

**RA***dio*

**D***etection*

**A***nd*

**R***anging*

(actually microwaves)

# WSR 88-D

## Weather Surveillance Radar 1988 - Doppler



Radar  
Data  
Acquisition  
(electronics)

Radar  
Product  
Generation  
(computer)

Principal  
User  
Processor  
(display)

# Radar Data Acquisition (RDA)



Radar Transmitter / Receiver

# WSR-88D Radar dome and Antenna



## WSR-88D System Components

The WSR-88D is comprised of three major components

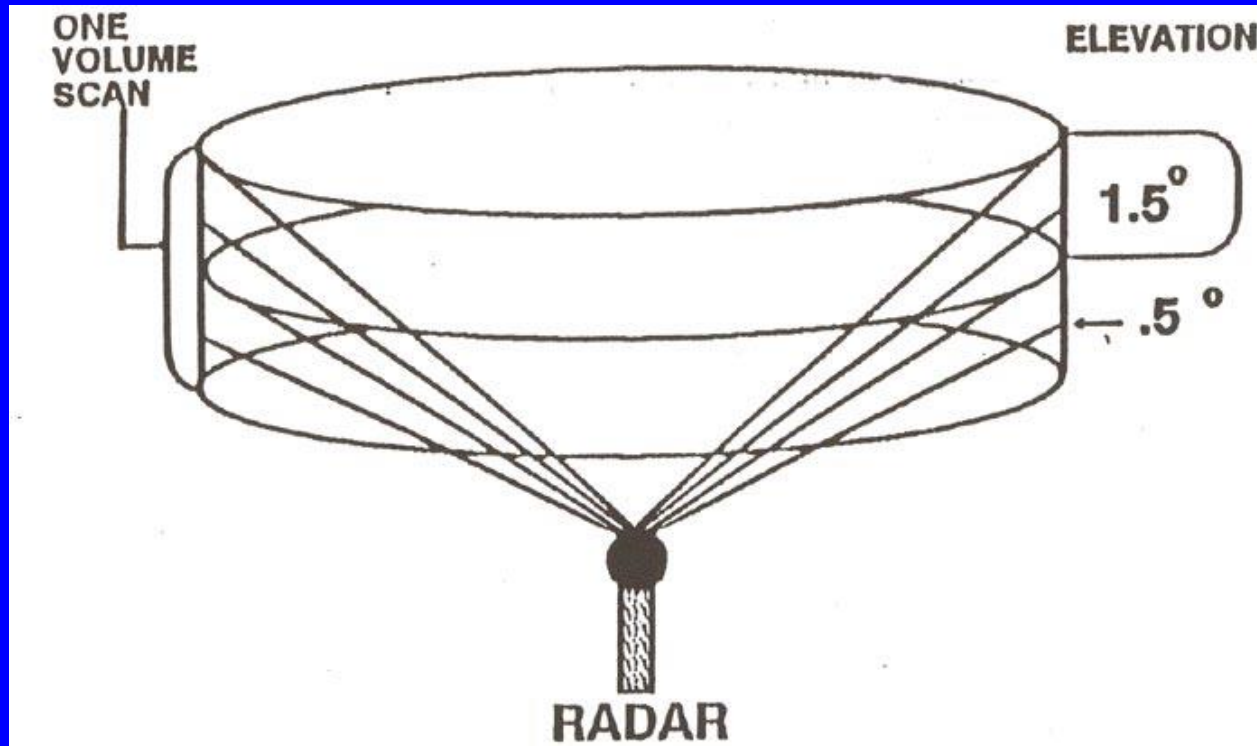
- 1) **Radar Data Acquisition (RDA)**: (Radar Antenna Transmitter/ Receiver)
- 2) **Radar Product Generation (RPG)**: Product generation (creating base and derived products) (e.g base reflectivity / base velocity / Vertical Integrated Liquid and more)
- 3) **AWIPs display of radar products**

# Radar Product Generation (RPG)



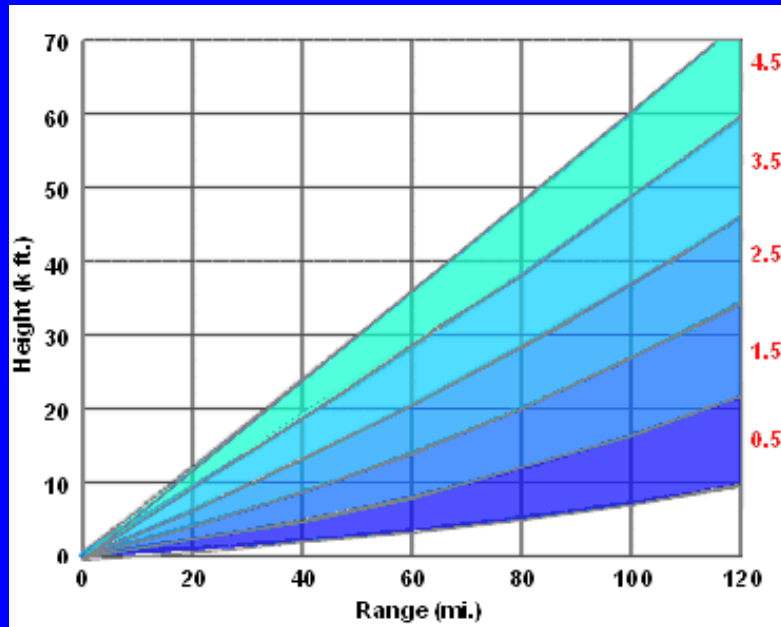
This part of the system generates products.  
Communications component – dedicated lines to other NWS offices, FAA, DOD and external users.

# Radar Scanning Techniques

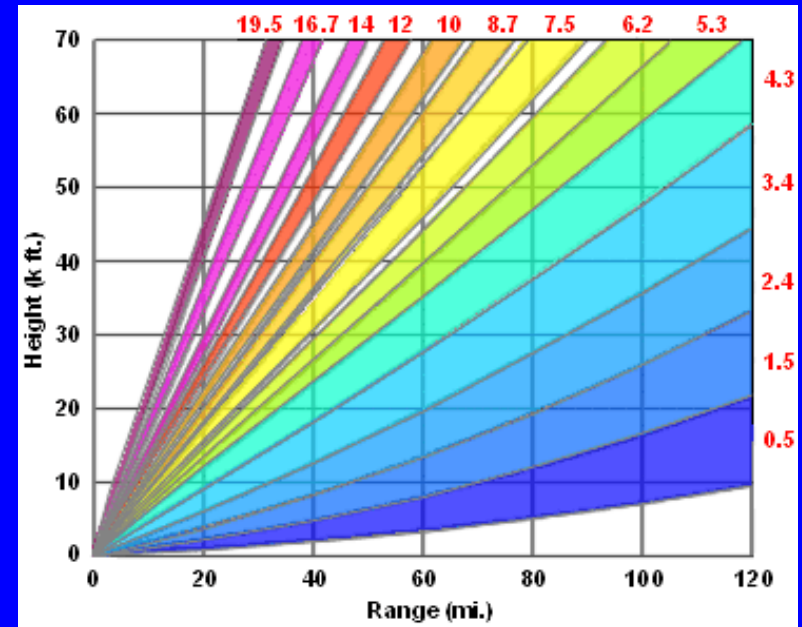


Radar first scans at the 0.5 degree elevation (360 degrees), then steps up to 1.5 degree slice (360 degree sweep), then steps up to 2.4 degree slice etc. This continues up to 19.5 degrees.

# Clear Air Mode



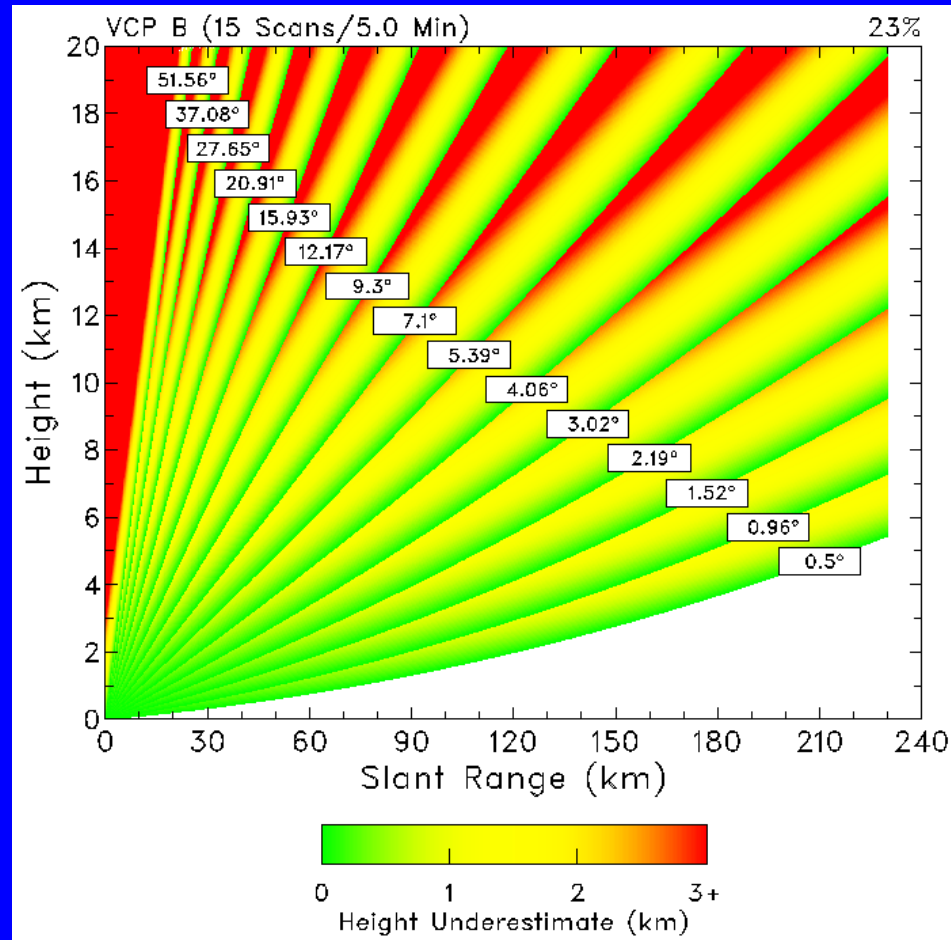
# Precipitation Mode



- reflectivity
- radial velocity
- spectrum width

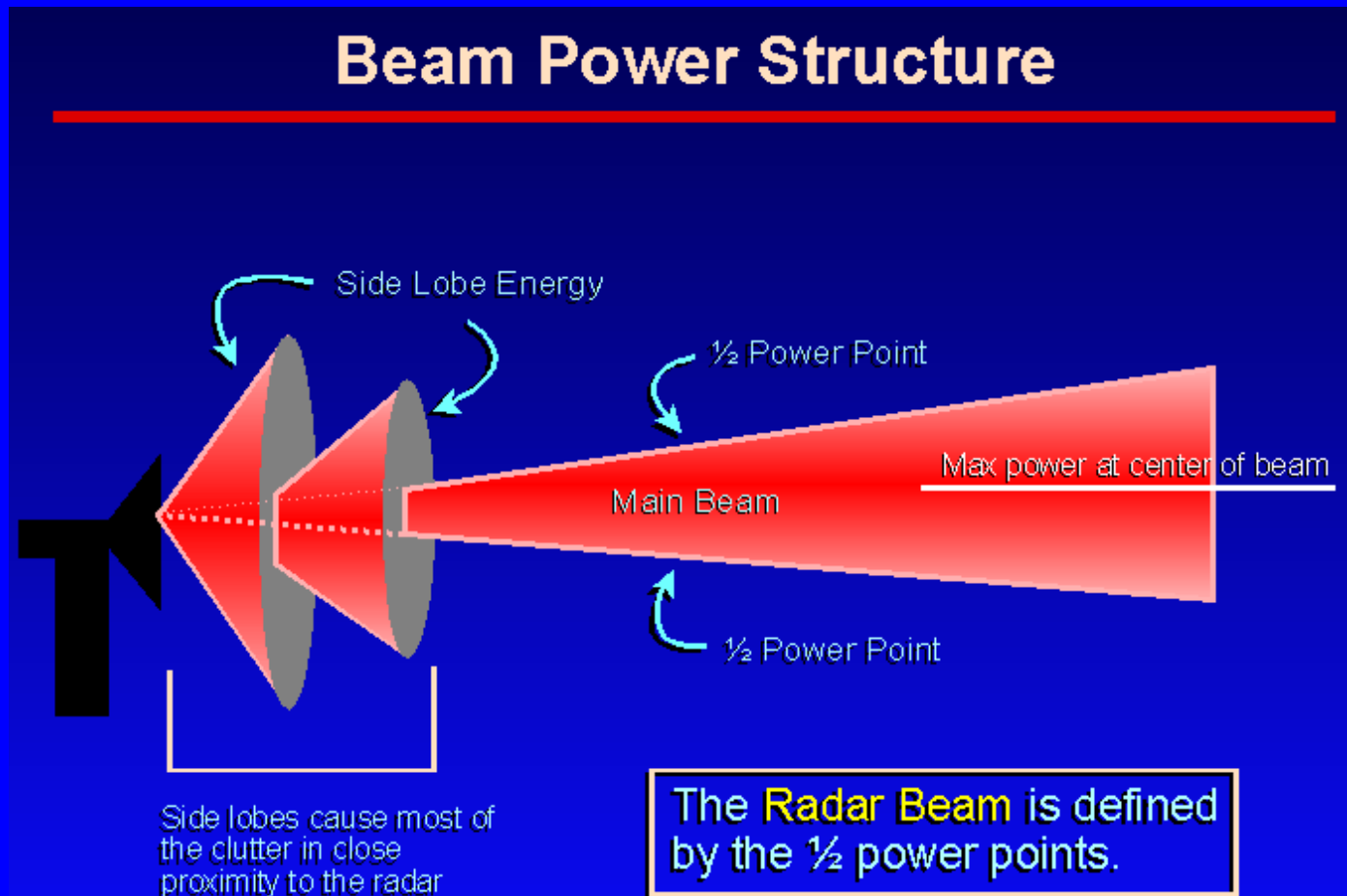


# Volume Coverage Pattern-12



Newest VCP used during severe weather events. VCP 12  
14 step elevation slices within 4.5 minutes.  
More elevation angles at lower levels (Sampling in greater  
detail at distant ranges).

# Radar Beam Width Considerations



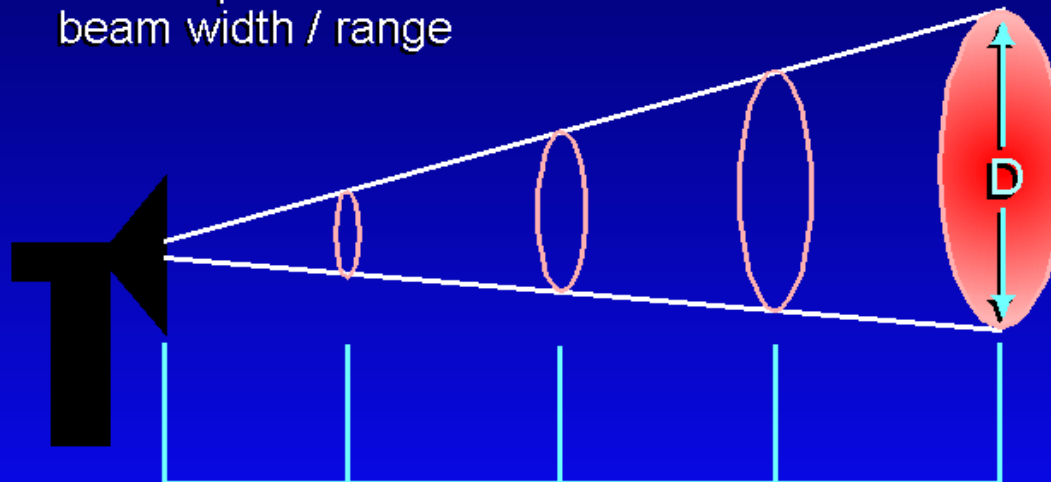
Compare the WSR-88D beam width as a pencil beam (0.95 degree) to the old conventional radar WSR-74S (2.0 degree) (flash light).

# Another Example of Radar Beam Characteristics

## .96 Degree Beam Resolution

Radar resolution  
with respect to  
beam width / range

D = Beam width



If R =	60 NM	120 NM	180 NM	240 NM
D =	1 NM	2 NM	3 NM	4 NM

Our pencil like beam width – finer resolution

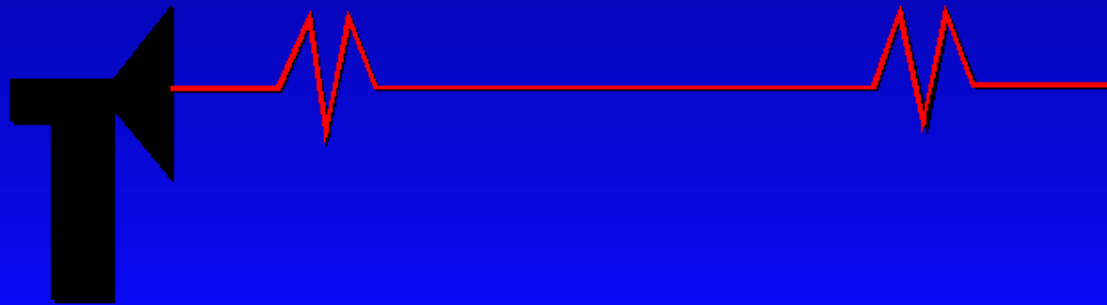
# Radar Beam Characteristics

## Pulse Repetition Frequency - PRF

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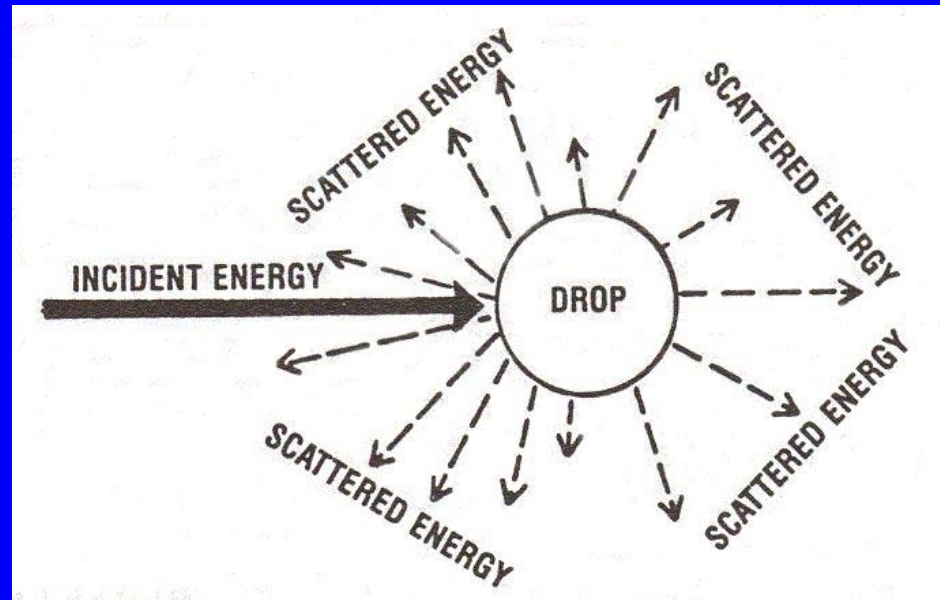
PRF controls the Max Radar Range  
and Max Unambiguous Velocities

PRF is the number of pulses per second transmitted by a radar



The Doppler radar sends pulses of energy out to a target (e.g. rainfall, snow, ice). In between each pulse the Doppler radar listens to the return signal.

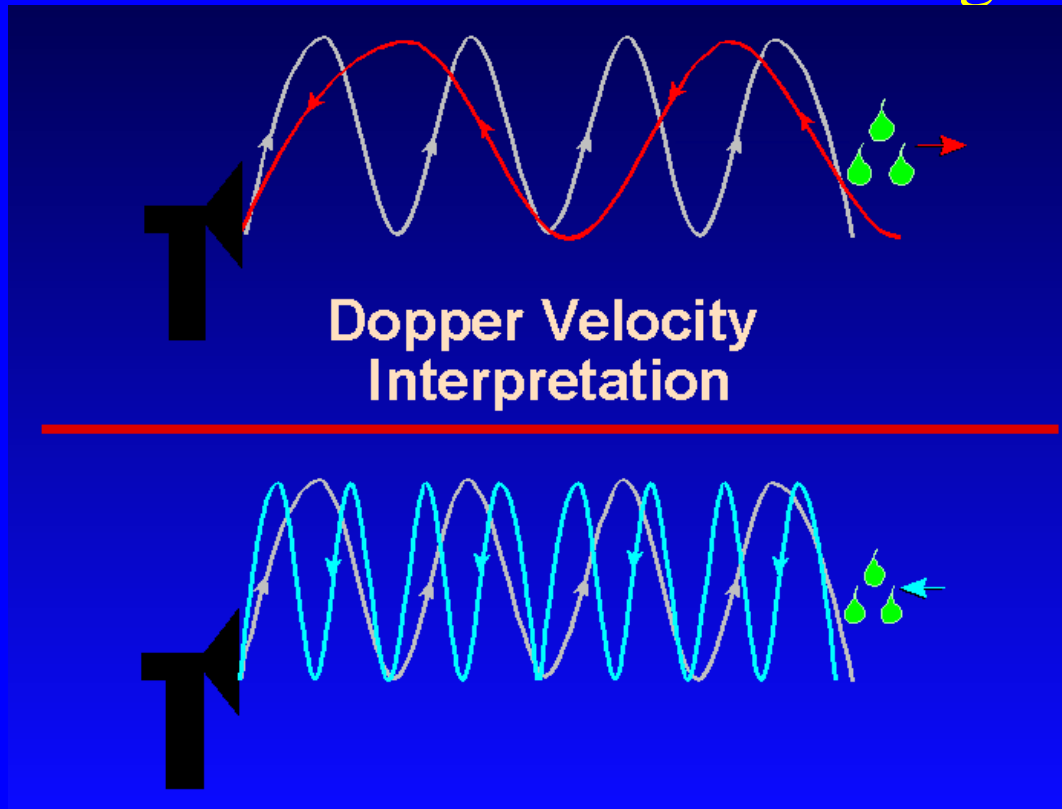
# Scattering of Energy



When a particle in the atmosphere scatters radio wave energy it redirects the energy in many different directions, including direction opposite to that in which the energy was originally traveling. This return energy is called “backscatter.”

The amount of energy the radar receives from backscatter is very small.

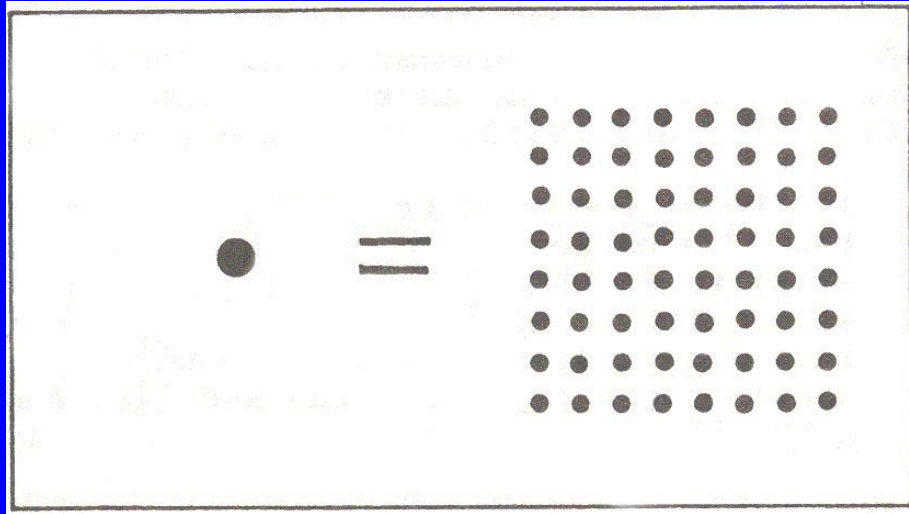
## Doppler Radar Characteristics cont' – What are the characteristics of the return signal?



White line represents the reference signal.

**Red line (top)** signifies that the precipitation particles (velocities) in the storm are moving away from the radar. Conversely, the light blue line (below) indicates that precipitation particles (velocities) are moving towards the radar.

# Effects of Drop Size on Reflectivity



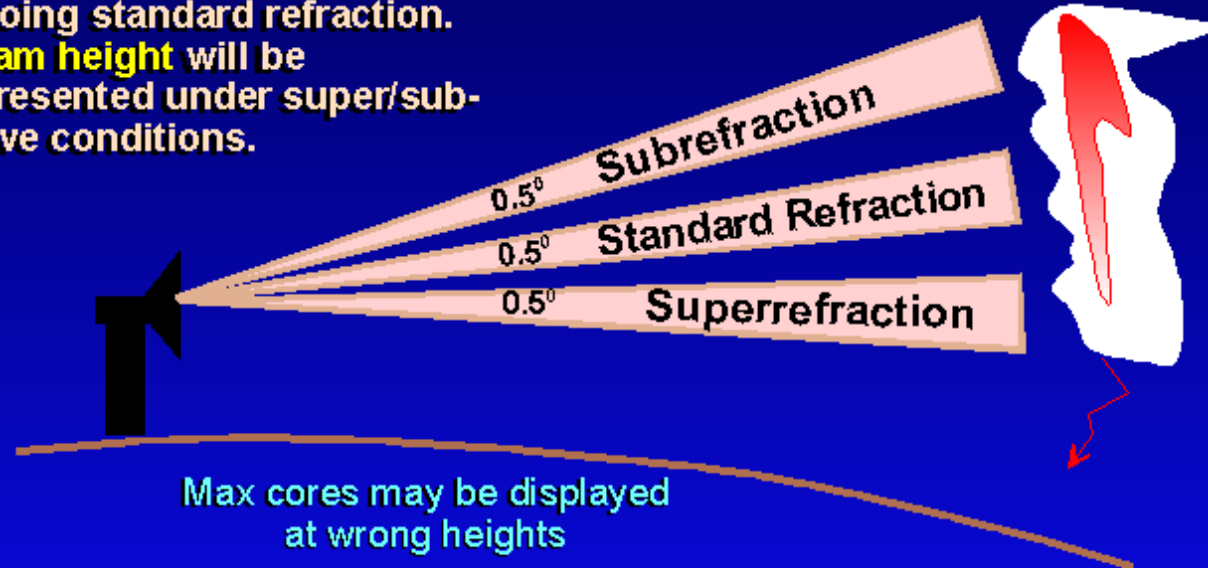
Reflectivity factor is determined by the sum of the 6<sup>th</sup> power of all drop size diameters.

- Power received is highly dependent upon particle size.  
(A 3 mm diameter drop would return 729 times as much power to the radar as a 1 mm diameter drop).

# Radar Beam Propagation

## Atmospheric Refraction

The radar assumes the beam is undergoing standard refraction. The **beam height** will be misrepresented under super/sub-refractive conditions.

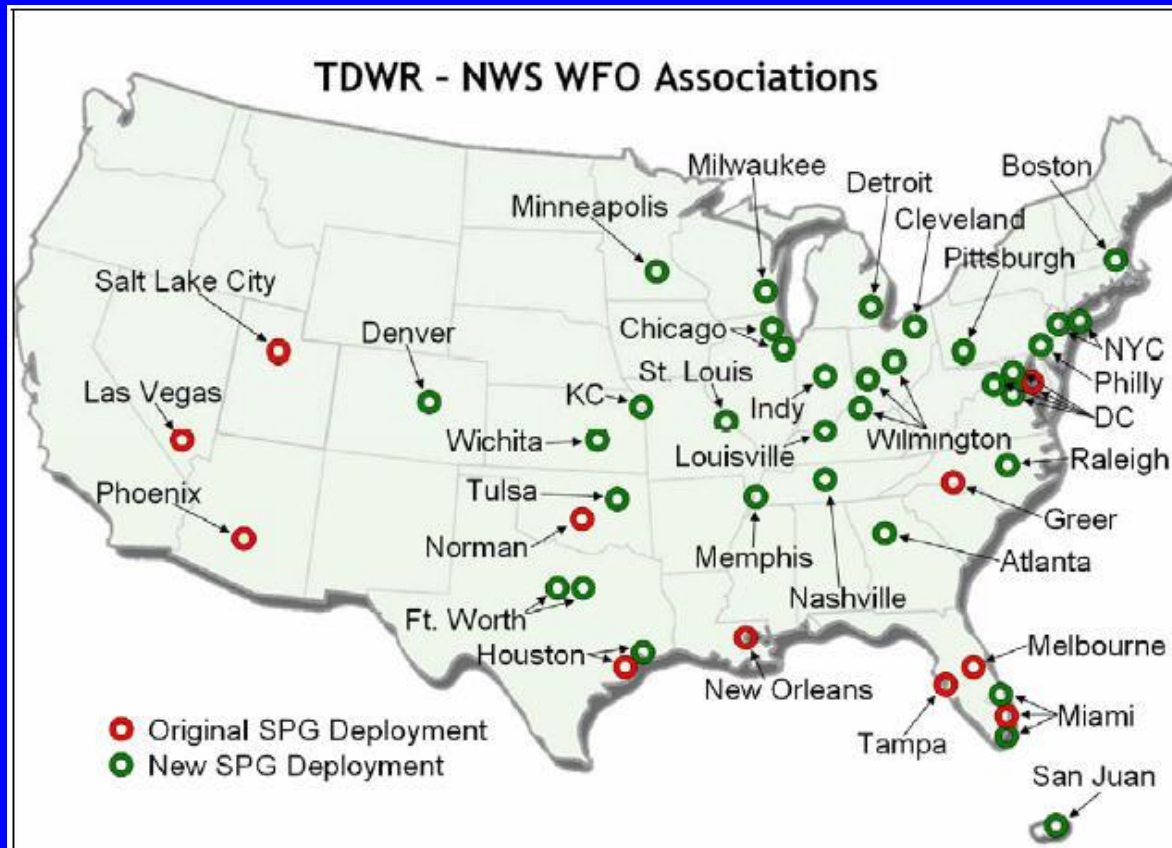


**Superrefraction:** The beam refracts more than standard. The beam height is lower than the radar indicates.

**Subrefraction:** The beam refracts less than standard. The beam height is higher than the radar indicates. Beam can overshoot developing storms.



# Terminal Doppler Weather Radars



- There are 45 terminal Doppler Weather Radars (TDWRs) across the United States.
- 5 cm wave length (more susceptible to attenuation – at times).

# TDWR Volume Coverage Patterns

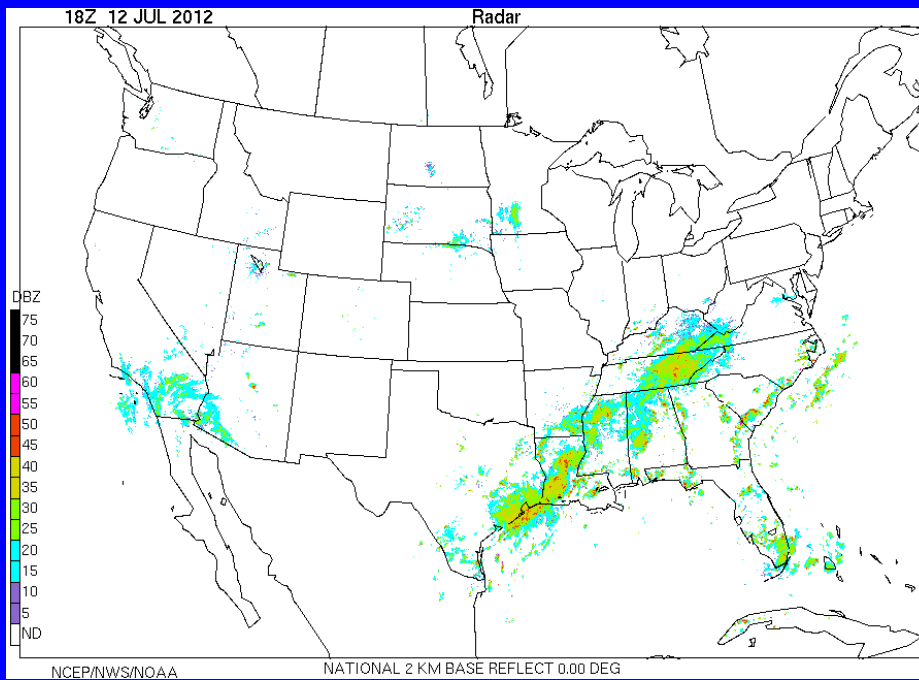
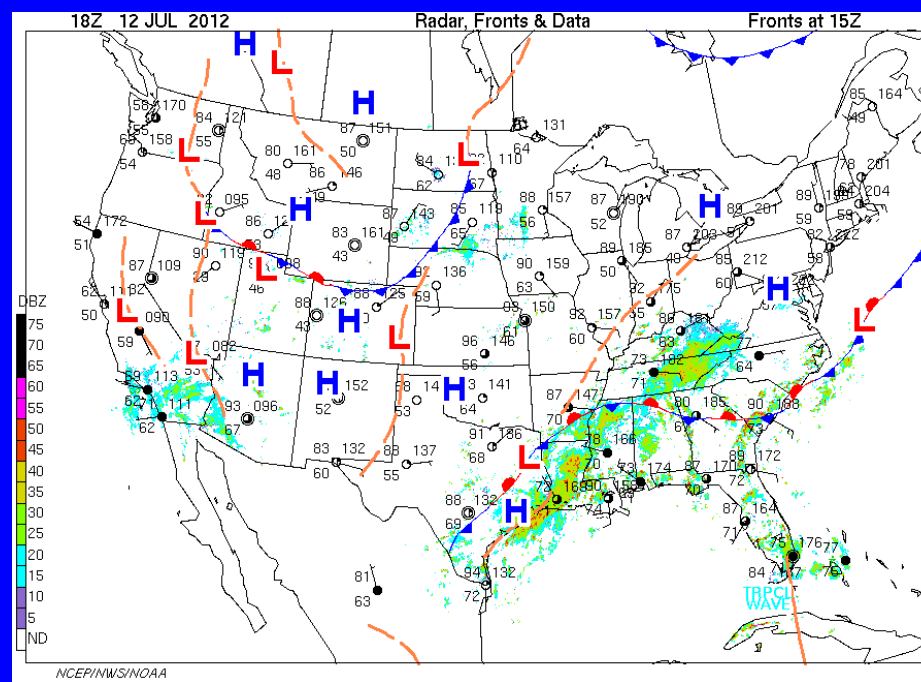
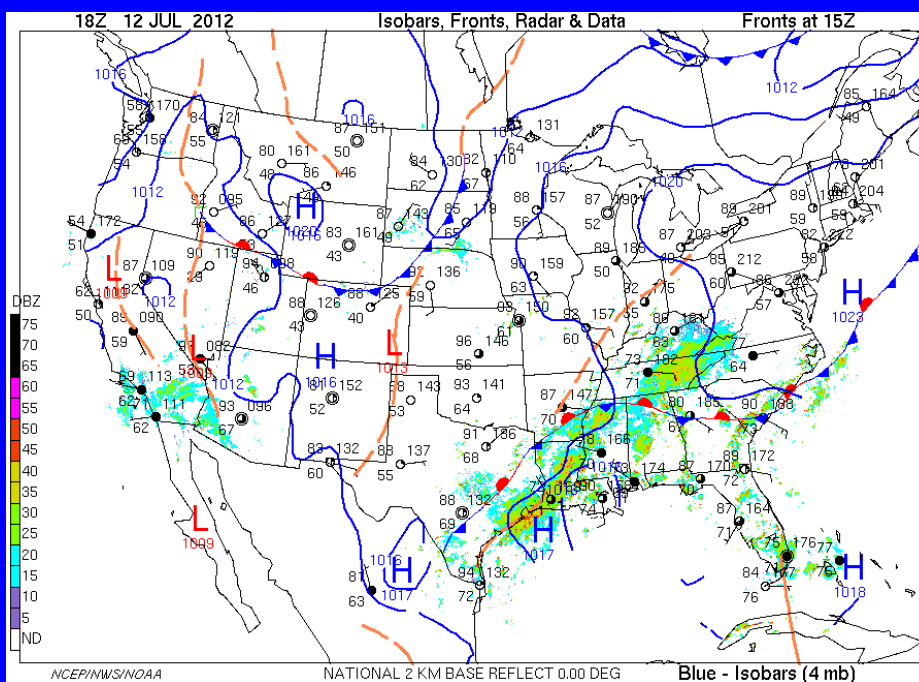


Higher elevation angles (VCP 80) focuses on storms closer to the airport.

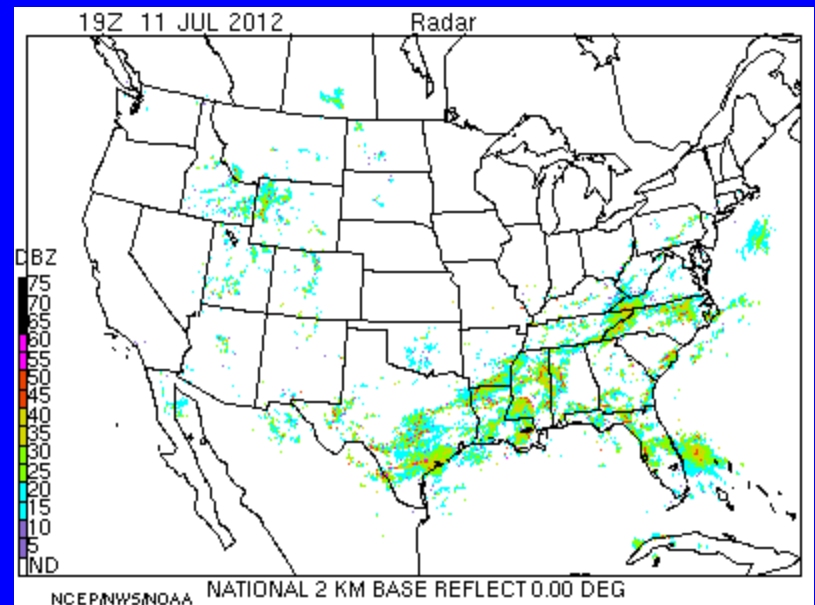
Lower elevation angles (VCP 90) will key upon storms at greater ranges from the TDWR.

*Questions?*

# Radar Imagery



## DataStreme images





# National Weather Service Enhanced Radar Image



## National Mosaic

Go to: [Standard Version](#)

Local weather forecast by "City, St"

### Base Reflectivity

[Full resolution version](#) (3400x1700 pixels - 220k)

Time of image: 1838 UTC 07/12/2012



Go to: [Loop of this Image](#)

#### Sectors

- Northern U.S.
- Pac. Northwest [Loop](#)
- Nrn. Rockies [Loop](#)
- Upper Miss. Vly. [Loop](#)
- Great Lakes [Loop](#)
- Northeast [Loop](#)

#### Southern U.S.

- Pac. Southwest [Loop](#)
- Srn. Rockies [Loop](#)
- Southern Plains [Loop](#)
- Srn. Miss. Vly. [Loop](#)
- Southeast [Loop](#)

#### U.S. Views

##### Reflectivity:

- National [Loop](#)
- Alaska [Loop](#)
- Hawaii [Loop](#)
- Guam [Loop](#)
- Puerto Rico [Loop](#)

#### Additional Info:

- [Radar FAQ](#)
- [Downloading Images](#)
- [GIS Users](#)
- [Doppler University](#)
- [Color Blindness Tool](#)
- [Credits](#)

National  
Radar  
Mosaic  
Sectors

(click image)



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# Houston/Galveston, TX Radar

Go to: [Standard Version](#)

Local weather forecast by "City, St"

[Radar Status Message](#)

### Adjacent Radars:



### Short Range Images

Reflectivity:  
[Composite](#)  Loop  
[Base](#)  Loop

Velocity:  
[Storm Relative](#)  Loop  
[Base](#)  Loop

Rainfall:  
[1-Hour Total](#)  Loop  
[Storm Total](#)  Loop

### Long Range Images

Reflectivity:  
[Base](#)  Loop

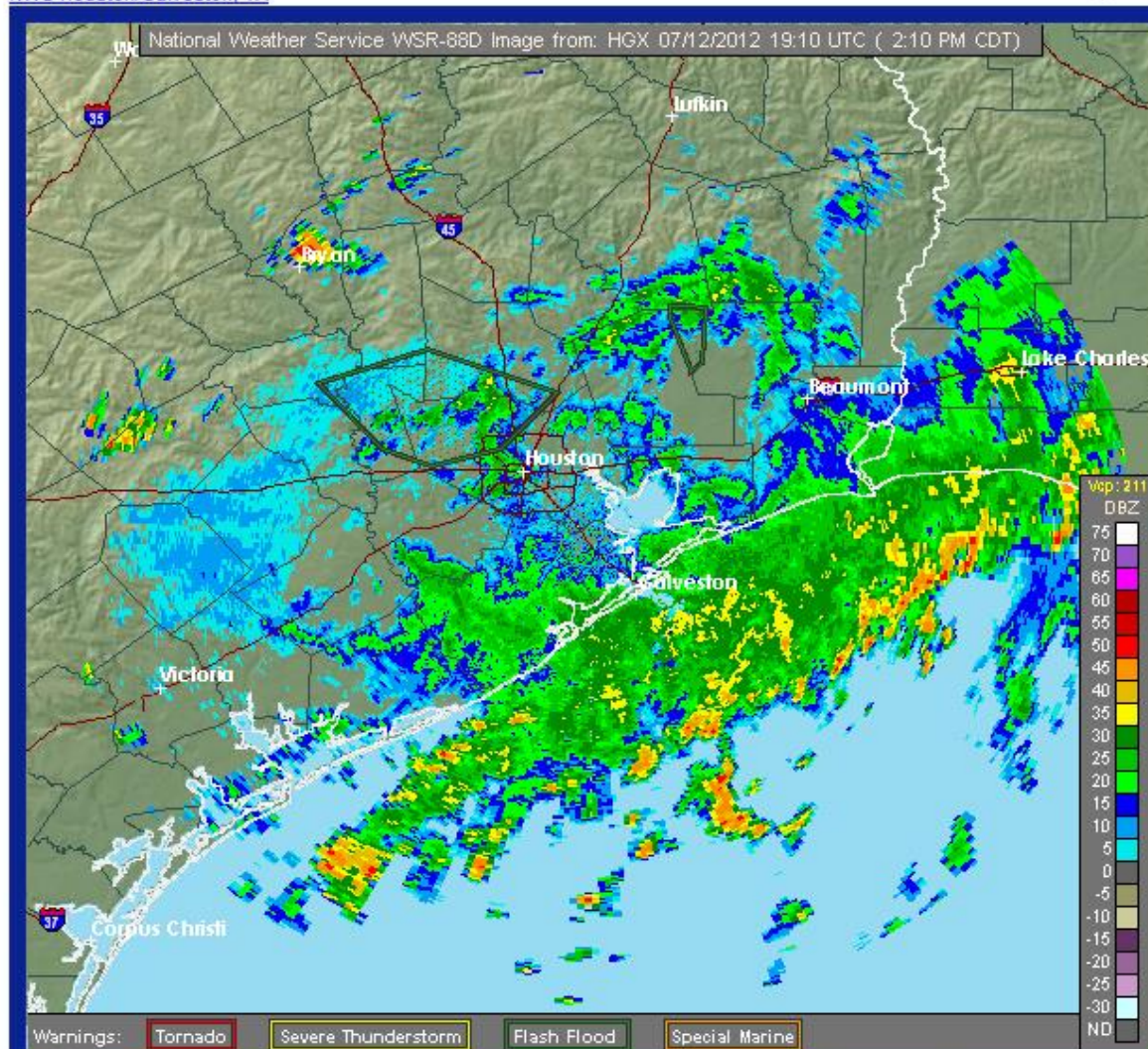
### U.S. Views

Reflectivity:  
[National](#)  Loop  
[Alaska](#)  Loop  
[Hawaii](#)  Loop  
[Guam](#)  Loop  
[Puerto Rico](#)  Loop  
[Radars by State](#)

Additional Info:  
[Radar FAQ](#)  
[Downloading Images](#)  
[Mobile Users](#)  
[GIS Users](#) **KML**  
[Doppler University](#)  
[Color Blindness Tool](#)  
[Credits](#)

## Base Reflectivity

[NWS Houston/Galveston, TX](#)



Topo  Radar  Counties  Rivers  Highways  Cities  Warnings  Legend

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# Houston/Galveston, TX Radar

Go to: [Standard Version](#)

Local weather forecast by "City, St"

[Radar Status Message](#)

### Adjacent Radars:



### Short Range Images

#### Reflectivity:

Composite  Loop  
Base  Loop

#### Velocity:

Storm Relative  Loop  
Base  Loop

#### Rainfall:

1-Hour Total  Loop  
Storm Total  Loop

MouseOver Off

### Long Range Images

#### Reflectivity:

Base  Loop

### U.S. Views

#### Reflectivity:

National  Loop  
Alaska  Loop  
Hawaii  Loop  
Guam  Loop  
Puerto Rico  Loop

### Radars by State

### Additional Info:

[Radar FAQ](#)  
[Downloading Images](#)  
[Mobile Users](#)

GIS Users **KML**

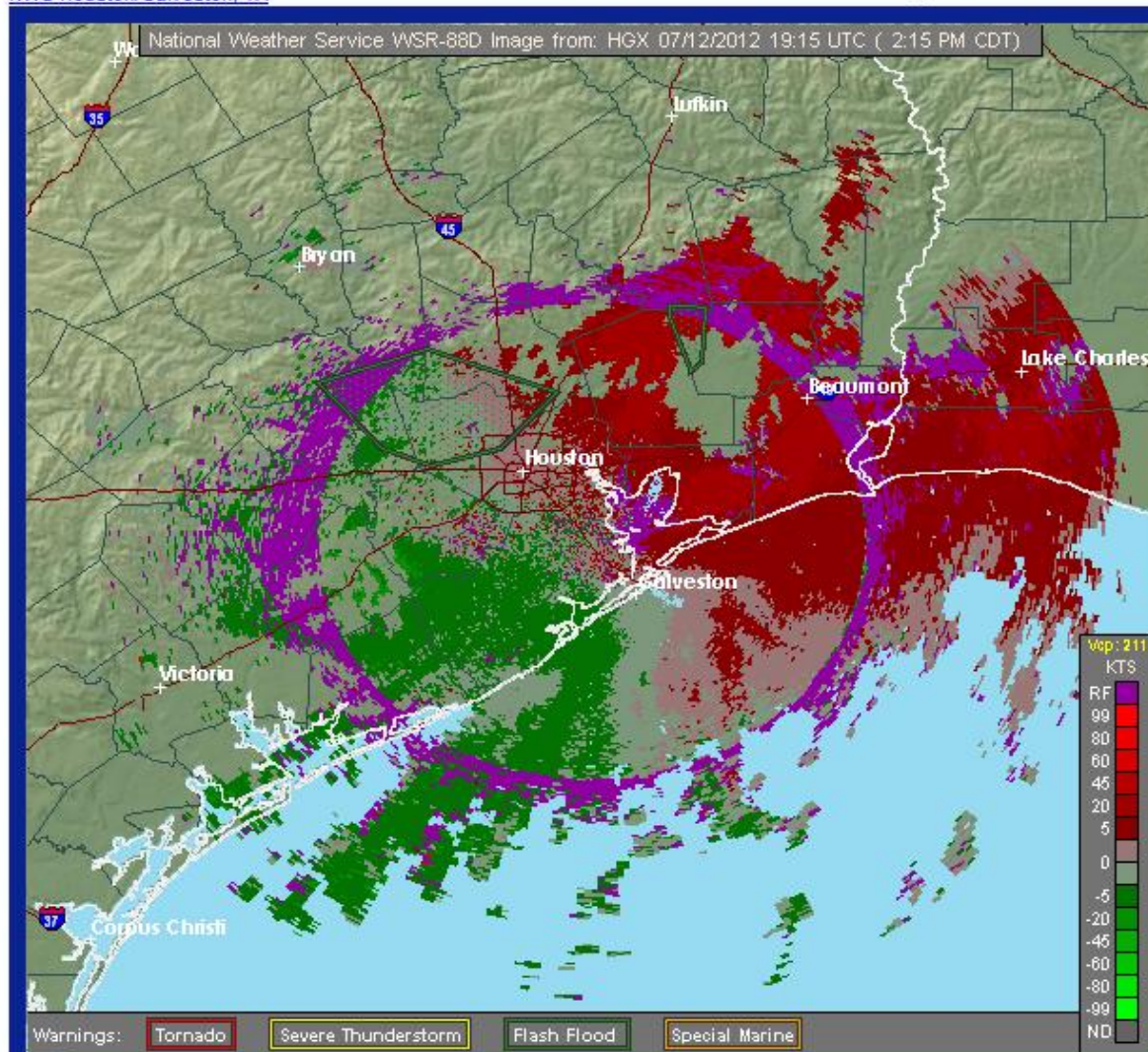
[Doppler University](#)

[Color Blindness Tool](#)

[Credits](#)

## Base Velocity

[NWS Houston/Galveston, TX](#)



Warnings:  Tornado  Severe Thunderstorm  Flash Flood  Special Marine

Topo  Radar  Counties  Rivers  Highways  Cities  Warnings  Legend

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# National Weather Service Enhanced Radar Image

## Houston/Galveston, TX Radar



Go to: [Standard Version](#)

Local weather forecast by "City, St"

[Radar Status Message](#)

Adjacent Radars:



Short Range Images

Reflectivity:

Composite Loop  
Base Loop

Velocity:

Storm Relative Loop  
Base Loop

Rainfall:

1-Hour Total Loop  
Storm Total Loop

MouseOver Off

Long Range Images

Reflectivity:

Base Loop

U.S. Views

Reflectivity:

National Loop  
Alaska Loop  
Hawaii Loop  
Guam Loop  
Puerto Rico Loop  
Radars by State

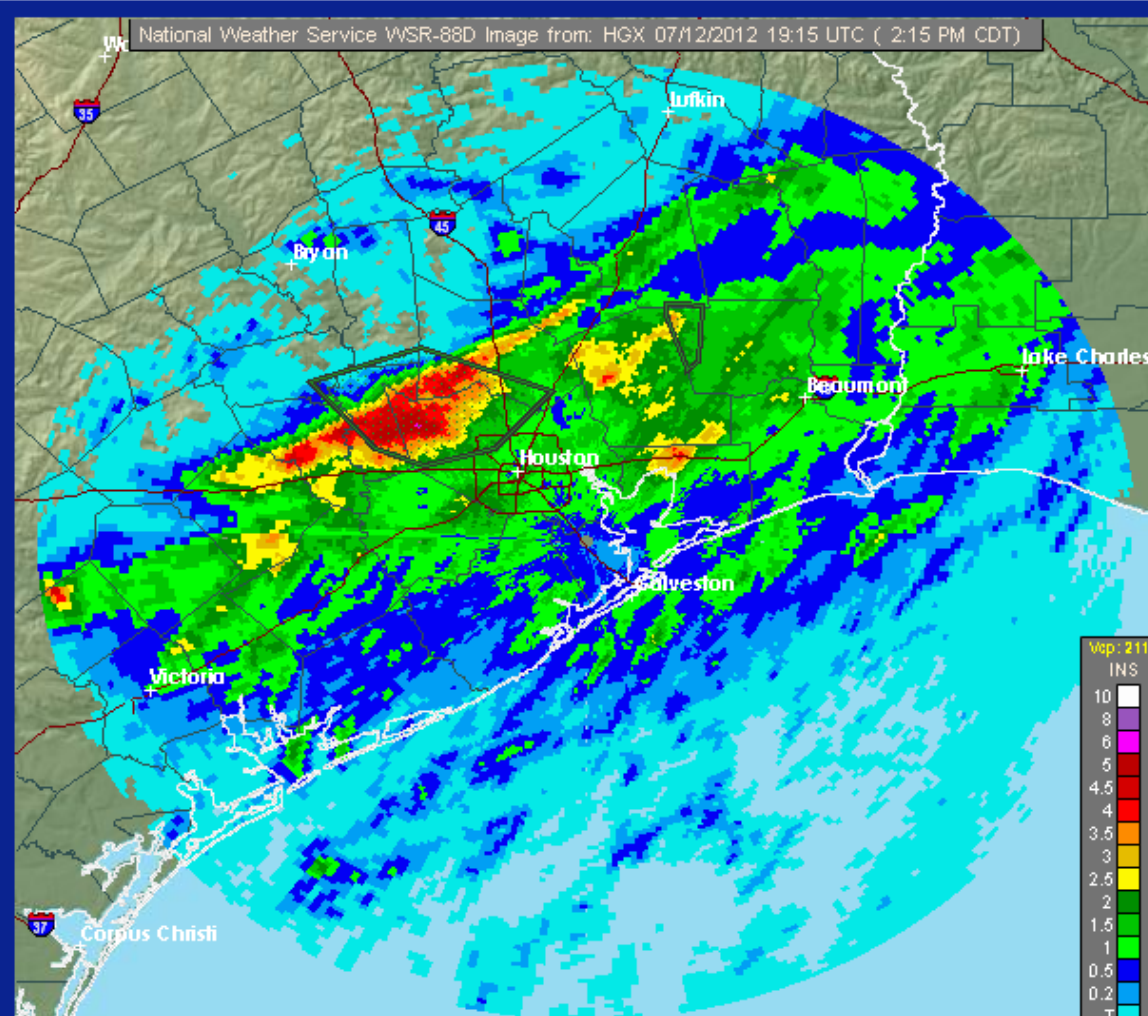
Additional Info:

[Radar FAQ](#)  
[Downloading Images](#)  
[Mobile Users](#)  
[GIS Users](#) **KML**  
[Doppler University](#)  
[Color Blindness Tool](#)  
[Credits](#)

### Storm Total Precipitation

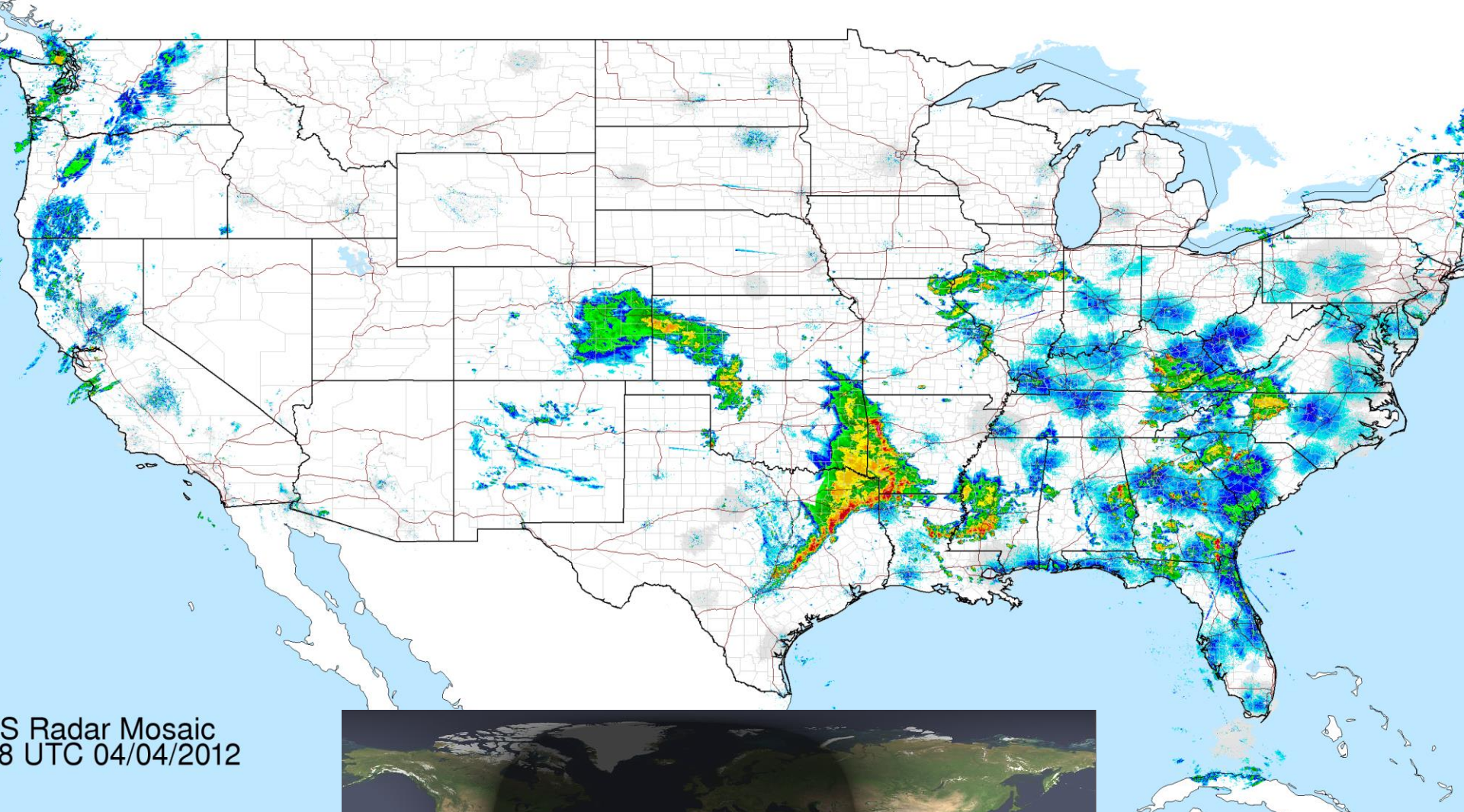
Radar Precip Est From 01:50 AM CDT Thu Jul 12 2012  
to 01:40 PM CDT Thu Jul 12 2012

[NWS Houston/Galveston, TX](#)

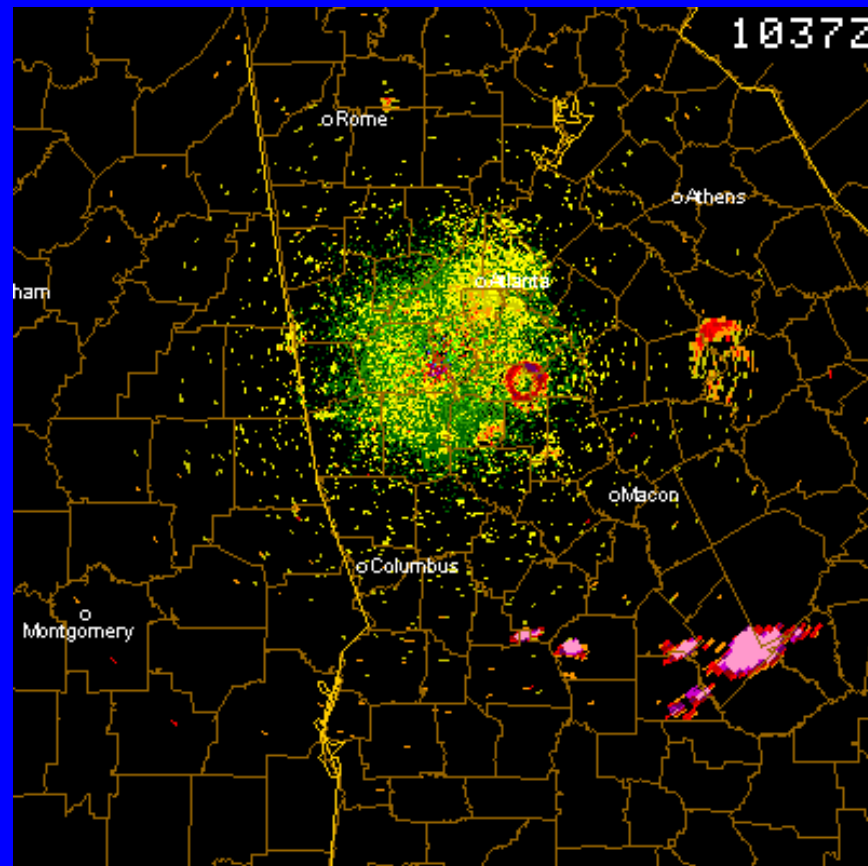


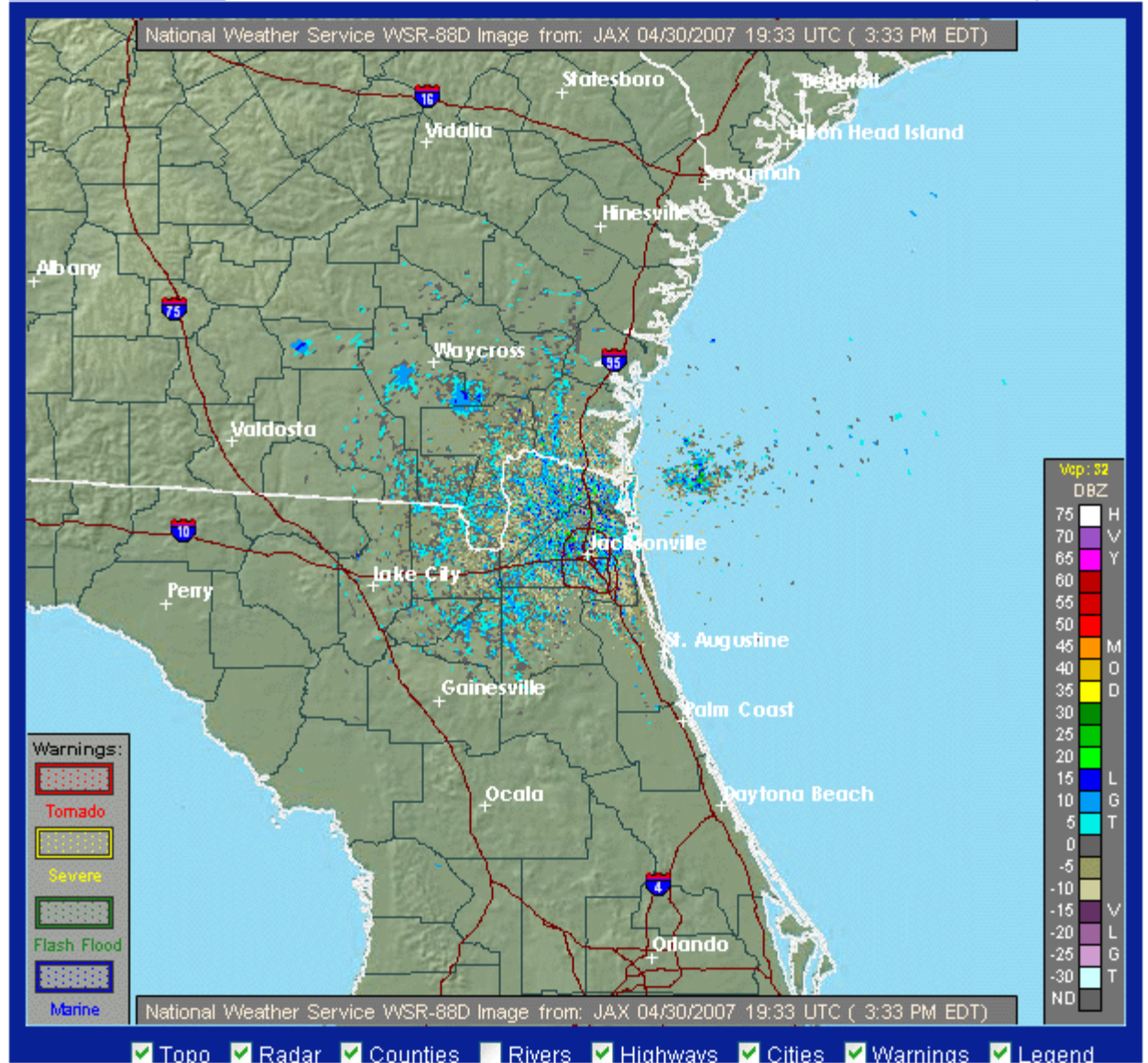
Warnings:  Tornado  Severe Thunderstorm  Flash Flood  Special Marine

Topo  Radar  Counties  Rivers  Highways  Cities  Warnings  Legend

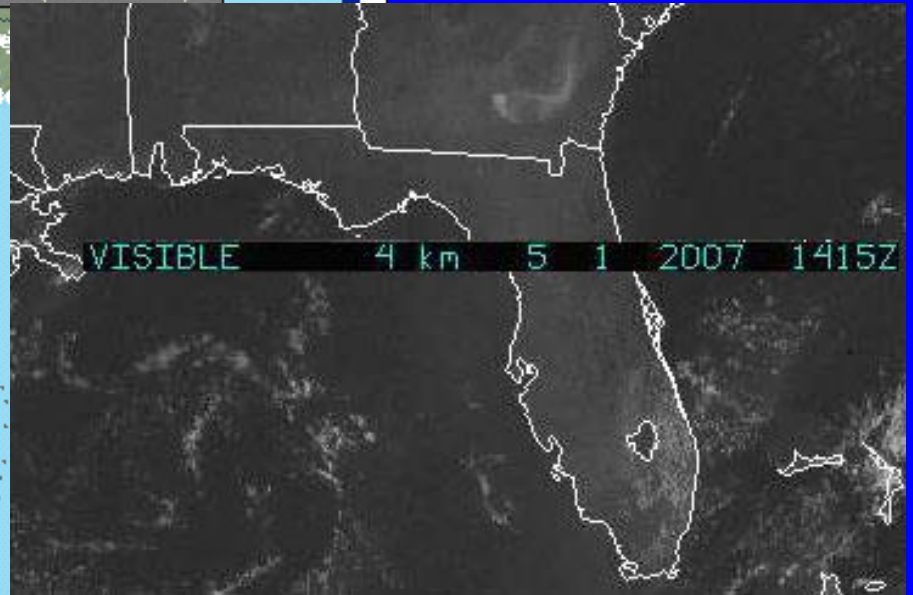
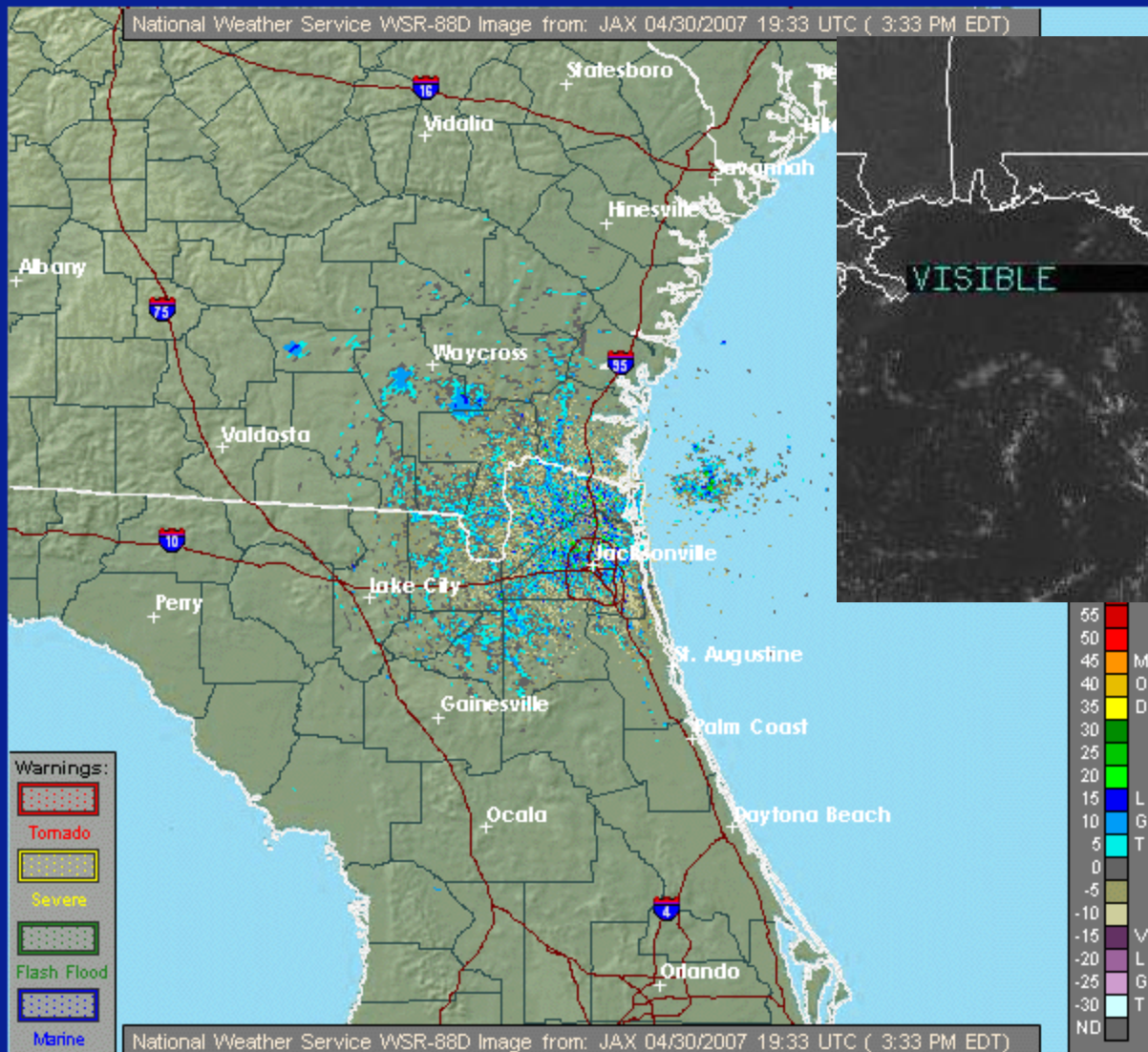


# *Targets?*





National Weather Service WSR-88D Image from: JAX 04/30/2007 19:33 UTC ( 3:33 PM EDT)

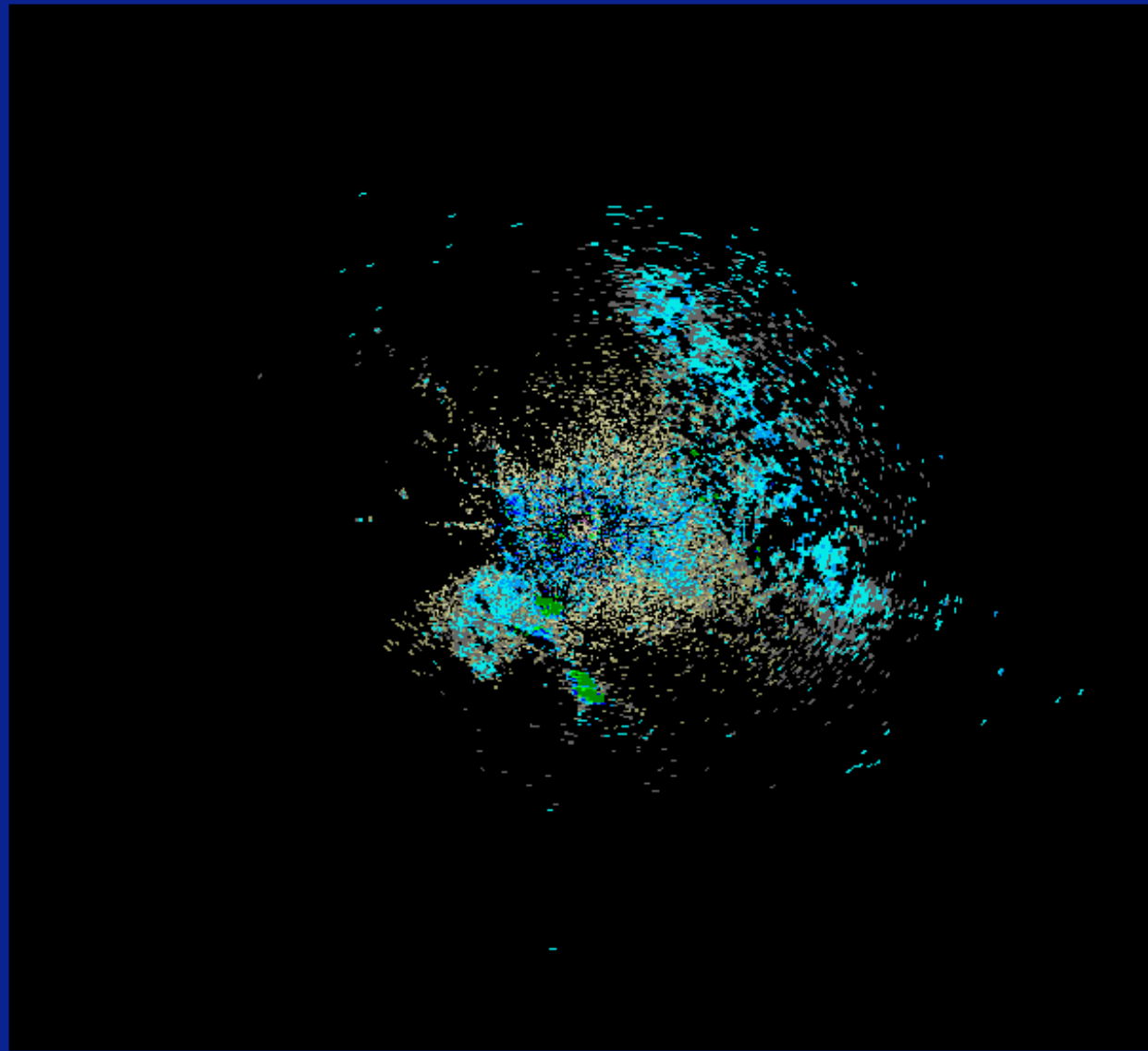


National Weather Service WSR-88D Image from: JAX 04/30/2007 19:33 UTC ( 3:33 PM EDT)

# “Ground Clutter”

NWS Sacramento, CA

08:04 AM PDT Tue Apr 25 2006

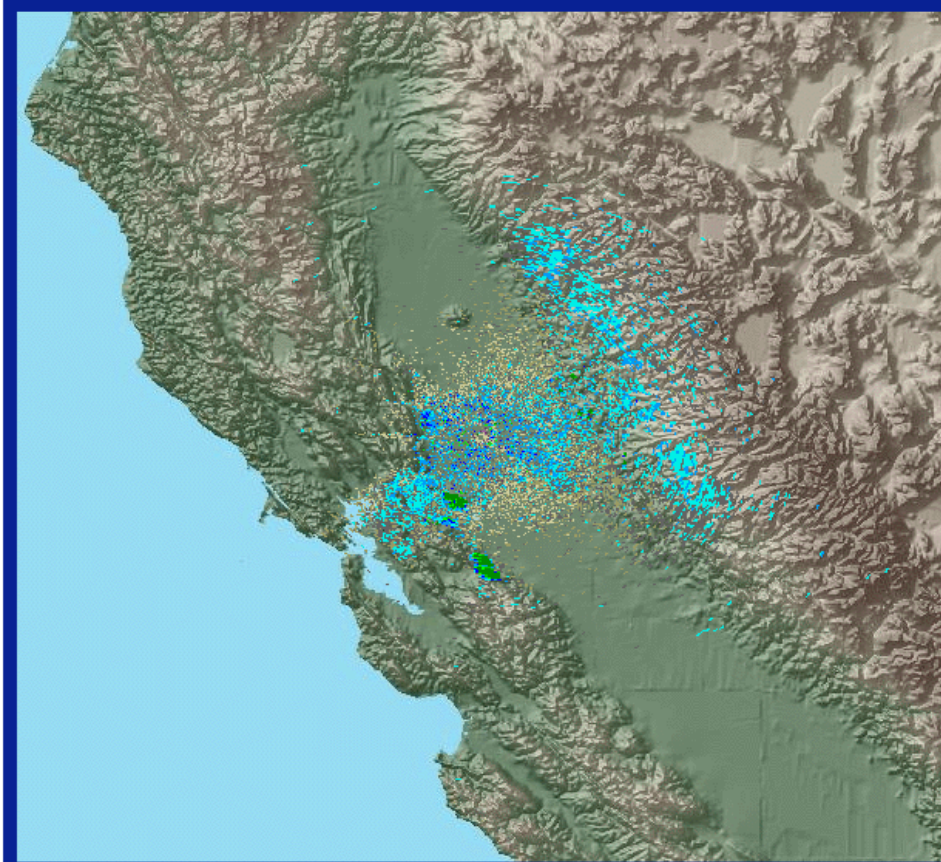
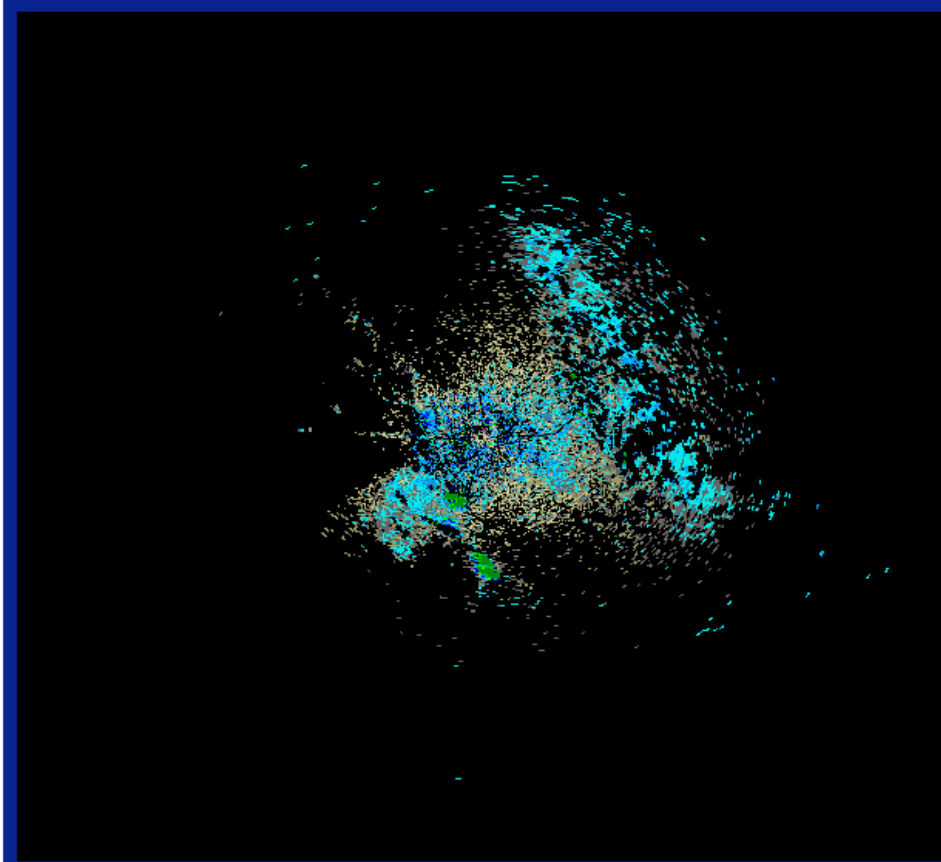


# “Ground Clutter”

NWS Sacramento, CA

08:04 AM PDT Tue Apr 25 2006 NWS Sacramento, CA

08:04 AM PDT Tue Apr 25 2006

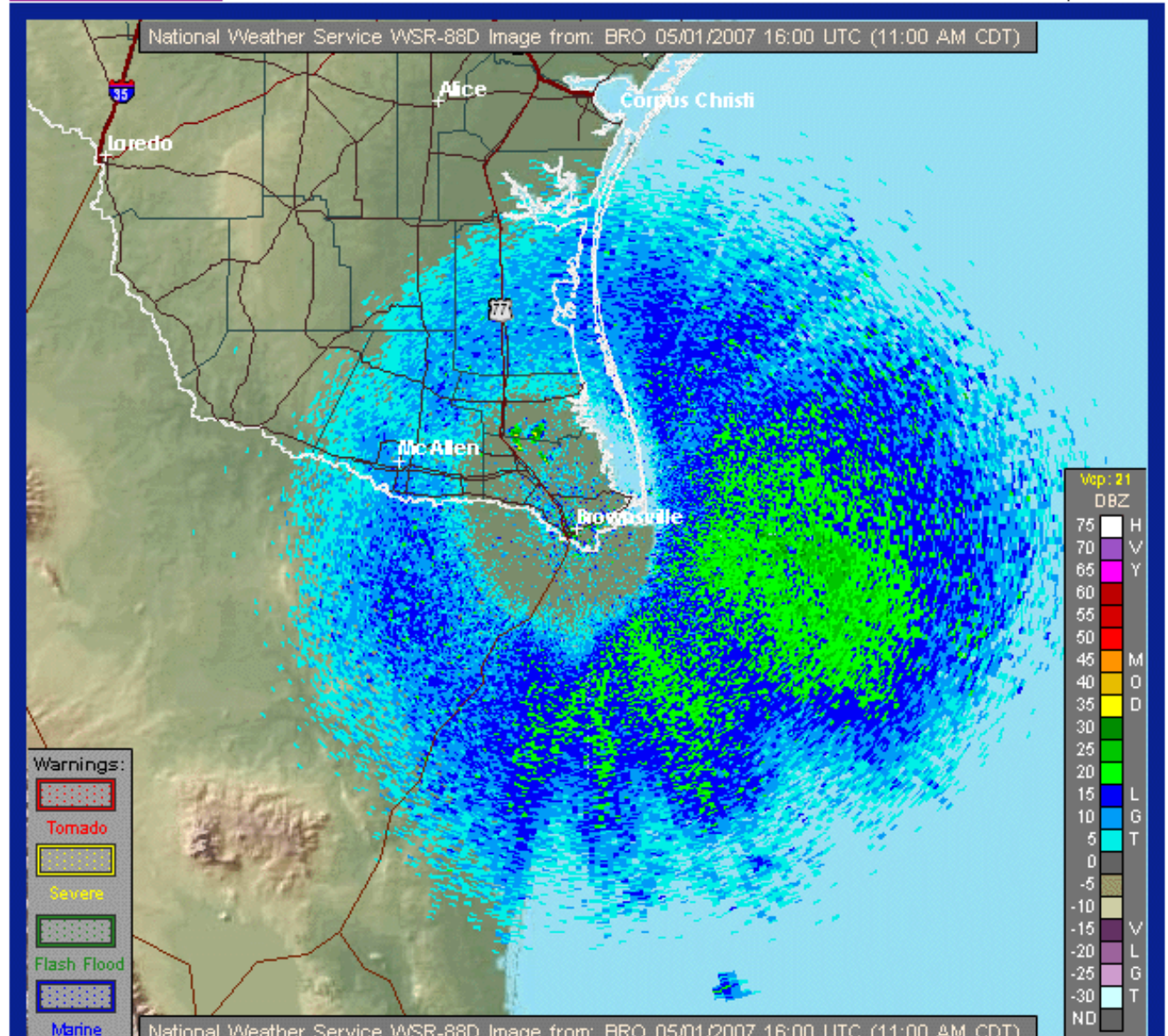


# “Ground Clutter”

## Base Reflectivity

NWS Brownsville, TX

11:00 AM CDT Tue May 01 2007



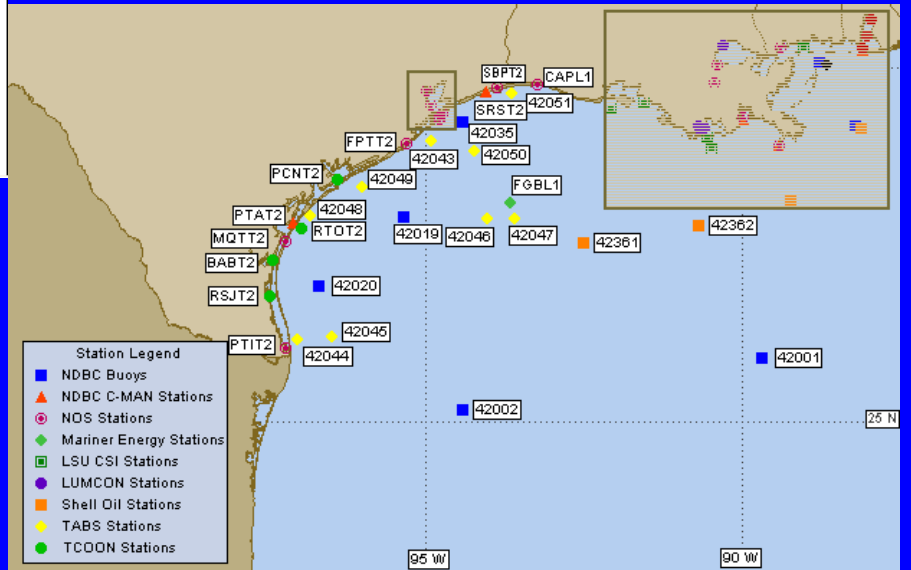
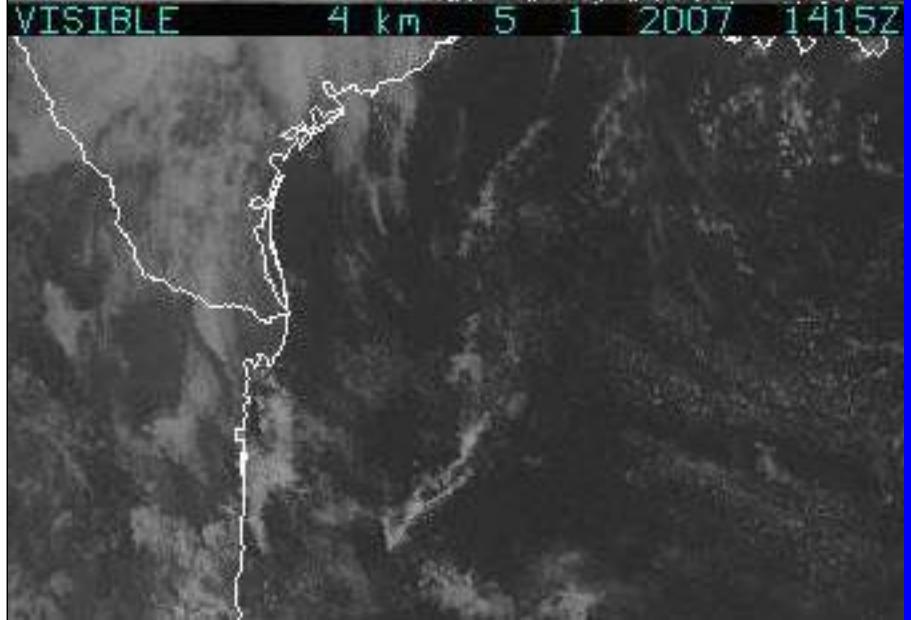
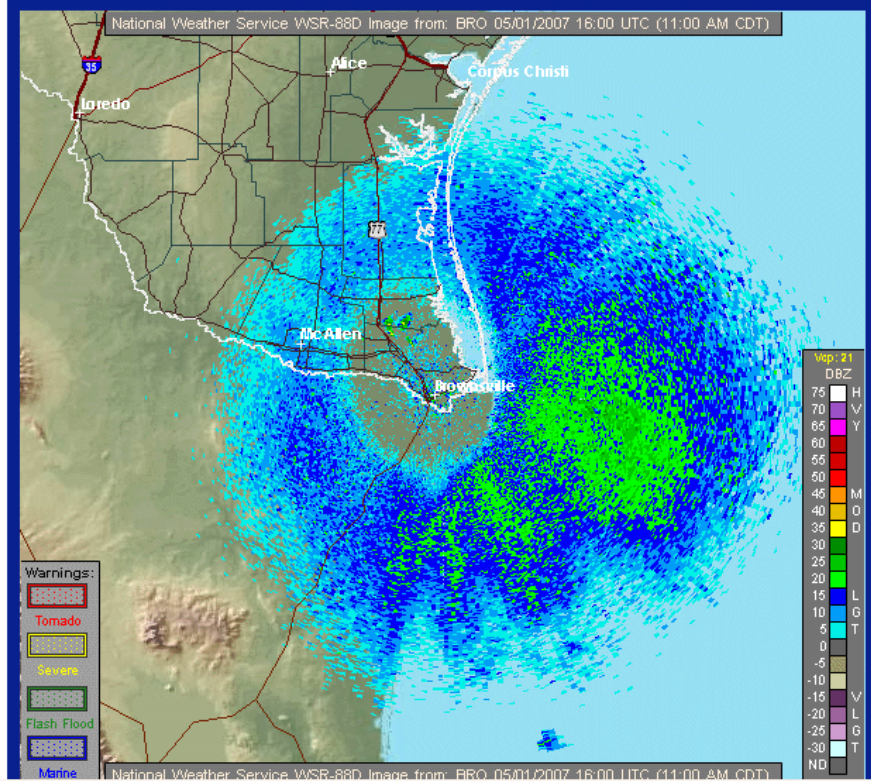


# “Ground Clutter”

Base Reflectivity

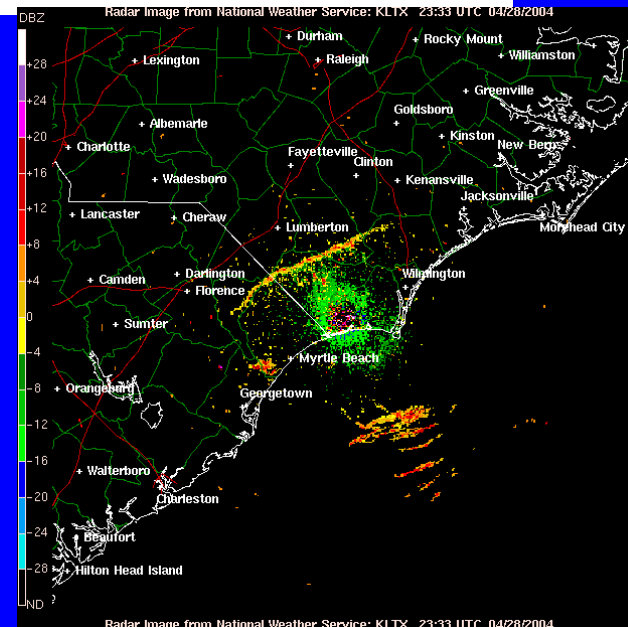
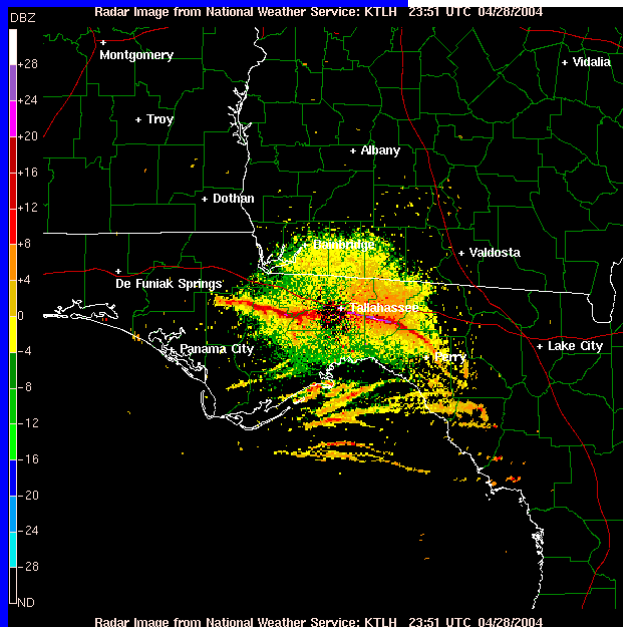
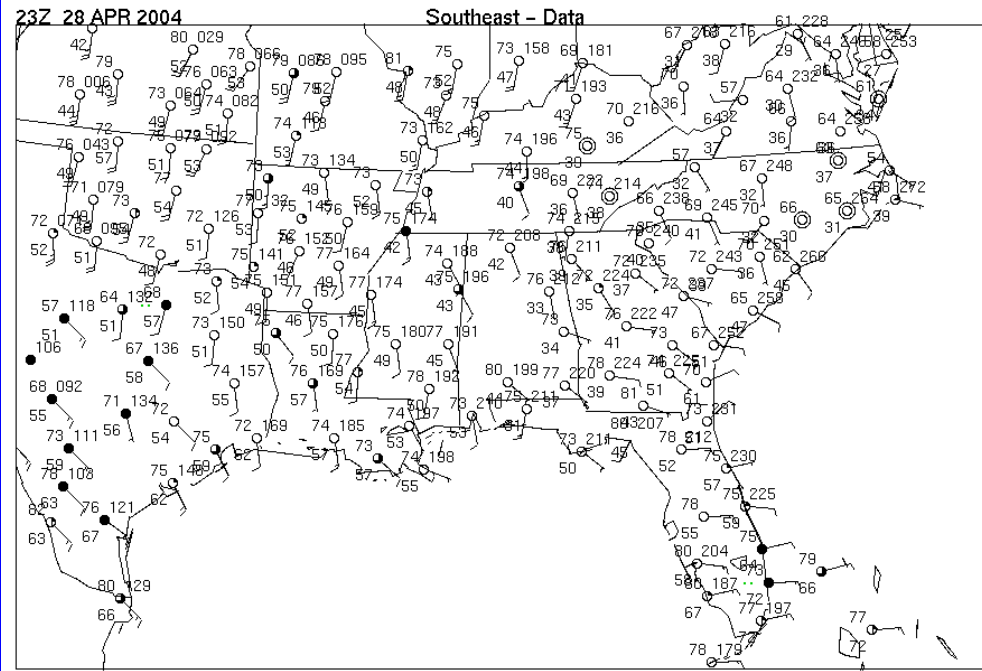
NWS Brownsville, TX

11:00 AM CDT Tue May 01 2007



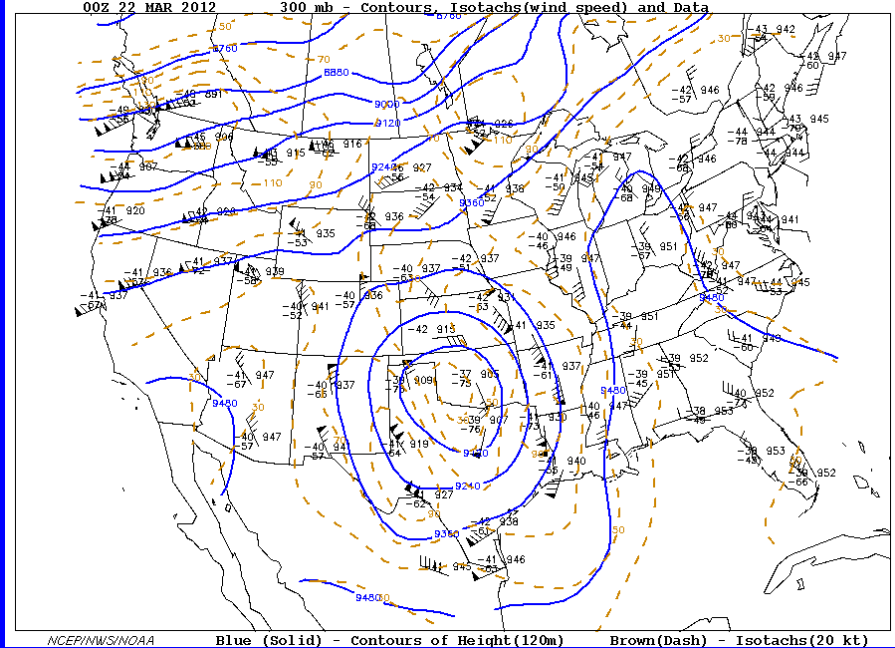
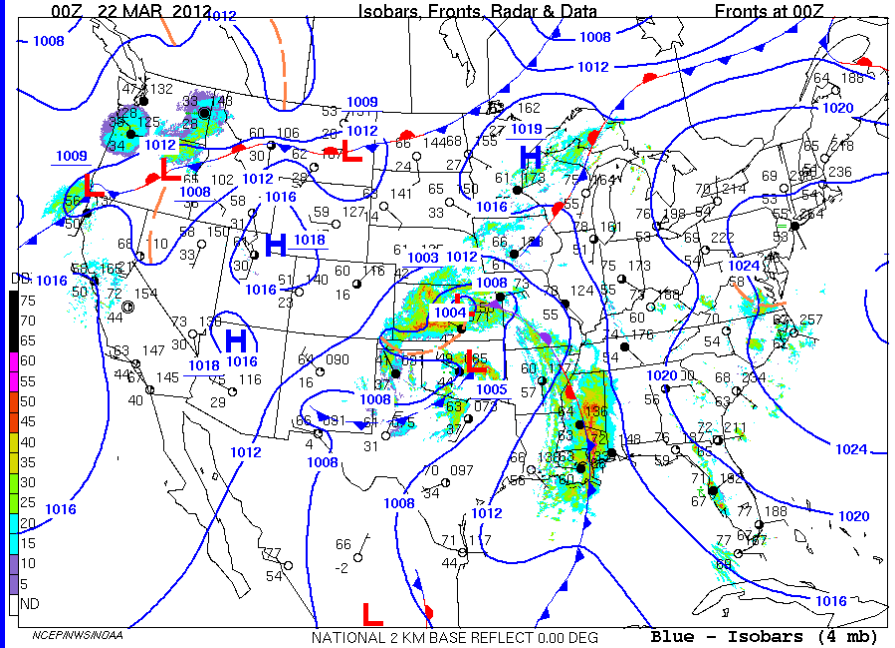
Buoy 42002  
Waves – 5.2 ft.  
Wind – 18 kts SE G 20  
steady for 24 hrs

# Sea Breezes 4/28/04

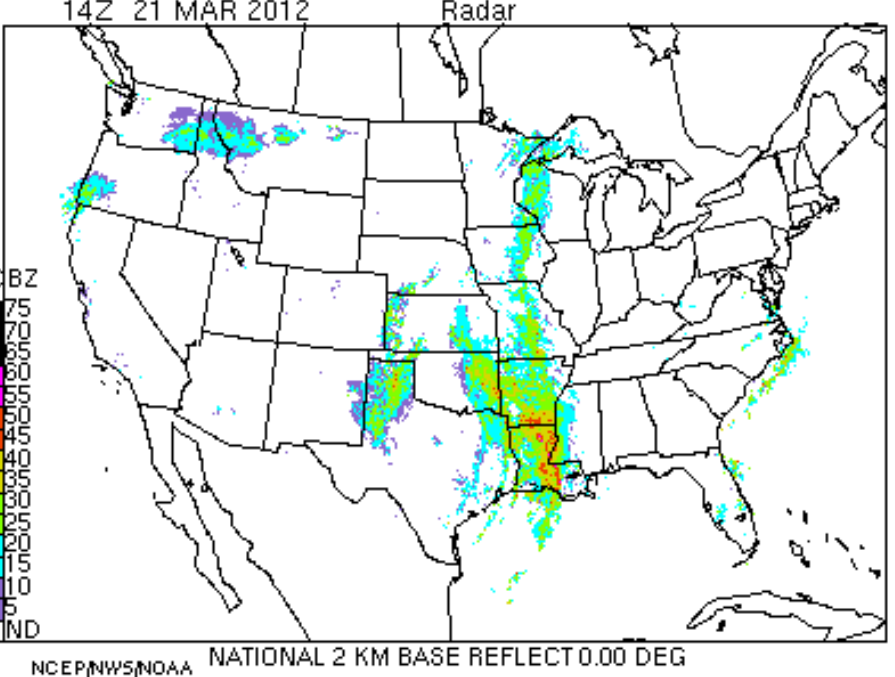
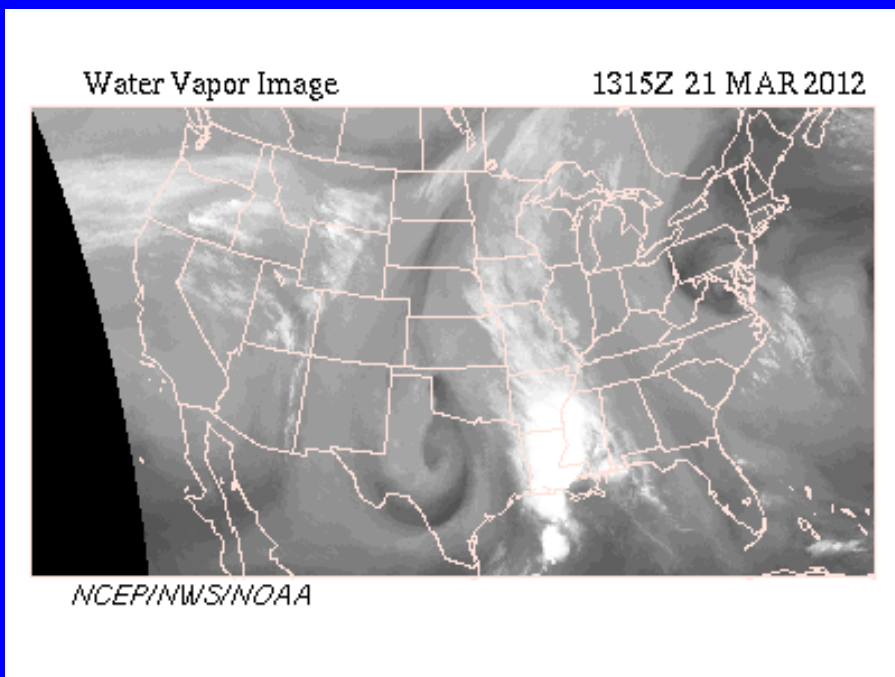


Precipitation

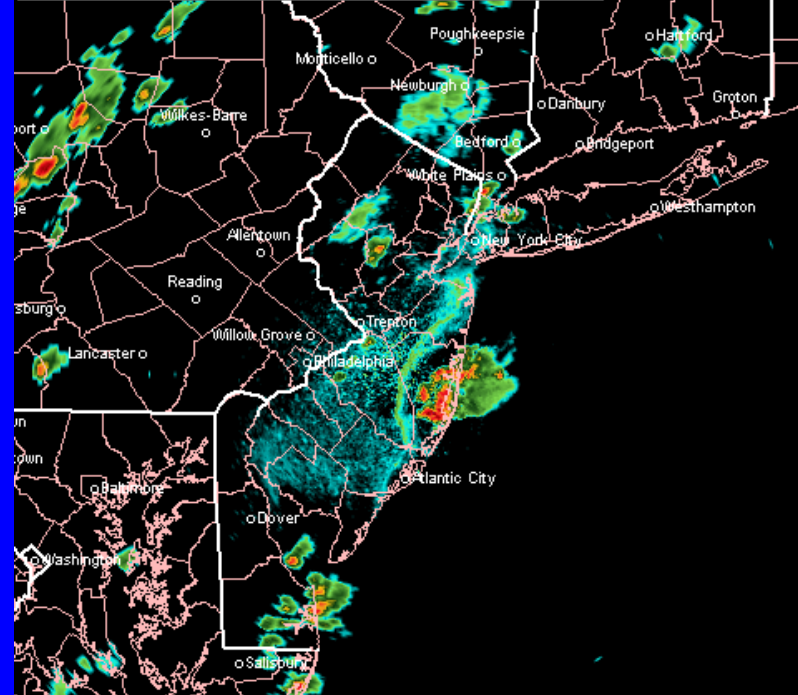
Patterns



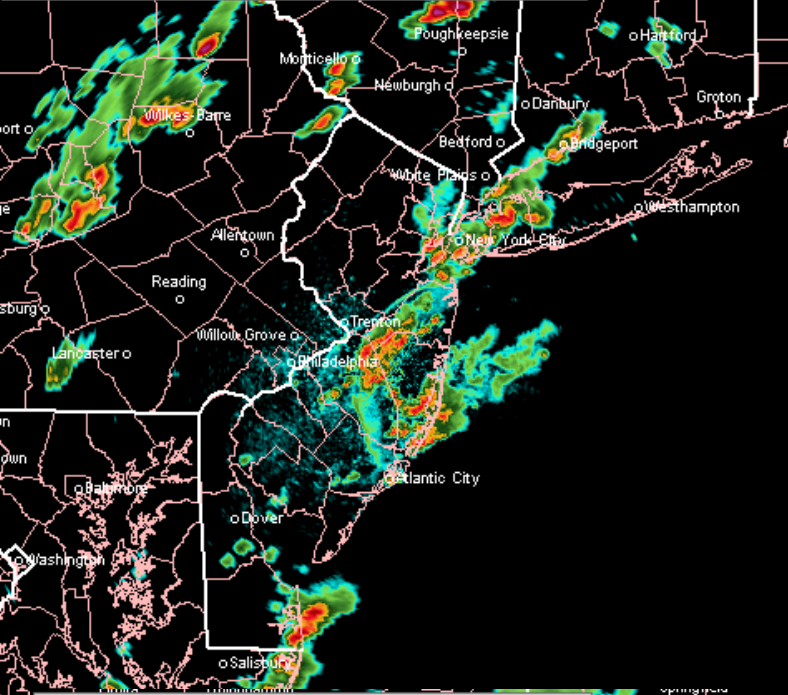
## “Stacked System”



© 2012 WeatherTAP.com - 06/22/2012 1:19 PM EDT (17:19 GMT)



© 2012 WeatherTAP.com - 06/22/2012 2:15 PM EDT (18:15 GMT)



BASE REFLECTIVITY

SITE: KDIX

D/T: 06/22/12 1814Z

RANGE: 460 KM

RES: 1KM X 1DEG

MODE: PRECIPITATION

UCP: 12

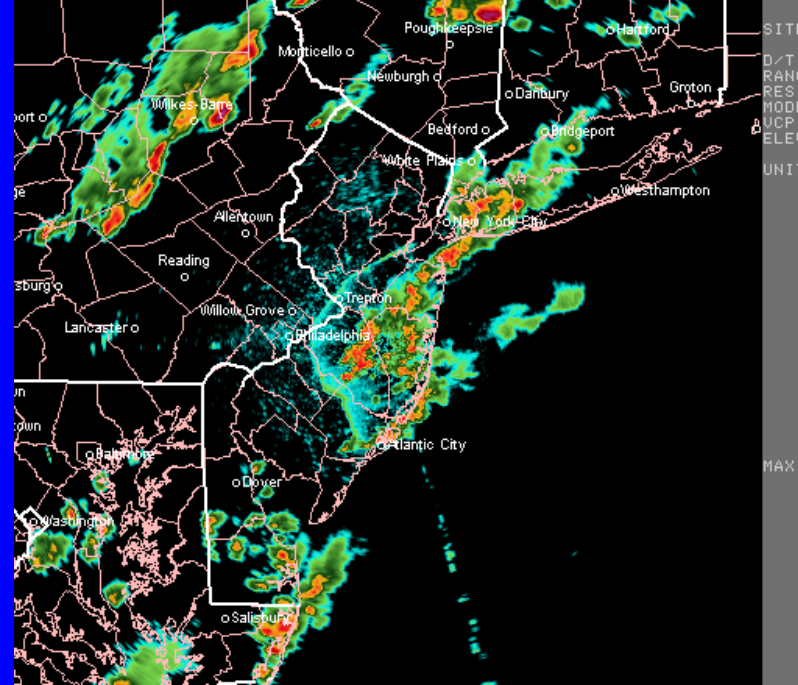
ELEV: 0.5 DEGREES

UNITS: DBZ

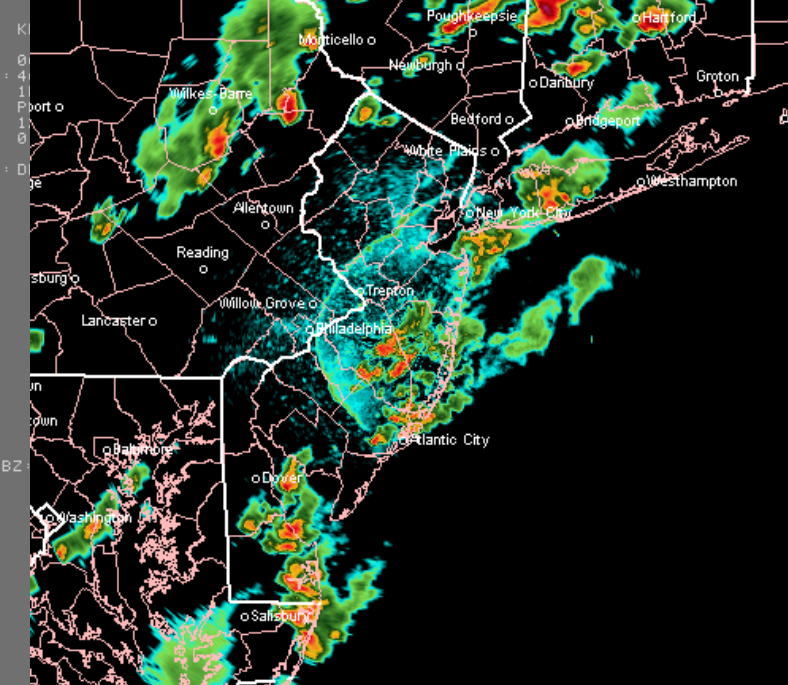
5
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75

MAX DBZ: 67

© 2012 WeatherTAP.com - 06/22/2012 2:51 PM EDT (18:51 GMT)



© 2012 WeatherTAP.com - 06/22/2012 3:25 PM EDT (19:25 GMT)



BASE REFLECTIVITY

SITE: KDIX

D/T: 06/22/12 1924Z

RANGE: 460 KM

RES: 1KM X 1DEG

MODE: PRECIPITATION

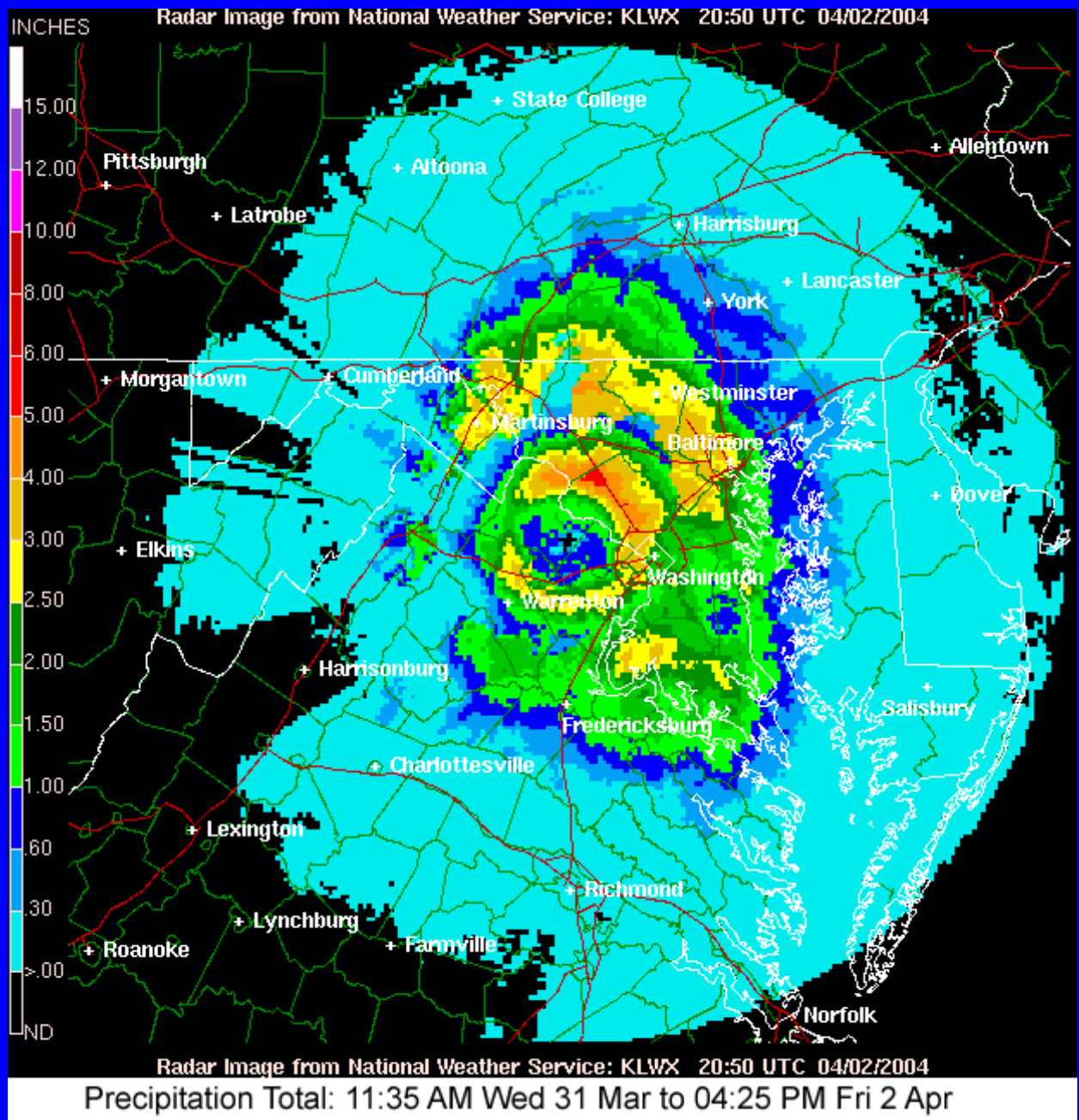
UCP: 12

ELEV: 0.5 DEGREES

UNITS: DBZ

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MAX DBZ: 60



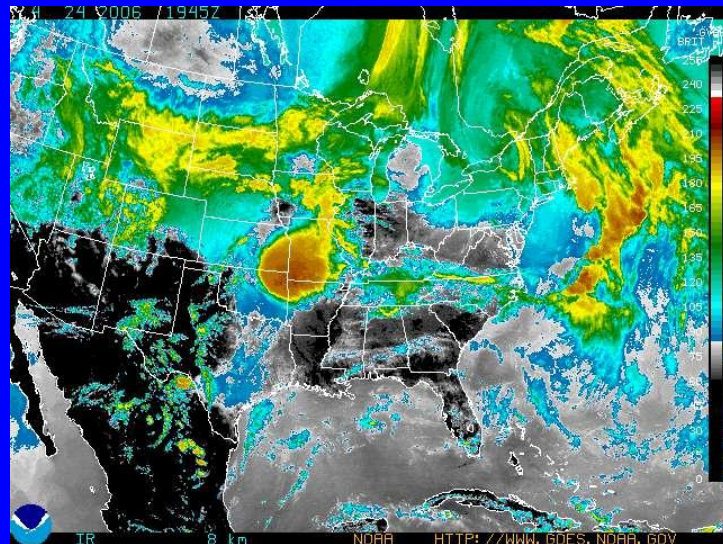
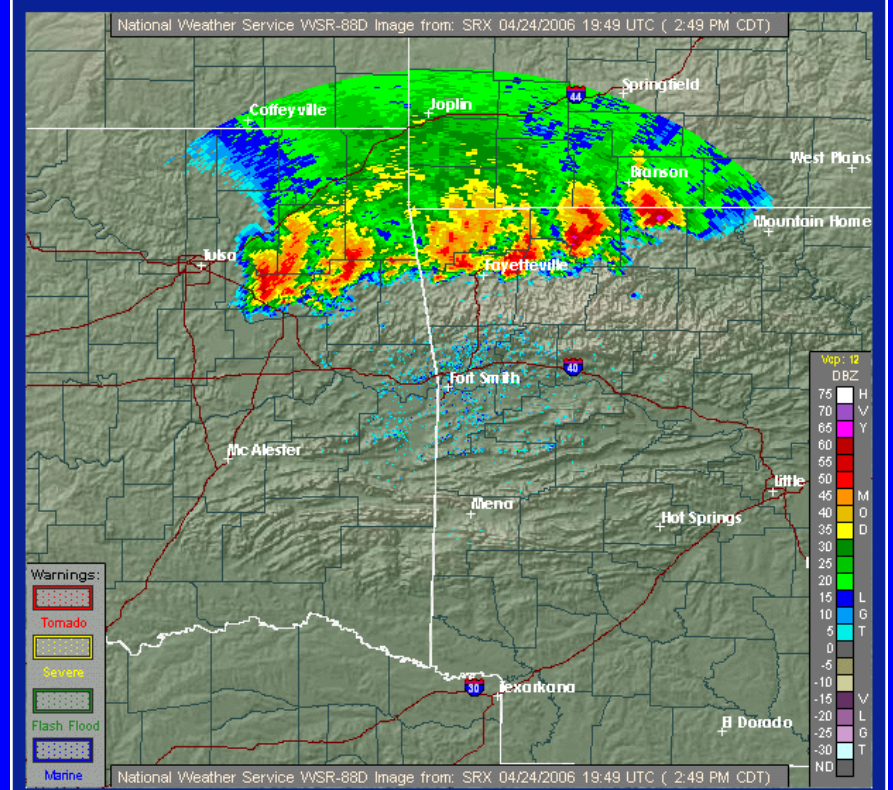
Threatening Weather

Signatures

# Mesoscale Convective Systems

NWS Tulsa, OK

02:03 PM CDT Mon Apr 24 2006

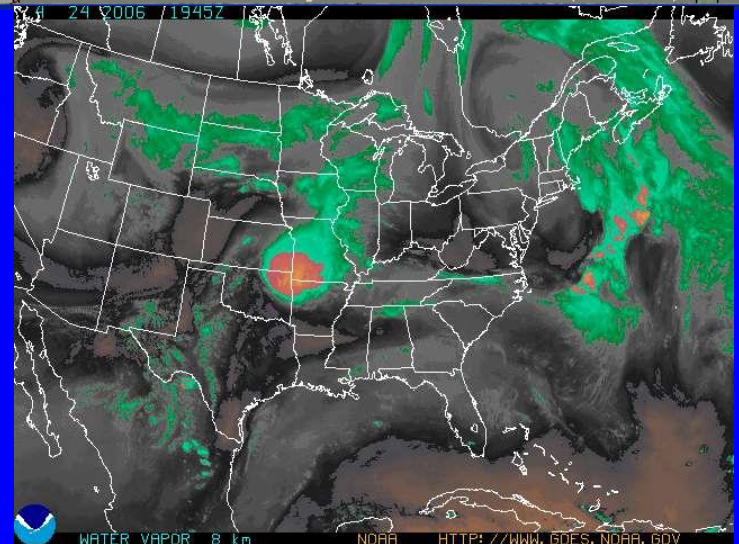


IR

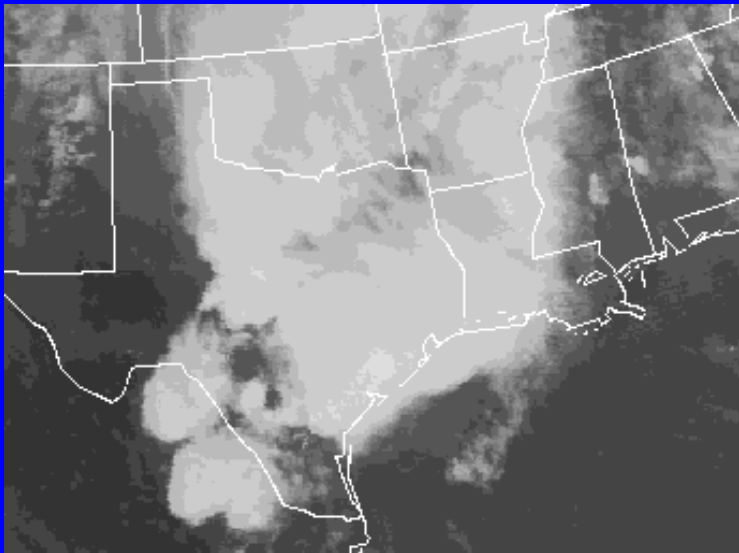
<

WV

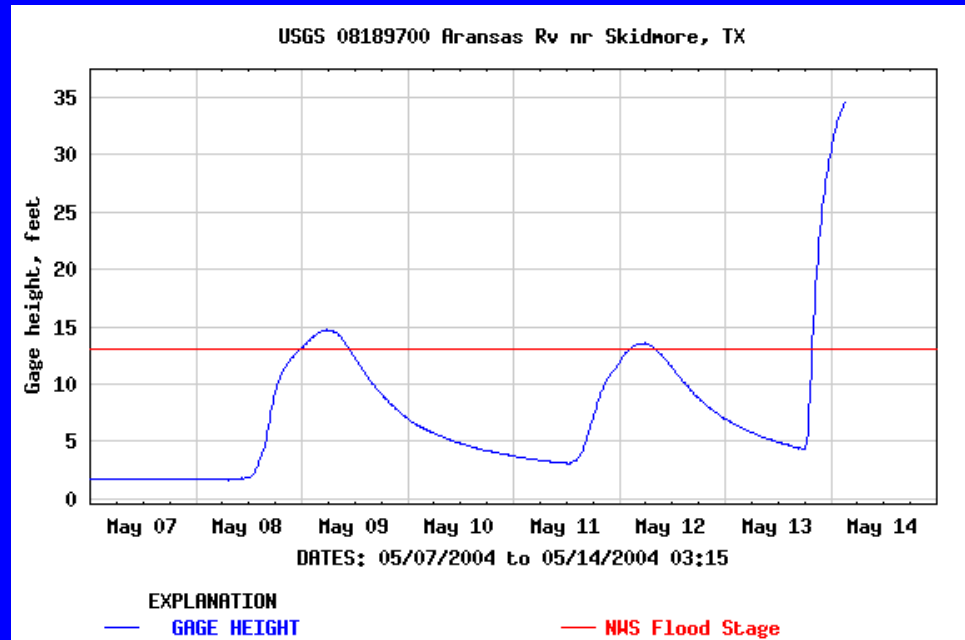
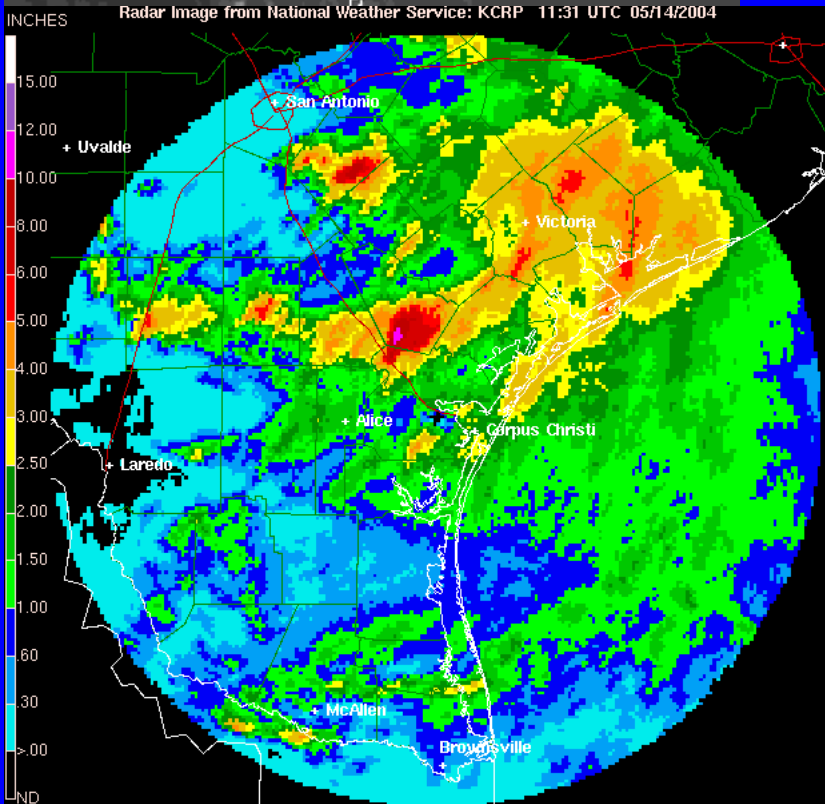
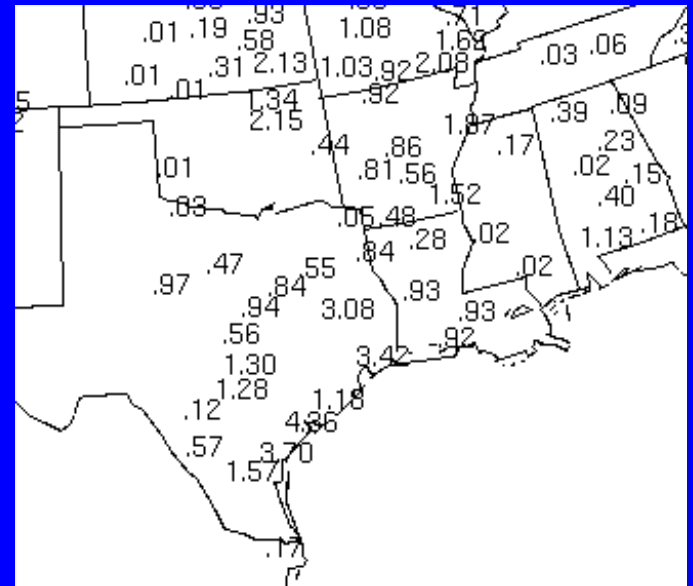
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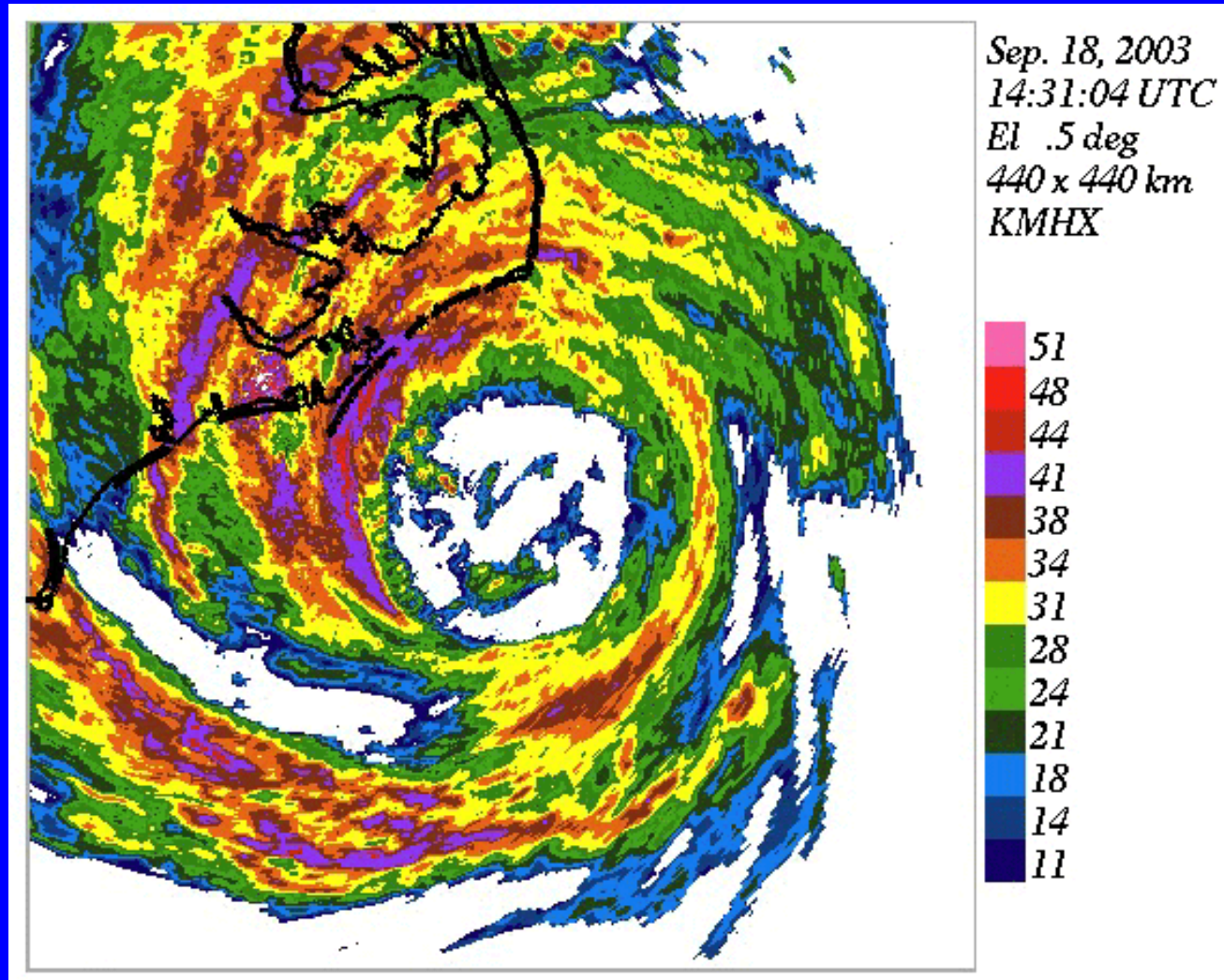


# Flash Flooding SE TX 5/14/04



Radar Image from National Weather Service: KCRP 11:31 UTC 05/14/2004

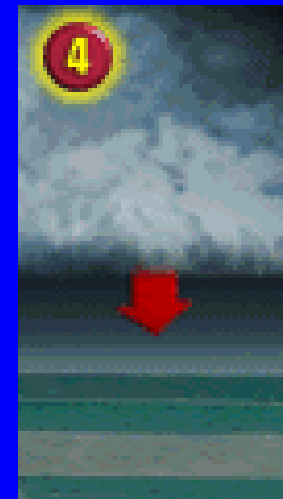
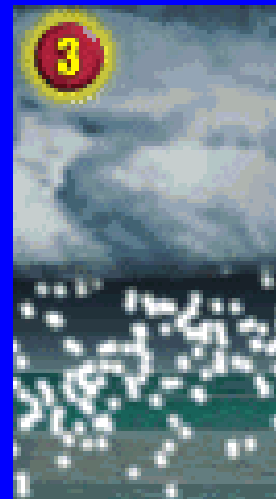
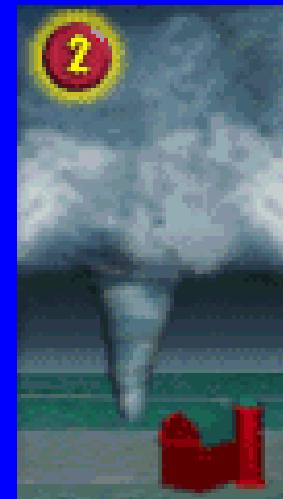
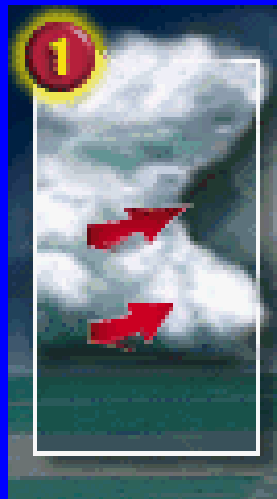
# Severe Weather Signatures



Hurricane Isabel

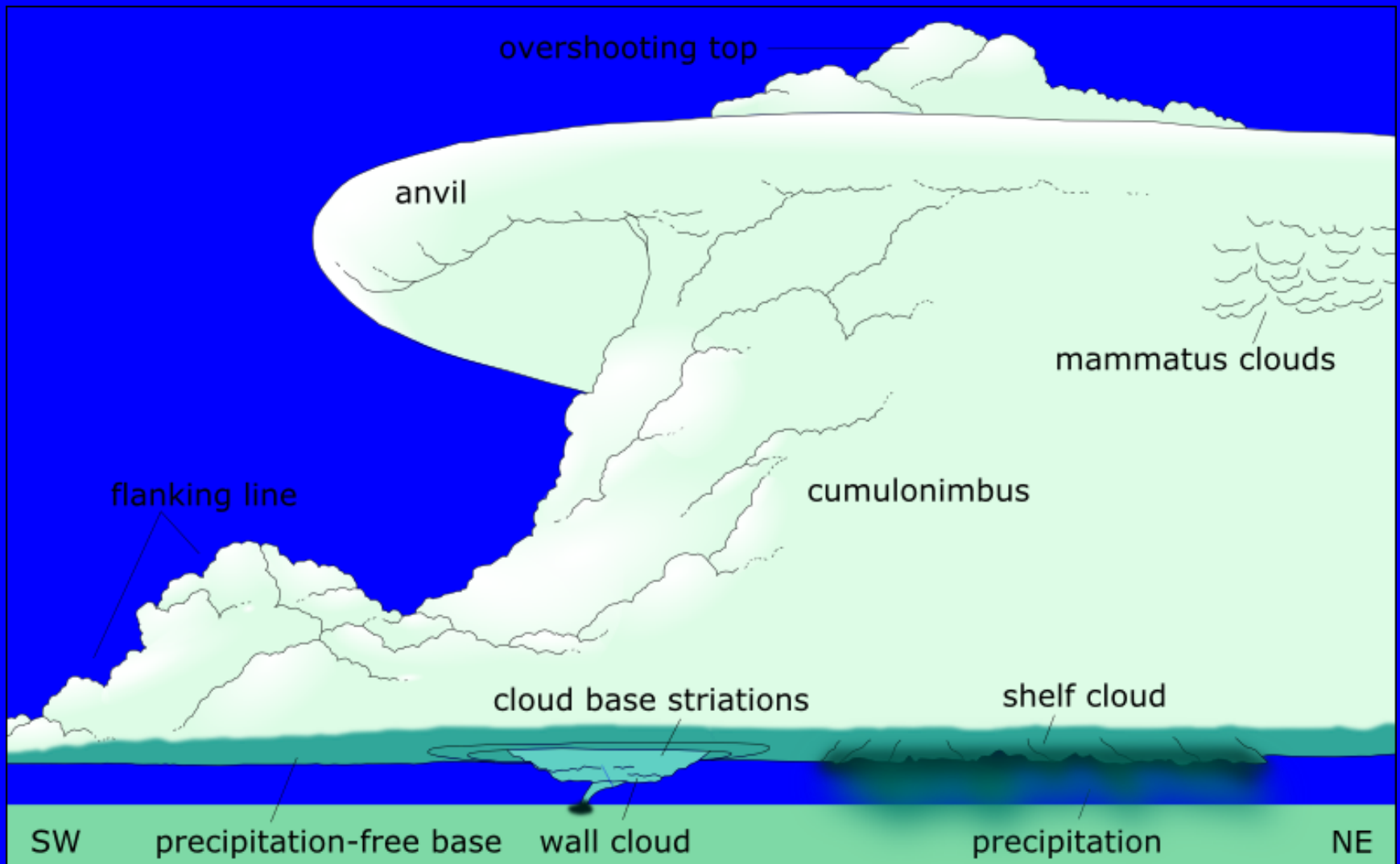
# Severe Thunderstorms

- Hail –  $\frac{3}{4}$  inch or larger
- Winds – 50 kts or more

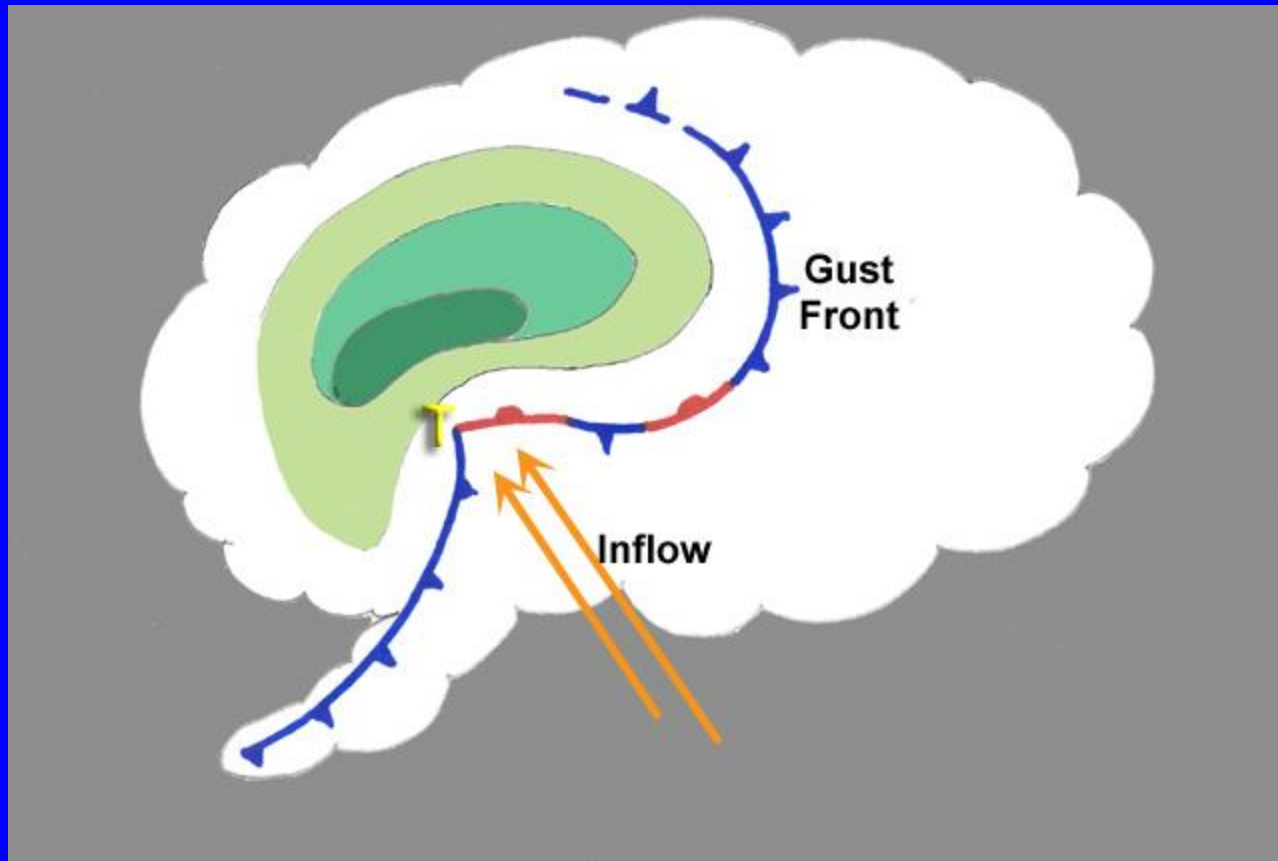


*Courtesy of USA Today*

# Schematic Diagram of the Supercell Storm



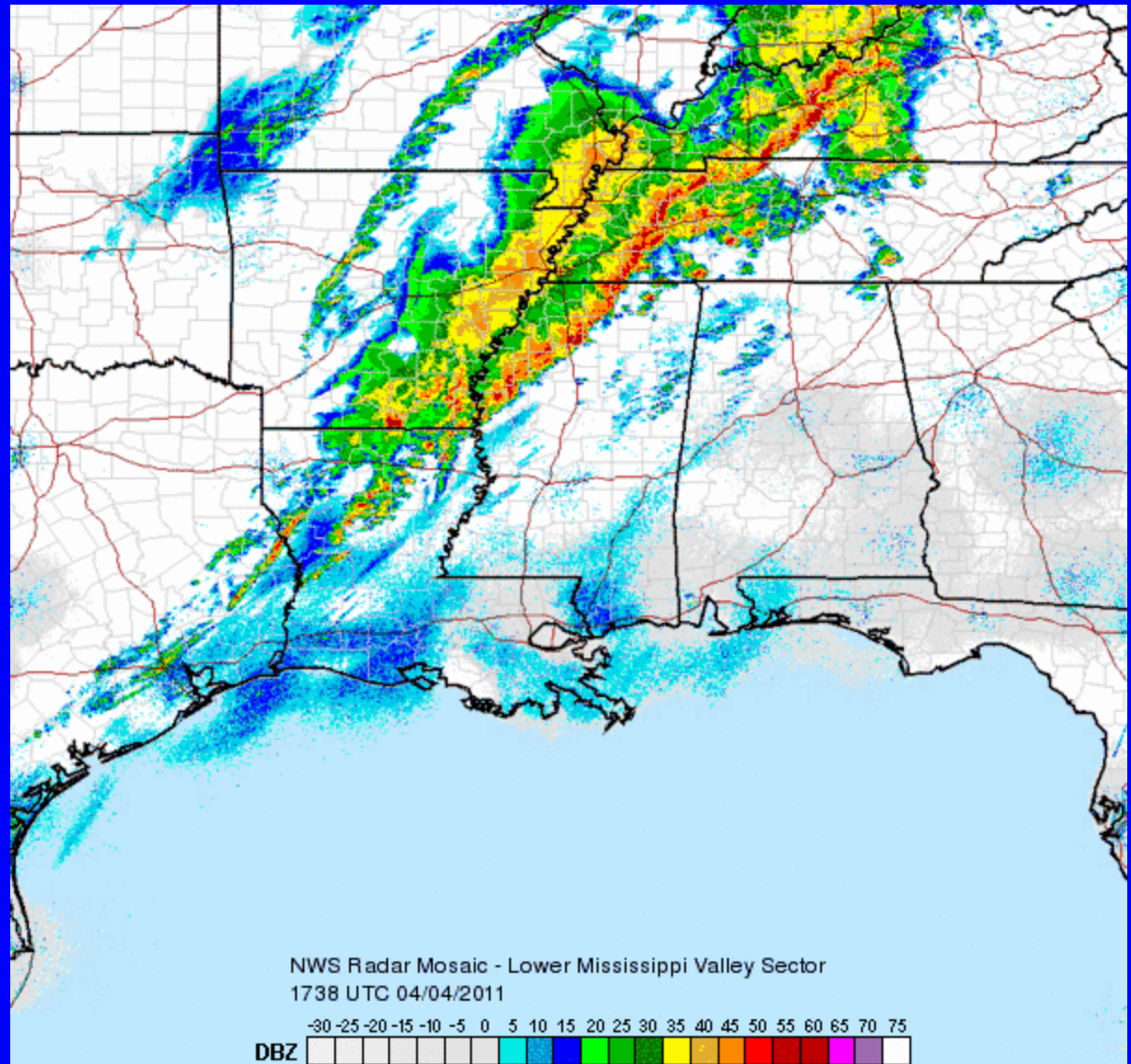
# Supercell Storm



Classic supercell. A tornado may form in the vicinity of the pendant or hook echo.

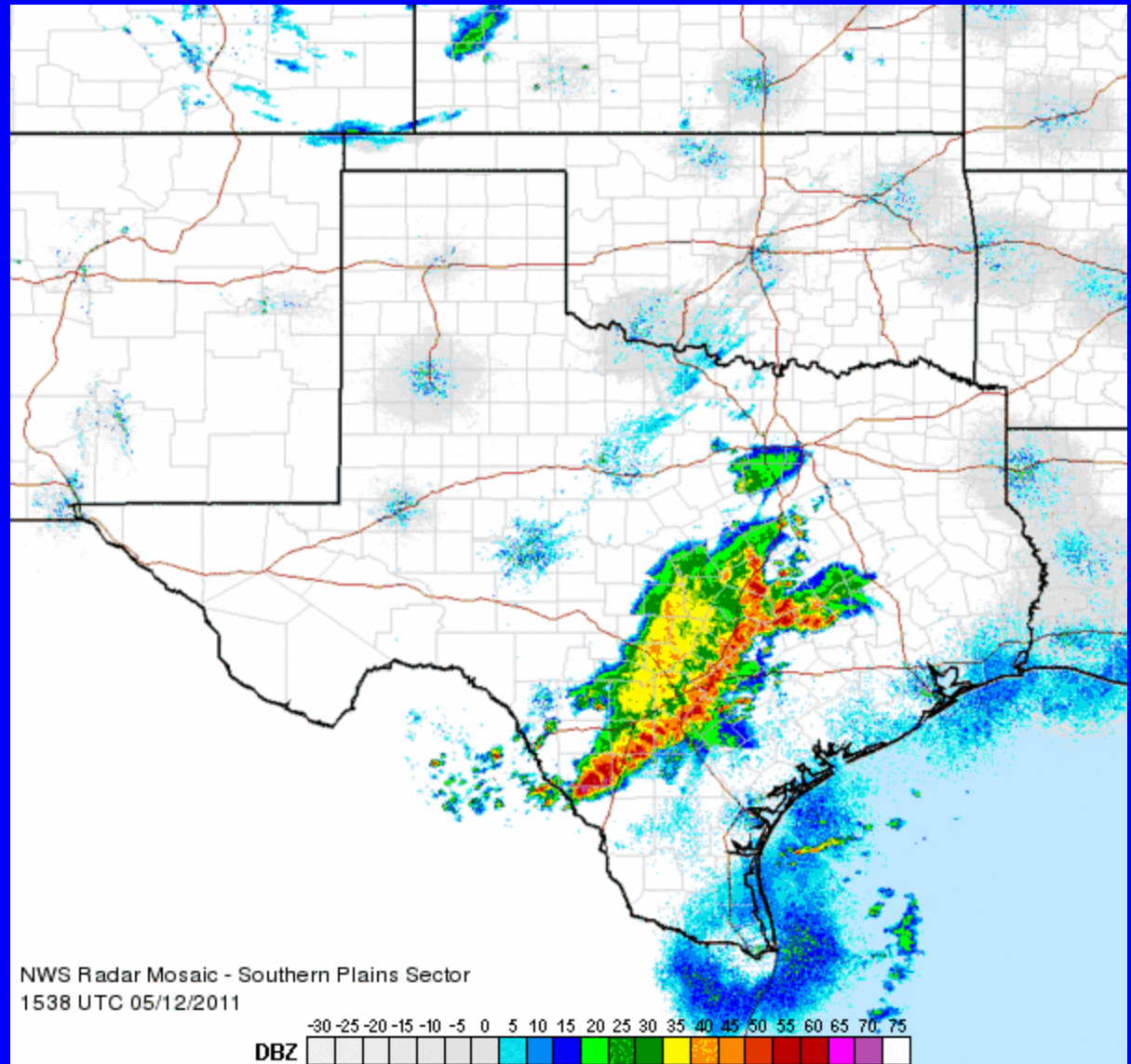
# Severe Weather Signatures

Squall  
line

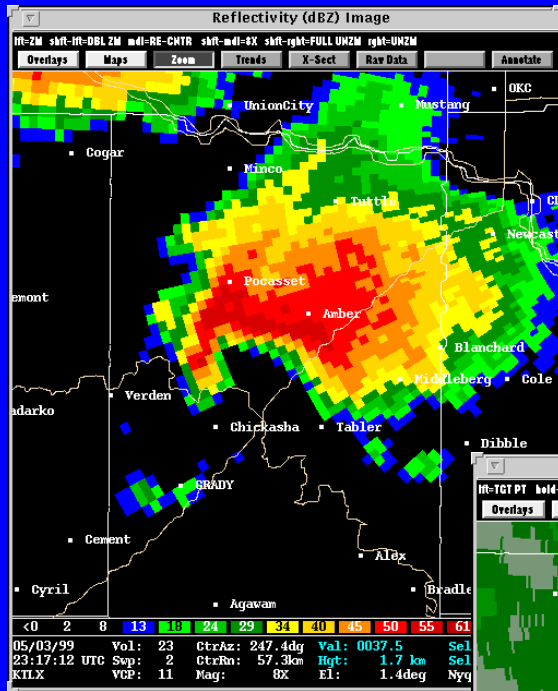


# Severe Weather Signatures

Bow  
echo

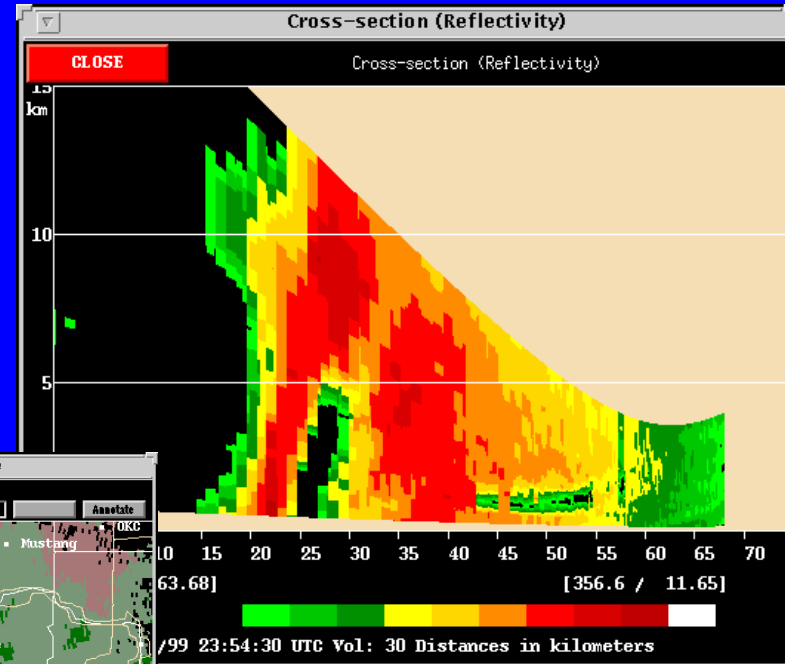
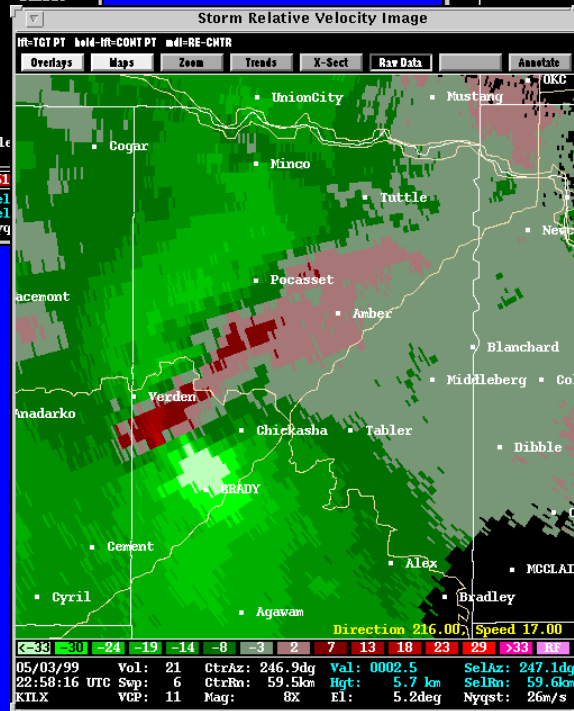


# Tornadic Radar Signatures



Refl: "Hook echo"

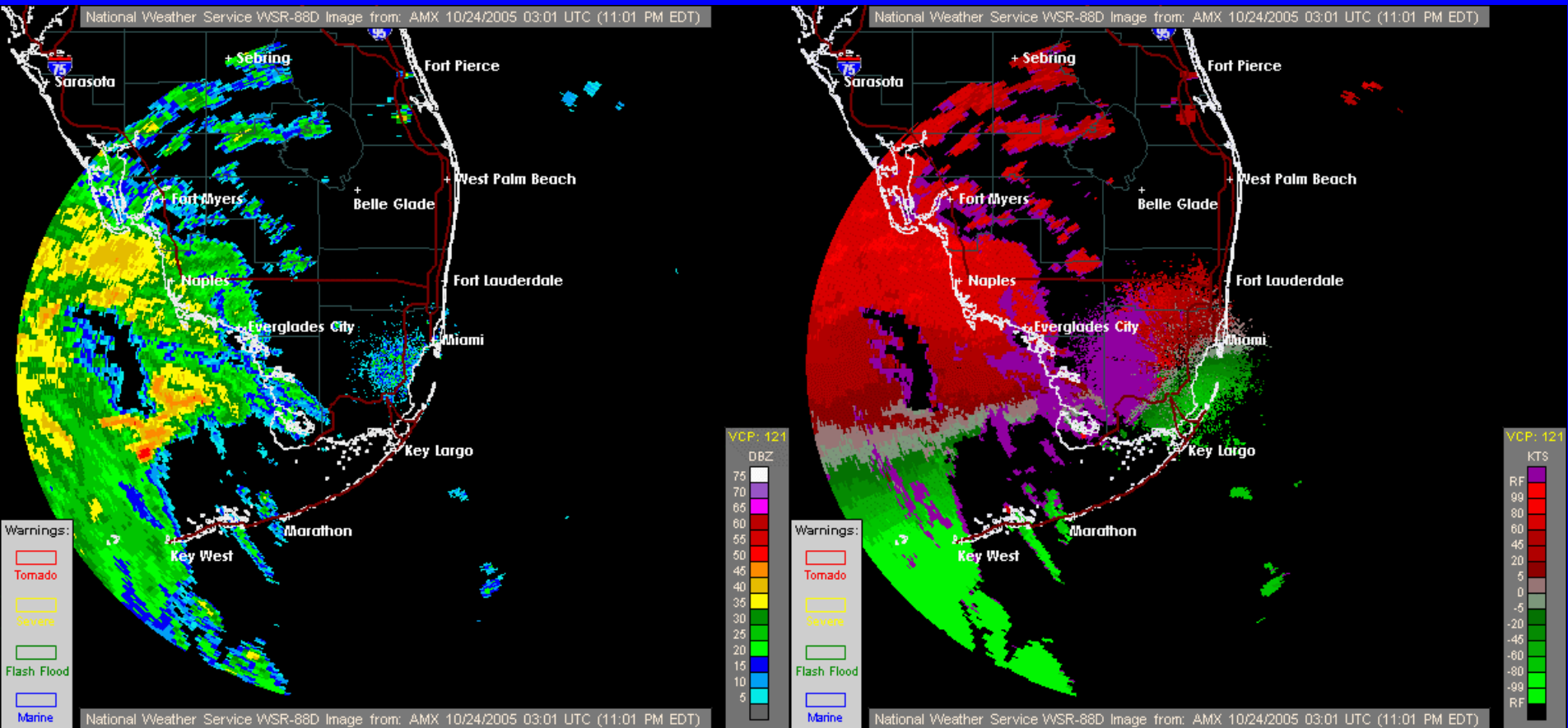
Vel: TVS



Refl: BWER



# Hurricane Wilma

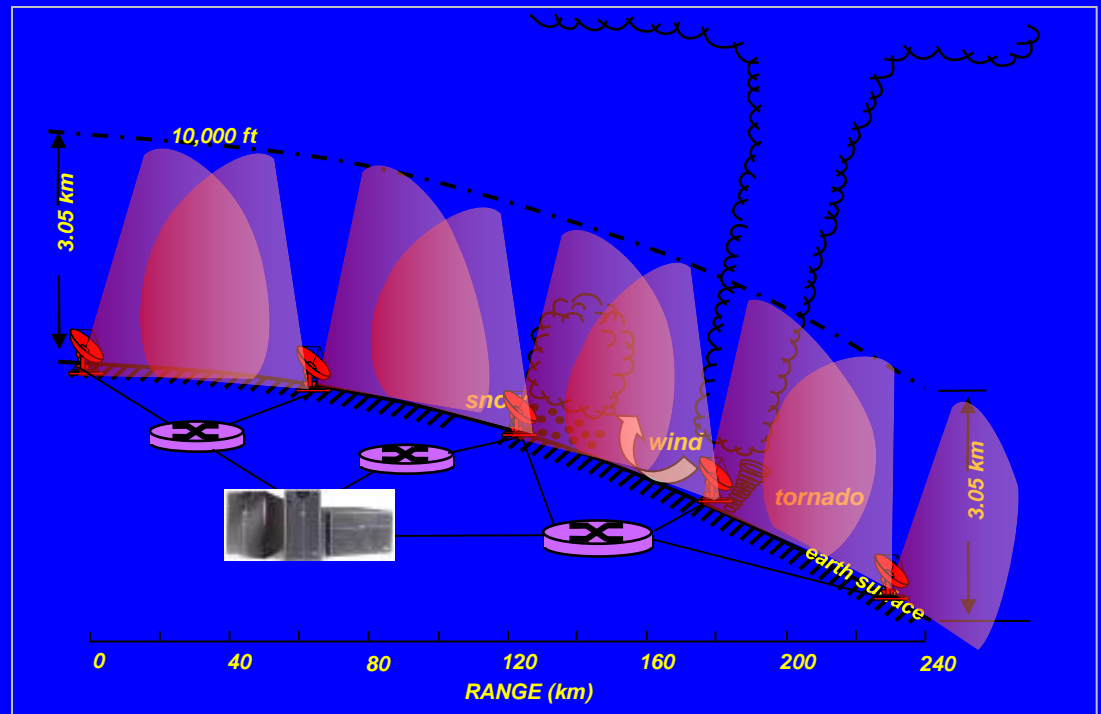


*Future?*

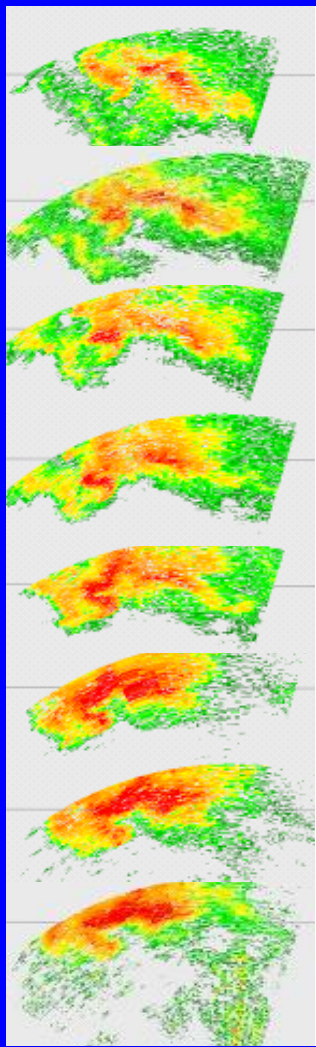
# Collaborative Adaptive Sensing of the Atmosphere CASA

## CASA Radar solution:

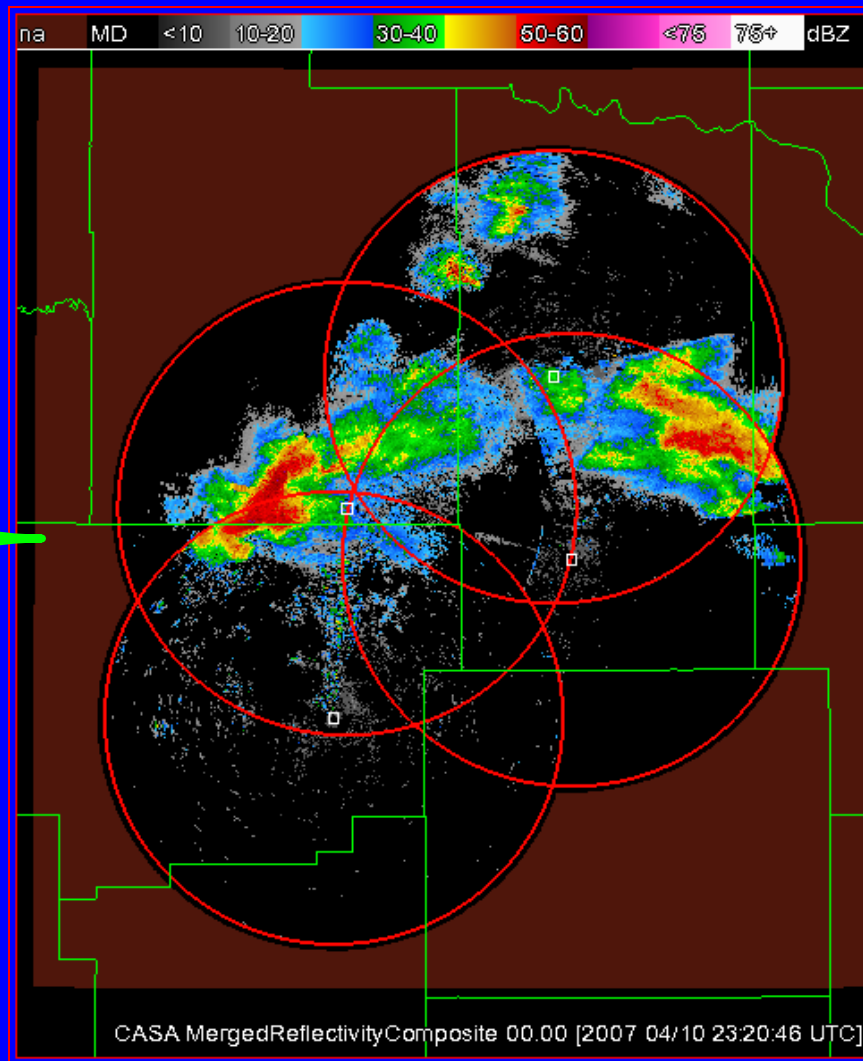
- ❑ *Short range (~ 40 km) radars deployed on cell towers*
- ❑ *Lower troposphere coverage*
- ❑ *100's meter resolution*
- ❑ *Rapid scanning as fast as 30 sec.*
- ❑ *Adaptive scanning based on user needs, evolving weather*



**“Sensing the Atmosphere where and when user needs are greatest”**

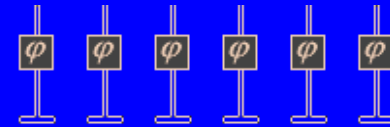
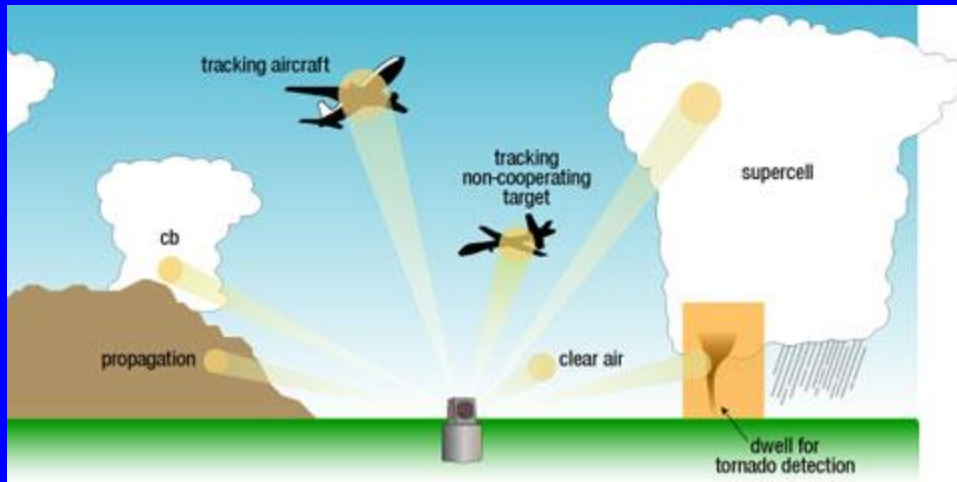


***CASA's Adaptive Sector scanning at multiple elevations from 1 to 14 degrees***



***Situational Awareness & Sector Scans each minute***

# Phased Array Weather Radars

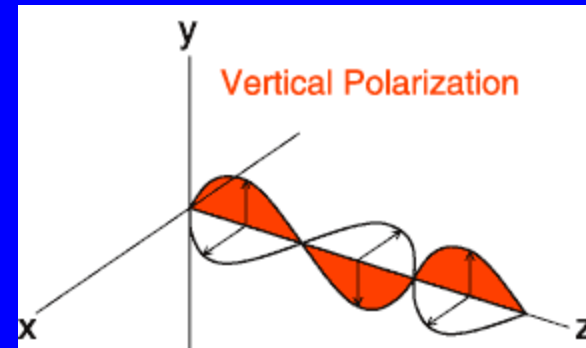
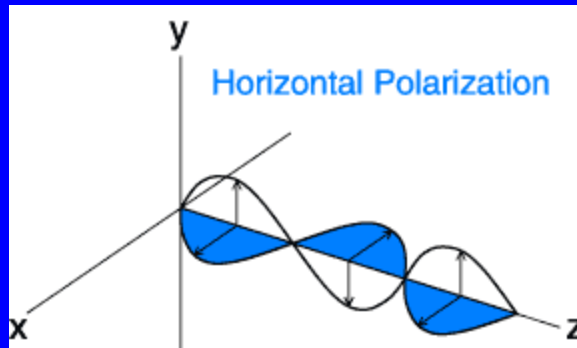


© 2008 Christian Wolff 

- 20 – 30 sec. volume scans vs 5 – 7 min.
- “dwell” and “adaptive scanning”
- lower failure rate



# Dual Polarization WSR-88D Upgrades



CONVENTIONAL DOPPLER RADAR

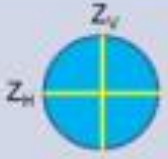




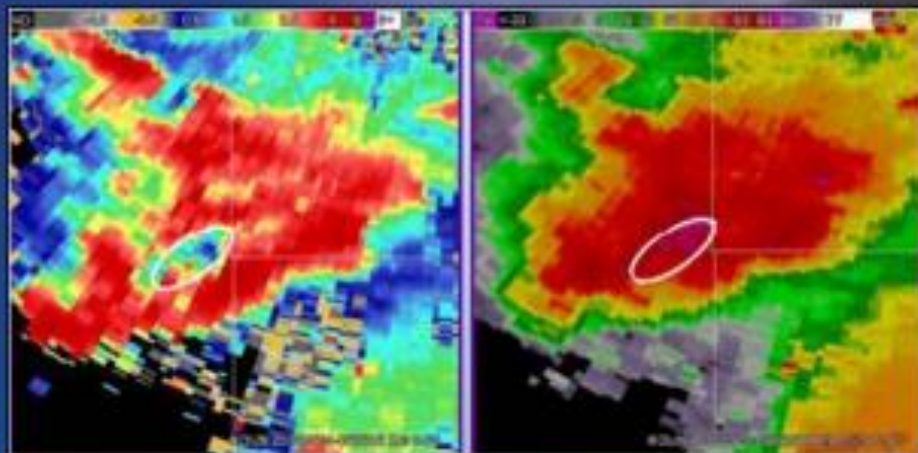
# How Dual-pol Data Will Aid Decision Makers

1. Better rainfall estimation
2. Positively identify precipitation type and intensity
3. Confirm a tornado

# Differential Reflectivity: ZDR

Good indicator of the mean drop shape of the dominant hydrometeor within the resolution volume.

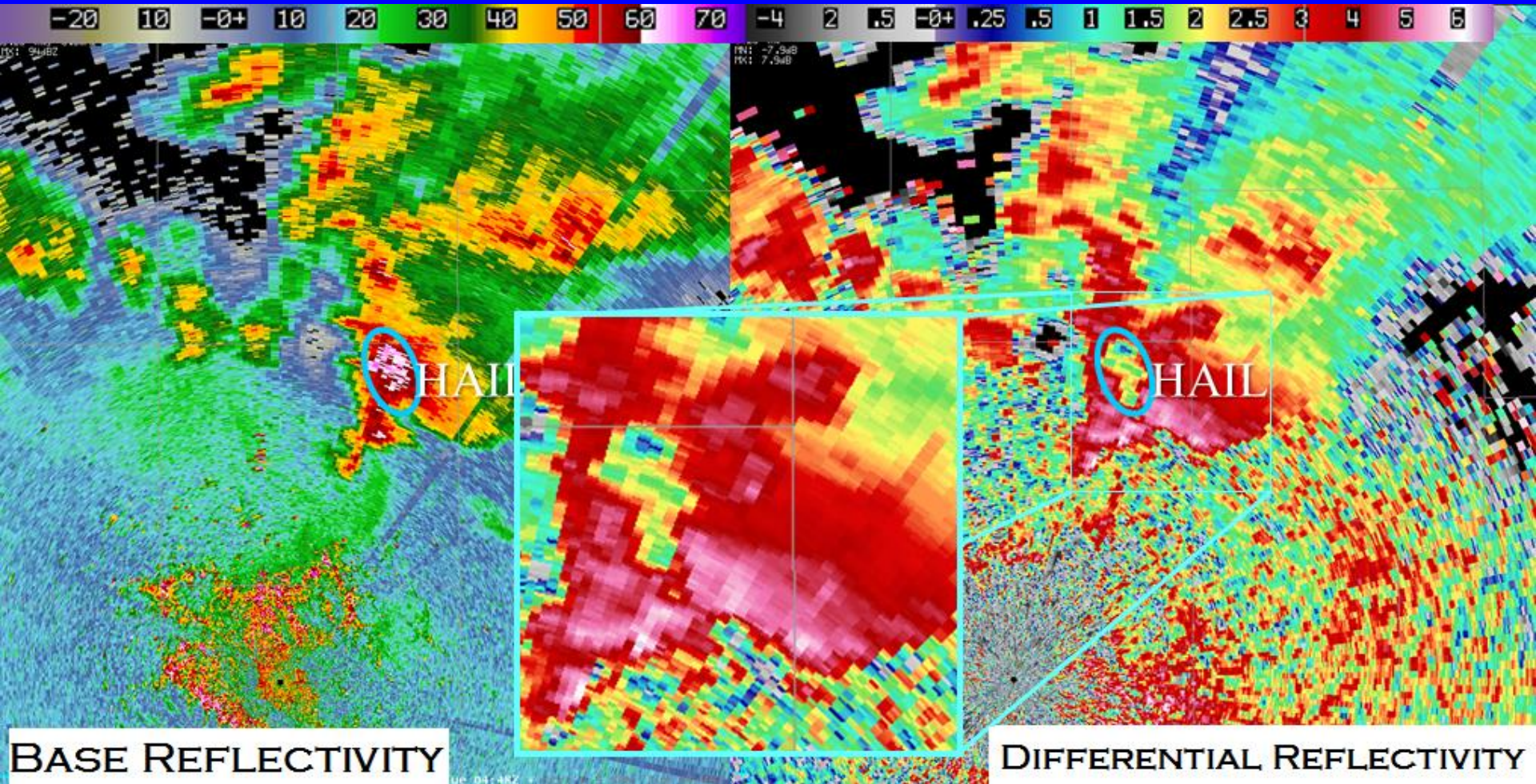
<u>Spherical</u> (drizzle, small hail, etc.)	<u>Horizontally Oriented</u> (rain, melting hail, etc.)	<u>Vertically Oriented</u> (i.e. vertically oriented ice crystals)
		
$Z_H \sim Z_V$	$Z_H > Z_V$	$Z_H < Z_V$
$Z_H - Z_V \sim 0$	$Z_H - Z_V > 0$	$Z_H - Z_V < 0$
<b>ZDR = 0 dB</b>	<b>ZDR &gt; 0 dB</b>	<b>ZDR &lt; 0 dB</b>



ABOVE: Lower ZDR values inside the white oval (left) suggest targets that are nearly round (most likely hailstones). In contrast, the high ZDR values surrounding the hail shaft suggest large raindrops, which are deformed into a flat "hamburger bun" shape as they fall. The Z values inside the white oval (right) show little difference from the surrounding areas, making it difficult to determine whether hail or large rain are being detected.


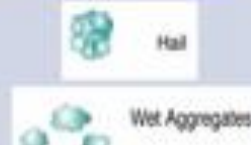

From NWS Phoenix

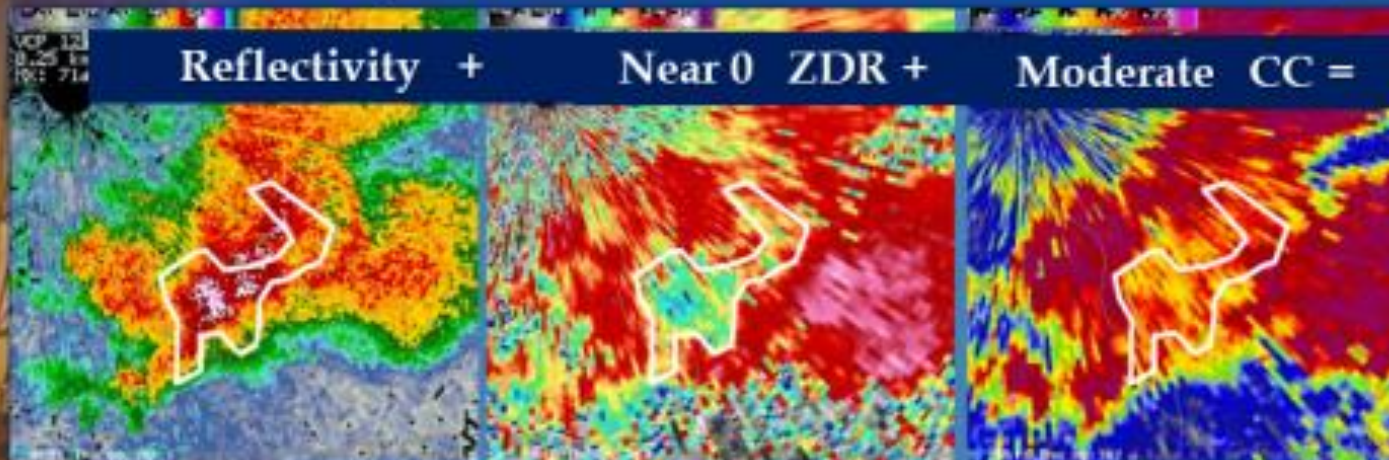




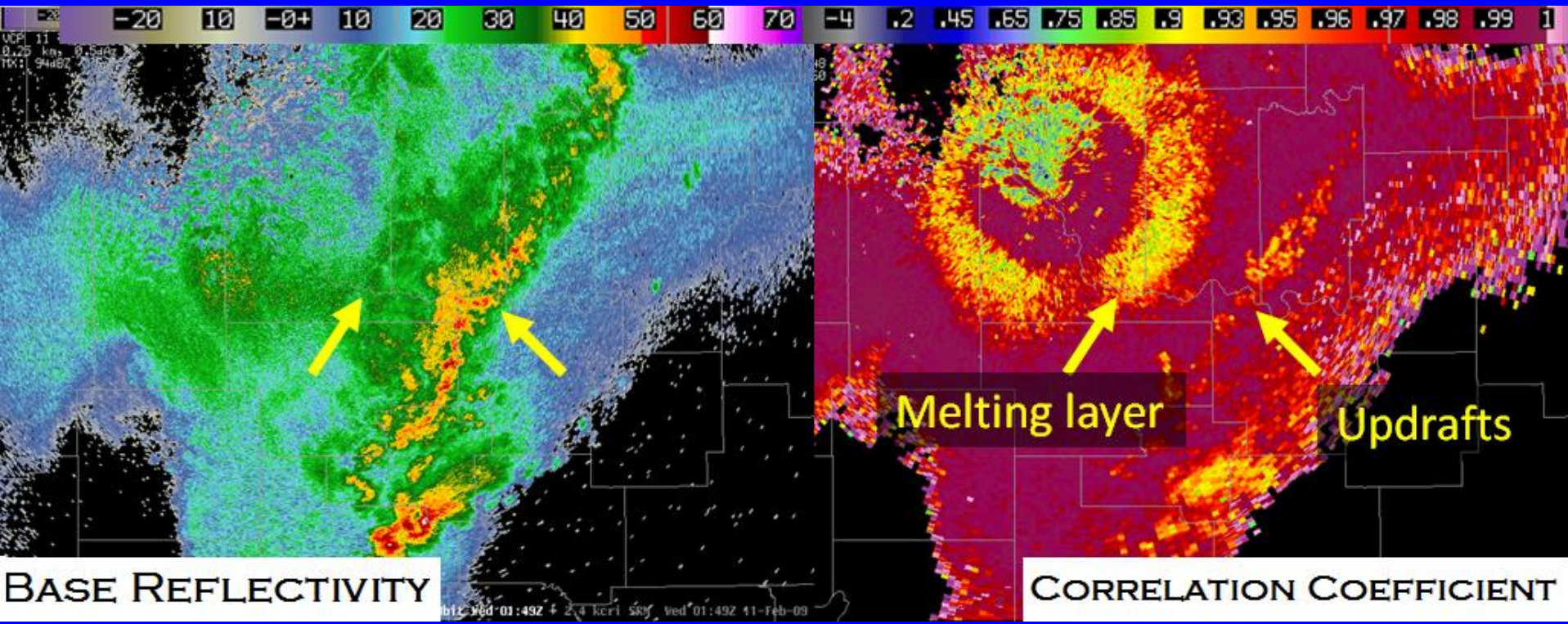
# Correlation Coefficient: CC

Measure of how similarly the horizontal and vertical pulses are behaving in a volume scan.

Non-Meteorological (birds, insects, etc.)	Metz (Non-Uniform) (hail, melting snow, etc.)	Metz (Uniform) (rain, snow, etc.)
		
Complex scattering from pulse-to-pulse. Horizontal and vertical pulses change in different manners from pulse-to-pulse	Somewhat complex scattering from pulse-to-pulse. Moderate differences from pulse-to-pulse for the horizontal and vertical pulses	Well-behaved scattering from pulse-to-pulse. Little differences from pulse-to-pulse for the horizontal and vertical pulses
Low CC (< 0.8)	Moderate CC (0.80 to 0.97)	High CC (> 0.97)

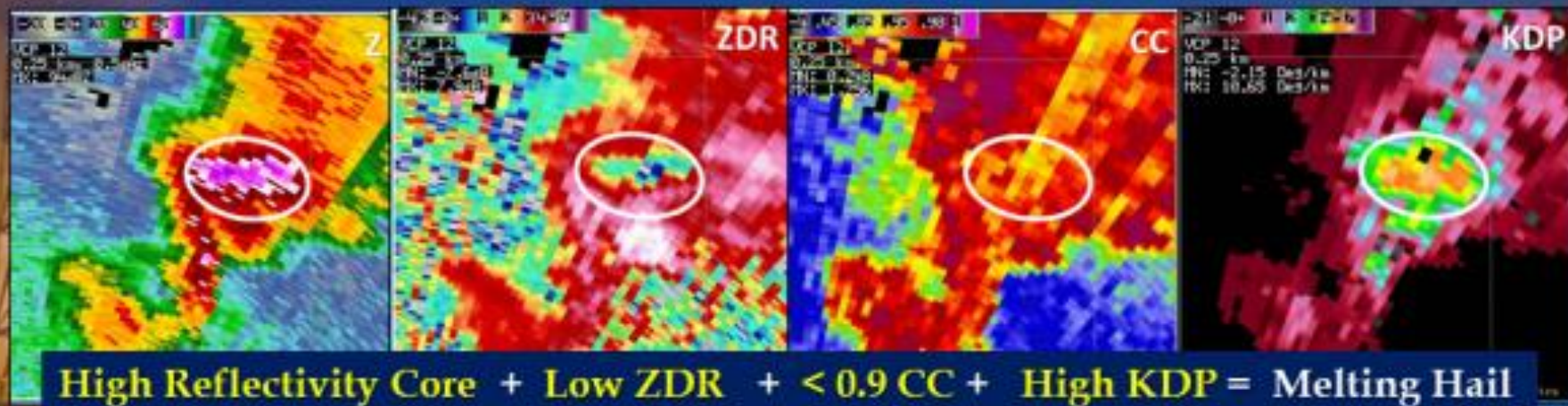
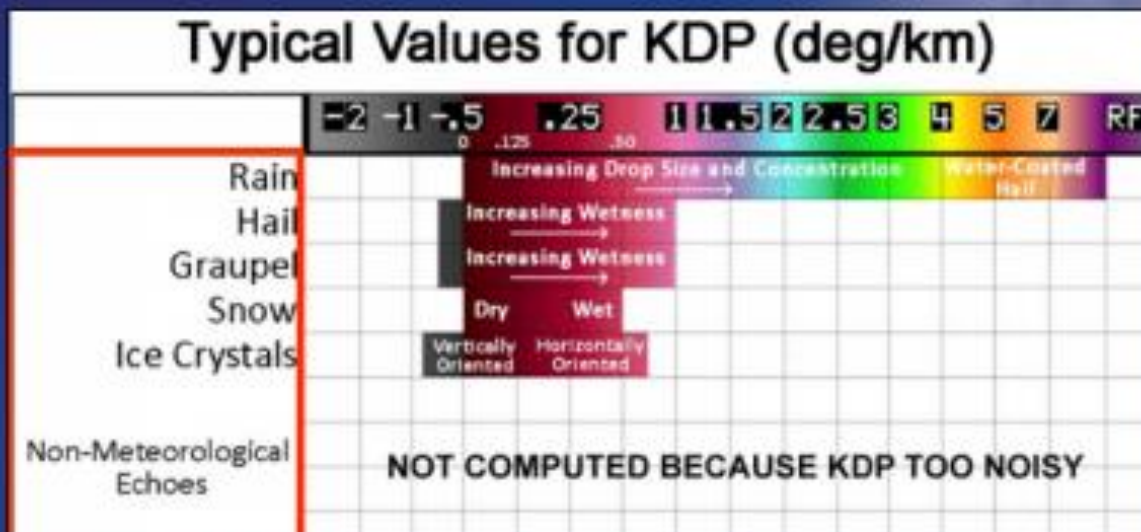


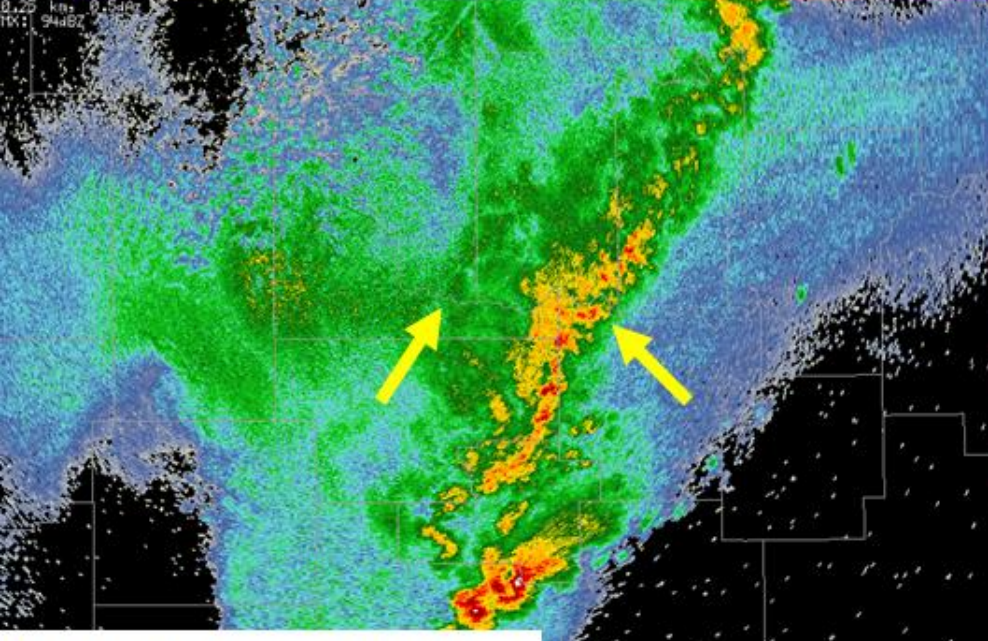
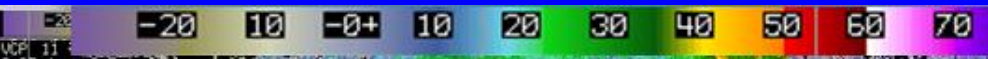
Likely a  
Hail Shaft!



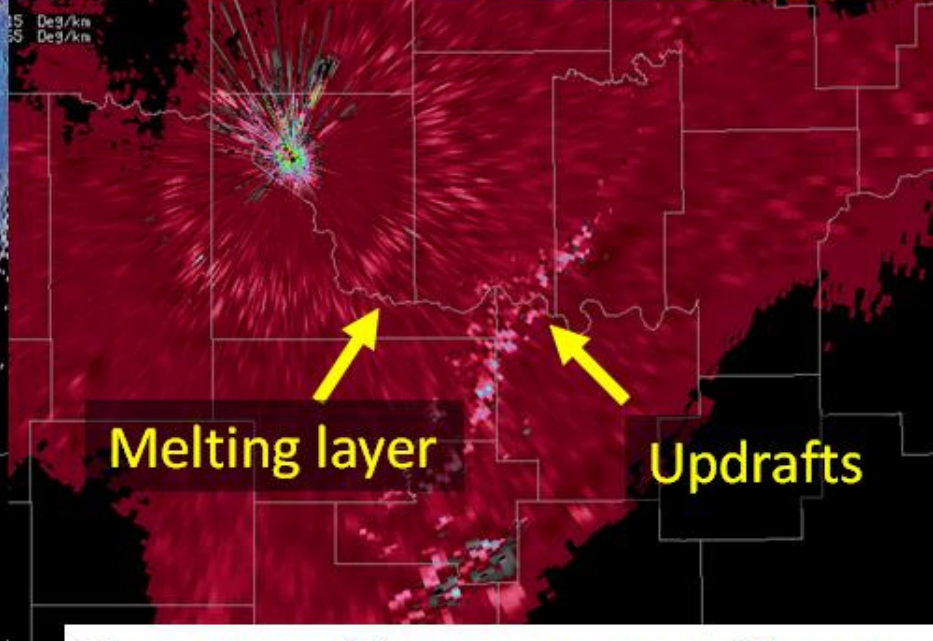
# Specific Differential Phase: KDP

The range derivative of the differential phase shift between the horizontal & vertical pulse phase. In other words, KDP shows where displacement of the vertical & horizontal pulses occur, and gives a value of how much phase shift occurred which is associated with a type of atmospheric target.





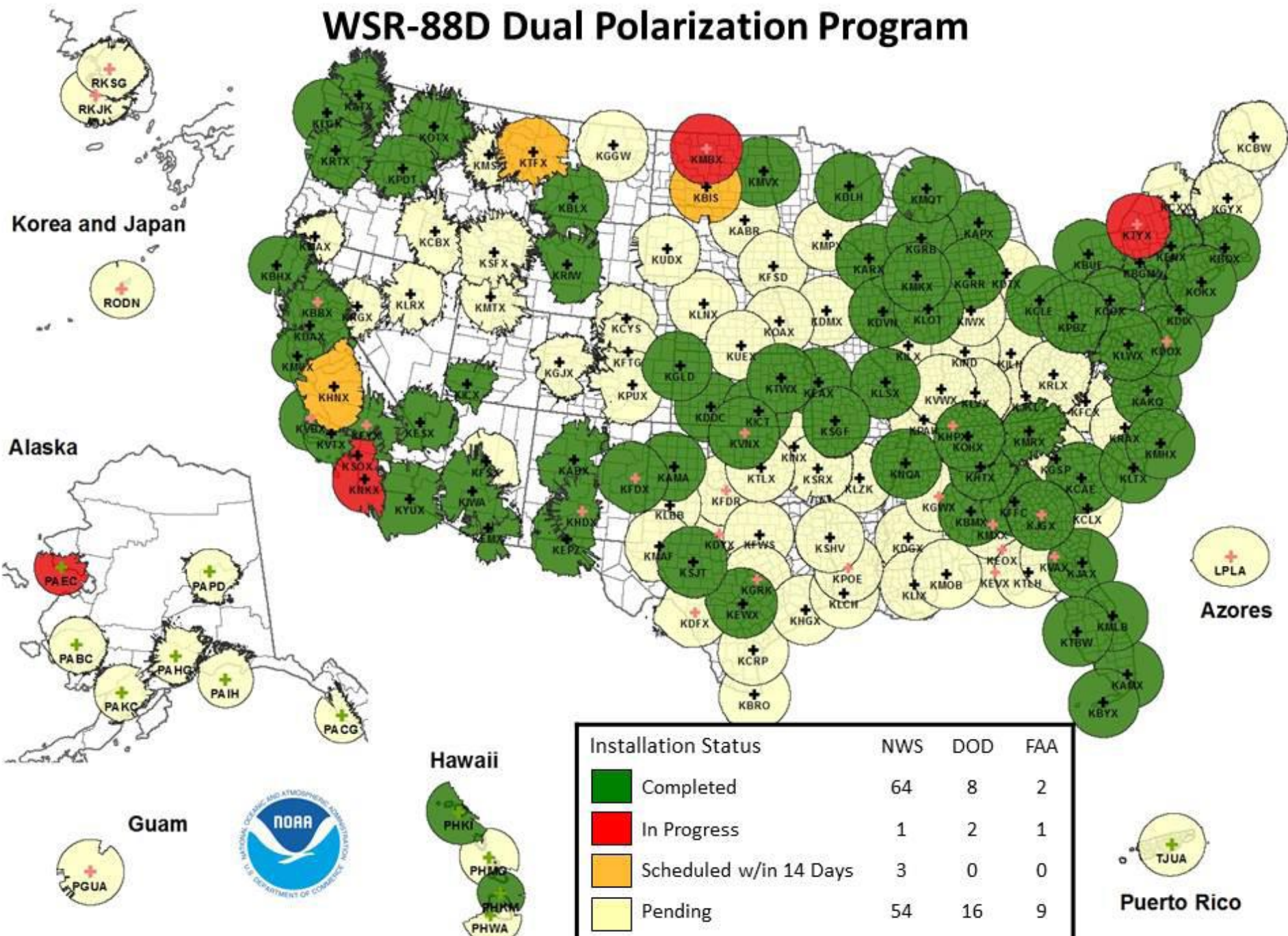
**BASE REFLECTIVITY**



**SPECIFIC DIFFERENTIAL PHASE**

11 Feb 01:49Z + 2.4 kcr1 SR9 Feb 01:49Z 11-Feb-09

# WSR-88D Dual Polarization Program



Installation Status	NWS	DOD	FAA
Completed	64	8	2
In Progress	1	2	1
Scheduled w/in 14 Days	3	0	0
Pending	54	16	9

Radar coverage shown is at 10,000 ft AGL or below

*Questions?*