

# Advanced Spotter Training 2021

*Austin Jamison  
National Weather Service – Phoenix, AZ*



*Photo: Mark Rebilas*

# About Our Office



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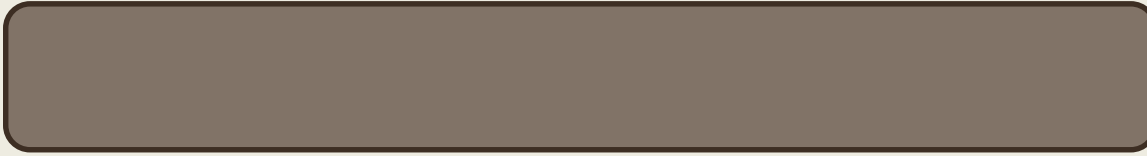


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# Program Outline



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# Five Fundamental Rules



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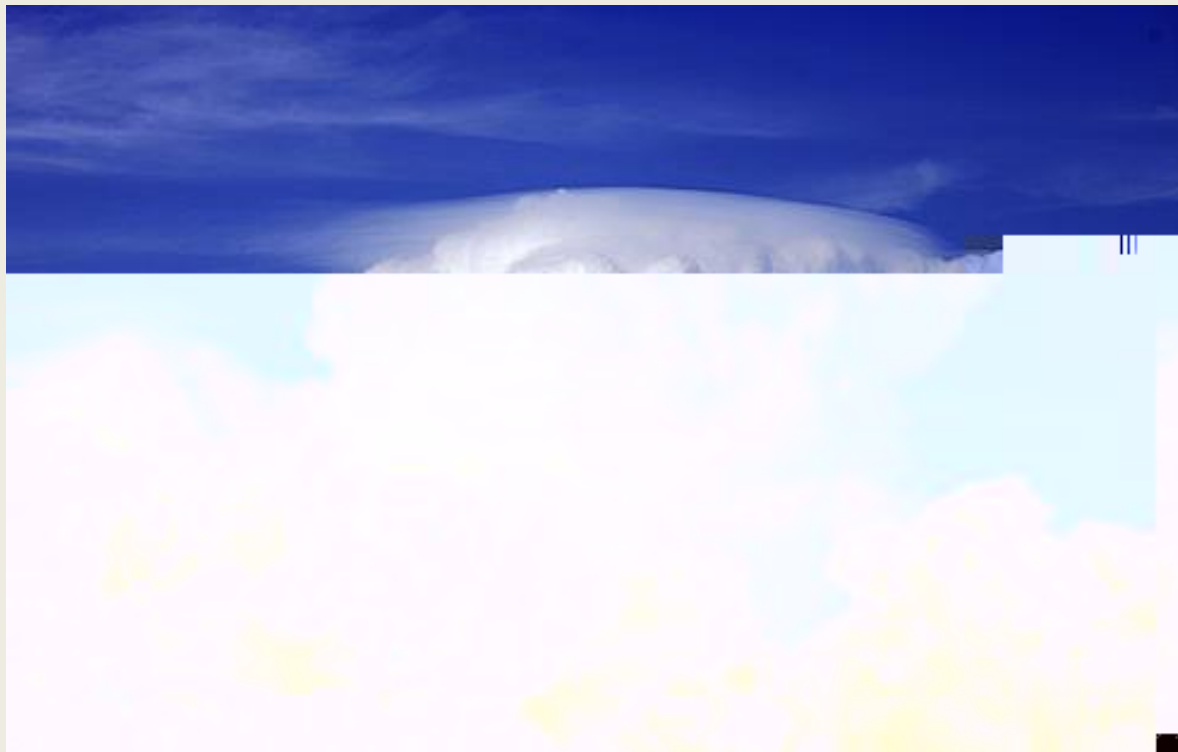


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# Organized Storm Ingredients



*Stan Celestian*



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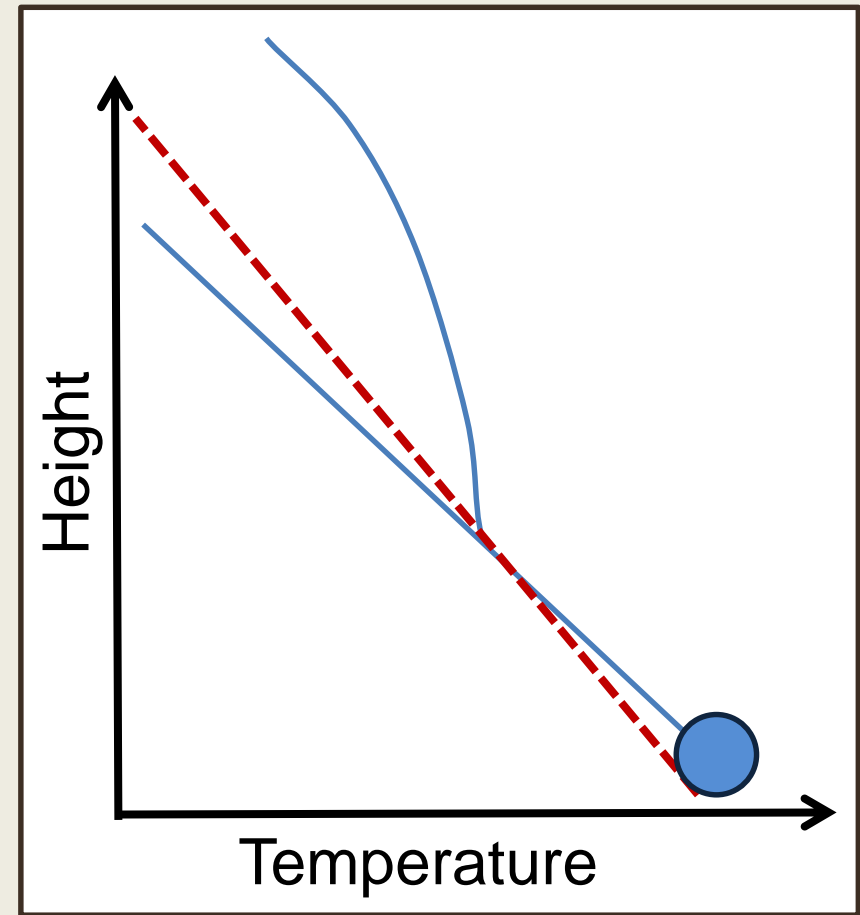
# Moisture

*Why is this?*

LATENT HEAT RELEASE –

condenses

warmed



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# Instability

**UNSTABLE**

**STABLE**



*Jeremy Perez*



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# How do we measure instability?

CAPE C A P E

CIN C In

| CAPE Value (J/kg) | Severe Weather Potential |
|-------------------|--------------------------|
|                   |                          |
|                   |                          |
|                   |                          |



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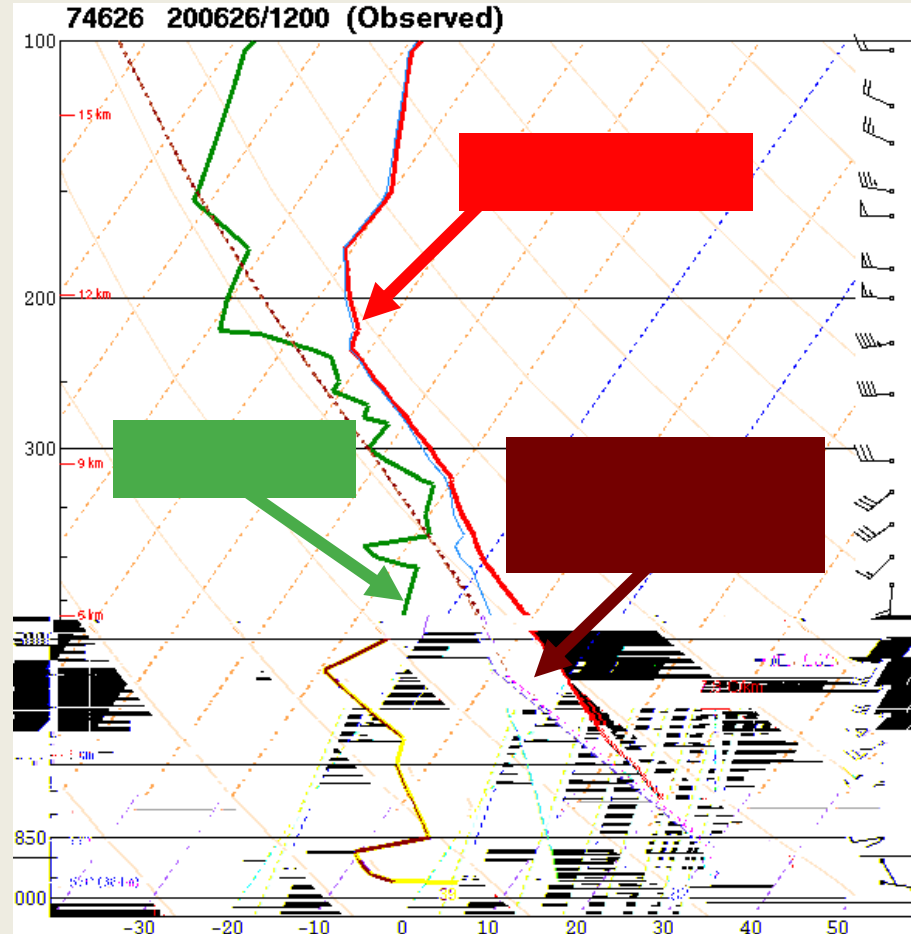


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# Thunderstorm Ingredients and Skew-T's

Skew T:



For real-time observed soundings:

<https://www.spc.noaa.gov/exper/soundings/>



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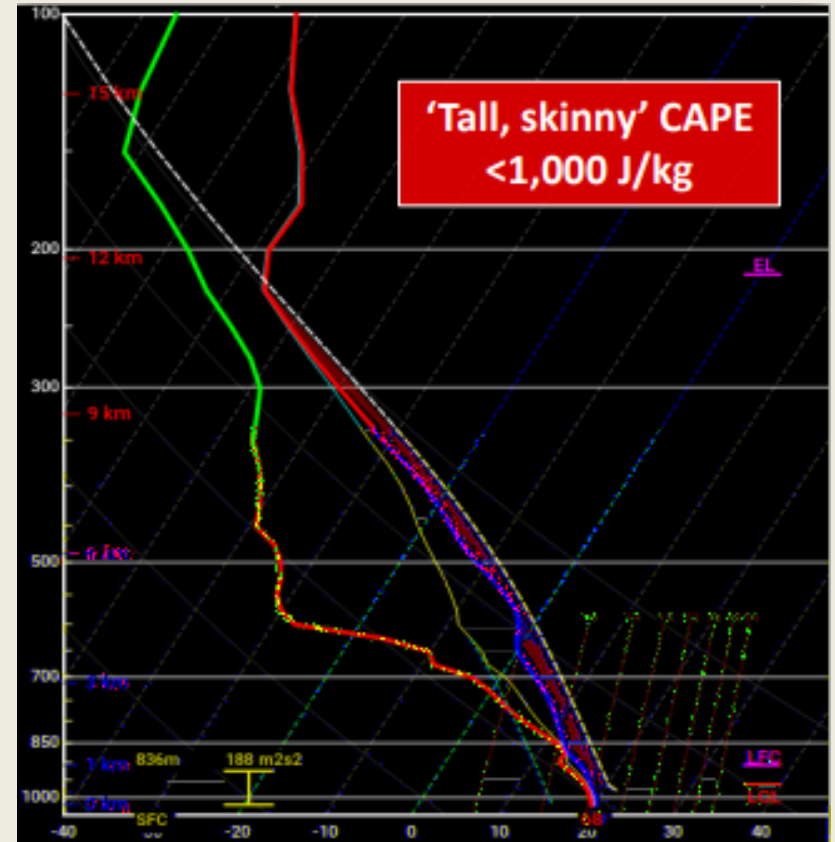
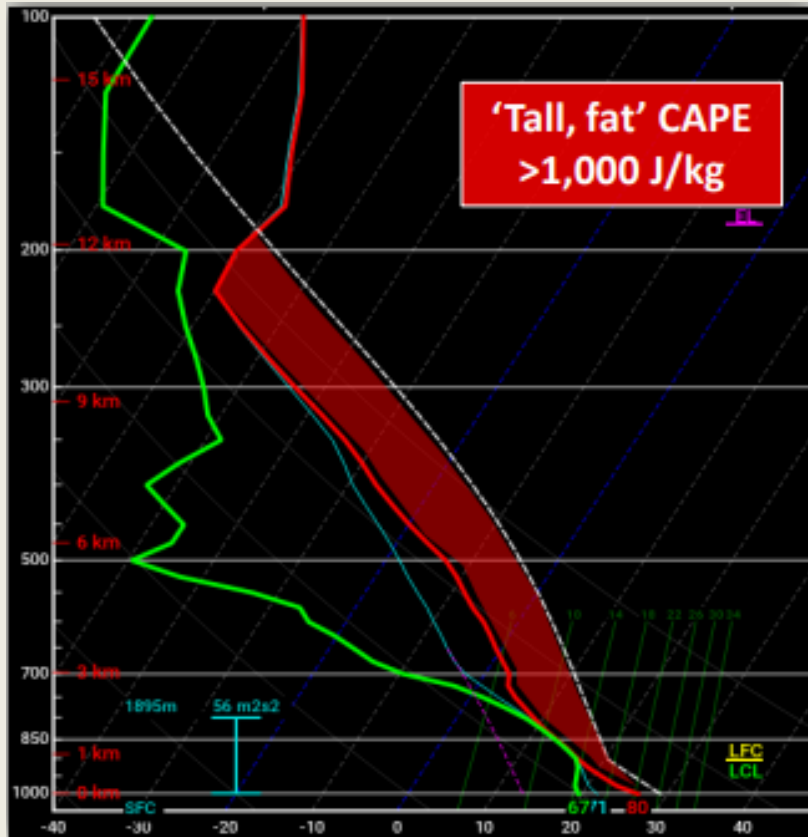


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# Instability – Weak vs. Strong CAPE



NWS Birmingham



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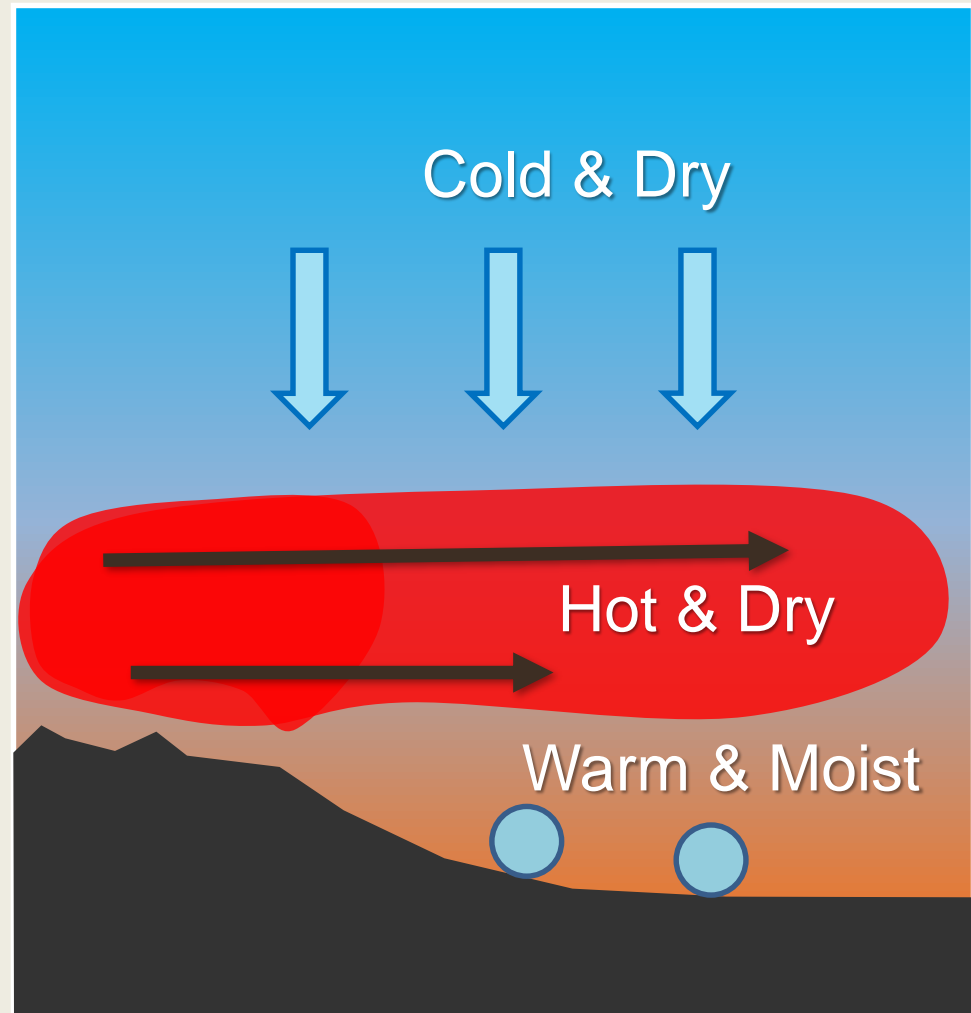


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# Instability – The Cap (aka CIN)



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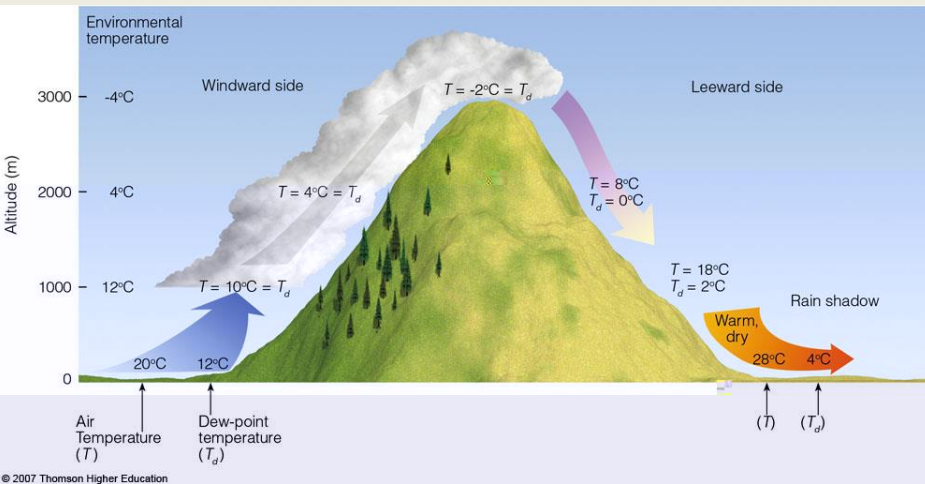
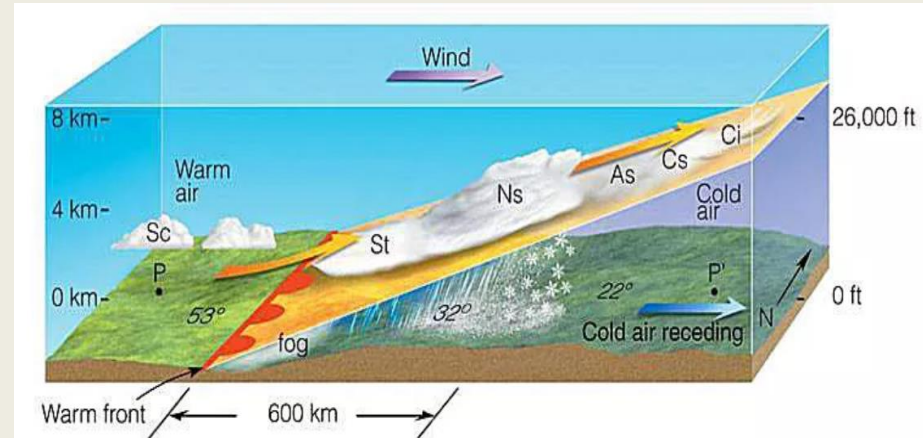


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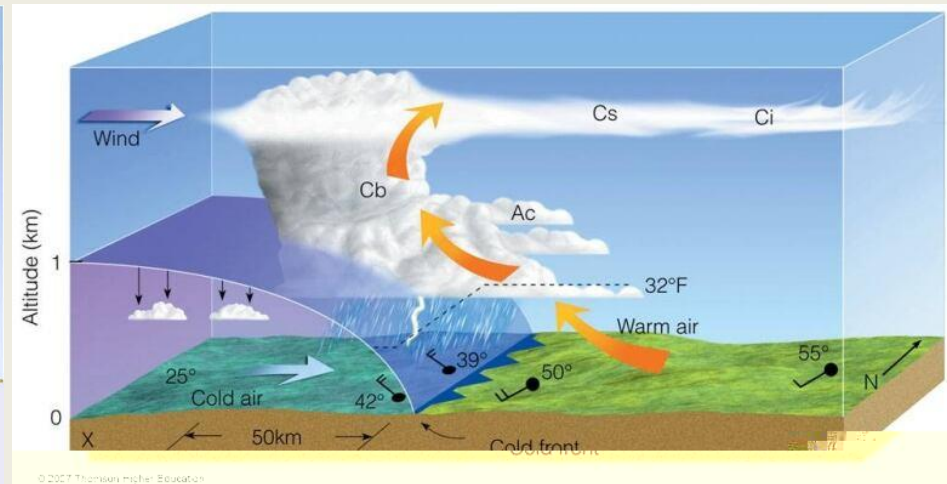


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# Lift



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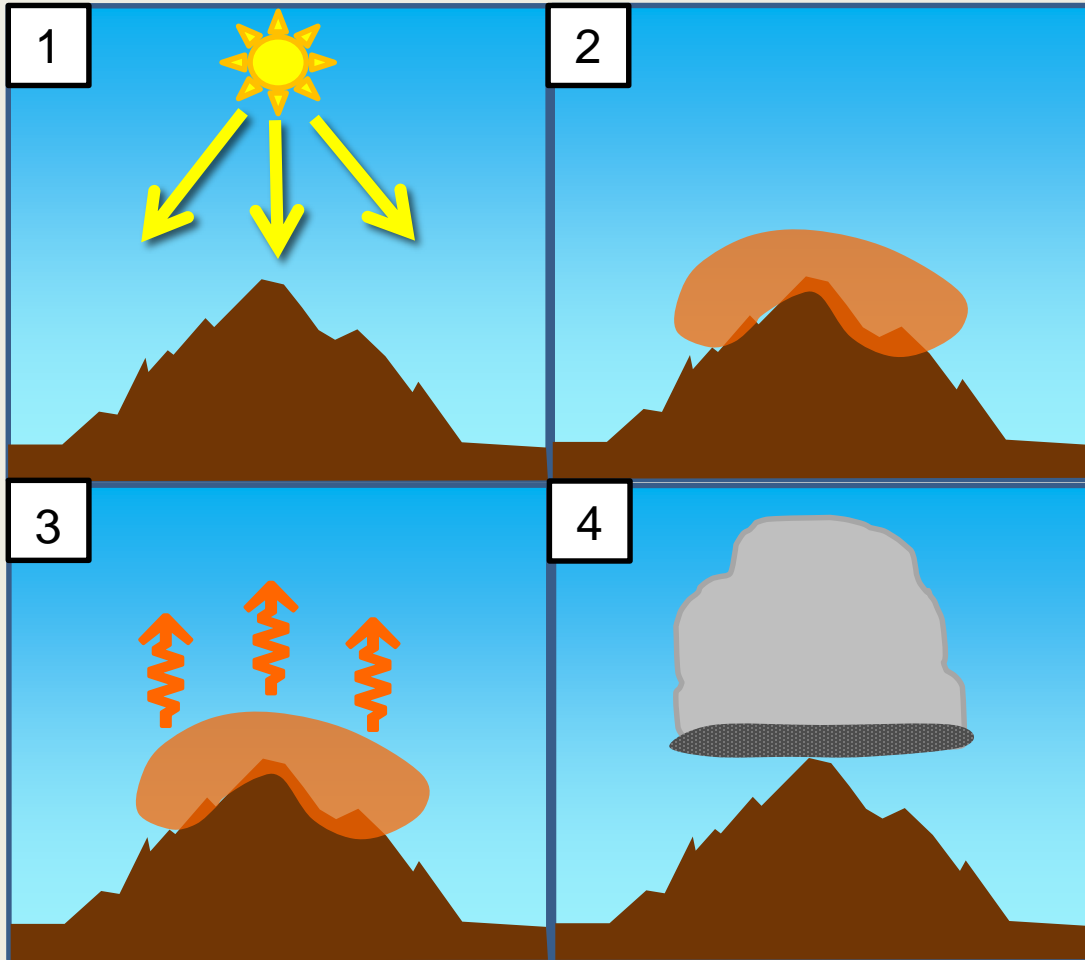


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# Lift – Elevated Heat Source



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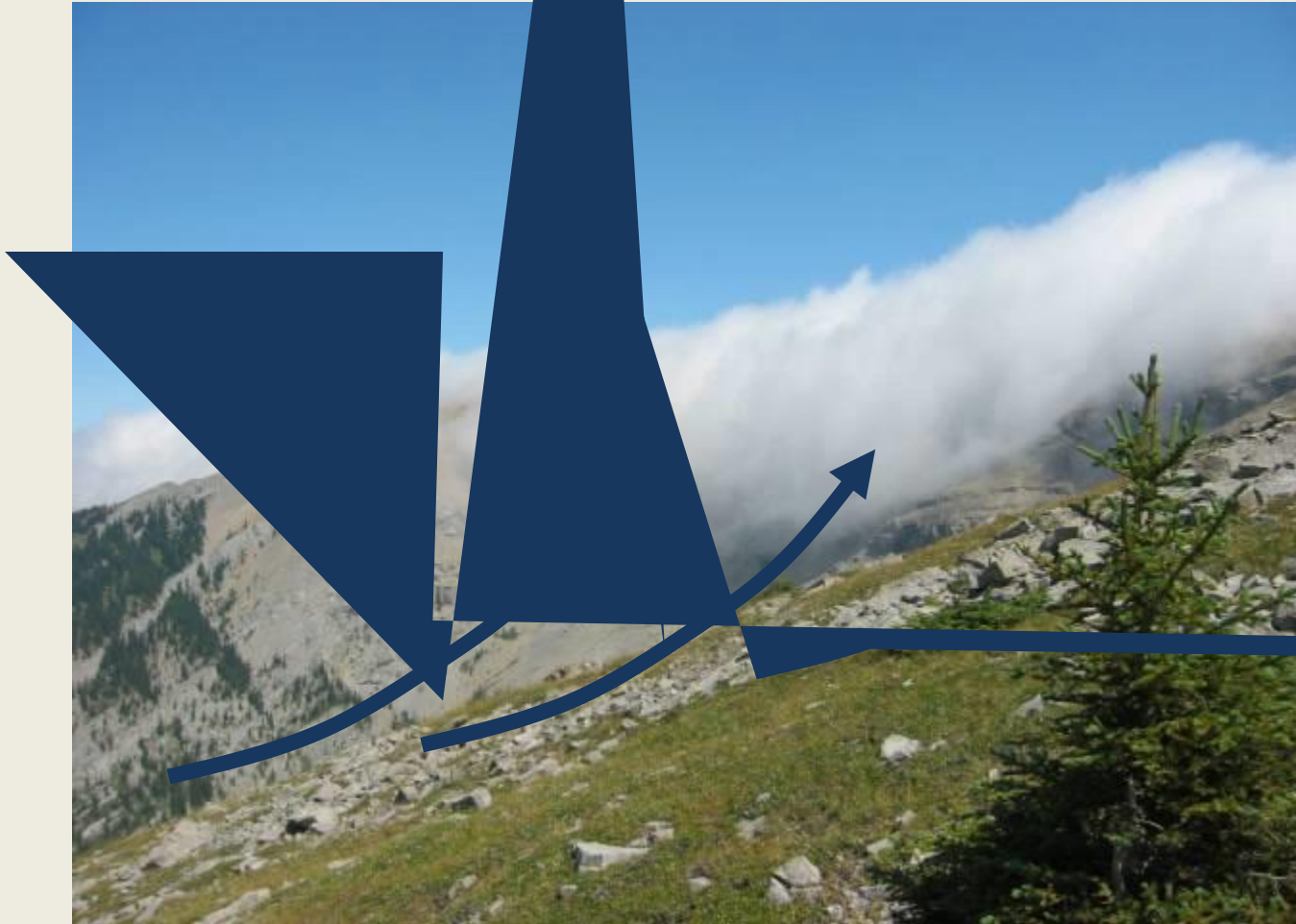


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# Lift – Upslope Flow



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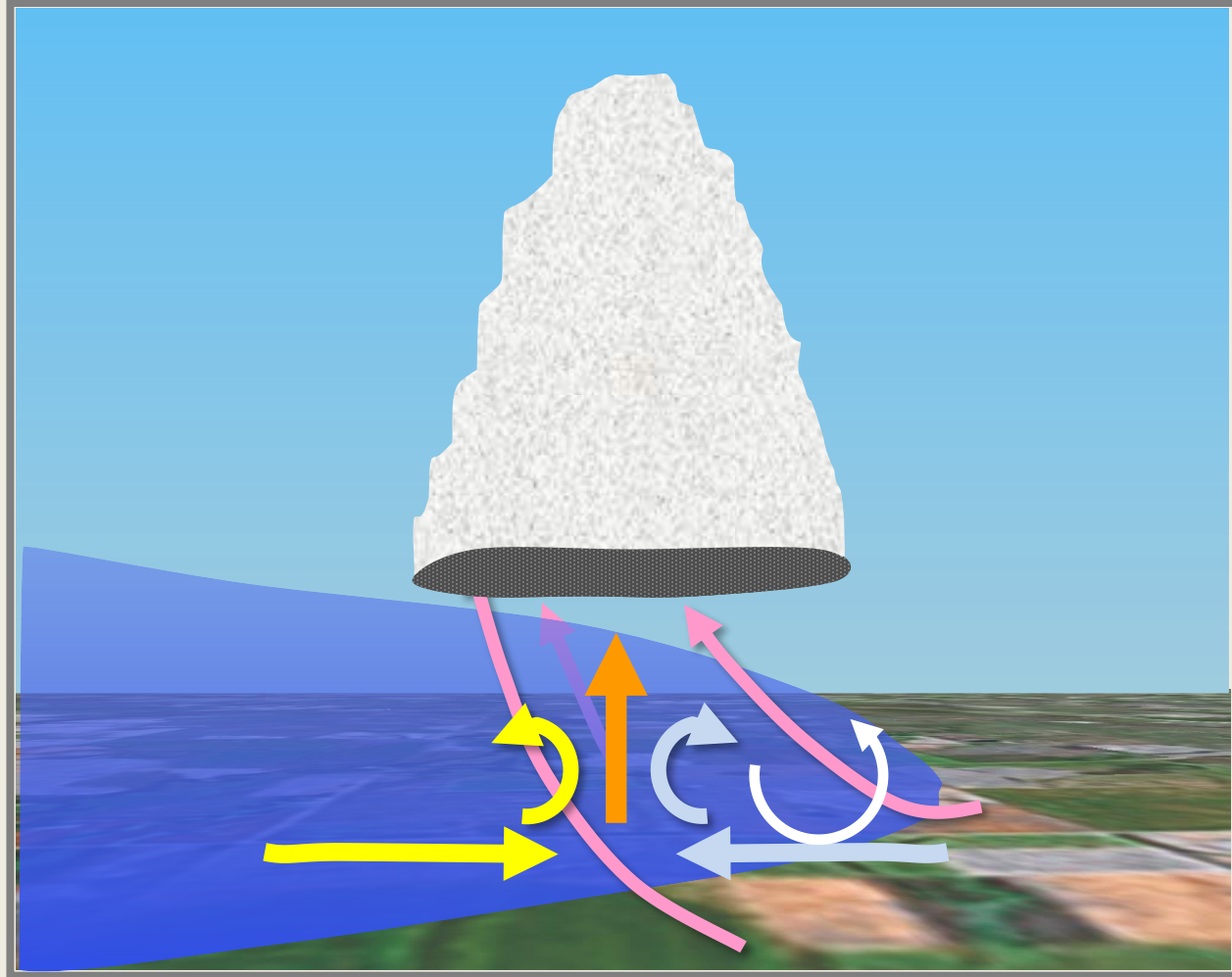


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# Lift – Fronts & Boundaries



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# Vertical Wind Shear



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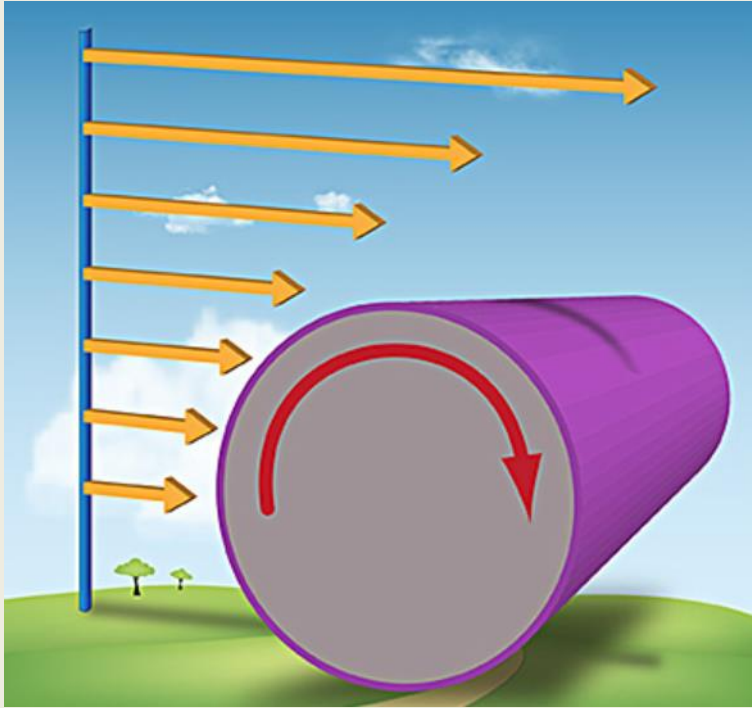
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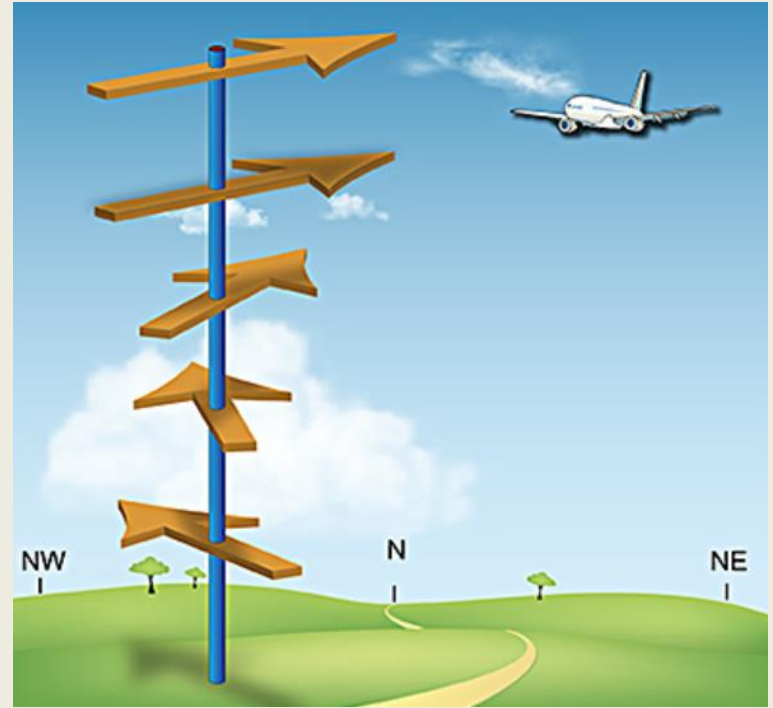
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# Wind Shear – Types



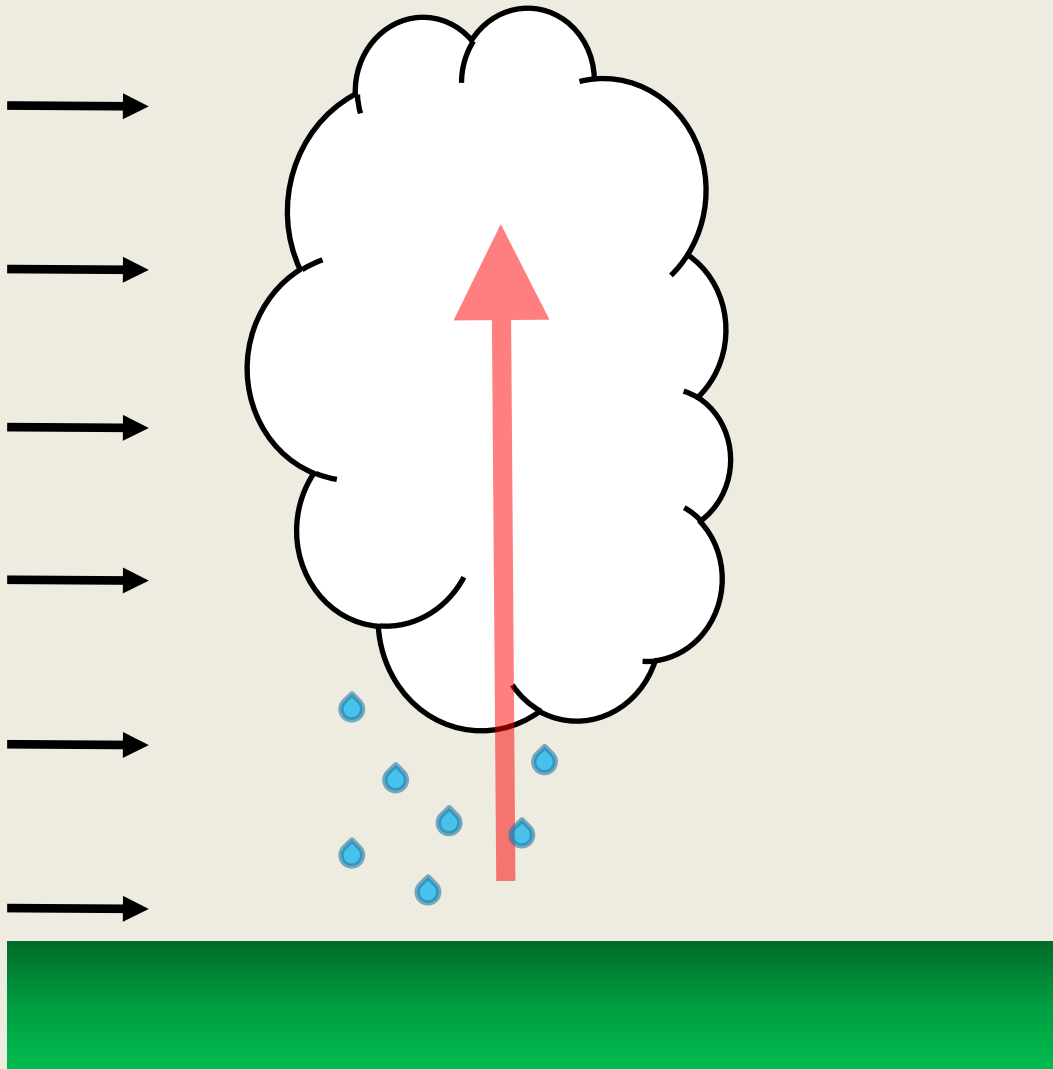
speed



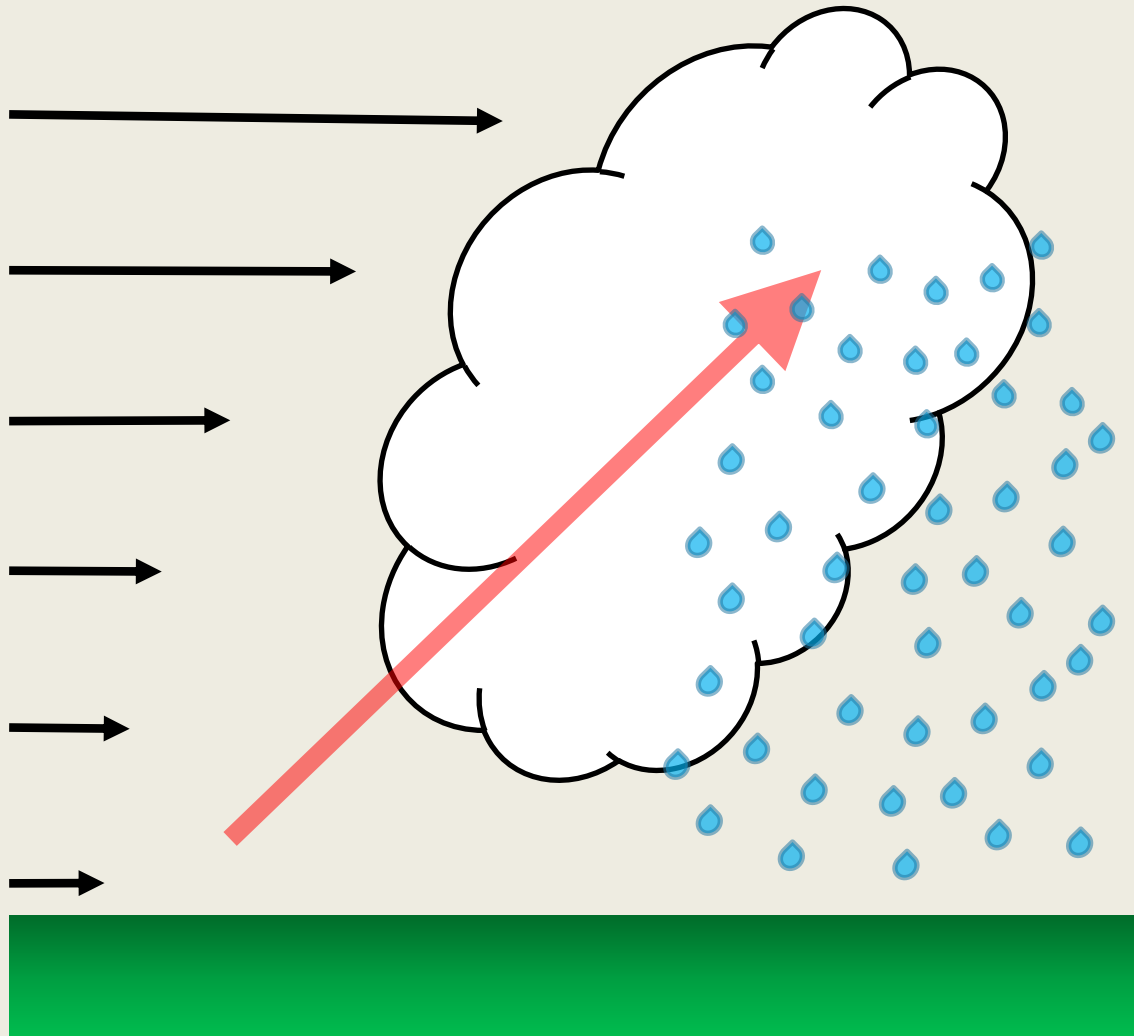
direction



# Weak Deep-Layer Shear



# Strong Deep-Layer Shear



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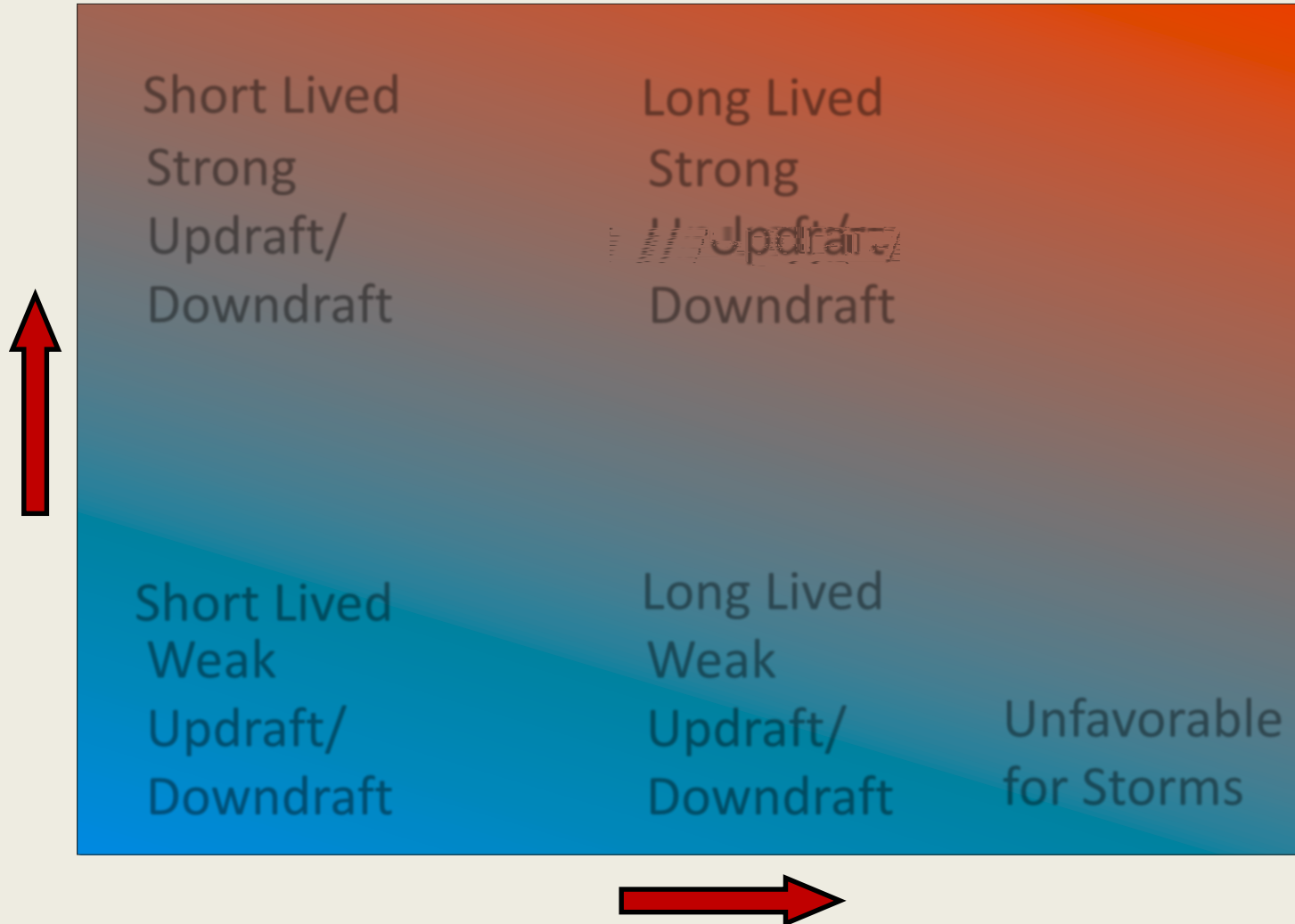


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# Instability and Vertical Shear



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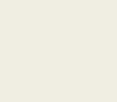
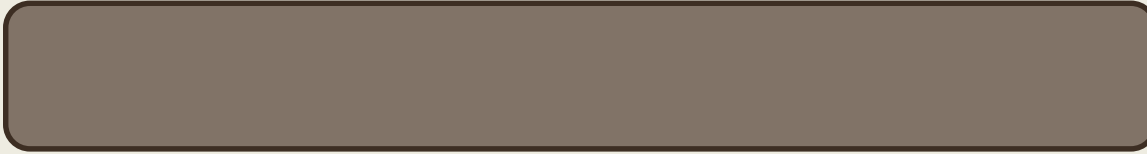


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# Program Outline



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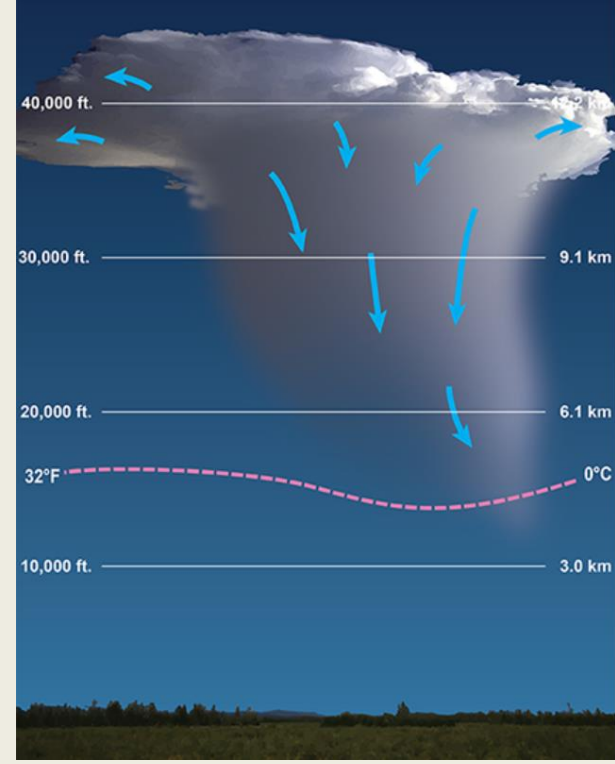
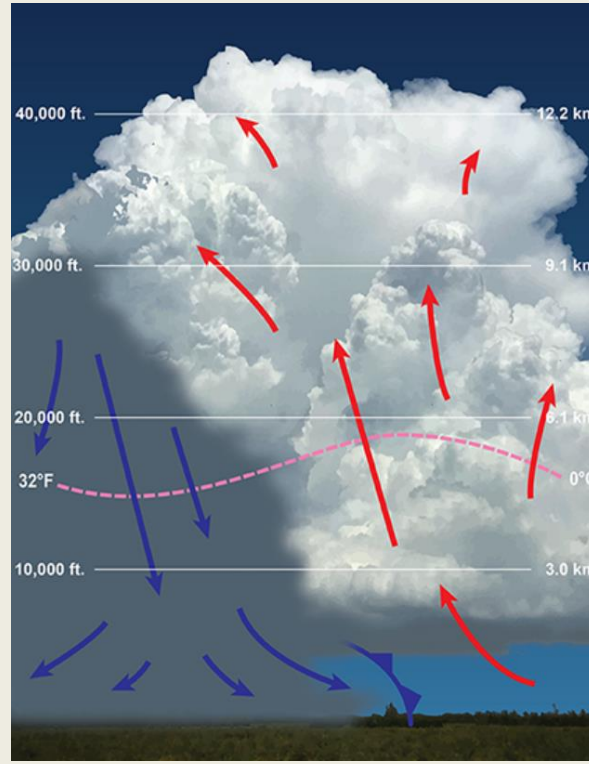
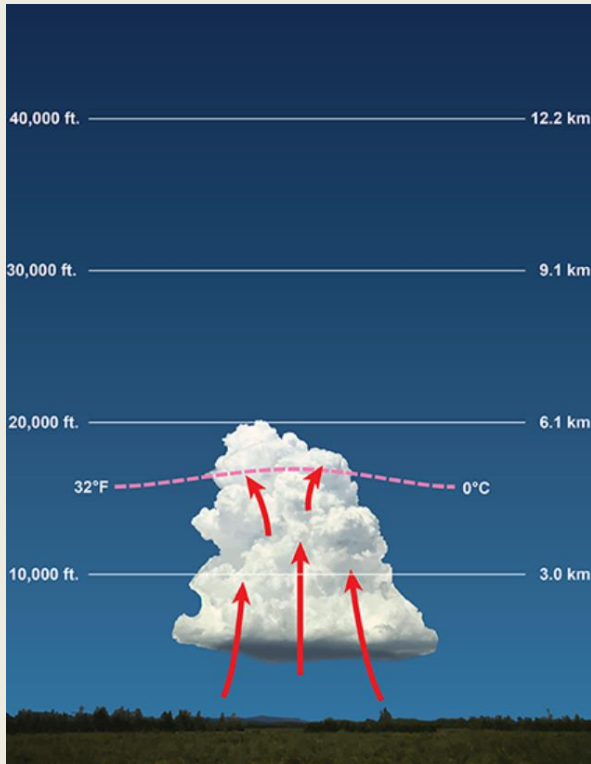


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# Ordinary Thunderstorms



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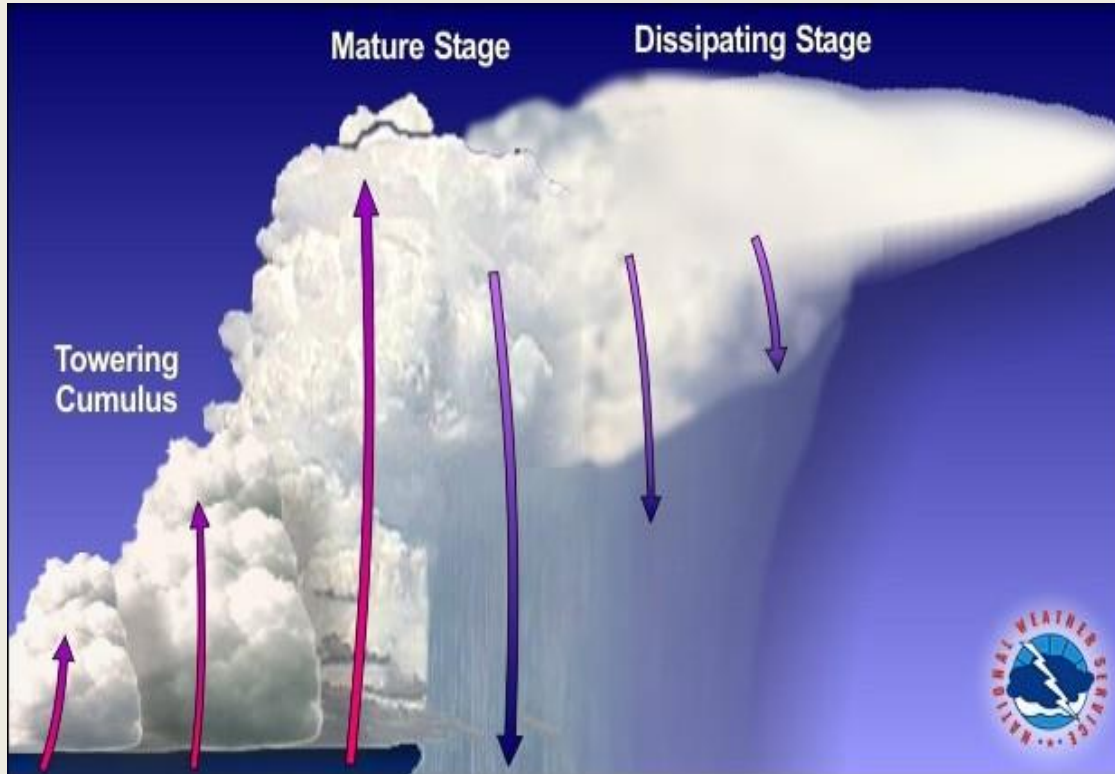


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# Multi-cell Thunderstorms



backbuilding



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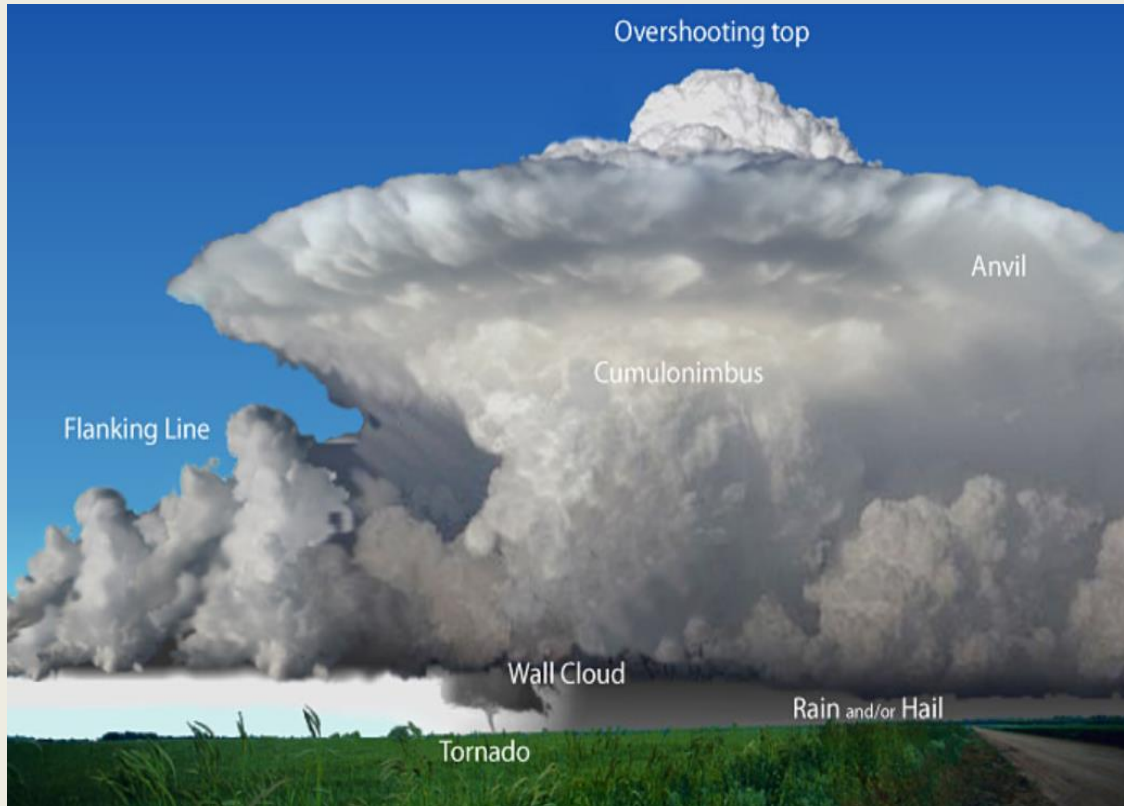


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# Supercell Thunderstorms



flash flood threat



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# Supercells Mesocyclone

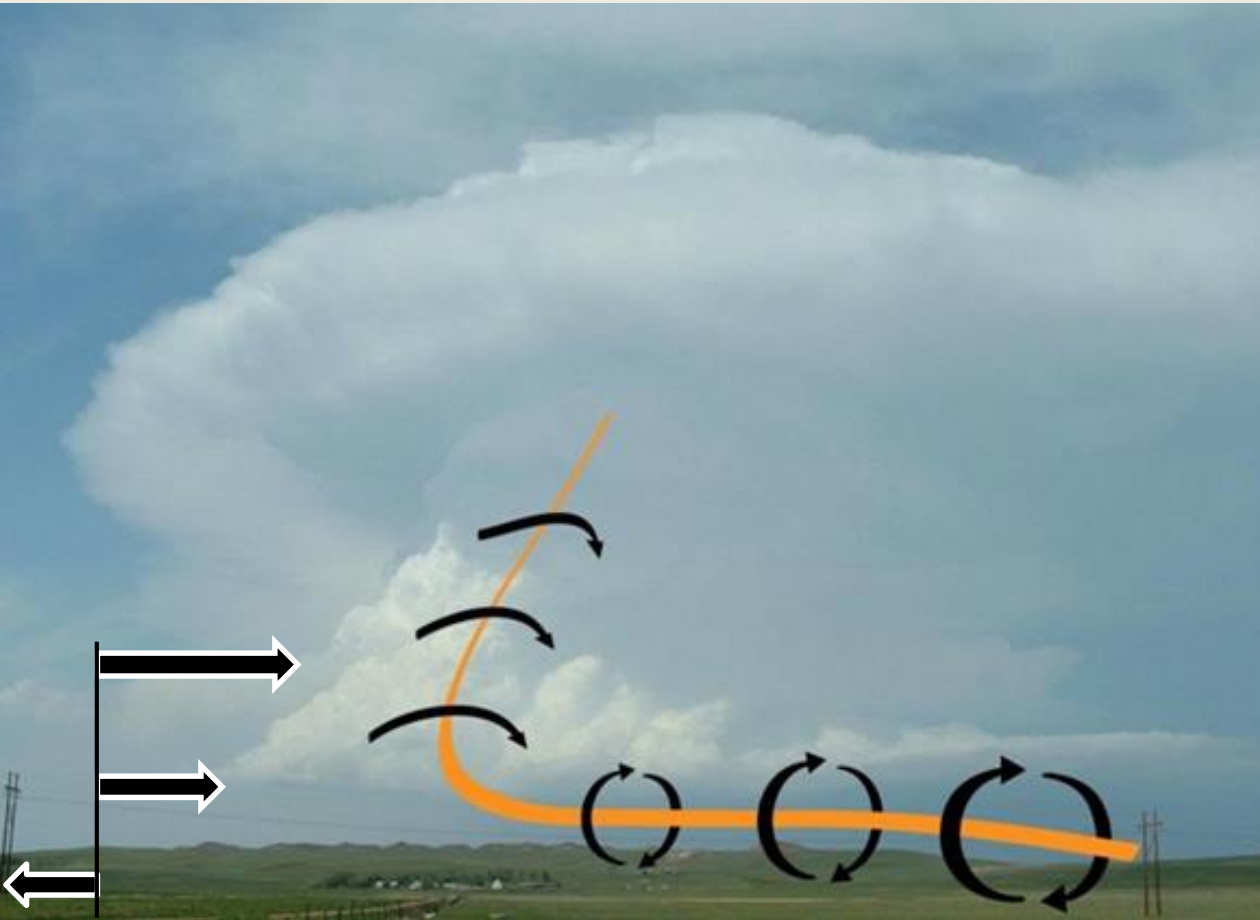


Photo: Markowski and Robinson (2010)



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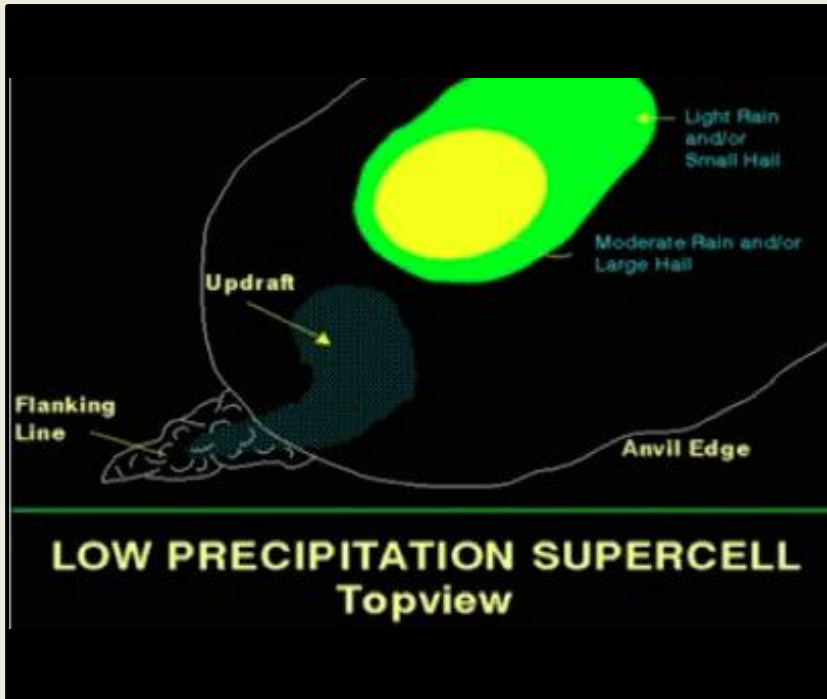


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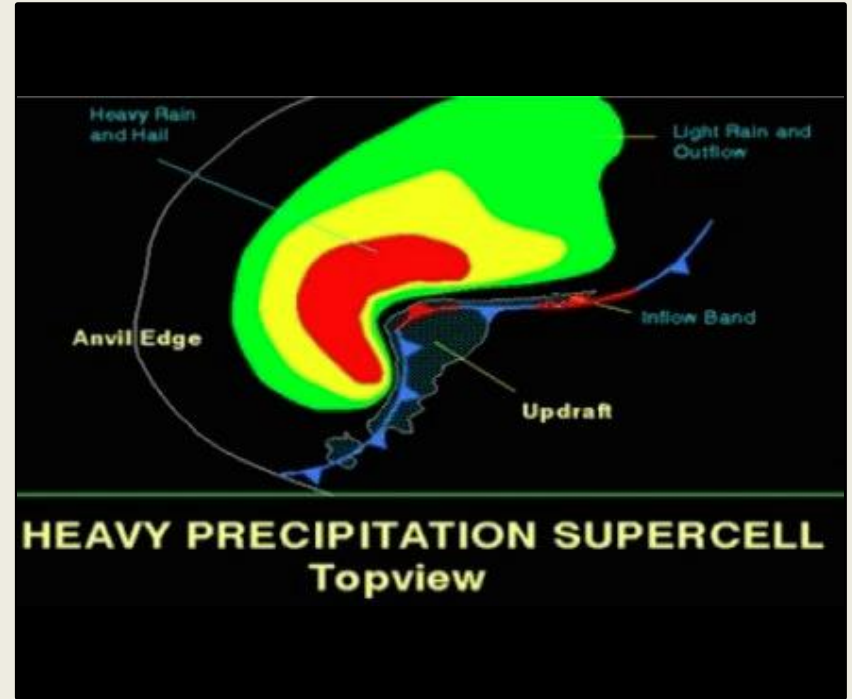


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# Types of Supercells



Low-Precip (LP) Supercells



High-Precip (HP) Supercells



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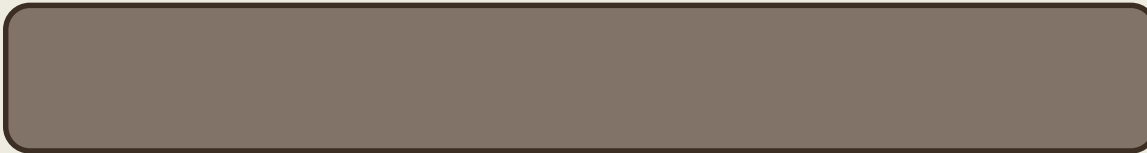


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# Program Outline



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# Tornadoes - Tornadogenesis

**3 step process to tornado formation**



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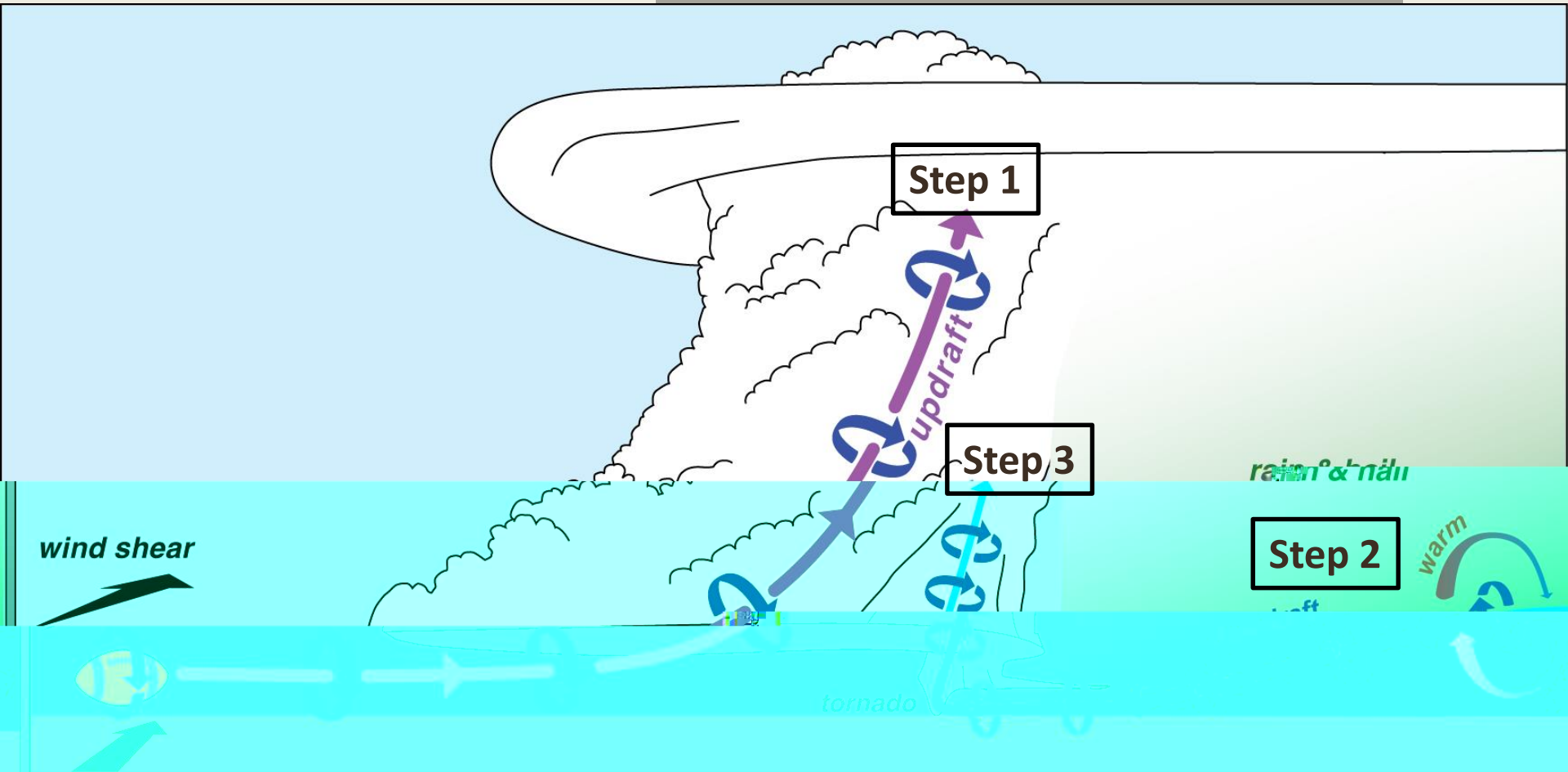


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# Tornadoes - Tornadogenesis



Images: <https://sites.psu.edu/tornadoes/>



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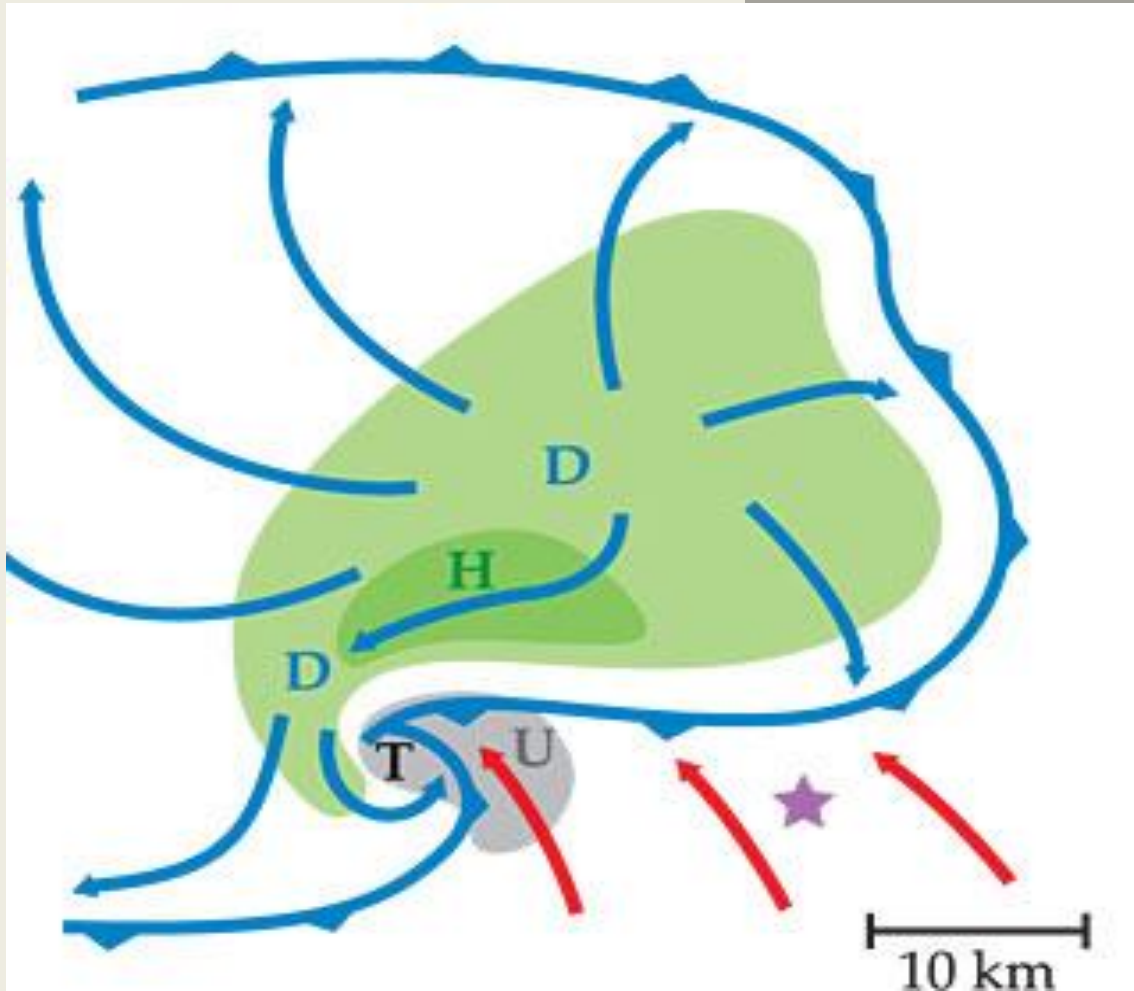


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# Tornadoes - Tornadogenesis



Tornadic Supercell Top View

Images: *Physics Today* - Markowski and Richardson (adapted from Lemon and Doswell)



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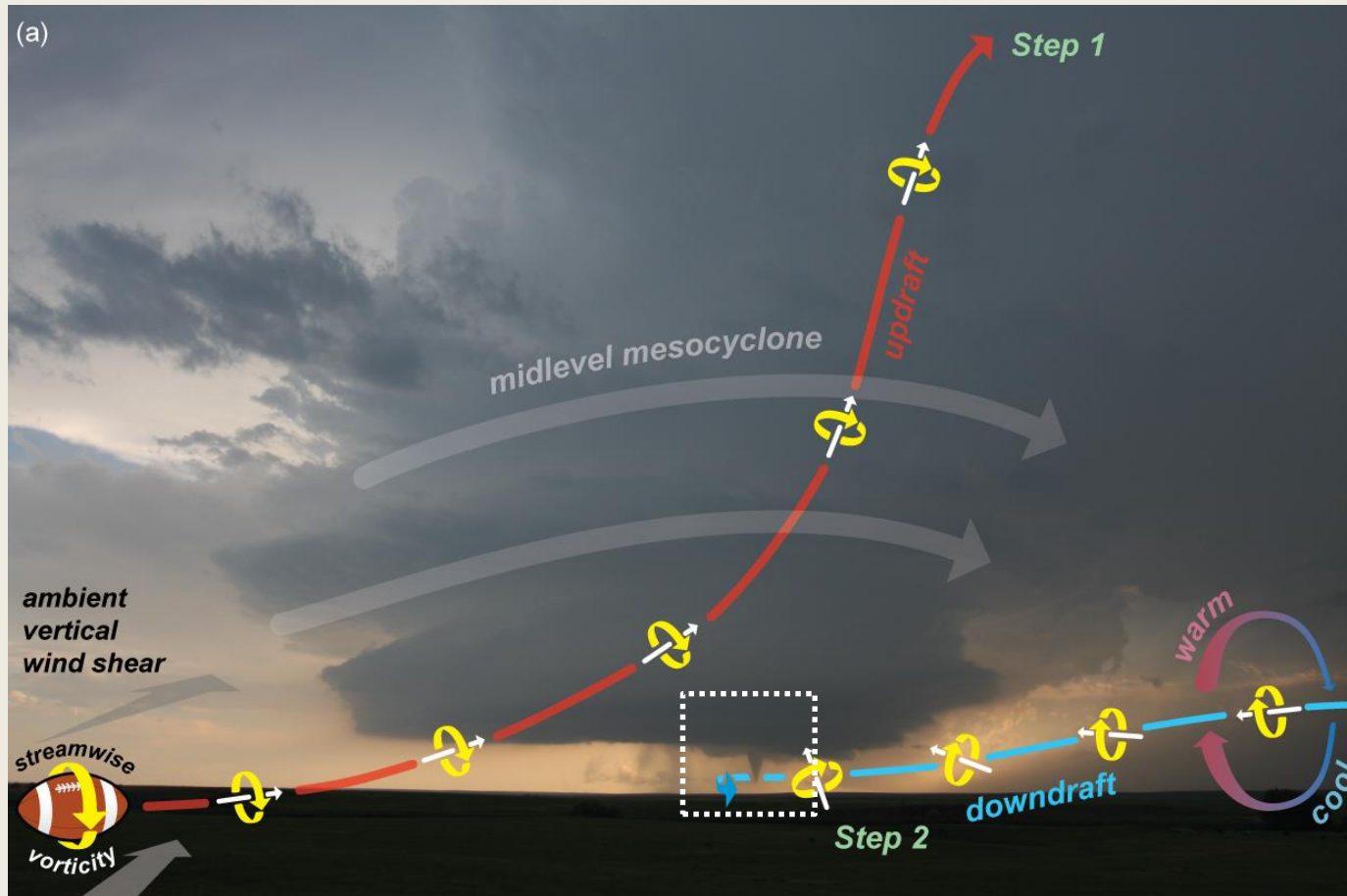
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# Tornadoes - Tornadogenesis

## Steps 1 & 2



Images: <https://sites.psu.edu/tornadoes/>



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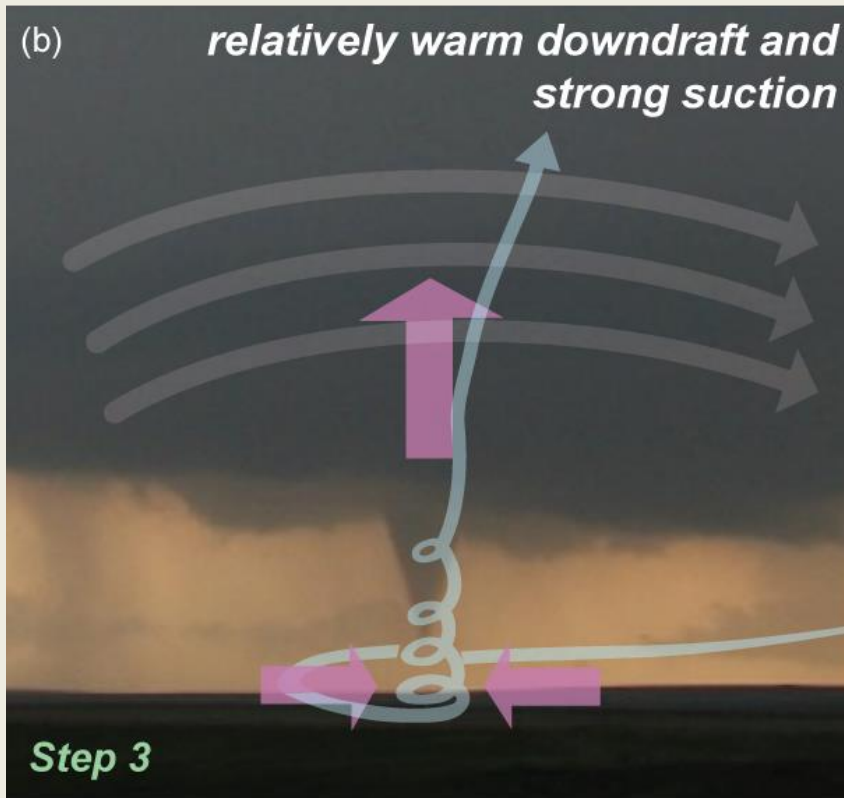
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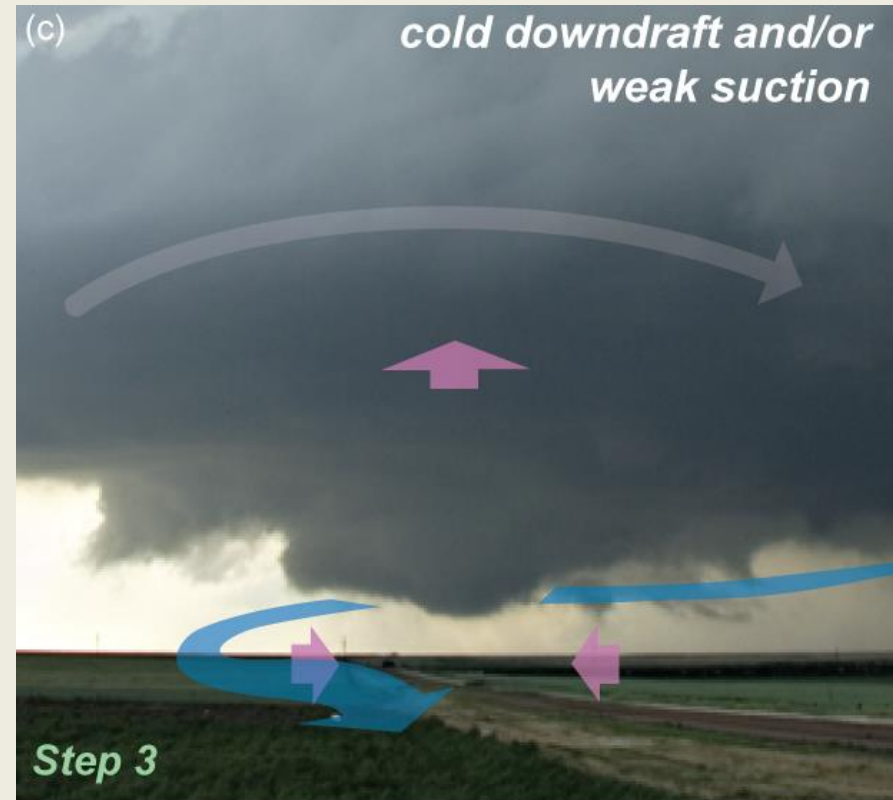
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# Tornadoes - Tornadogenesis

Step 3 - Tornado



Step 3 – No Tornado



Images: <https://sites.psu.edu/tornadoes/>



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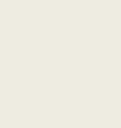
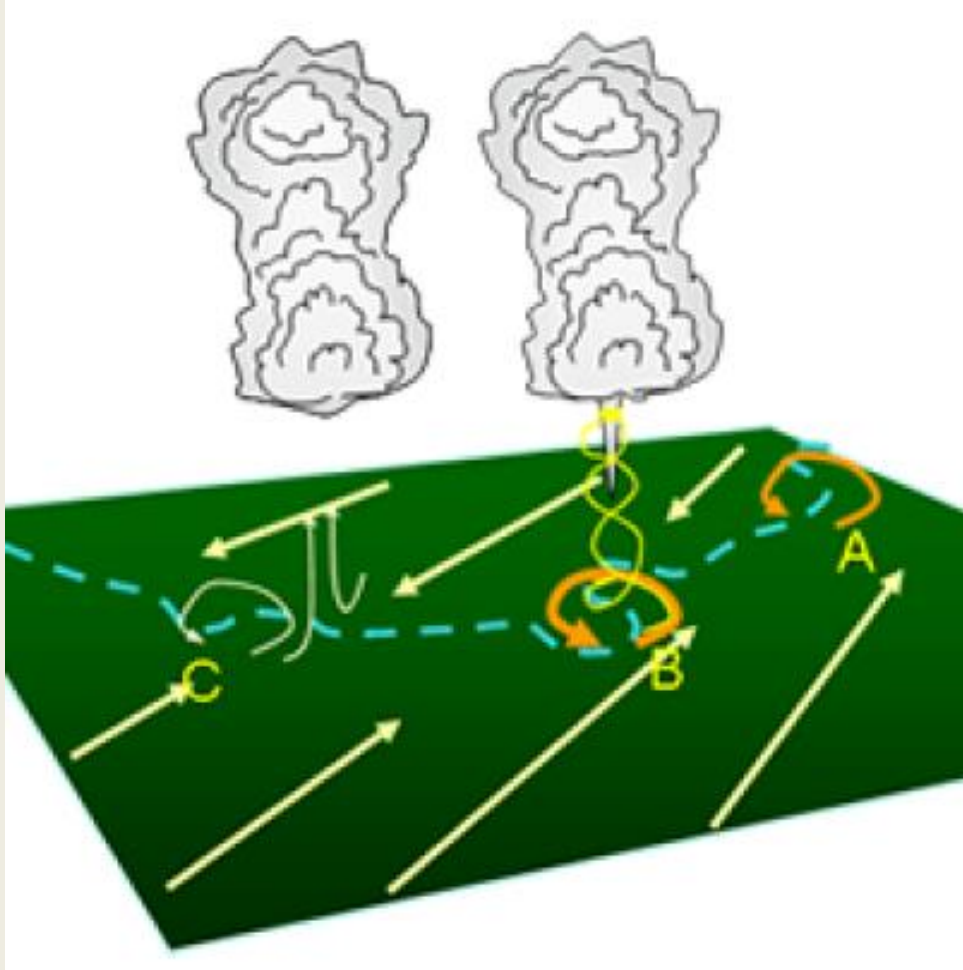


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# Landspouts – Formation

*Non-Supercell*



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# Landspouts



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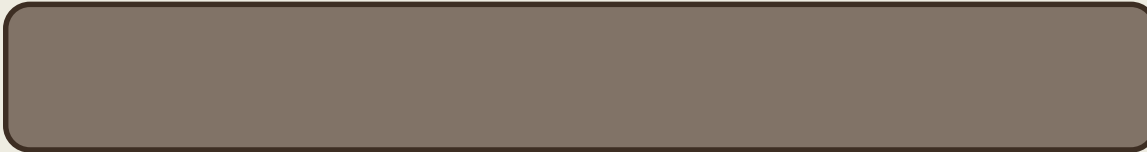
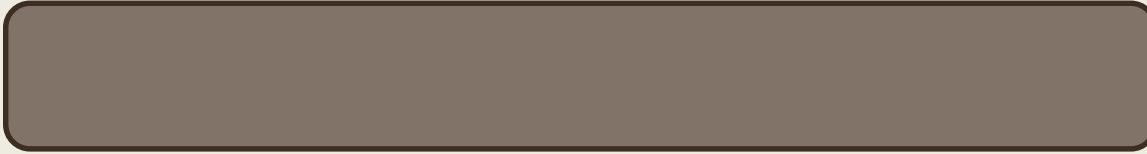


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# Program Outline



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# Monsoon Storm Evolutions



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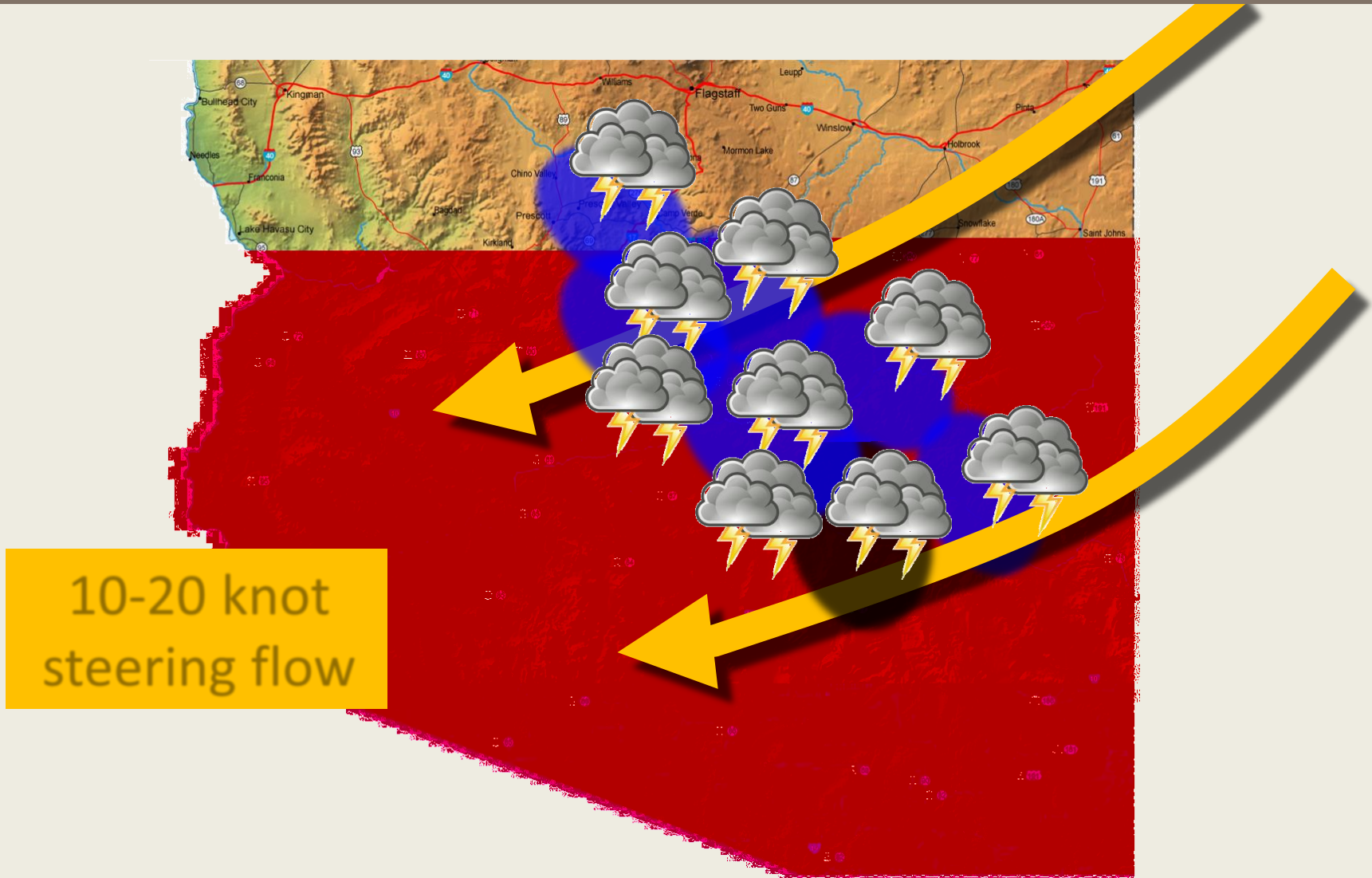


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# Mongollon Rim Storm Evolution



10-20 knot  
steering flow



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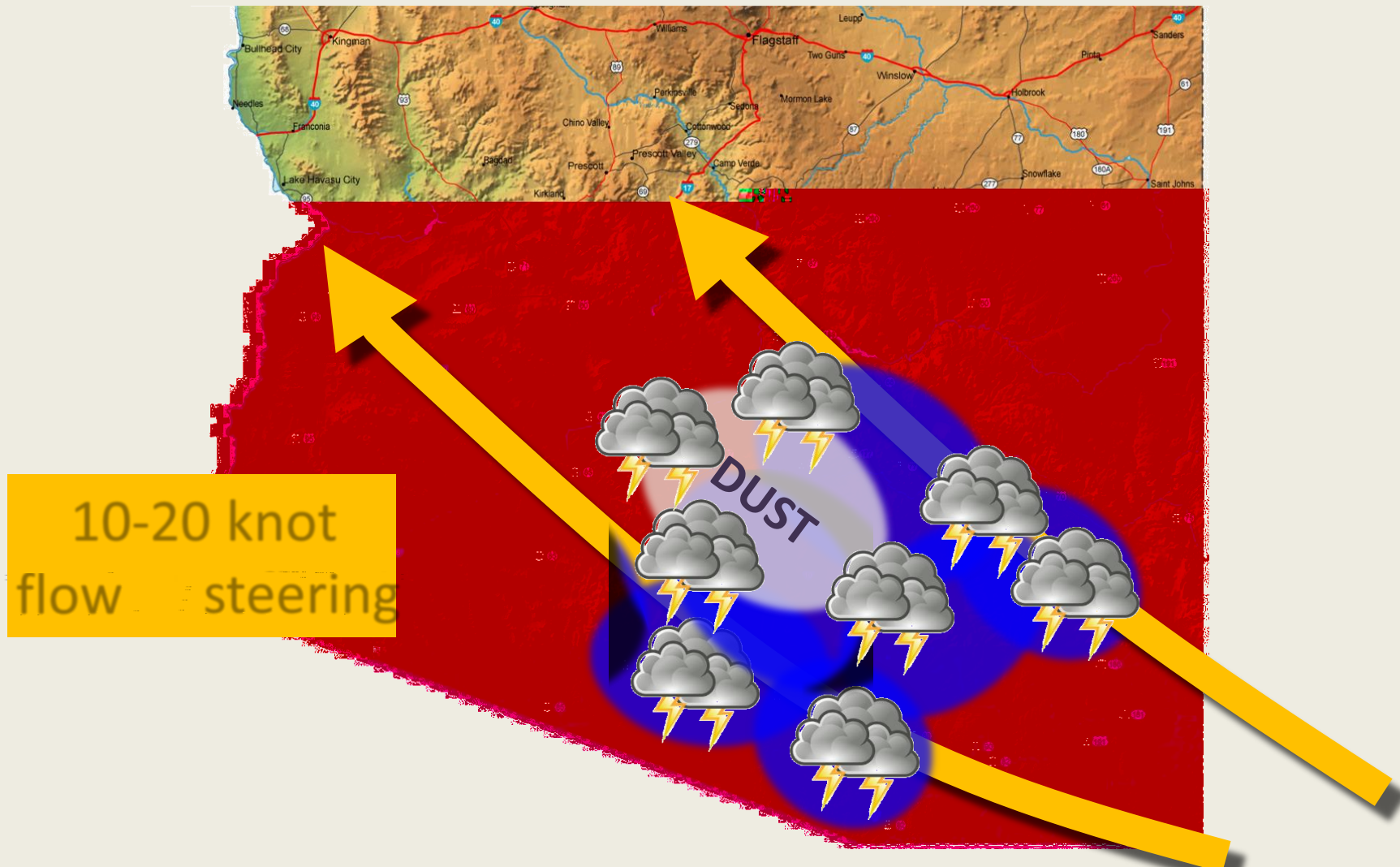


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# Southern Arizona Storm Evolution



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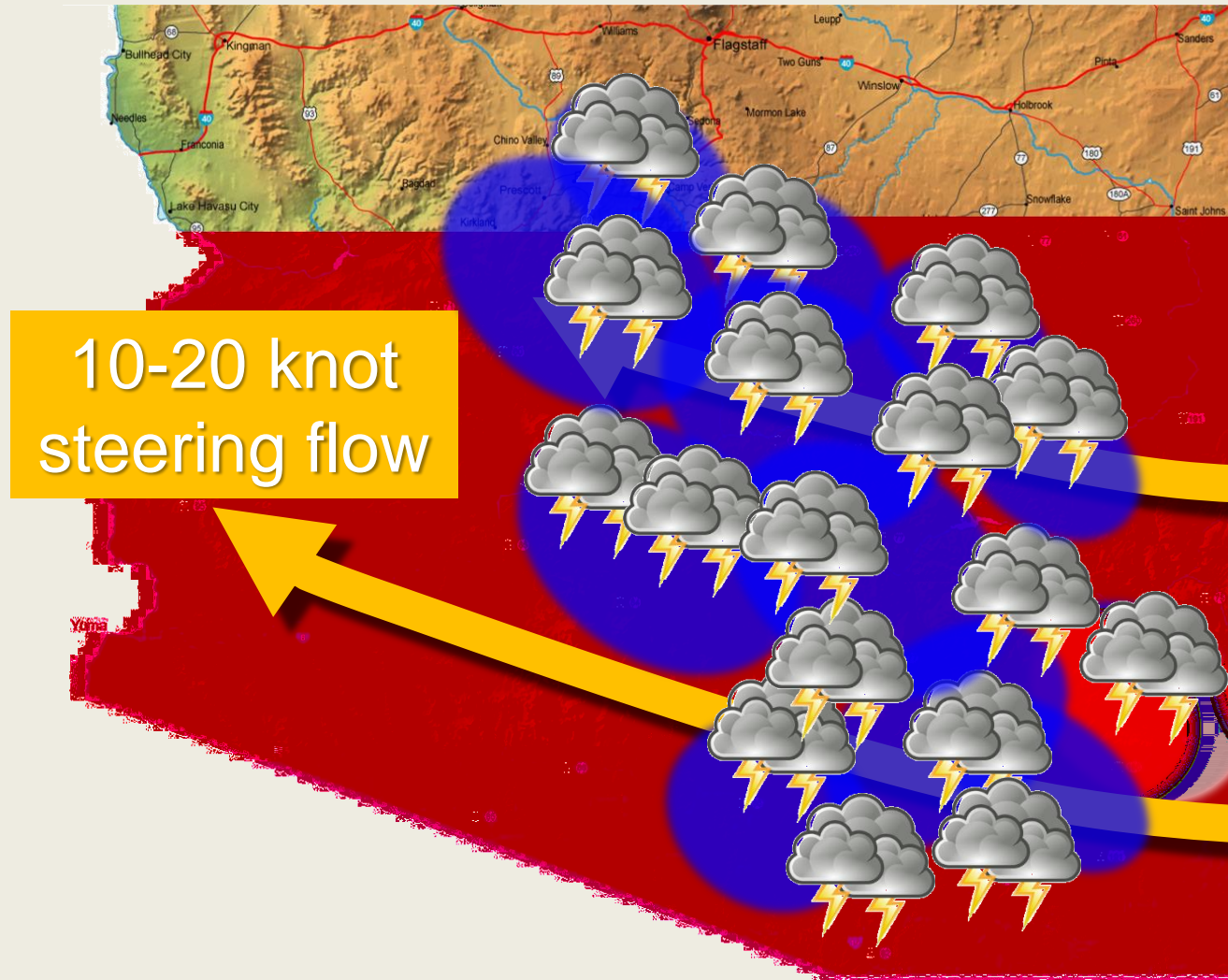


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# Combined Storm Evolution



10-20 knot  
steering flow



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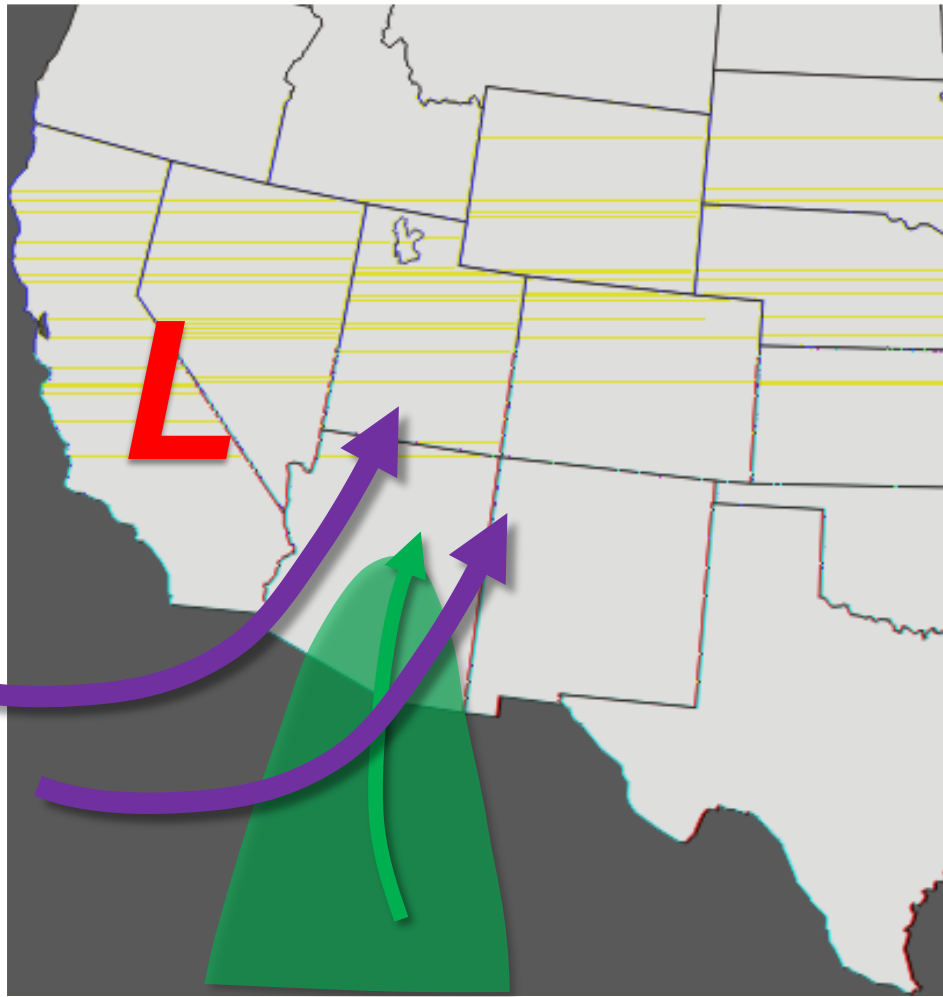
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# “Transition” Event



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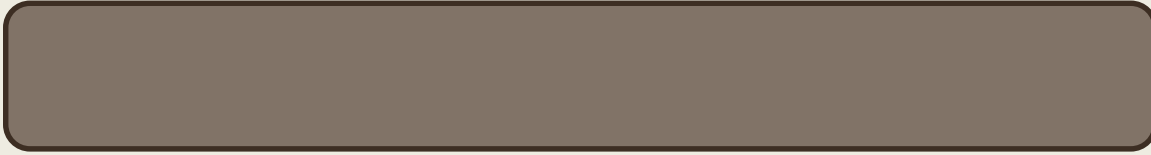


Break!

MIKE OLBINSKI  PHOTOGRAPHY

*Photo: Mike Oblinski Photography*

# Program Outline



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# Storm Prediction Center

[www.spc.noaa.gov](http://www.spc.noaa.gov)

**Storm Prediction Center**  
N O A A / National Weather Service

HOME NEWS SPC PRODUCTS WEATHER INFO FORECAST TOOLS RESEARCH OUTREACH NWS/INCEP Search SPC...

**A Moderate Risk of Severe Thunderstorms is forecast for Mon (05/20)**  
Severe thunderstorms capable of all severe hazards, including strong tornadoes, are expected across portions of the southern Plains on Monday.

Fire Overview Storm Outlook Watches WDS Storm Reports Mesosynopses Fire Hazards All Products Watches WDS Outlooks

**Thunderstorm Outlook**  
- Issued: 05/19/2019 at 0058Z

**Day 1 Convective Outlook**  
- Categorical Risk: Enhanced  
- Issued: 05/19/2019 at 0053Z

**TORNADO 0189**  
- Valid until: 05/19/2019 0700Z  
- States affected: AR, LA, TX  
- Issued: 05/19/2019 at 0000Z

**Day 3-8 Fire Weather Outlook**  
- Categorical Risk: No Areas  
- Issued: 05/18/2019 at 2048Z

**Day 2 Fire Weather Outlook**  
- Categorical Risk: No Critical

| Sat (05/18) | Sun (05/19) | Mon (05/20) | Tue (05/21) | Wed (05/22) | Thu (05/23) | Fri (05/24) | Sat (05/25) |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Light       | Slight      | Moderate    | Severe      | No Area     | No Area     | No Area     | No Area     |
| Level 1     | No Critical | No Area     | No Area     | No Area     | No Area     | No Area     | No Area     |

SPC Activity Chart  
20190519/0410

Significant Wind Probabilities: 19 May

Forecast Tools

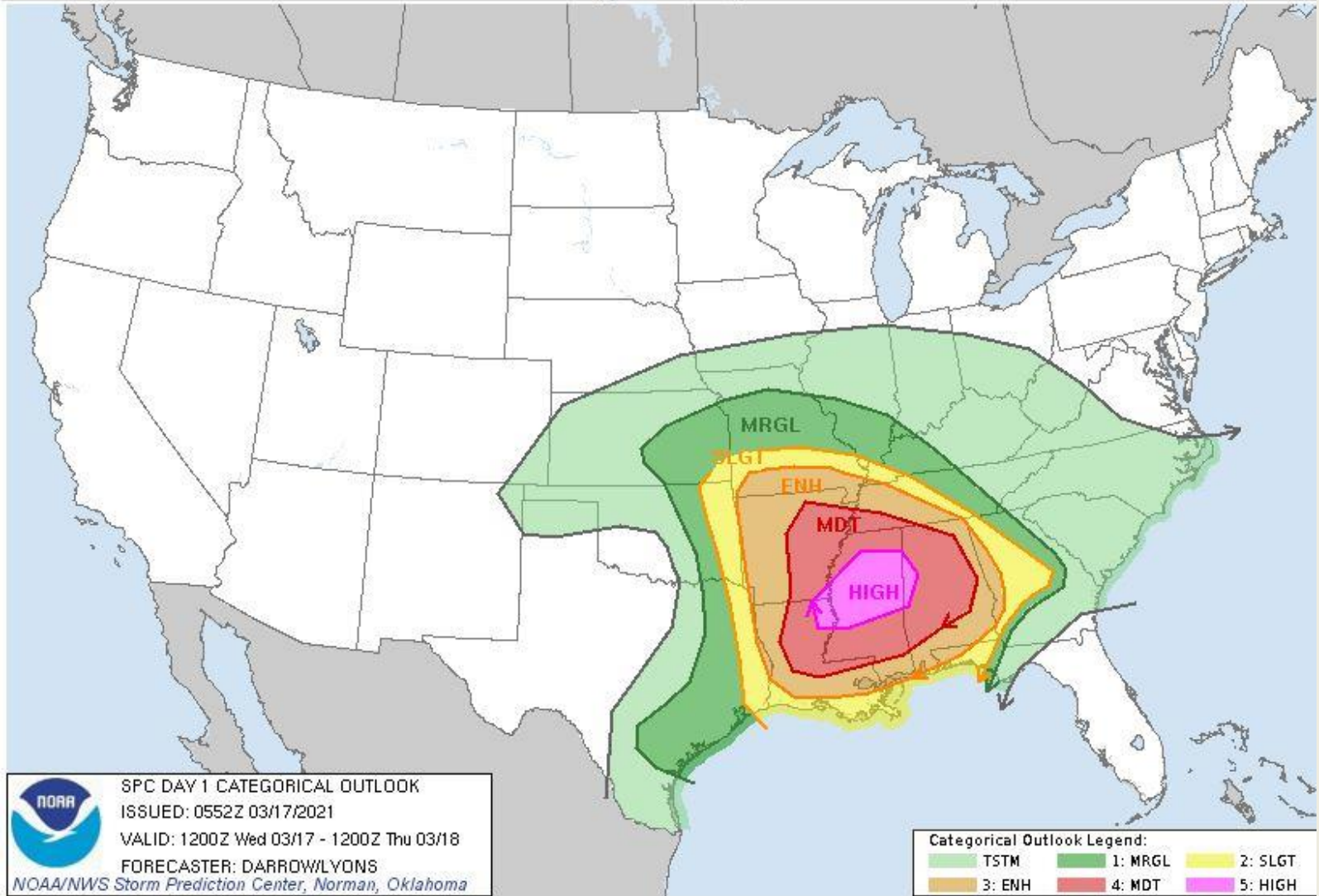
2019 Watch Summaries

What's My Risk?



# SPC Convective Outlook - example

Categorical Graphic



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# SPC Convective Outlook

## Risk Categories

### Understanding Severe Thunderstorm Risk Categories

| THUNDERSTORMS<br>(no label)                                   | 1 - MARGINAL<br>(MRGL)                                     | 2 - SLIGHT<br>(SLGT)   | 3 - ENHANCED<br>(ENH)                                  | 4 - MODERATE<br>(MDT)                    | 5 - HIGH<br>(HIGH)   |
|---|--|--|--|--|--|
| No severe*<br>thunderstorms<br>expected                       | Isolated severe<br>thunderstorms<br>possible               | Scattered<br>severe storms<br>possible                                       | Numerous<br>severe storms<br>possible                  | Widespread<br>severe storms<br>likely    | Widespread<br>severe storms<br>expected                    |
| Lightning/flooding<br>threats exist with all<br>thunderstorms | Limited in duration<br>and/or coverage<br>and/or intensity | Short-lived and/or<br>not widespread,<br>isolated intense<br>storms possible | More persistent<br>and/or widespread,<br>a few intense | Long-lived,<br>widespread and<br>intense | Long-lived, very<br>widespread and<br>particularly intense |



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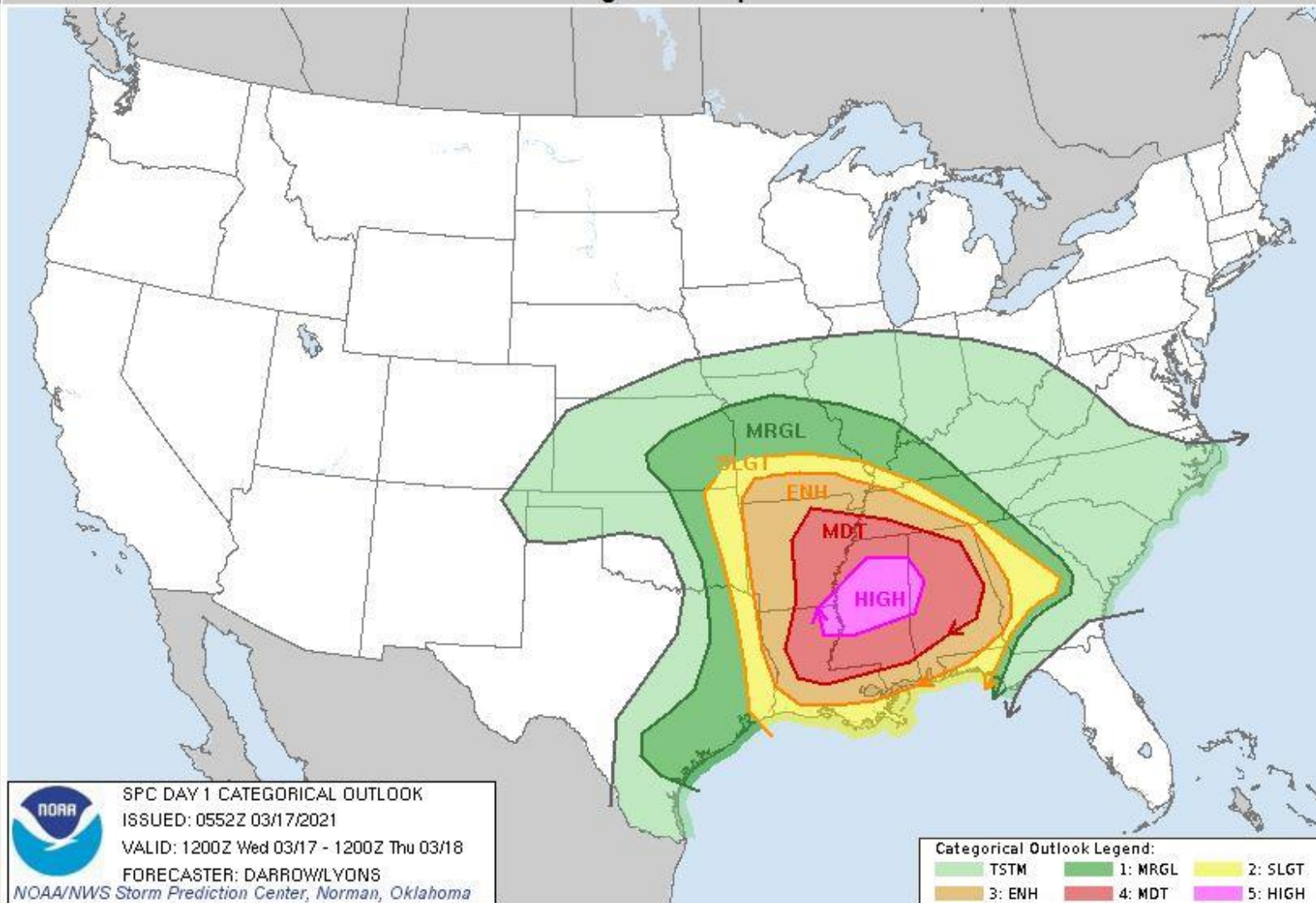
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# SPC Convective Outlook - example

Categorical Graphic



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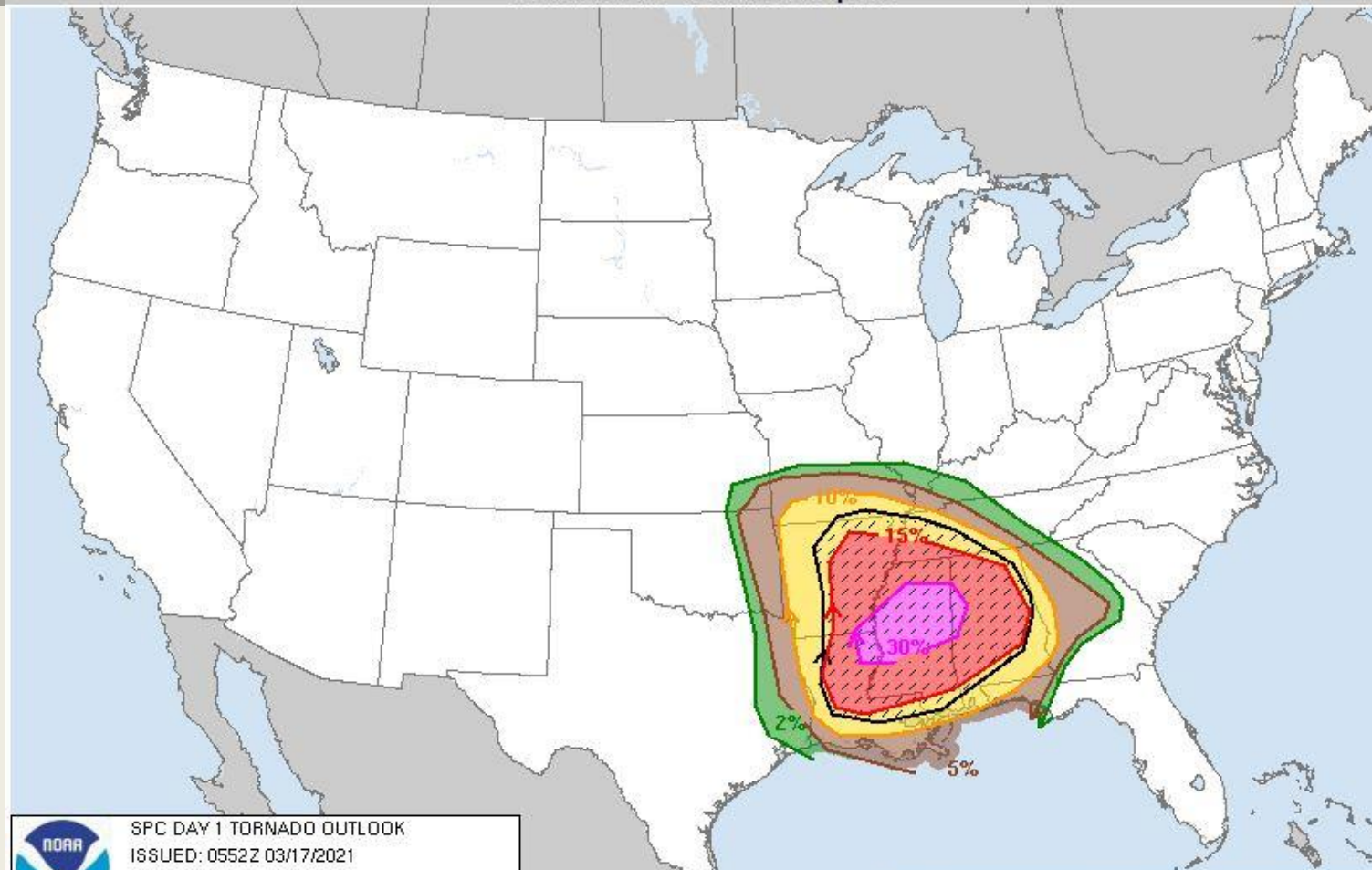
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# SPC Convective Outlook - example

Probabilistic Tornado Graphic



SPC DAY 1 TORNADO OUTLOOK  
ISSUED: 0552Z 03/17/2021  
VALID: 1200Z Wed 03/17 - 1200Z Thu 03/18  
FORECASTER: DARROWLYONS

NOAA/NWS Storm Prediction Center, Norman, Oklahoma

Tornado Probability Legend (in %):



Probability of a tornado within 25 miles of a point.

Hatched Area: 10% or greater probability of EF2 - EF5 tornadoes within 25 miles of a point.



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# SPC Convective Outlook - example



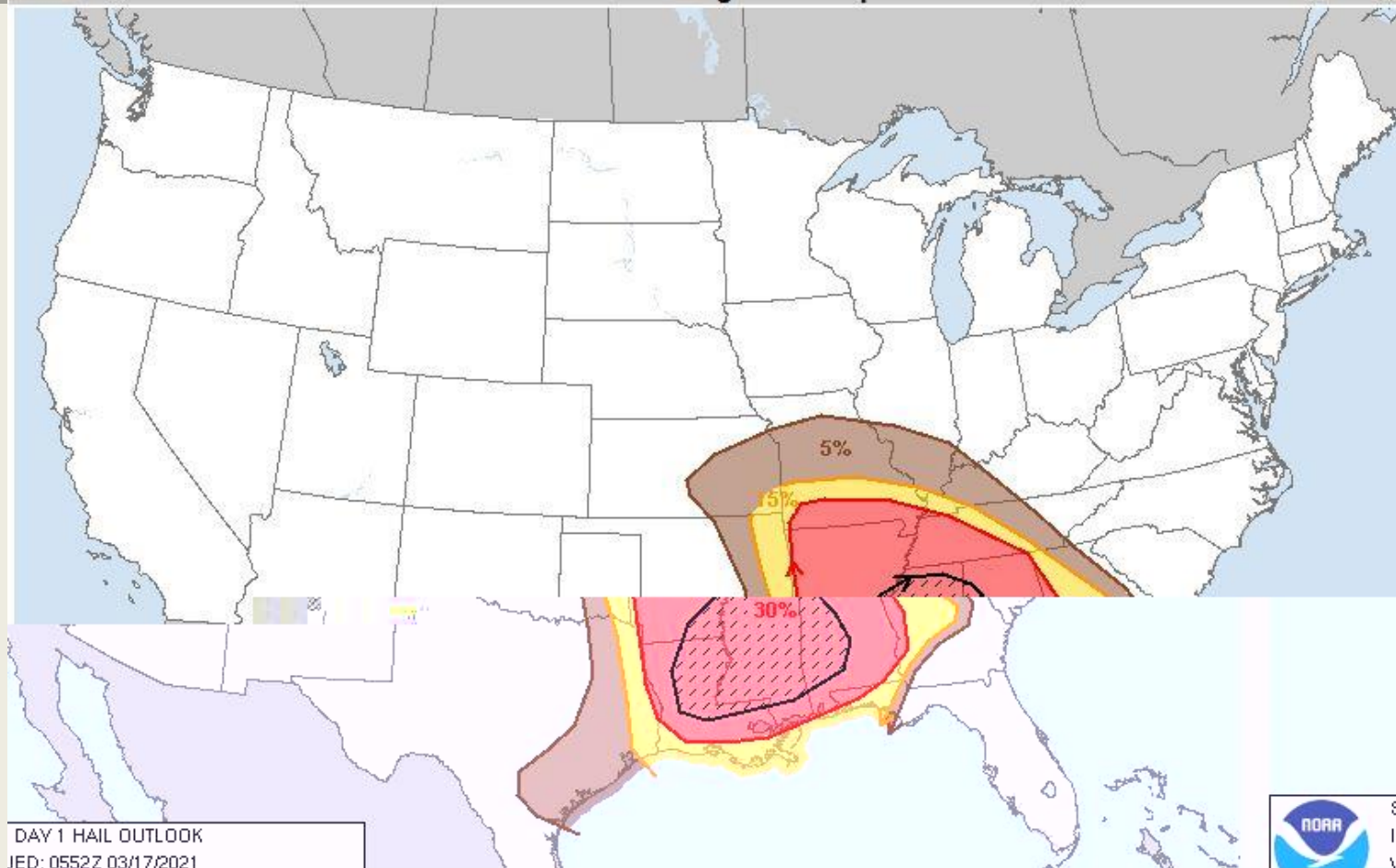
/NWSPhoenix



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# SPC Convective Outlook - example

Probabilistic Large Hail Graphic



DAY 1 HAIL OUTLOOK  
JED: 0552Z 03/17/2021  
ID: 1200  
FORECASTER: DARROWLYONS

all 1/4" or larger, or in 25 miles of a point  
10% or greater probability of hail 1/2" or larger, or in 25 miles of a point



Hail Probability Legend (in %):  
5 15 30 45 60 Sig



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URGENT - IMMEDIATE BROADCAST REQUESTED  
Tornado Watch Number 36  
NWS Storm Prediction Center Norman OK  
645 PM CDT Wed Mar 17 2021

The NWS Storm Prediction Center has issued a

\* Tornado Watch for portions of  
Alabama  
Eastern Mississippi  
Coastal Waters

\* Effective this Wednesday night and Thursday morning from 645 PM  
until 300 AM CDT.

...THIS IS A PARTICULARLY DANGEROUS SITUATION...

\* Primary threats include...  
Several tornadoes and a few intense tornadoes likely  
Widespread damaging winds and scattered significant gusts to 80  
mph likely  
Scattered large hail events to 1.5 inches in diameter possible

SUMMARY...A further strengthening of low/mid-level winds this  
evening will support a combination of semi-discrete convective  
cells along the Gulf of Mexico coast, including some segments across much of eastern  
Mississippi into Alabama. Tornadoes, including a few strong, aside  
from damaging winds will be the most prevalent hazards.

The tornado watch area is approximately along and 100 statute miles  
north and south of a line from 15 miles northwest of Pine Belt MS to  
35 miles southeast of Anniston AL. For a complete depiction of the  
watch see the associated watch outline update (WOU564 KWNS WOU6).

PRECAUTIONARY/PREPAREDNESS ACTIONS...

REMEMBER...A Tornado Watch means conditions are favorable for  
tornadoes and severe thunderstorms in and close to the watch  
area. Persons in these areas should be on the lookout for  
threatening weather conditions and listen for later statements  
and possible warnings.

&&

OTHER WATCH INFORMATION...CONTINUE...WW 29...WW 31...WW 32...WW  
33...WW 34...WW 35...

AVIATION...Tornadoes and a few severe thunderstorms with hail  
surface and aloft to 1.5 inches. Extreme turbulence and surface wind  
gusts to 70 knots. A few cumulonimbi with maximum tops to 500. Mean  
storm motion vector 24040.

...Guyer



NOAA/NWS/Storm Prediction Center

WOL

WVIL

WGRE

WERSO

WLD0

317/2353 UTC

# Main Mesoanalysis Page

NOAA's National Weather Service  
**Storm Prediction Center**

Site Map News Organ

Local forecast by "City, St" or "ZIP"  
City, St

**SPC Mesoscale Analysis Pages** (National Sector Archive | Mobile Version)  
Click [here](#) to view a multimedia introduction of the Mesoanalysis Pages. (5.8MB)

| National | NW | SW | N Plns | C Plns | MW | S Plns | NE | EC | SE |
|----------|----|----|--------|--------|----|--------|----|----|----|
|----------|----|----|--------|--------|----|--------|----|----|----|

NOAA SPC Mesoscale Analysis Sectors  
1h Composite Radar  
Valid 1754Z-1859Z  
National Weather Service Storm Prediction Center Norman, Oklahoma

National Weather Service • Since 1870

These 10 fixed sectors can be used to see regional gridded mesoanalysis data across the United States. This information is provided by SPC as a way of sharing the latest severe weather diagnostic techniques with local forecasters.

Misc

# Drop-Down Menu: Thermo

## SPC Mesoscale Analysis

Change Sector

Image Archive & Loops

SPC Homepage

Mobile Version

NEW: Double-click map for tornado climatology and environmental breakdowns.

Surface: 05/19/19 05 UTC

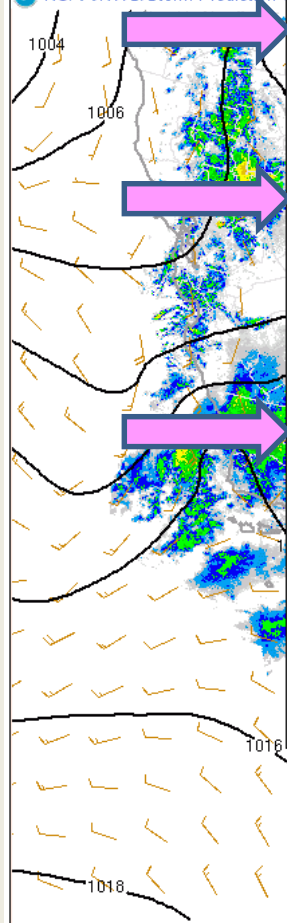
Model: 19051904f001

Auto-refresh is set to every minute [OFF 1 min 5 min]

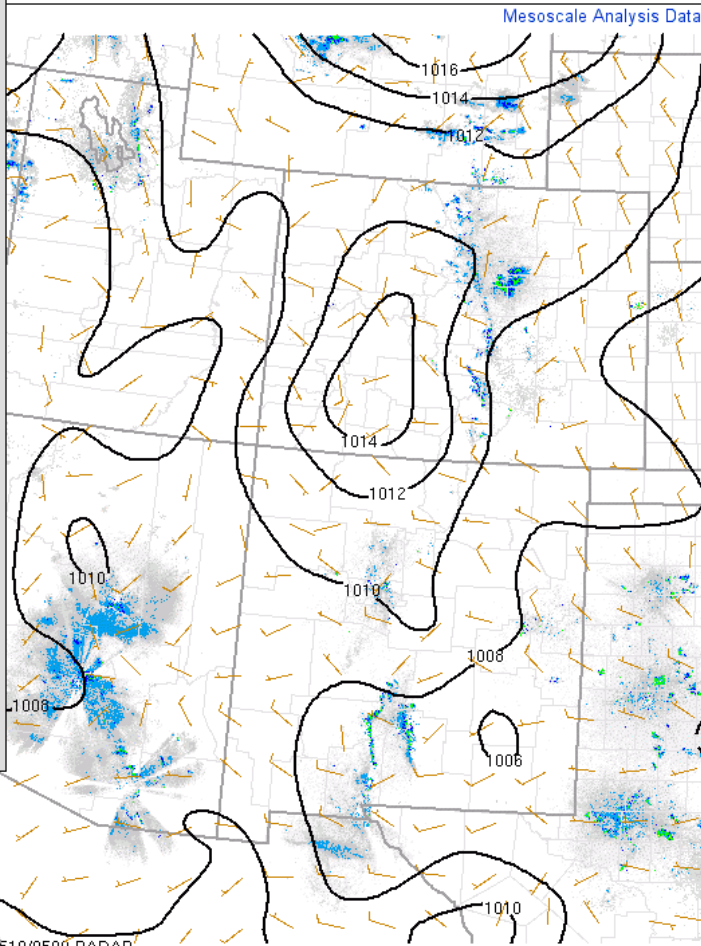
### Operational EMC RAP

Observations Surface Upper Air Thermodynamics Wind Shear Composite Indices Multi-Parameter Fields Heavy Rain Winter Weather Fire Weather Classic Beta

NOAA/NWS/Storm Prediction



- CAPE - Surface-Based
- CAPE - 100mb Mixed-Layer
- CAPE - Most-Unstable / LPL Height
- \*New\* EL Temp / MUCAPE / MUCIN
- CAPE - Normalized
- CAPE - Downdraft
- Surface-based Lifted Index
- Mid-Level Lapse Rates
- Low-Level Lapse Rates
- \*New\* Max 2-6 km AGL Lapse Rate
- LCL Height
- LFC Height
- LCL-LFC Mean RH
- 3-hour Surface-Based CAPE Change
- 3-hour Surface-Based CIN Change
- 3-hour 100mb Mixed-Layer CAPE Change
- 3-hour Most-Unstable CAPE Change
- 3-hour Low-Level LR Change
- 6-hour Mid-Level LR Change



Trends/Forecast

|                |    |    |                    |    |    |    |
|----------------|----|----|--------------------|----|----|----|
| -4             | -2 | -0 | +0                 | +2 | +4 | +6 |
| - SfcOA Diag - |    |    | - RAP/SfcOA Fcst - |    |    |    |

Image overlays:

- County Boundaries
- County Warning Areas
- Highways & Cities
- ARTCC Regions
- NWS Watches & Warns
- SPC Day1 Outlook

Image underlays:

Opacity

- None
- Radar
- Terrain
- Population
- Surface Obs

Current SPC Products

Show popup images?

**Day1 Convective Outlook**  
Issued at 0502 UTC  
Probabilities: **Torn Hail Wind**

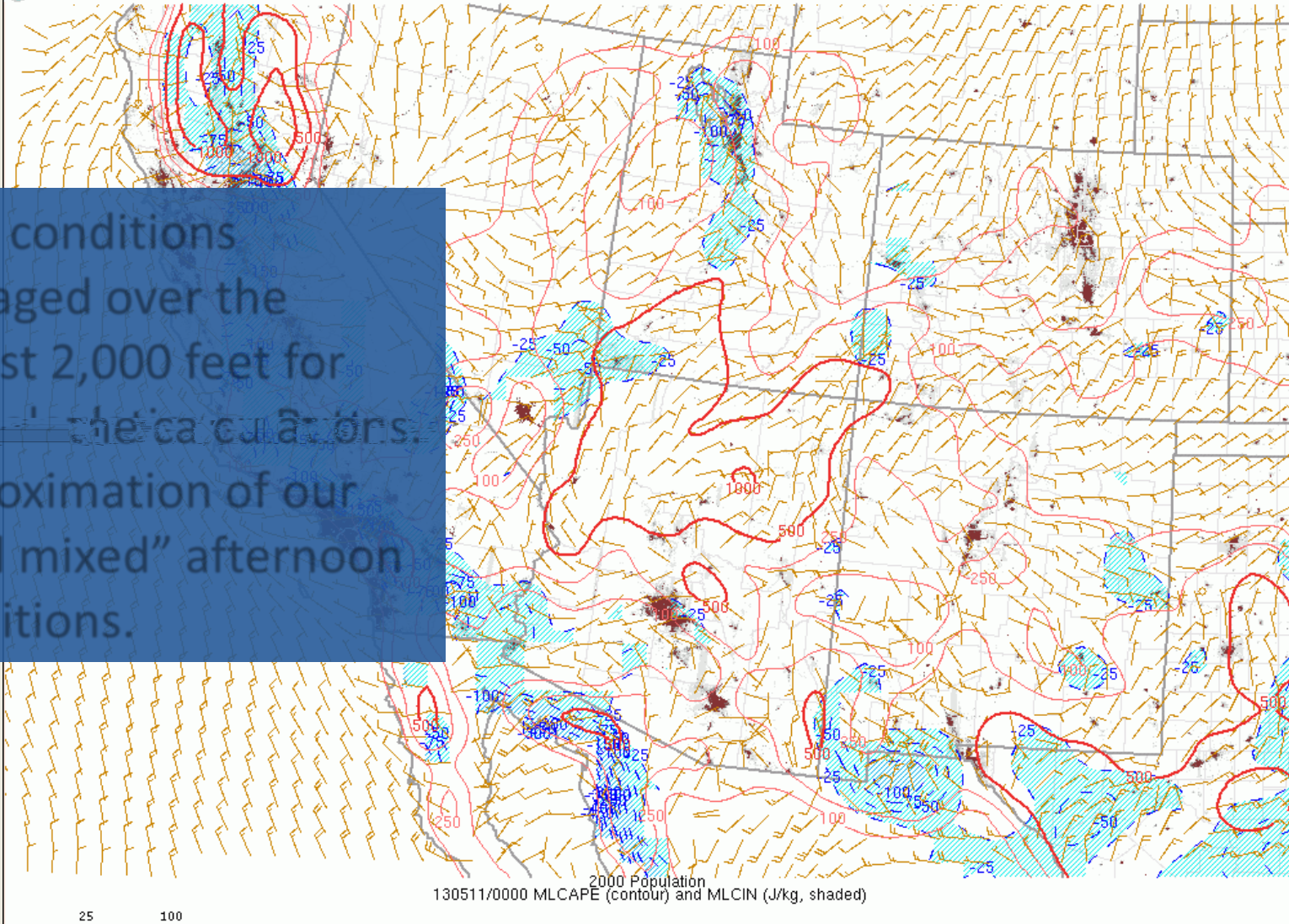
**Day1 National Fire Outlook**  
Issued at 1639 UTC  
This list updates automatically.

20190519/0500 RADAR  
190519/0500 MSL Pressure and surface wind

# Mixed-Layer CAPE

NOAA/NWS/Storm Prediction Center

Mesoscale Analysis Data



Uses conditions averaged over the lowest 2,000 feet for better physical calculations. approximation of our "well mixed" afternoon conditions.



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# Downdraft CAPE

## SPC Mesoscale Analysis

Auto-refresh is set to every minute [OFF 1 min 5 min]

Change Sector Recent Image Archive & Loops SPC Homepage Mobile Version

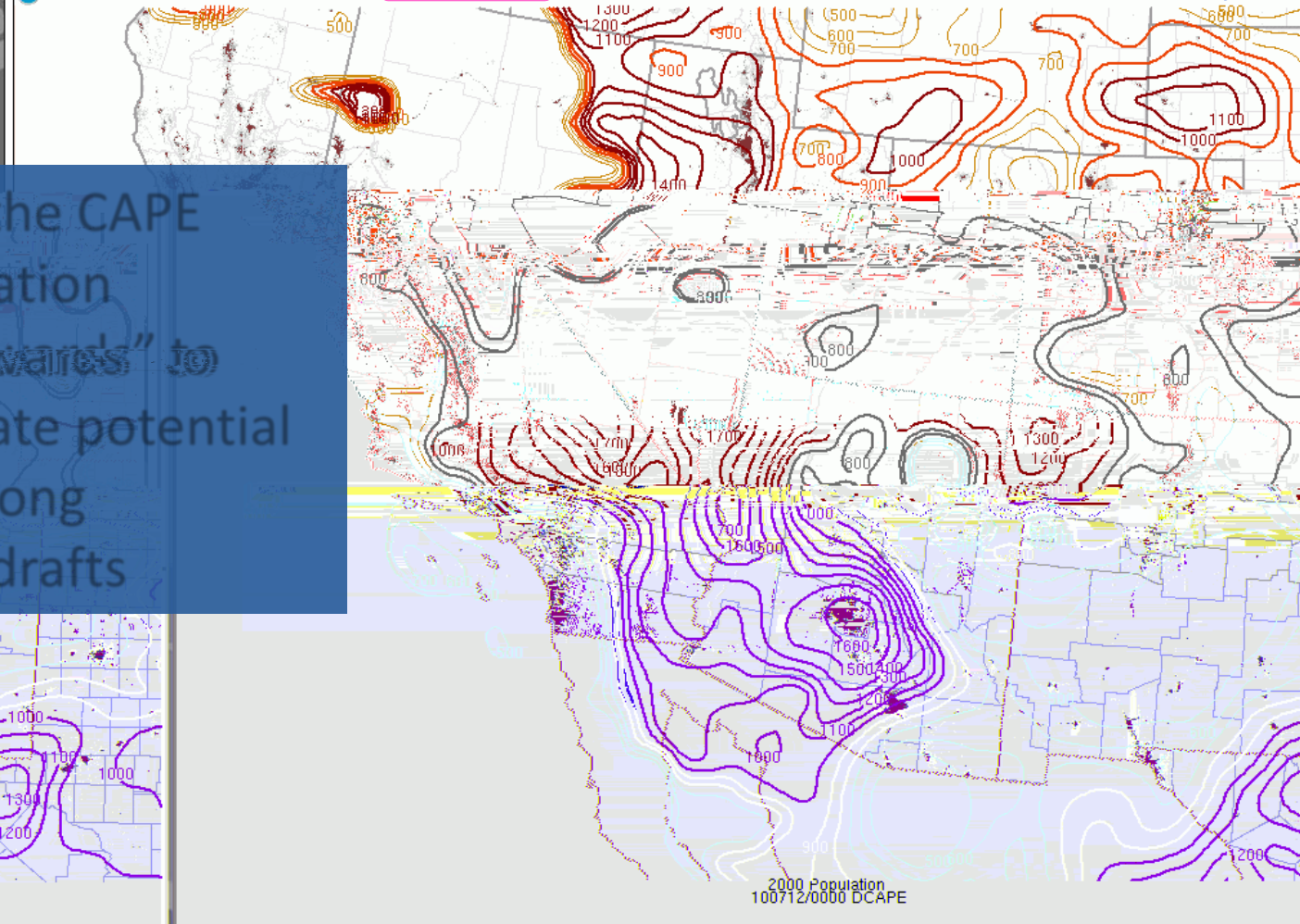
Surface: 07/12/10 00 UTC

RUC: 10071123f001

Observations Basic Sfc Basic UA Kinematic **Thermodynamics** Wind Shear Composite Indices Multi-Parameter Fields Heavy Rain Winter Weather Fire Weather

NOAA/NWS/Storm Prediction Center

Mesoscale Analysis Data



Runs the CAPE calculation "backwards" to estimate potential for strong downdrafts



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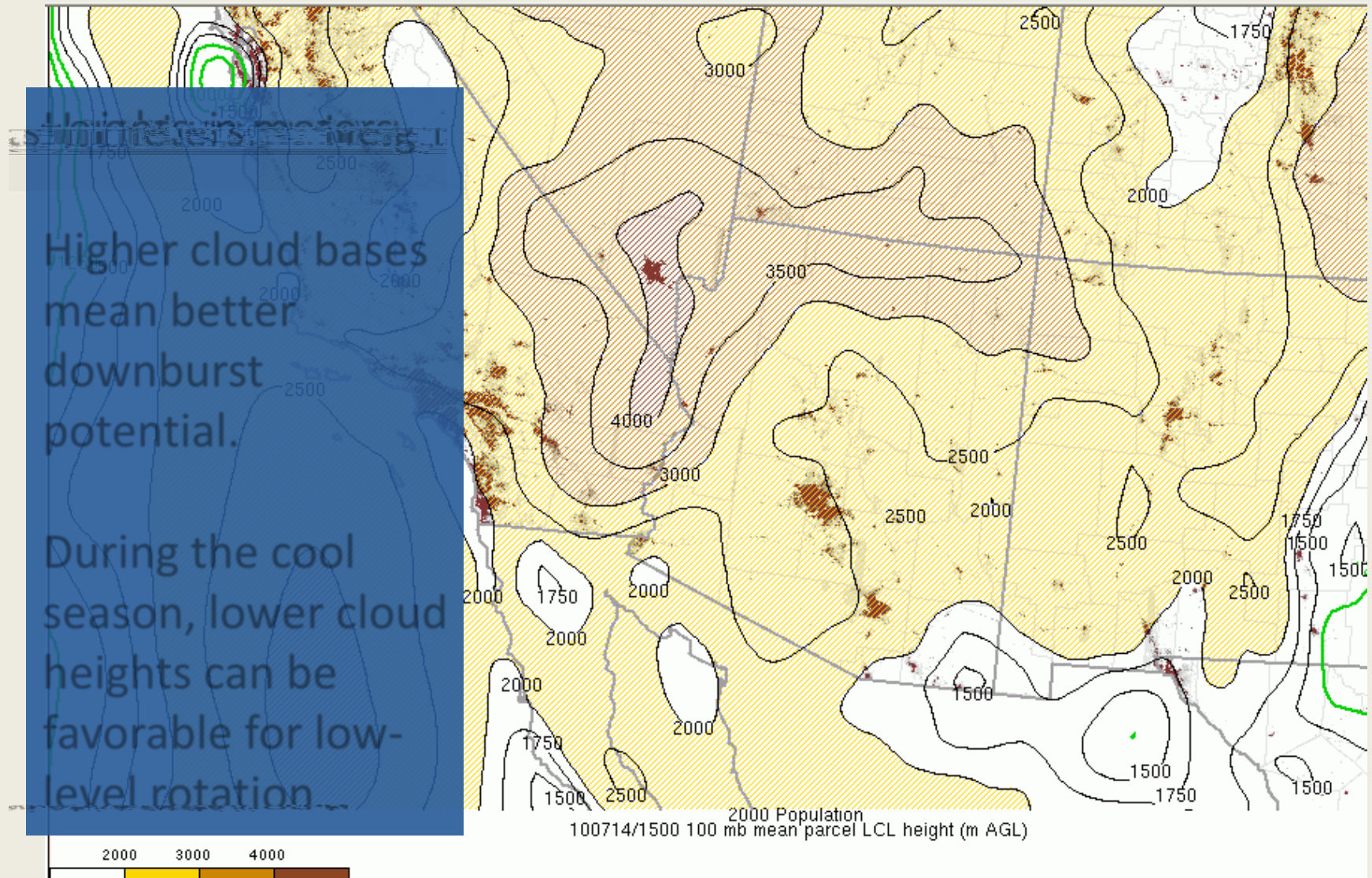


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# LCL (Cloud Height)



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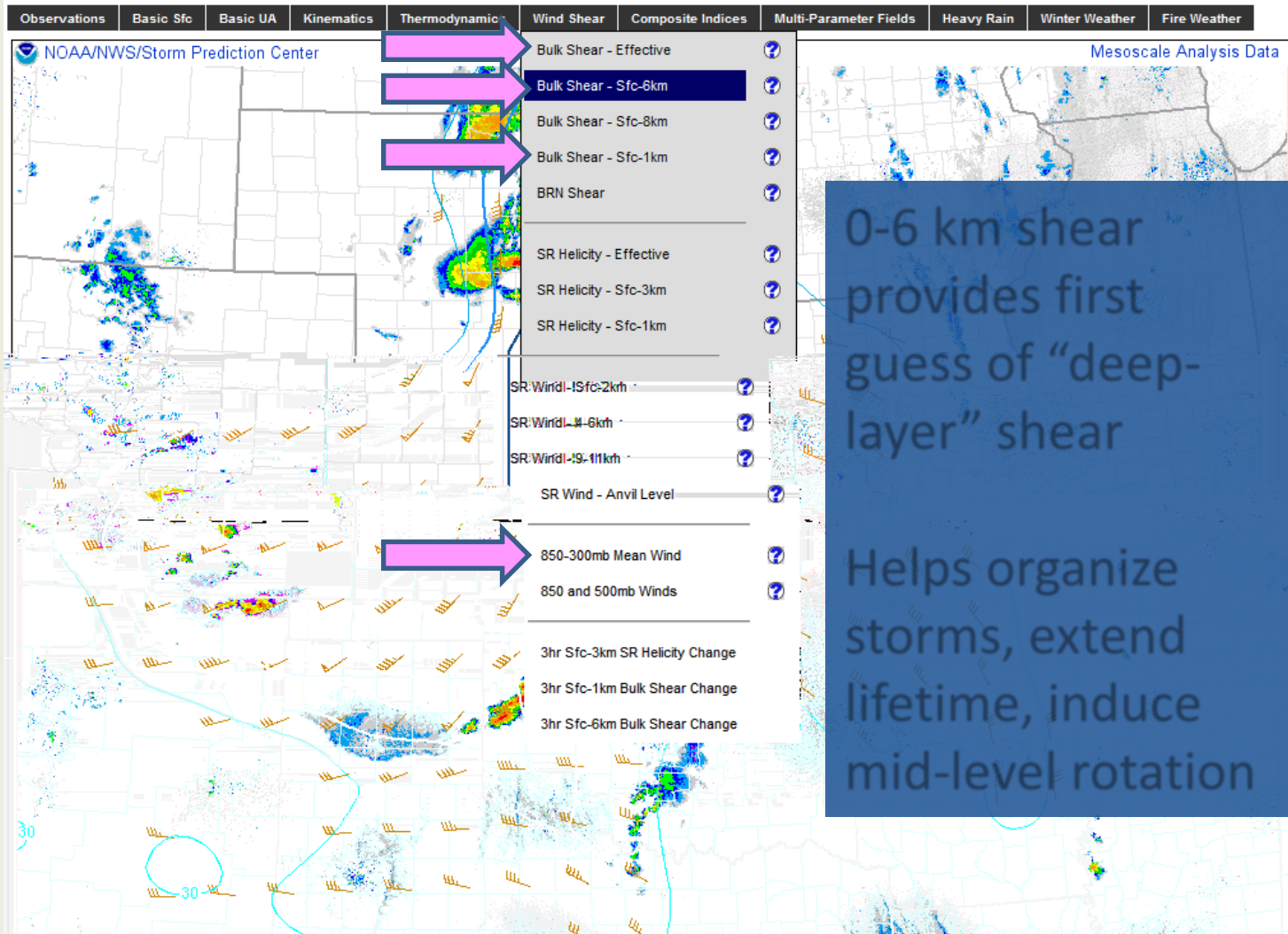


# Wind Shear

## SPC Mesoscale Analysis

Auto-refresh is set to every minute [OFF 1 min 5 min]

Change Sector Image Archive & Loops SPC Homepage Mobile Version



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# “Effective” Wind Shear

## SPC Mesoscale Analysis

Auto-refresh is set to every minute [OFF 1 min 5 min]

Change Sector Recent Image Archive & Loops SPC Homepage Mobile Version

Surface: 07/12/10 00 UTC

RUC: 10071123f001

Observations Basic Sfc Basic UA Kinematics Thermodynamics **Wind Shear** Composite Indices Multi-Parameter Fields Heavy Rain Winter Weather Fire Weather

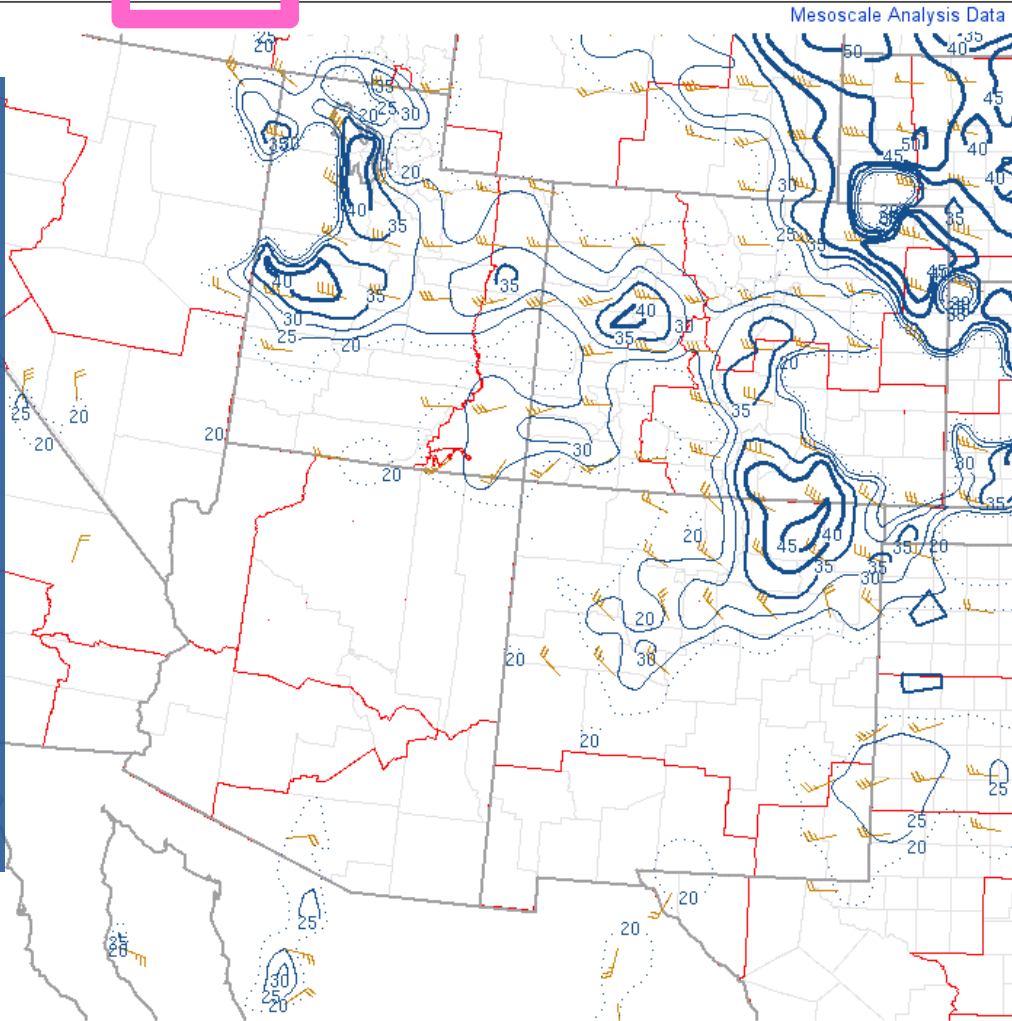
NOAA/NWS/Storm Prediction Center

Mesoscale Analysis Data

Shear through half of the expected storm height.

A substitute for 0-6 km shear...better for “short” storms

lower shear values are plotted on map.



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# 0-1 km Wind Shear

## SPC Mesoscale Analysis

Auto-refresh is set to every minute [OFF 1 min 5 min]

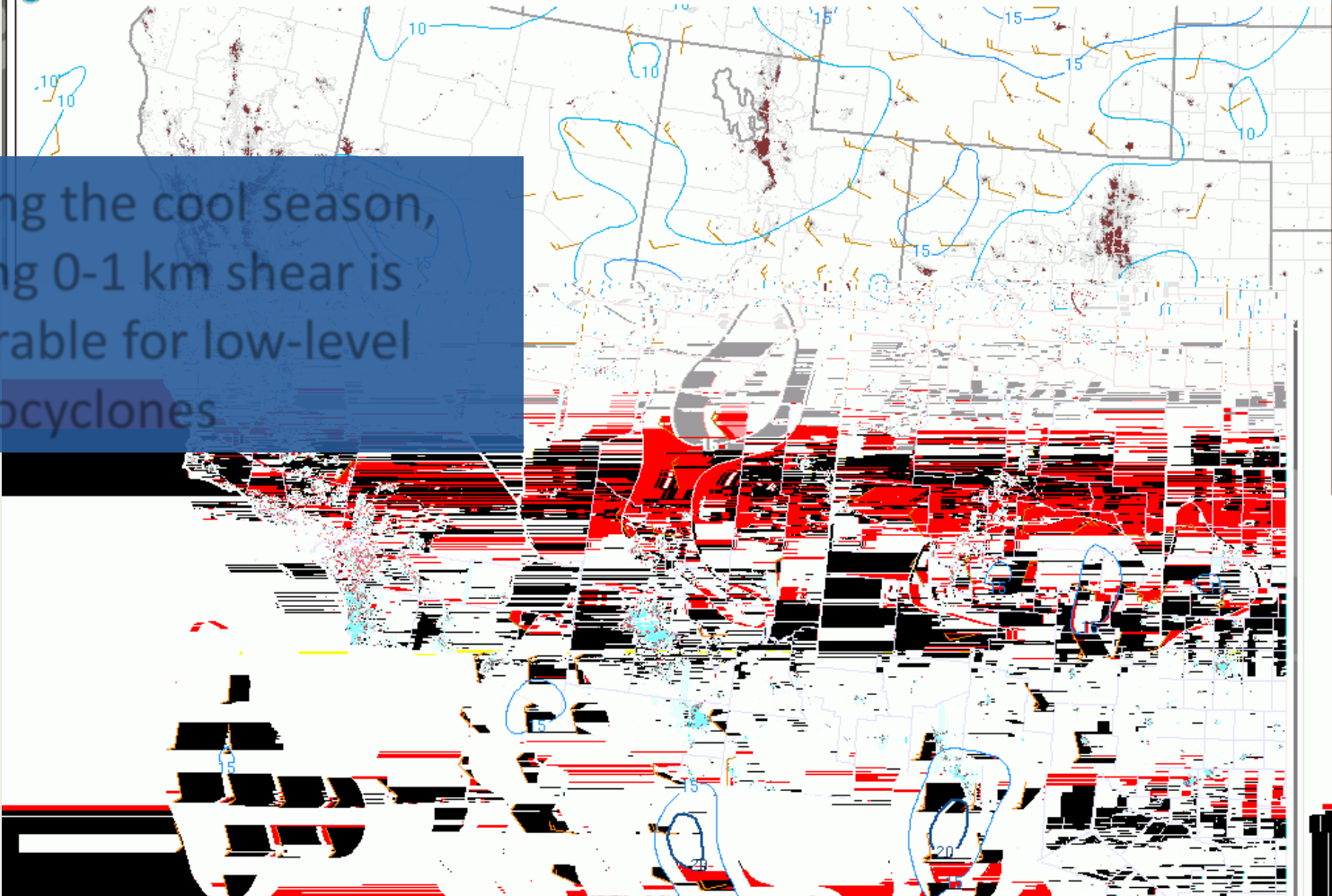
Change Sector Recent Image Archive & Loops SPC Homepage Mobile Version

Surface: 07/12/10 00 UTC

RUC: 10071123f001

Observations Basic Sfc Basic UA Kinematics Thermodynamics **Wind Shear** Composite Indices Multi-Parameter Fields Heavy Rain Winter Weather Fire Weather

NOAA/NWS/Storm Prediction Center Mesoscale Analysis Data



During the cool season, strong 0-1 km shear is favorable for low-level mesocyclones



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# 850-300 mb Mean Wind

## SPC Mesoscale Analysis

Auto-refresh is set to every minute [\[OFF 1 min 5 min\]](#)

[Change Sector](#) [Image Archive & Loops](#) [SPC Homepage](#) [Mobile Version](#)

[Observations](#) [Basic Sfc](#) [Basic UA](#) [Kinematics](#) [Thermodynamic](#) [Wind Shear](#) [Composite Indices](#) [Multi-Parameter Fields](#) [Heavy Rain](#) [Winter Weather](#) [Fire Weather](#)

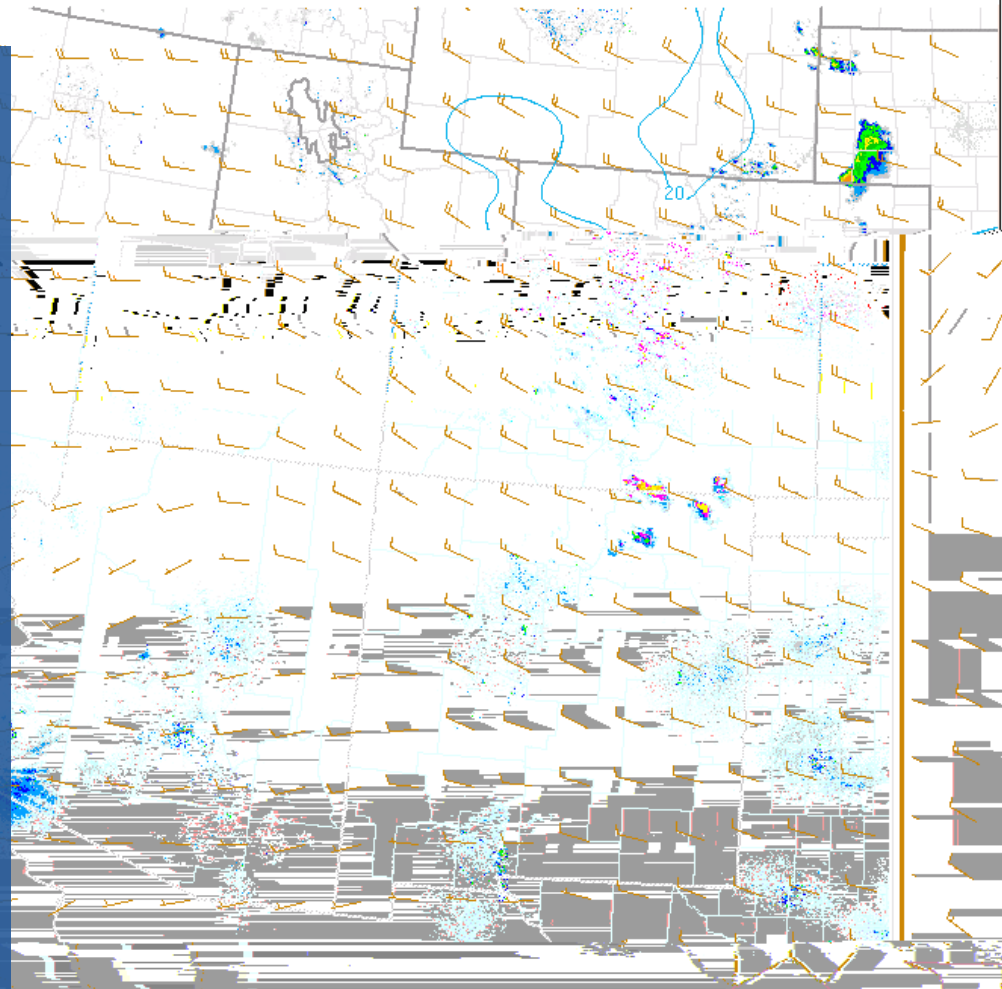
NOAA/NWS/Storm Prediction Center

Mesoscale Analysis Data

Mean wind  
through the  
5,000-30,000  
foot layer

Provides a good  
“first guess” of  
storm motion

Does not take  
propagation into  
account



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# Key Parameter Guidelines

**CAPE:**

**CIN:**

**Downdraft CAPE:**

**Deep layer shear (effective or 6 km):**

**0-1 km shear (cool season or transition):**

**LCL height (cool season/transition):**



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# Program Outline



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# What is Radar?

RA D A R



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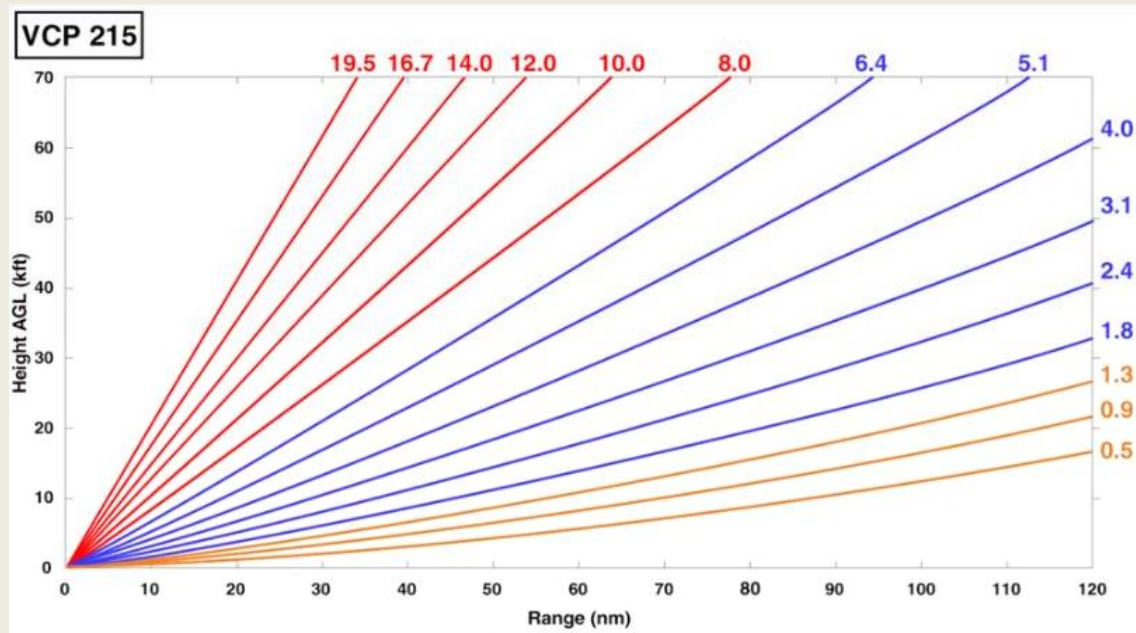
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# How Does Radar Work?





# WSR-88D Overview



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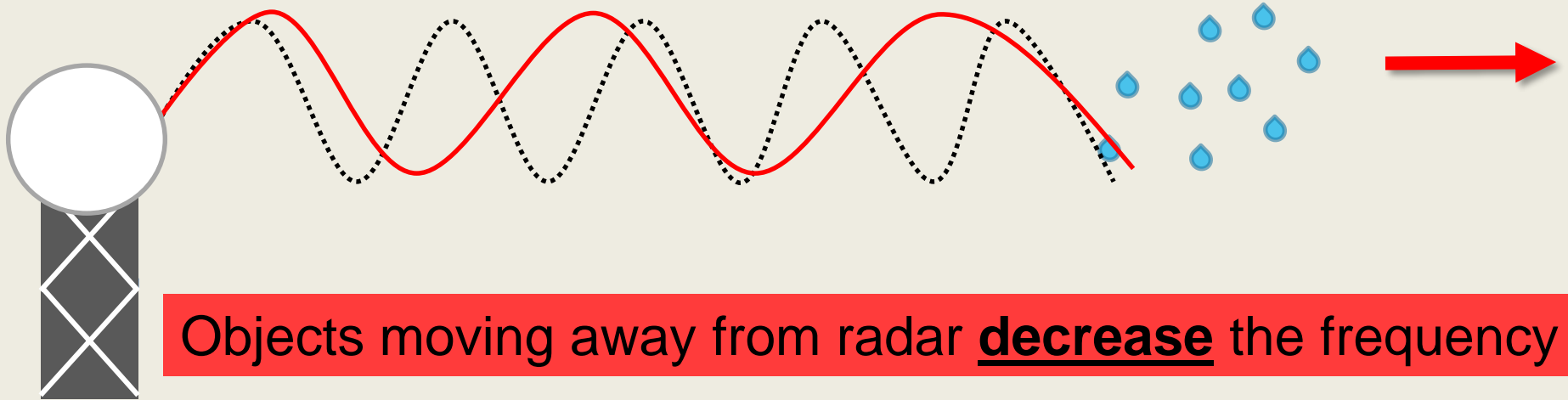


/NWSPhoenix

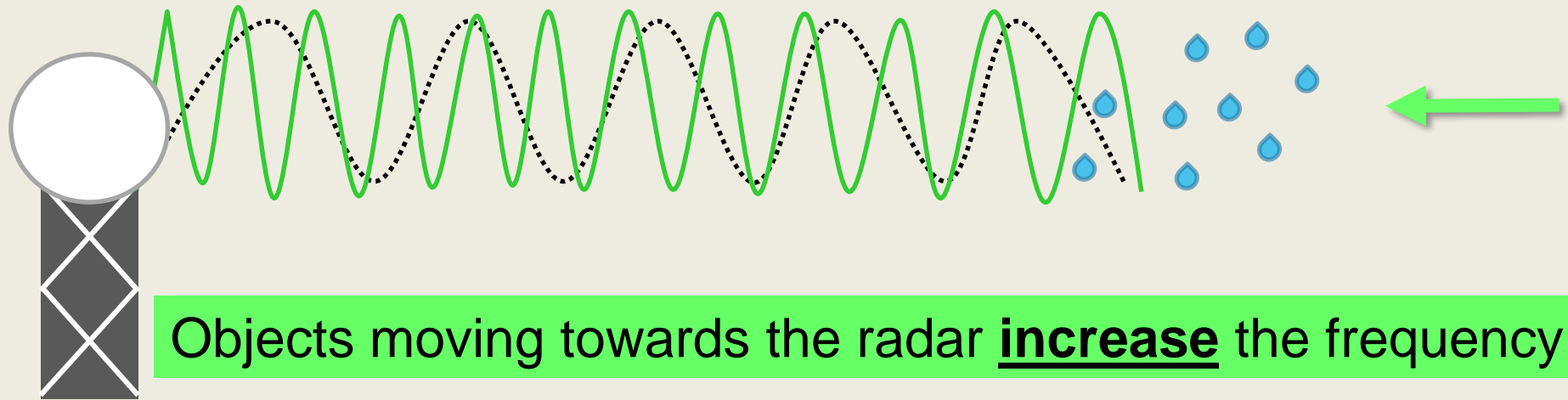


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# WSR-88D Velocity



Objects moving away from radar **decrease** the frequency



Objects moving towards the radar **increase** the frequency



# RADAR Limitations

## *Beam Spreading*



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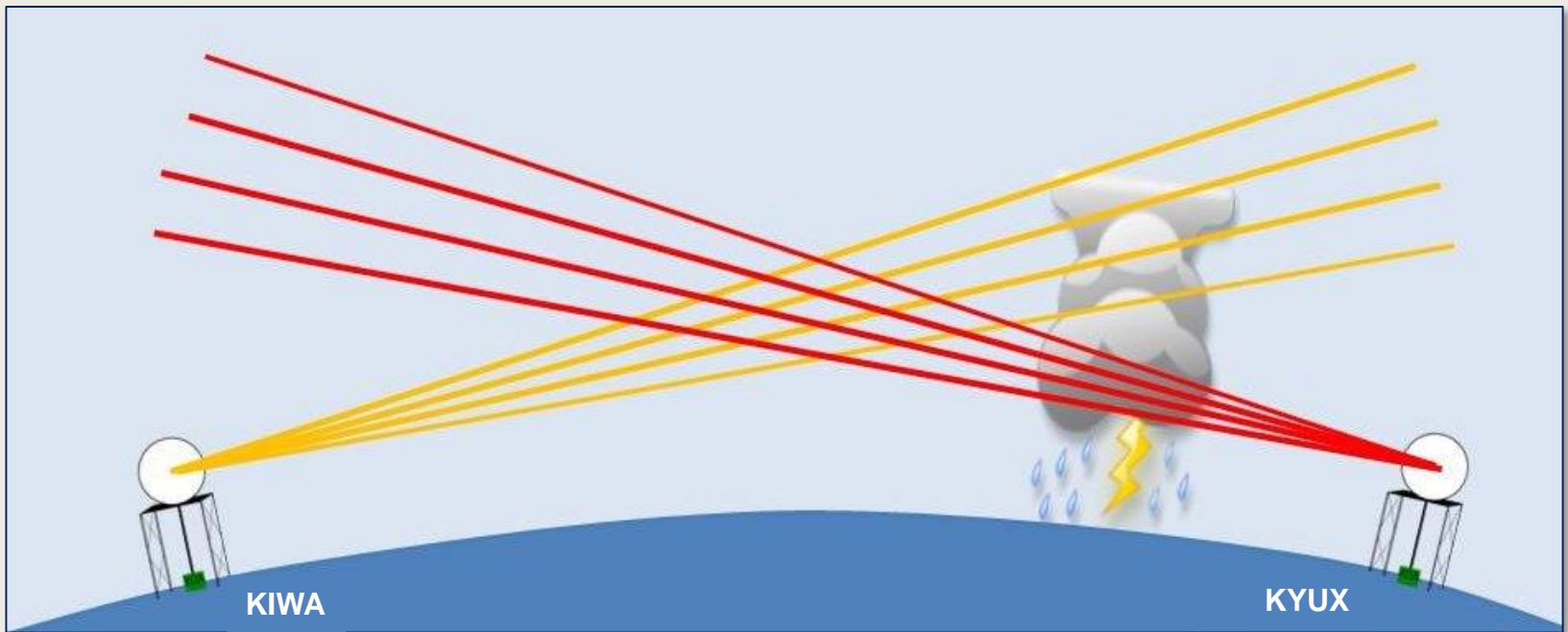
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# RADAR Limitations

## *Curvature*



Due to the curvature of the earth, the radar beam will increase in height relative to the ground meaning only higher and higher hydrometeors will be detected. At increasing distances, low objects become undetectable.



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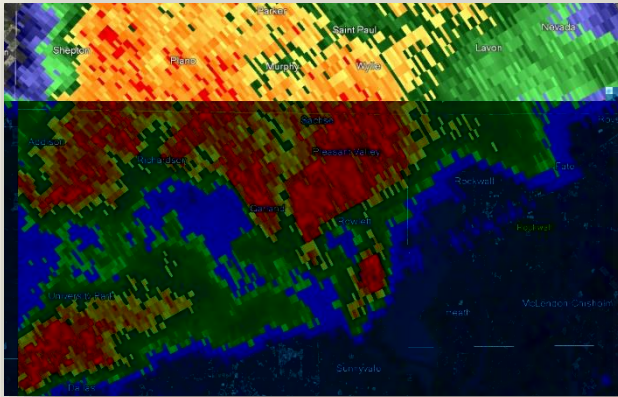


/NWSPhoenix

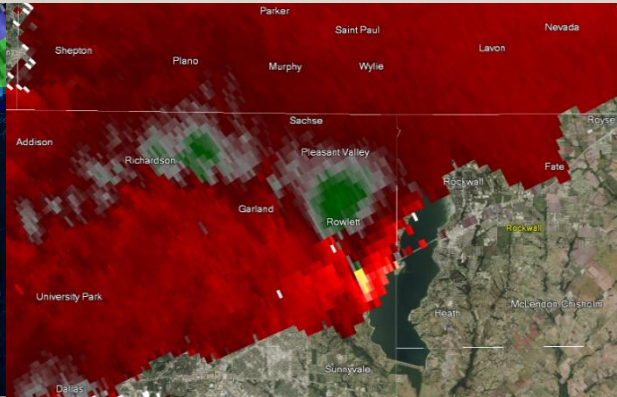


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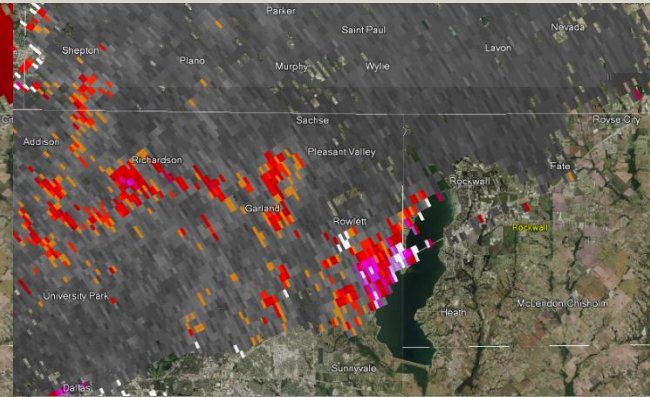
# Classic Radar Products



Reflectivity



Velocity



Spectrum Width



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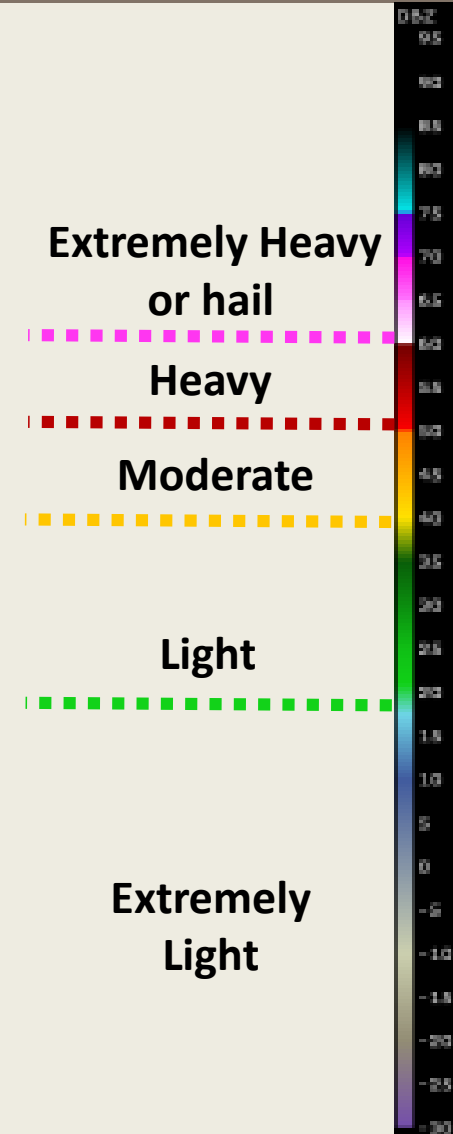
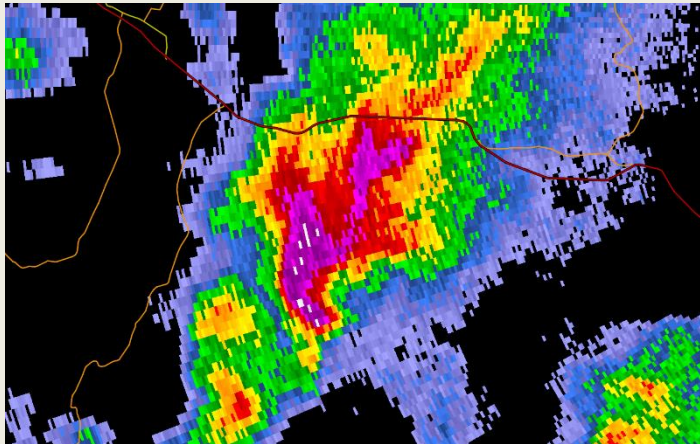


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# Reflectivity: What & How Much



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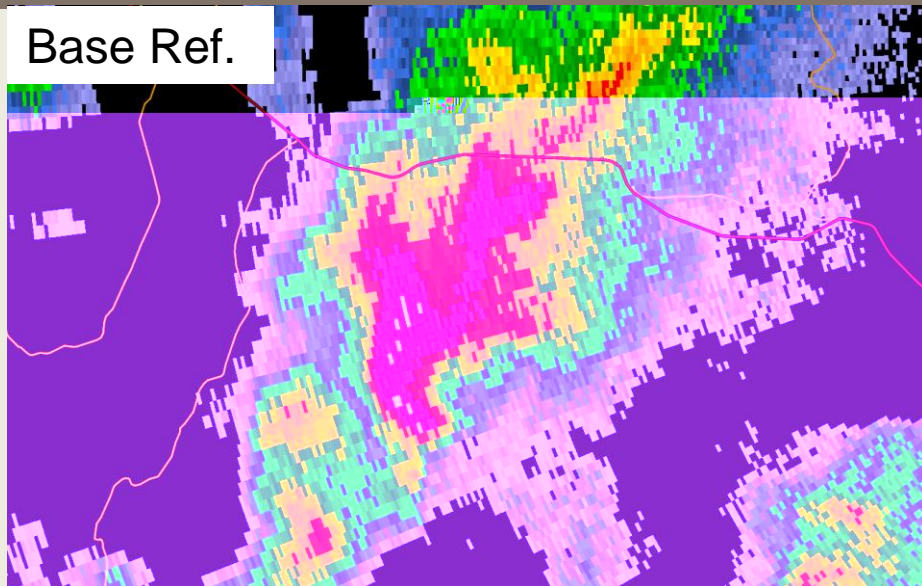
/NWSPhoenix



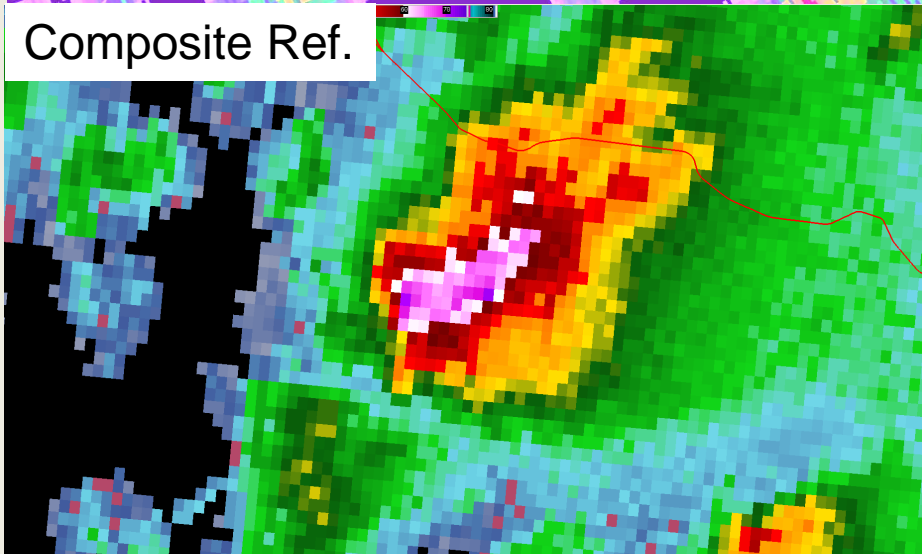
www.weather.gov/psr

# Base vs. Composite Reflectivity

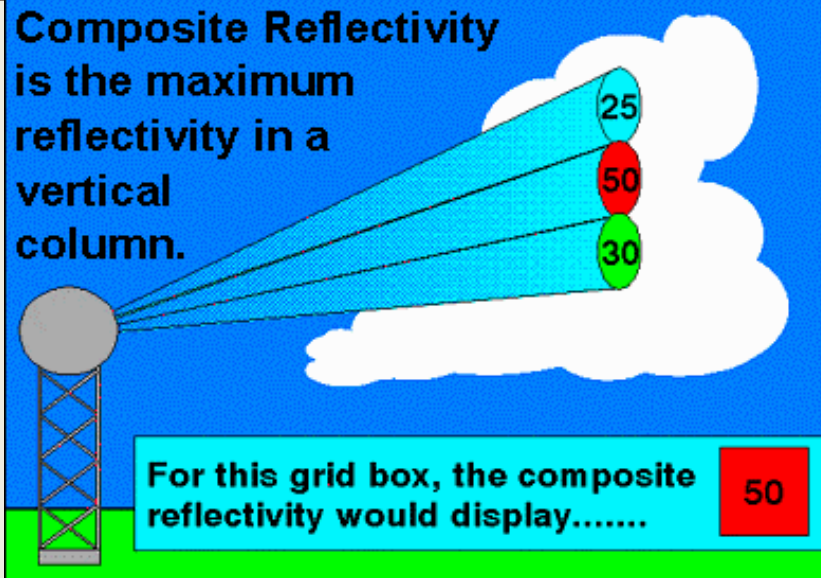
Base Ref.



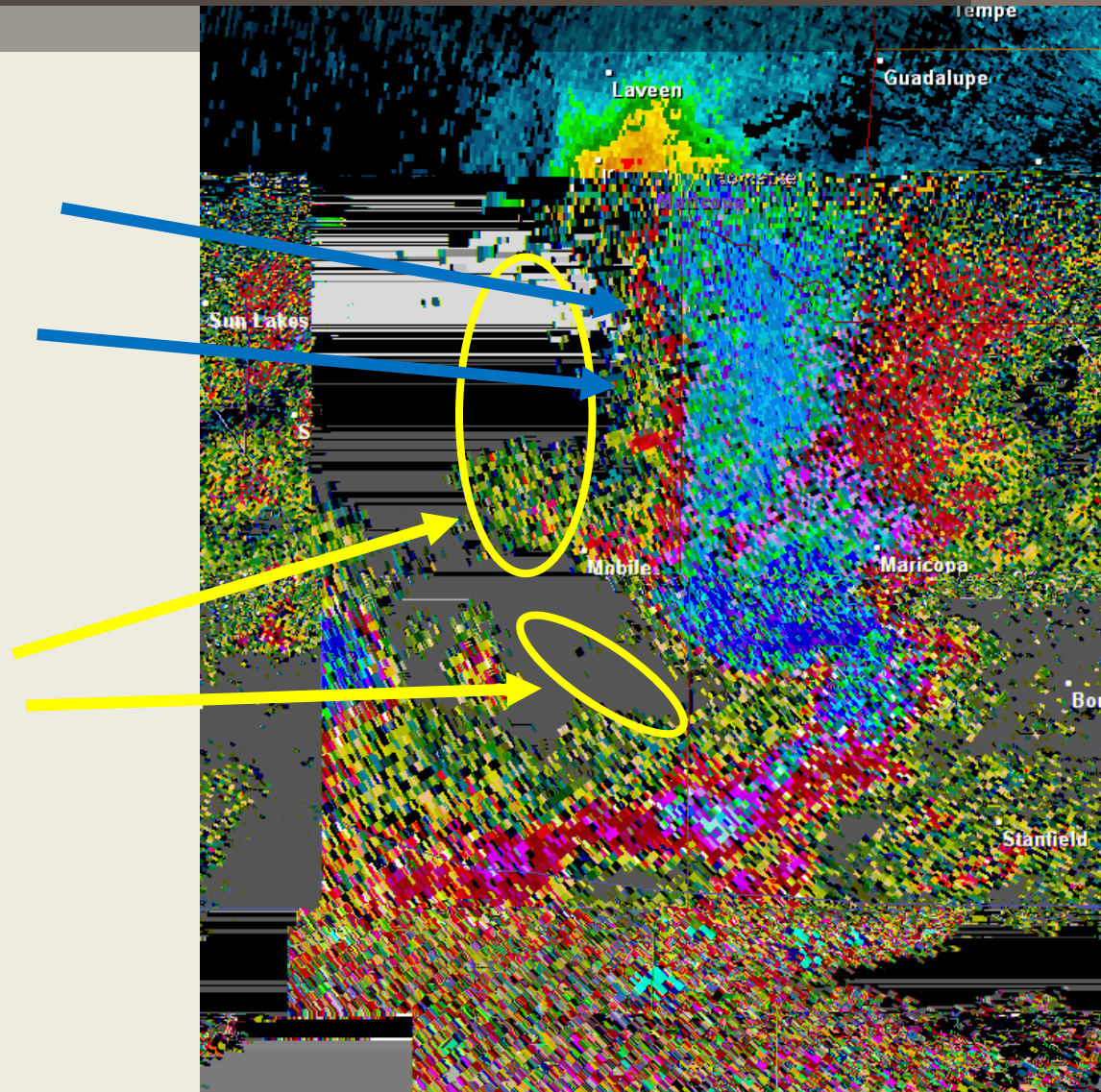
Composite Ref.



Composite Reflectivity is the maximum reflectivity in a vertical column.



# Radar Applications: Reflectivity



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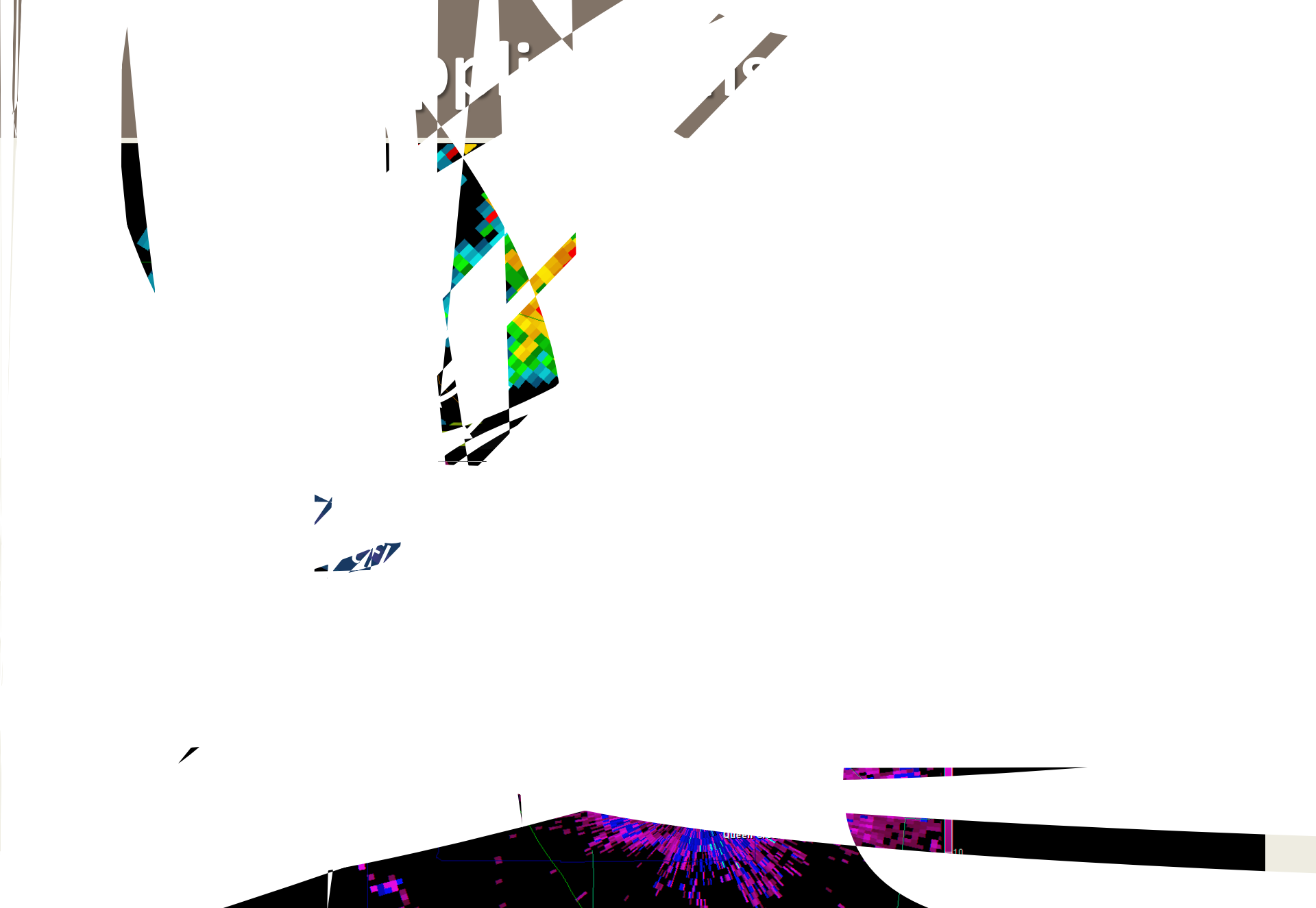


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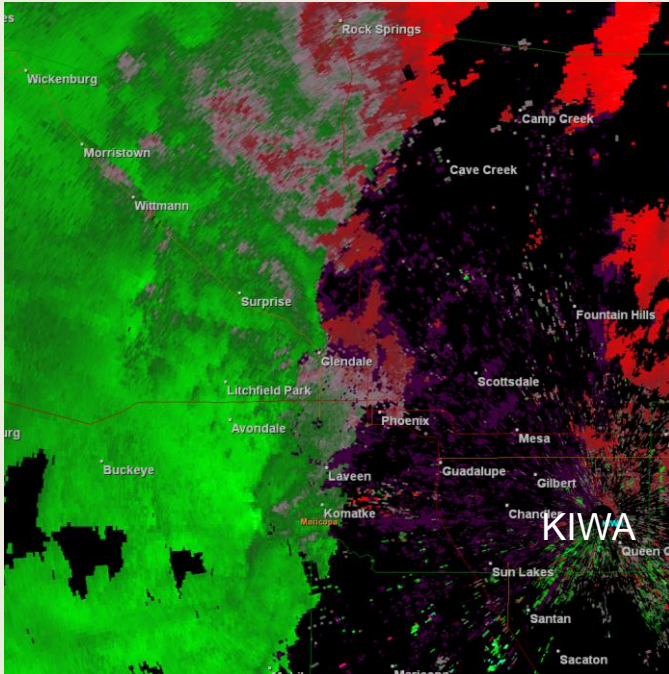


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# Velocity: Which Direction & How Fast

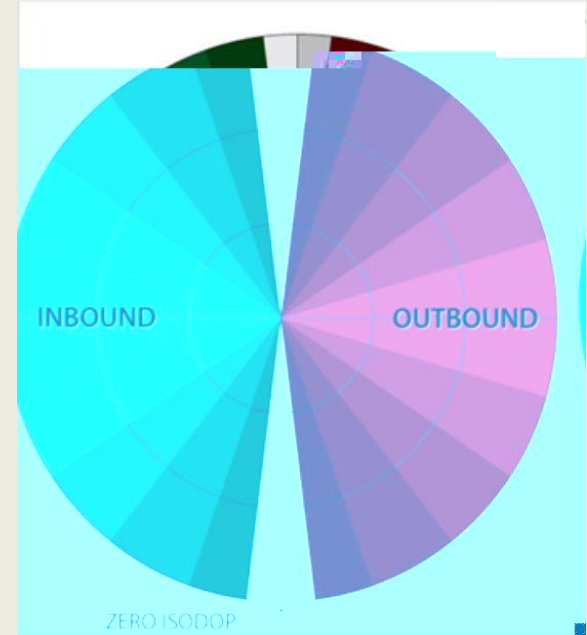


## Radial velocity

---

---

zero



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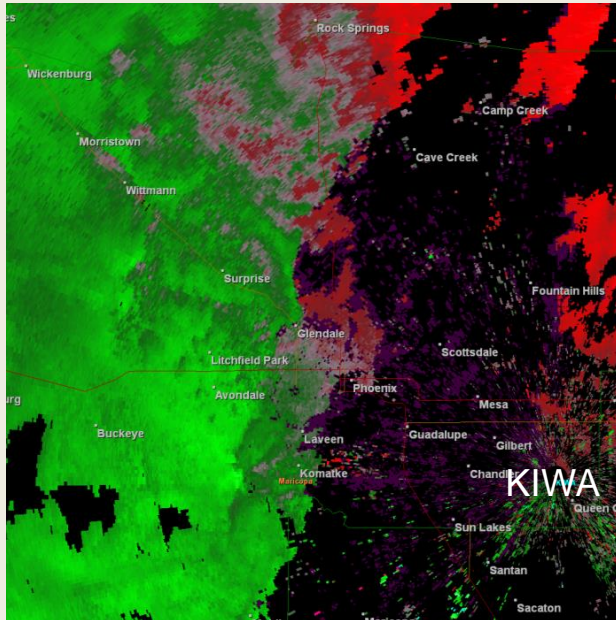


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# Base Velocity vs. Storm Relative Velocity

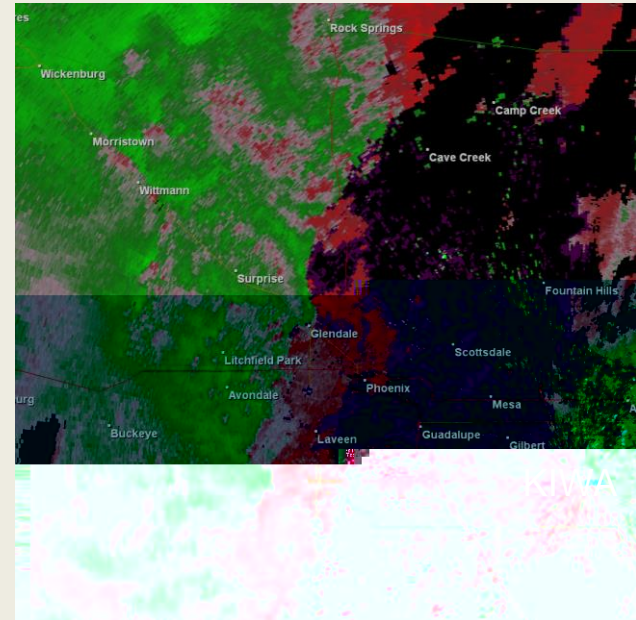
## Base Velocity

Best for estimating straight line wind speeds



## Storm Relative Velocity

Best for identifying rotation



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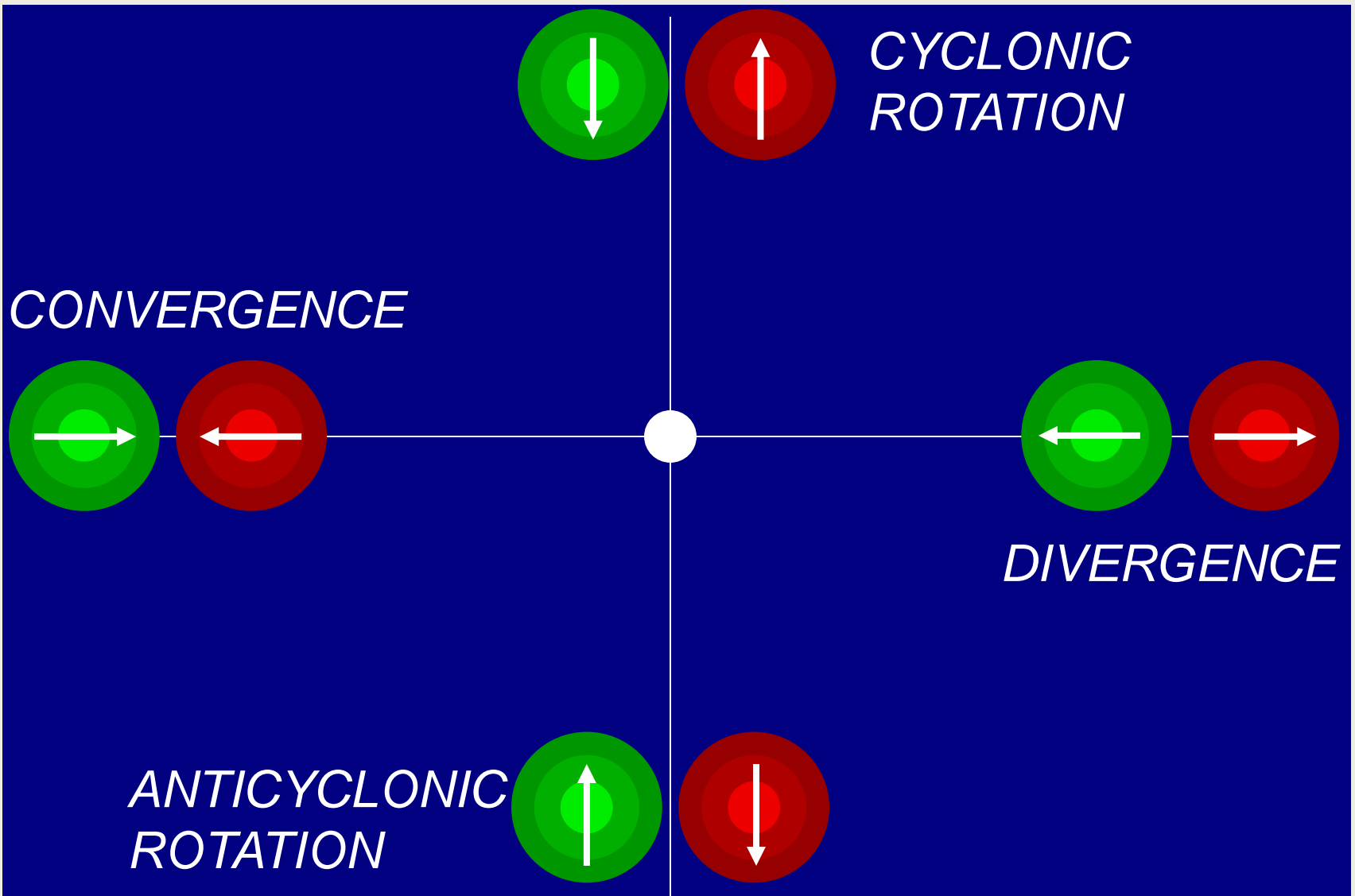


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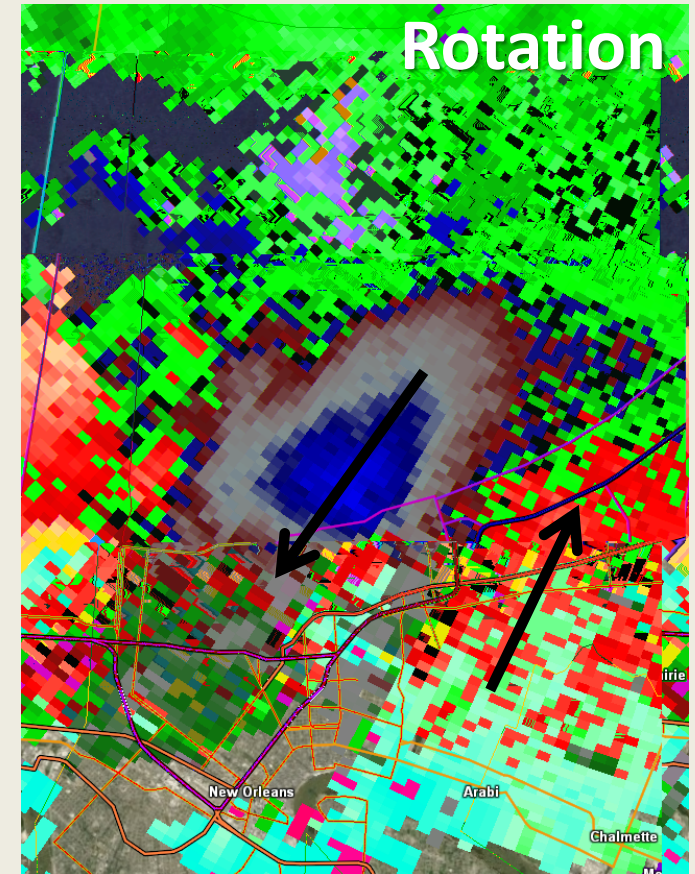
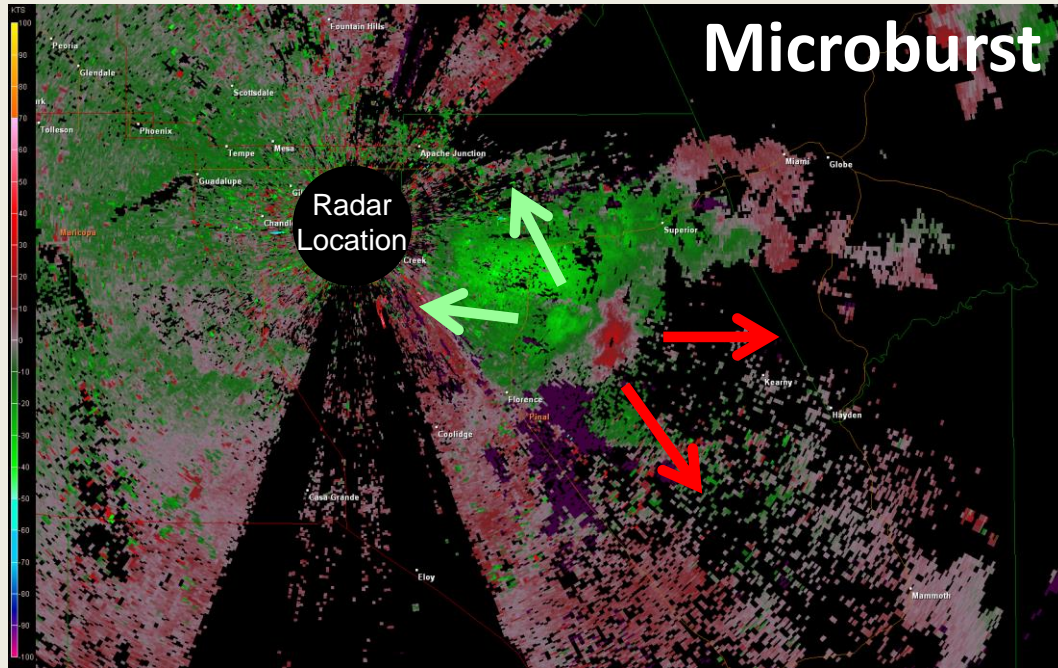


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# Radial Velocity Signatures



# Velocity Signatures



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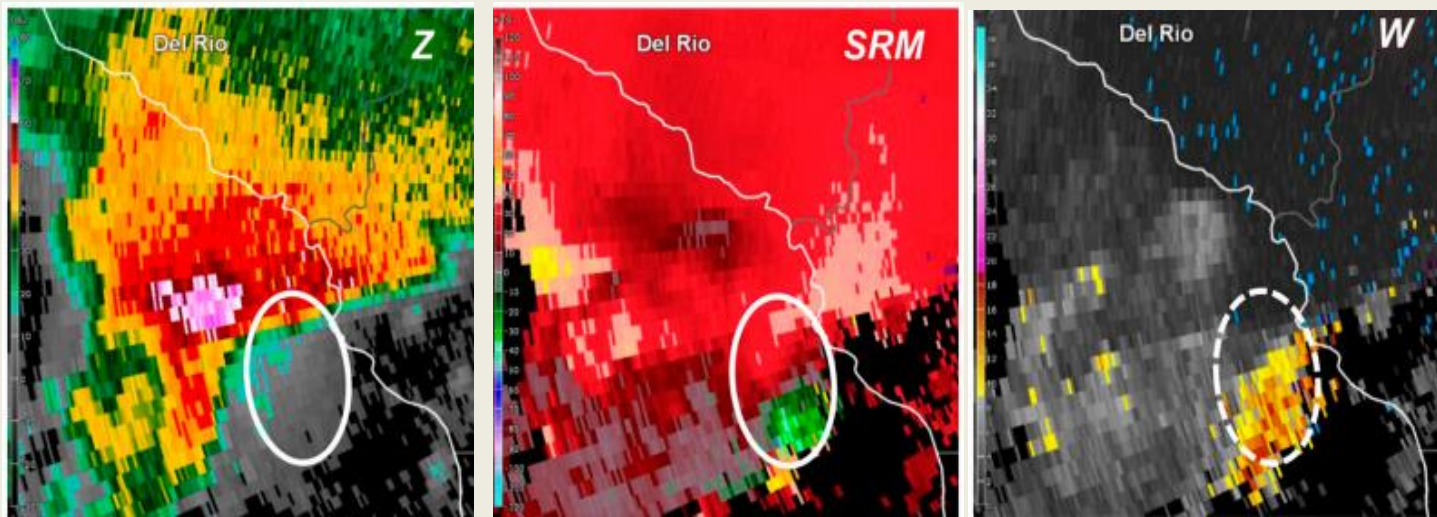


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# Spectrum Width: Variability of Motion



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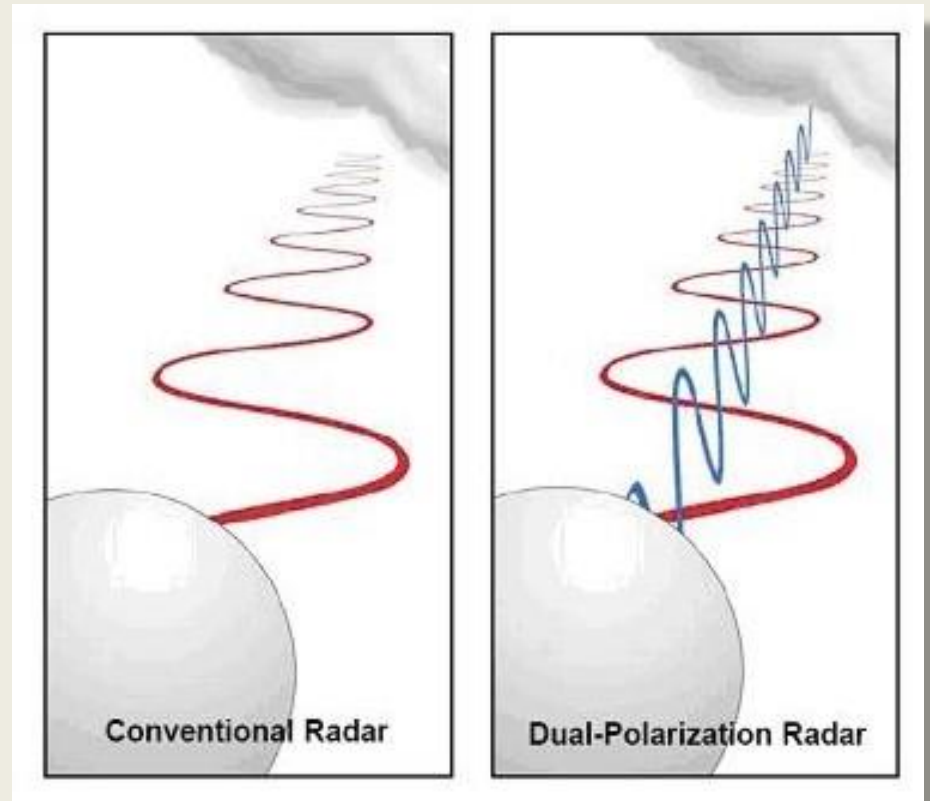


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# Dual Polarization



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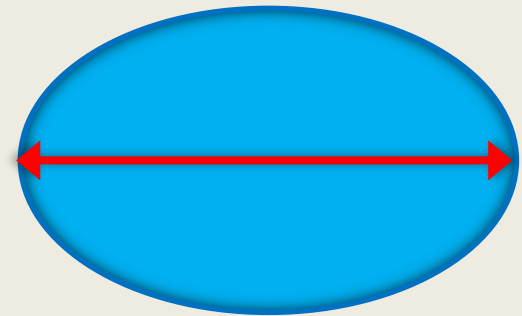


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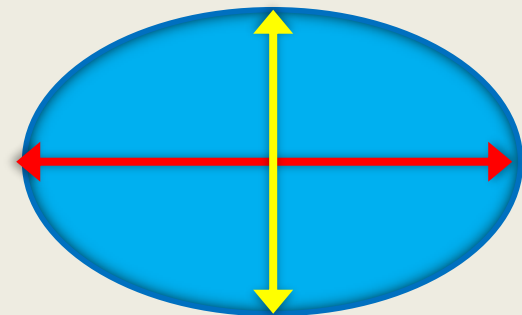
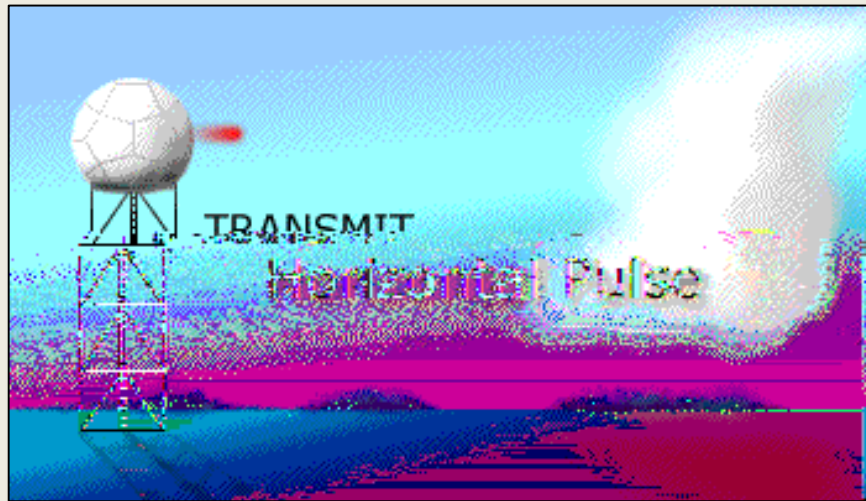
# Dual Polarization



**Reflected Energy → Reflectivity**



**Bigger the drop, the more energy reflected, the higher the reflectivity.**

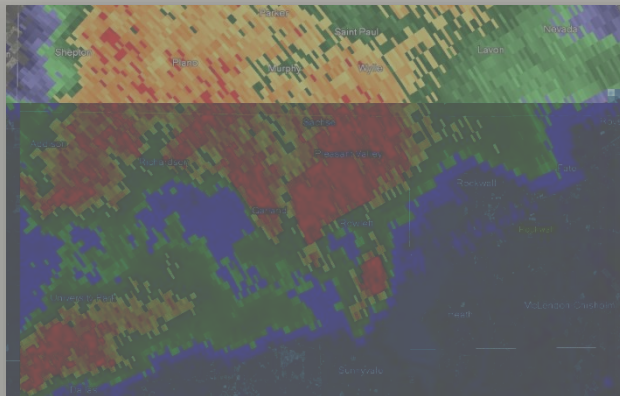


**For a big drop, there is more energy reflected in the horizontal than vertical.**

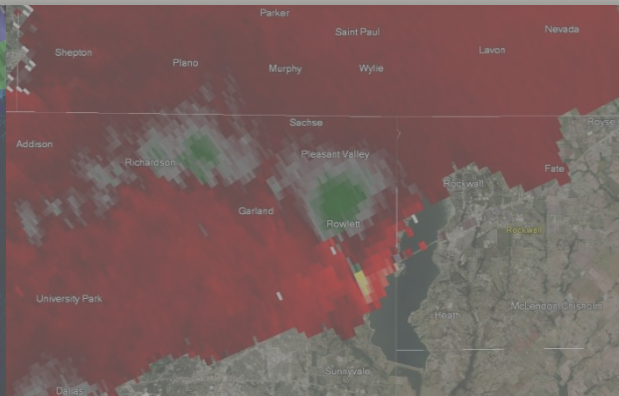




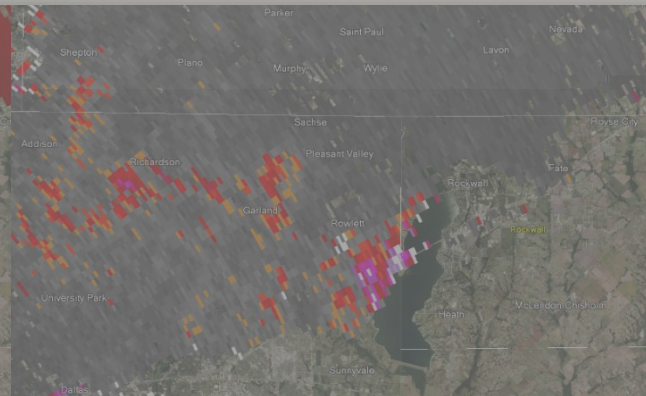
# Dual-Pol Radar Products



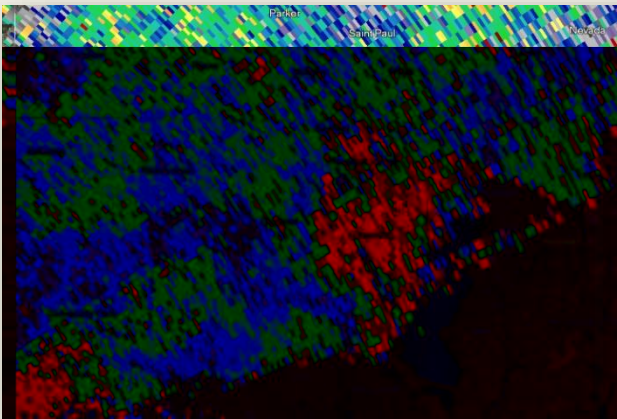
Reflectivity



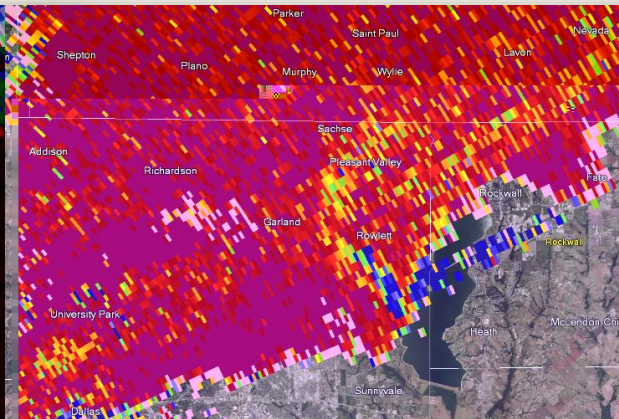
Velocity



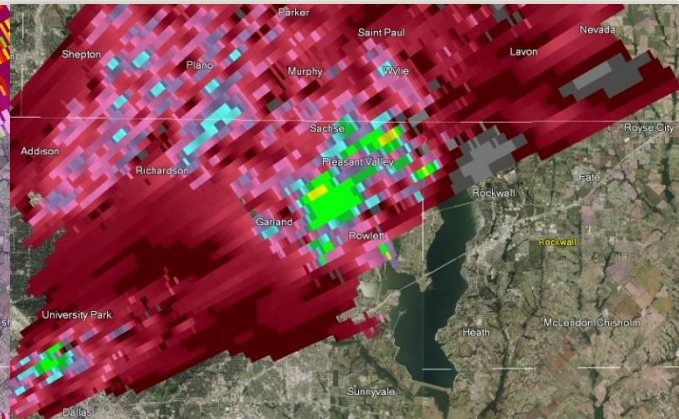
Spectrum Width



Differential Reflectivity



Correlation Coefficient



Specific Differential Phase



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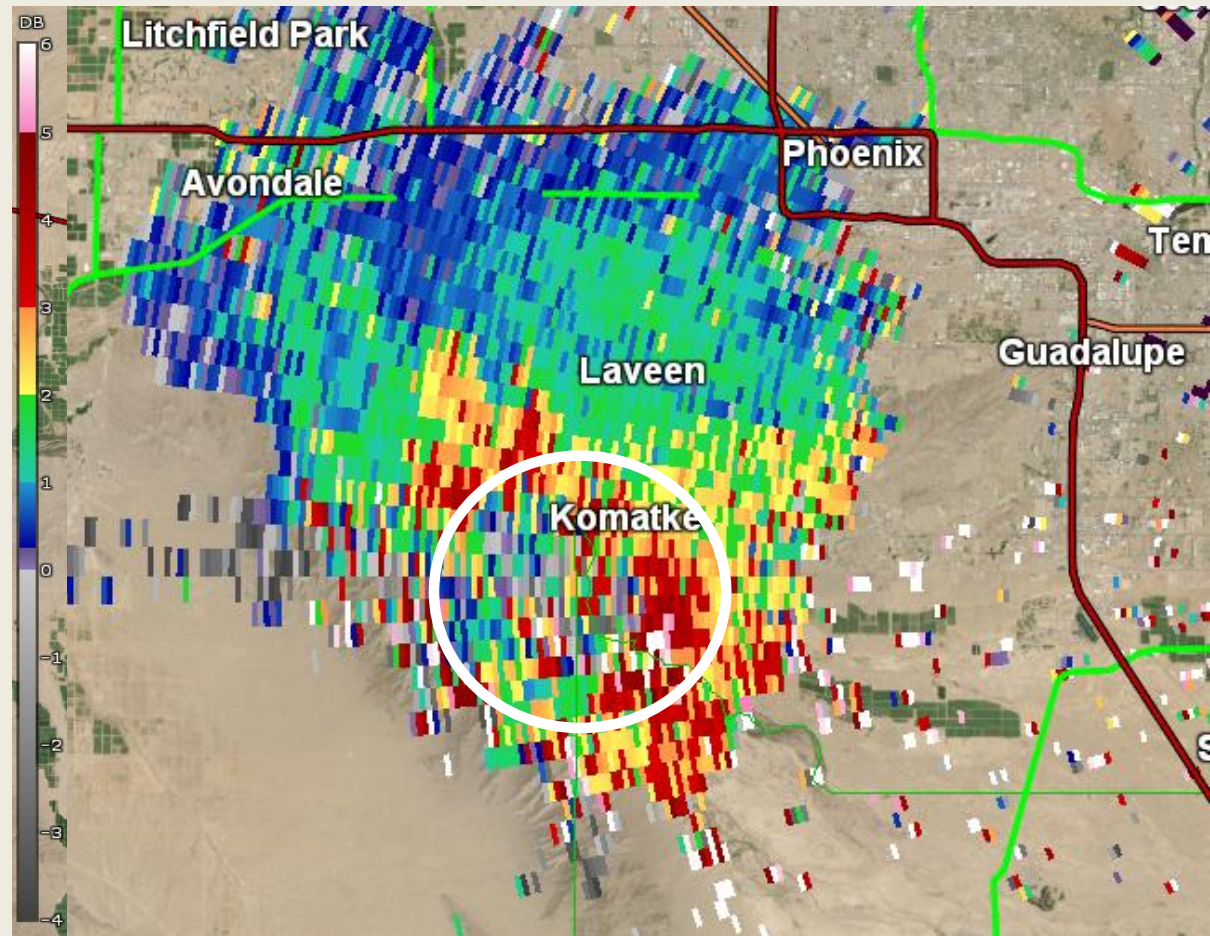


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# Differential Reflectivity: What Shape



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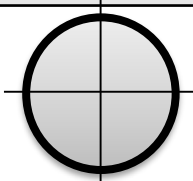
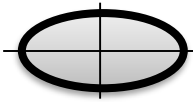
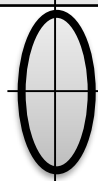


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# Differential Reflectivity: What Shape

| Spherical   | Horizontally Oriented   | Vertically Oriented   |
|---|---|---|
| $X = Y$   | $X > Y$   | $Y > X$   |
|  |  |  |
| $Z_{DR} \sim 0 \text{ dB}$  | $Z_{DR} > 0 \text{ dB}$   | $Z_{DR} < 0 \text{ dB}$   |

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A measure of the mean shape of particles in the sampling volume.



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# Differential Reflectivity: What Shape

## Spherical



$$Z_{DR} = 0 \text{ dB}$$

## Small, non-spherical

horizontal:



$$Z_{DR} > 0 \text{ dB}$$

vertical:



$$Z_{DR} < 0 \text{ dB}$$



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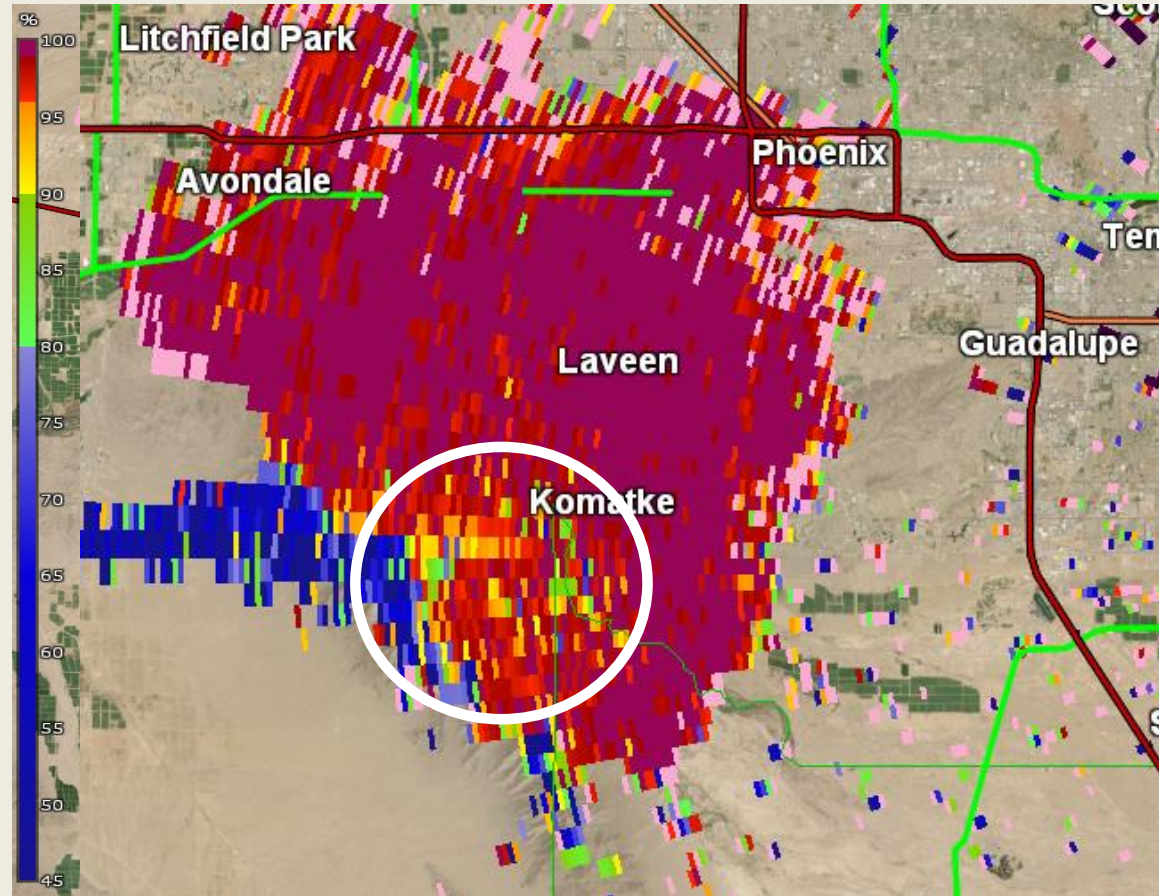


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# Correlation Coefficient: How Similar



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# Correlation Coefficient: How Similar

| Meteorological<br>(Uniform) | Meteorological<br>(Non-Uniform)           | Non-<br>Meteorological    |
|-----------------------------|---|---------------------------|
| Rain, Snow, etc             | Hail, Wet<br>Aggregates<br>(melting snow) | Birds,<br>insects, debris |
| High CC (>0.97)             | Moderate CC<br>(0.80 to 0.97)             | Low CC (<0.8)             |

Units:  
None

*NWS State College*



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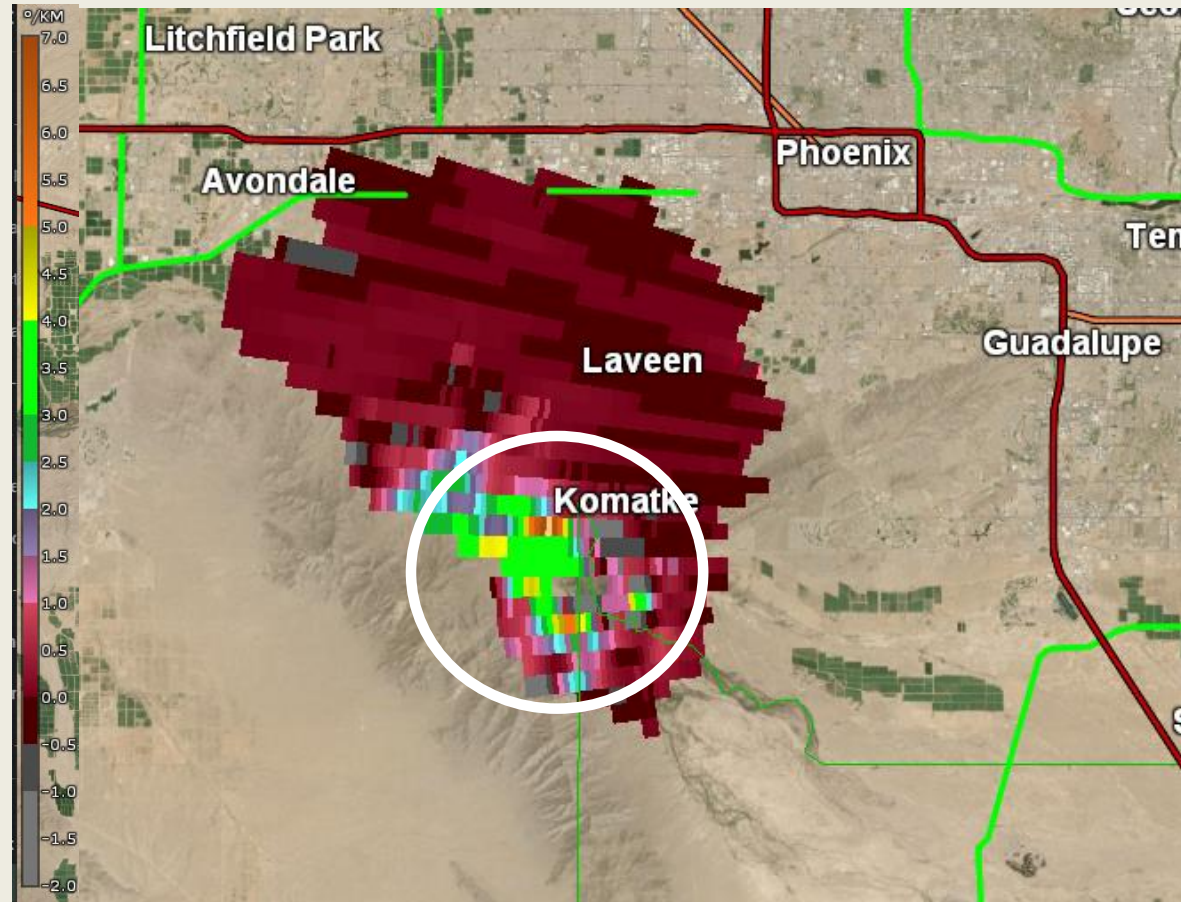


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# Specific Differential Phase: How Many



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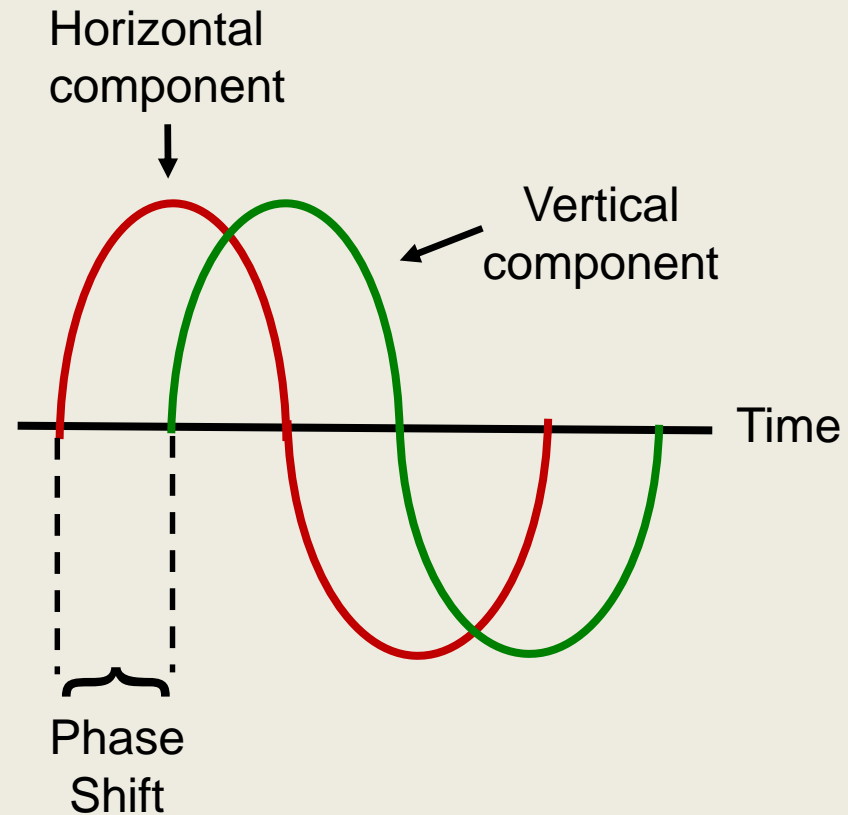
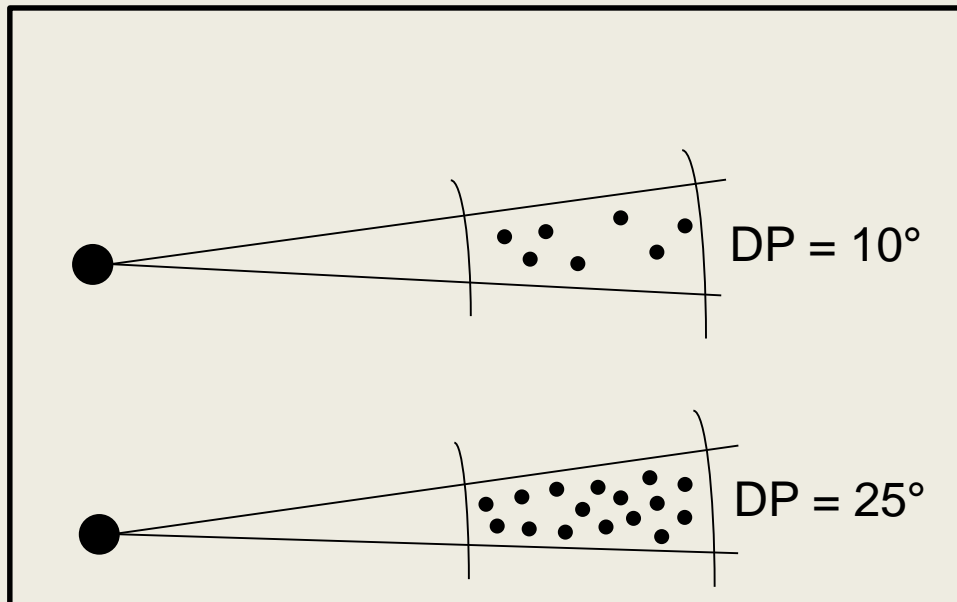
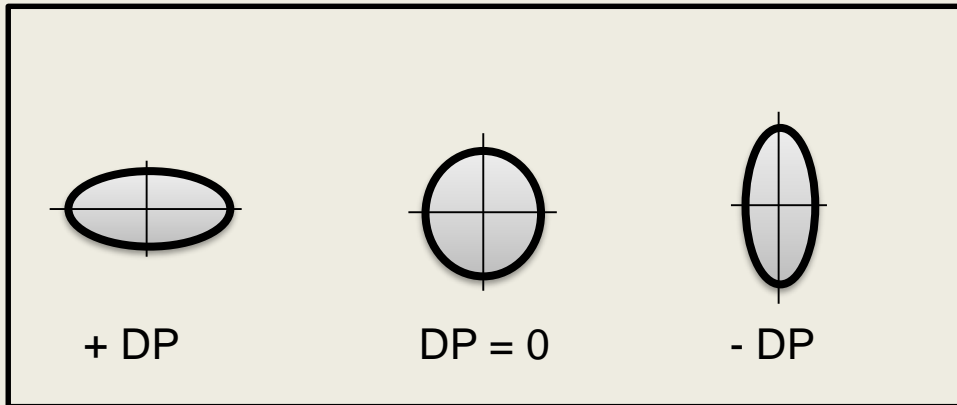


/NWSPhoenix



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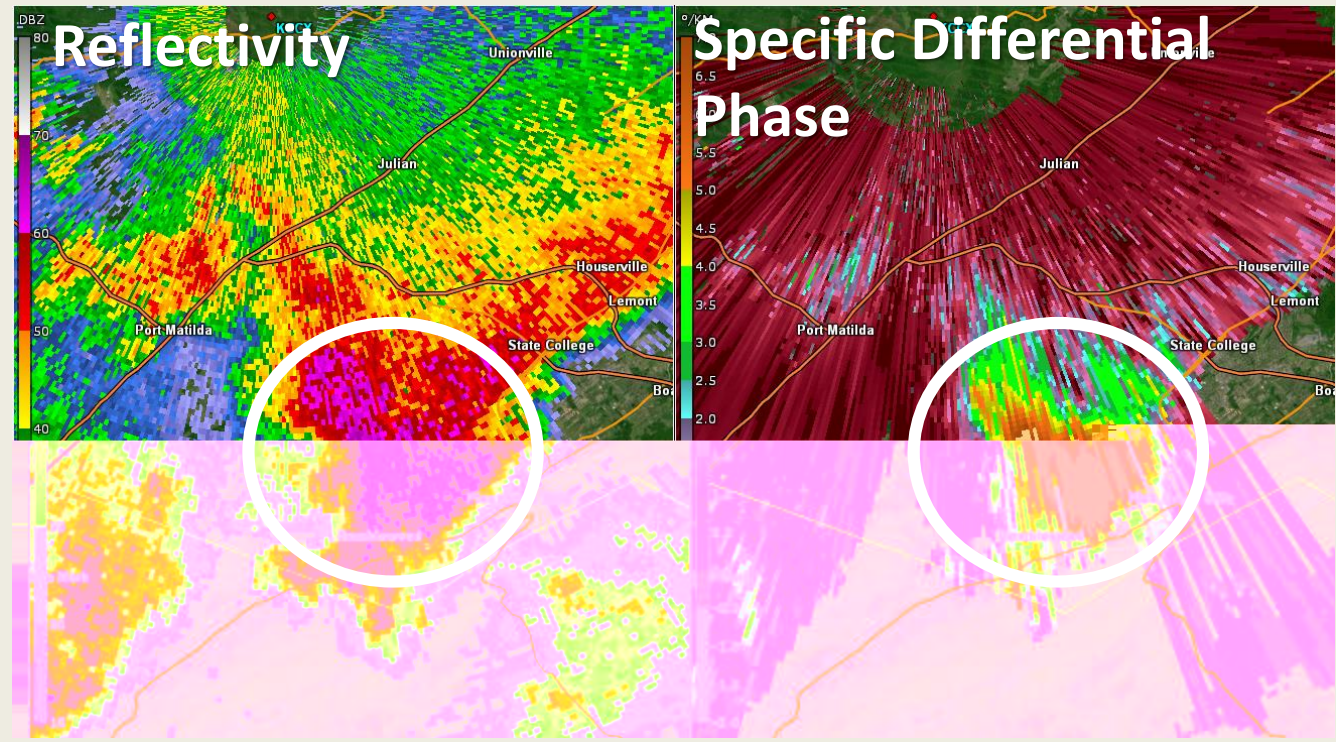
# Specific Differential Phase: Phase Shift



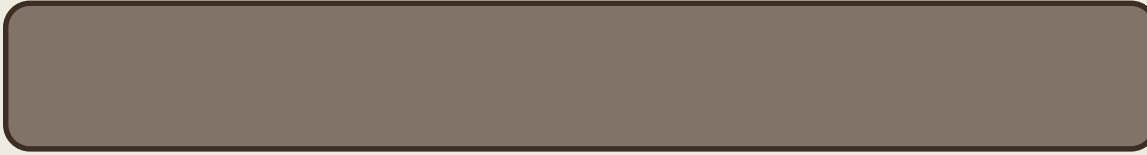


# Specific Differential Phase: Application

very heavy rain  
or  
large amounts of  
small melting hail



# Program Outline



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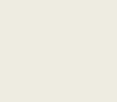


/NWSPhoenix



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# Case Study #1



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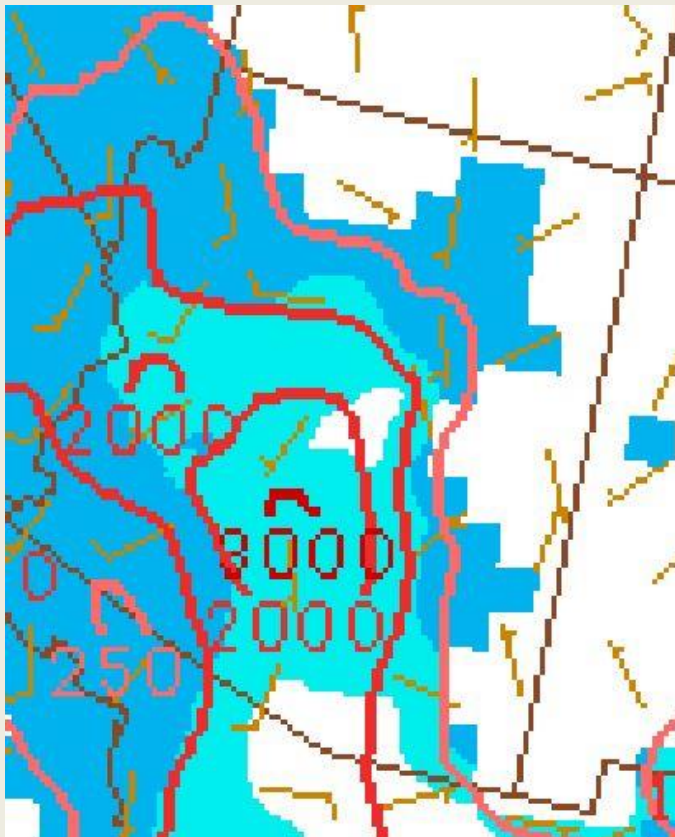
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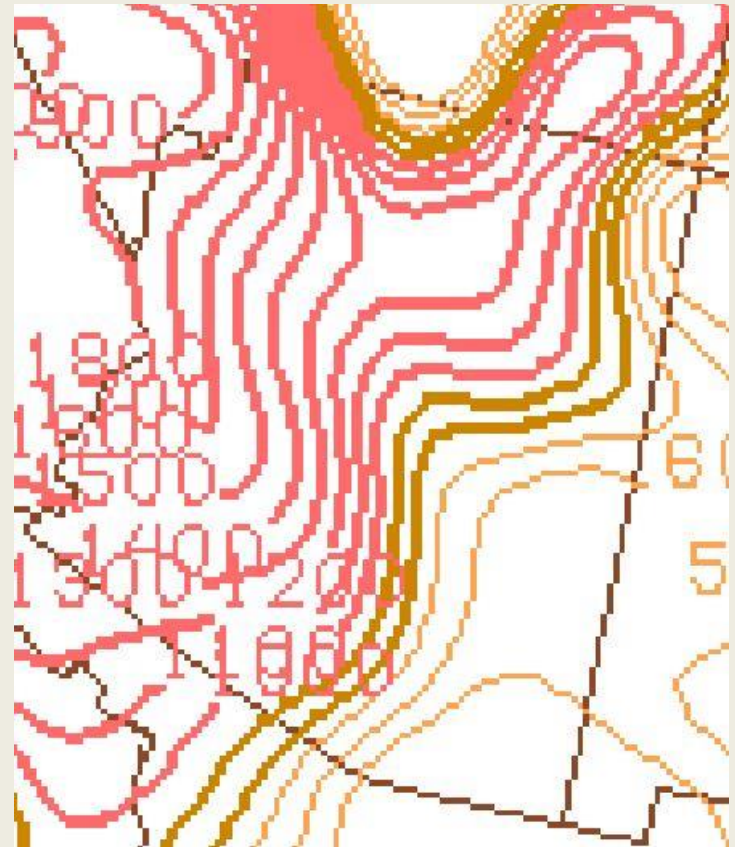
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# Thermodynamics

MLCAPE



DCAPE



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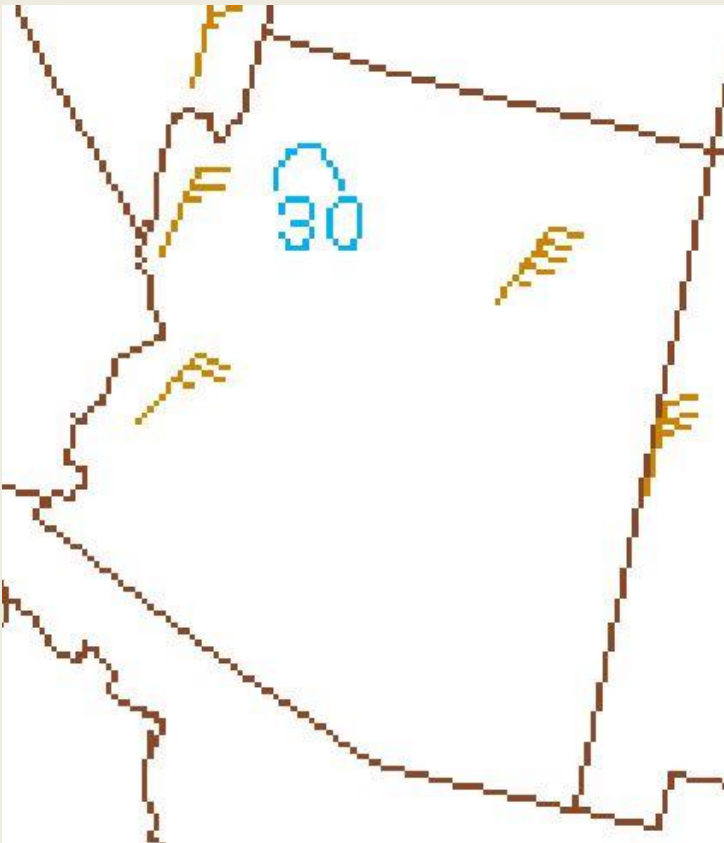
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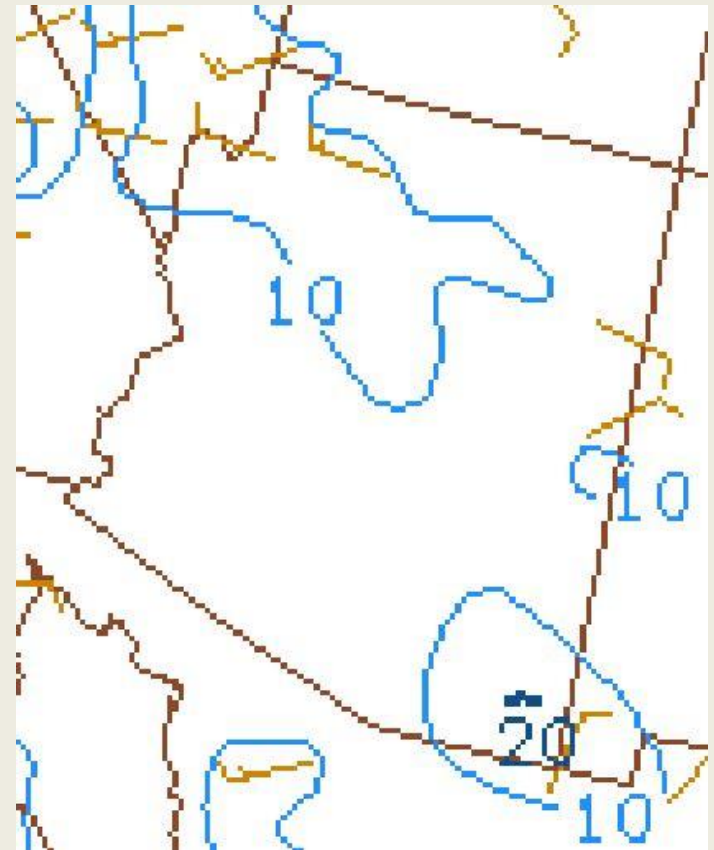
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# Kinematics

Effective Shear



0-1km Shear



# Kinematics

850mb - 300mb  
Average Winds



/NWSPhoenix



@NWSPhoenix



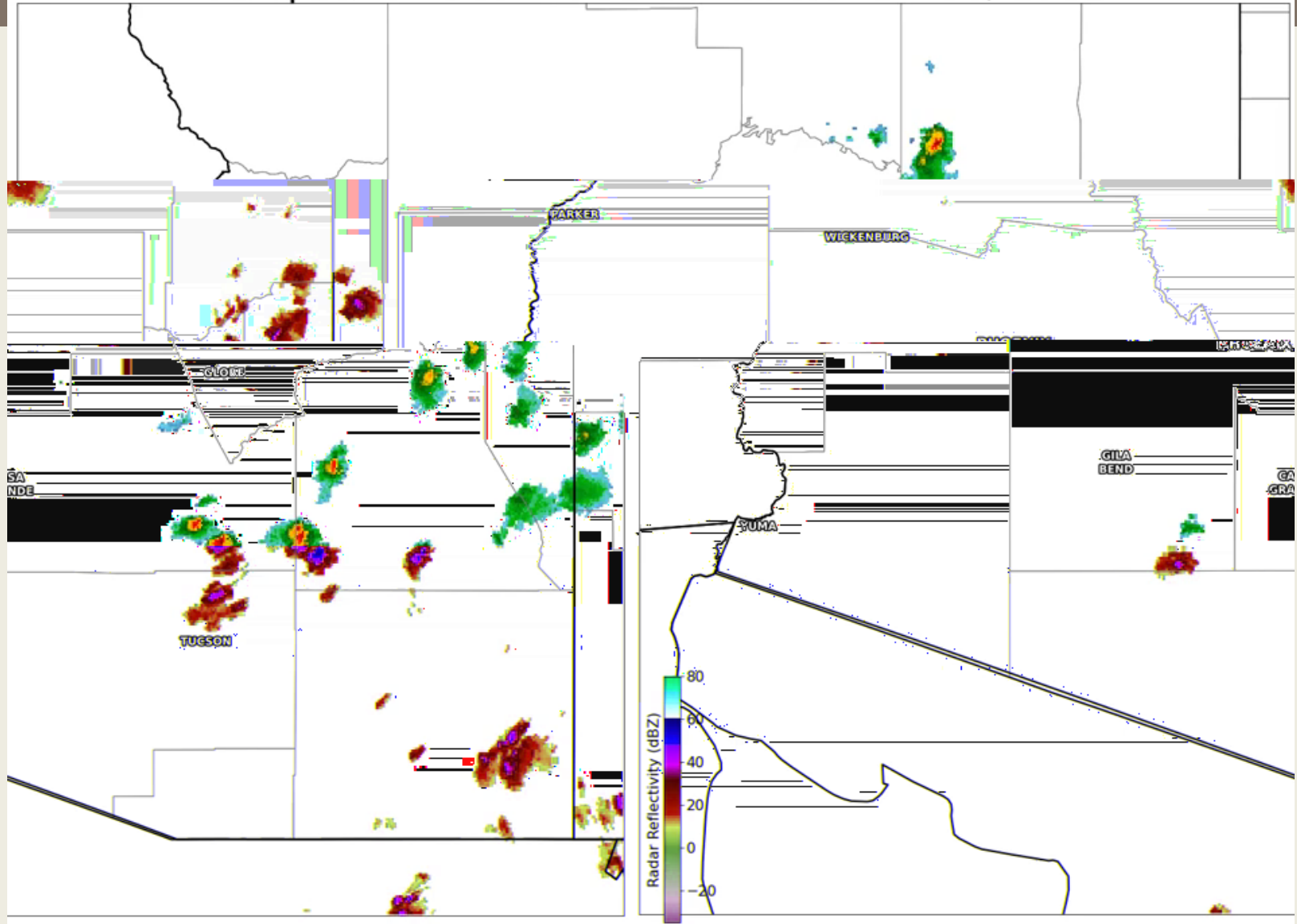
/NWSPhoenix



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# Reflectivity Loop

Composite Radar at 12:00 PM on Mon 16, 2021



/NWSPhoenix



@NWSPhoenix



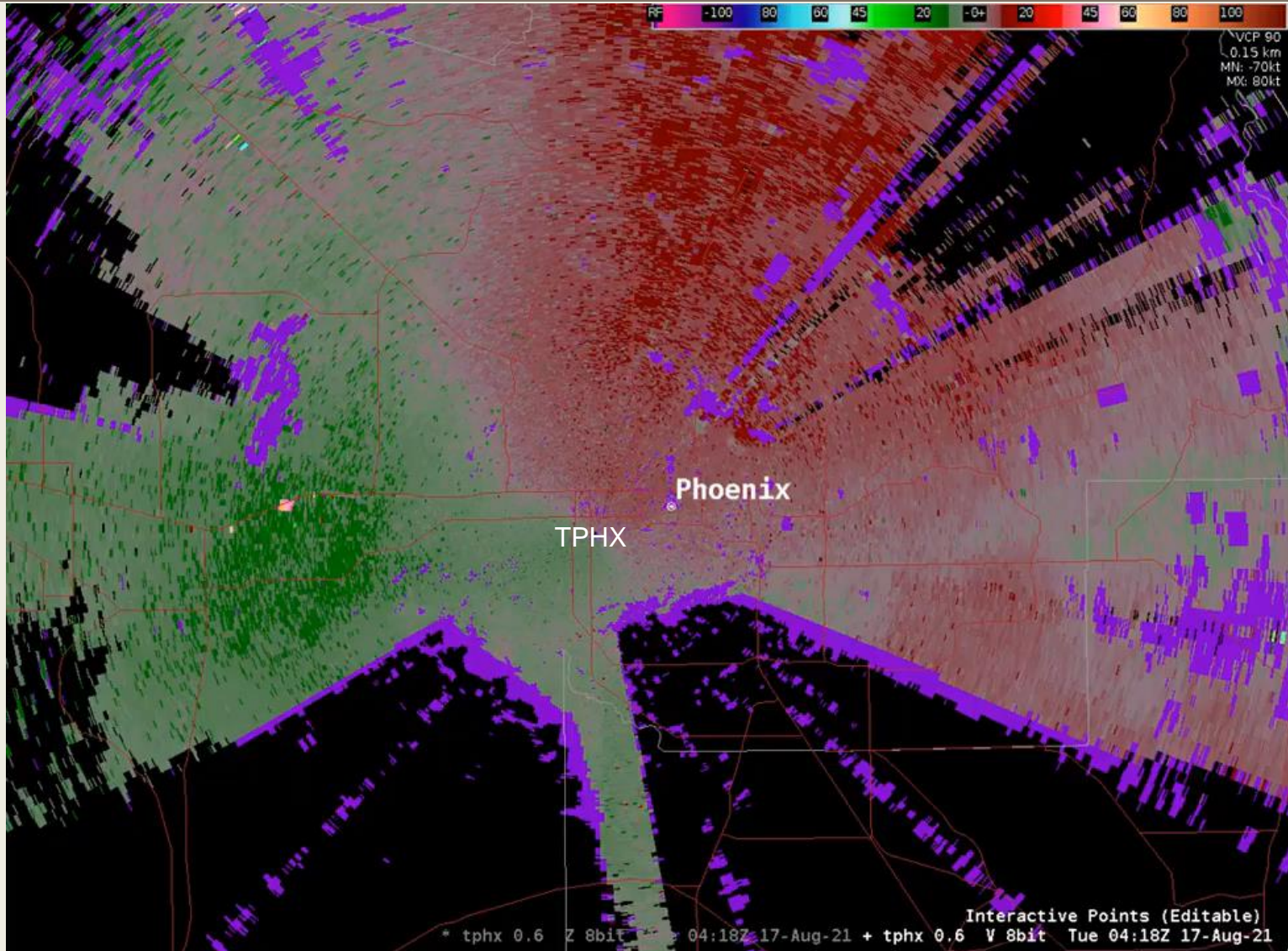
/NWSPhoenix



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# Base Velocity Loop

9:19 PM – 12:59 AM



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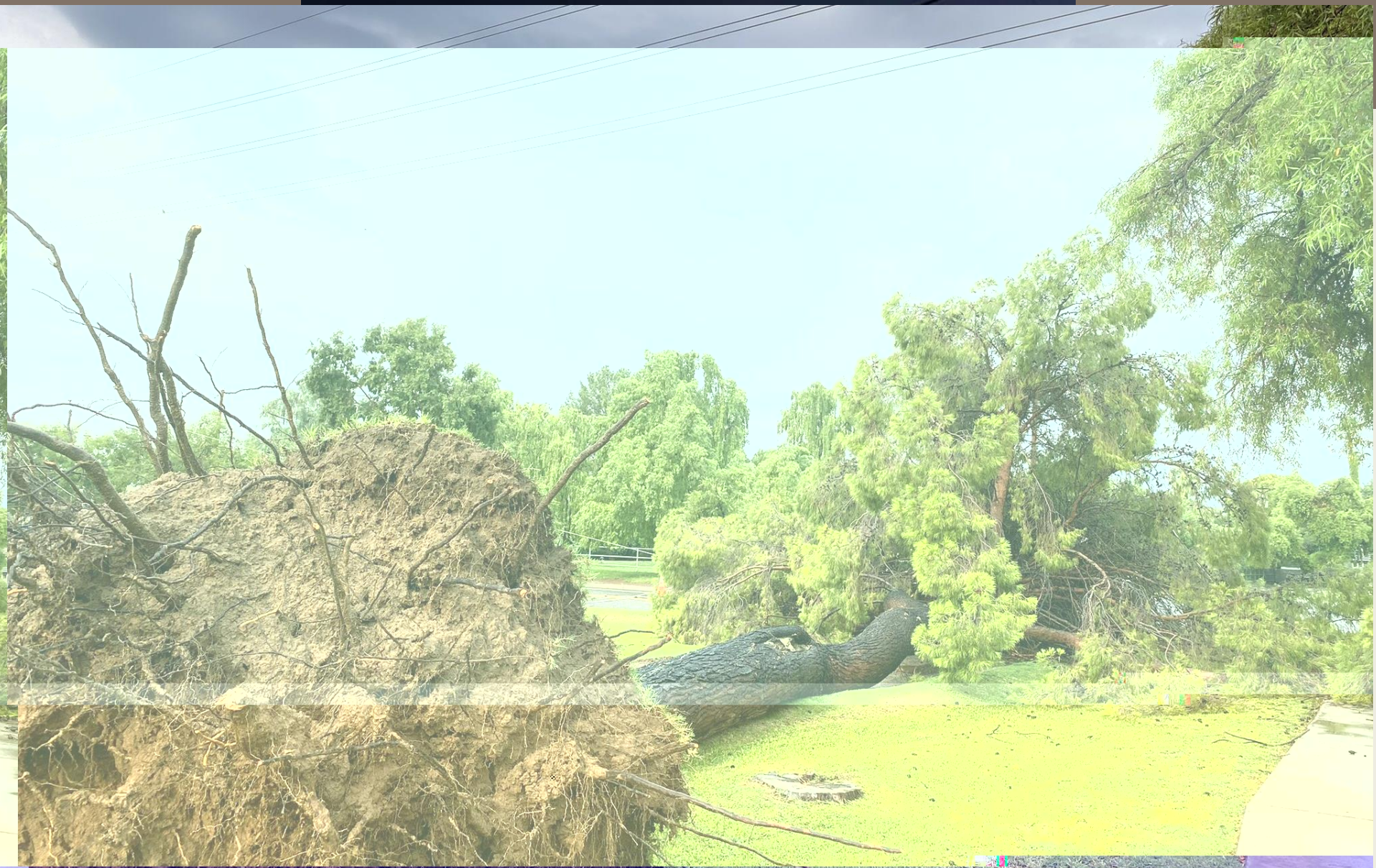


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Phoenix

Kim Quintero AZ Family

 /NWSPhcnix

Laveen

@reinazee

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# Case Study #2



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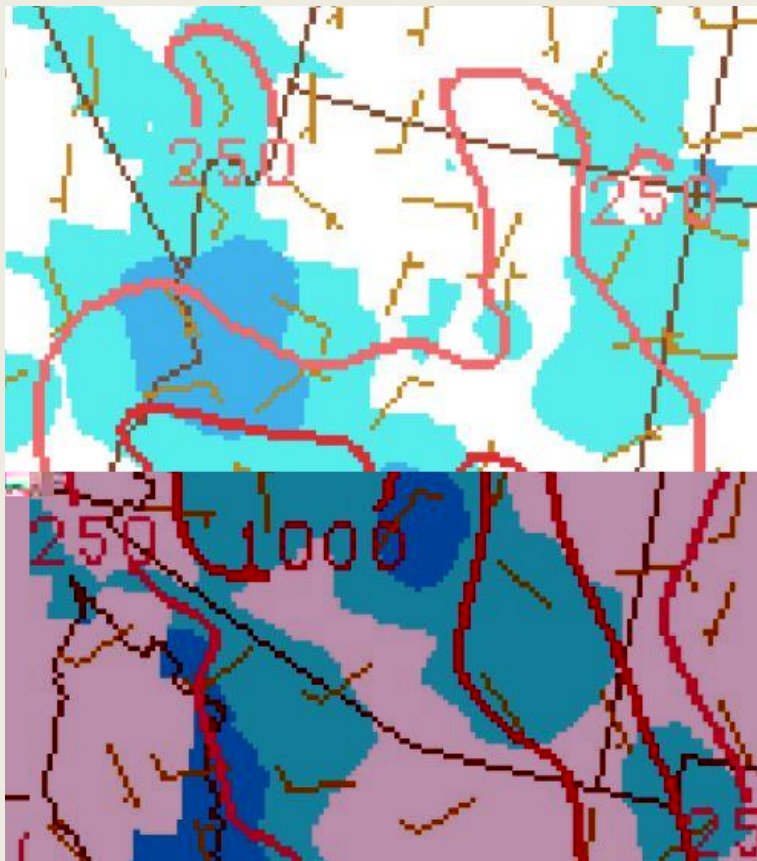
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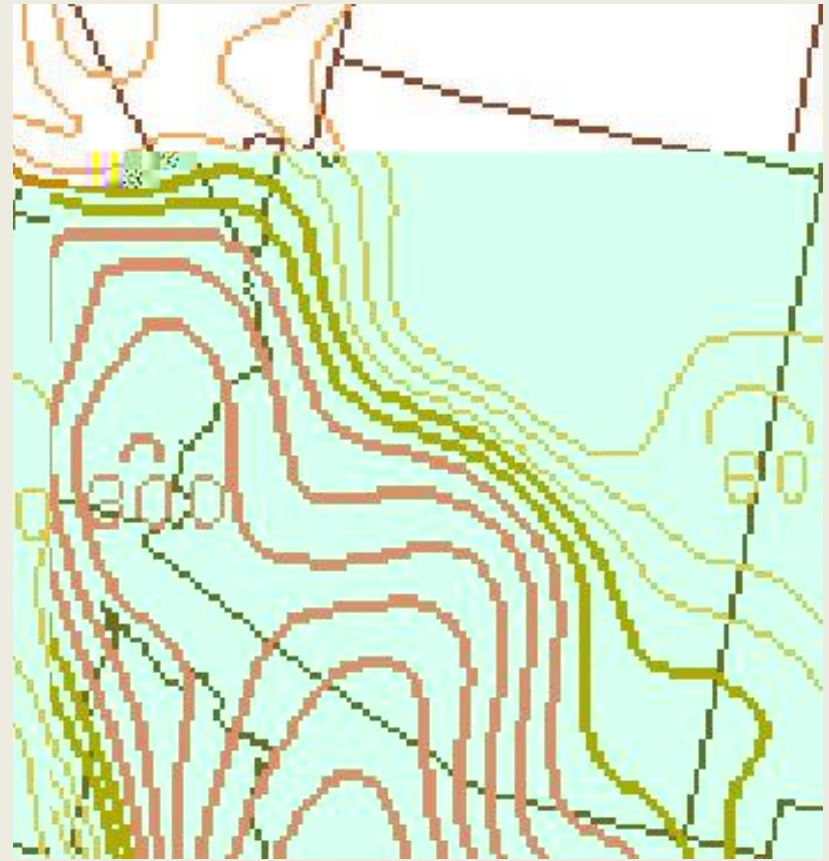
[www.weather.gov/psr](http://www.weather.gov/psr)

# Thermodynamics

MLCAPE



DCAPE



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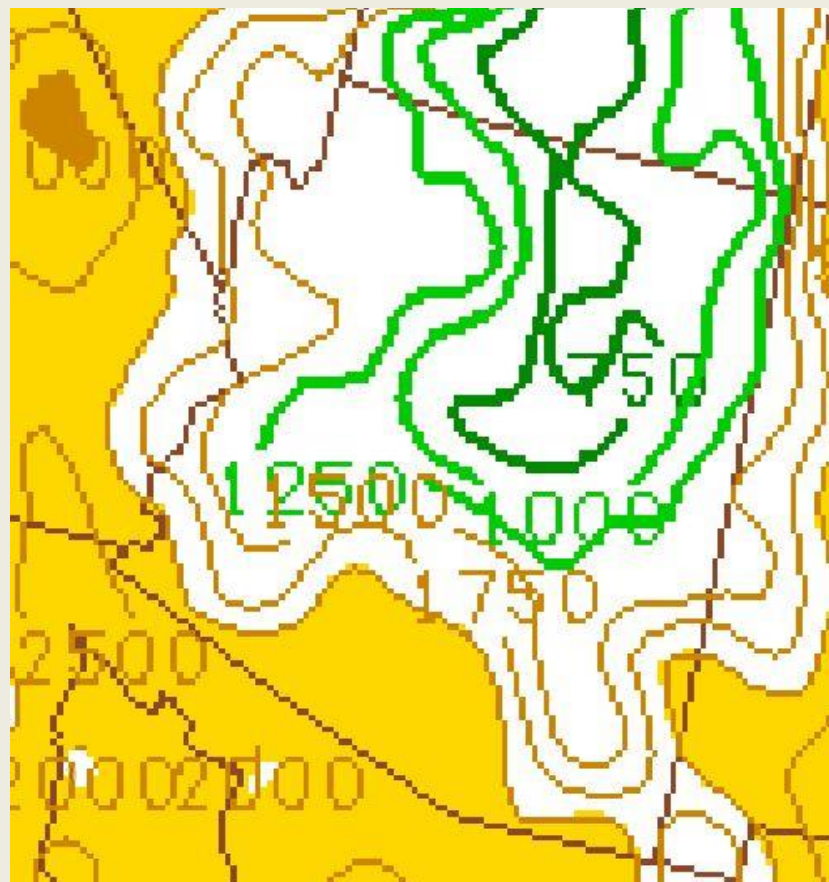
/NWSPhoenix



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# Thermodynamics

## LCL Height



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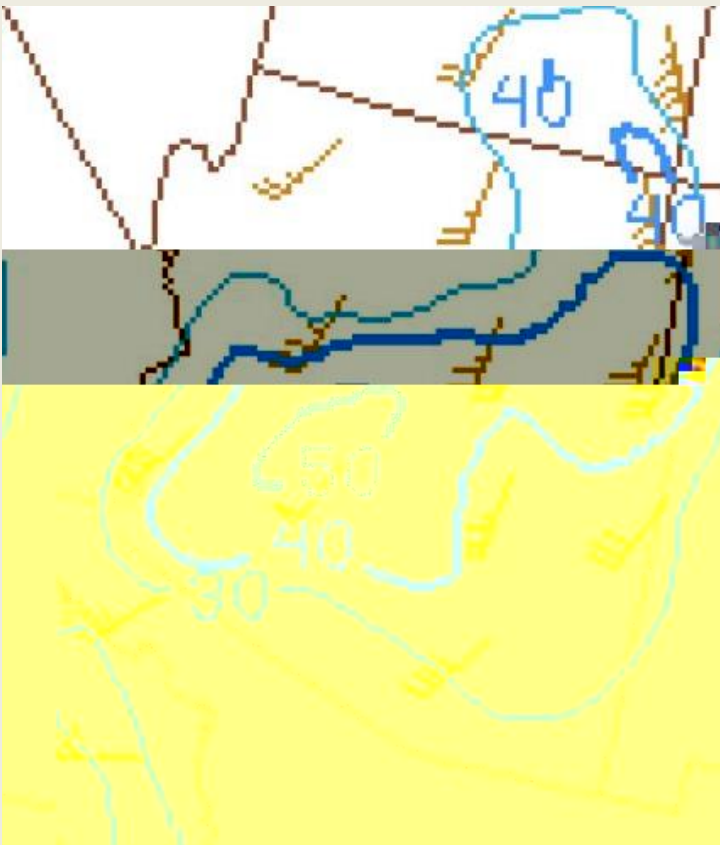
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# Kinematics

Effective Shear



0-1km Shear



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# Kinematics

850mb - 300mb Average Winds



/NWSPhoenix



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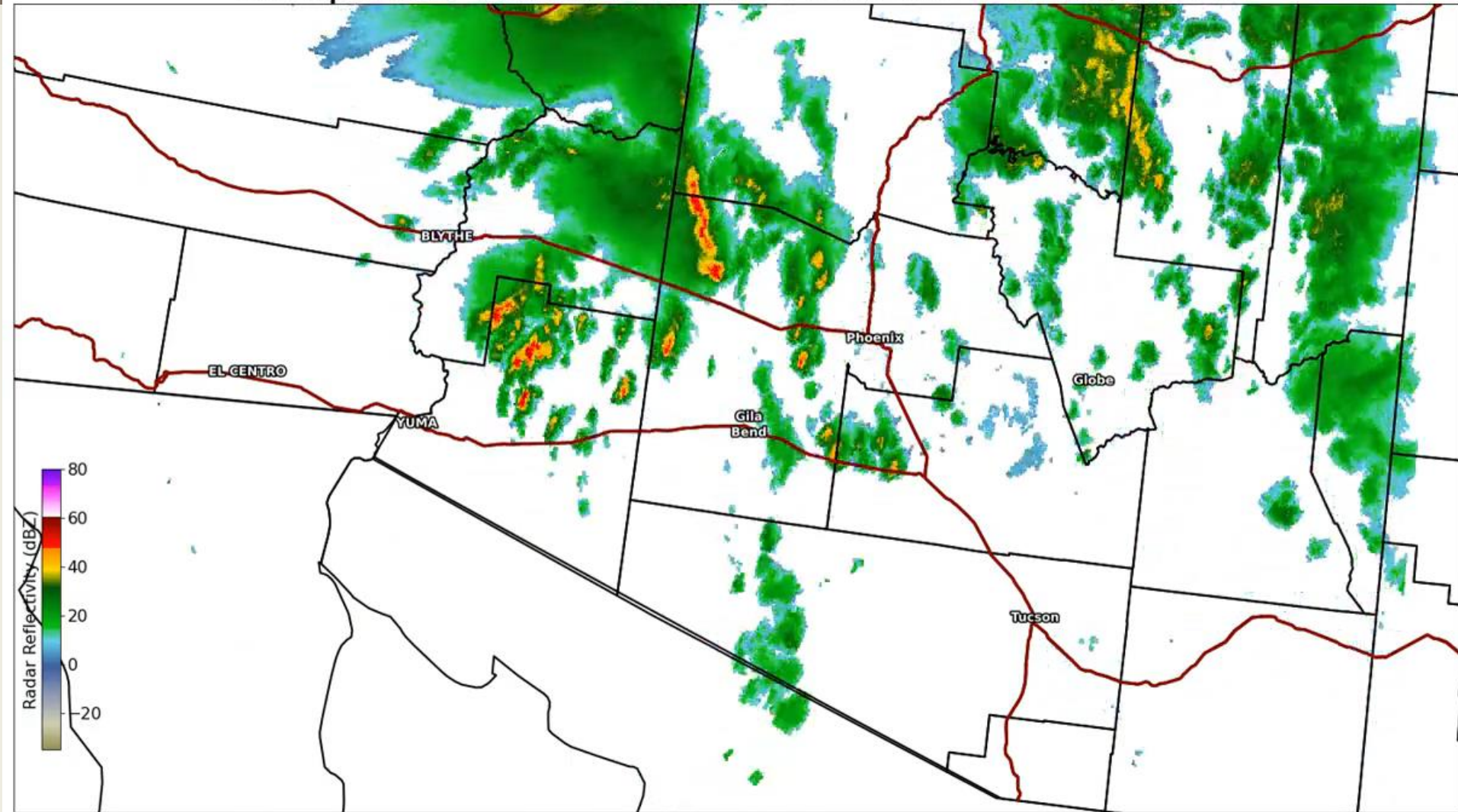
/NWSPhoenix



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# Reflectivity Loop

Composite Radar at 11:00 AM on Oct 05, 2021



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# Base Reflectivity Loop

2:06 PM – 6:36 PM



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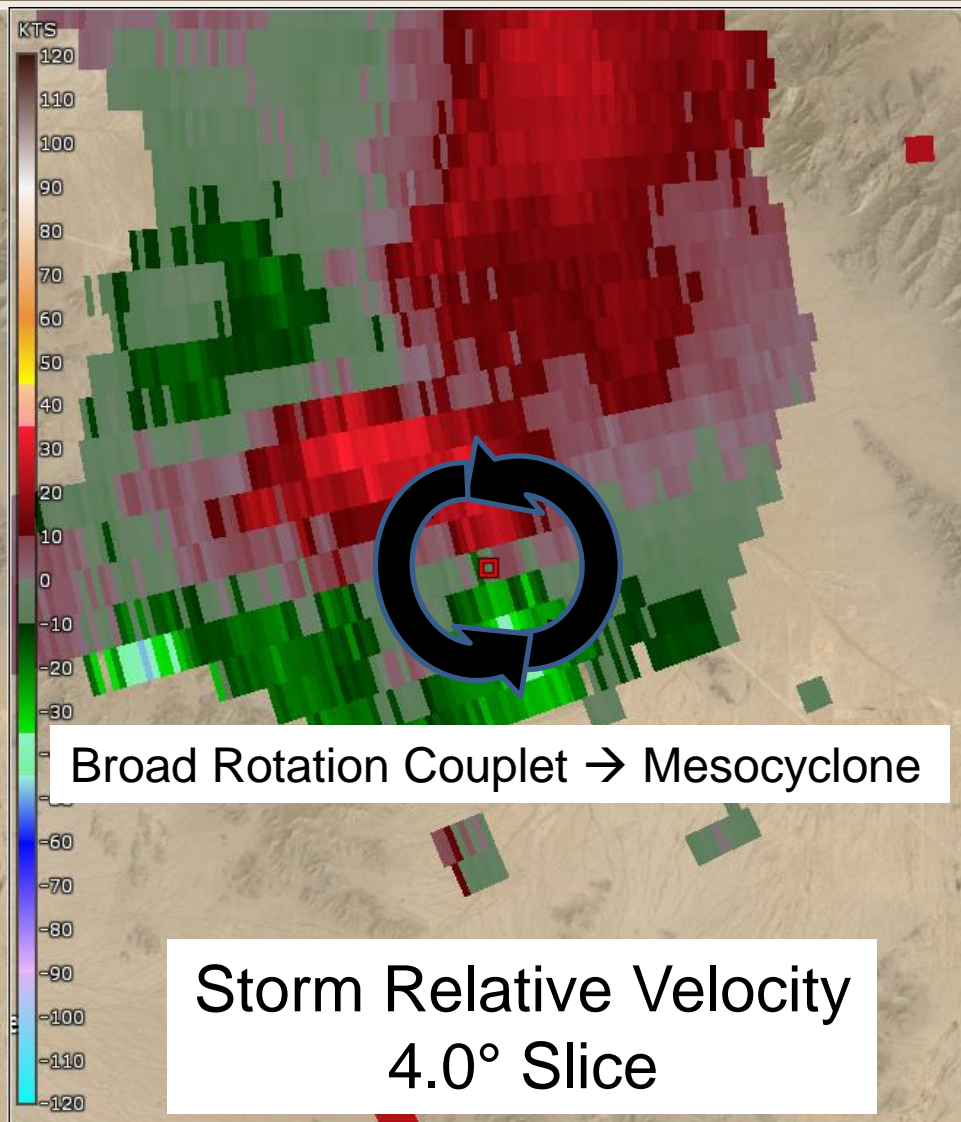
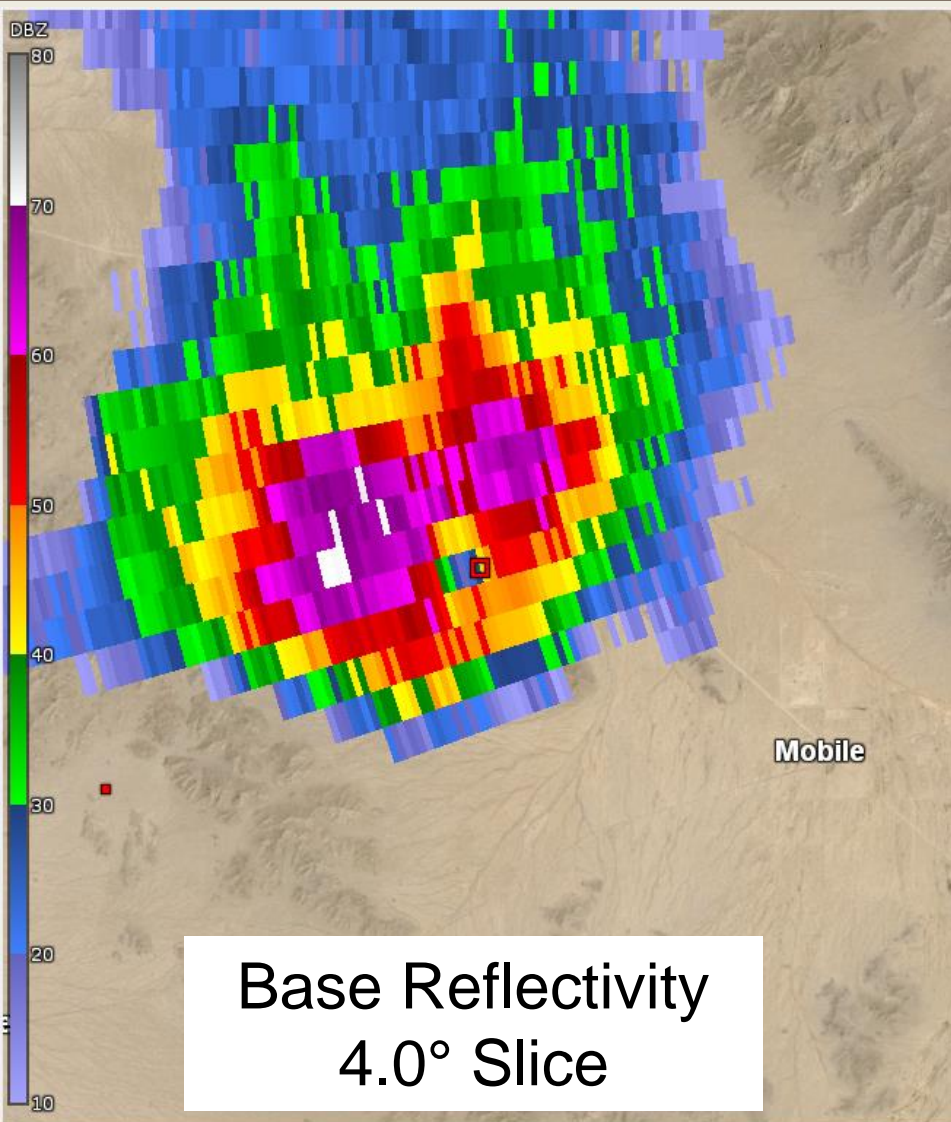
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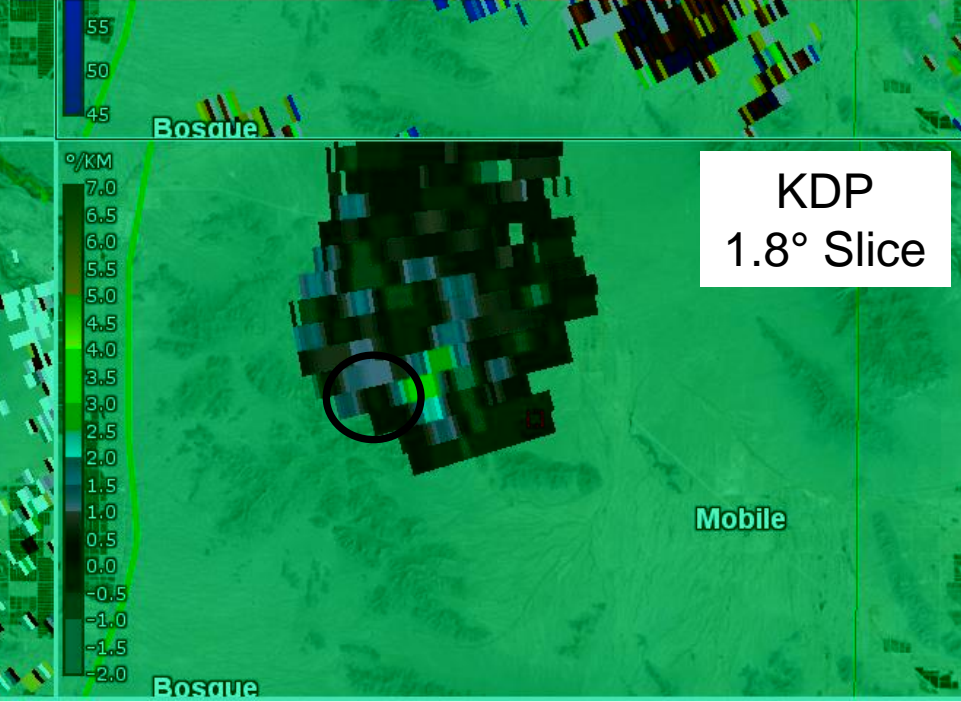
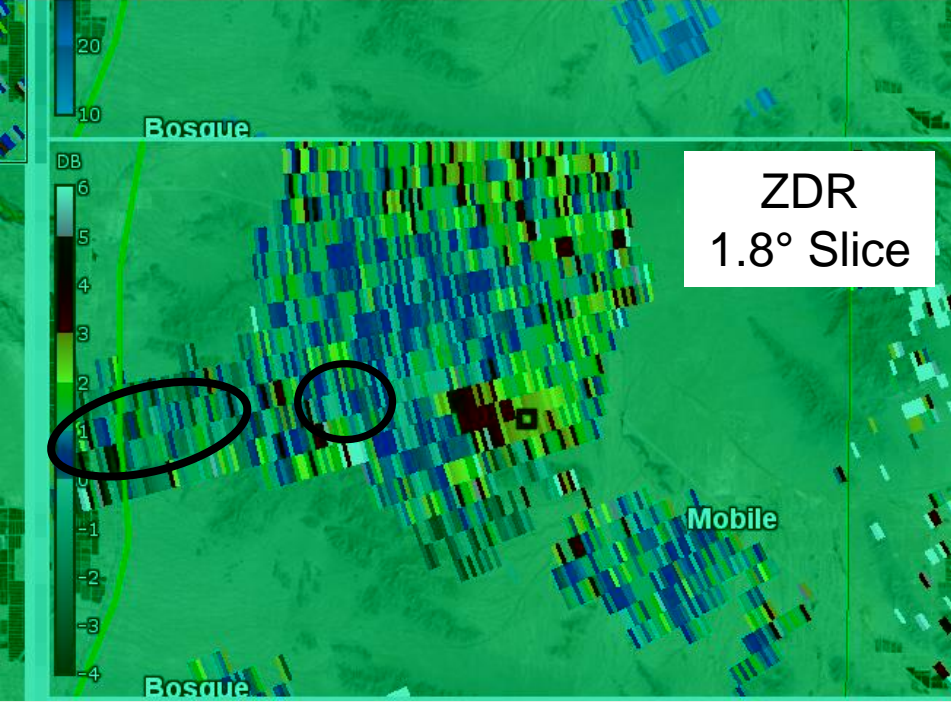
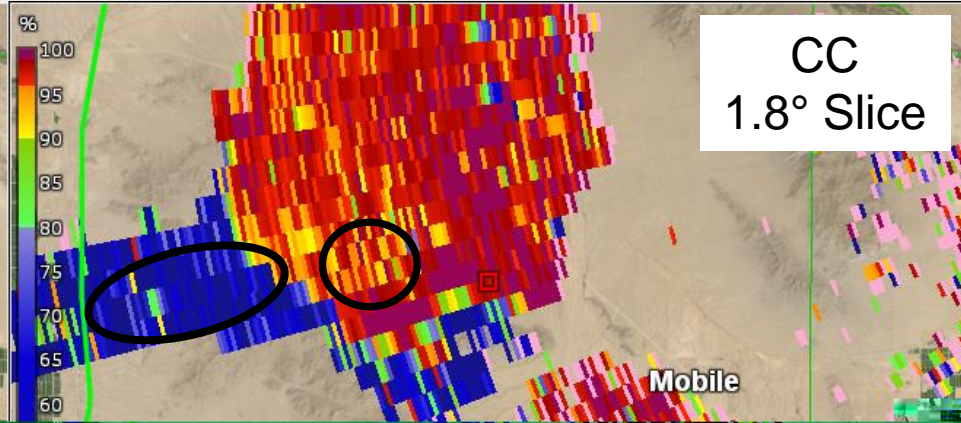
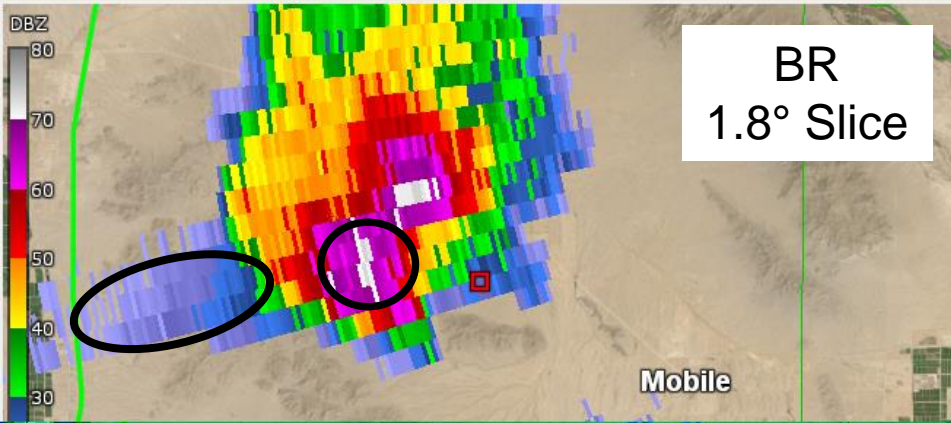


# 5pm

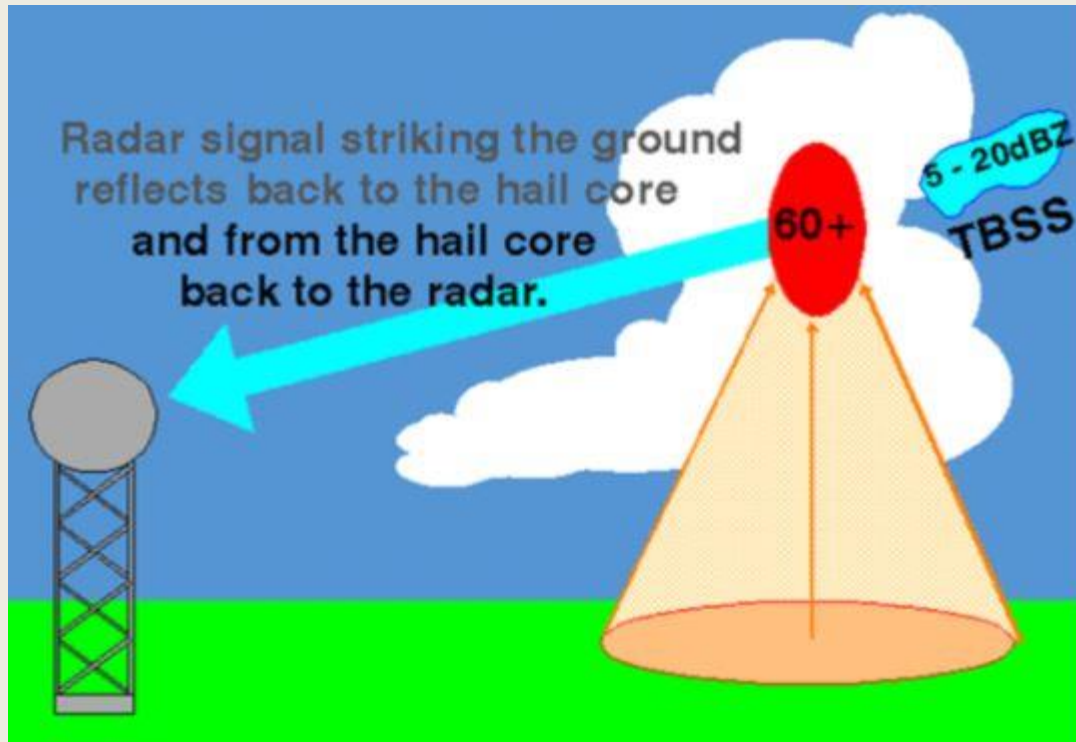


# Dual Pol Data

5PM



# Three Body Scatter Spike (Hail Spike)



NWS WDTD



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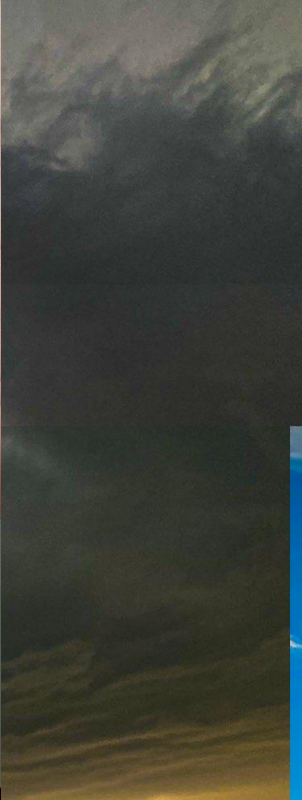
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Phoenix

William Pitts

Mike Davis

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# Course Summary



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**Questions? Contact Us!**

