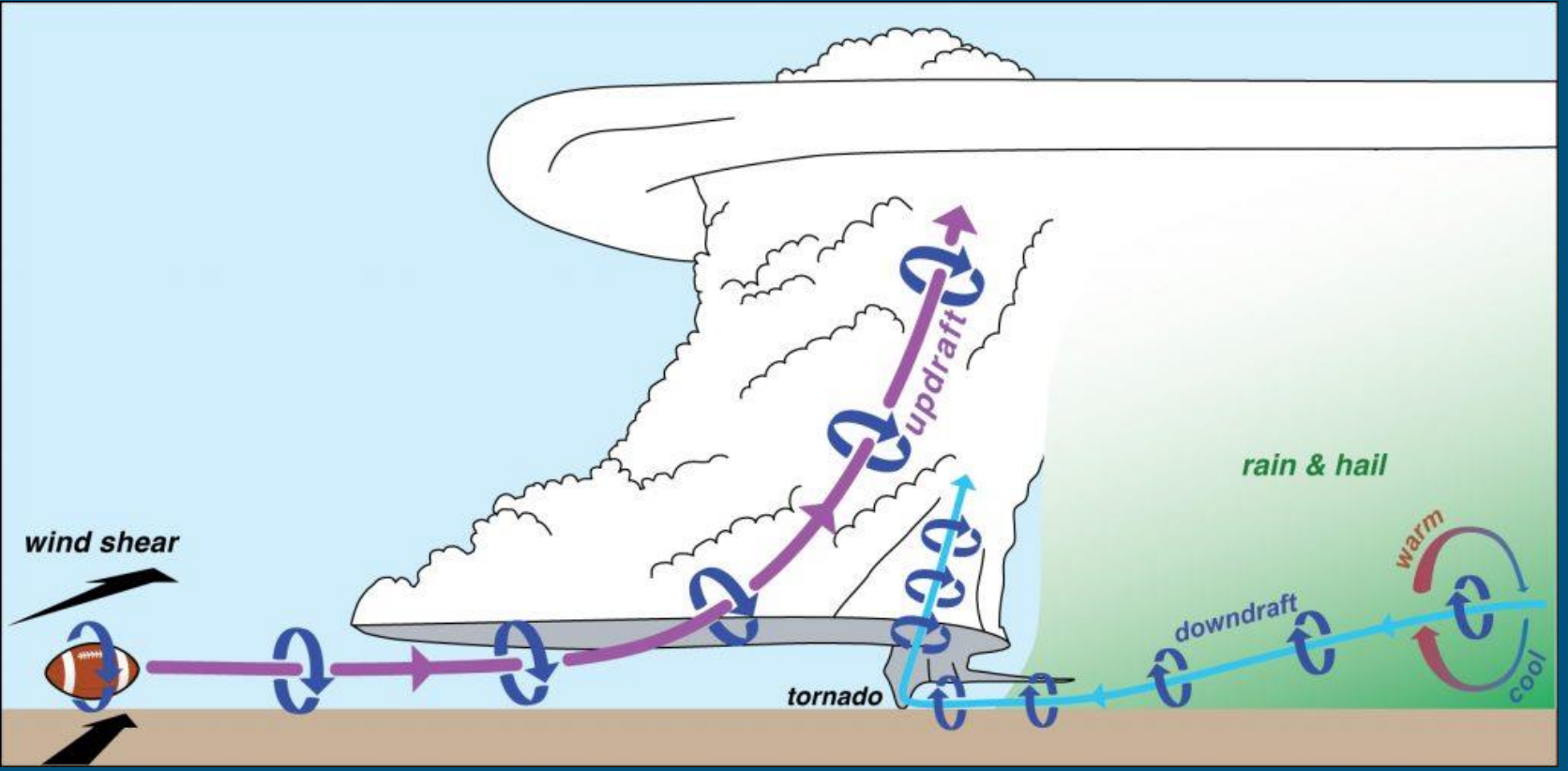
Thunderstorm updraft tilts horizontal vorticity into the vertical → rotating thunderstorm!



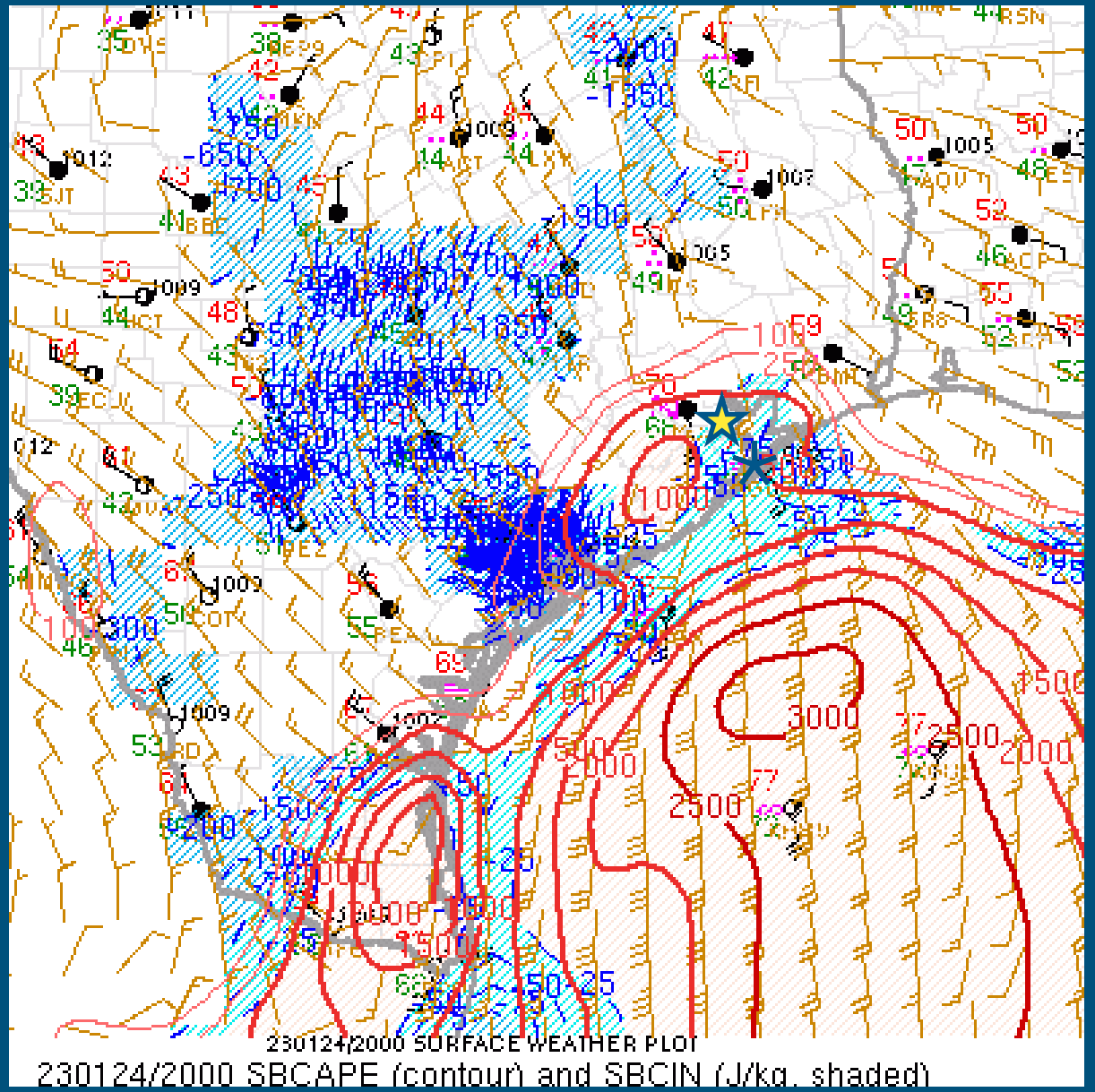




Published in: Paul Markowski; Yvette Richardson; *Physics Today* **67,** 26-31 (2014)
DOI: 10.1063/PT.3.2514

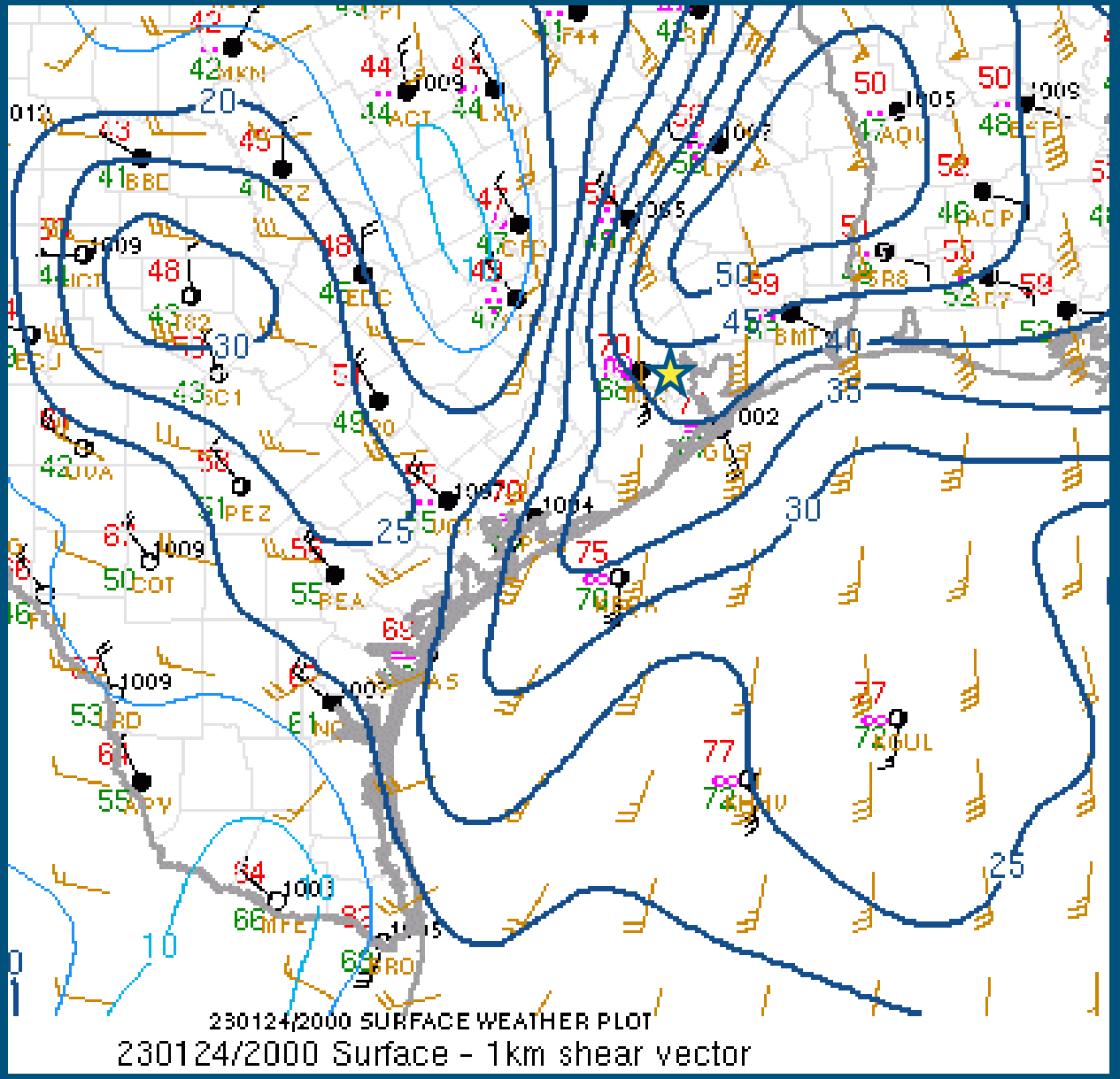



Phil Markowski, PSU

# SPC Mesoanalysis 2 pm January 24th




CAPE: Instability




Low-level Wind Shear

# How Does a Severe Thunderstorm Differ from Ordinary Cell?

- Typically has a very strong updraft which supports large hail
- May have a very strong downdraft or downburst which can lead to strong outflow and damaging “straight-line-winds”
- Some thunderstorms are rotating, contain circulations (“mesocyclones”); these are called “supercells”, are the most severe type of storms (largest hail, tornadoes, etc)
- Can sometimes tell if a storm has a strong updraft, downdraft or is a supercell (and thus likely severe) by noting certain features visually and/or on radar.

# Mature Thunderstorm/ Cumulonimbus Cloud

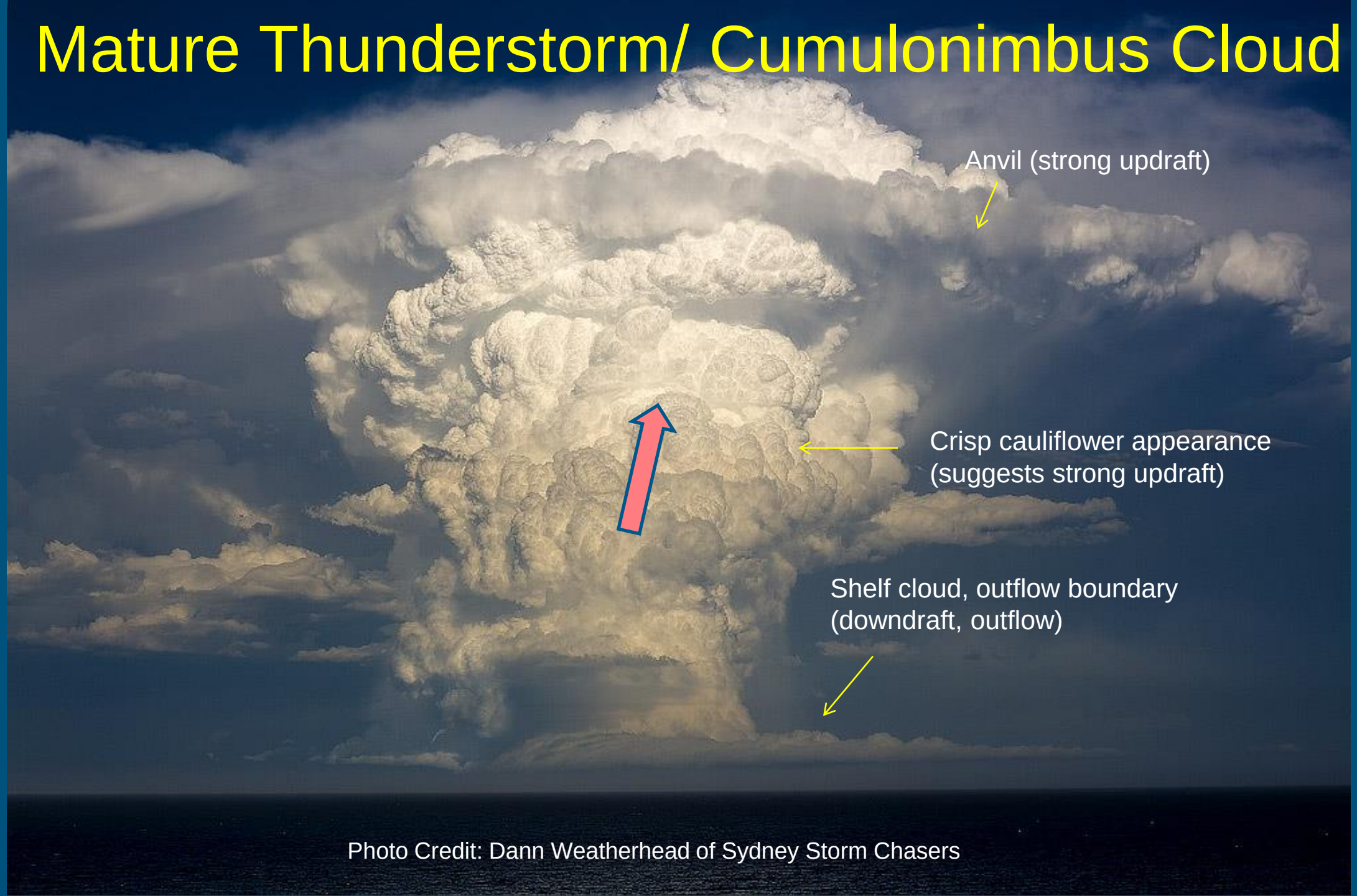
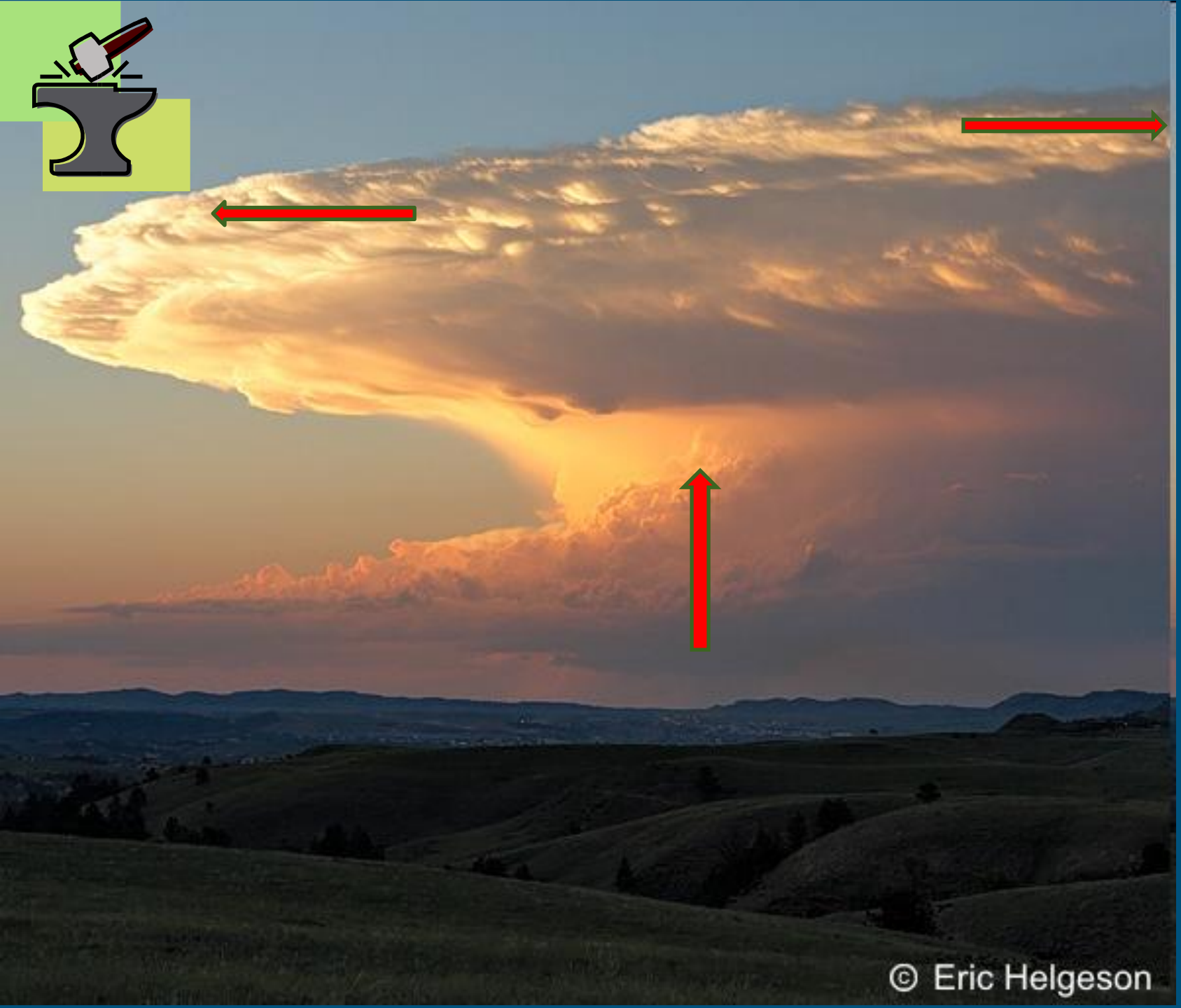



Photo Credit: Dann Weatherhead of Sydney Storm Chasers

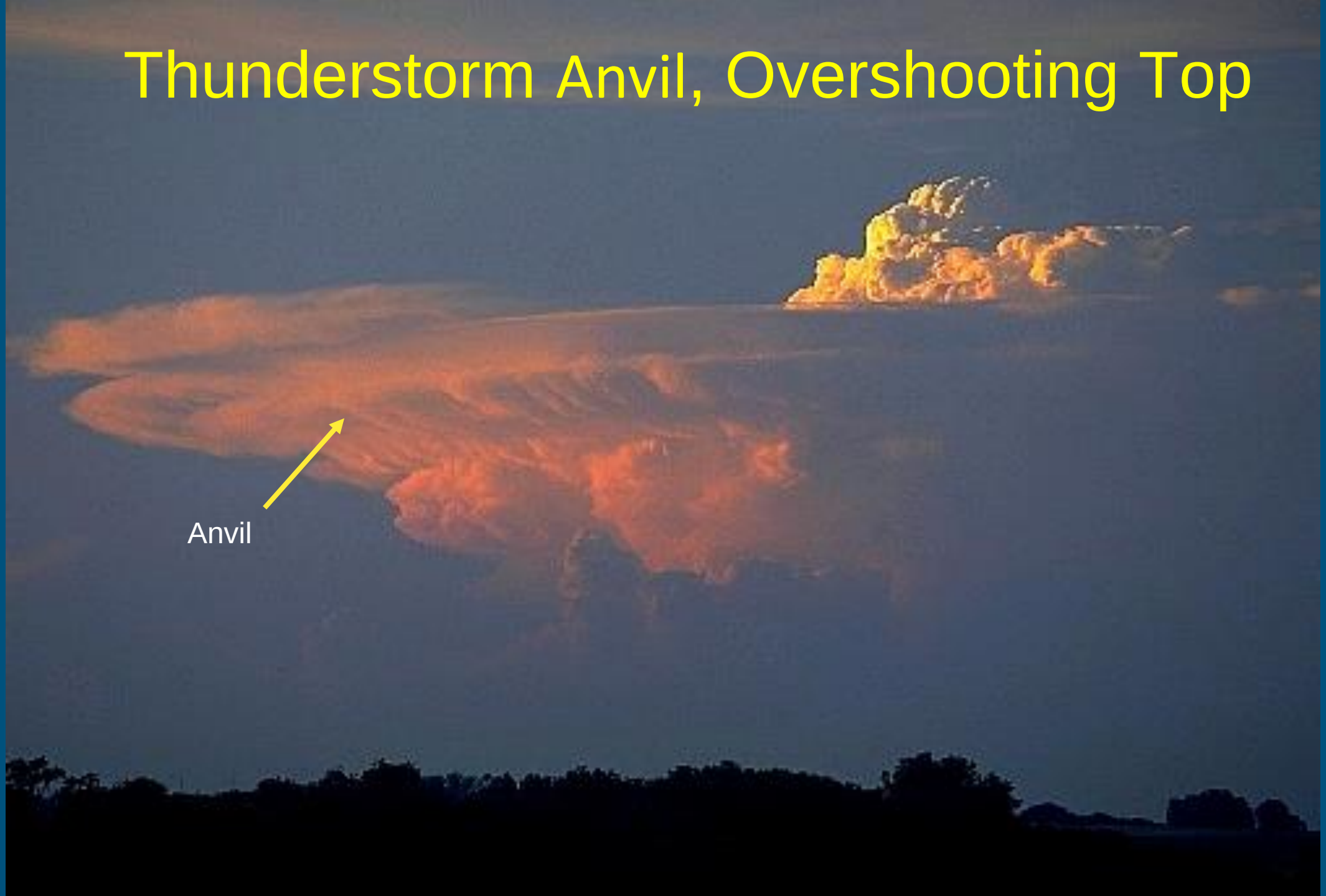



# Thunderstorm Anvil

Strong updraft hits a more stable layer called the tropopause which acts like a lid; the moist, cloudy air then spreads out.

The flat top part of this storm resembles a blacksmiths anvil;
a well-defined anvil suggests a strong updraft and possibly a severe storm

# Thunderstorm Anvil, Overshooting Top



# Overshooting Top Taken from Airplane (strong updraft indicator)


(used with permission Stu Ostro)

# Strong Downdraft/Downburst Indicators

- Downdraft hits ground, spreads out (outflow)
- Rain or dust boot or foot sometimes with a curl at the leading edge (gust front)
- Shelf cloud sloping away from the storm's downdraft area
- Dust cloud blowing out ahead or around right flank of storm

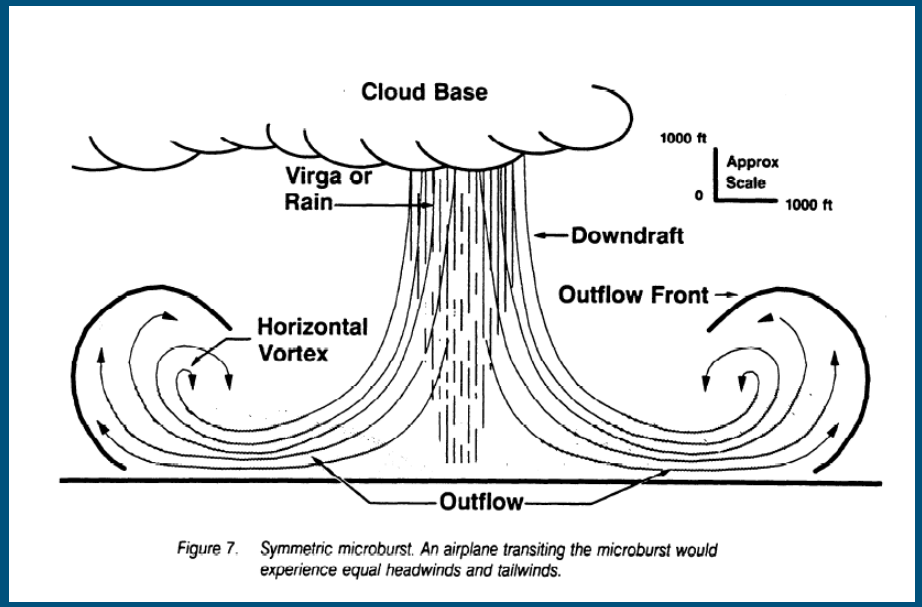


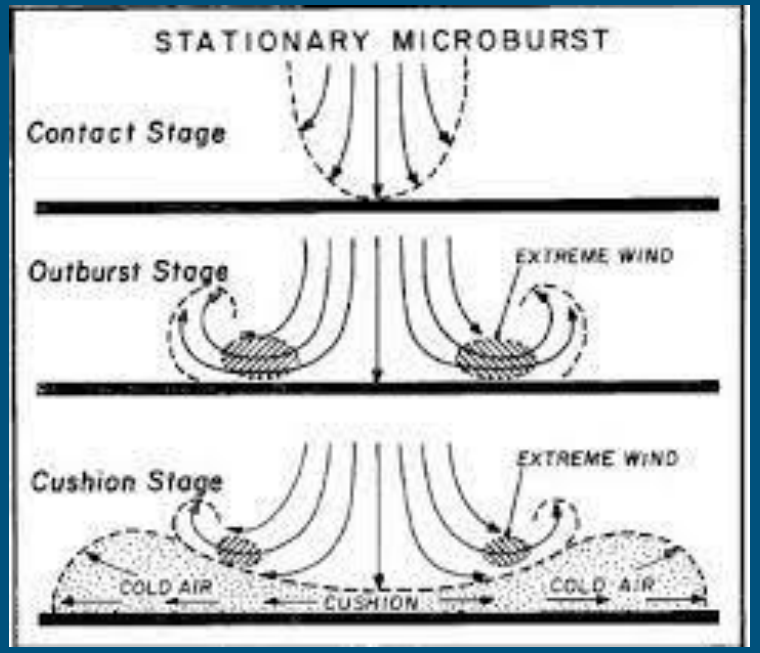

*Figure 7. Symmetric microburst. An airplane transiting the microburst would experience equal headwinds and tailwinds.*

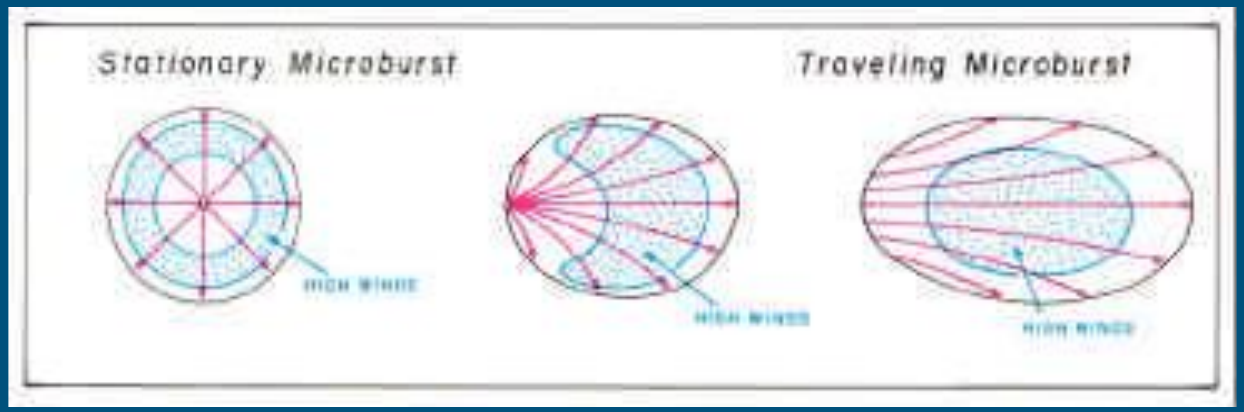
# Rain Shaft

Downdraft part of the storm

# Strong Localized Downburst Called a Microburst

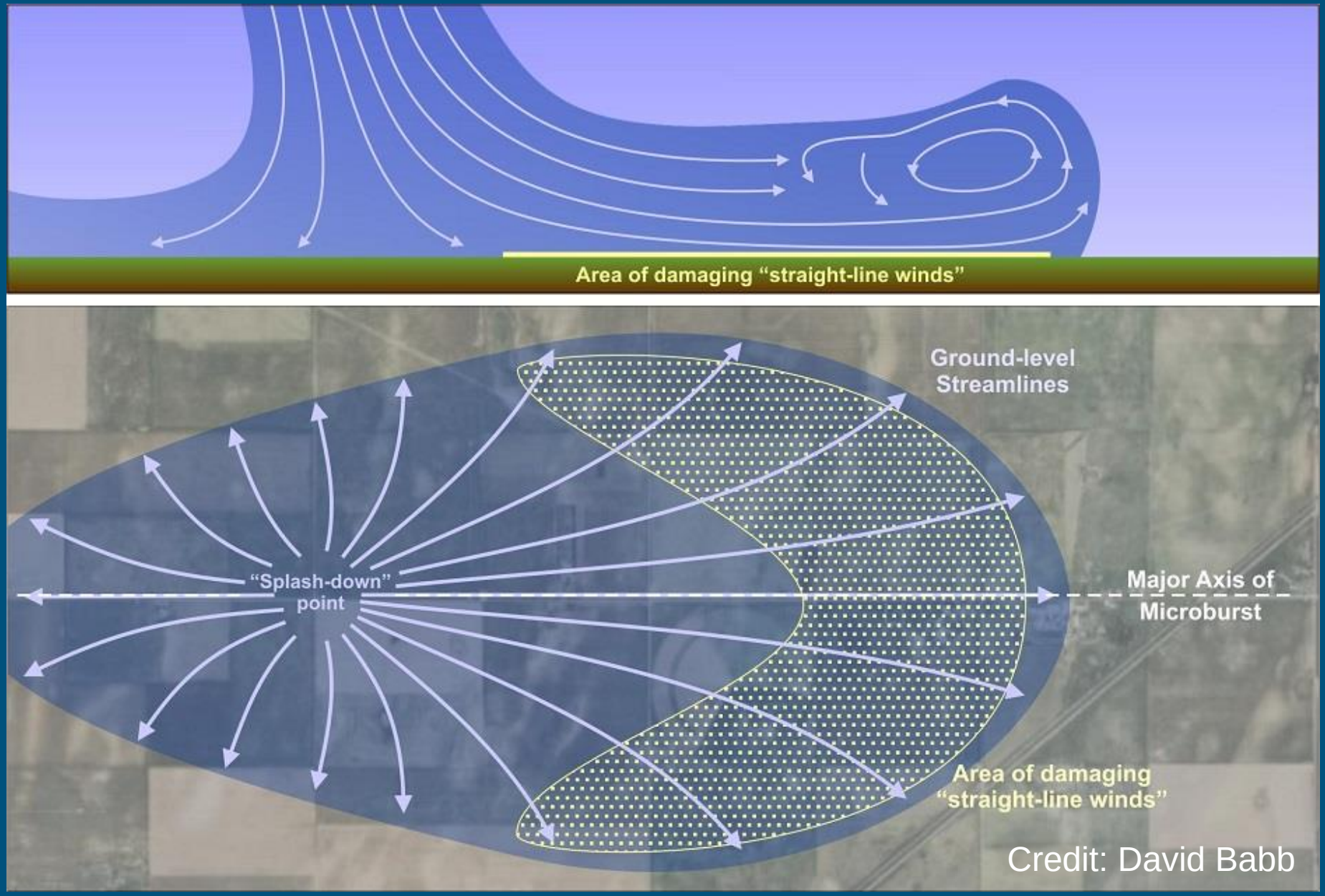
- Strong descending air current drops out of storm (rain cooled heavy, dense air)
- Air contacts the ground, spreads out (sometimes leading to damaging high winds)
- Think of it like pouring a bucket of water on the ground




From Fujita, 1985

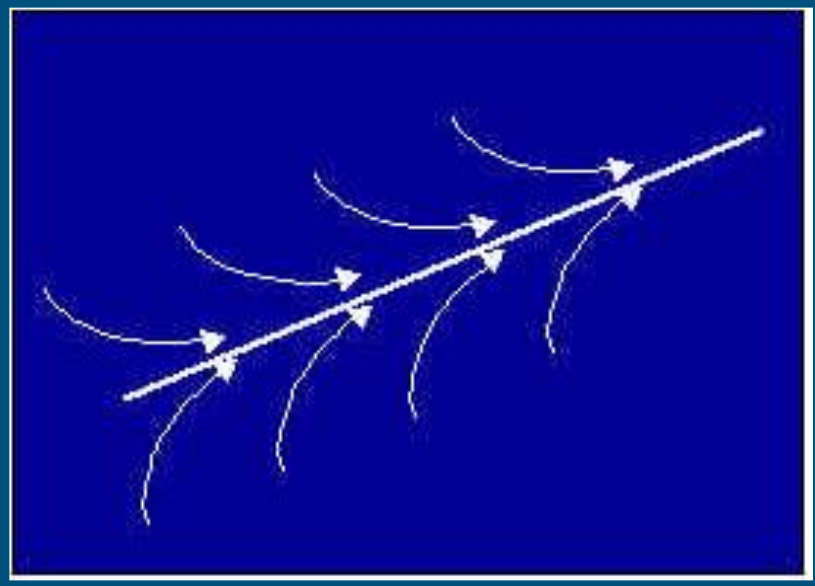
# Damage Pattern Microburst

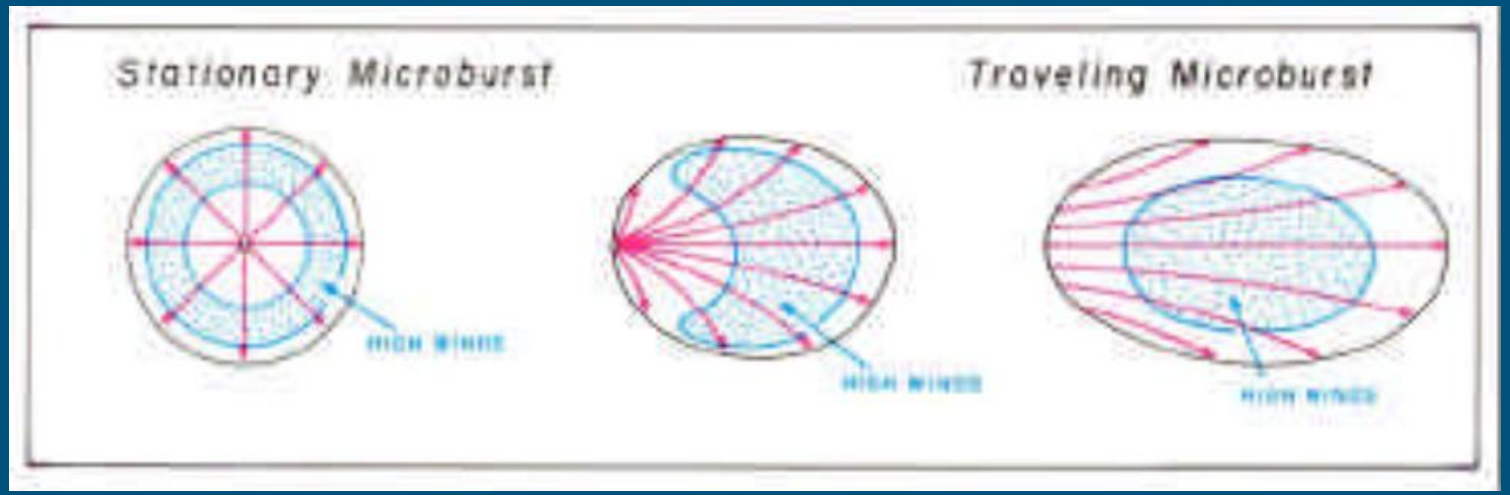


# Damage Pattern Microburst Versus Tornado


Tornado:
Narrow well defined track, rotation about a vertical axis. Convergence into the path.

Downburst:
Divergence, broad diffuse track, no rotation about a vertical axis.

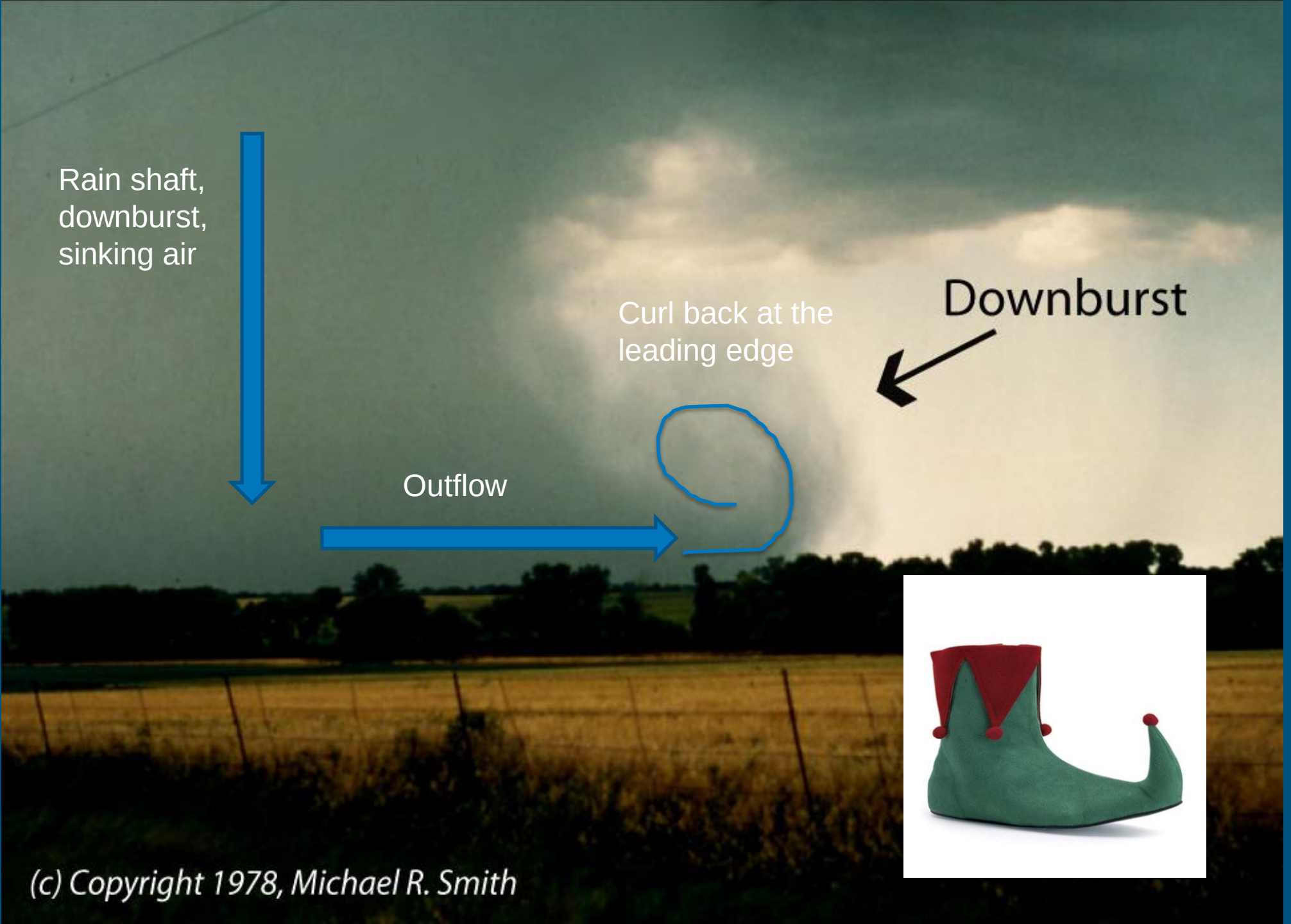


# Downburst Signature

Rain shaft indicating downdraft, deflection near the ground, curl back at the leading edge

Kind of like an Elf Boot?



Andrew Pritchard | **SkyDrama.Net**
Microburst near Manchester, IL | March 15 2016

# Downburst, Microburst Signature

See this, think strong winds, outflow coming out of storm

# Visual Indication of Microburst

## Rain Foot or Rain Boot

Rain shaft (ankle)
deflects out (toe)

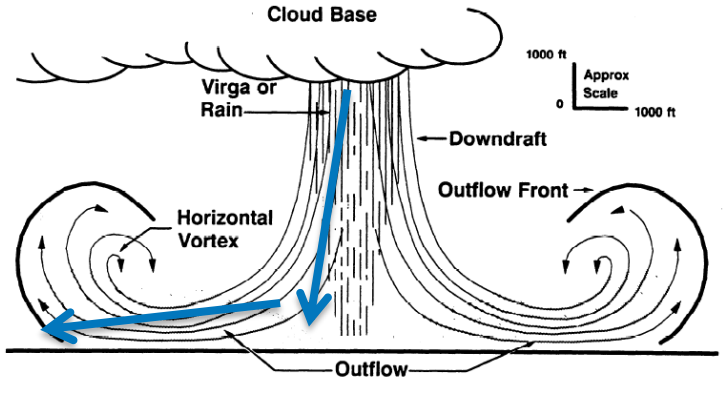



Figure 7. Symmetric microburst. An airplane transiting the microburst would experience equal headwinds and tailwinds.



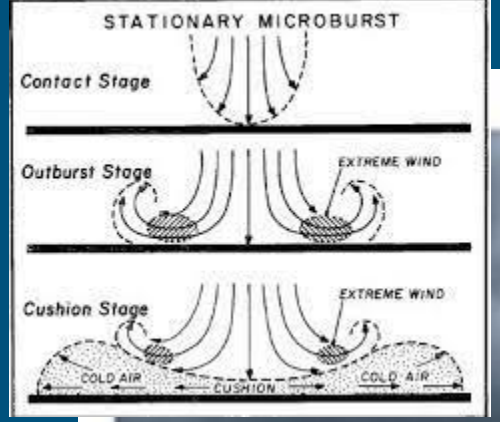
# Microburst Life Cycle (Visual)

Small-scale downburst, wind swath width < 2.5 mi.



Time duration for this sequence as little as 5 to 10 minutes.

Descending rain/hail core from storm to ground; high winds, heavy precipitation.



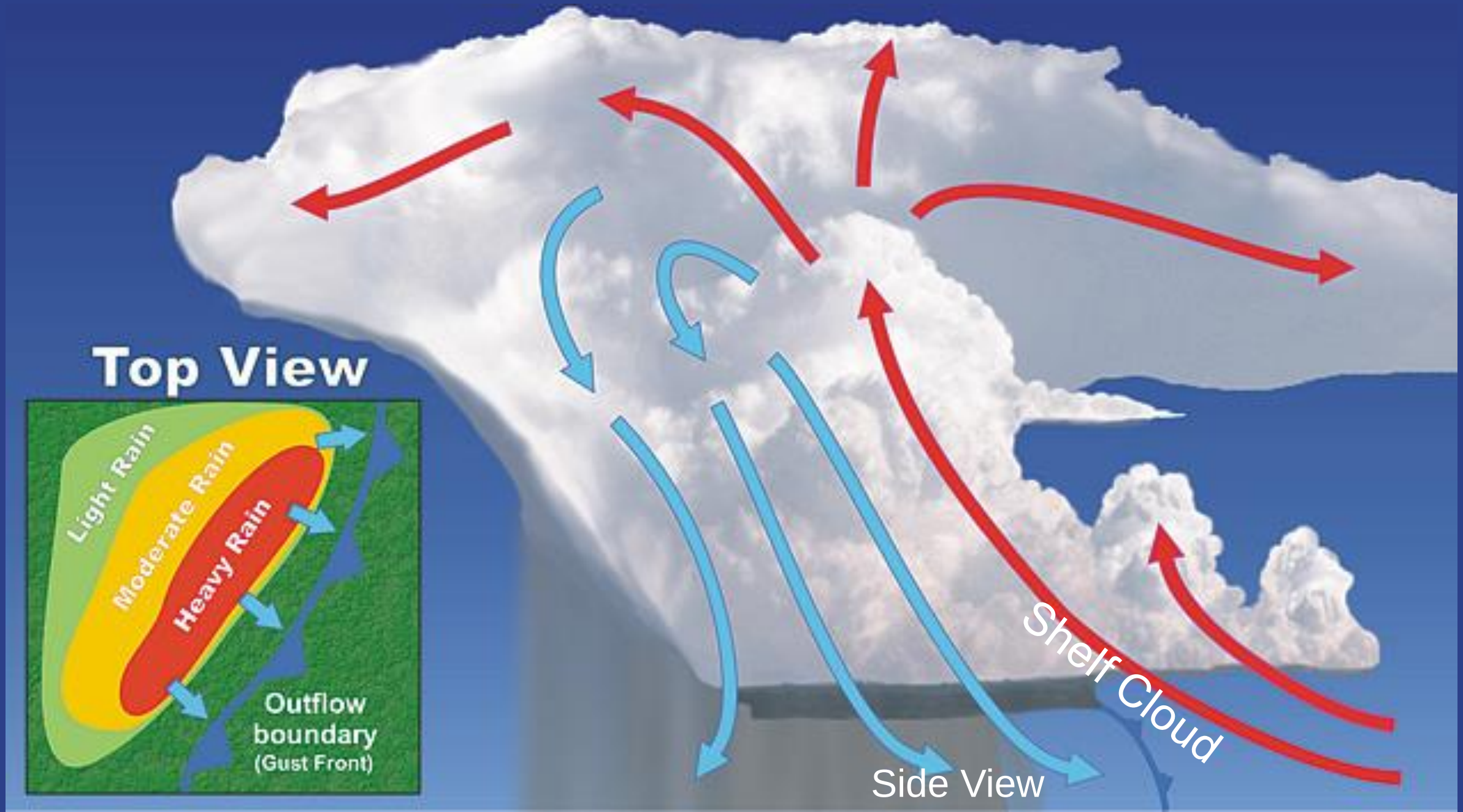

Entire sequence 5 to 10 minutes

Photo Credit: Peter Thompson
Queensland, Australia

# Microburst Time Lapse

# Downburst (Straight Line) Winds


# Another Downdraft Related Formation: Shelf Cloud



# Shelf Cloud

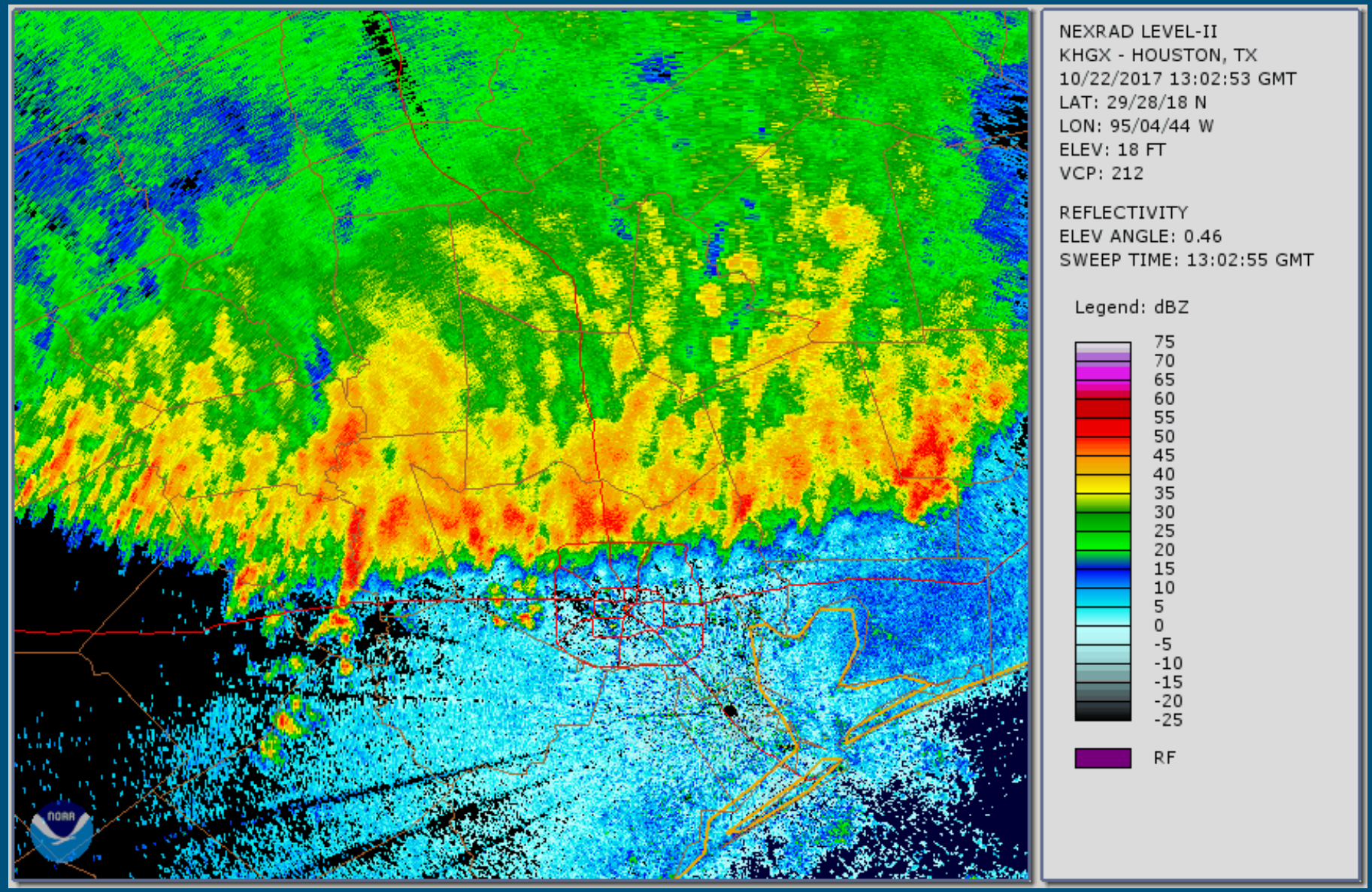
Rain-cooled air sinks and spreads forward into warm moist air; result a horizontally elongated cloud that slopes away from rain behind

Photo by Aaron Gilstad-ND Atmospheric Resource Board

# Shelf Cloud: Front View, Storm Approaching

# Wings Over Houston Air Show 2017

# Squall Line, Outflow, Radar Fineline



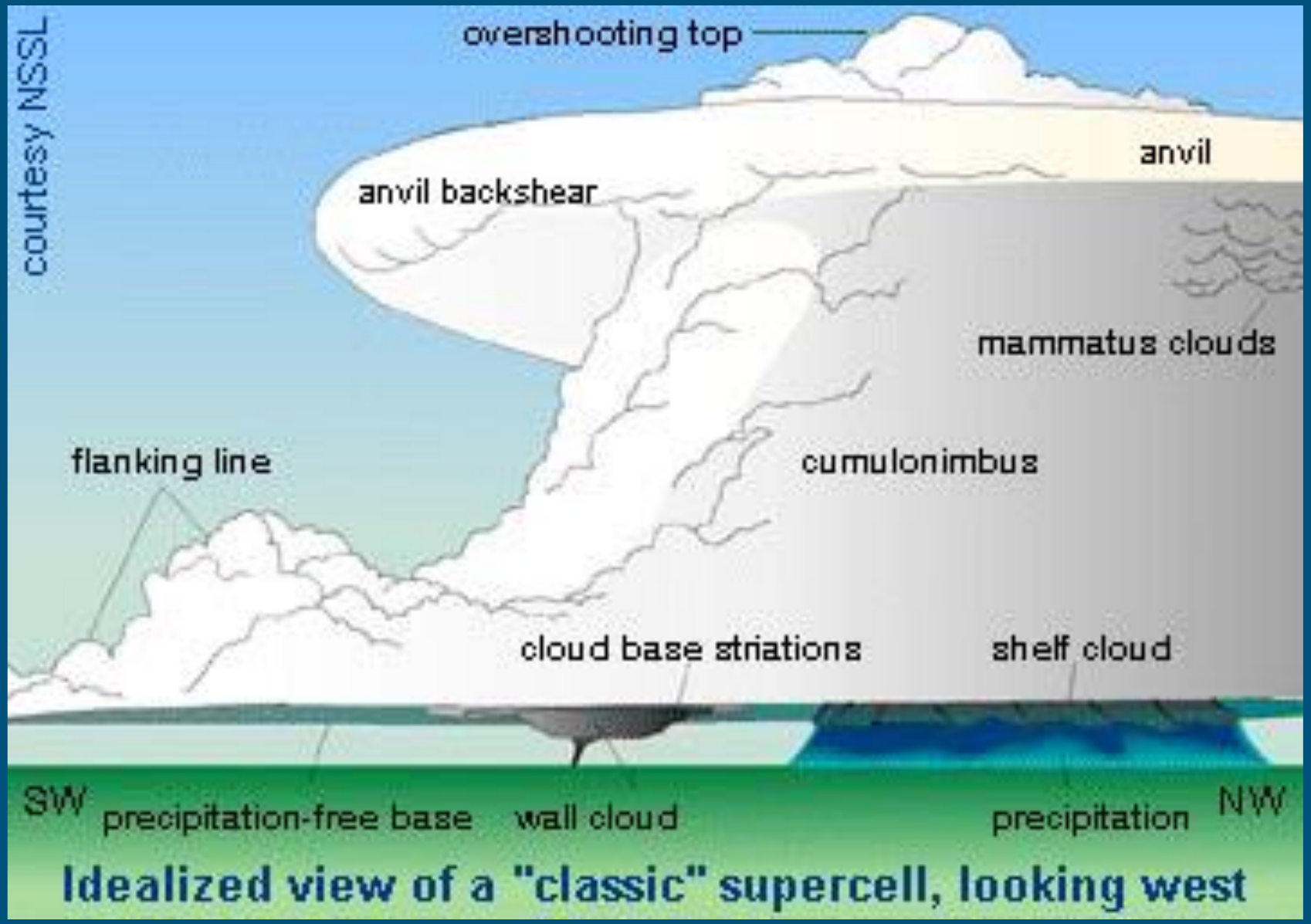

832.349.4334


SHOCKWAVE
HOUSTON AIRPORTS
CORNWICH
& MOZZARELLA


AREPAS

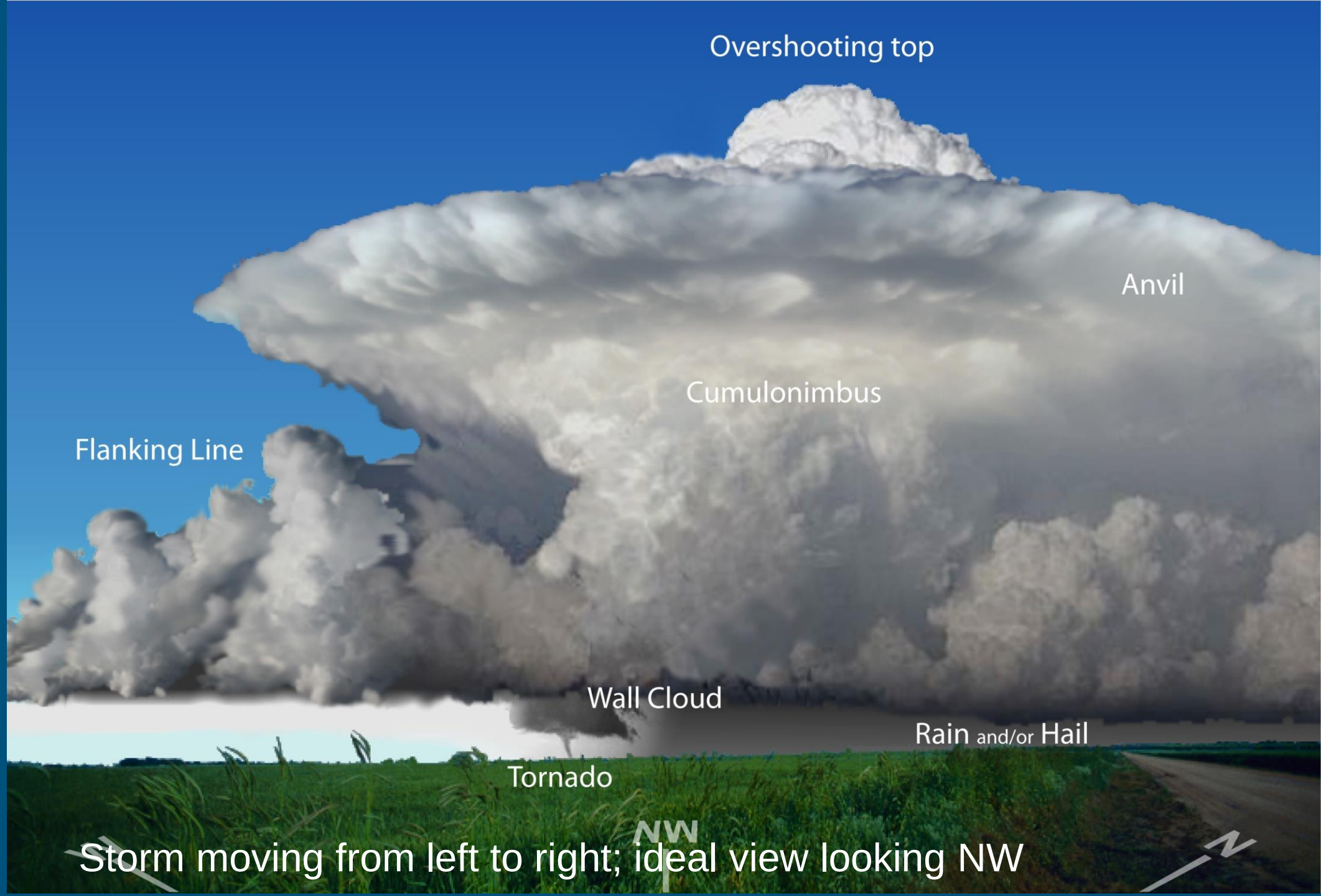
# Supercell Thunderstorm

- An especially severe type of thunderstorm
- Forms when vertical wind shear is high; entire storm is rotating.
- This type of storm leads to most of our strong tornadoes, largest hail

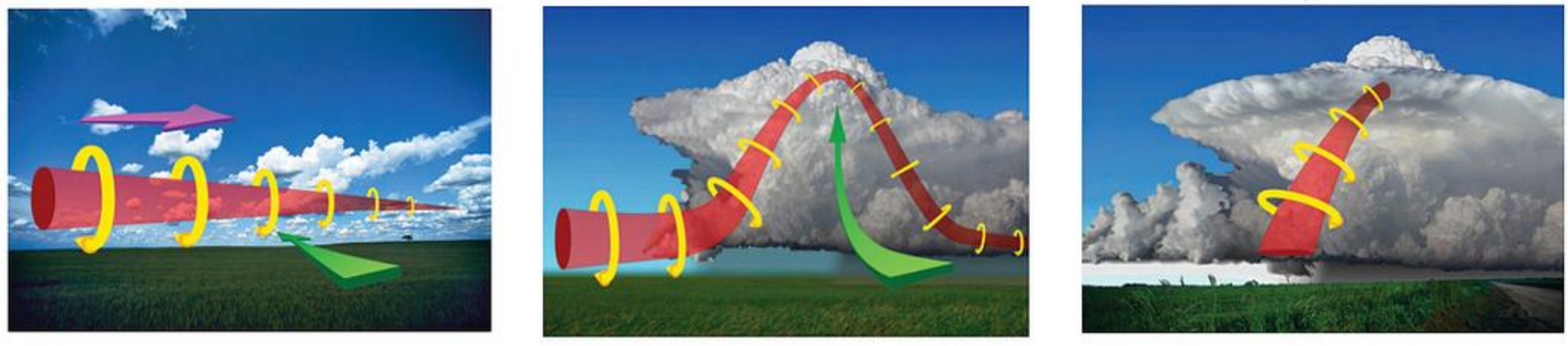


# Supercell

Rotating thunderstorm, especially dangerous type

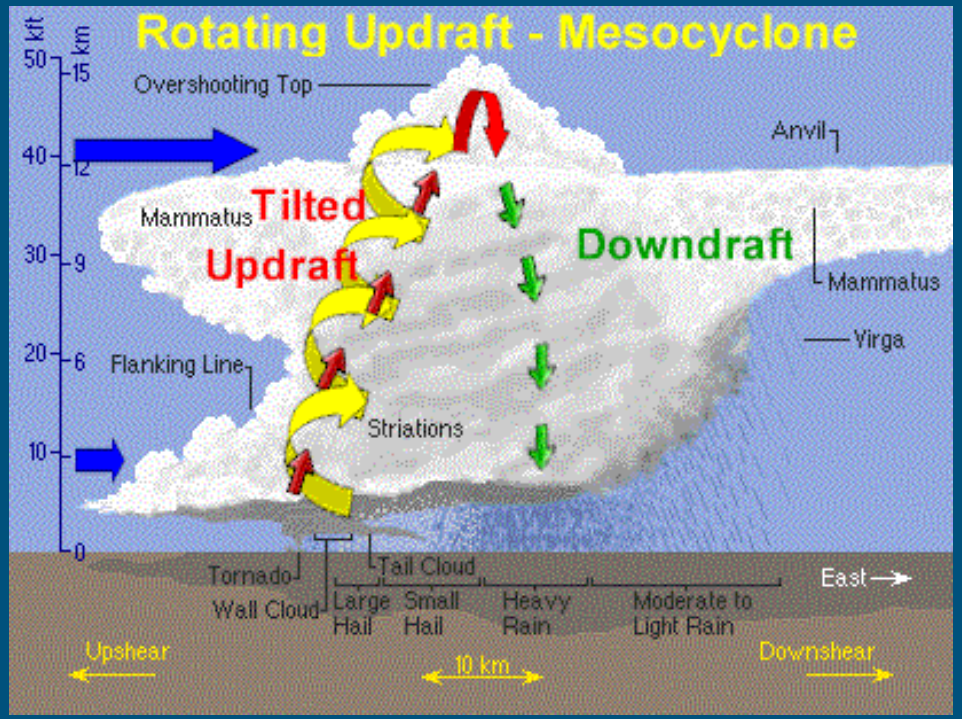


# Vertical Wind Shear Can Lead to Rotating Thunderstorm Called a Supercell (most Severe Type)



Initial spin in the horizontal gets tilted into the vertical to produce rotating in the storm called a mesoscyclone.

Similar processes near ground for tornado formation.




Low Level Clues: Updraft
(Updraft)
Wall Cloud
(Downdraft)
Heavy Rain
Strong winds all surge IN towards the wall cloud
Photo: Dennis Cavanaugh


©1993 David Blanchard
Classic Supercell
Moving from left to right
Underside of anvil
Grooves or striations
Rain Free Base, Updraft
heavy rain, downdraft


NOAA

# Classic Supercell

## Storm likely moving away

# Wall Clouds

Updraft portion of supercell. Look for rotation.

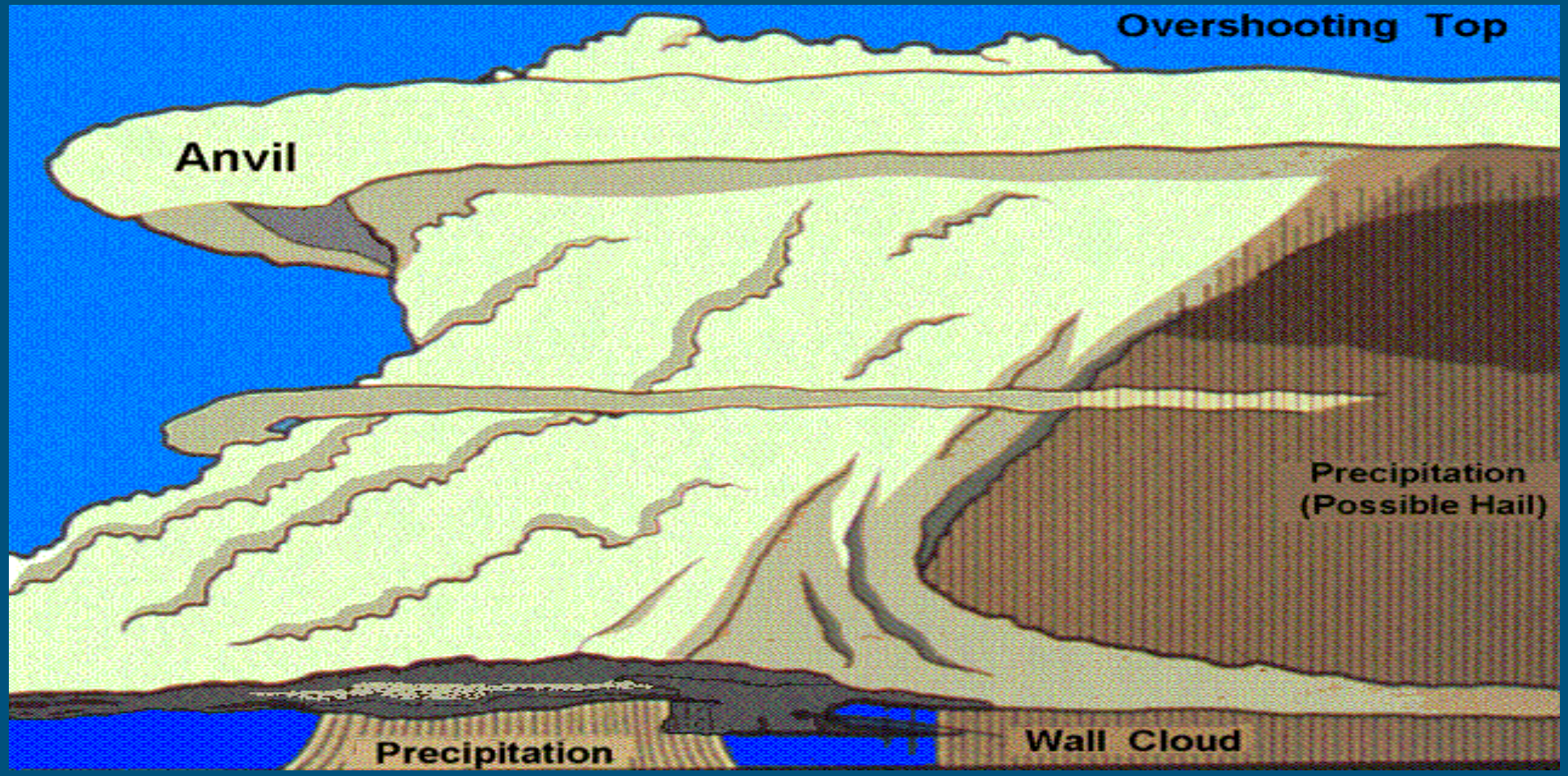
# Lowering of Rain-free Base; Can you See Rotation?

# Supercell in Fast Motion

Look for rotation, updrafts, outflows, etc

Used with Permission Mike Oblinski

# High Precipitation Supercell




- Very heavy rainfall
- Large hail and damaging winds
- Large tornadoes possible, but they may be “rain wrapped” and difficult to see

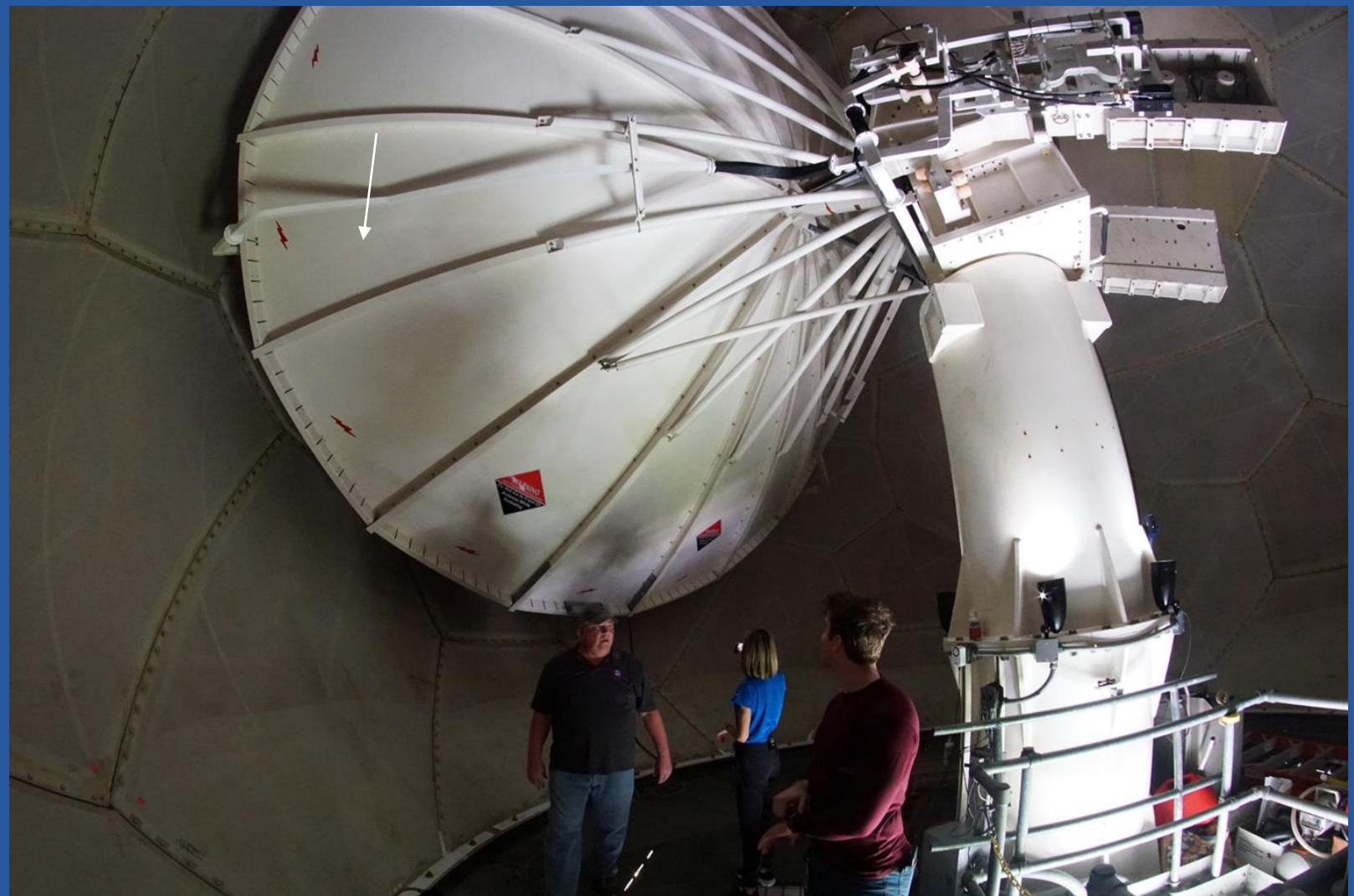
# Visibility Challenges

The rain curtains, shaft can block your view, especially from certain directions.

# Weather Radar

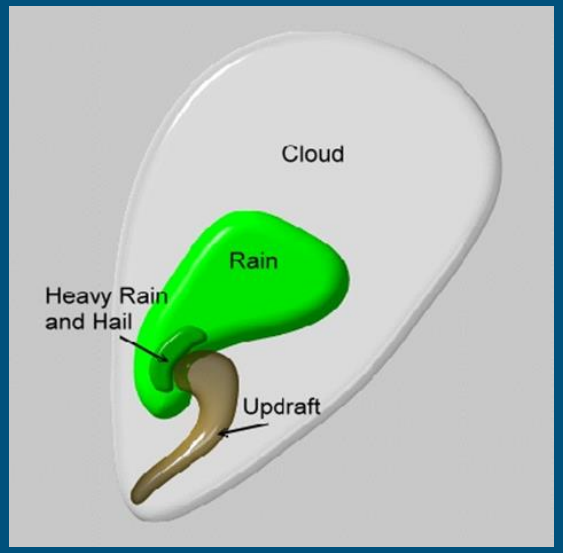
Radome made of rigid fiberglass

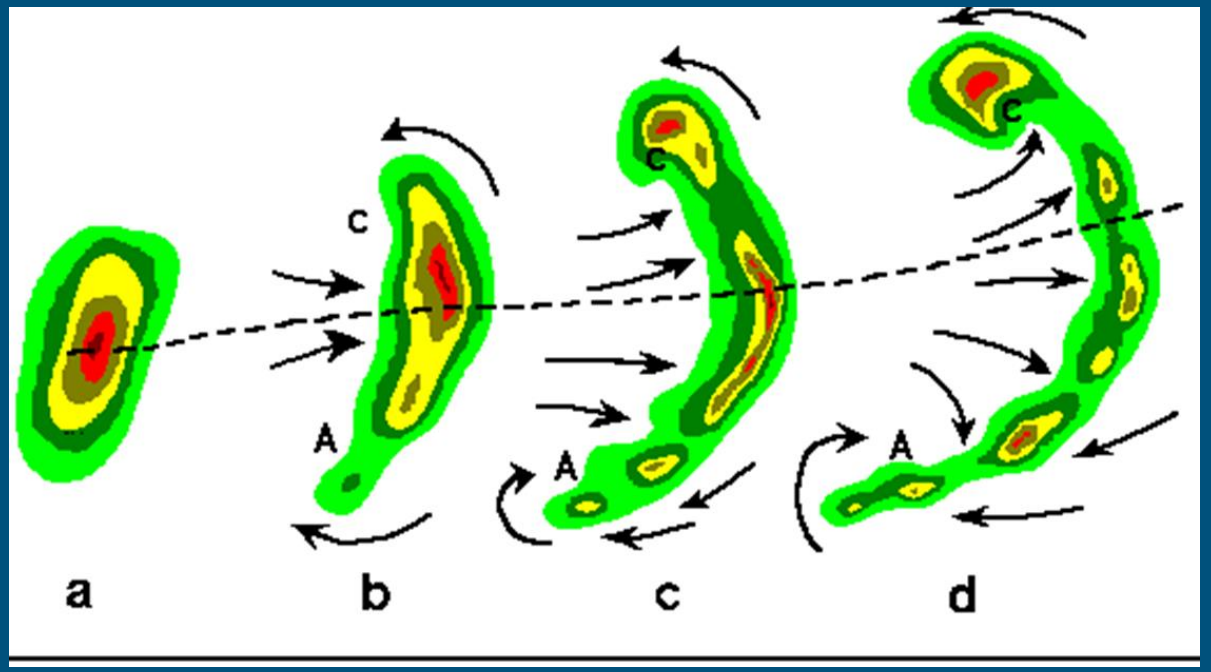
WSR-88D is the primary technology tool for evaluating storms, determine severity, making warning decisions

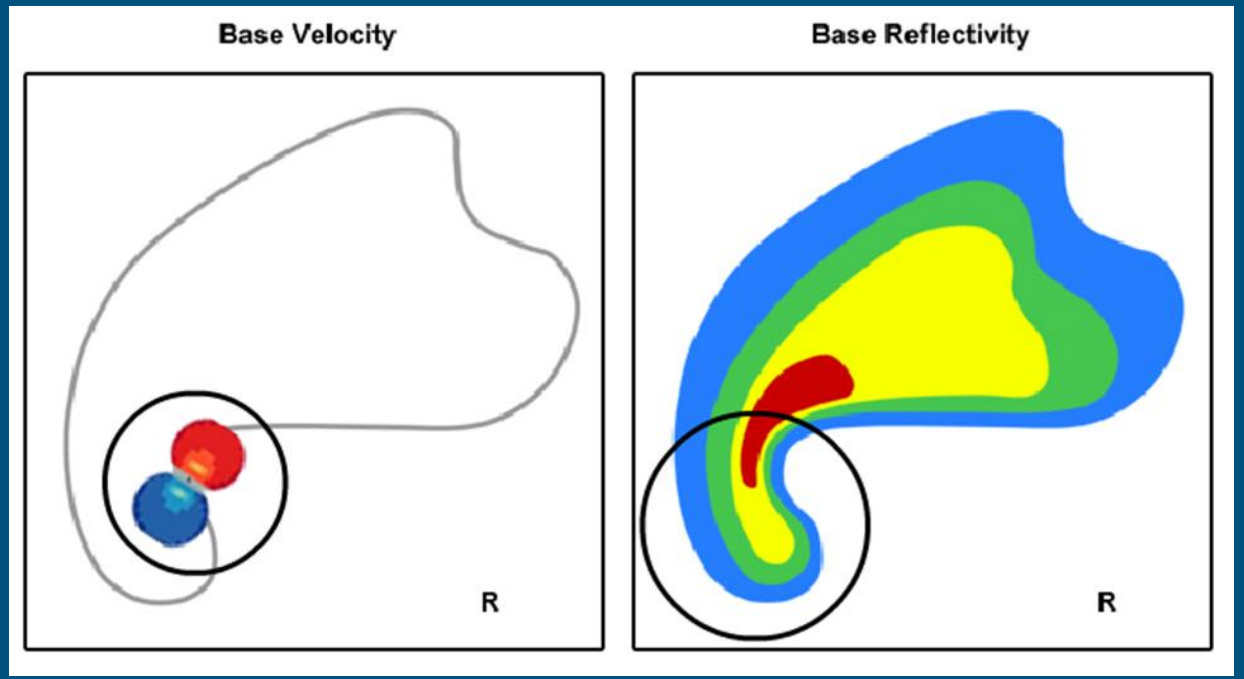


# Severe Storm Appearance on Radar

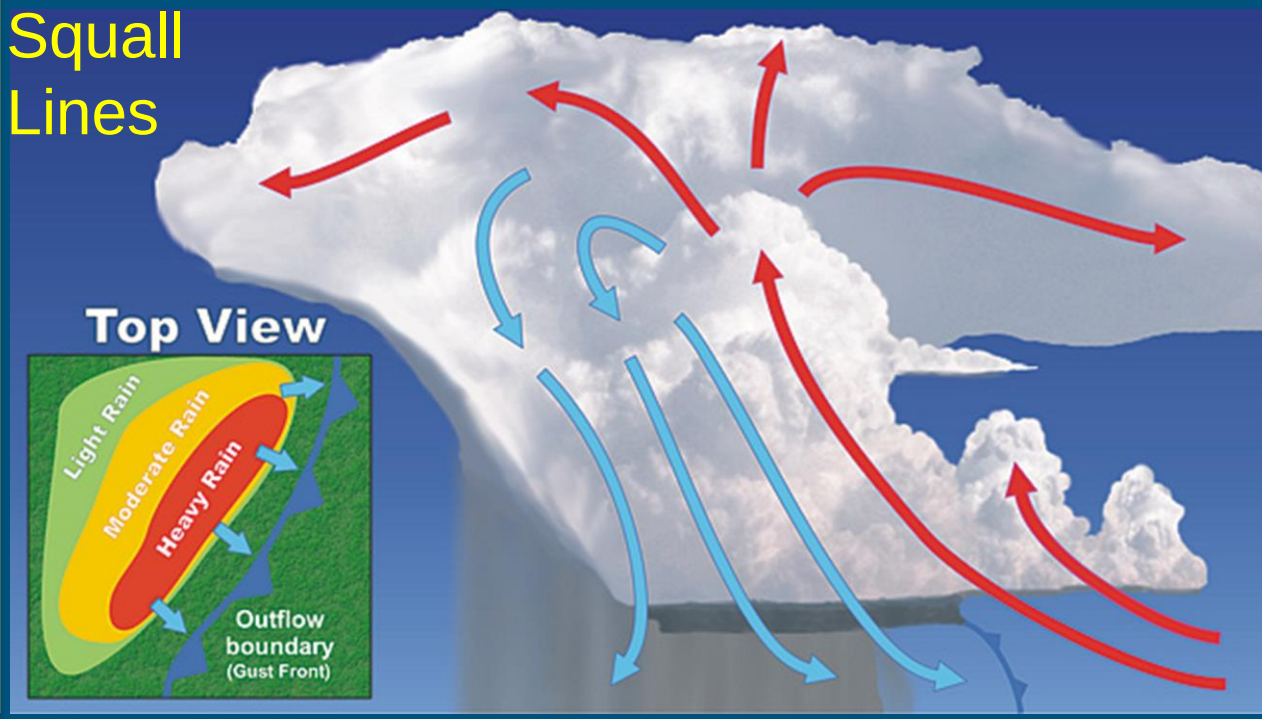
## Supercells




## Squall Lines



# Supercell Appearance on Radar

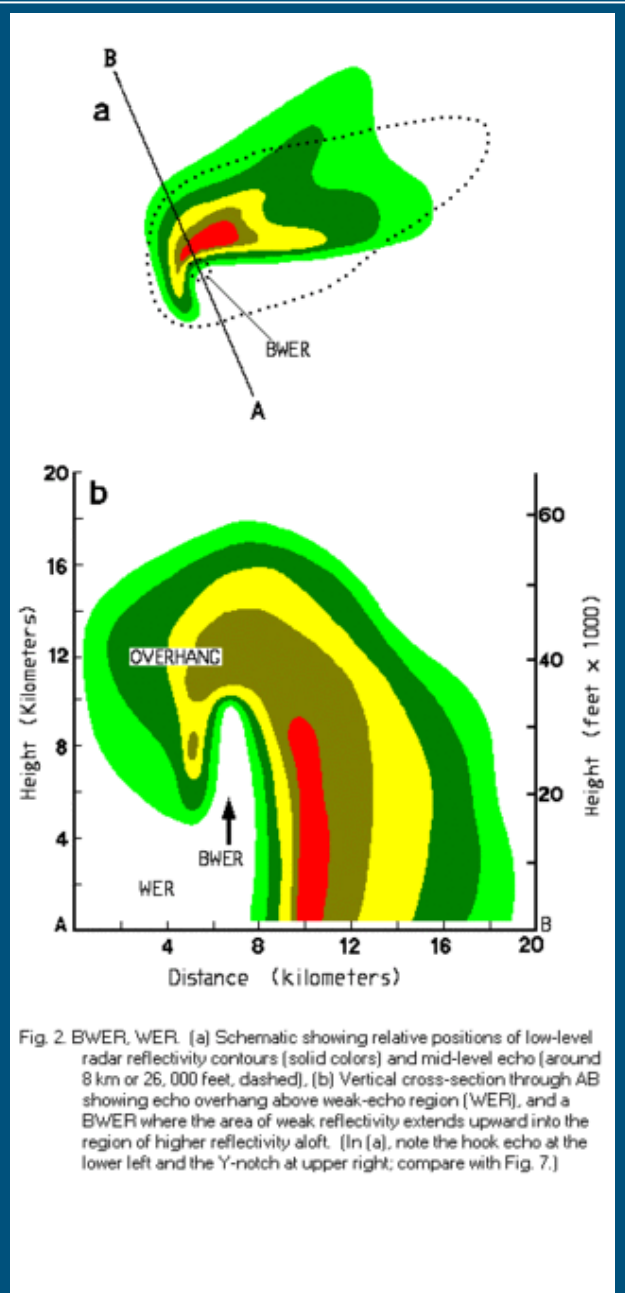
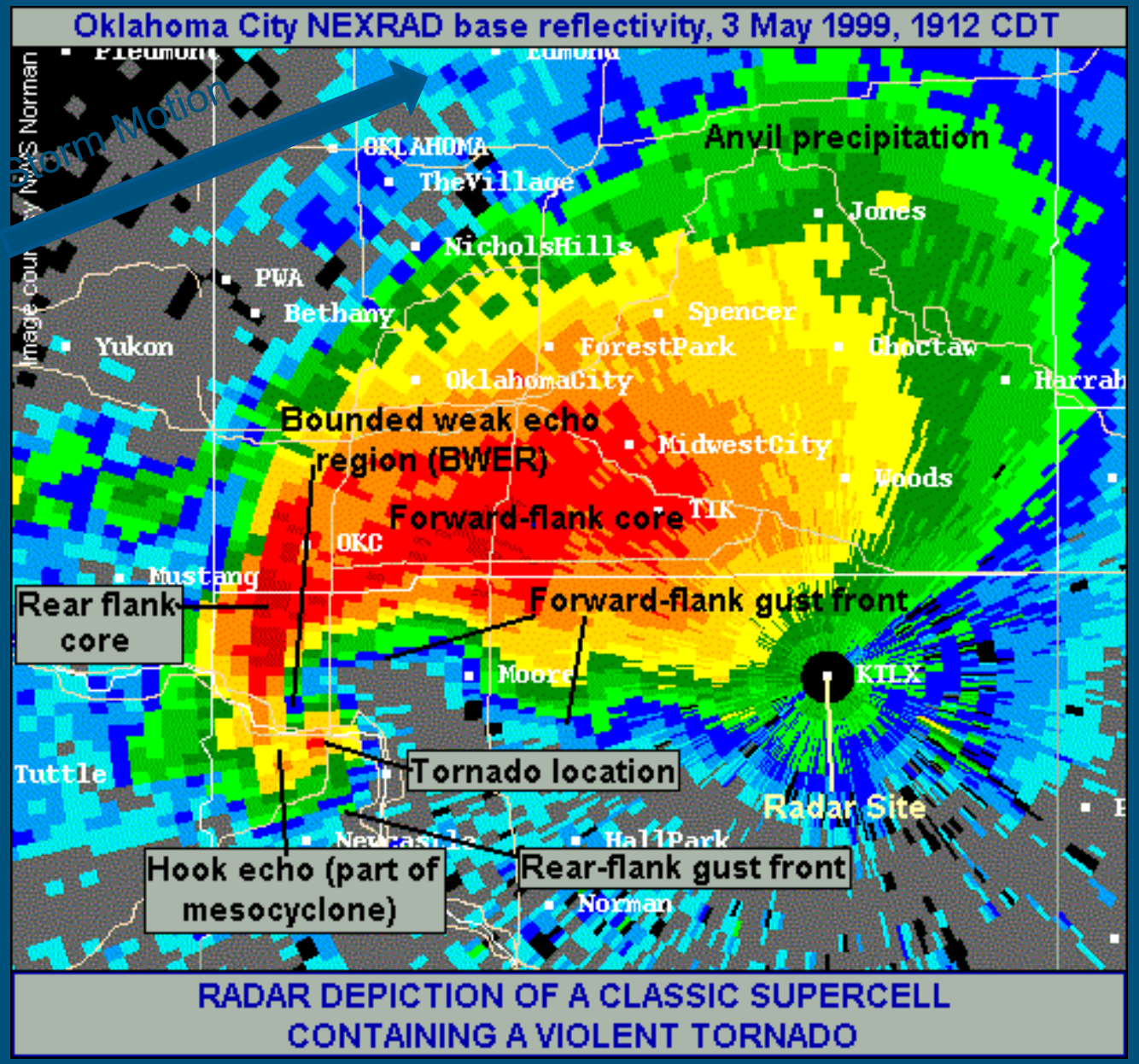
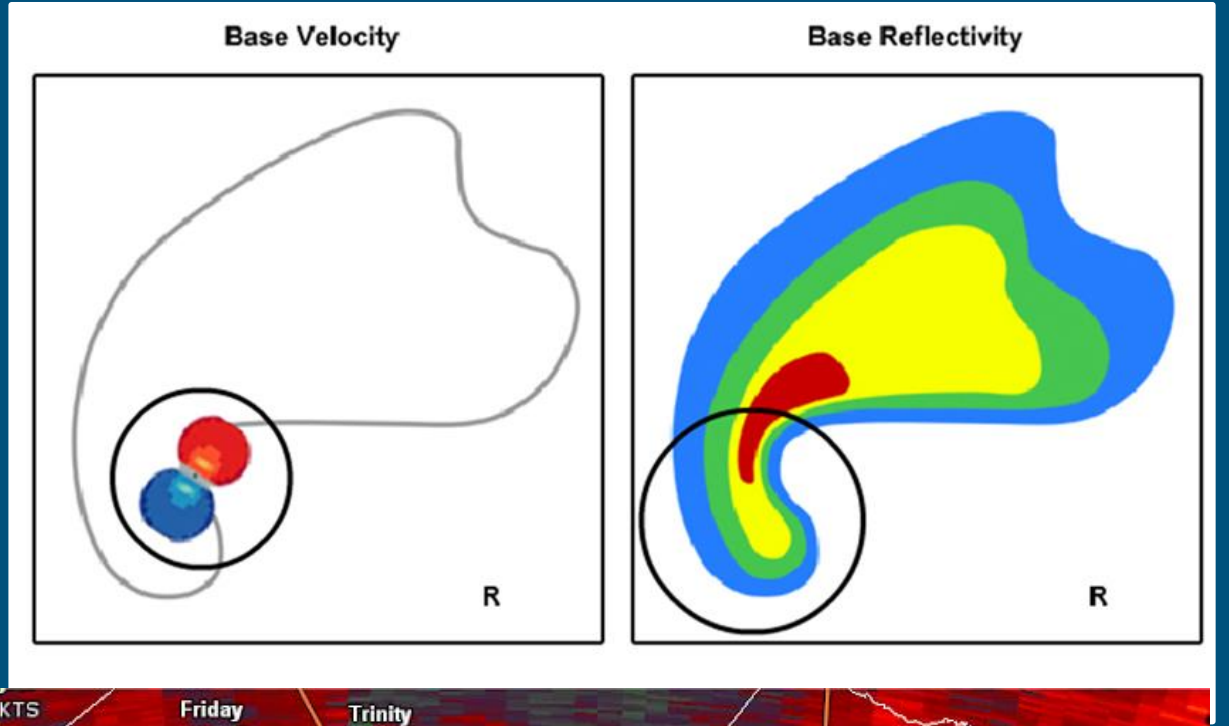


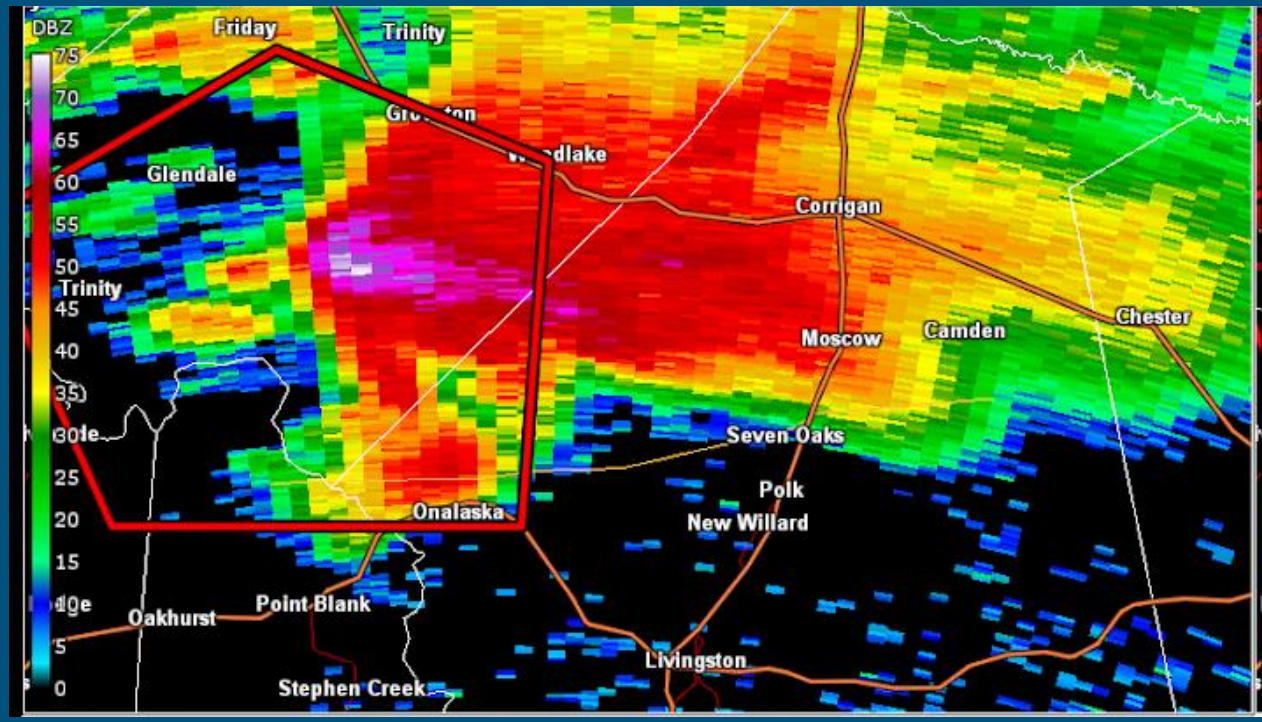

Fig. 2. BWER, WER. (a) Schematic showing relative positions of low-level radar reflectivity contours (solid colors) and mid-level echo (around 8 km or 26, 000 feet, dashed). (b) Vertical cross-section through AB showing echo overhang above weak-echo region (WER), and a BWER where the area of weak reflectivity extends upward into the region of higher reflectivity aloft. (In (a), note the hook echo at the lower left and the Y-notch at upper right; compare with Fig. 7.)

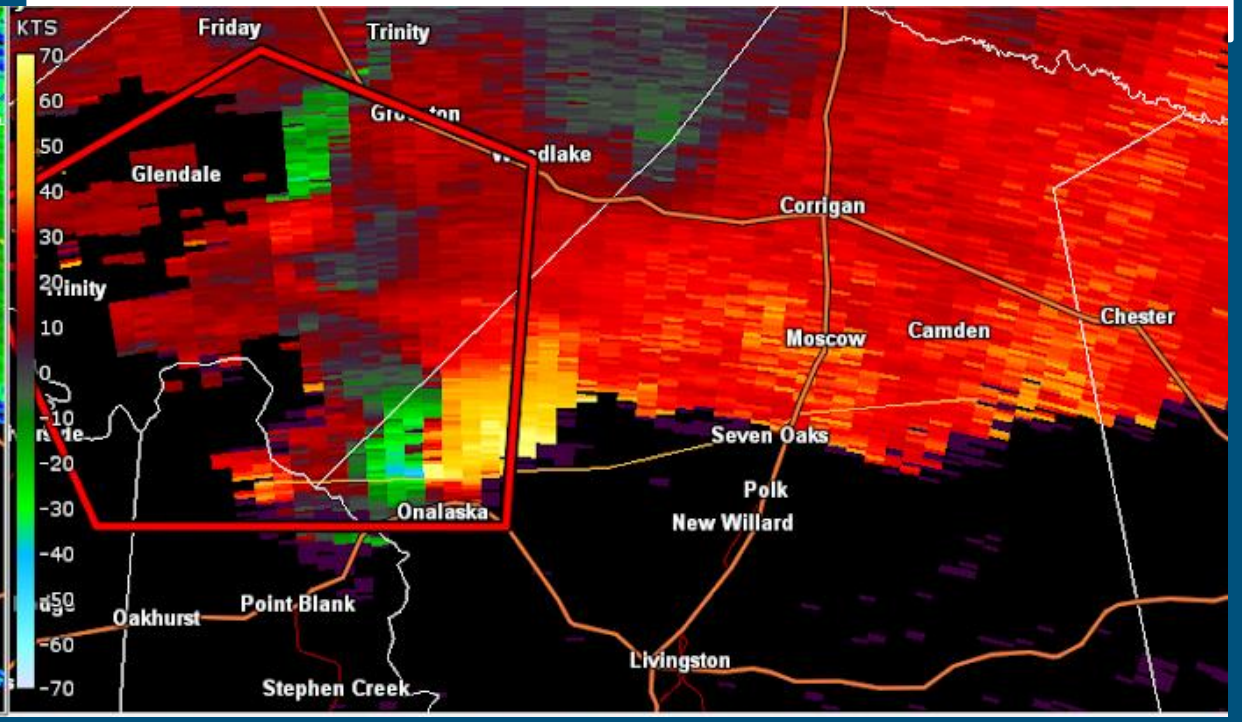


# Supercells

Reflectivity: Hook echo, hail core
Velocity: Circulation, mesocyclone; if strong and tight, tornado vortex signature (TVS)

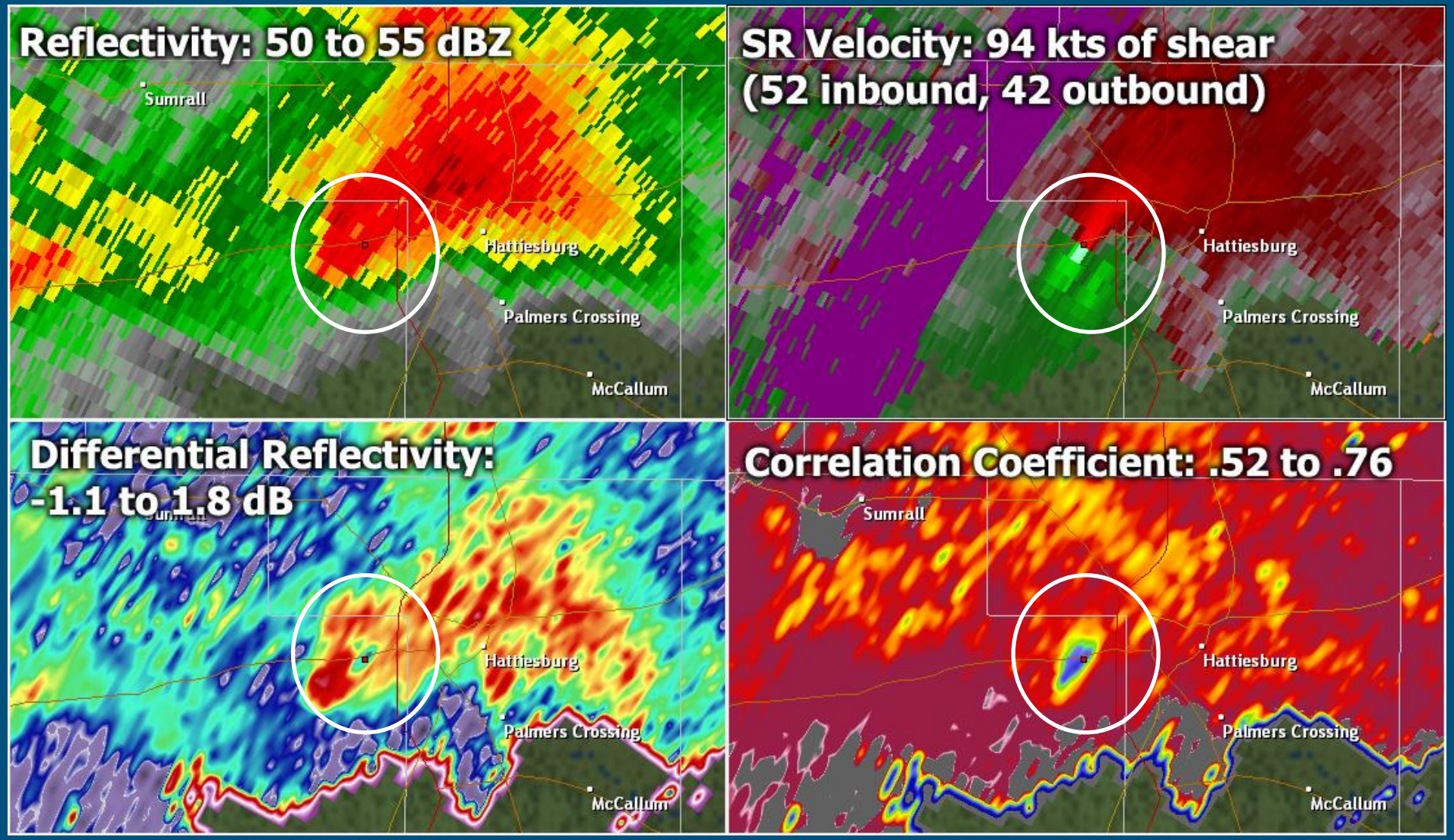


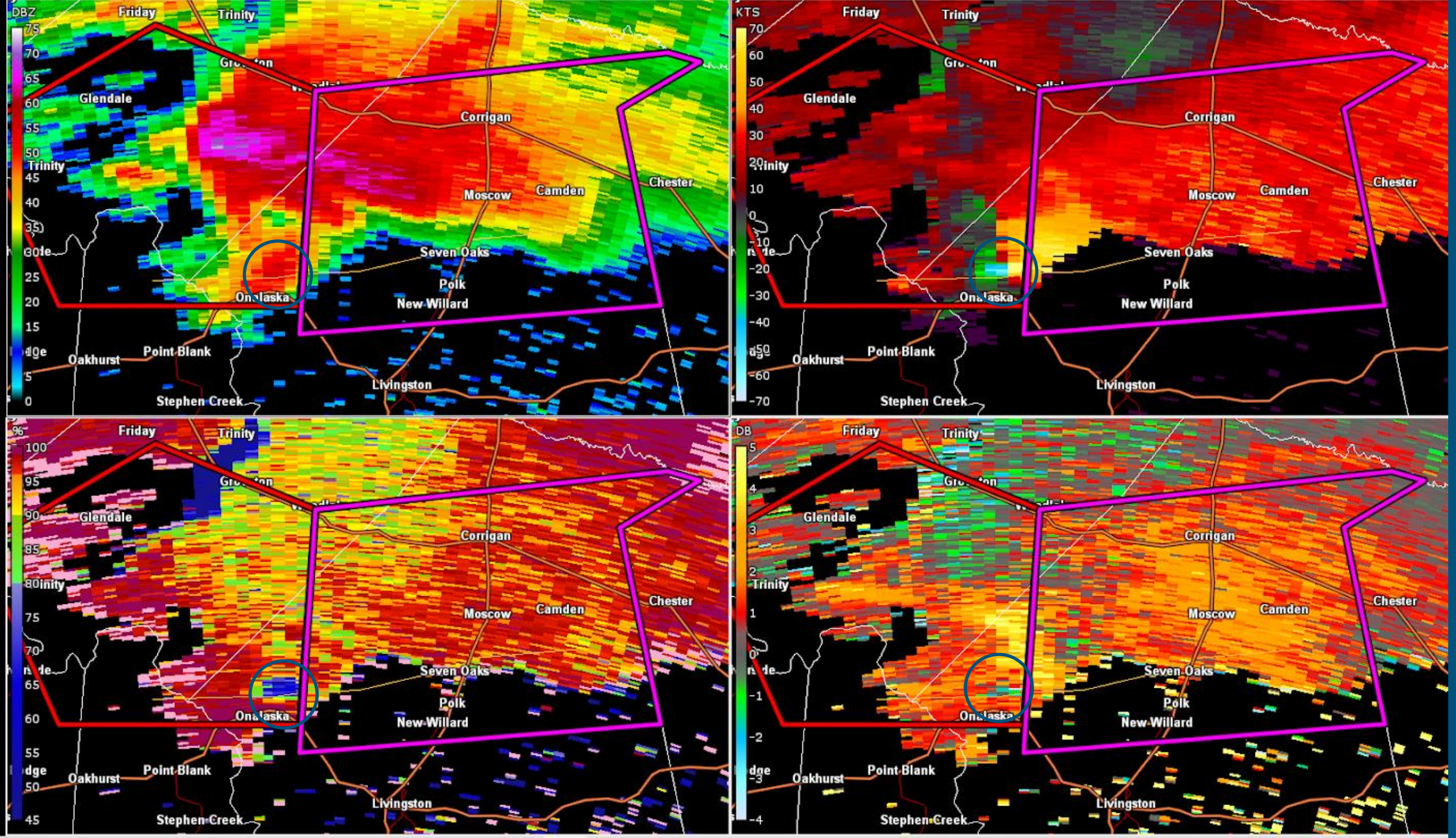



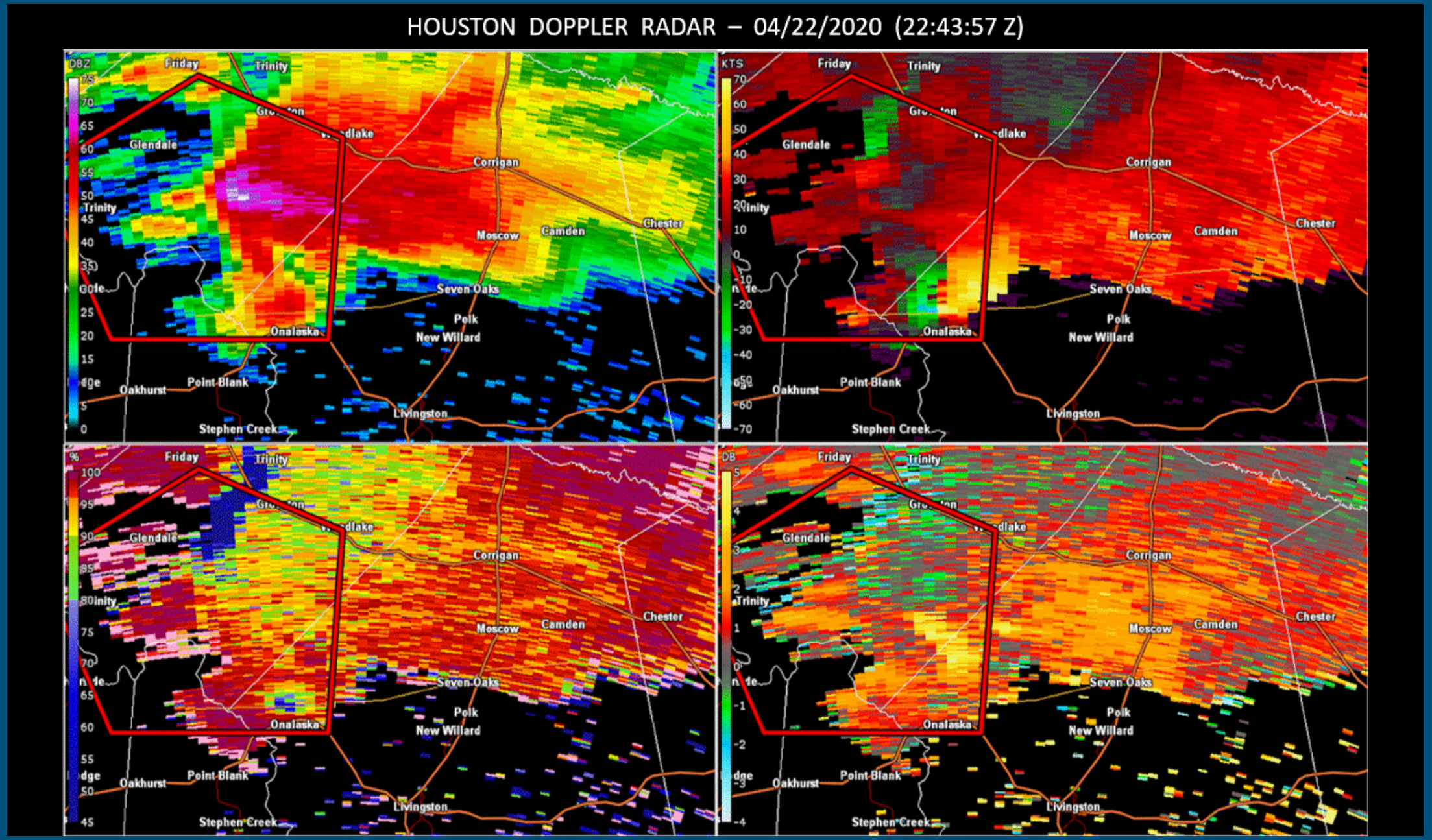
# Tornado Debris Signature (TDS)

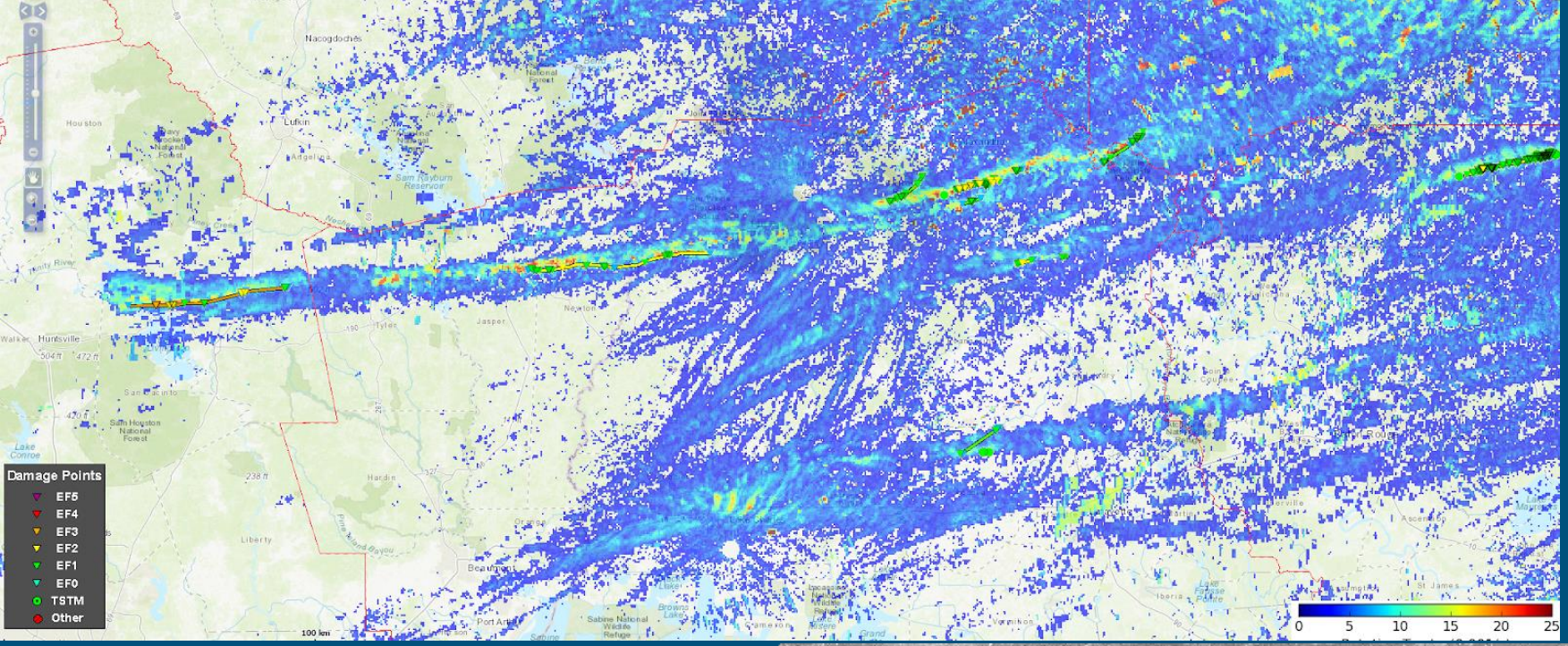
Combination of high reflectivity; strong, tight mesocyclone; low differential reflectivity; and low correlation coefficient implies radar is detecting lofted debris from a tornado!




DBZ
KTS
%
DB
Friday
Trinity
Glendale
Corrigan
Moscow
Camden
Chester
Seven Oaks
Polk
New Willard
Oakhurst
Point Blank
Livingston
Stephen Creek

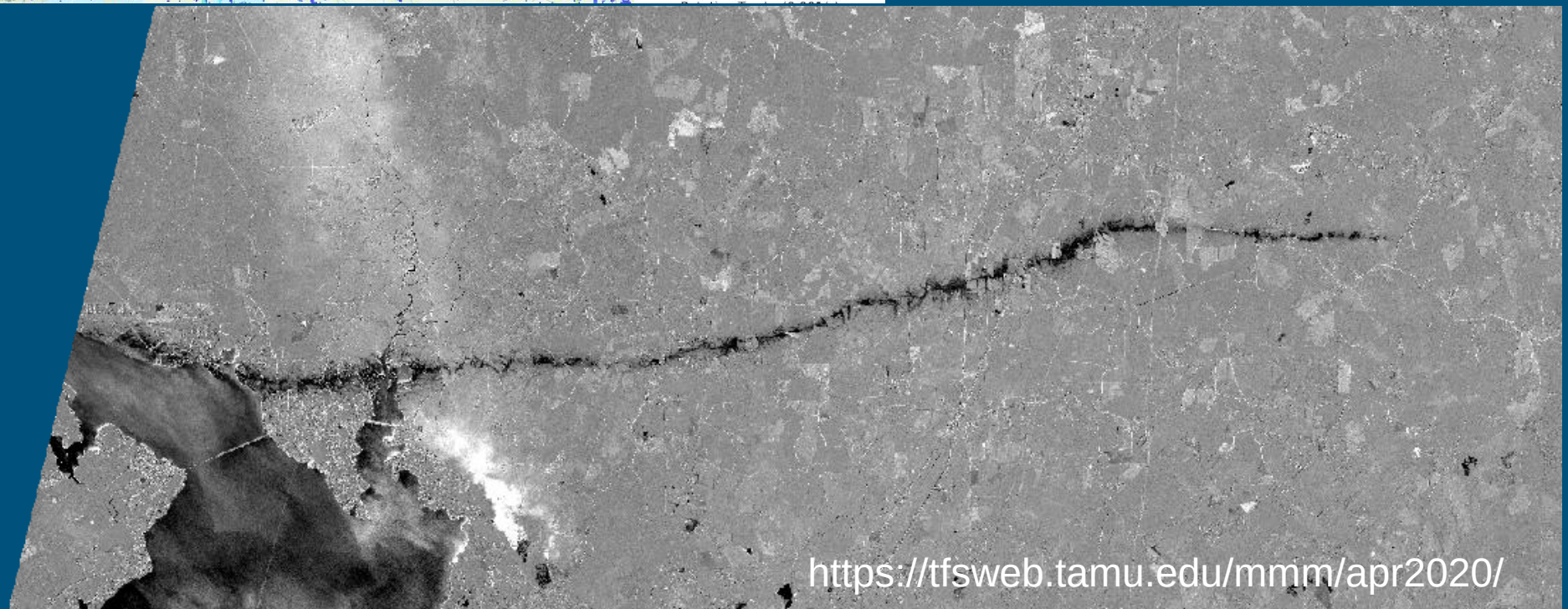
# Onalaska/Polk County EF3 Tornado April 22nd, 2020



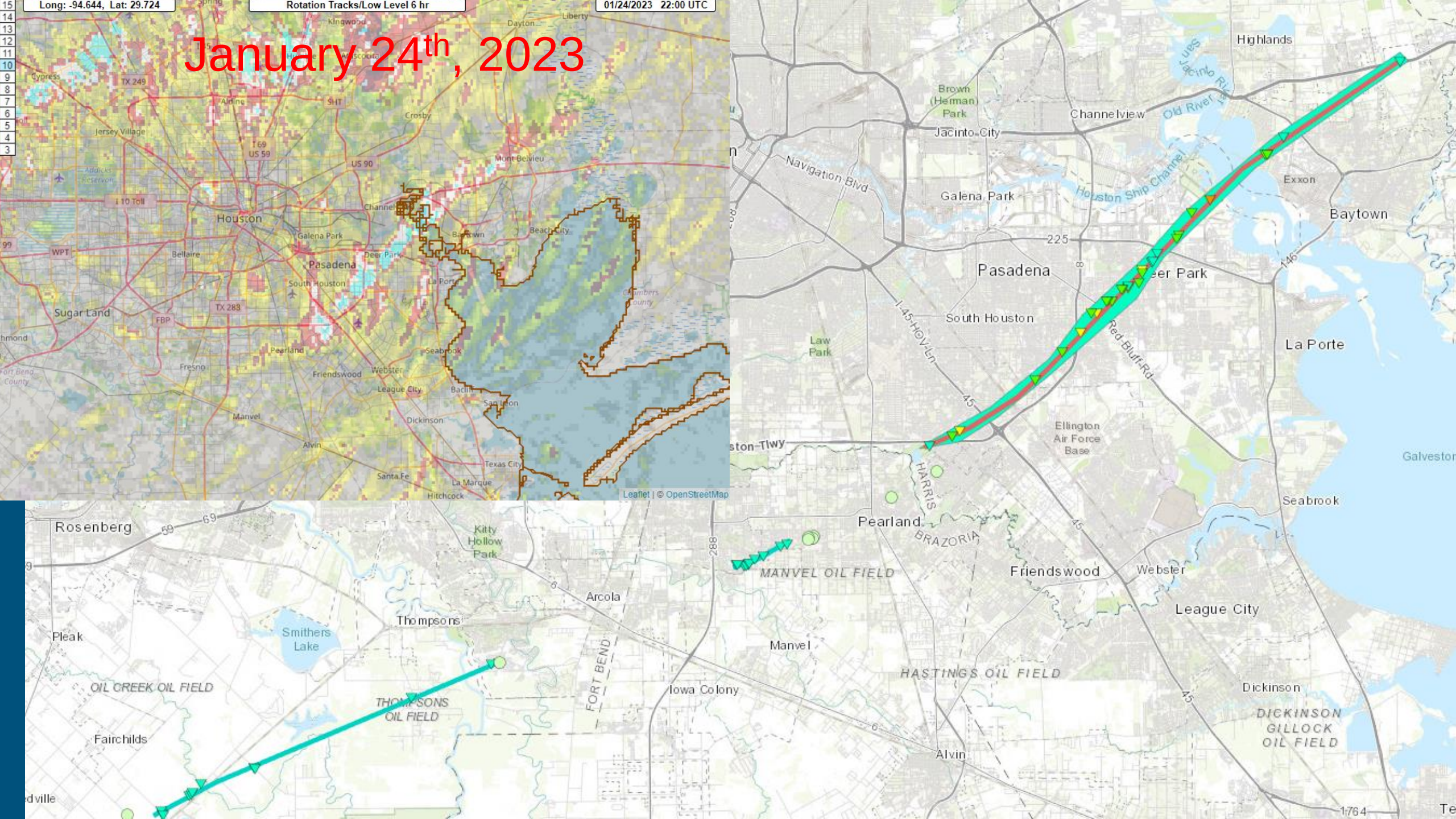


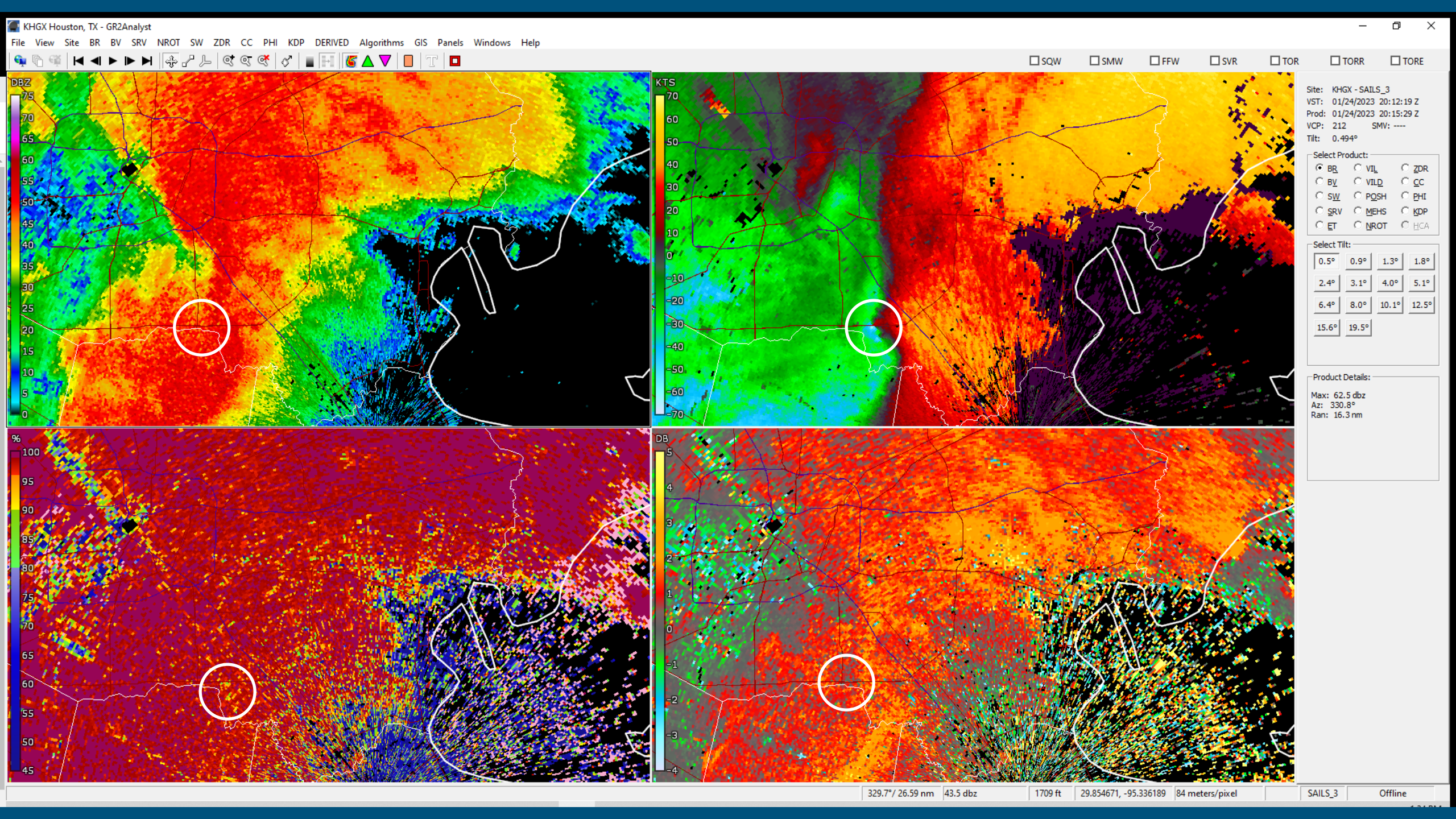

# Mesocyclone Track

Before and after sentinel imagery difference showing damage scar



https://tfsweb.tamu.edu/mmm/apr2020/


Long: -94.644, Lat: 29.724
Rotation Tracks/Low Level 6 hr
01/24/2023 22:00 UTC
January 24th, 2023
Houston
Pasadena
Sugar Land
Baytown
La Porte
Pearland
Seabrook
Friendswood
Webster
League City
Dickinson
Alvin
Manvel
Rosenberg
Pleak
Fairchilds
Arcola
Thompsons
Iowa Colony
Highlands
Channelview
Galena Park
South Houston
Deer Park
Ellington Air Force Base
MANVEL OIL FIELD
HASTINGS OIL FIELD
OIL CREEK OIL FIELD
THOMPSONS OIL FIELD
DICKINSON GILLOCK OIL FIELD
Leaflet | © OpenStreetMap


KHGX Houston, TX - GR2Analyst
File View Site BR BV SRV NROT SW ZDR CC PHI KDP DERIVED Algorithms GIS Panels Windows Help
SQW SMW FFW SVR TOR TORR TORE
DBZ
KTS
%
DB
Site: KHGX - SAILS_3
VST: 01/24/2023 20:12:19 Z
Prod: 01/24/2023 20:15:29 Z
VCP: 212 SMV: ----
Tilt: 0.494°
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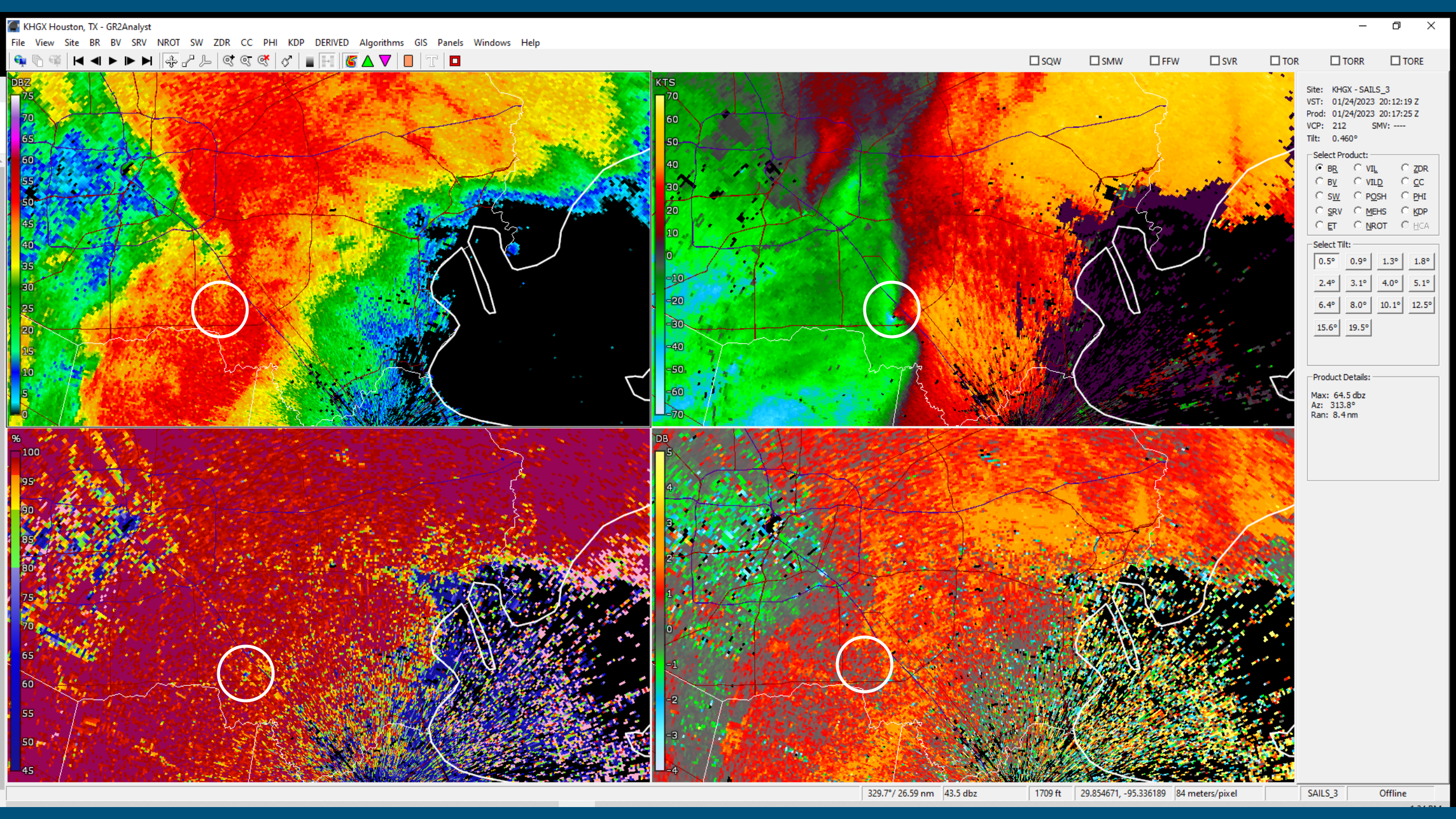
BR VIL ZDR
BV VILD CC
SW POSH PHI
SRV MEHS KDP
ET NROT HCA
Select Tilt:
0.5° 0.9° 1.3° 1.8°
2.4° 3.1° 4.0° 5.1°
6.4° 8.0° 10.1° 12.5°
15.6° 19.5°
Product Details:
Max: 62.5 dbz
Az: 330.8°
Ran: 16.3 nm
329.7°/ 26.59 nm
43.5 dbz
1709 ft
29.854671, -95.336189
84 meters/pixel
SAILS_3
Offline


KHGX Houston, TX - GR2Analyst
File View Site BR BV SRV NROT SW ZDR CC PHI KDP DERIVED Algorithms GIS Panels Windows Help
SQW SMW FFW SVR TOR TORR TORE
DBZ
KTS
%
DB
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Prod: 01/24/2023 20:17:25 Z
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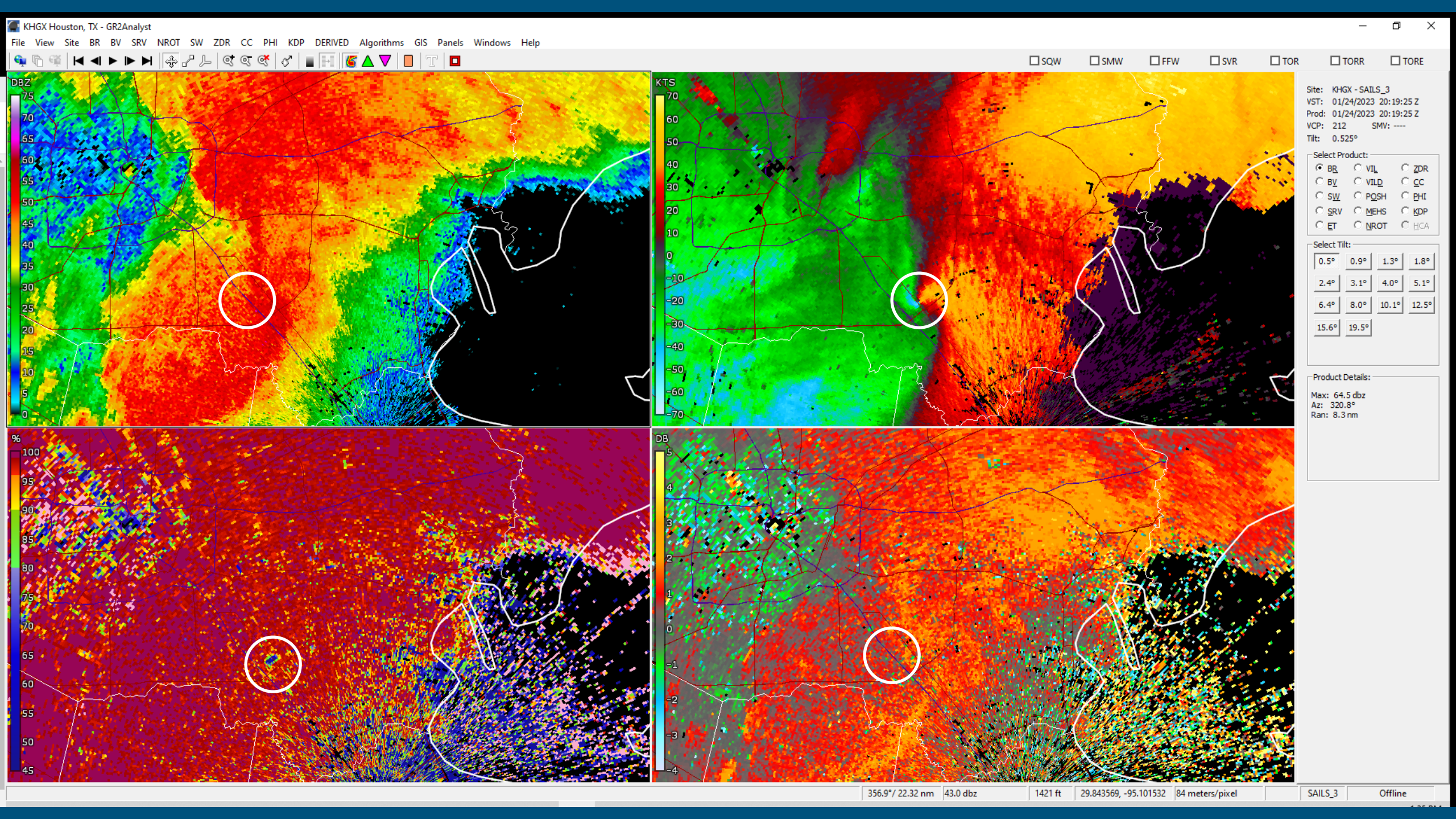
BV VILD CC
SW POSH PHI
SRV MEHS KDP
ET NROT HCA
Select Tilt:
0.5° 0.9° 1.3° 1.8°
2.4° 3.1° 4.0° 5.1°
6.4° 8.0° 10.1° 12.5°
15.6° 19.5°
Product Details:
Max: 64.5 dbz
Az: 313.8°
Ran: 8.4 nm
329.7°/ 26.59 nm
43.5 dbz
1709 ft
29.854671, -95.336189
84 meters/pixel
SAILS_3
Offline


KHGX Houston, TX - GR2Analyst
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SQW SMW FFW SVR TOR TORR TORE
DBZ
KTS
%
DB
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Prod: 01/24/2023 20:19:25 Z
VCP: 212 SMV: ----
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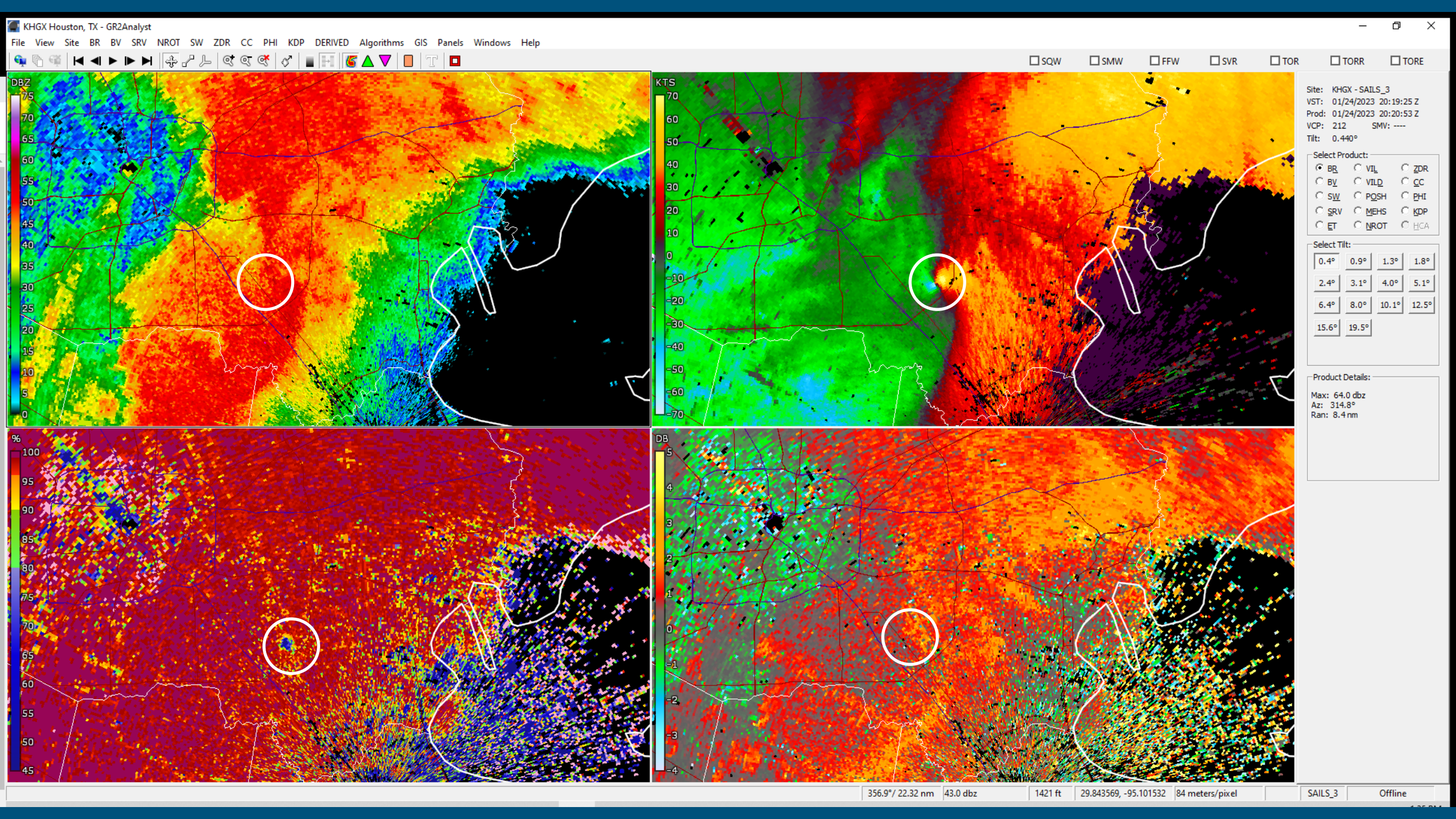
BV VILD CC
SW POSH PHI
SRV MEHS KDP
ET NROT HCA
Select Tilt:
0.5° 0.9° 1.3° 1.8°
2.4° 3.1° 4.0° 5.1°
6.4° 8.0° 10.1° 12.5°
15.6° 19.5°
Product Details:
Max: 64.5 dbz
Az: 320.8°
Ran: 8.3 nm
356.9°/ 22.32 nm
43.0 dbz
1421 ft
29.843569, -95.101532
84 meters/pixel
SAILS_3
Offline


KHGX Houston, TX - GR2Analyst
File View Site BR BV SRV NROT SW ZDR CC PHI KDP DERIVED Algorithms GIS Panels Windows Help
SQW SMW FFW SVR TOR TORR TORE
DBZ
KTS
%
DB
Site: KHGX - SAILS_3
VST: 01/24/2023 20:19:25 Z
Prod: 01/24/2023 20:20:53 Z
VCP: 212 SMV: ----
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Select Product:
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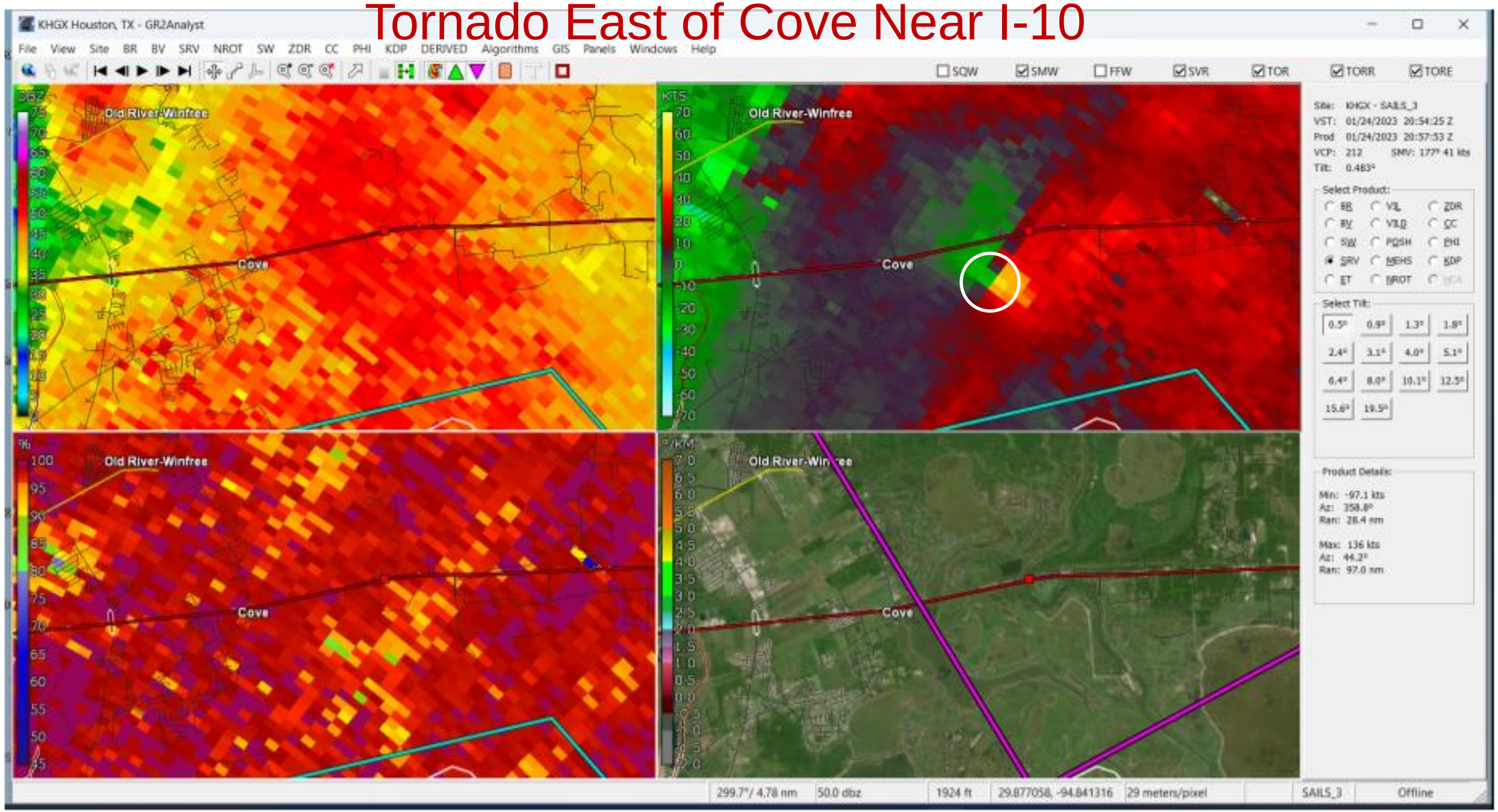
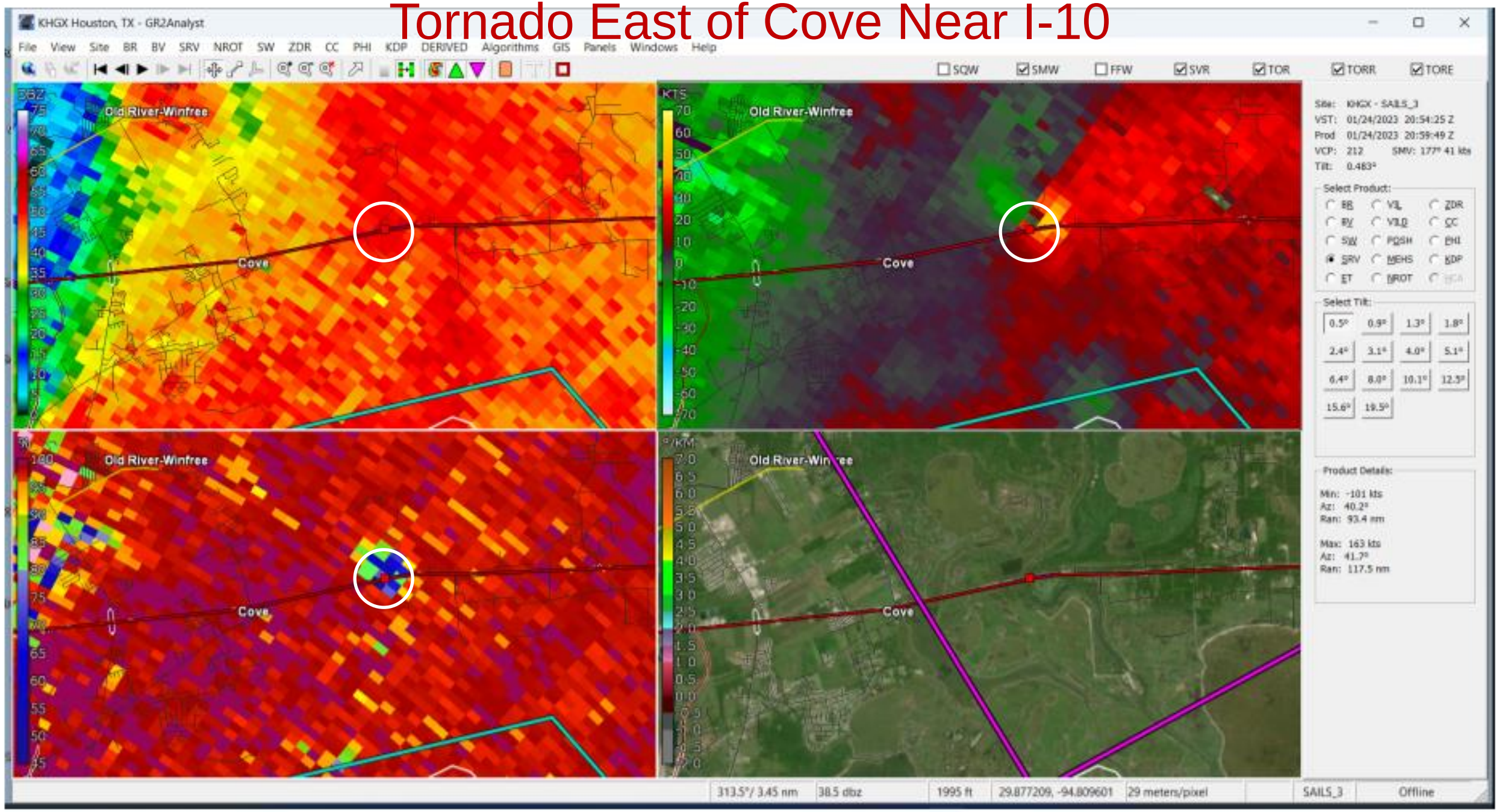
BV VILD CC
SW POSH PHI
SRV MEHS KDP
ET NROT HCA
Select Tilt:
0.4° 0.9° 1.3° 1.8°
2.4° 3.1° 4.0° 5.1°
6.4° 8.0° 10.1° 12.5°
15.6° 19.5°
Product Details:
Max: 64.0 dbz
Az: 314.8°
Ran: 8.4 nm
356.9°/ 22.32 nm
43.0 dbz
1421 ft
29.843569, -95.101532
84 meters/pixel
SAILS_3
Offline

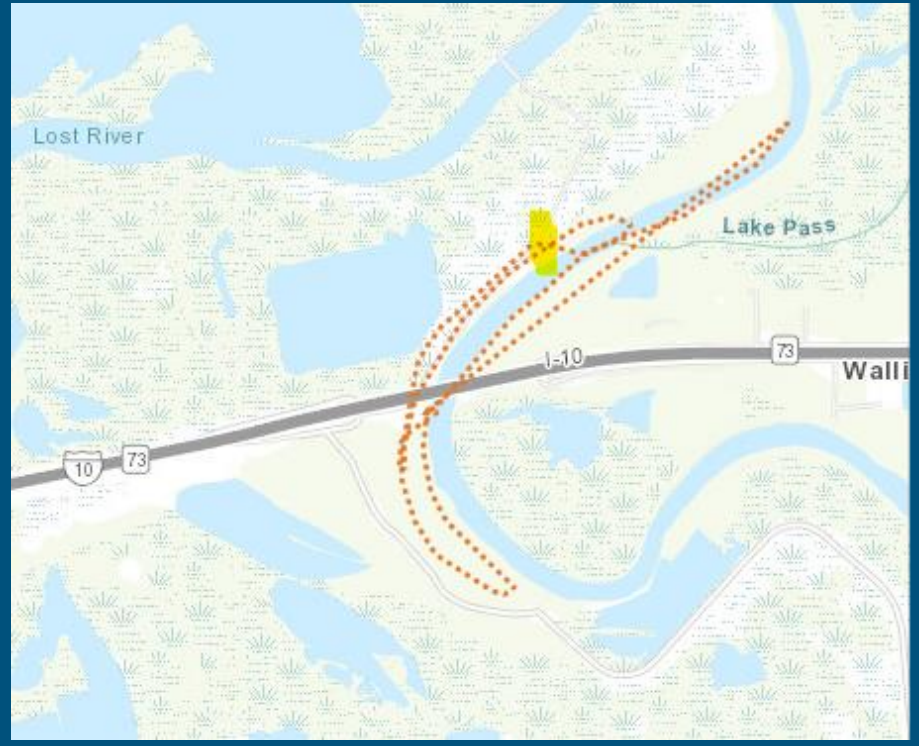
# Tornado East of Cove Near I-10

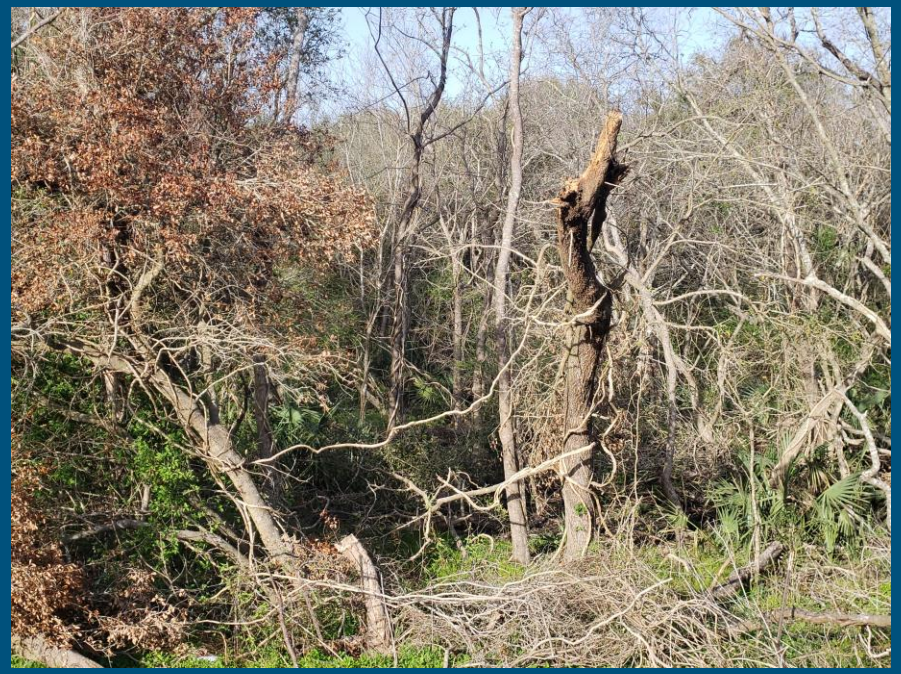


# Tornado East of Cove Near I-10

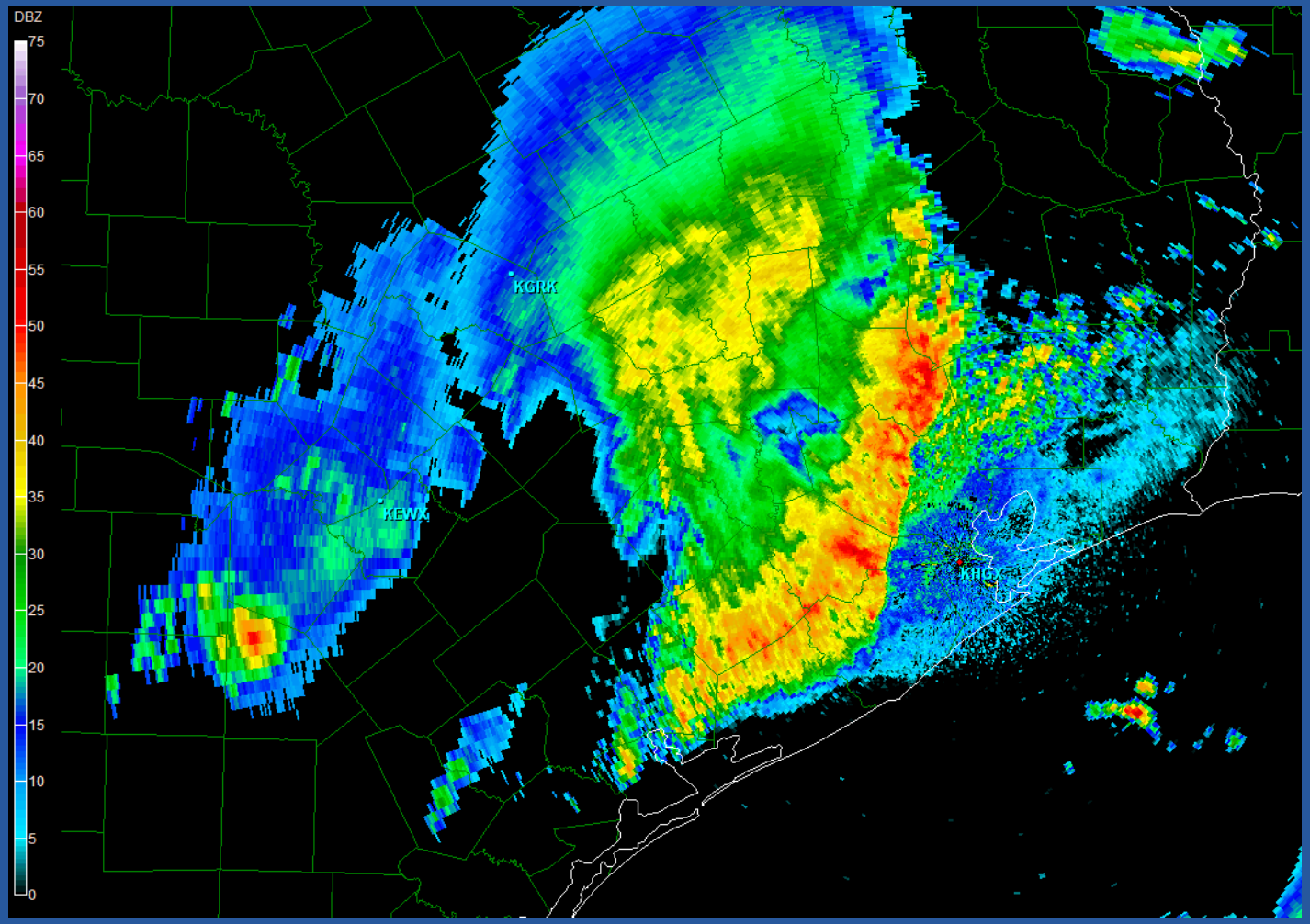


# Drone Survey from Chambers County



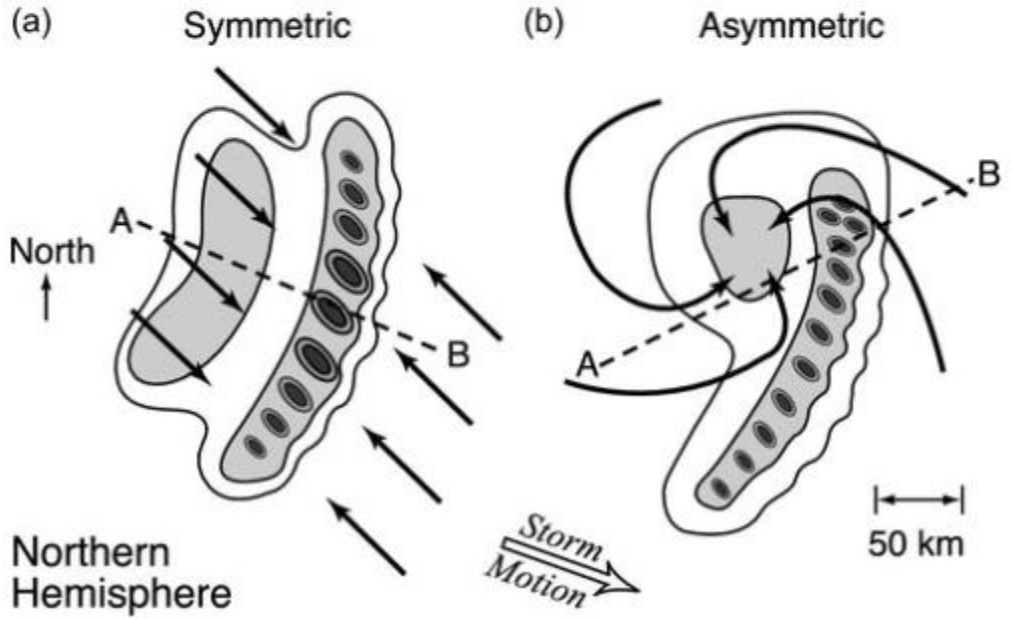



# Squall Lines: High Winds




May 2nd, 1993: Trees down, roofs damaged Harris, Brazoria, Galveston Counties; 98 mph wind gust reported at Scholes Field in Galveston; numerous homes, business were damaged

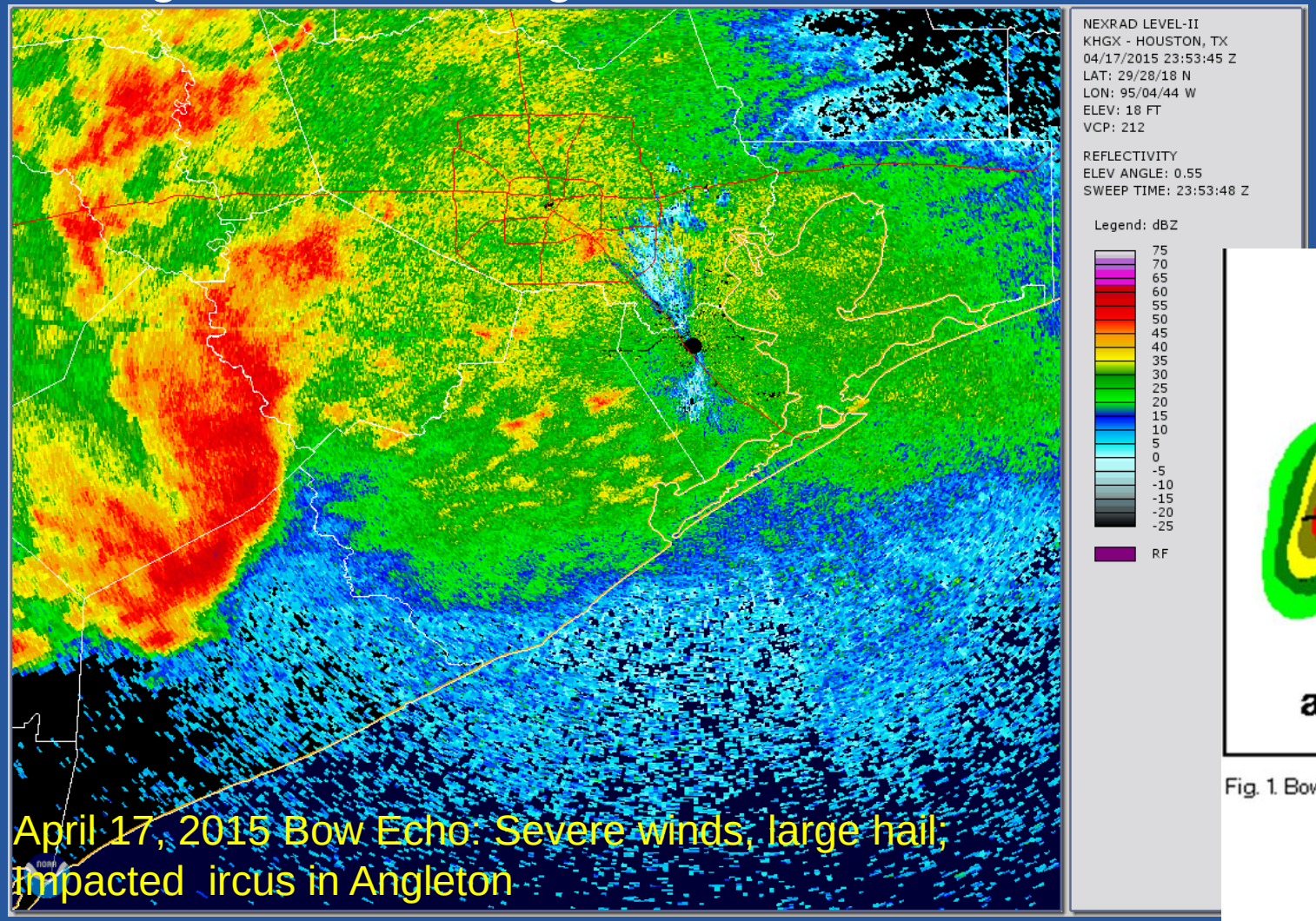
Squall-line MCSs with trailing stratiform regions have been studied extensively. A schematic representation of the low altitude radar echo typically associated with this pattern is shown in Figure 9.8. The schematic is based on a study of the mesoscale systems that occurred during springtime in Oklahoma over a 6-year period.7 The characteristics of the idealized radar-echo pattern may be summarized as follows:



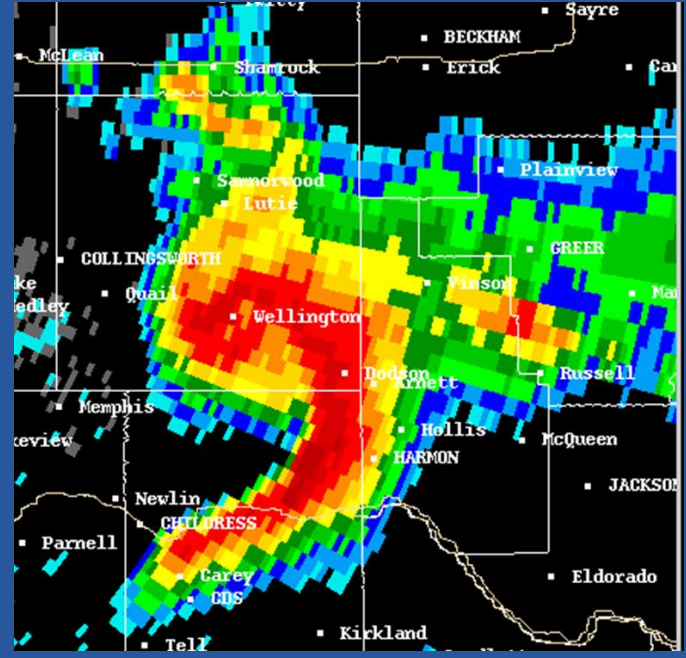

From Houze, 1993: Cloud Dynamics

# Bow Echo

Cell evolves into a bow shape, possibly boomerang or comma. Indicates strong rear inflow downdraft, potential for strong to severe straight-line winds.




April 17, 2015 Bow Echo: Severe winds, large hail; Impacted ircus in Angleton



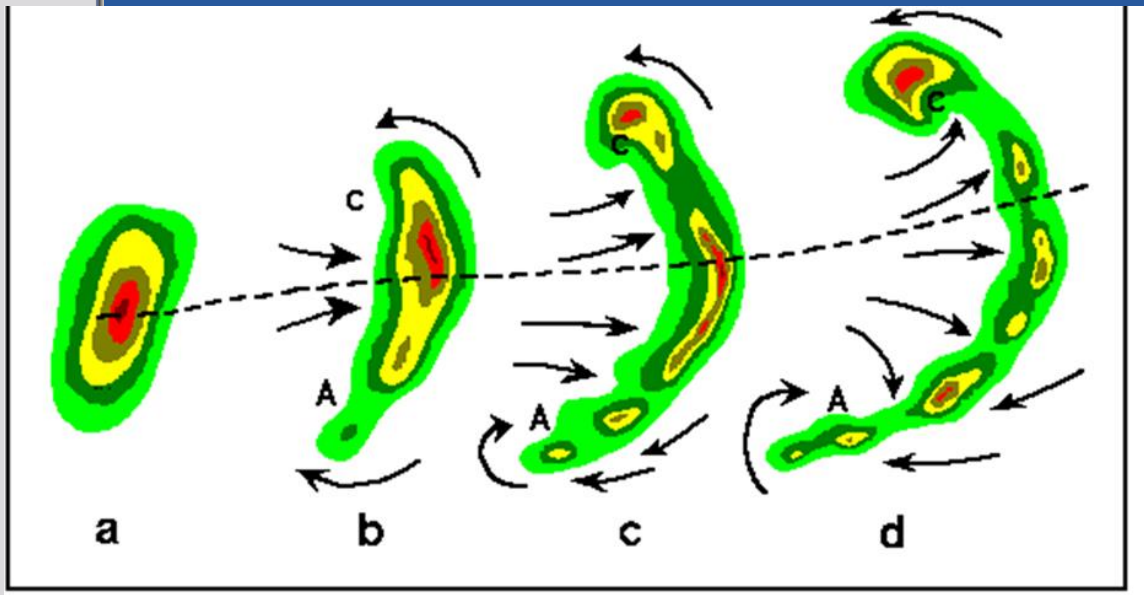




Fig. 1. Bow Echo. Typical evolution of a thunderstorm radar echo (a) into a bow echo (b,c) and into a comma echo (d). Dashed line indicates axis of greatest potential for downbursts. Arrows indicate wind flow relative to the storm. Note regions of cyclonic rotation (C) and anticyclonic rotation (A); both regions, especially C, are capable of supporting tornado development in some cases.

# Review:  What is This?

Shelf Cloud indicating leading edge of storm outflow (outflow boundary, gust front)

# Review:  What is This?

Anvil, overshooting top, indicating strong updraft

# Review:  What is This?

Wall Cloud indicating updraft region of a supercell thunderstorm, the most severe type

# Review:  What is This?

Rain Boot, light blocking rain shaft: Strong downdraft, damaging wind potential

Note curl at the leading edge (the toe)

# Review:  What is This?

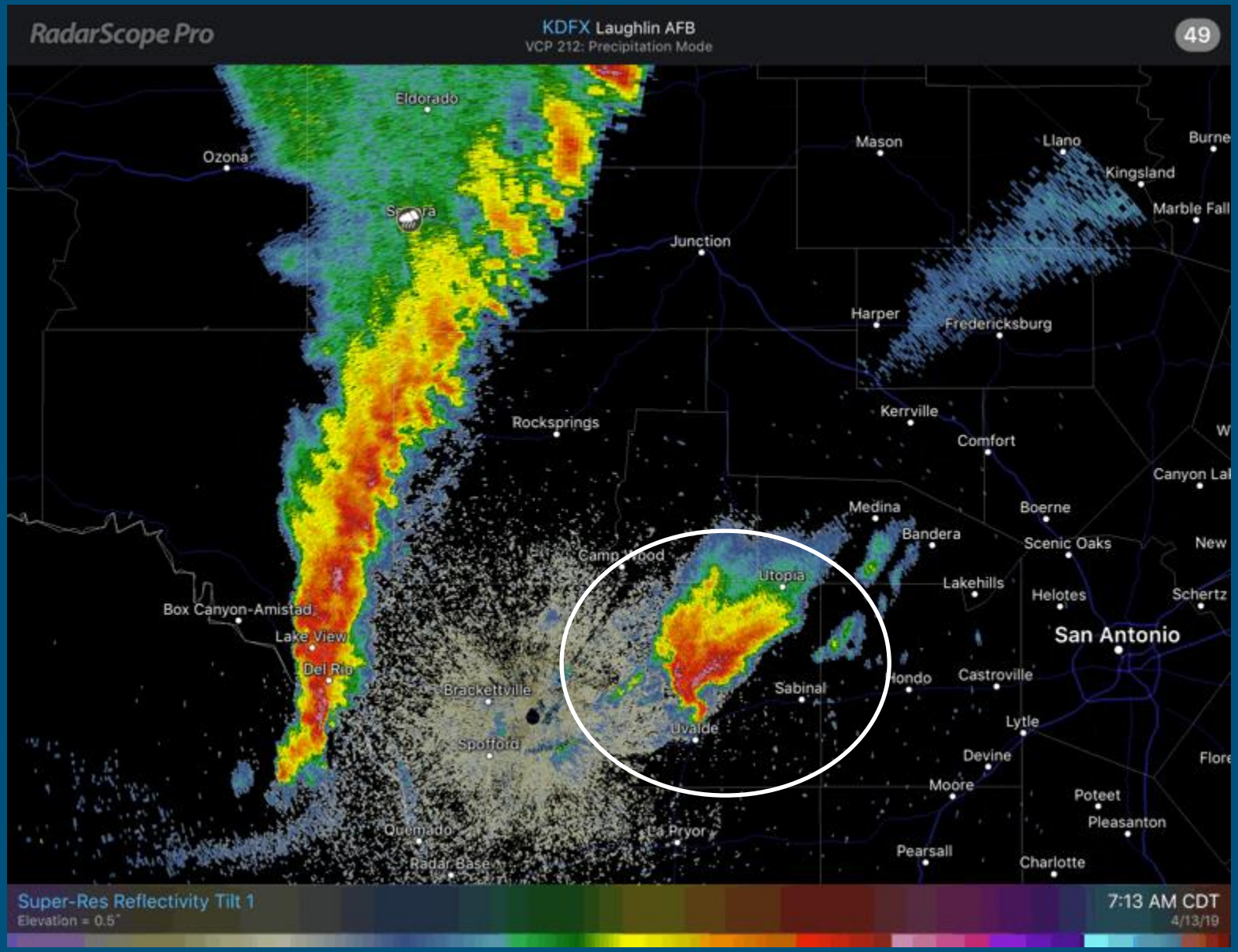
Most likely a rain shaft

# Review:  What is This?

Likely a Wall Cloud indicating updraft region of a supercell thunderstorm, the most severe type

"Underwood @ Pasadena Blvd in La Porte going North bound. The massive tornado that was in Baytown." Redline_K9_Rescue (Reddit)

# What Types of Thunderstorms Do We See Here?




April 13th, 2019 7 AM

# More Training/Resources

https://www.weather.gov/hgx/skywarn

Latest Spotter Field Guide

https://www.weather.gov/media/owlie/SGJune6-11(1).pdf