

# Table of Contents

## Topic: Base and Derived Products

Click to jump to lesson

Lesson 1	<a href="#">Introduction to Base and Derived Products</a>
Lesson 2	<a href="#">Base Reflectivity (Z)</a>
Lesson 3	<a href="#">Base Velocity (V)</a>
Lesson 4	<a href="#">Storm-Relative Motion (SRM)</a>
Lesson 5	<a href="#">Base Spectrum Width (SW)</a>
Lesson 6	<a href="#">Correlation Coefficient (CC)</a>
Lesson 7	<a href="#">Differential Reflectivity (ZDR)</a>
Lesson 8	<a href="#">Specific Differential Phase (KDP)</a>
Lesson 9	<a href="#">Base Data Cross-Section Tools (Volume Browser &amp; GR2Analyst)</a>
Lesson 10	<a href="#">Range-Defined Quasi-Vertical Profiles (RDQVP)</a>
Lesson 11	<a href="#">Storm Cell Identification and Tracking (SCIT) Algorithm</a>
Lesson 12	<a href="#">Storm Tracking Information (STI)</a>
Lesson 13	<a href="#">Hail Index (HI)</a>
Lesson 14	<a href="#">Digital Vertically Integrated Liquid (DVIL)</a>
Lesson 15	<a href="#">Composite Reflectivity (CZ)</a>
Lesson 16	<a href="#">Enhanced Echo Tops (EET)</a>
Lesson 17	<a href="#">Velocity Azimuth Display Wind Profile (VWP)</a>
Lesson 18	<a href="#">Mesocyclone (MD) &amp; Digital Mesocyclone (DMD)</a>
Lesson 19	<a href="#">Tornadic Vortex Signature (TVS)</a>
Lesson 20	<a href="#">Hydrometeor Classification (HC)</a>
Lesson 21	<a href="#">Melting Layer (ML)</a>
Lesson 22	<a href="#">PPS Rainfall Products</a>
Lesson 23	<a href="#">QPE Rainfall Products</a>

# Introduction to Base and Derived Products

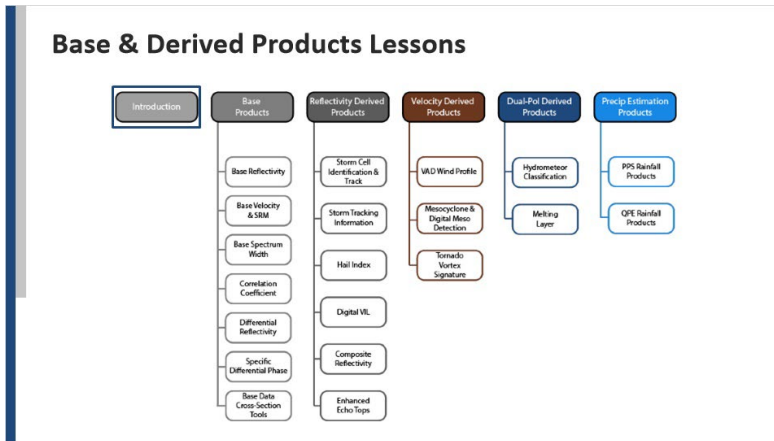
## *Introduction*



### **Notes:**

Welcome to the Radar and Applications Course topic on Base and Derived Products. This lesson introduces this topic where you will learn about the most operationally relevant products produced by the WSR-88D. You'll learn when, why, and how to use them (aka: their applications), as well as when to question or even ignore their output (aka: their limitations). This lesson will take approximately 15 minutes to complete.

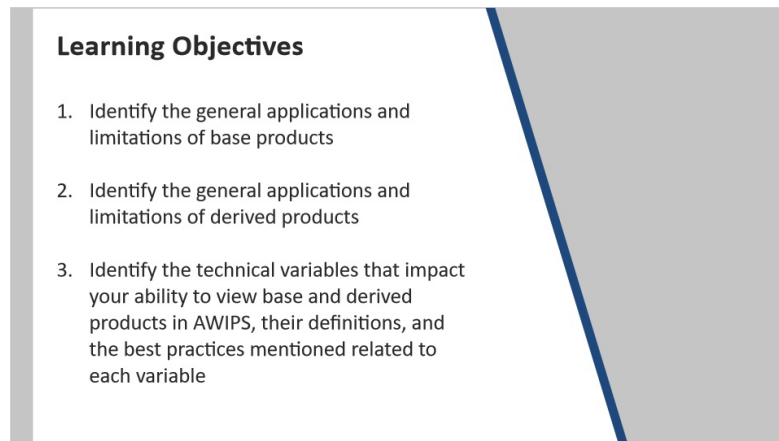
## Base & Derived Products Lessons



### Notes:

Here is a roadmap for the lessons in this topic. This lesson is the Introduction, highlighted on the screen, that provides an overview of the entire topic.

## ***Learning Objectives***



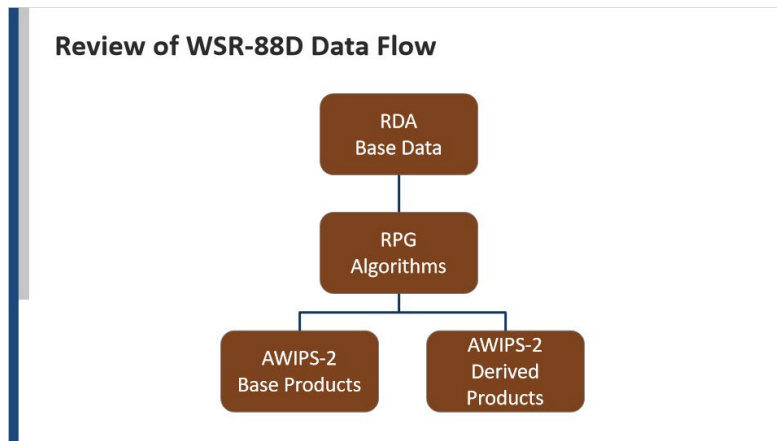
**Learning Objectives**

1. Identify the general applications and limitations of base products
2. Identify the general applications and limitations of derived products
3. Identify the technical variables that impact your ability to view base and derived products in AWIPS, their definitions, and the best practices mentioned related to each variable

### **Notes:**

These are the learning objectives for this lesson. Please take a moment to review the objectives and click on the next button when you are ready to advance to the next slide.

## Review of WSR-88D Data Flow



### Notes:

Recall that base data are collected by the RDA and sent to the RPG to be processed by the meteorological algorithms residing at the RPG. Ultimately the RPG will then produce and distribute both base and derived products to the user workstations.

## Base Vs. Derived Products

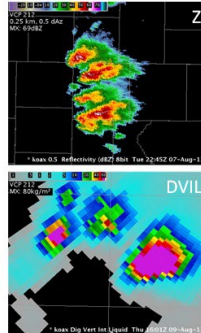
### Base Vs. Derived Products

#### Base:

Closest thing to truth (e.g., Z, ZDR)

#### Derived:

Product resulting from a computer algorithm ingesting and manipulating base data (e.g., TVS, HI)

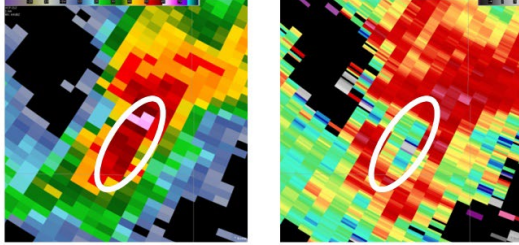


### Notes:

So, what are base and derived products? Base products are basically the closest thing you can get to the truth. It's Base Reflectivity, Differential Reflectivity, and similar products that visualize the base data streams. Derived products are products generated from a computer algorithm ingesting and manipulating the base data. Examples of derived products include the Tornado Vortex Signature or the Hail Index products.

## ***Base Products' Applications***

### **Base Products' Applications**



1. Great for analyzing significant meteorological features (e.g. hook echoes)
2. Help build conceptual models

### **Notes:**

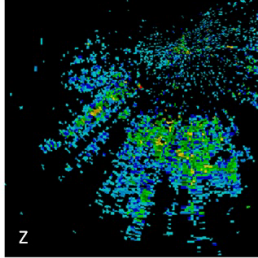
In general, base products are great for recognizing and analyzing significant meteorological features such as hook echoes, hail cores, etc. Base products also help you develop and apply conceptual models that make storm analysis and warning issuance quicker and more efficient.

## ***Base Products' Limitations #1: Ground Clutter***

### **Base Products' Limitations #1: Ground Clutter**

Ground clutter contamination mitigation:

- Invoke clutter suppression
- View higher elevation angle
- Use adjacent radar site products

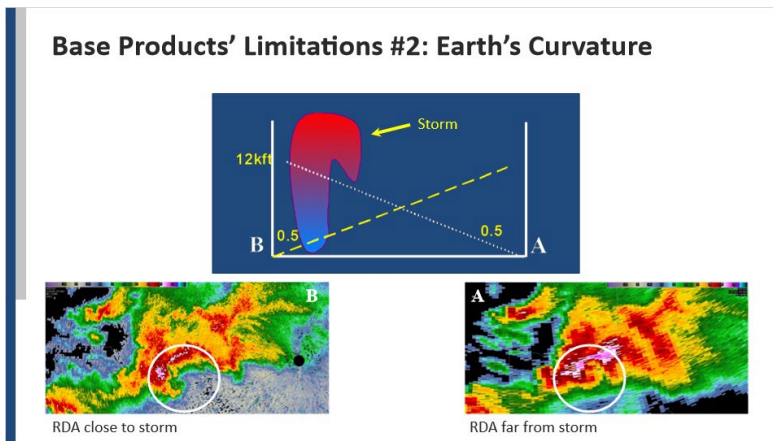


Ground clutter contamination near RDA site

### **Notes:**

The next few slides will cover general limitations of all base products. The first limitation is ground clutter. Ground clutter is usually an issue near the radar where tall objects or beam bending can cause the radar returns from objects on the ground. Ground clutter often appears speckled in nature. To help mitigate ground clutter contamination, you can invoke clutter suppression at the RPG, view a higher elevation, or view data from a nearby radar.

## Base Products' Limitations #2: Earth's Curvature



### Notes:

As you know...the earth is round! While this is hardly a shocking revelation, it does play an important role in our next limitation.

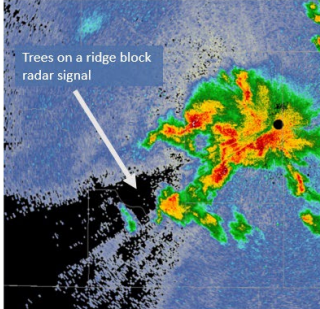
The radar beams propagate away from the radar at increasing altitudes with range due to the earth's curvature. In other words, the beam samples higher and higher into the atmosphere the further away the transmitted signal travels. When the radar beam is 10s of kilometers away, it may be sampling the midlevels of a storm. In the example provided, radar B is very near the storm and notice how you can see a hook echo, an inflow notch, and other details. The same storm viewed from radar A, which is farther away, appears different because it is sampling a different part of the storm, among other reasons. This is a classic example of the earth's curvature limitation.

## Base Products' Limitations #3: Beam Blockage

**Base Products' Limitations #3: Beam Blockage**

Beam blockage mitigation:

- Choose higher slice
- Query other radars
- Ground truth from spotters



Beam blockage evident WSW of RDA site

### Notes:

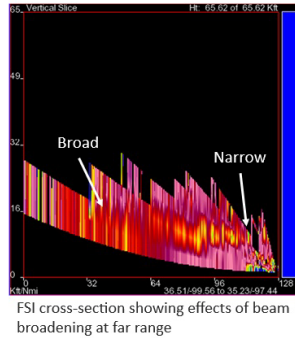
Beam blockage occurs when tall objects near the radar completely, or partially, absorb (or reflect) the radiation from the radar pulse. Since much of the transmitted signal is blocked, targets down radial from such objects cannot be observed properly by the radar. Beam blockage manifests itself as a wedge of low-value, or missing, returns. Here is an example from the KVNK radar in NW Oklahoma. When you see beam blockage in radar data, you can mitigate these effects by either choosing a higher slice, looking at a nearby radar, or obtaining ground truth from spotters in those regions.

## Base Products' Limitations #4: Beam Broadening

### Base Products' Limitations #4: Beam Broadening

Beam broadening mitigation:

- Choose a closer radar



### Notes:

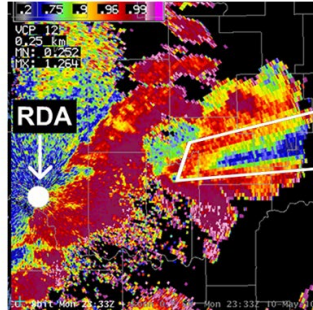
As the radar beam propagates away from the radar, it broadens. In fact at 60 km from the radar, the beam is roughly 1 km wide! This broadening effectively smears all radar signatures. For example, the melting layer, shown by the yellowish/orange colors in the image, becomes broader the farther away from the radar it is sampled. To reduce beam broadening effects, you must view data from a closer radar, if one is available.

## Base Products' Limitations #5: Non-Uniform Beam Filling

### Base Products' Limitations #5: Non-Uniform Beam Filling

Non-uniform beam filling (NBF) mitigation:

- Choose a different radar

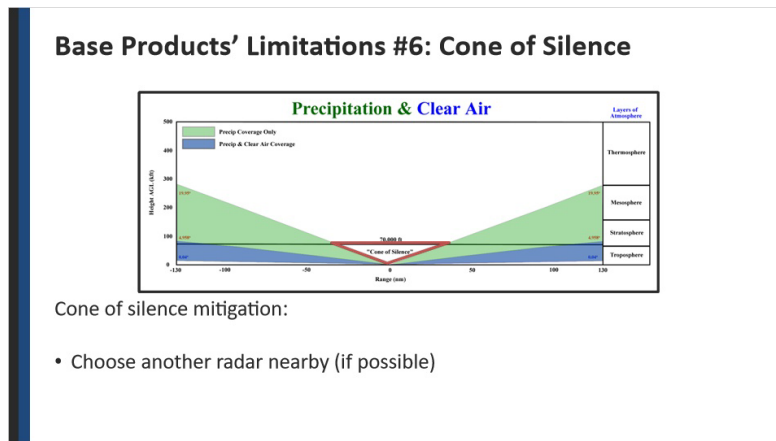


NBF visible at farther ranges ENE of RDA site

### Notes:

Non-Uniform beam filling (or NBF) has been around for as long as radar has, but has gained visibility recently with the WSR-88D upgrade to dual-polarization. While there are many degrees of non-uniform beam filling, it is only operationally significant when storms line up along a radial or the radar samples a significant hail core in a storm around the height of the environmental melting level. An example of NBF is noted in the image on the right by the radials of reduced Correlation Coefficient (CC; Ryzhkov and Zrnice, 1998; Gosset 2004). When NBF impacts your storm analysis, you need to use data from a different radar to mitigate the issue.

## Base Products' Limitations #6: Cone of Silence

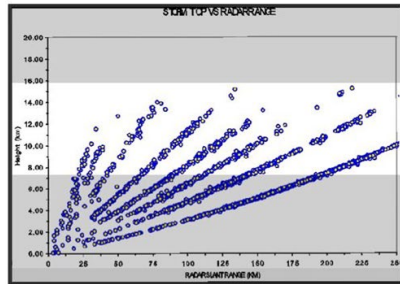


### Notes:

Recall that the highest elevation scanned by the WSR-88D is 19.5 degrees. So, this means there is a lot of the atmosphere that is not sampled! The unsampled region above the highest tilt is called the cone of silence. The cone of silence impacts your analysis only when storms are located close to the radar. If you experience cone of silence issues, choose a different radar where the storm of interest is not in its cone of silence.

## Base Products' Limitations #7: Beam Height Estimations

### Base Products' Limitations #7: Beam Height Estimations



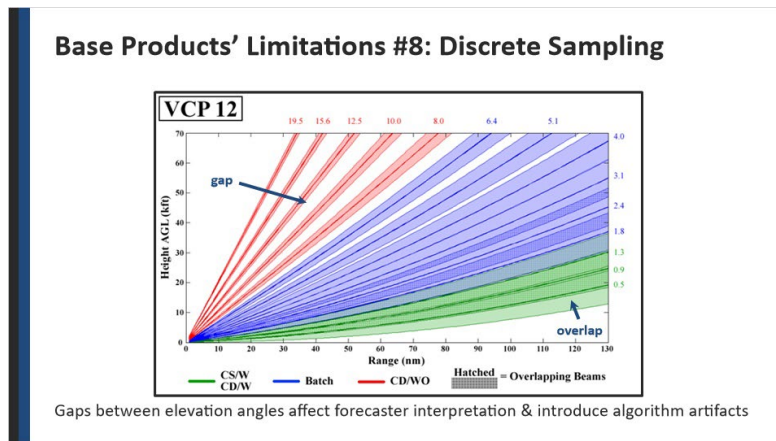
Plot of estimated storm top heights as a function of range

Remember that displayed beam heights are only estimates!

### Notes:

As the antenna rotates, it doesn't stay exactly on the elevation defined. For example, when we say the radar is at 0.5 degrees, it could be 0.4 or 0.6 degrees and still be in spec. However, a slight difference here can mean the height estimate of the beam may have significant errors at far ranges. Likewise, changes in the atmospheric temperature structure can lead to errors in beam height estimates. AWIPS-2 assumes a standard atmosphere for beam height estimates, which is usually not true. So, always keep in mind that the beam heights listed are only "estimates" and in actuality they could be as much as a few thousand feet off.

## Base Products' Limitations #8: Discrete Sampling

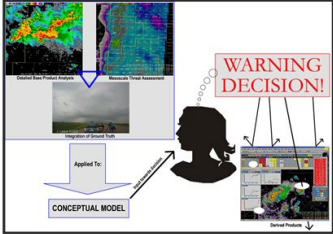


### Notes:

In the lowest elevations, there are no gaps between elevation slices. In fact, you can see from the figure shown here that there is even some overlap. On the other hand, the upper portions of each volume scan often have substantial gaps, especially above 8 degrees. These gaps affect forecaster interpretation as well as introduce artifacts in algorithm output.

## Derived Products' Applications

**Derived Products' Applications**



1. Rapid analysis of large amounts of data
2. Use as safety net

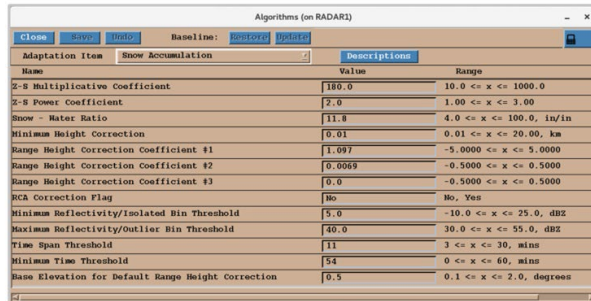
Never use for warning decision alone!

### Notes:

Now that we have covered base products, let's talk about the applications and limitations of derived products. The primary advantage to using derived products is they speed up analysis of large amounts of data. However, you should only use derived products as a safety net. Basically, if you see something in a derived product that grabs your attention, then you should verify that signature with your knowledge of the base data before making a warning decision. One thing you should never do is issue a warning based solely on derived products!

## Derived Products' Limitations

### Derived Products' Limitations



Adaptation Item	Value	Range
Z-R Multiplicative Coefficient	180.0	10.0 <= x <= 1000.0
Z-R Power Coefficient	2.0	1.00 <= x <= 3.00
Snow - Water Ratio	11.8	4.0 <= x <= 100.0, in/in
Minimum Height Correction	0.01	0.01 <= x <= 20.00, km
Range Height Correction Coefficient #1	1.097	-5.0000 <= x <= 5.0000
Range Height Correction Coefficient #2	0.0069	-5.0000 <= x <= 5.0000
Range Height Correction Coefficient #3	0.0	-5.0000 <= x <= 5.0000
RCA Correction Flag	No	No, Yes
Minimum Reflectivity/Isolated Bin Threshold	5.0	-10.0 <= x <= 25.0, dBZ
Maximum Reflectivity/Outlier Bin Threshold	40.0	30.0 <= x <= 55.0, dBZ
Time Span Threshold	11	3 <= x <= 30, mins
Minimum Time Threshold	54	0 <= x <= 60, mins
Base Elevation for Default Range Height Correction	0.5	0.1 <= x <= 2.0, degrees

Based on data that may not be representative (e.g. climate region, VCP mode)

### Notes:

Recall that derived products result from a computer algorithm ingesting base data and analyzing it for significant features. Well, not every location experiences the same types of weather and the algorithms were developed using data from certain locations. So, the data used to develop the algorithm may not be representative of all areas.

## Adaptable Parameters Help Mitigate Issues

### Adaptable Parameters Help Mitigate Issues

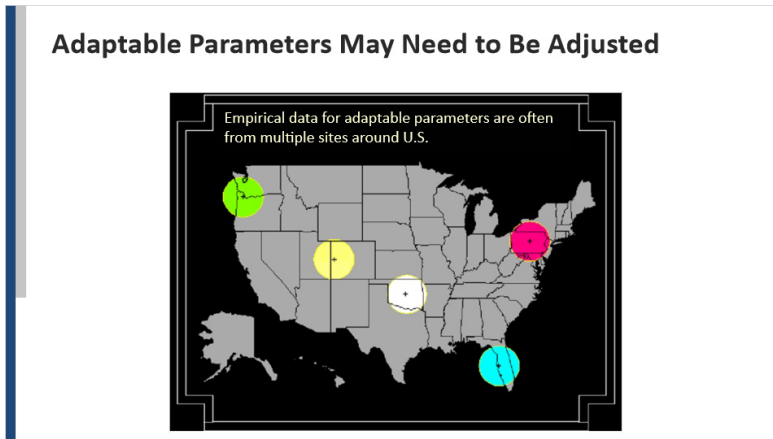
Adaptation Item	Value	Range
Z-S Multiplicative Coefficient	100.0	10.0 <= x <= 1000.0
Z-S Power Coefficient	2.0	1.00 <= x <= 3.00
Snow - Water Ratio	11.8	4.0 <= x <= 100.0, 10/in
Minimum Height Correction	0.01	0.01 <= x <= 20.00, km
Range Height Correction Coefficient #1	1.000	0.0000 <= x <= 0.0000
Range Height Correction Coefficient #2	0.0000	-0.5000 <= x <= 0.5000
Range Height Correction Coefficient #3	0.0	-0.5000 <= x <= 0.5000
RCA Correction Flag	No	No, Yes
Minimum Reflectivity/Isolated Bin Threshold	5.0	-10.0 <= x <= 25.0, dBZ
Minimum Reflectivity/Outlier Bin Threshold	00.0	20.0 <= x <= 55.0, dBZ
Time Span Threshold	11	3 <= x <= 30, mins
Minimum Time Threshold	54	0 <= x <= 60, mins
Base Elevation for Default Range Height Correction	0.5	0.1 <= x <= 2.0, degrees

- Value in an algorithm which can be changed
- Most meteorological adaptable parameters are ROC controlled
- Changes affect output on product

### Notes:

Fortunately, adaptable parameters help address problems related to RPG algorithms! Many products use adaptable parameters that allow for modification of algorithm behavior. Most of these parameters are password protected by the Radar Operations Center, but a few can be changed by the local office. Any changes made to the adaptable parameters will impact the look and feel of the product for ALL users. An example adaptable parameter window is shown here for the Snow Accumulation Algorithm.

## ***Adaptable Parameters May Need to Be Adjusted***



### **Notes:**

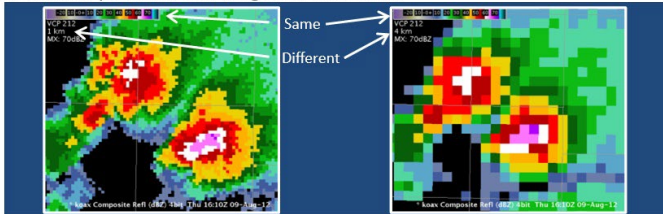
Most algorithms were optimized empirically using a series of datasets. However, to perform best in your area at different times of the year, the adaptable parameters for a particular algorithm may need to be modified. This process takes both research and coordination with the Radar Operations Center.

## Data Levels & Resolution Definitions

### Data Levels & Resolution Definitions

Data Levels:

- How much precision can we get with the data



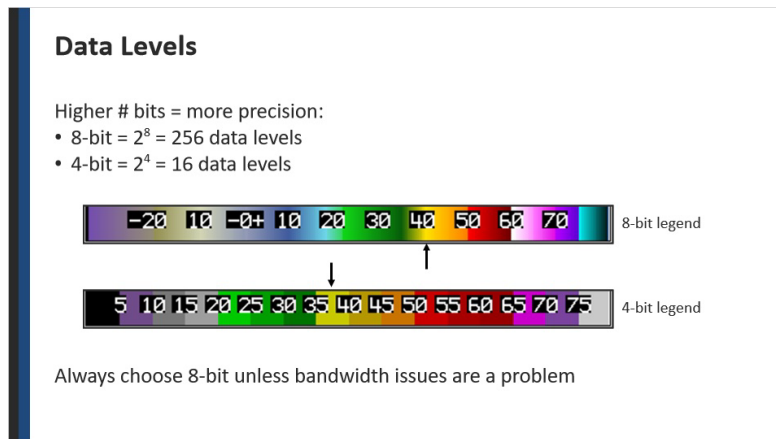
Data Resolution:

- How much detail can we see with the data

### Notes:

Two important definitions to remember here are data levels and resolutions. Data levels tell you how much precision we can get with the data. The higher the data levels, the more precision that is possible. Data resolution tells us how much detail can we see with the data. The higher the data resolution, the more detail we can see. The next few slides will go into a little more depth of these definitions.

## Data Levels



### Notes:

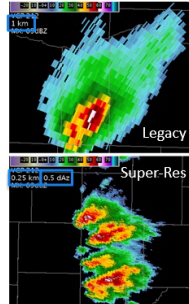
Data levels are characterized by how many bits are available to record them. The more bits available, the more precise the data are. For example, 8-bit products have 256 data levels while 4-bit products only have 16 data levels. To figure out exactly how many data levels are available, just raise 2 to the power of the product bit number.

The color bars at the bottom of this slide illustrate the difference very nicely. The top color bar is for 8-bit Base Reflectivity, while the bottom legend is for 4-bit Base Reflectivity. Notice how for 4-bit, a single color represents roughly a 5 dBZ range, whereas for 8-bit products each color represents a much smaller range. So with 8-bit we can delineate smaller increments in reflectivity changes than 4-bit can. Recent changes with the RPG have greatly reduced the number of 4-bit products available. When you have a choice between 4-bit and 8-bit, you should choose 8-bit unless your office is experiencing issues with your local bandwidth that causes loadshedding.

## Data Resolution

### Data Resolution

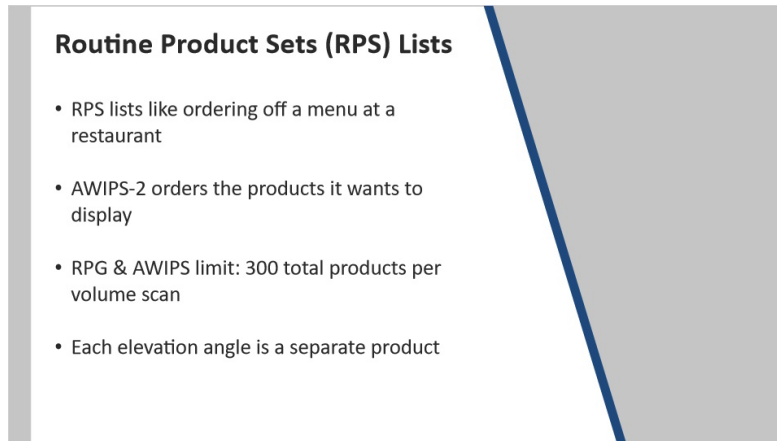
- Azimuthal
  - Typically 1 degree, but super-resolution = 0.5 deg (dAz)
- Range
  - Varies between 0.25 km, 1 km, 2 km and 4 km
- Use highest resolution products where available
  - Lone exception: Raw CC



### Notes:

Radar data resolution can be broken out into two categories: azimuthal and range resolution. For WSR-88D products, most products will have an azimuthal resolution of 1 degree, except for super-resolution products which will be 0.5 degree azimuthal resolution. Most WSR-88D products have a range resolution of 0.25 km, but coarser resolution products are still available (i.e. 1, 2 and 4 km). It's highly recommended to use the highest resolution data available for all products unless you experience performance issues with your workstation or load shedding issues occur with your radar connections. There is one important caveat to this point, however. Dual-polarization base products are generally 1 degree in azimuthal resolution even on super-res tilts. The exception is the Raw Correlation Coefficient product which is available in super-res. However, while this product can have some utility for tornadic debris signature detection, we don't recommend that you use Raw CC for general purposes. More on this caveat will be explained in the Correlation Coefficient lesson later on in this course.

## ***Routine Product Sets (RPS) Lists***



**Routine Product Sets (RPS) Lists**

- RPS lists like ordering off a menu at a restaurant
- AWIPS-2 orders the products it wants to display
- RPG & AWIPS limit: 300 total products per volume scan
- Each elevation angle is a separate product

### **Notes:**

The last item to cover is the Routine Product Sets (or RPS) list. The RPS list is similar to an order off of a menu. Just like we can't eat everything off the menu (well at least I hope you can't), your local AWIPS can't download all products that are possibly generated from your dedicated RPG. The RPS list allows you to select the products that are most relevant to your operations.

RPS lists are Volume Coverage Pattern (VCP) dependent. AWIPS and the RPG limits you to a total of 300 total products per volume scan. For elevation-based products, each product for a specific tilt counts as one of those products. So, collecting every tilt of the base data products, while important, does add up quickly on your RPS list.

## ***RPS Lists: Primary Vs. Supplemental AWIPS Connections***

### **RPS Lists: Primary Vs. Supplemental AWIPS Connections**

- Primary connections have significantly more bandwidth than supplemental connections
  - Primary: ~ 1 Mbps common in CONUS
  - Supplemental: 64 Kbps common, but can be closer to 200 Kbps
- RPS lists for supplemental connection sites should be more selective than primary radars
- Loadshedding issues most likely with:
  - Faster VCPs
  - Widespread precip

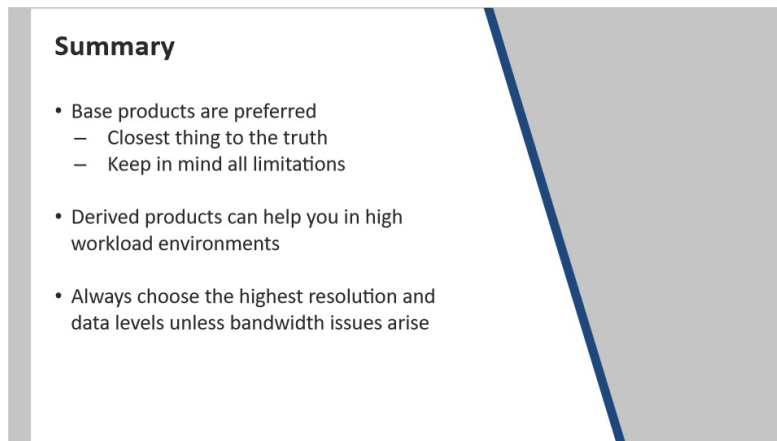
### **Notes:**

When building RPS Lists, it's important to know whether the products you request are from your dedicated radar (through a primary AWIPS connection) or a non-dedicated radar (through a supplemental AWIPS connection). Primary AWIPS connections have significantly more bandwidth than supplemental connections. And when I say significantly more, it's anywhere from 5-20 times the bandwidth, on average (Frashier, 2016).

When building a RPS List for a supplemental connection, forecasters should be selective. These sites are often radars located in surrounding areas that provide improve coverage of the fringes of your CWA. You probably don't need to include base data products for the entire volume from these sites. A little trial and error should help figure out what elevation(s) serve as a good cutoff.

The smaller bandwidth on supplemental connections may result in loadshedding in certain situations. Loadshedding occurs most frequently with faster VCPs (such as VCP 12 or 212) and in widespread precipitation as the product file sizes tend to increase with increasing storm coverage.

## Summary



**Summary**

- Base products are preferred
  - Closest thing to the truth
  - Keep in mind all limitations
- Derived products can help you in high workload environments
- Always choose the highest resolution and data levels unless bandwidth issues arise

### Notes:

Here is a brief summary of this lesson. Remember that base products are the closest thing we have to meteorological truth, but these products have several important limitations. Derived products are great as a safety net, especially in high workload environments, but you should never issue a warning based solely on a derived product. Finally, always choose products with the largest number of data levels and highest resolution possible unless bandwidth issues arise. One such example would be requesting products using an RPS List on a supplemental AWIPS connection. Please proceed to the next slide to take the quiz.

## ***1.32 Thanks for Your Attention!***

**Thanks for Your Attention!**

This concludes:  
Base & Derived Products: Introduction

Your are now ready for:  
Base Reflectivity (Z)

Questions?

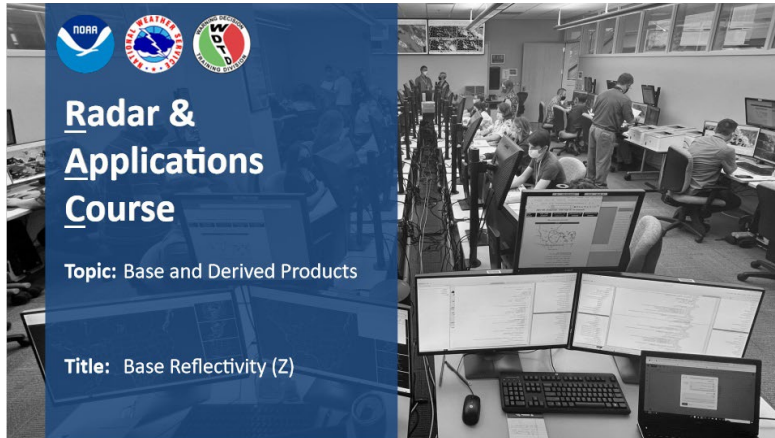
"Send an email" link in side panel  
or email  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

### **Notes:**

If you have passed the quiz, then you have successfully completed this lesson. You are now ready to move onto the next lesson, Base Reflectivity (Z). If you have any questions, please contact us using any of the e-mail addresses listed on the bottom of the slide.

# Base Reflectivity (Z)

## Introduction




### Notes:

Hello there and welcome to this lesson on base reflectivity!


## Course Completion

**Course Completion Options**

**Option 1: "This topic is new to me."**  
Take the course to receive credit  
(80% score required)



**Option 2: "I understand this topic already."**  
Successfully test out to receive credit  
(100% score required)



Click on either icon!

### Notes:

To get credit for this course, you have two options. If base reflectivity is a relatively new topic to you, option one allows you to go through the course as normal and take the quiz at the end to receive credit. However, if you feel you have solid prior knowledge of the topic material, option 2 allows you to receive credit by successfully testing out of the material - note that you must score 100% to demonstrate you have solid mastery of the topic material. Click on either icon to choose.

## What is Z?

**What is Z?**

**Reminder:**

- Z comes from the Weather Radar Equation!

**What influences Z:**

The slide contains several radar reflectivity maps. One map shows a 'TORNADO WARNING' over a region. Another map shows two distinct areas labeled 'Cell A' and 'Cell B'. A schematic at the bottom left shows a radar beam with an arrow indicating the 'direction of propagation'. An upward-pointing arrow on the right is labeled 'Z', representing the vertical axis of the radar scan. A small credit line at the bottom left reads 'Image Credit: Kumjian (2013)'.

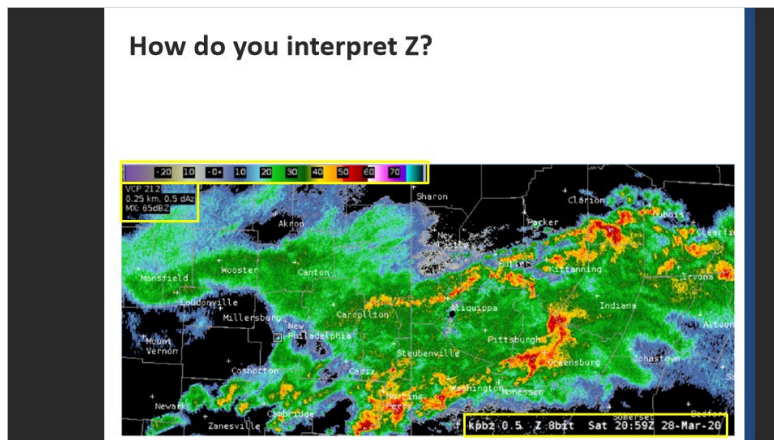
### Notes:

Base reflectivity, or  $Z$ , is the most useful and foundational product we build our analysis off of. Because we see it displayed nearly everywhere we look, it's easy to forget where it came from and what it fundamentally represents. Remember from earlier training that we derived the reflectivity factor from the weather radar equation - that's where it comes from. Reflectivity was one of the OG base products produced by the WSR-88D before dual-polarization came along and represents the average power returned from targets in just the horizontal channel as shown by the schematic here.

Now, in order to interpret  $Z$ , we need to first understand what target properties influence the amount of power that's returned. For targets in a sample volume, reflectivity is influenced by two things: the number of targets and the diameter, or size, of those targets. So the more numerous and larger sized hydrometeors there are, the higher the reflectivity values will be! Now, you'll notice here that diameter is raised to the 6th power. This is important to note because it means that reflectivity will be more heavily influenced or weighted by the size of a target more so than the actual number of targets.

Taking a step back, when we look at images of reflectivity like the one shown here, we can generally conclude that cell A is producing either more numerous hydrometeors or larger-sized hydrometeors than cell B due to having higher reflectivity values associated with it.

## How do you interpret Z?



### Notes:

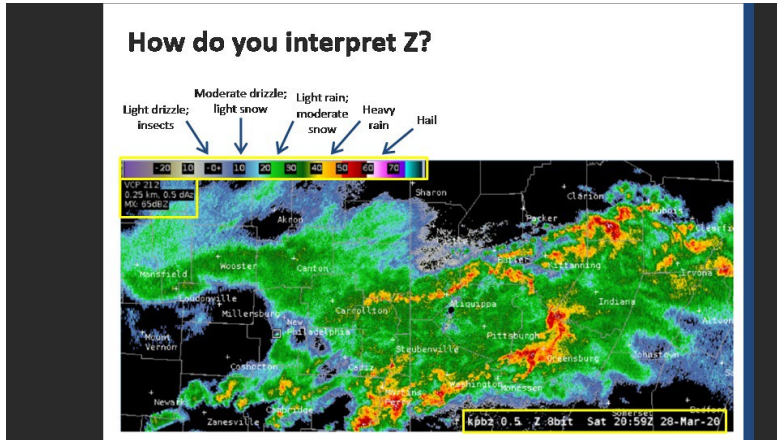
Now that we've covered what target properties influence reflectivity, let's talk about how we interpret a typical display of reflectivity that you'd see in AWIPS. Click on each of the highlighted legends to learn more and when you're done, you can move on to the next slide.

**Z Values:** If you remember from the Weather Radar Equation module, reflectivity is displayed in logarithmic units, known as decibels of Reflectivity, or dBZ, to make its legend scale manageable. Shown here are typical values of reflectivity for various hydrometeor types – a quick summary of these is also available for download in the "Resources" tab.

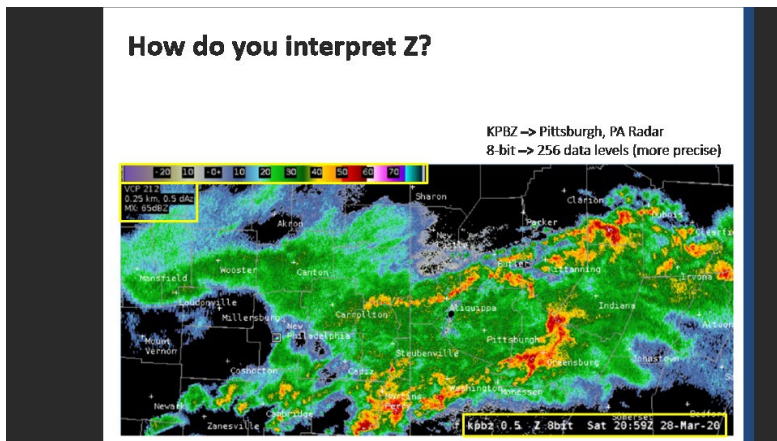
**Z Upper Legend:** When viewing reflectivity, the legend in the upper corner tells you what volume coverage pattern, or VCP, the radar is in, what the angular and range resolution of the radar is, and what the highest reflectivity value in your display is.

**Z Lower Legend:** This product legend tells you which radar you are viewing reflectivity from, the number of data levels available, and the current time and date.

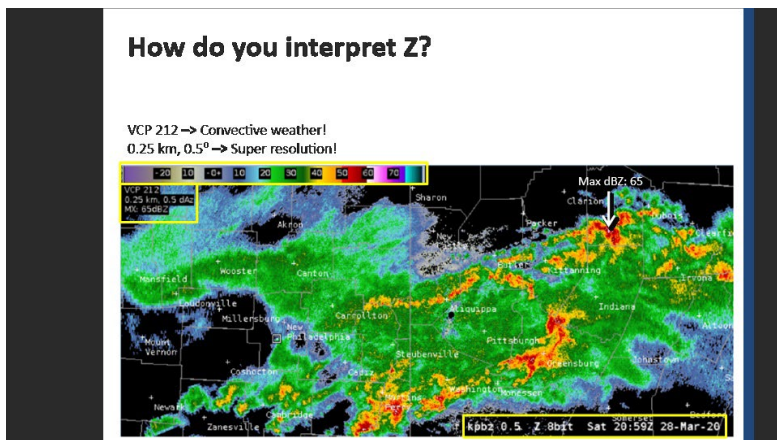
## Z Values Legend (Slide Layer)



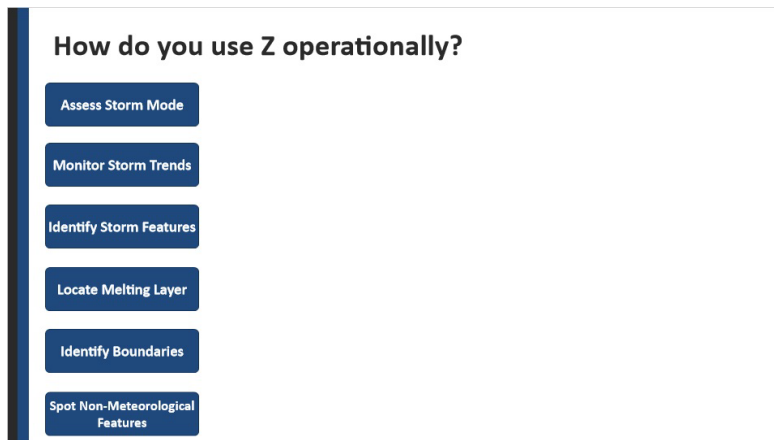
## Lower Legend (Slide Layer)



## Upper Legend (Slide Layer)



## How do you use Z operationally?



### Notes:

There's a reason reflectivity is one of the most useful radar products - it can be used in a variety of ways operationally as listed here. Click on each one to see an example and then you can move on.

*Assess Storm Mode:* One of the quickest ways to assess what type of storms you have across your CWA is to look at reflectivity. By knowing what the storm mode is, that tells us what hazards we can generally expect with them. So using reflectivity, I want you to click on which storm you think would pose the greatest hazard risk based on storm mode in this example.

*Monitor Storm Trends:* By quickly monitoring trends in reflectivity over time, you can get a general feel for if a storm is strengthening or weakening. In this loop, notice how we can see Storm A increasing in intensity towards the end of the loop which tells us we should take a closer look at this storm.

*Identify Storm Features:* Several very important storm features are readily apparent in reflectivity. In this example of a classic supercell, we see a well-defined hook echo where we'd expect the tornado to be, a broad inflow notch indicative of a healthy updraft, and strong gradient in reflectivity along the inflow side indicative of a well organized supercell. Seeing these storm features in reflectivity alone tells us this storm is likely tornadic.

*Locate Melting Layer:* Since the melting layer consists of melting snowflakes that the radar thinks are giant raindrops, it will appear as a ring of enhanced power returns as you go up in tilt. We'll talk later on why the melting layer matters operationally but for now, just know that you can use reflectivity to locate it. So let's practice this:

go ahead and use the slider bar to go up in tilt and when you think you spot the melting layer, click on the corresponding tilt number to indicate which tilt you see it at.

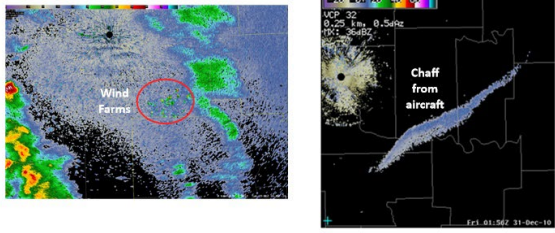
*Identify Boundaries:* Because winds along a front or outflow boundary can kick up leaves, insects, or birds, you often will see weak power returns in reflectivity along the leading edge of boundaries. In this example, we see a remnant outflow boundary located to the south of the radar from previous convection that occurred over the area.

*Spot Non-Meteorological Boundaries:* Reflectivity can be used to help spot targets that are non-meteorological such as wind farms, migrating birds or bats, smoke plumes from fires, or chaff from aircraft. You'll often see these non-meteorological targets more readily apparent when the radar is in clear-air mode due to increased sensitivity of the radar.

## Spot Non-Meteorological Features (Slide Layer)

**How do you use Z operationally?**

- Assess Storm Mode
- Monitor Storm Trends
- Identify Storm Features
- Locate Melting Layer
- Identify Boundaries
- Spot Non-Meteorological Features

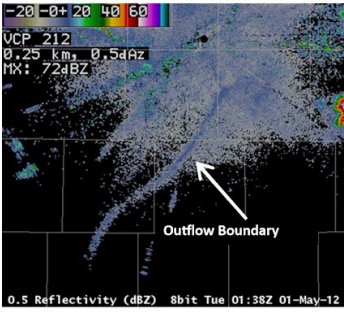


- Use Z to spot non-meteorological targets of interest
  - Targets more apparent in clear-air mode (VCP 31/32/35)

## Identify Boundaries (Slide Layer)

**How do you use Z operationally?**

- Assess Storm Mode
- Monitor Storm Trends
- Identify Storm Features
- Locate Melting Layer
- Identify Boundaries
- Spot Non-Meteorological Features



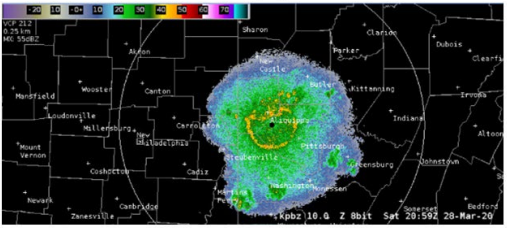
- Use Z to identify any fronts or outflow boundaries

## Locate Melting Layer (Slide Layer)

**How do you use Z operationally?**

- Assess Storm Mode
- Monitor Storm Trends
- Identify Storm Features
- Locate Melting Layer
- Identify Boundaries
- Spot Non-Meteorological Features

Remember, you're looking for a ring of enhanced Z values...

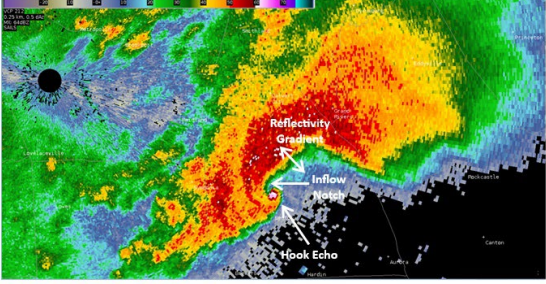


- Use Z to locate the melting layer evident as a ring of enhanced power returns from melting hydrometeors

## Identify Storm Features (Slide Layer)

**How do you use Z operationally?**

- Assess Storm Mode
- Monitor Storm Trends
- Identify Storm Features
- Locate Melting Layer
- Identify Boundaries
- Spot Non-Meteorological Features

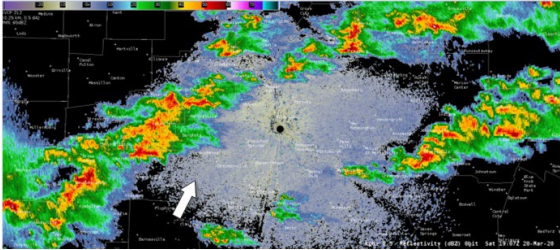


○ Use Z to identify key features of severe or tornadic storms

## Monitor Storm Trends (Slide Layer)

**How do you use Z operationally?**

- Assess Storm Mode
- Monitor Storm Trends
- Identify Storm Features
- Locate Melting Layer
- Identify Boundaries
- Spot Non-Meteorological Features



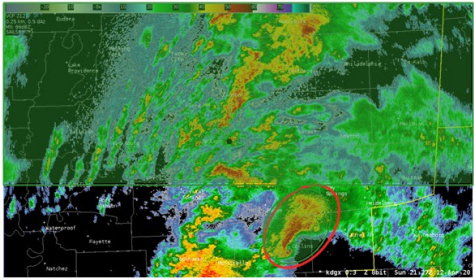
○ Use Z to quickly monitor storm intensity over time

## Assess Storm Mode (Slide Layer)

**How do you use Z operationally?**

- Assess Storm Mode
- Monitor Storm Trends
- Identify Storm Features
- Locate Melting Layer
- Identify Boundaries
- Spot Non-Meteorological Features

Hint: Does anything else look more organized (i.e. supercell-like?)



○ Use Z to assess storm mode and anticipate related hazards


## What are limitations of Z?

**What are limitations of Z?**

A few radar sampling issues that also affect Z:

- Attenuation
- Beam Blockage
- Beam Height
- Beam Number or size driving up Z?

Z shows us WHERE...  
...but DP shows us WHY



### Notes:

Because reflectivity represents the average power returned to the radar, nearly all of the radar sampling issues you learned about in the earlier training are also inherent limitations of Z, such as attenuation, beam blockage, etc. Instead of revisiting these, let's focus on a bigger-picture limitation of Z.

If we take a look again at what target properties influence reflectivity values, you'll notice that it's BOTH the number of targets and the size of targets. Further, you'll notice that target size receives a heavier weighting than number. And therein lies the big-picture limitation when using Z - when we look at areas of enhanced Z values, we don't know if those are due to a large number of droplets or rather just a few large hailstones. For example, in this image, we've got two supercells, cell A and cell B, that appear identical based on reflectivity values alone. However, cell B was actually producing more intense rainfall rates and had a higher flooding potential than cell A due to having more numerous droplets. Yet you wouldn't know that just based on reflectivity alone.

So, reflectivity does a great job at showing you where the most intense cells are but in terms of what's driving up that intensity, THAT is where we our DP variables come to the rescue and can give us that information so stay tuned to unlock the full power of dual-polarization information!

## Main Takeaways

### Your Main Takeaways: No Fluff Edition

#### What is Z?

- The average power returned in the horizontal channel

#### What determines Z?

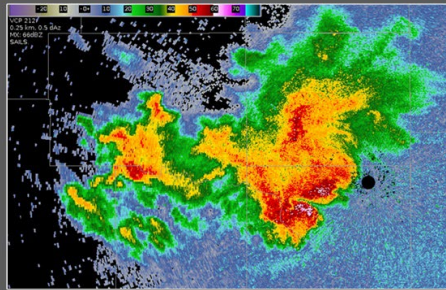
- The number and size of targets

#### How can you use Z operationally?

- Assess Storm Mode
- Monitor Storm Trends
- Identify Storm Features
- Locate Melting Layer
- Identify Boundaries
- Spot Non-Meteorological Features

#### What is a big-picture limitation of Z?

- It shows you where the most intense cells are but not about what is behind that intensity
  - Is it lots of tiny drops? Ice pellets? Dry hailstones? → Only Dual-Pol variables know!



### Notes:


Before you take the quiz, here are the main takeaways about reflectivity for your review. Click “next” when ready.

## Contact Information

### Contact Information

RAC Help Email:  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

Lesson Author Email:  
[katy.christian@noaa.gov](mailto:katy.christian@noaa.gov)



Once you've completed the quiz, hit "Exit" to close out!

### Notes:

If you've got any questions about the material in this training, please feel free to send the RAC team or myself at the addresses shown here. If not, click "exit" to close out of this module.

# Base Velocity (V)

## Introduction




### Notes:

Hello there and welcome to this lesson on base velocity!


## Course Completion

**Course Completion Options**

**Option 1: "This topic is new to me."**  
Take the course to receive credit  
(80% score required)



**Option 2: "I understand this topic already."**  
Successfully test out to receive credit  
(100% score required)



Click on either icon!

### Notes:

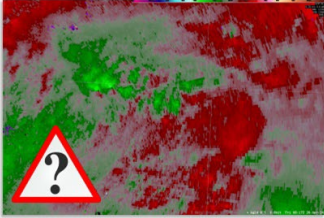
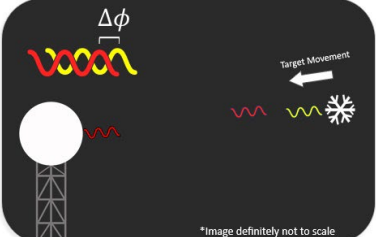
To get credit for this course, you have two options. If velocity is a new topic to you, option one allows you to go through the course as normal and take the quiz at the end to receive credit. However, if you feel you have solid prior knowledge of the topic material, option 2 allows you to receive credit by successfully testing out of the material ahead of time - note that you must score 100% to demonstrate you have solid mastery of the topic material. Click on either icon to choose.

## What is $V_R$ ?

**What is  $V_R$ ?**

$$V_R = \frac{\lambda}{4\pi} \frac{\Delta\phi}{\Delta t}$$

$\Delta\phi$ : phase shift  
 $\Delta t$ : time between pulses  
 $\lambda$ : radar wavelength



**$V_R$ :** The power weighted mean radial velocity of all targets in a sample volume

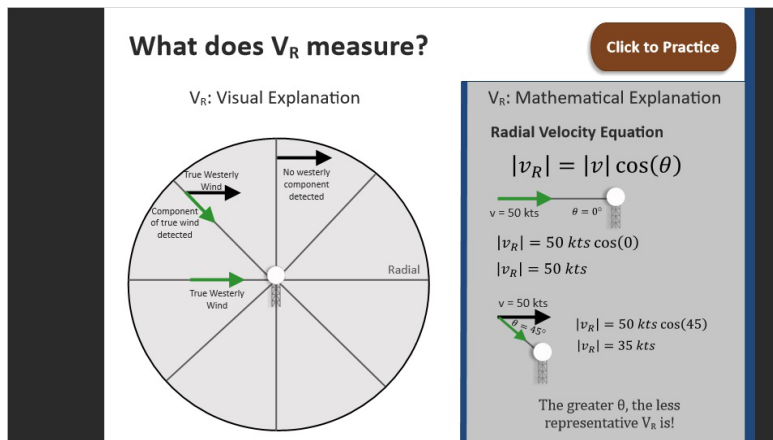
\*Image definitely not to scale

### Notes:

Unlike base reflectivity that we learned about earlier, base velocity is harder to understand and even harder to quickly interpret when viewing in AWIPS or other platforms. So let's start at the beginning with a simplified description. When a radar sends out an electromagnetic pulse and receives a backscattered signal from targets, it keeps track of the phase of the wave. Now, in our example, if the targets in that sample volume are moving towards the radar, the returned phase will look different due to having to travel a shorter distance. By comparing the shift in phase between the two returned signals as shown here, we're able to calculate the movement, or radial velocity, of those targets through the following relationship where delta phi is the phase shift, delta t is the time between pulses, and lambda is the wavelength of the radar.

Because there are typically multiple targets in a sample volume that don't all have the same velocity, the mean velocity from the most power weighted targets is calculated and the resulting product is known as base radial velocity.

## What does $V$ measure?



### Notes:

Now that we know how we get radial velocity, let's visualize what it's actually measuring. Because Doppler radars scan azimuthally at a fixed location, the velocity the radar measures is only the component that is moving either directly towards or away from the radar along a radial. For example, in this radar display, let's say we have a pure westerly wind throughout as shown by the green arrow. When the radar is scanning directly west, it will be able to measure 100% of the magnitude of that westerly wind that is flowing along the radial. However, as the radar looks to the northwest, it won't be able to see the full component of that westerly wind - only part of it will be detected (indicated by the green line) - and as a result, this component will have a lower magnitude. And when the radar looks directly north, no component of that westerly wind is moving towards or away from the radar so its magnitude will be zero.

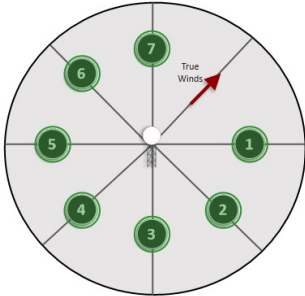
Mathematically, this is summarized by the Radial Velocity Equation where  $V_r$  is the radial velocity,  $V$  is the true target velocity, and  $\theta$  is the angle between the true target velocity and the radial. So using the example to the left, let's say the true target velocity is 50 kts and when the radar is looking directly west, the angle between the radial and true wind is zero so the radial velocity is the same as the true velocity! However, as the radar looks to the northwest, the angle between the true westerly wind and radial is 45 degrees which means that our radial velocity is only 35 knots so the true wind magnitude is not being fully sampled.

Essentially what you need to know is that the greater the angle between the radial and true target velocity, the less representative of the true winds radial velocity will be. So let's practice this really quick - click here to do so.

## Practice Question

**Practice Question:** The true target velocity is from the southwest as shown by the red arrow. Click on one of the areas (numbered 1-7) where radial velocity will not be able to measure any portion of the true wind.

Great job! When the radar scans to the NW (#6) or SE (#2), it will not be able to measure any portion of the true wind so  $V_R$  will equal 0!



**Hint:** Which direction(s) are perpendicular to a southwest wind?

**Not so fast...answer the question first or else, no blue sky days ;)**

## How do you interpret $V_R$ ?

**How do you interpret  $V_R$ ?**

**$V_R$  Color Interpretation:**

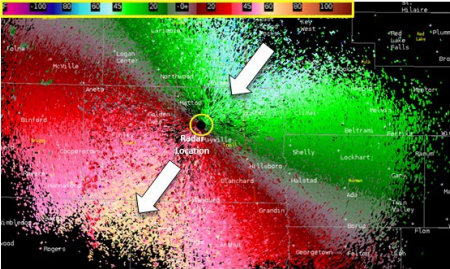
- Greens/Cooler Colors: Inbounds
- Reds/Warmer Colors: Outbounds

**$V_R$  Value Interpretation:**


- Greens/Inbounds: Negative
- Reds/Outbounds: Positive

Default velocity color table is red-green

“Green Towards, Red Away!”



“PANT”  
Positive Away,  
Negative Towards



### Notes:

Since interpreting base velocity is tricky, you are going to get lots of practice on this in the next topic. But for now, I just want you to master interpreting what radial velocity colors and values mean when viewing.

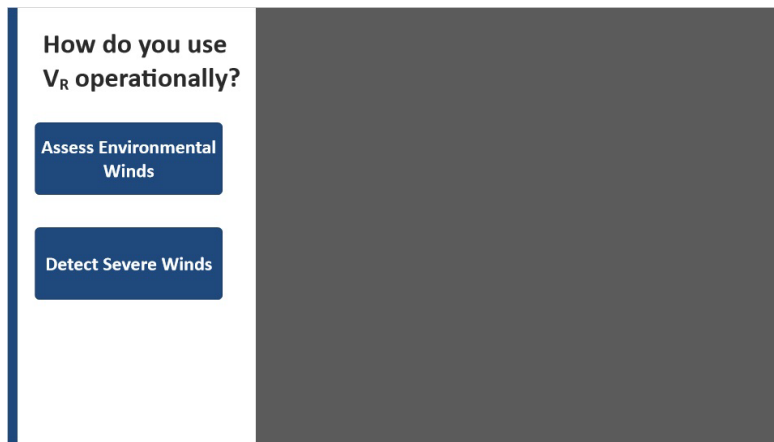
As a quick note, the velocity color table we are about to discuss and use throughout RAC is by default red-green but I recognize that for those with color blindness, a different color table may be used. No matter what color table you use though, the concepts discussed are still applicable.

So let's start with the color: Green, or cooler colors, always mean inbound velocities moving towards the radar while red, or warmer colors, always mean outbound velocities moving away from the radar. To help remember this, just think “Green

Towards, Red Away" when looking at velocity.

Alright, let's move on to values. In AWIPS, radial velocity values are listed in knots and you can see the corresponding legend scale in the upper left or by sampling them out in AWIPS. Now, you'll notice that the green colors, or inbound velocities, are always negative while the red colors, or outbounds, are always positive. The reason why this convention was established was in the early days, the radar was pointed straight up. Since downdrafts have a negative vertical motion and their winds move towards the radar, inbounds, or the green colors, were assigned a negative value. There have been several acronyms developed to help remember this but the one that sticks with me mainly because I live with this furball shown here is "PANT": Positive Away, Negative Towards."

## ***How do you use V operationally?***



### **Notes:**

Alright, we've got the fundamentals out of the way so let's now talk about the most common ways that velocity is used operationally. Click on each one to learn more and when you're done you can move on.

#### ***Assess Environmental Winds:***

In the absence of significant vertical motion, base velocity is representative of the environmental wind field so you can use V to determine the overall wind speed and direction. You can assess wind patterns in velocity such as veering, backing, confluent, or diffluent flow and each of these can each tell you something unique about what's going on in your environment. The radar image shown is actually an example of veering winds in base velocity and if we were to look at the sounding taken a couple hours prior to this radar image, we can confirm a veering wind profile as seen by the clockwise turning of the wind barbs with height. You will get practice identifying these patterns using velocity in a later module so just hang tight for now.

#### ***Assess Severe Winds:***

Base velocity is the product to use for storms that are capable of producing severe winds, such as pulse storms, microbursts, derechos, or QLCS/Squall Lines, as it will show you areas of enhanced velocities towards or away from the radar. In this example, click where you think the strongest winds are.

## Detect Severe Winds (Slide Layer)

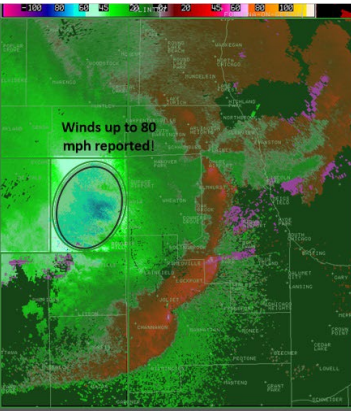
**How do you use  $V_R$  operationally?**

**Assess Environmental Winds**

**Detect Severe Winds**

**Use  $V_R$  to assess severe winds with:**

- Pulse Storms
- Microbursts
- Derechos
- QLCS/Squall Lines



Use the  $V_R$  colorbar legend to locate the area with the greatest values on the display.

## Assess Environmental Winds (Slide Layer)

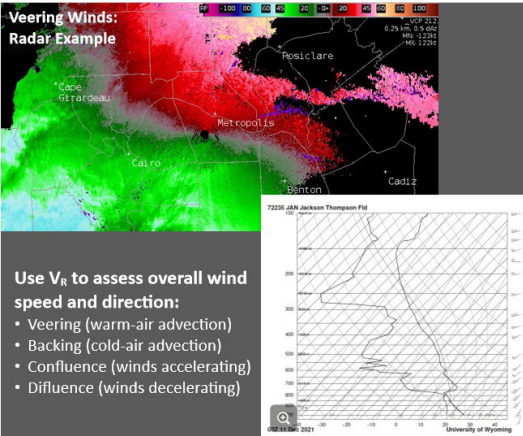
**How do you use  $V_R$  operationally?**

**Assess Environmental Winds**

**Detect Severe Winds**

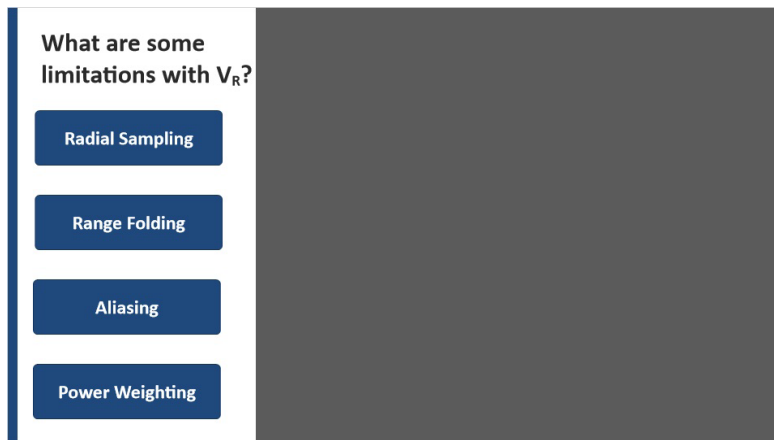
**Use  $V_R$  to assess overall wind speed and direction:**

- Veering (warm-air advection)
- Backing (cold-air advection)
- Confluence (winds accelerating)
- Diffluence (winds decelerating)



Use the  $V_R$  colorbar legend to locate the area with the greatest values on the display.

## What are some limitations of $V$ ?



### Notes:

When using radial velocity, there are a few features you may notice in the data which are common limitations. Click on each one to learn more and when you're done you can move on.

#### *Radial Sampling:*

A few minutes ago in a few slides far away, you learned about the fundamentals of what radial velocity is actually measuring - only the component of the wind along a radial. This fundamental concept is also hugely important for you to recognize as a limitation when viewing velocity data - radial velocity will measure less of the true wind as it becomes increasingly closer to perpendicular to a radial. Think of these areas as "blind spots" in your radar's line of sight. Quantitatively, the table here shows how much of the actual wind is measured based on the angle between the true winds and radial.

#### *Range Folding:*

You learned about range folding in the previous topic but just as a reminder, range folding is evident as purple blocks in radial velocity and indicates areas where the radar is not able to accurately assign velocity values. In this image, we see range-folded data both close to and far away from the radar. Range-folded data limits the use of radial velocity because we don't know what the exact values are in those areas.

#### *Aliasing:*

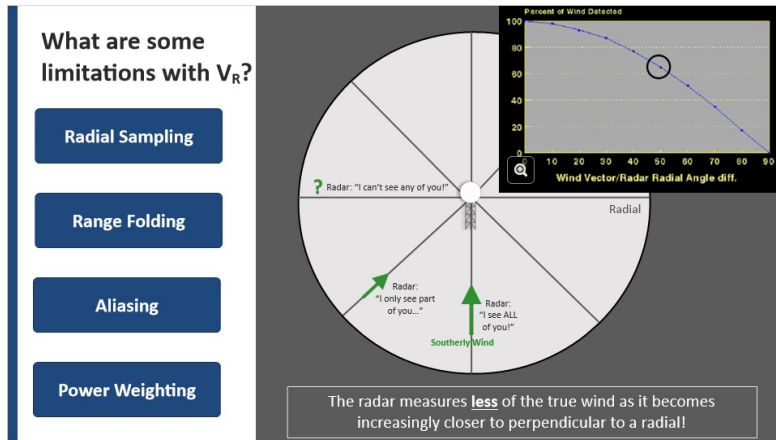
In the previous topic, you learned that when the shift in phase is greater than 180 degrees, the radar uses other possible aliases, or guesses, which can sometimes be downright questionable to incorrect. Areas of incorrectly dealiased velocities stick

out by how they don't fit in with surrounding velocities as shown in this example where, to name just a few, we have an area where the inbound velocity values are significantly lower than the surrounding values and another area where we have an inbound velocity gate that is randomly sandwiched between outbounds - in both cases, these velocity values do not fit with the surrounding velocity values or overall pattern. In areas where we suspect velocity aliasing, we shouldn't use these velocity gates because they are untrustworthy and could hamper our interpretation.

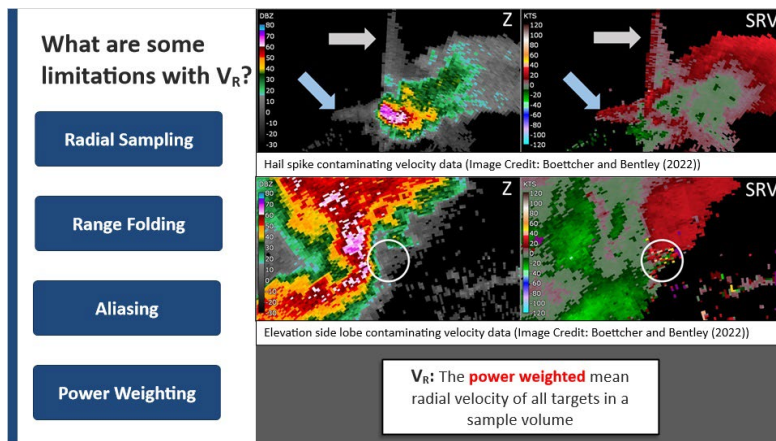
*Power Weighting:*

This limitation is almost so subtle it's subliminal as it's fundamentally part of the definition of radial velocity. Remember that because there are typically multiple targets in a sample volume that don't all have the same velocity, we take the radial velocity from the most power-weighted object. While most of the time, the most power weighted object's velocity is representative, but there are times where things like a three-body scatter spike from hail or the cumulative returned power from side lobes can display radial velocity values that are not representative of what's in that sample volume. You'll learn more about how hail spikes and elevation side lobes contaminate velocity data later, but for now just now that the power-weightedness of velocity can sometimes become a limitation.

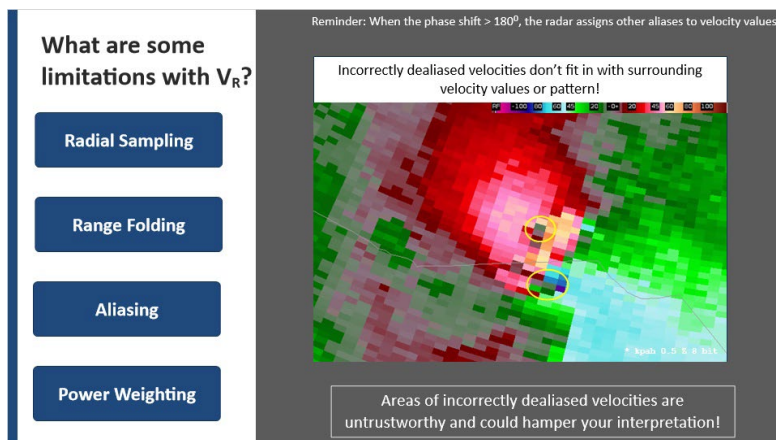
## Radial Sampling (Slide Layer)



## Power Weighting (Slide Layer)



## Aliasing (Slide Layer)

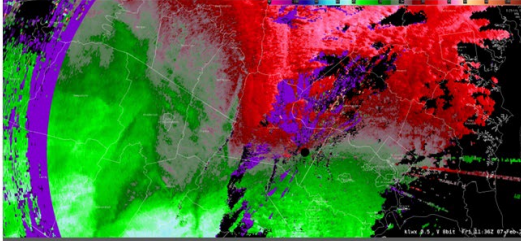


## Range Folding (Slide Layer)

**What are some limitations with  $V_R$ ?**

- Radial Sampling
- Range Folding
- Aliasing
- Power Weighting

Purple blocks -> radar can't accurately assign velocities!



Areas of range folded data limit your interpretation and use of radial velocity!

## Main Takeaways

**Your essential takeaways – no extras**

**What is  $V_R$ ?**

- The power weighted mean radial velocity of all targets in a sample volume

**What does  $V_R$  measure?**

- Only the component of wind moving directly towards or away from the radar along a radial

**How do you interpret  $V_R$ ?**

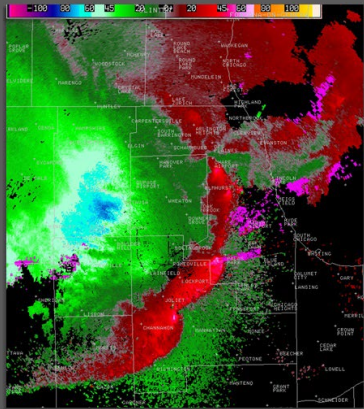
- "Green Towards; Red Away"
- "PANT: Positive Away; Negative Towards"

**How do you use  $V_R$  operationally?**

- Assess Environmental Winds
- Detect Severe Winds

**What are limitations of  $V_R$ ?**

- Radial Sampling
- Range Folding
- Aliasing
- Power Weighting



### Notes:


Before you take the quiz, here are the main takeaways for your review. Click "next" when ready.

## Contact Information

### Contact Information

RAC Help Email:  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

Lesson Author Email:  
[katy.christian@noaa.gov](mailto:katy.christian@noaa.gov)



Once you've completed the quiz, hit "Exit" to close out!

### Notes:

If you've got any questions about the material in this training, please feel free to send it to the RAC team or myself at the addresses shown here. If not, click "exit" to close out of this module.

# Storm Relative Motion (SRM)

## Introduction




### Notes:

Hello there and welcome to this lesson on storm relative motion!


## Course Completion

**Course Completion Options**

**Option 1: "This topic is new to me."**  
Take the course to receive credit  
(80% score required)



**Option 2: "I understand this topic already."**  
Successfully test out to receive credit  
(100% score required)



Click on either icon!

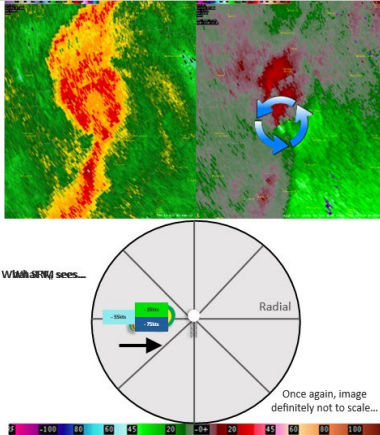
### Notes:

To get credit for this course, you have two options. If storm relative motion is a new topic to you, option 1 allows you to go through the course as normal and take the quiz at the end to receive credit. However, if you feel you have solid prior knowledge of the topic material, option 2 allows you to receive credit by successfully testing out of the material ahead of time. Note that you must score 100% to demonstrate you have solid mastery of the topic material. Click on either icon to choose.

## What is SRM?

### What is SRM?

- **SRM =  $V_r$  – Average Storm Motion**
  - Views storm as if it were completely still
  - Follows the flow of the storm (similar to Lagrangian framework)
- **SRM reveals features about the storm ITSELF**
  - Localized Shear
  - Divergence/Convergence
- **SRM depends on your selected storm motion source in AWIPS**



Once again, image definitely not to scale...

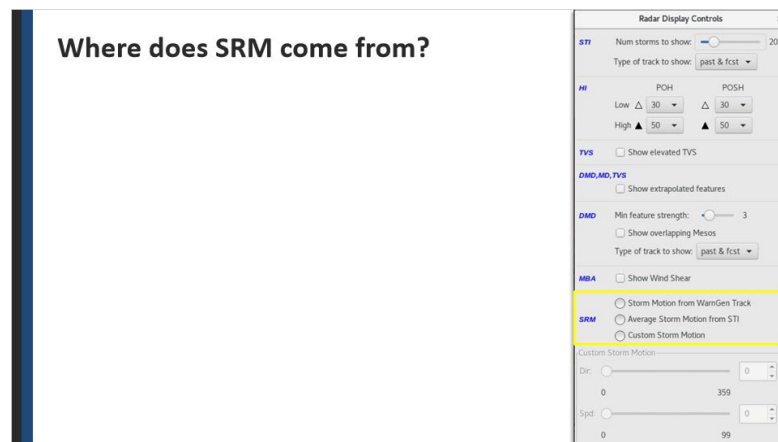
### Notes:

Remember how you learned all about what radial velocity is from the last module? Well, that is essentially what storm relative motion, or SRM is, BUT with the average storm motion removed. In other words, SRM is showing you what a storm looks like if it were completely still. To make those years of calculus classes worth it, I like to think of SRM as being similar to a Lagrangian Framework where you are following the flow whereas radial velocity is like a Eulerian framework where the radar is the fixed point you are viewing flow at. Because of this, SRM allows you to more easily identify features that are associated with the storm ITSELF, such as areas of shear, divergence, or convergence.

For example, let's say you have a fast-moving storm moving directly to the east at a speed of 55 knots. Now, let's say this storm is rotating, with 20 knots of winds towards the radar and 20 knots away. If we were to just view radial velocity, we'd see 75 knots of inbound velocities AND 35 knots of inbound velocities, and as a result, the area of localized shear wouldn't be readily visible to us and would appear unbalanced. However, if we were to view SRM, the storm motion would be subtracted out, allowing us to clearly see the area of rotation, with balanced inbounds and outbounds on both sides now.

SRM is dependent on whatever storm motion you select in AWIPS and is then produced on the fly based on that. So, what are the storm motion options in AWIPS? You can find them by clicking on "Tools" then "Radar Display Controls" in the AWIPS menu. Go ahead and do so just like you would in real life.

## Where does SRM come from?



### Notes:

In the "Radar Display Controls" panel, there is an area called "SRM" that allows you to choose what your storm motion is based off of. Select each radio button to learn more.

### *WarnGen Track:*

Remember from AWIPS Fundamentals that WarnGen is the tool we use to issue warnings and statements for severe thunderstorms, tornadoes, etc. Tracking the motion of a storm is part of the process when you use WarnGen so it makes sense that there is an option for defining SRM based off of your WarnGen track. This is one of the more popular options because you're always going to be tracking a storm when using WarnGen so it almost guarantees that your SRM values will be representative of the storms you're looking at so long as you do a good job with your tracking. In this image of SRM, we can see the storm motion source in the upper legend of the as being "track."

### *STI:*

STI stands for Storm Tracking Information and this is a product that comes from an RPG algorithm that you'll learn about later on. All you need to know for now though is that you can use the average cell motion velocity from the STI product as a basis for SRM. Because it's taking the average motion from multiple cells, it provides a good first guess for what the overall storm motion should be in a given environment. In this image of SRM, note the storm motion source being listed as from STI in the upper legend.

### Custom Storm Motion:

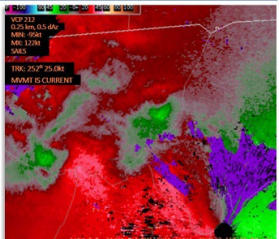
Custom storm motion is just that - storm motion that is set by the user alone and requires the user to input the approximate direction the storm is moving from and the speed it is moving at. In this image of SRM, note the storm motion source being listed as user."

### WarnGenTrack (Slide Layer)

#### Where does SRM come from?

**Storm Motion from WarnGen Track\***

- ❖ Storm motion from your last track in WarnGen
  - One of the more popular SRM options due to representing your current storms



\* Remember that we use WarnGen to track & warn on storms!

Image Credit: NOAA EWP Blog

#### Radar Display Controls

STI Num storms to show: 20  
Type of track to show: past & fcst

HI POH POSH  
Low Δ 30 Δ 30  
High ▲ 50 ▲ 50

TVS  Show elevated TVS

DMD, MD, TVS  Show extrapolated features

DMD Min feature strength: 3  
 Show overlapping Mesos  
Type of track to show: past & fcst

MBA  Show Wind Shear

Storm Motion from WarnGen Track  
 Average Storm Motion from STI  
 Custom Storm Motion

Custom Storm Motion:  
Dir: 0  
0 359  
Spd: 0  
0 99

### Custom Motion (Slide Layer)

#### Where does SRM come from?

**Custom Storm Motion**

- ❖ Storm motion set by the user that requires storm direction (degrees) and storm speed (kts)




Image Credit: NOAA EWP Blog

#### Radar Display Controls

STI Num storms to show: 20  
Type of track to show: past & fcst

HI POH POSH  
Low Δ 30 Δ 30  
High ▲ 50 ▲ 50

TVS  Show elevated TVS

DMD, MD, TVS  Show extrapolated features

DMD Min feature strength: 3  
 Show overlapping Mesos  
Type of track to show: past & fcst

MBA  Show Wind Shear

Storm Motion from WarnGen Track  
 Average Storm Motion from STI  
 Custom Storm Motion

Custom Storm Motion:  
Dir: 0  
0 359  
Spd: 0  
0 99

# STI (Slide Layer)

## Where does SRM come from?

### Average Storm Motion from STI\*

- ❖ Storm motion that is the collective average cell velocity from **STI**
  - Provides a good “first guess velocity”

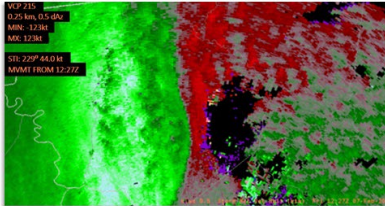


Image Credit:  
NOAA EWP Blog

\* STI: Storm Tracking Information (RPG Algorithm Product)

Radar Display Controls

**STI** Num storms to show: 20  
Type of track to show: past & fcst

**H** POH POSH  
Low Δ 30 Δ 30  
High ▲ 50 ▲ 50

**TVS**  Show elevated TVS

**DMD, MD, TVS**  Show extrapolated features

**DMD** Min feature strength: 3  
 Show overlapping Mesos  
Type of track to show: past & fcst

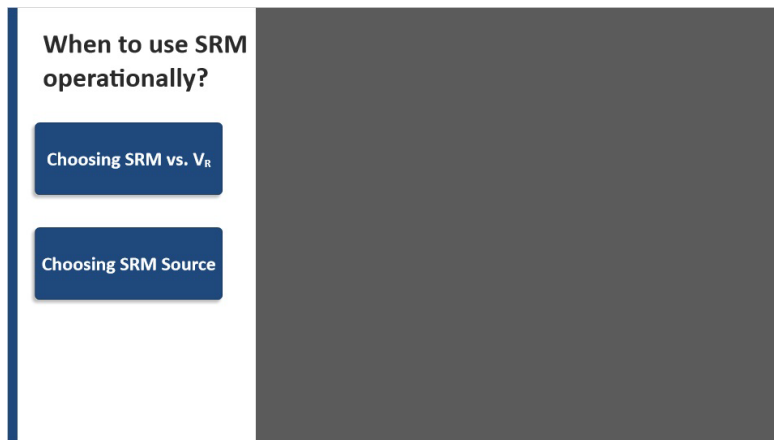
**MBA**  Show Wind Shear

**SRM**  Storm Motion from WamGen Track  
 Average Storm Motion from STI  
 Custom Storm Motion

Custom Storm Motion

Dir: 0  
0 359  
Spd: 0  
0 99

## ***When to use SRM operationally?***



### **Notes:**

When it comes to using SRM operationally, you need to know when to choose SRM over Radial Velocity and what SRM source to then choose. Click on each one to learn more.

#### *Choosing SRM vs. $V_R$*

Anytime you want to see features associated with the storm itself, such as rotation with a mesocyclone, areas of convergence or divergence within a storm, or localized shear associated with a tornado, you should use SRM over Radial Velocity because it will remove velocities associated with the storm's movement, allowing you to easily spot and identify those velocities associated with storm features. This is especially true if your storms are moving fast because storm features in velocity may be overshadowed or dominated by velocities associated with the storm's movement itself.

Conversely, anytime you are concerned with detecting severe winds associated with pulse storms, microbursts, derechos, or Squall Lines, you should use Radial Velocity as it will show you the winds relative to the ground and not relative to the storm itself like SRM would.

So taking a step back, if your primary threat for the day is severe winds, use V but if it's tornados, use SRM. And if you have both of these threats on the same day, use both for their respective purposes and also go buy a 5-hour energy drink.

#### *Choosing SRM Source*

Choosing which source to use as your SRM basis is dependent on the operational event at hand.

If it's at the beginning of a weather event and you or your office hasn't issued a warning yet, it's best to use the average storm motion from STI as your basis as it will provide a good first guess as to what the overall storm motion in that environment is.

Once you or your office has started issuing warnings, it's best to use the storm motion from WarnGenTrack as your basis as that will be more representative and tailored to the storms you are actually looking at vs. a collective storm motion average from the STI product.

And lastly, if you have storms that are deviating significantly from the motion of surrounding storms, such as you'd often see in solitary storms or storms in a weak upper-level steering flow, it's best to use the custom storm motion as your basis for SRM. Note that when you change your SRM source, it just changes it on your own AWIPS computer and won't affect other machines in your office.

## Choosing SRM Source (Slide Layer)

### When to use SRM operationally?

Choosing SRM vs.  $V_R$

Choosing SRM Source

\* Changing SRM source just impacts your AWIPS machine

Use once you've started to issue warnings

Use at the start of a weather event and/or if no warnings have been issued

Use for storms deviating significantly from surrounding storm motion

## Choosing SRM vs. $V_R$ (Slide Layer)

### When to use SRM operationally?

Choosing SRM vs.  $V_R$

Choosing SRM Source

SRM	Velocity
<ul style="list-style-type: none"> <li>❖ Use to see features about a storm!                             <ul style="list-style-type: none"> <li>○ Rotation with a mesocyclone</li> <li>○ Convergence or divergence in a storm</li> <li>○ Localized shear with a tornado</li> </ul> </li> <li>❖ Identify storm features with fast-moving storms</li> </ul>	<ul style="list-style-type: none"> <li>❖ Use to detect severe winds with a storm!                             <ul style="list-style-type: none"> <li>○ Pulse storms</li> <li>○ Microbursts</li> <li>○ Derechos</li> <li>○ Squall lines</li> </ul> </li> <li>❖ Identify winds relative to the ground!</li> </ul>

**Threat Type?**

Severe Winds → Velocity

Tornadoes → SRM


Both Winds + TORs → Use Both!

## What are the limitations of SRM?

**What are the limitations of SRM?**

1. SRM has the same limitations as  $V_R$ 
  - Radial sampling
  - Improper aliasing
  - Range folding
  - Power weighting
2. SRM is only as accurate as its storm motion input

**Pulse Storm**  
(not green eggs and ham)




Custom Storm Motion  
Direction: 90°  
Speed: 10 kts


2 weeks later on  
same AWIPS  
machine...

If SRM isn't  
changed...

**Supercell**



Custom Storm Motion  
Direction: 90°  
Speed: 10 kts



SRM depends on  
YOU to correctly  
update with the  
relevant source!

### Notes:

Because SRM is just radial velocity but without the contribution from the storm's velocity, the same limitations and issues you may run into when using radial velocity are also the same when using SRM. If you remember, these are radial sampling, improper aliasing, range folding, and power weighting. In addition to these, there's a big-picture limitation with SRM that could derail your operational use. Since SRM is dependent on using whatever storm motion source you have selected from the "Radar Display Controls" panel, if THAT is not an accurate reflection of your current storms, your SRM values and then operational interpretation will be skewed.

For example, let's say the last convection that occurred over your CWA was popcorn convection from diurnal heating under weak upper level flow. Whoever worked that shift had custom set the storm motion to 90 degrees at 10 knots due to the storm's motion being driven mostly by outflow boundaries and very erratic. Now, fast-forward 2 weeks and you're working at that same AWIPS machine. A newly developing supercell is approaching from the Southwest out ahead of a cold front. If you do not reselect your storm motion choice from the Radar Display Controls panel, your SRM velocities are going to be way off because it's subtracting out a storm motion associated with storms 2 weeks ago and is not representative of the current environment. So, just remember that a big-picture limitation of SRM is that it depends on you, the user, to correctly update its storm motion source and if it isn't up to date, your interpretation won't be either.

## Main Takeaways

### Your Module Relative Takeaways

#### What is SRM?

- Radial velocity but with the average storm motion removed

#### Where does SRM come from?

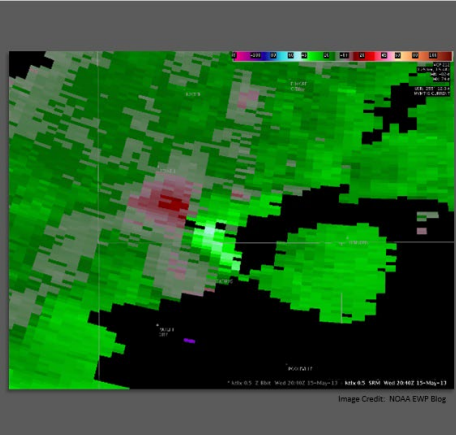
- SRM comes from whatever source the user selects:
  - Storm motion from **STI**
  - Storm motion from **WarnGen track**
  - Storm motion from **custom defined motion**

#### When to use SRM operationally?

- Use SRM to see **storm relevant features**
  - Rotating updraft (i.e. mesocyclone)
  - Localized shear with a tornado
  - Convergence/divergence in a storm

#### What are limitations of SRM?


- SRM has the same limitations as  $V_R$
- SRM depends on the user to select the most representative storm motion source!



### Notes:

Before you take the quiz, here are your module relative takeaways. Click “next” when ready.

## Contact Information

Contact Information	
RAC Help Email: <a href="mailto:nws.wdtd.rachelp@noaa.gov">nws.wdtd.rachelp@noaa.gov</a>	
Lesson Author Email: <a href="mailto:katy.christian@noaa.gov">katy.christian@noaa.gov</a>	

Once you've completed the quiz, hit "Exit" to close out!

### Notes:

If you've got any questions about the material in this training, please feel free to send it to the RAC team or myself at the addresses shown here. If not, click "exit" to close out of this module.

# Base Spectrum Width

## Introduction




## Notes:

Hello friend and welcome to this lesson on base spectrum width!


## Course Completion

**Course Completion Options**

**Option 1: "This topic is new to me."**  
Take the course to receive credit  
(80% score required)



**Option 2: "I understand this topic already."**  
Successfully test out to receive credit  
(100% score required)

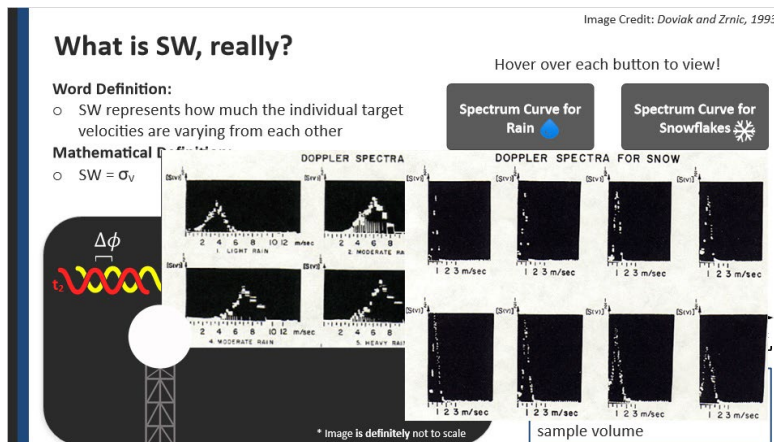


Click on either icon!

## Notes:

To get credit for this course, you have two options. If spectrum width is a relatively new topic to you, option one allows you to go through the lesson as normal and take the quiz at the end to receive credit. However, if you feel you have solid prior knowledge of the topic material, option 2 allows you to receive credit by successfully testing out of the material ahead of time - note that you must score 100% to demonstrate you have solid mastery of the topic material. Click on either icon to choose.

## What is SW, really?



### Notes:

In order to understand spectrum width, we need to make sure we've got our base velocity understanding locked down so let's quickly recap. When a radar beam sends out a pulse and receives a signal back, it is actually sampling thousands of targets - snowflakes, raindrops, dust, bugs, you name it - and each of these targets have their own unique radial velocity. Remember what base velocity does is use the shift in phase between two pulses to calculate the mean velocity from the most power weighted of these targets. If we were to plot this, you'd end up with something like this where the peak in this curve represents the mean radial velocity and everything around it is those individual target velocities. What spectrum width represents is how much all these individual target velocities are varying from each other, or graphically speaking, spectrum width is the spread or width part of this curve. In mathematical terms, it's the standard deviation of all those individual targets. Remember this graph is referred to as the Doppler Power Spectrum and if you're curious, hover over either of these buttons to see real-life examples of what it looks like for rain targets vs. snowflake targets.

## What does SW tell you? (Part 1)

### What does SW tell you?

**Question:** What meteorological situations would cause your target velocities to vary greatly from each other?

type your text here



### Notes:

We now know that spectrum width represents how much individual target velocities are varying from each other so what does a high or low spectrum width value tell you operationally? I want you to first think about what meteorological situations would cause your target velocities to vary a lot from each other? Think of at least two situations, type them down here, and hit the red button when done.

## What does SW tell you? (Part 2)

<b>What does SW tell you?</b>	Your Answer for Comparison: <code>StudentAnswerSW</code>
<b>SW is high here:</b> 	<b>SW is low here:</b> 

### Notes:

Situations where SW values are high - or in other words, when target velocities within a radar pulse deviate greatly from each other - include the following:

- Areas of turbulence, such as near the top of a storm or along a boundary
- Areas of strong shear, such as near a tornadic circulation where targets are moving at different radial velocities
- Areas characterized by very different particle phases, such as in the melting layer, because targets there all have different terminal fall velocities
- And lastly, in situations where your mean velocity estimates are less representative or accurate, that is indicative that there is a wide range in target velocities


What about low SW values - what causes those?

- In areas with unidirectional and smooth flow, such as flow over a lake or inflow into an intense updraft where there is turbulence dampening
- In areas where targets are similar in size, shape, and composition, they all move at similar speeds, and this can occur in environments such as warm, stratiform rain
- And lastly, in situations where your mean velocity estimate is more representative or accurate, that is indicative of fairly uniform target velocities

To summarize all this up in the form of an orchestra analogy - think of low SW as if every musician in an orchestra was playing the exact same note at the exact same time with perfect rhythm - the sound is very uniform. However, if each musician starts playing their own song, at their own tempo, the sound becomes chaotic with a "spread" of notes - that's high SW values.

## *How do you use SW operationally?*

How do you use SW operationally?



Click on each icon and once done, click the "next" button!

### **Notes:**

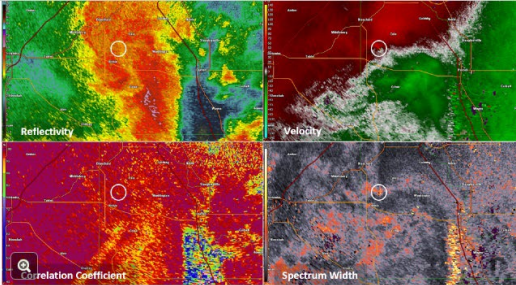
Now that we've talked about what leads to high or low SW values, we now arrive at the million dollar question - how can SW help you in operations? To find out, click on each mystery icon and once done, click the "next" button!

## Tornadoes

**How to use SW operationally?**

**Background:**

- Near a circulation (example to the right), targets are moving at different radial velocities
- SW values will be high there!



Note: L2 Radar Imagery in GR2 - SW colorbar is different in GR2 vs. AWIPS.  
(Image Credit: Raven Vasquez)

**BLUF:** Use SW to draw your attention to circulations that require interrogation

- Advantageous when storm is far from radar, disorganized, rain-wrapped

[Click to return to home](#)

### Notes:

Near a circulation, SW values will be high due to targets moving at different radial velocities within the storm-scale region of rotation. As such, it is helpful to use SW during operations to quickly draw your attention to circulations that require further interrogation with your other radar variables. This is especially true when a storm is far from the radar, is disorganized, or is rain-wrapped, all of which make it difficult to see features, for example, in reflectivity such as the hook. In this example of an EF2 tornado, the area of rotation in velocity along the outflow boundary is fairly subtle and could be easy to miss due to the lack of standout features in reflectivity as it is completely rain-wrapped. However, there is a locally enhanced area of SW in the same area as the circulation which should kick us to interrogate it further with our other radar variables and consider issuing a warning if warranted.

## Velocity QC

### How to use SW operationally?

Large variability between target velocities → Less accurate  $V_e$  estimates → High SW values ≠ Bad Velocity Data

**Question:** At the top of the storm (tilt 6.4) in the area of weak Z values, is the velocity data bad there?

type your text here

Submit

Well, that hurt my feelings...answer first! :)

Using SW to QC  $V_R$  - BLUF:  
"Do these high SW values make meteorological sense?"

- High SW within shear, turbulence, boundaries, etc.
- High SW within noisy V. data, clear air, etc.

### Notes:

Using SW to quality control velocity data has historically been touted as one of the primary uses of SW but has unfortunately been oversimplified throughout the years. In order to be done right, however, it must be applied holistically. Remember how we said that when there is a lot of variability between the individual target velocities, your mean velocity estimate will be less accurate and as such, SW values will be high. However, it is not correct to say that high SW equals bad velocity data. Instead, to holistically use high SW to assess velocity data quality, you should always ask yourself: "In this area of high SW, does that make meteorological sense?" If you're dealing with strong shear, turbulence, or a boundary, something real IS happening there and it's not necessarily bad data. However, if SW values are high and the velocity data there appears noisy and nothing truly meteorological is happening as evidenced by your other radar variables, the data there is suspect and is less trustworthy. Take this example – click on the slide handle and then use the up arrow key to go up in tilt to the very top of the storm and take a look at the SW values in the area of weak reflectivities – is the velocity data bad here? Type in your answer and hit submit when done.

## Answer (Slide Layer)

**How to use SW operationally?**

Large variability between target velocities → Less accurate  $V_e$  estimates → High SW values ≠ Bad Velocity Data

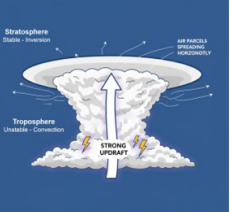
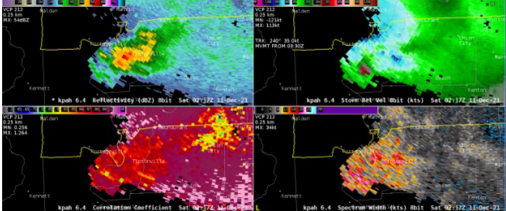
**Question:** At the top of the storm (tilt 6.4) in the area of weak Z values, is the velocity data bad there?  
**Answer:** Since we are at storm top, SW will be high due to turbulence so  $V_e$  is not bad!

**Your Answer for Comparison:** [StudentAnswerVelocityQC](#)

[Click to return to home](#)

**Using SW to QC  $V_R$  - BLUF:**  
"Do these high SW values make meteorological sense?"

High SW within shear, turbulence, boundaries, etc. High SW within noisy  $V_e$  data, clear air, etc.



Top of storm (6.4 tilt)

### Notes:


If you are a "risk adverse air parcel", near the top of a thunderstorm is not where you want be unless you're practicing exposure therapy. The overshooting top is the transition zone where the strong vertically bound updraft within the Troposphere enters the horizontally stable Stratosphere and as such, the velocity of all of our individual targets there varies quite a bit and makes for a turbulent, chaotic environment. As such, at the top of the storm, it makes sense meteorologically that our spectrum width values will be high as we see at 6.4 and as such, we can generally trust velocity data there as well.

## Boundaries

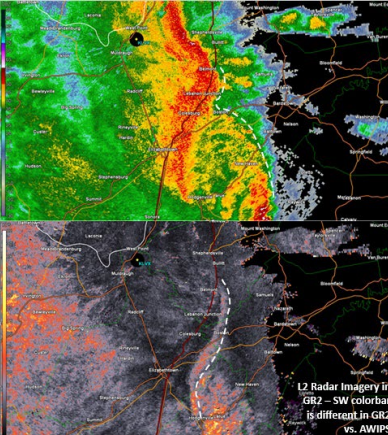
**How to use SW operationally?**

**Background:**

- On the leading edge of boundaries (fronts, gust fronts, etc.), there is low-level turbulence
- Enhanced SW values will “pop” brightly there!

 **BLUF:** Use SW alongside V/SRM to help identify boundaries!

[Click to return to home](#)



L2 Radar Imagery in GR2 - SW colorbar is different in GR2 vs. AWIPS

### Notes:

On the leading edge of boundaries, such as cold fronts, outflow boundaries, or gust fronts, there is often low-level turbulence which causes SW values to “pop” more brightly than your other base products. For example, while V and SRM are also used for locating boundaries, there can be times where SW will reveal those more clearly. Similarly, there are times when reflectivity may not clearly show the leading edge but SW will. Here’s an example of this where if you were to just use reflectivity, you might assume the frontal boundary aligns with the leading edge of the storms in Z. However, taking a quick look at spectrum width, you can see how the frontal boundary is actually shifted well behind the main line on the southern side. As you’ll learn later on, boundaries are an important instigator for tornado spin-ups so it’s crucial to be aware of where your boundaries are and using SW to supplement V/SRM can quickly help with this.

## Summary Specs

### Summary Specs

**What is SW?**

- SW represents the variability or spread of individual target velocities within a radar pulse

**What does SW tell you?**

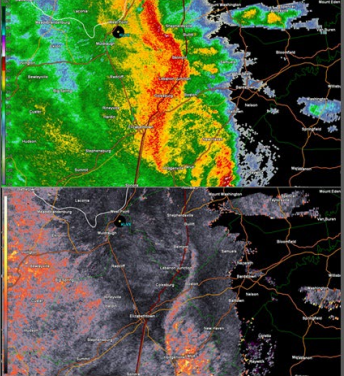
- **High SW:** Turbulence, shear, mixed-phase hydrometeors, less reliable  $V_h$  estimates
- **Low SW:** Smooth flow, uniform hydrometeors, more reliable  $V_h$  estimates

**How to use SW operationally?**

- Locating circulations
- Identifying boundaries
- Quality-controlling  $V_h$  data

**Important tidbits about SW?**

- SW is NOT a standalone product – always use it alongside other radar variables!
- High SW values in meteorologically significant areas are expected!



See the "Resources" tab for list of references cited and additional reading material.

### Notes:

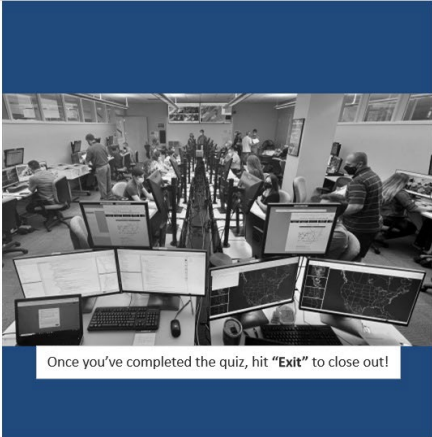
To make sure you're up to spec before you take the quiz, here are the main takeaways for your review. Click "next" when ready.

## Contact Information

### Contact Information

RAC Help Email:  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

Lesson Author Email:  
[katy.christian@noaa.gov](mailto:katy.christian@noaa.gov)



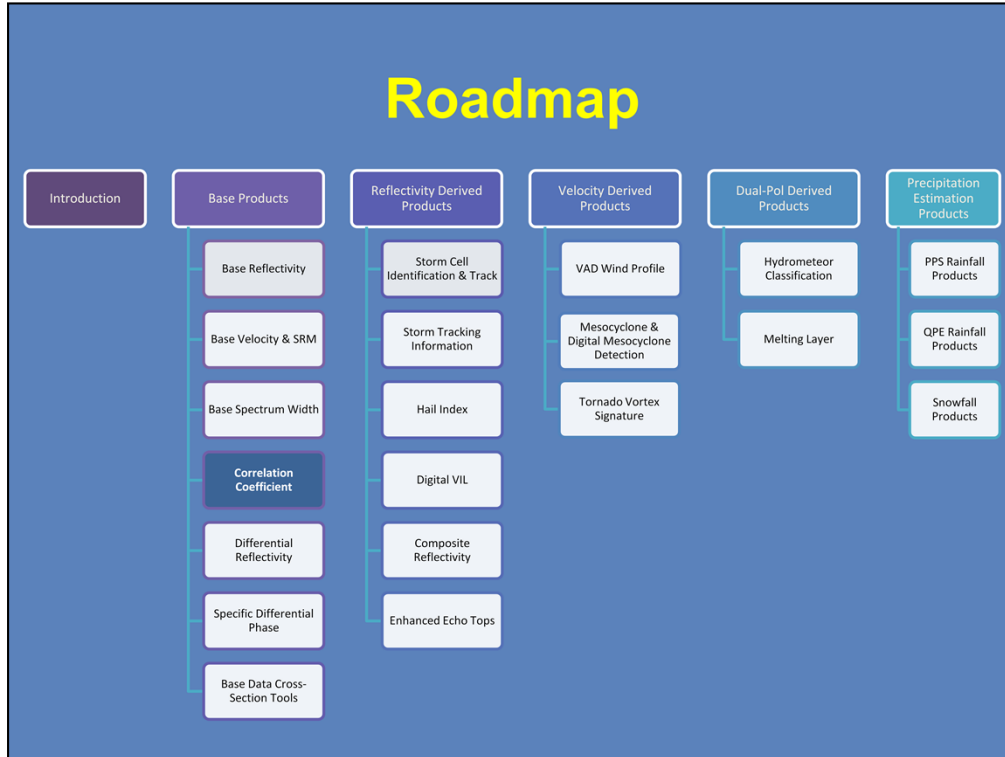
Once you've completed the quiz, hit "Exit" to close out!

### Notes:

If you've got any questions about the material in this training, please feel free to send it to the RAC team or myself at the addresses shown here. If not, click "exit" to close out of this module.



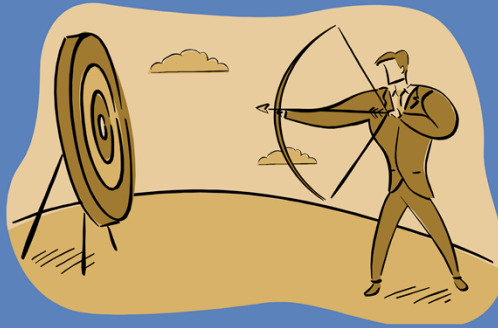
Welcome to Topic 4, Correlation Coefficient. This is the first of the three dual-pol base products. Let's get started.



Here is the Topic 4 lessons roadmap, for reference. As mentioned, this is the first of three dual pol lessons in the base products topic.

## Learning Objective

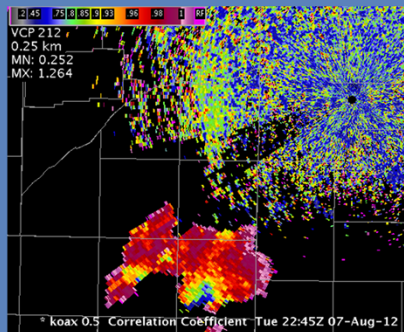
Identify the characteristics, limitations, and applications (strengths) of the Correlation Coefficient (CC) products




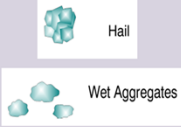

Here is the learning objective for this lesson. Take a moment to read this slide and advance the slide when you are ready.

## Definition

CC is a measure of how similarly the horizontally and vertically polarized pulses are behaving from pulse to pulse in a resolution volume



Correlation coefficient (CC) is defined as the measure of how similarly the horizontally and vertically polarized pulses are behaving from pulse to pulse within a resolution volume.

<u>Non-Meteorological</u> (birds, insects, etc.)	<u>Metr (Non-Uniform)</u> (hail, melting snow, etc.)	<u>Metr (Uniform)</u> (rain, snow, etc.)
		
Complex scattering from pulse-to-pulse.	Somewhat complex scattering from pulse-to-pulse.	Well-behaved scattering from pulse-to-pulse.
<b>Low CC (&lt; 0.8)</b>	<b>Moderate CC (0.80 to 0.97)</b>	<b>High CC (&gt; 0.97)</b>

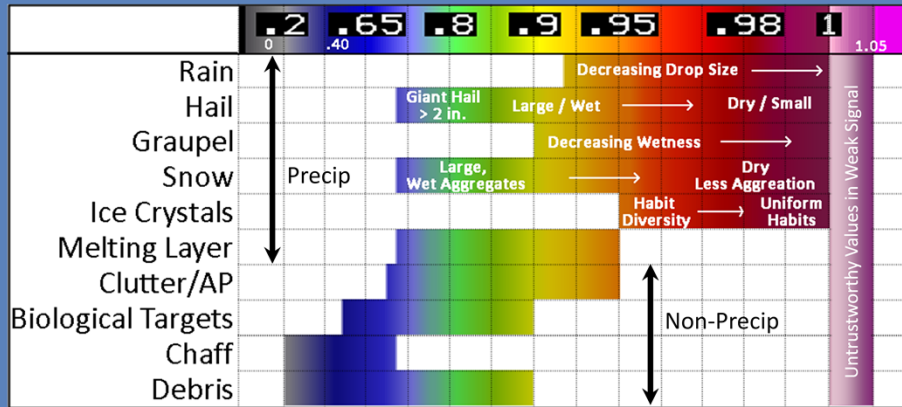
In terms of the Dual-Pol base products, CC will usually be your first stop on the journey to determining precipitation types, and discriminating between meteorological and non-meteorological echoes. The chart here illustrates this.

For non-meteorological echoes such as birds, insects and ground clutter, the scattering of these objects can be quite complex. This causes the horizontal and vertical pulses to change in different manners from pulse-to-pulse, resulting in CC typically below 0.8.

For meteorological echoes that are non-uniform in shape and size, such as hail and melting snow, the scattering of these objects can be complex, but not nearly to the degree of complexity as the non-meteorological echoes. This results in CC between 0.8 and 0.97.

Lastly, for meteorological echoes that are fairly uniform in shape and size such as rain and snow, the scattering off the objects is quite well-behaved with CC greater than 0.97.

## Typical Values for CC



non-meteorological:  
meteorological:

CC < 0.8,  
CC > 0.9

Now that we've seen a general idea of the CC values, here is a chart that dives into a little more detail. The thing to note with this chart is that there is pretty good break between CC values in non-meteorological echoes (bottom half of the chart), and meteorological echoes (top half of the chart). Basically, CC less than 0.8 is going to be non-meteorological, and CC greater than 0.9 is going to be meteorological.

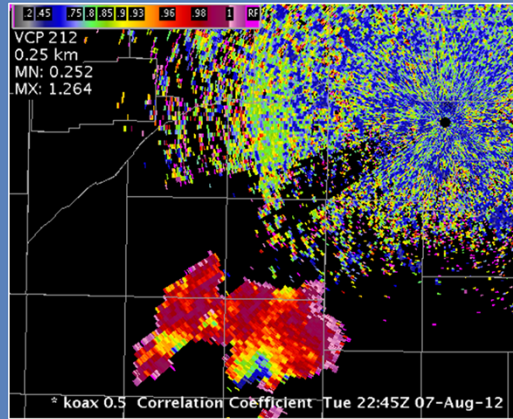
## Products Available

Product Name	Units	AWIPS ID	RPG ID	RPG Code	Data Levels	Range Res	Az Res	Max Range
<i>Correlation Coefficient Data Array Product</i>	--	<i>CC</i>	<i>DCC</i>	<i>161</i>	<i>8-bit (16)</i>	<i>0.25 km</i>	<i>1 deg</i>	<i>300 km</i>
<i>Super Res Correlation Coefficient Data Array Product</i>	--	<i>SDC</i>	<i>SDC</i>	<i>167</i>	<i>8-bit (256)</i>	<i>0.25 km</i>	<i>0.5 deg</i>	<i>300 km</i>

We will discuss these two 8-bit CC products in this lesson, with the first one being the one you're used to, the processed CC data. But now with 88D build 16.1 completed, we also have a super-resolution version of CC – what you're used to seeing in GR2 Analyst. There are some advantages to this product but also some key limitations, which we will discuss later in the lesson.

## General Product Characteristics

- Polar coordinate display
- 1° beamwidth
- Displayed relative to the RDA site
- Available for any elevation angle of the current VCP



CC products are displayed in polar coordinates with a 1 degree beamwidth and data are displayed relative to the RDA site. CC is available for all elevation angles for the current VCP.

# Menu Locations

CC combined with all  
base data

Individual CC products  
(elevation-based)

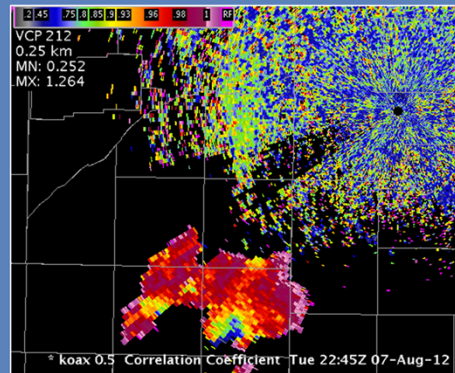
Product Name	Time
----- Best Res Z+SRMB combo -----	
0.5 Z+SRMB	07.2245
0.9 Z+SRMB	07.2245
1.5 Z+SRMB	07.2245
All Tlts Z+SRMB	07.2245
koax HI Z+SRMB tlts	
----- Best Res Z+V -----	
0.5 Z+V	07.2245
0.9 Z+V	07.2245
1.5 Z+V	07.2245
All Tlts Z+V	07.2245
koax HI Z+V tlts	
----- 4-Panel Z+SRM/ZDR+V/KDP+HC/CC+SW -----	
0.5 base data	07.2245
0.9 base data	07.2245
1.5 base data	07.2245
All Tlts base data	07.2245
koax HI base data tlts	
----- 4-Panel Z/ZDR+HC+KDP/CC -----	
0.5 HC analysis	07.2245
0.9 HC analysis	07.2245
1.5 HC analysis	07.2245
All Tlts HC analysis	07.2245
koax HI HC analysis tlts	
----- Best Res Base Products -----	
koax Z	
koax V	
koax SRM	
koax SW	
koax ZDR	
koax CC	
koax KDP	
koax Precip	
koax Derived Products	
koax Algorithm Overlays	
koax Four panel	
koax Data Quality	
koax 4-bit/Legacy Prods	
Radar Applications	

You can find the CC products combined with all base data in your dedicated radar drop-down menu in the first two options highlighted. And, the individual, elevation-based CC products can be found in the third option.

## 8-Bit Correlation Coefficient

- $1^\circ \times 0.25 \text{ km}$
- Range: 162 nm

Note: In the split cuts, there will be a difference between resolutions for Z, V, SRM and SW



The 8-bit CC product is  $1 \text{ deg} \times 0.25 \text{ km}$  resolution and extends to a range of 162 nm. It is worth noting here when viewing products in the split cut elevations, toggling between CC and Z,V, SRM or SW there will be a difference in resolutions. This should not change your interpretation though.

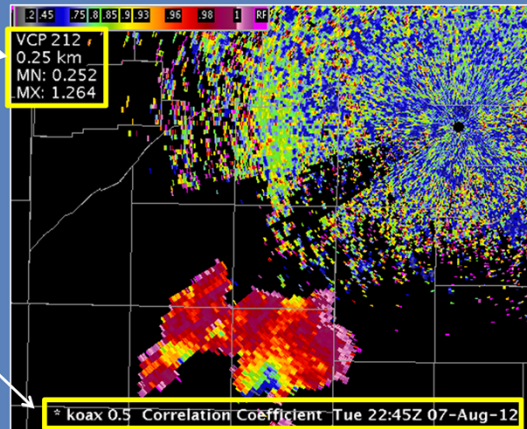
## 8-Bit Correlation Coefficient

### Product Annotation:

- VCP
- Range Resolution
- Min CC
- Max CC

### Product Legend:

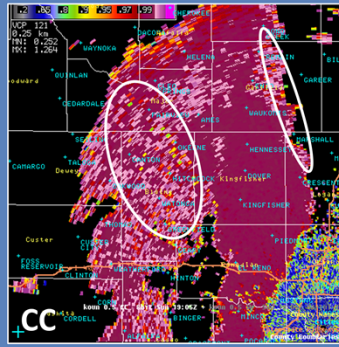
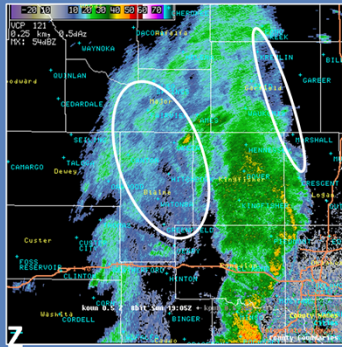
- RPG ID
- Elevation angle
- Product Name
- Date/Time (in UTC)



As with the other base products, the product annotation is in the upper-left portion of your display with the legend at the bottom.

## CC Limitations

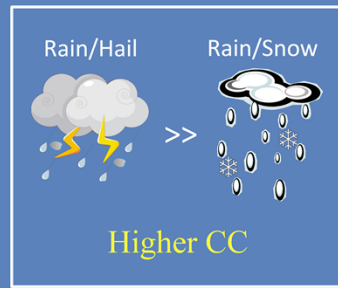
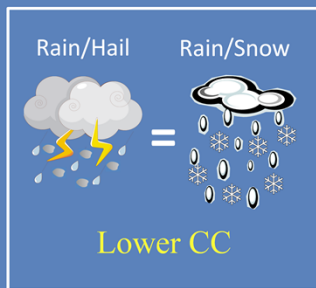
- Low SNR
  - Characterized by  $CC > 1.0$
  - Commonly seen in (1) low Z and (2) fringes of precip



What are the limitations of CC? The first one we'll look at is regions of low signal-to-noise ratio (SNR). In the regions, CC becomes unreliable and can be noted by CC greater than 1.0 which shows up as a pink color in AWIPS-2. The most common regions of low SNR are in low Z regions (usually less than 20 dBZ), and along the fringes of precipitation.

## CC Limitations

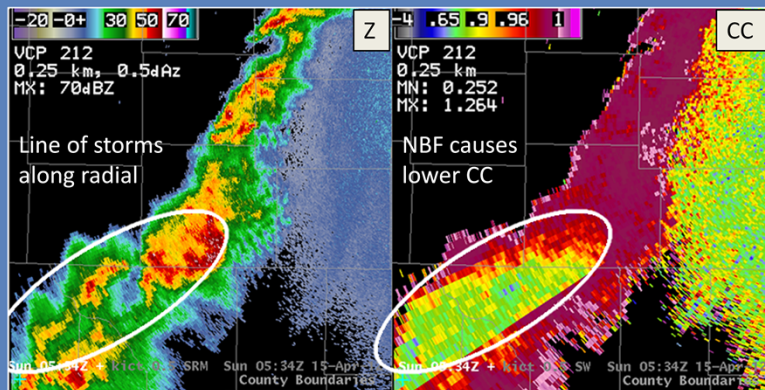
- Mixture of hydrometeors
  - More diversity = lower CC
  - Contributing factors:
    - Shape, size, orientation, and backscatter differential phase shift



When two or more types of hydrometeors are present within a pulse volume, the correlation coefficient will decrease. The amount of decrease in the correlation coefficient is dependent upon the relative contributions of each hydrometeor type present to the overall signal. The lowest correlation coefficient will occur when relatively equal contributions of each hydrometeor type to the signal are similar. For example, if snow and rain contribute relatively equally to the signal, the correlation coefficient will be lower than if the rain contributed more to the signal than did the snow.

## CC Limitations

- Non-uniform beam filling (NBF)
  - Radial “valleys” of lower CC



Non-uniform beam filling (NBF) can be detrimental to CC. It occurs when significant gradients of reflectivity and the polarimetric variables exist within the radar beam. The result of these gradients is an increase in the bias of the polarimetric variables, especially for CC. In CC, it is noted by a negative bias, so you will see a noticeable drop in CC in areas of NBF.

The most common situations are when storms line up along a radial and areas downstream of a significant hail core, as shown in this example. Notice how the NBF dropped the CC down the rest of the radial.

## CC Limitations

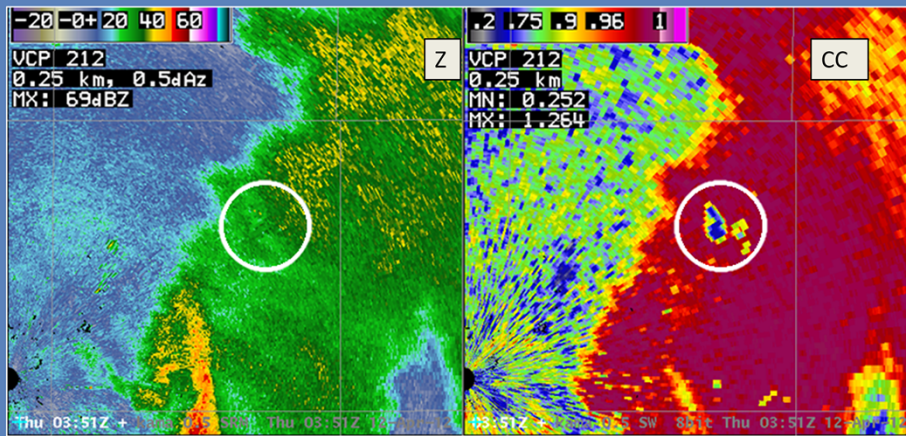
- Range folding in the batch cuts
  - Between  $1.65^\circ$  &  $6.5^\circ$



The last limitation with CC that we'll look at is in the batch cuts, where range folding may obscure some signatures in CC. As a refresher, the batch cuts for the WSR-88D network are elevation angles between 1.65 degrees and 6.5 degrees. In these cuts, each radial uses a series of alternating low and high PRF pulses and the dual-pol variables are only computed using the high PRF pulses which are subject to range folding. Here is an example of RF affecting CC.

# CC Applications

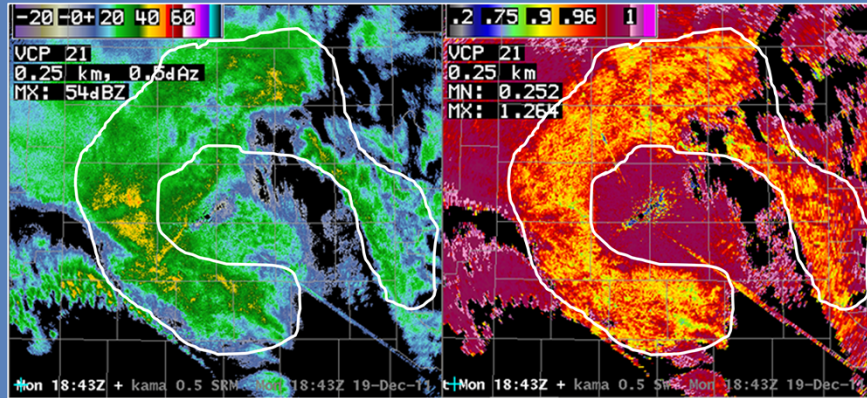
- Discriminating between meteorological and non-meteorological echoes



Now, on to the applications of CC. For one, it is best at discriminating between meteorological and non-meteorological echoes – which is why I mentioned that this will probably be – and should be – your first stop on the Dual Pol trail of products. Here is an example where in Z, it is very difficult, if not impossible, to see that the encircled region is mostly non-precipitation. However, switching over to CC, it becomes readily apparent by the very low values of CC, less than 0.5 that we have non-meteorological echoes.

# CC Applications

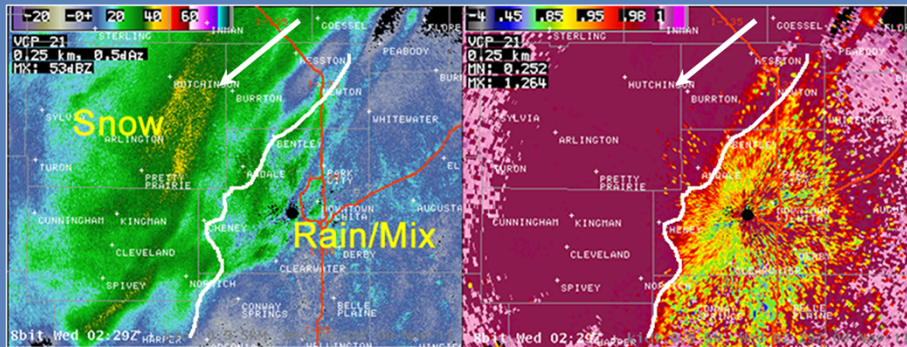
- Identifying the melting layer
  - Ring of lower CC



The next biggest advantage of CC is identification of the melting layer. It almost always manifests itself as a ring of lower CC as long as there is sufficient precipitation present. In the example below, note how the melting layer does not show very clearly in Z, but in CC it stands out like a sore thumb.

# CC Applications

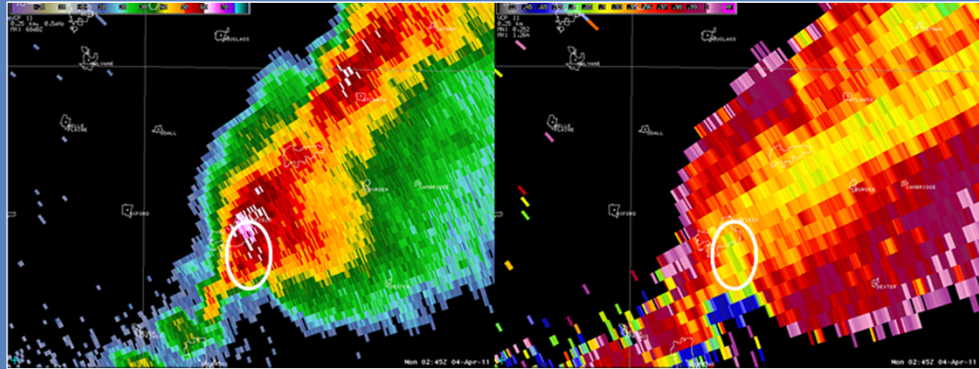
- Identifying regions of rain vs. snow



Applying the melting layer signature concept to rain/snow transitions, CC is great at delineating rain/mix areas from all snow. In this example, reflectivity shows what appears to be a bright band to the west, but when looking at CC we see that that is all snow (and based on surface temps below freezing). The true transition region is further east as seen in CC. So, without CC, the rain snow transition line would have been misplaced.

## CC Applications

- Identify regions of significant severe hail
  - $CC < 0.9$
  - Diameters  $> 2$  inches (i.e. golfballs)



When hail becomes significantly large, and we'll define this as hail larger than golf balls, CC begins to behave oddly. This is because at 2 inches or greater, Mie scattering becomes quite dominant which causes CC values to dip below 0.9 in hail. Therefore, when reflectivity is high, and you suspect large hail based on storm structure, if CC is less than 0.9, there is almost no doubt that hail larger than golf balls are present. Also, notice how the hail core messes with the CC values down those radials, which draws back to our discussion on limitations and something to keep in mind.

## CC Applications

- Identify regions of irregularly shaped hydrometeors
  - i.e large, spiky hail

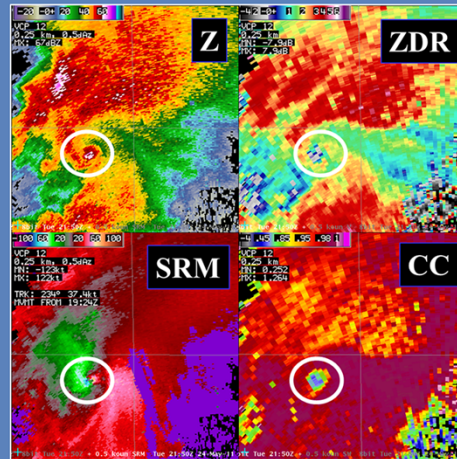


Hail like this stone can cause  
CC values of 0.75 or lower

The same logic can be applied to spiky hail. Larger protuberances can cause CC to behave very oddly, reducing CC. There is not as much of a relationship here as with the previous slide. But, if CC are anomalously low, roughly less than 0.75, it is possible that irregularly shaped hail present.

# CC Applications

- Identify tornadic debris
  - Low CC (typically < 0.9)
  - Must be associated with velocity couplet!
  - Extent of damage unknown
  - Enhance wording in subsequent statements

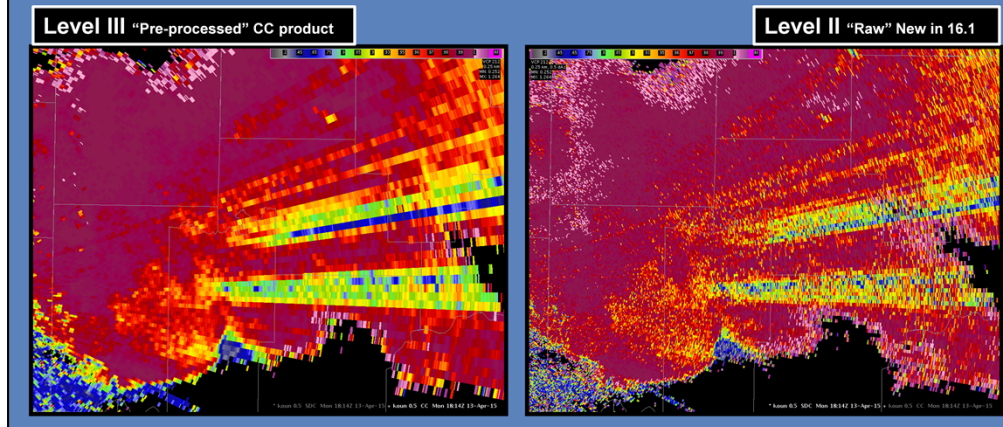


Probably one of the most well known and useful signatures with CC is the tornadic debris signature, or TDS. When you see a storm capable of producing a tornado by first looking at a combination of reflectivity, velocity, and SRM, CC can be used to help confirm the existence of a tornado. If you see CC's less than 0.9 co-located with the velocity couplet and within a region favorable for tornadoes, then you can confidently say that there is a tornado causing damage.

Note that the extent of the damage is unknown, although research suggests that this assessment may be possible but that is still to be determined. What you can do is use more confident wording in your subsequent warning statements to convey that a tornado is definitely occurring. You can also monitor trends in CC what stage in the potential life cycle of the tornado is occurring.

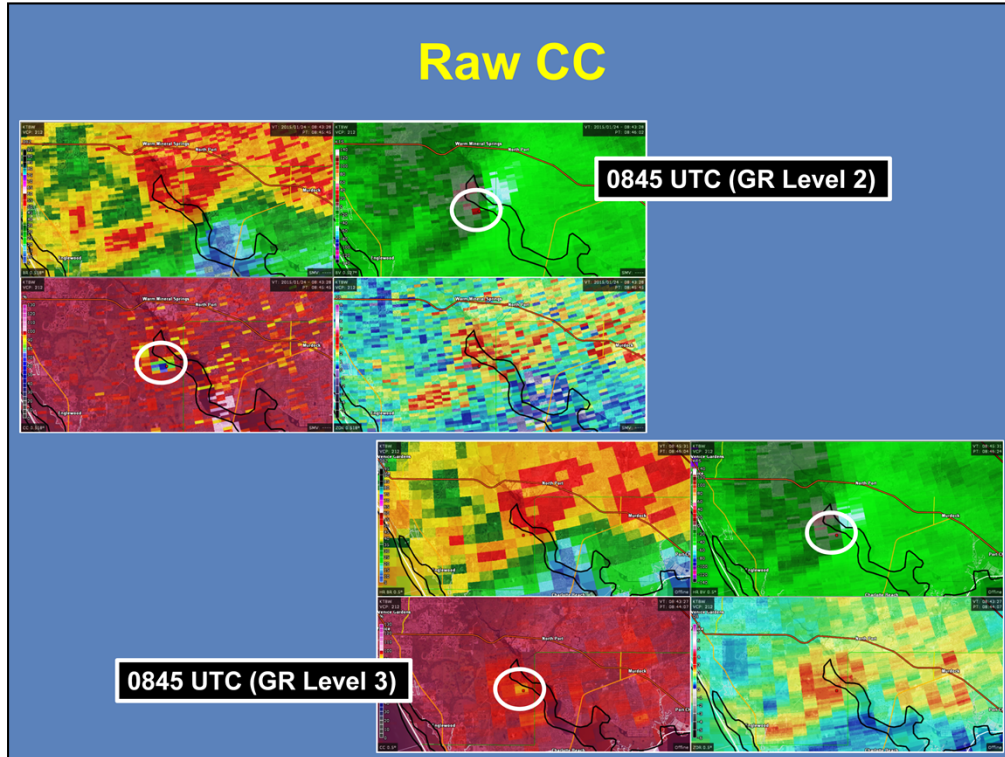
## Raw CC

- “Raw” = Level II data
  - Available in AWIPS as of Build 16.1
  - As appears on GR Analyst
  - No Dual-Pol Preprocessing (Level III)
  - Earliest possible detection of Tornadic Debris Signature



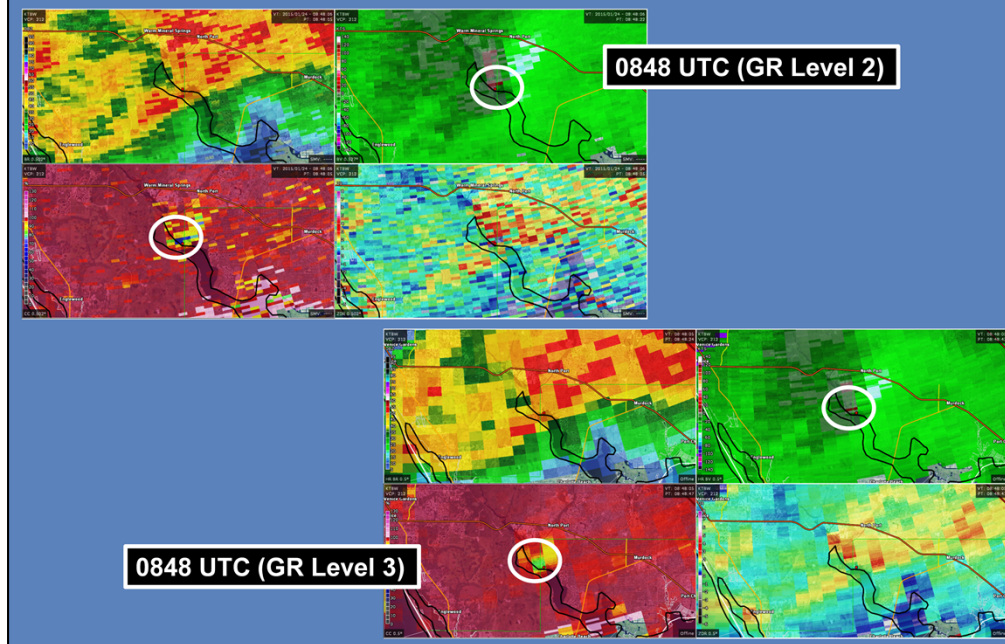
The second significant update with RDA/RPG Build 16.1 is the addition of the Raw CC Product. This product has been added to RPG product suite at the request of numerous WFOs, particularly in the southeastern U.S. Comparisons of the Level II Raw CC data on GR Analyst with the Level III CC product on AWIPS during warning operations has shown that Tornadic Debris Signatures (TDS) are easier to see in the Level II data. This is of particular importance where tornadoes can spin up along squall lines, and/or occur at night, conditions more likely in the southeastern U.S.

The example images on the bottom show the Level III data on the left and the Level II Raw CC on the right. Notice how the latter looks like it has finer detail, only because it is not Pre-Processed, which is why it is considered “Raw”.



Here's an example of an overnight TDS. The Level II four panel is on the upper left, with a corresponding Level III four panel on the lower right. Note that in both images there is a local minimum in CC collocated with the small velocity couplet. However, the CC minimum in the Level II image, compared to the minimum in the Level III image, is more visually apparent, and the minimum itself is lower. It looks more like a TDS in the Level II image than in the Level III image.

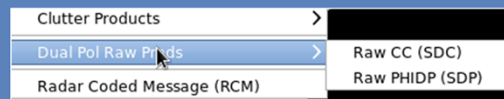
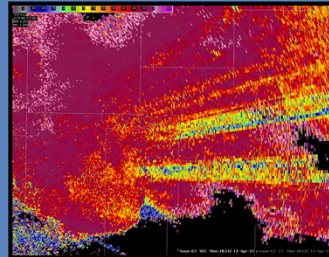
## Raw CC



Stepping forward to the next volume scan, the visual difference between the Level II and the Level III CC images is still apparent. Switch back and forth between this slide and the previous one, if you want to get a sense of this progression – then move to the next slide, when you're ready.

# Raw CC

- “Raw” not the same as “best res” (may look that way)
- Other than TDS detection, Raw CC should *not* be used as a replacement of current / preprocessed CC (Level III)
- Menu design supports this:



It is important to remember that “Raw” for CC does **not** mean the same thing as best res or Super-Res for a product like reflectivity.

The Raw CC is **just** the CC base data from the RDA generated as a product. Other than TDS detection, the Raw CC should not be your new “go-to” CC. For all other applications, the Level III, Preprocessed CC is still superior (think winter weather, hail, etc.). The design of menu supports this as well, keeping the Raw CC product in a menu stream separate from the Level III CC product.

## Summary: CC & Raw CC

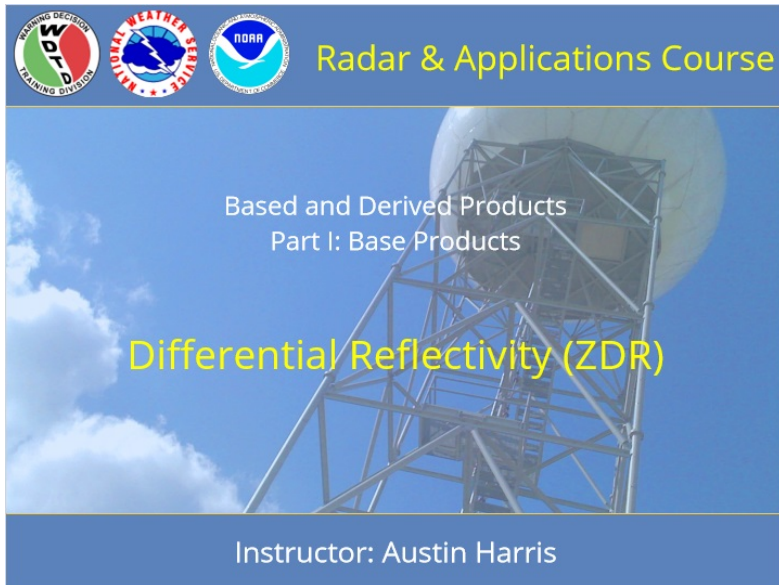
- Similarity of horizontal and vertical pulses in a resolution volume
- Meteorological vs. Non-meteorological echoes
- Melting layer, rain/snow, hail and TDS
- Standard radar limitations apply, plus:
  - Low SNR, NBF and RF in the batch cuts

In summary, we have seen that CC is a measure of the similarity of the horizontal and vertical pulses in a resolution volume. It is best at discriminating meteorological and non-meteorological echoes and can definitively identify the melting layer, rain/snow transitions, large hail and tornadic debris. While standard limitations do apply, other considerations while looking at CC are low SNR, NBF and RF in the batch cuts.

# Differential Reflectivity (ZDR)

## 1. Introduction

### 1.1 Title Slide



WFO TRAINING DECISION MAKING DIVISION

NOAA WEATHER SERVICE

NOAA

Radars & Applications Course

Based and Derived Products  
Part I: Base Products

Differential Reflectivity (ZDR)

Instructor: Austin Harris

#### Notes:

Welcome to the lesson on ZDR.

## 1.3 Learning Objectives

### Learning Objectives

---

- To **understand** the following about ZDR:
  1. What is it?
  2. What should we use it for?

#### Notes:

The learning objective for this lesson is to understand the following about ZDR:

What is it?

And what should we use it for?

## 2. Homepage

### 2.1 Homepage: ZDR

**Differential Reflectivity (ZDR)**

Click to learn more:

- What is ZDR?
- Why is it useful?
- Limitations

Additional info

Quiz

VCP 212  
0.25 km  
MN: -7.9dB  
MX: 7.9dB

koax 0.5 Diff Reflectivity (dB) 8bit Tue 22:45Z 07-Aug-12

#### Notes:

Welcome to the homepage for this lesson on Differential Reflectivity, or ZDR. From here, you can click on these three buttons to learn more about what ZDR is, why it is useful, and some of its limitations when using it in operations. Once you feel comfortable with these materials, click here to take the quiz.

## 3. What is ZDR?

### 3.1 What is ZDR?

The image shows a presentation slide with a blue background. At the top left, the title "What is 'ZDR'?" is written in yellow. Below the title, there is a section "Click to learn more:" with five white buttons: "Definition", "Interpretation", "ZDR for Rain", "ZDR for Hail", and "ZDR for Snow/Ice". To the right of these buttons is a dark blue box with the heading "Definition" and a bullet point: "Difference between the horizontal and vertical reflectivity factors (in dBZ units)". Below the bullet point, the equation  $ZDR = Z_H - Z_V$  is displayed in white.

#### Notes:

##### Definition

Differential reflectivity, or ZDR, is just that: the difference between the horizontal and vertical reflectivity factors in dBZ units.

##### Interpretation

ZDR is a good indicator of the dominant drop shape. For example, spherical objects will have near 0 dB because the horizontal and vertical reflectivity factors will be similar. Meanwhile, ZDR will be positive for horizontally oriented objects and negative for vertically oriented objects.

##### ZDR for rain

Rain will always have a positive ZDR due to the pancake-shape nature of all drops. And the larger the drop, the larger the ZDR.

##### ZDR for hail

Hail, unlike rain, tends to tumble as it falls making it appear spherical to the radar. This causes near zero ZDR. The classic severe hail signature is where this near-zero ZDR is co-located with high reflectivity, like in the example shown.

One caveat to this classic signature is small, melting hail, which will appear to the radar as large rain drops. This causes ZDR values to become extremely large (as high as 5-6 dB).

##### ZDR for snow/ice

For snow and ice, interpreting ZDR can be tricky. You have to ask yourself, is the snow wet or dry? low or high density?

or do they have a preferred orientation? It's complicated but don't worry: we'll discuss these in more detail throughout the lesson.

## Definition (Slide Layer)

### What is "ZDR" ?

Click to learn more:

- Definition
- Interpretation
- ZDR for Rain
- ZDR for Hail
- ZDR for Snow/Ice

#### Definition

- Difference between the horizontal and vertical reflectivity factors (in dB units)

$$ZDR = Z_H - Z_V$$

## Depends on (Slide Layer)




### What is "ZDR" ?

Click to learn more:

- Definition
- Interpretation
- ZDR for Rain
- ZDR for Hail
- ZDR for Snow/Ice

#### Interpretation

- Indicator of dominant drop shape

Spherical <small>(droplets, small hail, etc.)</small>	Horizontally Oriented <small>(rain, melting hail, etc.)</small>	Vertically Oriented <small>(i.e. vertically-oriented sea crystals)</small>
		
$Z_H \sim Z_V$	$Z_H > Z_V$	$Z_H < Z_V$
$Z_H - Z_V \sim 0$ ZDR = 0 dB	$Z_H - Z_V > 0$ ZDR > 0 dB	$Z_H - Z_V < 0$ ZDR < 0 dB

## Rain (Slide Layer)







### What is "ZDR" ?

Click to learn more:

- Definition
- Interpretation
- ZDR for Rain
- ZDR for Hail
- ZDR for Snow/Ice

#### ZDR for Rain

- Larger the drop, larger the ZDR

Major Axis Diameter (mm)	Image	ZDR (dB)
< 0.3 mm		~ 0.0 dB
1.35 mm		~ 1.3 dB
1.75 mm		~ 1.9 dB
2.65 mm		~ 2.8 dB
2.90 mm		~ 3.3 dB
3.68 mm		~ 4.1 dB
4.00 mm		~ 4.5 dB

## Hail (Slide Layer)

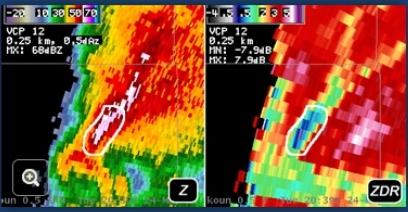
### What is "ZDR" ?

Click to learn more:

- Definition
- Interpretation
- ZDR for Rain
- ZDR for Hail
- ZDR for Snow/Ice

#### ZDR for Hail

- Hail tumbles ( $-0$  dB)
- Small, melting hail appears as giant raindrops (5-6 dB)



## Snow/ice (Slide Layer)

### What is "ZDR" ?

Click to learn more:

- Definition
- Interpretation
- ZDR for Rain
- ZDR for Hail
- ZDR for Snow/Ice

#### ZDR for Snow/Ice

- Interpreting can be tricky
- Wet or dry?
- Low or high density?
- Preferred orientation?

Snow	ZDR
Dry / Aggregated	0.2 to 0.3 dB
Wet / Melting	2 to 3 dB

Ice	ZDR
Low-density / Random orientation	< 1 dB
High-density / Preferred Orientation (Horizontal)	As high as 4 to 5 dB
High-density / Preferred Orientation (Vertical)	- 2 to 0 dB

## 4. Why is it useful?

### 4.1 Why is it useful?

### What is "ZDR" used for ?

Click to learn more:

- Hail
- ZDR Columns
- Tornadic Debris Signature
- Melting Layer
- Rain vs Snow

#### Hail

- Identify hail as **low ZDR** co-located with high Z

#### Notes:

##### HAIL

ZDR can be used to identify hail as low ZDR co-located with high Z.

## ZDR COLUMNS

When intense updrafts develop, liquid water will be lofted well above the melting layer. This process will result in a ZDR column, which is an area of locally high ZDR within an updraft.

Again this is a feature that you're only going to see at mid to high-levels, above the melting layer in a thunderstorm updraft region.

## TDS

Like CC, ZDR can help identify a tornadic debris signature, or TDS. Since the debris has no preferred orientation, ZDR will be near 0 or slightly negative.

When you see this signature in ZDR, it gives you added confidence that a tornado is causing damage. However, remember to look at Z, SRM, and CC before ZDR when identifying a TDS.

## RAIN VS SNOW

Like CC, ZDR can be used to identify rain/snow transition regions.

## MELTING LAYER

The melting layer will manifest itself in ZDR as a ring of high dB. This is because during the melting layer, the water coated ice looks like large rain drops, giving off the very high dBs.

## Hail (Slide Layer)

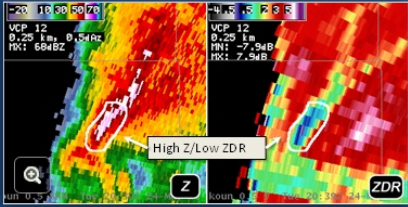
### What is "ZDR" used for ?

Click to learn more:

- Hail
- ZDR Columns
- Tornadic Debris Signature
- Melting Layer
- Rain vs Snow

#### Hail

- Identify hail as **low ZDR** co-located with high Z



## ZDR Columns (Slide Layer)

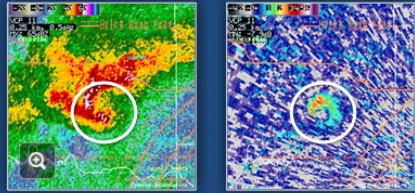
### What is "ZDR" used for ?

Click to learn more:

- Hail
- ZDR Columns
- Tornadic Debris Signature
- Melting Layer
- Rain vs Snow

#### ZDR Columns

- Identify intense updrafts (ZDR columns)
- ZDR > 1 found above melting layer



## TDS (Slide Layer)

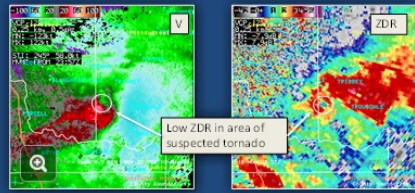
### What is "ZDR" used for ?

Click to learn more:

- Hail
- ZDR Columns
- Tornadic Debris Signature
- Melting Layer
- Rain vs Snow

#### Tornadic Debris Signature

- Identify a Tornadic Debris Signature (TDS)
- ZDR ~0 or slightly negative



## Rain vs snow (Slide Layer)

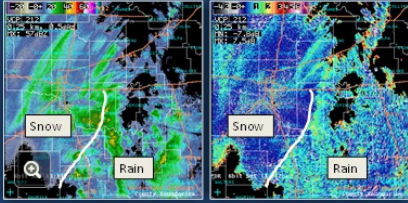
### What is "ZDR" used for ?

Click to learn more:

- Hail
- ZDR Columns
- Tornadic Debris Signature
- Melting Layer
- Rain vs Snow

#### Rain vs Snow

- Identify rain / snow transition regions
  - Rain: ZDR > 1
  - Snow: ZDR ~0



## Melting Layer (Slide Layer)

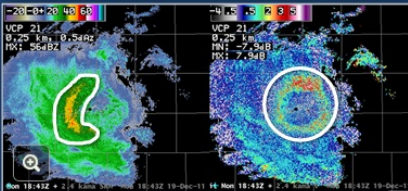
### What is "ZDR" used for ?

Click to learn more:

- Hail
- ZDR Columns
- Tornadic Debris Signature
- Melting Layer
- Rain vs Snow

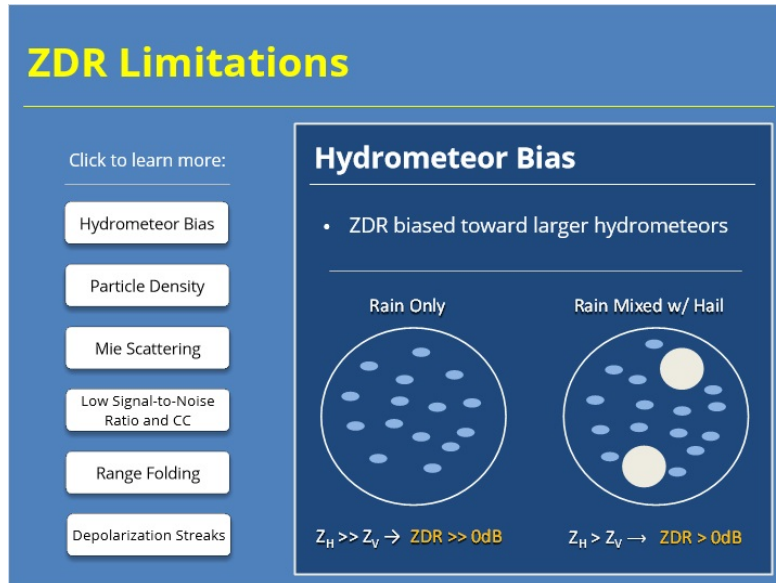
#### Melting Layer

- Identify the melting layer as the ring of high ZDR



## 5. Limitations

### 5.1 Limitations



The infographic is titled "ZDR Limitations" in yellow text on a blue background. On the left side, there is a vertical list of six white buttons with blue text: "Click to learn more:", "Hydrometeor Bias", "Particle Density", "Mie Scattering", "Low Signal-to-Noise Ratio and CC", "Range Folding", and "Depolarization Streaks". The "Hydrometeor Bias" button is highlighted. To the right of this list is a white box with a blue border titled "Hydrometeor Bias". Inside this box, there is a bullet point: "ZDR biased toward larger hydrometeors". Below this, there are two circular diagrams. The left diagram is labeled "Rain Only" and shows a circle containing many small blue dots. Below it is the text  $Z_H \gg Z_V \rightarrow ZDR \gg 0dB$ . The right diagram is labeled "Rain Mixed w/ Hail" and shows a circle containing many small blue dots and two larger yellow circles. Below it is the text  $Z_H > Z_V \rightarrow ZDR > 0dB$ .

#### Notes:

##### HYDROMETEOR BIAS

Z and ZDR are biased towards larger targets. For example, in the image on the left, the radar samples pure rain. In this case, ZDR is going to be positive. The image on the right has exact same amount of rain and drop sizes, but with some hail mixed in the volume. The ZDR will be lower for this example because ZDR will be more influenced by the larger hailstones, which are characterized by lower ZDR values.

##### PARTICLE DENSITY

The lower the particle density, the lower the ZDR. Therefore snow, which has a lower density than rain, tends to have a lower ZDR than rain.

##### MIE SCATTERING

Mie scattering, which occurs when targets are around 2 inches or greater in diameter, causes ZDR values to switch signs.

In other words, for a horizontally oriented particle that is roughly 2 inches in diameter, you would expect ZDR values to be positive, but it may actually appear negative. The opposite would also be true for vertically oriented particles.

Operationally, you will most likely see this impact with large hail. So, if you see high Z, low CC (< 0.9) and negative ZDR values, there is a good chance that golf ball size or larger hail is present.

##### LOW SNR / CC

When the signal-to-noise ratio is small, the ZDR will become noisy. The same is true for when the CCs drop below .95, like in the example shown.

## RANGE FOLDING

Range folding will obscure data in the batch cuts

## DEPOLARIZATION STREAKS

Depolarization streaks are seen as radial spikes of high or low ZDR. These are most common when look at a thunderstorm on one of the higher elevation scans.

See the reference shown for more information on what these streaks are.

## Hydro bias (Slide Layer)

**ZDR Limitations**

Click to learn more:

- Hydrometeor Bias
- Particle Density
- Mie Scattering
- Low Signal-to-Noise Ratio and CC
- Range Folding
- Depolarization Streaks

### Hydrometeor Bias

- ZDR biased toward larger hydrometeors

Rain Only	Rain Mixed w/ Hail
$Z_H \gg Z_V \rightarrow ZDR \gg 0dB$	$Z_H > Z_V \rightarrow ZDR > 0dB$

## Particle density (Slide Layer)

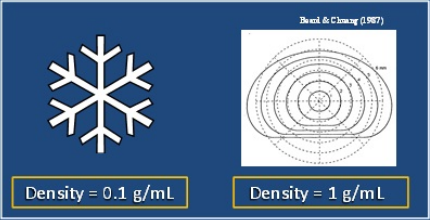
### ZDR Limitations

Click to learn more:

- Hydrometeor Bias
- Particle Density
- Mie Scattering
- Low Signal-to-Noise Ratio and CC
- Range Folding
- Depolarization Streaks

#### Particle Density

- Lower the particle density, the lower the ZDR



The diagram shows a snowflake on the left with a density of 0.1 g/mL and a rain drop on the right with a density of 1 g/mL. The rain drop is shown as a series of concentric circles, with a reference to 'Rosen & Chang (1987)'. Below the diagrams is the equation  $ZDR_{ice} < ZDR_{liquid}$ .

Density = 0.1 g/mL      Density = 1 g/mL

$ZDR_{ice} < ZDR_{liquid}$

## Mie Scattering (Slide Layer)

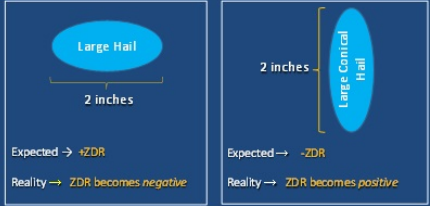
### ZDR Limitations

Click to learn more:

- Hydrometeor Bias
- Particle Density
- Mie Scattering
- Low Signal-to-Noise Ratio and CC
- Range Folding
- Depolarization Streaks

#### Mie Scattering

- Causes ZDR values to flip signs in hail > 2 inches



The diagram illustrates the effect of hail size on ZDR. On the left, a 'Large Hail' is shown as a blue oval with a horizontal dimension of '2 inches'. Below it, the text reads 'Expected → +ZDR' and 'Reality → ZDR becomes negative'. On the right, a 'Large Circular Hail' is shown as a blue oval with a vertical dimension of '2 inches'. Below it, the text reads 'Expected → -ZDR' and 'Reality → ZDR becomes positive'.

Large Hail      2 inches

Expected → +ZDR      Expected → -ZDR

Reality → ZDR becomes negative      Reality → ZDR becomes positive

## Low SNR / CC (Slide Layer)

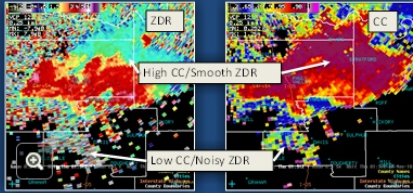
### ZDR Limitations

Click to learn more:

- Hydrometeor Bias
- Particle Density
- Mie Scattering
- Low Signal-to-Noise Ratio and CC
- Range Folding
- Depolarization Streaks

#### Low signal-to-noise ratio / CC

- ZDR is noisy in:
  - Low signal-to-noise ratio
  - Low CC (< .95)



## Range Folding (Slide Layer)

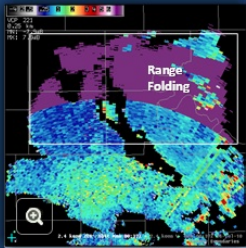
### ZDR Limitations

Click to learn more:

- Hydrometeor Bias
- Particle Density
- Mie Scattering
- Low Signal-to-Noise Ratio and CC
- Range Folding
- Depolarization Streaks

#### Range Folding

- RF obscures ZDR data in the batch cuts (between 1.65° and 6.5°)



Mitigate by:

- Changing PRF
- Clutter suppression
- Tilt up
- Select another radar

## Depolarization streaks (Slide Layer)

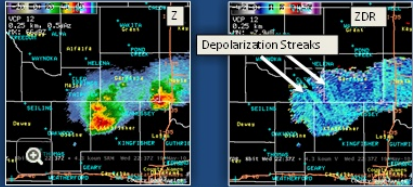
### ZDR Limitations

Click to learn more:

- Hydrometeor Bias
- Particle Density
- Mie Scattering
- Low Signal-to-Noise Ratio and CC
- Range Folding
- Depolarization Streaks

#### Depolarization Streaks

- Radial spikes of high or low ZDR
- Most common when viewing thunderstorms on higher tilts



Reference for cross-coupling depolarization streaks (Ryzhkov and Zrnic, 2007)

## 6. Additional info

### 6.1 Additional Info

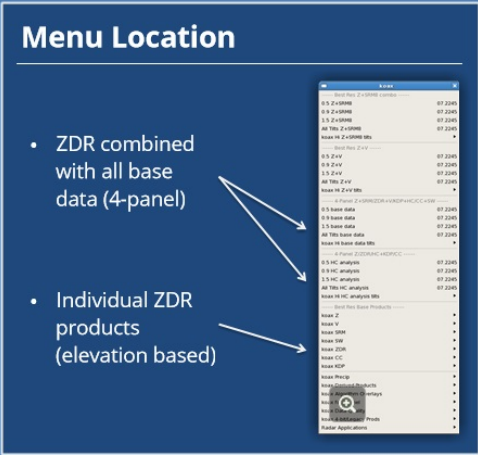
### Additional Info

Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### Menu Location

- ZDR combined with all base data (4-panel)
- Individual ZDR products (elevation based)



Notes:

## Menu loc (Slide Layer)


### Additional Info

Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### Menu Location

- ZDR combined with all base data (4-panel)
- Individual ZDR products (elevation based)



The screenshot shows a menu with several expandable sections. The first section is 'ZDR combined with all base data (4-panel)', which includes sub-items like 'ZDR', 'R', 'W', and 'V'. The second section is 'Individual ZDR products (elevation based)', which includes sub-items like 'ZDR', 'R', 'W', and 'V' for different elevation levels.

## Ann and legend (Slide Layer)


### Additional Info

Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### Annotation and Legend

- Product Annotation:**
  - VCP
  - Range/Az Resolution
  - Min ZDR
  - Max ZDR
- Product Legend:**
  - RPG ID, elevation angle, product name, units, data levels, date/time (UTC)



The screenshot shows a radar plot with a legend and product information. The legend is located in the bottom right corner and includes a color scale for ZDR. The product information is located in the bottom left corner and includes the product name 'ZDR', units 'dBZ', and date/time '2014-07-11T07:00:00Z'.

## Products available (Slide Layer)

### Additional Info

Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### Products Available

- Super-res is not available with ZDR at this time (8-bit only)

Product Name	Units	AWIPS ID	RPG ID	RPG Code	Data Levels	Range Res	Az Res	Max Range
Vertical Reflectivity Data Array Product	dB	ZDR	DZD	359	8-bit (256)	0.25 km	0.5 deg	300 km

## Super-res vs 8-bit (Slide Layer)

### Additional Info

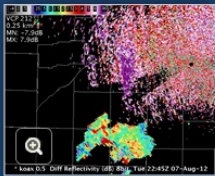
Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### 8-bit

##### 8-bit ZDR

- 1.0° × 0.25 km
- For all tilts



- In the split-cuts, you'll notice ZDR and CC are different resolutions than Z, V/SRM, and SW

# Specific Differential Phase (KDP)

## 1. Introduction

### 1.1 Title Slide



WFO TRAINING DIVISION

NWS

NOAA

Radar & Applications Course

Based and Derived Products  
Part I: Base Products

Specific Differential Phase (KDP)

Instructor: Austin Harris

#### Notes:

Welcome to the lesson on KDP

## 1.3 Learning Objectives

### Learning Objectives

---

- To **understand** the following about KDP:
  1. What is it?
  2. What should we use it for?

#### Notes:

The learning objective for this lesson is to understand the following about KDP:

What is it?

And what should we use it for?

## 2. Homepage

### 2.1 Homepage: KDP

The screenshot shows a blue-themed interface for the Specific Differential Phase (KDP) lesson. At the top, the title "Specific Differential Phase (KDP)" is displayed in yellow. Below the title, a section labeled "Click to learn more:" contains four white buttons with rounded corners:  $\Phi_{DP}$ , "What is KDP?", "Why is it useful?", and "Limitations". To the right of these buttons is a radar plot showing KDP data. The plot includes a color scale at the top and a data box with the following text: "WCP 212", "0.25 km", "MN: -2.05 Deg/km", and "MX: 5.65 Deg/km". The plot itself shows a cluster of red and orange pixels on a black background. At the bottom of the interface, there are two more buttons: "Additional Info" on the left and "Quiz" on the right, both with rounded corners.

#### Notes:

Welcome to the homepage for this lesson on Specific Differential Phase, or KDP. From here, you can click on these four buttons to learn more about KDPs predecessor, PHI DP, KDP itself, why it's a useful product, as well as its limitations in operations. Once you feel comfortable with these materials, click here to take the quiz.

## 3. Differential Phase

### 3.1 Differential Phase

The infographic features a blue background with a yellow title 'Differential Phase ( $\Phi_{DP}$ )'. On the left, there is a section titled 'Click to learn more:' with two buttons: 'Definition' and 'Interpretation'. The 'Definition' button is highlighted. To the right, under the heading 'Definition', a bullet point states: 'Difference between the horizontal and vertical two-way propagation phase shifts'. Below this, the formula  $\Phi_{DP} = \Phi_H - \Phi_V$  is displayed in a white box.

#### Notes:

##### DEFINITION

First off, it's important to know what Differential Phase is because KDP is derived from it. So, what is Phi DP? It's the difference between the horizontal and vertical two-way propagation phase shifts.

##### INTERPRETATION

The shape of the target affects PhiDP in the same way that it does ZDR. Horizontally oriented targets will produce an increasing, positive differential phase shift. Vertically oriented targets will produce a decreasing, negative differential phase shift, and spherical targets will be near zero. Unlike ZDR, PhiDP is dependent on particle concentration. The more particles there are in a pulse volume, the higher the PhiDP.

##### PHIDP IN RAIN

Just like with ZDR, the larger the raindrop, the more horizontally oriented it will be making for a larger PhiDP. But unlike ZDR, a large number of drops will also lead to a large PhiDP.

##### PHIDP IN HAIL

Since hail tends to tumble as it falls, it appears spherical on radar which causes PhiDP to be near zero. The one caveat to this is that when small, sub-severe hail is nearly melted, it appears on radar as large raindrops which can cause PhiDP to be very high.

For the most part, PhiDP in rain is unaffected by the presence of hail. This means that if we have two pulse volumes with the same amount and type of rain and one has hail and the other does not, PhiDP will be identical despite the presence of hail.

## PHIDP IN SNOW/ICE

PhiDP in snow and ice is typically near zero degrees since they don't fall with a preferred orientation.

The one exception to this rule is when ice crystals become aligned due to some outside force, such as a strong electric field inside a thunderstorm. This forcing leads to crystal alignment and can cause PhiDP to go large and positive when the orientation is horizontal, and large and negative when the orientation is vertical.

### Definition (Slide Layer)

## Differential Phase ( $\Phi_{DP}$ )

Click to learn more:

- Definition
- Interpretation

### Definition

- Difference between the horizontal and vertical two-way propagation phase shifts

$$\Phi_{DP} = \Phi_H - \Phi_V$$

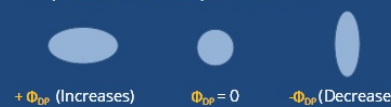
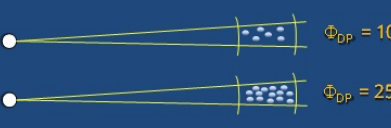
### Interpretation (Slide Layer)

## Differential Phase ( $\Phi_{DP}$ )

Click to learn more:

- Definition
- Interpretation

### Interpretation

- Dependent on shape (like ZDR)
  - 
- Dependent on particle concentration
  - 

## 4. What is KDP?

### 4.1 What is KDP?

The image shows a presentation slide with a blue background. At the top left, the title "What is KDP?" is written in yellow. Below the title is a navigation menu with five buttons: "Definition", "Why not  $\Phi_{DP}$ ?", "Why KDP?", "Comparison", and "Typical Values of KDP". To the right of the menu is a "Definition" section. It contains a bullet point: "KDP is the range derivative of the differential phase shift ( $\Phi_{DP}$ )". Below this is a mathematical equation for KDP: 
$$KDP = \frac{\Phi_{DP}(r_2) - \Phi_{DP}(r_1)}{2(r_2 - r_1)}$$

#### Notes:

##### DEFINITION

Specific differential phase shift, or KDP, is the range derivative of the differential phase shift, PhiDP.

##### WHY NOT PHIDP?

Why not PhiDP? Well in short, it's because PhiDP is cumulative and difficult to interpret when compared to KDP as you'll see later on.

For more information regarding why it's cumulative, check out the notes tab in this lesson which will explain the graphic below.

Notes: Well, let's look at the example here of Phi DP for two rain shafts at 30 and 70 km from the radar. As the horizontal and vertical pulses propagate toward the first rain shaft, they experience zero differential phase shifting, so Phi DP is zero. As the pulses go through the first rain shaft, the horizontal pulse slows down faster than the vertical pulse resulting in a positive differential phase shift. We'll say it is 20 degrees. After exiting the rain shaft, the pulses enter clear air and experience zero additional differential phase shifting. However those bins in the clear air will show a differential phase shift of 20 degrees because the differential phase shift cannot reset itself along a radial. In the second rain shaft, the differential phase shift will increase again, and let's say it increases by 15 degrees. In those bins and any bin further down range, the differential phase shift will be 35 degrees. As you can see, the differential phase shift is cumulative and the absolute value tells you nothing about what is going on in that particular bin, but rather all that has happened along the radial up to that point.

##### WHY KDP?

So why KDP over PhiDP? Well KDP shows where PhiDP is changing, which is more meteorologically relevant. If you would like more information about this, see the notes section which will explain the graphic below.

Notes: Up until the rain shaft no differential phase shifting is occurring, so 0 degrees divided over any distance will give 0 degrees/distance. Therefore, anywhere within 25 km of the radar has a KDP of 0 deg/km. Inside the rain shaft, we said there was differential phase shifting of 20 degrees. If we divide this by twice the distance over which it occurred (10 km) we get a KDP of 2 deg/km. In the clear air past the first rain shaft, the differential phase shift remains 20 degrees but does not change over this distance. So, KDP will go back to 0 deg/km in this region because the difference between any two differential phase shifts over any distance in this region will be 0. In the second rain shaft, the differential phase shift increases from 20 degrees to 35 degrees, so it increases by 15 degrees. Dividing this value by twice the distance over which it occurred (10 km) gives a KDP of 1.5 deg/km. Past the second rain shaft, the KDP goes back to 0 deg/km for the same reasons it did in the clear air in between the two rain shafts. As you can see, KDP is much better at giving you information about what is happening at that particular bin than is Phi DP.

## COMPARISON

Here is an example of PhiDP and KDP in AWIPS2. Notice how PhiDP is cumulative, meaning that the values increase downradial. Meanwhile, it is easier to discern regions of interest in KDP.

## TYPICAL VALUES FOR KDP

Here are the typical values for KDP given various types of echoes. Notice how there's a large range of KDP for rain. This is advantageous for spotting regions of heavy rain, as we'll show later.

## Definition (Slide Layer)

**What is KDP?**

Click to learn more:

- Definition
- Why not  $\Phi_{DP}$ ?
- Why KDP?
- Comparison
- Typical Values of KDP

**Definition**

- KDP is the range derivative of the differential phase shift ( $\Phi_{DP}$ )

$$KDP = \frac{\Phi_{DP}(r_2) - \Phi_{DP}(r_1)}{2(r_2 - r_1)}$$

## Why not phi dp (Slide Layer)

### What is KDP?

Click to learn more:

- Definition
- Why not  $\Phi_{DP}$ ?
- Why KDP?
- Comparison
- Typical Values of KDP

#### Why not $\Phi_{DP}$ ?

- $\Phi_{DP}$  is cumulative, difficult to interpret

The diagram shows two vertical profiles of a rain shaft. The left profile has a 25 km clear air layer below a 5 km rain shaft. The right profile has a 35 km clear air layer below a 5 km rain shaft. Below the profiles, a temperature profile is shown with a magnifying glass over the first 5 km. The temperature starts at 0 deg and increases to 20 deg in the first 5 km, then remains constant at 20 deg for the next 35 km, and finally increases to 35 deg in the last 5 km.

0 deg	increasing to 20 deg	20 deg	increasing to 35 deg	35 deg
-------	----------------------	--------	----------------------	--------

## Why KDP (Slide Layer)

### What is KDP?

Click to learn more:

- Definition
- Why not  $\Phi_{DP}$ ?
- Why KDP?
- Comparison
- Typical Values of KDP

#### Why KDP?

- Shows where  $\Phi_{DP}$  is changing, which is more meteorologically significant

The diagram shows two vertical profiles of a rain shaft, identical to the one in the first slide. Below the profiles, a temperature profile is shown with a magnifying glass over the first 5 km. The temperature starts at 0 deg/km, increases to 2 deg/km in the first 5 km, then remains constant at 2 deg/km for the next 35 km, and finally decreases to 0 deg/km in the last 5 km.

0 deg/km	2 deg/km	0 deg/km	1.5 deg/km	0 deg/km
----------	----------	----------	------------	----------

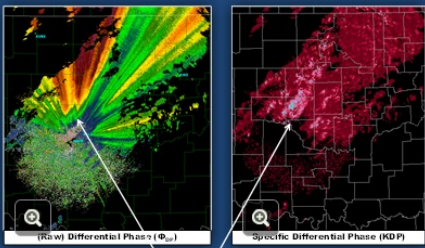
## Comparison (Slide Layer)

### What is KDP?

Click to learn more:

- Definition
- Why not  $\Phi_{DP}$ ?
- Why KDP?
- Comparison
- Typical Values of KDP

#### Comparison



- Rain from a thunderstorm easier to spot in KDP

## Typical Values (Slide Layer)

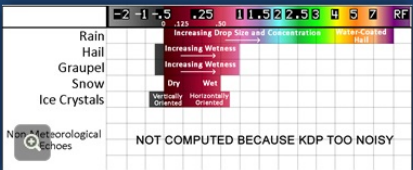
### What is KDP?

Click to learn more:

- Definition
- Why not  $\Phi_{DP}$ ?
- Why KDP?
- Comparison
- Typical Values of KDP

#### Typical Values for KDP

- Large range for rain



Rain	Increasing Wetness
Hail	Increasing Wetness
Graupel	Increasing Wetness
Snow	Dry
Ice Crystals	Wet

NOT COMPUTED BECAUSE KDP TOO NOISY

## 5. Why is it useful?

### 5.1 Why is it useful?

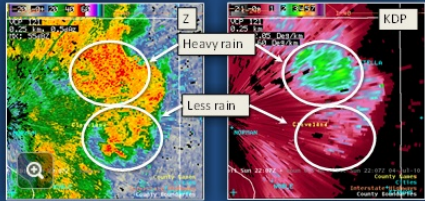
## Why is KDP useful?

Click to learn more:

- Heavy Rain
- Rain / Hail Mix
- Small Hail Caveat
- Warm vs Cold Rain

### Heavy Rain

- Identify heavy rain with KDP of 4-5° / km



#### Notes:

##### HEAVY RAIN

The primary advantage of KDP is its ability to detect heavy rain. In this example, we show two areas of similar reflectivity. However looking at KDP, we see that the northern region has much heavier rainfall.

##### RAIN/HAIL MIX

KDP is mostly immune to hail contamination. Here is an example to illustrate. For the furthest west circle, we see high reflectivity, moderate ZDR around 4 db telling us we have good-sized drops, and high KDP telling us there's a lot of liquid water in this region. Flash flooding could be a concern here.

Contrast that with the middle circle, which has even higher reflectivity, near zero ZDR and near zero KDP. This is likely hail.

Lastly, we see lower reflectivity with the easternmost circle, high ZDR and low KDP. This tells us we have large rain drops, but in low concentrations in this region, so rainfall is going to be minimal.

##### SMALL HAIL CAVEAT

In small, mostly melted hail the KDP's will be as large as 5-6 degrees per km. KDP rarely gets this high even in the heaviest pure rain.

##### WARM VS COLD RAIN

Here is the example from 2 slides ago, except now we are showing ZDR and KDP together. Recall that Z was similar in both areas highlighted here. Note, to the north, ZDR are moderately high but don't really exceed 3 dB. However, to the south, ZDR are approaching 4-5 dB. This tells us that larger drops are occurring to the south and smaller drops to the north. But, KDP is telling us heavier rain is occurring to the north. What gives? This is an example of how KDP, with ZDR, can reveal warm-rain vs cold-rain processes. And, if you see warm-rain processes, this indicates very efficient rainfall.

## Heavy rain (Slide Layer)


### Why is KDP useful?

Click to learn more:

- Heavy Rain
- Rain / Hail Mix
- Small Hail Caveat
- Warm vs Cold Rain

#### Heavy Rain

- Identify heavy rain with KDP of 4-5° / km



## Rain / hail mix (Slide Layer)

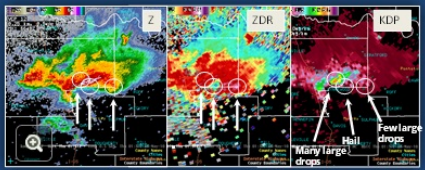
### Why is KDP useful?

Click to learn more:

- Heavy Rain
- Rain / Hail Mix
- Small Hail Caveat
- Warm vs Cold Rain

#### Rain / Hail Mix

- Identifying rain, hail, or rain mixed with hail



## Small hail caveat (Slide Layer)

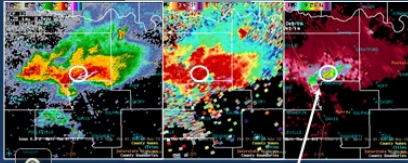
### Why is KDP useful?

Click to learn more:

- Heavy Rain
- Rain / Hail Mix
- Small Hail Caveat
- Warm vs Cold Rain

#### Small Hail Caveat

- Small, mostly melted hail will have  $KDP > 5-6^\circ / km$



KDP rarely gets this high even in the heaviest pure rain

## Warm vs cold rain (Slide Layer)

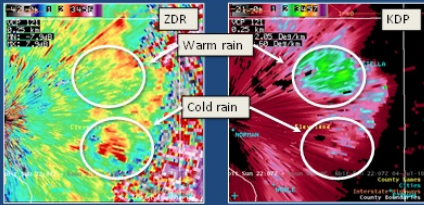
### Why is KDP useful?

Click to learn more:

- Heavy Rain
- Rain / Hail Mix
- Small Hail Caveat
- Warm vs Cold Rain

#### Warm vs Cold Rain

- Identify warm (efficient) vs cold rain (inefficient) processes



## 6. Limitations

### 6.1 Limitations

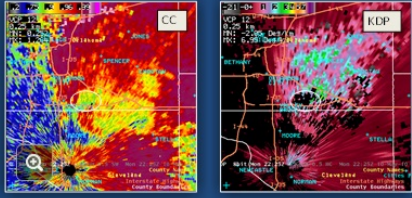
### KDP Limitations

Click to learn more:

- CC < 0.9
- Low Signal-to-Noise Ratio
- Non-uniform Beam Filling
- Range Folding

#### CC < 0.9

- KDP not shown for CC < 0.9



#### Notes:

CC < 0.9

KDP is not shown for CC < 0.9 and will appear as black holes in the data.

LOW SNR

KDP will be noisy in region of low signal-to-noise ratio, like in the example shown.

NFB

Non-uniform beam filling will cause the CC to decrease down the radials that experience it. And since KDP isn't computed for CC < 0.9, the KDP will drop out in these areas.

RF

Range folding will obscure KDP data in the batch cuts, as it does with many of the other dual pol products.

## CC < 0.9 (Slide Layer)

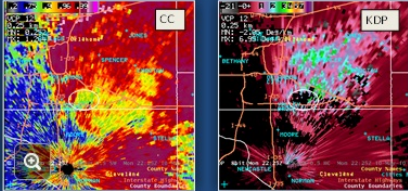
### KDP Limitations

Click to learn more:

- CC < 0.9
- Low Signal-to-Noise Ratio
- Non-uniform Beam Filling
- Range Folding

#### CC < 0.9

- KDP not shown for CC < 0.9



## Low SNR (Slide Layer)

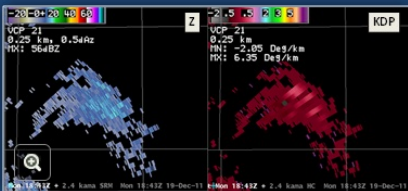
### KDP Limitations

Click to learn more:

- CC < 0.9
- Low Signal-to-Noise Ratio
- Non-uniform Beam Filling
- Range Folding

#### Low Signal-to-Noise Ratio

- Noisy in regions of low signal-to-noise ratio



## NBF (Slide Layer)

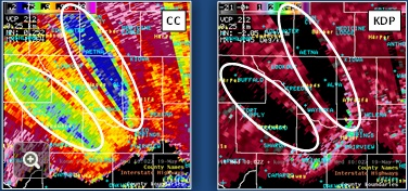
### KDP Limitations

Click to learn more:

- CC < 0.9
- Low Signal-to-Noise Ratio
- Non-uniform Beam Filling
- Range Folding

#### Non-uniform Beam Filling

- Not available in areas of non-uniform beam filling



## RF (Slide Layer)

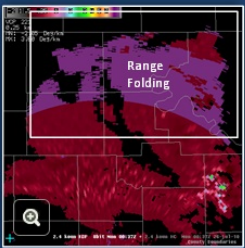
### KDP Limitations

Click to learn more:

- CC < 0.9
- Low Signal-to-Noise Ratio
- Non-uniform Beam Filling
- Range Folding

#### Range Folding

- RF will obscure KDP data in the batch cuts (between 1.65° and 6.5°)



Mitigate by:

- Changing PRF
- Clutter suppression
- Tilt up
- Select another radar



## Menu loc (Slide Layer)


### Additional Info

Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### Menu Location

- KDP combined with all base data (4-panel)
- Individual KDP products (elevation based)



## Ann and legend (Slide Layer)


### Additional Info

Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### Annotation and Legend

- Product Annotation:**
  - VCP
  - Range/Az
  - Resolution
  - Min KDP
  - Max KDP
- Product Legend:**
  - RPG ID, elevation angle, product name, units, data levels, date/time (UTC)



## Products available (Slide Layer)

### Additional Info

Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### Products Available

- This lesson focuses on these products available in AWIPS
- Second better known as "Raw Phi DP"

Product Name	Units	AWIPS ID	SPG ID	SPG Code	Data Levels	Range Res.	Az Res.	Max Range
Specific Differential Phase Data Array Product	deg/km	ADP	OND	363	8-bit (256)	0.25 km	0.5 deg	300 km
Specific Differential Phase Data Array Product	deg/km	SDP	SDP	368	8-bit (256)	0.25 km	0.5 deg	300 km

## Super-res vs 8-bit (Slide Layer)

### Additional Info


Click to learn more:

- Menu Locations
- Annotation and Legend
- Products Available
- 8-bit

#### 8-bit

##### 8-bit KDP

- 1.0° x 0.25 km
- For all tilts



- In the split-cuts, you'll notice KDP (and CC/ZDR) is a different resolution than Z, V/SRM, and SW

# Base Data Cross-Section Tools

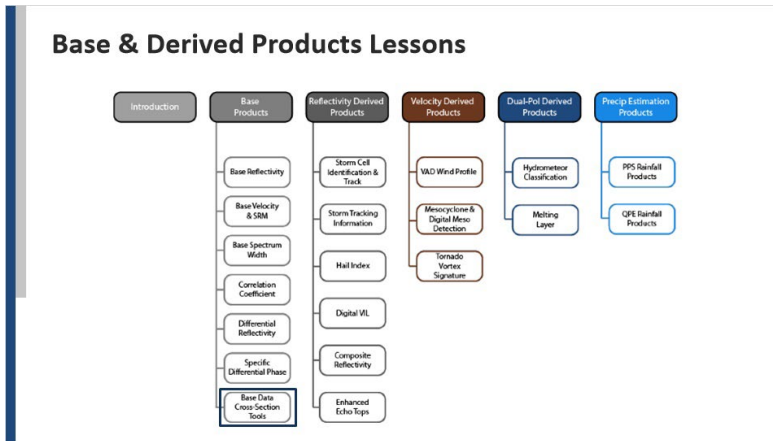
## *Introduction*



### **Notes:**

Welcome to this lesson on Base Data Cross-Section Tools. This training is part of the Base and Derived Products topic in the Radar and Applications Course. Let's get started.

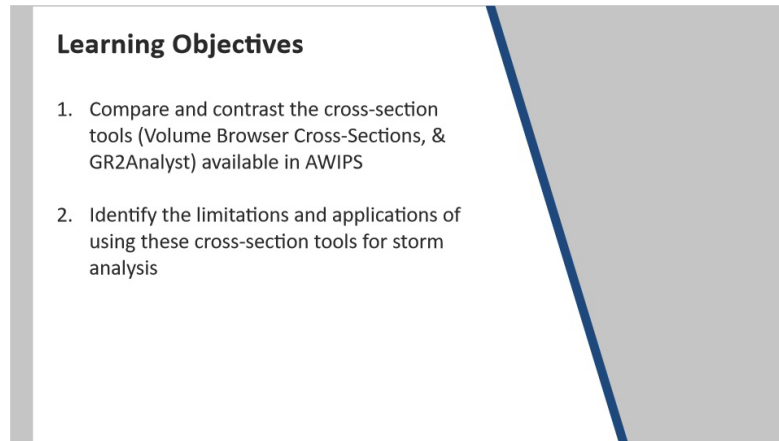
## Base & Derived Products Lessons



### Notes:

Here is a roadmap for the lessons in this topic. This lesson on the Base Data Cross-Section Tools, highlighted on the slide, is the last part of the Base Products Section of this topic.

## ***Learning Objectives***



**Learning Objectives**

1. Compare and contrast the cross-section tools (Volume Browser Cross-Sections, & GR2Analyst) available in AWIPS
2. Identify the limitations and applications of using these cross-section tools for storm analysis

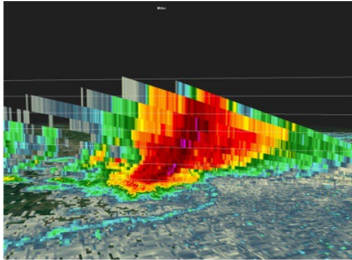
### **Notes:**

Here are the learning objectives for this lesson. Take a moment to read these objectives. Advance the slide when you are ready.

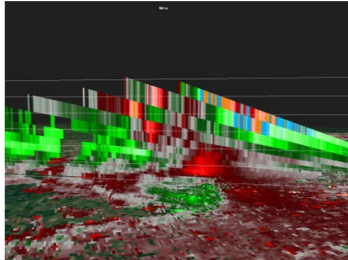
## ***Cross-Sectional Analysis***

### **Cross-Sectional Analysis**

Great way to assess severity of storms



Reflectivity Cross-Section



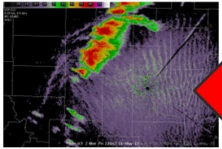
Velocity Cross-Section


### **Notes:**

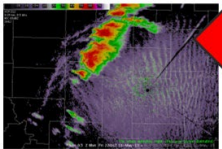
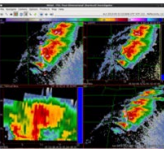
Cross-sections are a great way to assess storm severity, especially cross-sections of base data like Z, V, ZDR, CC, etc. This lesson introduces the two tools most NWS forecasters can use to generate cross-sections. Interpretation of cross-section plots will be covered in the convective storms topic lessons found later in the course.

## Note on FSI

**Note on FSI**

1) 

2) 



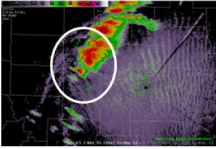
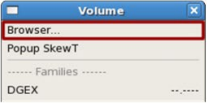
3)  

### Notes:

In previous versions of this course, we discussed the Four-Dimensional Storm Interrogator (FSI) as one of the Cross-Section tools available to NWS forecasters. Due to technical issues, the current guidance to NWS forecast offices is to disable FSI on their operational systems. As a result, we have removed the FSI content from this lesson. There are plans for a FSI replacement tool in AWIPS. Once that cross-section tool becomes available, this lesson will include information on using that tool. As of right now, we don't know when that new tool will be available.

## **Reminder: Choosing a Baseline for the Volume Browser (VB)**

**Reminder: Choosing a Baseline for the Volume Browser (VB)**

- 1) 
- 2) 
- 3) 
- 4) 

### **Notes:**

Now let's discuss cross-sections generated using the Volume Browser. Here are the steps for loading a cross-section using this tool:

1. Load a 0.5 deg base data display with Reflectivity;
2. Load "Baselines" from the Tools menu;
3. Adjust one of the baseline's length and orientation to sample your storm of interest; and
4. Start the Volume Browser from the Volume menu.

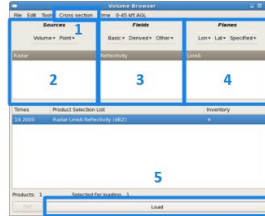
We will cover the remaining steps on the next slide.

## Reminder: Using the Volume Browser

### Reminder: Using the Volume Browser

Loading data via the VB:

1. "Cross Section" from Tools menu
2. "Sources" choose "Radar"
3. "Fields" choose product of choice
4. "Planes" choose adjusted baseline
5. Click "Load"

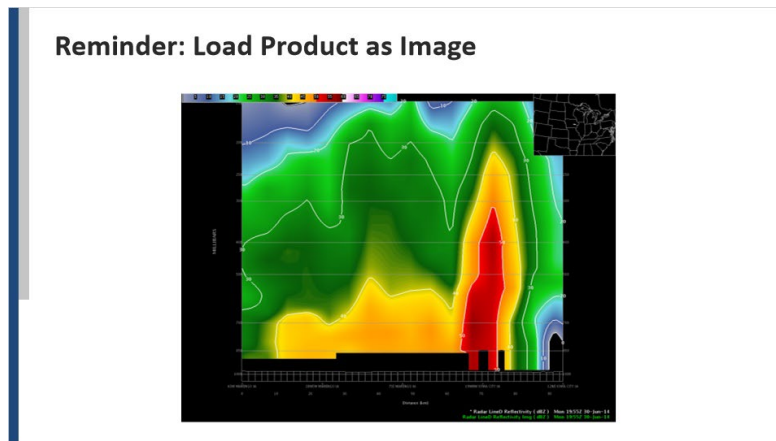


### Notes:

Once the Volume Browser window appears, follow these steps:

1. Choose "cross-section" from the tools menu;
2. Choose "Radar" for the Source;
3. Choose the base data product you want to view for the Fields;
4. Choose the baseline you edited for the Planes; and
5. Once the product you selected appears in the bottom panel, click "Load".

## ***Reminder: Load Product as Image***



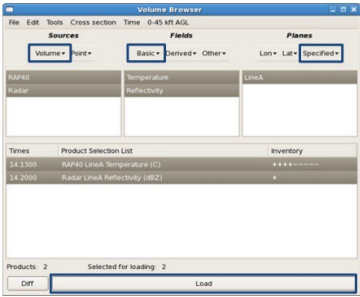
### **Notes:**

When your cross-section first loads, it appears initially as just contours. You will likely want to make your radar product cross-section an image product instead. To make that change, right-click over the product legend info and choose "Load as Image" from the menu that appears. Here's an important note: You will want to create a new color table specifically for cross-sections if you continue to use them. The cross-section plots use a smaller range of values than standard PPI displays, so using the same color table in a volume browser cross-section will make storms appear visually weaker.

One other thing you should know. One major issue limits use of Volume Browser cross-sections at the moment. Only Reflectivity will display properly. The functionality should be addressed at some point in the future, but the fix has been kicked down the road for now.

## Overlaying Environmental Data

**Overlaying Environmental Data**



The screenshot shows the 'Volume Browser' window with the following configuration:

- Sources:** Volume
- Fields:** Basic
- Planes:** Lon, Lat, Specified
- Parameters:** Radar (selected), Temperature, Reflectivity, LinA
- Product Selection List:**

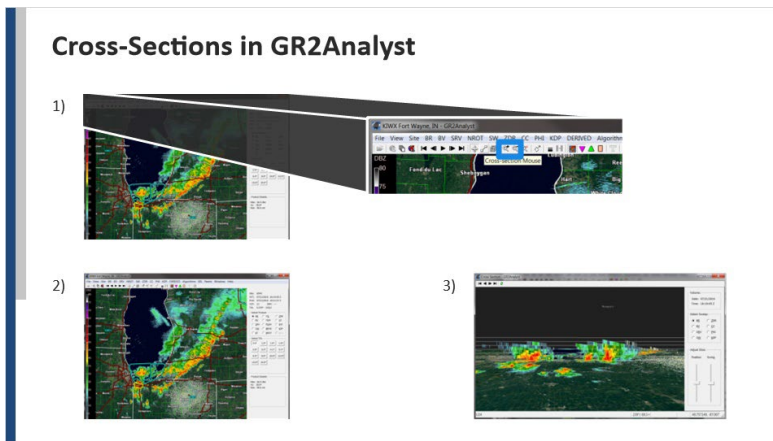
Times	Product Selection List	Inventory
14-1300	RAFA0 LinA Temperature (C)	++++
14-2000	Radar LinA Reflectivity (dBZ)	+
- Product:** 2
- Selected for loading:** 2
- Buttons:** Off, Load

Add the data source in the VB window along with radar data

### Notes:

With Volume Browser product cross-sections, you can overlay environmental data such as temperature directly on your image. Just choose the data source and field for the parameter you want to overlay, then use same baseline for your Plane, and AWIPS will plot the parameter on top of the original cross-section.

## 1.11 Cross-Sections in GR2Analyst

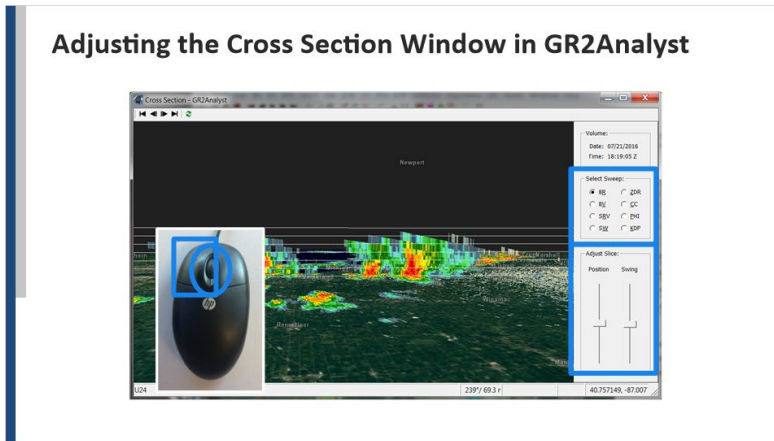


### Notes:

Next, let's talk about GR2Analyst. Unlike the previous method of generating cross-sections, we have not been training you on how to use this application in previous lessons. However, for the sake of time, I'm just going to assume that most NWS forecasters have an elementary knowledge of GR2Analyst as a third-party application. With that in mind, here are the steps for generating a vertical cross-section:

- 1.
2. Select the Cross-section Mouse from the toolbar in the main GR2Analyst window;
3. Drag out a straight-line in the display window; and
4. The cross-section will appear in a new Cross Section window.

## ***Adjusting the Cross Section Window in GR2Analyst***



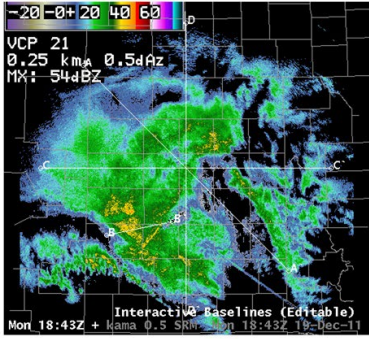
### **Notes:**

You have several options available to adjust the cross-section display in GR2Analyst:

1. To zoom in and out, you can use the scroll wheel;
2. A left-mouse click and hold will allow you to drag or rotate your display in three-dimensions;
3. You can use the "Select Sweep" radio buttons on the right to change the product shown in the display; and
4. The "Adjust Slice" slider bars allow you to fine tune the location of your cross-section baseline.

## ***Product Limitations #1: Baselines Don't Dynamically Update (VB)***

**Product Limitations #1: Baselines Don't Dynamically Update (VB)**

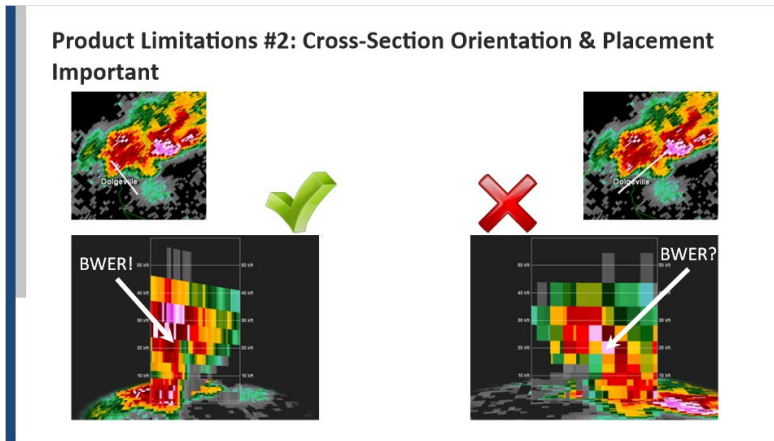


Must re-load product from VolumeBrowser to display new cross-sections

### **Notes:**

Unlike in GR2Analyst, cross-sections generated by the Volume Browser do not dynamically update when you change the baseline. In other words, each time you change the baseline, you must re-load the product from within the Volume Browser to display the new cross-section. This workflow can be prohibitively cumbersome during high end events.

## ***Product Limitations #2: Cross-Section Orientation & Placement Important***

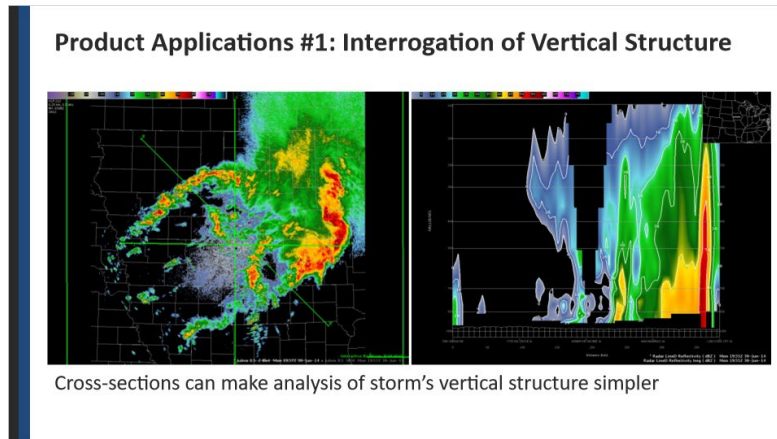


### **Notes:**

The last limitation we will mention regards the orientation of the cross-section. Improper orientation of your cross-section baseline can result in you missing important storm features. Let's use the example we show on the slide.

In the reflectivity images shown, I suspect a thunderstorm has a Bounded Weak Echo Region (BWER), and I want to analyze the storm using a cross-section. The baseline on the left properly dissects the updraft, allowing me to clearly see the BWER and reflectivity overhang. The baseline on the right still dissects the updraft, but the BWER's appearance is questionable. So, you can see how the orientation and placement of the baseline is crucial when searching for specific features.

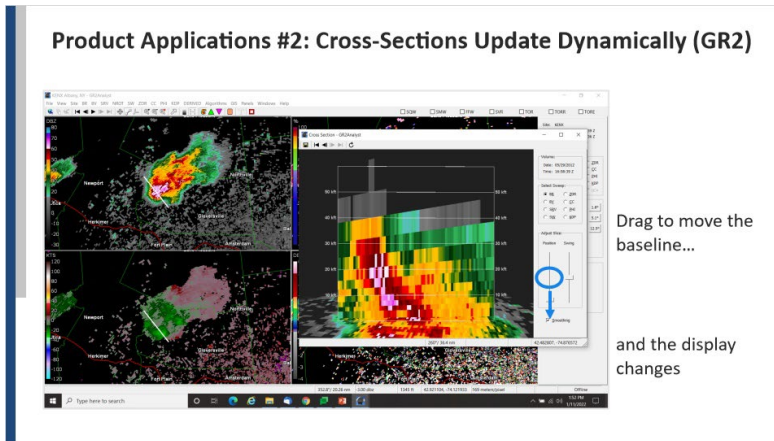
## ***Product Applications #1: Interrogation of Vertical Structure***



### **Notes:**

Now let's look at some applications with these products. Both types of cross-sections are much easier to create than the old RPG-based cross-sections. These solutions make it simpler to analyze the vertical structure of storms in real-time, which aides in warning operations.

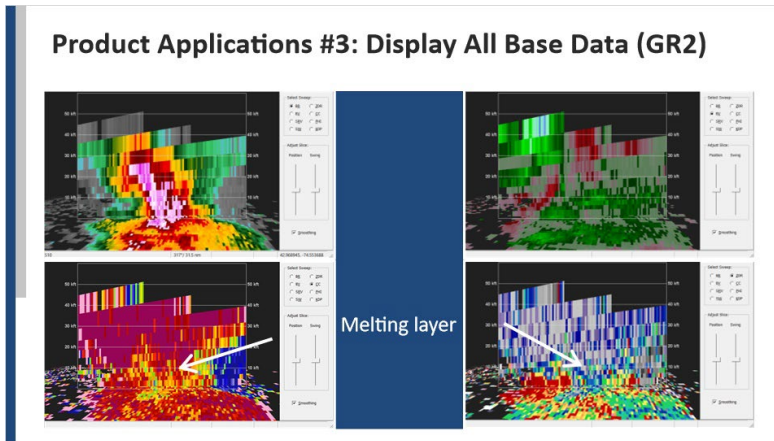
## Product Applications #2: Cross-Sections Update Dynamically (GR2)



### Notes:

If you choose GR2Analyst to display cross-sections, the application allows for dynamically updating your baseline. For example, if you click and drag down the Position slider you will see the display change in the Cross Section panel. You can adjust the position of the cross-section or swing it using this tool.

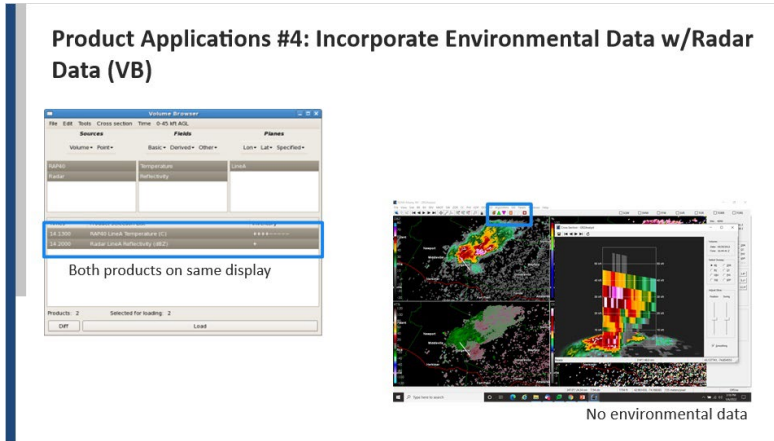
### ***Product Applications #3: Display All Base Data (GR2)***



#### **Notes:**

The Volume Browser only generates cross-sections for Reflectivity. GR2Analyst can display all base data in a cross-section, which can be very handy if you are trying to identify a feature, like the melting layer, as in the Correlation Coefficient and Differential Reflectivity images shown here.

## ***Product Applications #4: Incorporate Environmental Data w/Radar Data (VB)***



### **Notes:**

Lastly, the Volume Browser cross-sections allow you to overlay environmental data directly on the display. GR2Analyst has the ability overlay surface data and other GIS shape files on the standard plots, too, but its cross-section displays doesn't provide the same capabilities as the volume browser cross-sections.

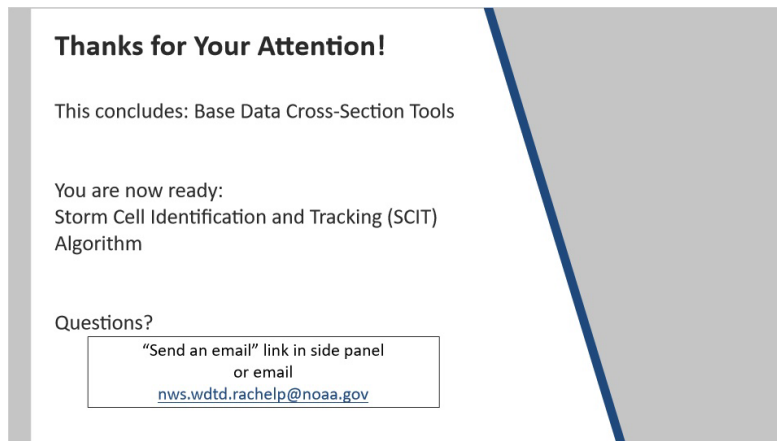
## ***Summary: Cross Sections***

<b>Summary: Cross Sections</b>	
<b>Volume Browser (VB):</b>	<b>GR2Analyst (GR2):</b>
<u>Applications</u>	<u>Applications</u>
<ul style="list-style-type: none"><li>• Overlay environmental data (i.e. temp)</li><li>• Easy interrogation of storms</li></ul>	<ul style="list-style-type: none"><li>• Dynamically updates</li><li>• Displays all base data</li><li>• Easy interrogation of storms</li></ul>
<u>Limitations</u>	<u>Limitations</u>
<ul style="list-style-type: none"><li>• Does not dynamically update</li><li>• Only Z available for now</li></ul>	<ul style="list-style-type: none"><li>• Not integrated into AWIPS</li></ul>

### **Notes:**

In summary, both the Volume Browser and GR2Analyst are all useful tools for doing cross-sectional analysis. There are several advantages to these tools. First, all base data are available (at least with GR2 Analyst). It's easier to update the data when needed. You can also include environmental data into your analysis. While there are limitations with these tools, most of the limitations exist with any cross-sectional tool you would use for radar analysis.

## ***Thanks for Your Attention!***



**Thanks for Your Attention!**

This concludes: Base Data Cross-Section Tools

You are now ready:  
Storm Cell Identification and Tracking (SCIT)  
Algorithm

Questions?

"Send an email" link in side panel  
or email  
[nws.wtdt.rachelp@noaa.gov](mailto:nws.wtdt.rachelp@noaa.gov)

### **Notes:**

If you have passed the quiz, then you have successfully completed this lesson. You are now ready to move onto the next lesson (on the SCIT algorithm). If you have any questions, please contact us using the e-mail address listed below.

# Range-Defined Quasi-Vertical Profiles (RDQVPs)

## *Introduction*



## **Notes:**

Welcome to this lesson in the base and derived products section of RAC titled "Range-Defined Quasi-Vertical Profiles or RDQVPs."

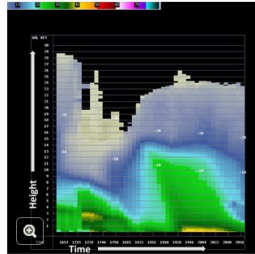
## What is the RDQVP?

### What is the RDQVP?

- Time-height profiles of base data products centered on the RDA location
  - Developed by Tobin and Kumjian (2017)
  - Range-weighted vertical profiles of Z, ZDR, CC and KDP
  - Averages data from within **50 km** of RDA
  - **NOT** to be mistaken for cross-sections

#### More details:

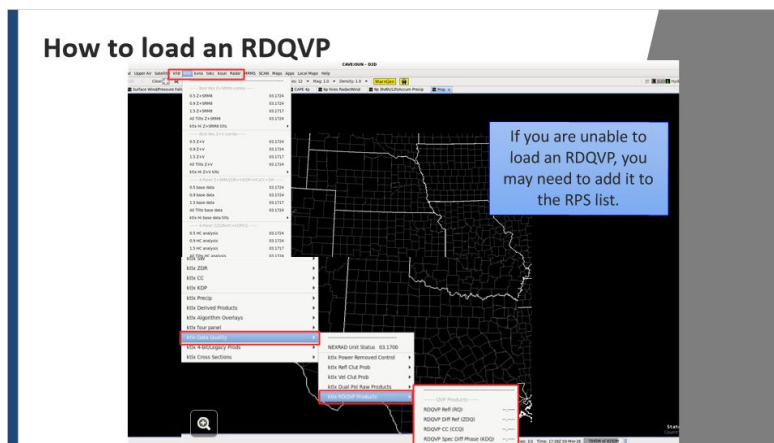
- Doesn't use SAILS or MRLE tilts
- Supplemental low-level tilts (SLEA) are used
- 20-meter resolution up to a height of 30 kft



### Notes:

Let's first begin with what is a Range Defined Quasi-Vertical Profile? It's a time-height profile of base data products centered on the RDA location developed by Tobin and Kumjian 2017. The product provides range-weighted vertical profiles of reflectivity, differential reflectivity, correlation coefficient, and specific differential phase, with time plotted on the x-axis and height in kft on the y-axis. The data is averaged from within 50 kilometers of the RDA at each height to create profiles each volume scan. These should NOT be mistaken for traditional cross-sections. Note, RDQVPs do not use SAILS or MRLE tilts, but does include supplemental low-level tilts. These products have a 20-meter resolution up to a vertical height of 30 kft.

## How to load an RDQVP



### Notes:

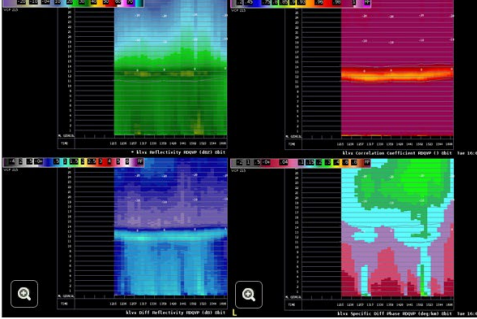
You can load an RDQVP by going to the AWIPs drop-down menu, selecting the radar you would like to view, scrolling all the way to the bottom and selecting {your radar} data quality, then selecting {your radar} RDQVP products. You will then have the option to individually load the RDQVP products you would like to view. If you are having trouble viewing the RDQVP, you may need to add it to the RPS list.

## RDQVP Demonstration

**RDQVP Demonstration**

- Example of a 4-panel (Z, CC, ZDR, KDP)
  - V and SW can also be displayed
- Not adjustable: height, height resolution, number of volume scans

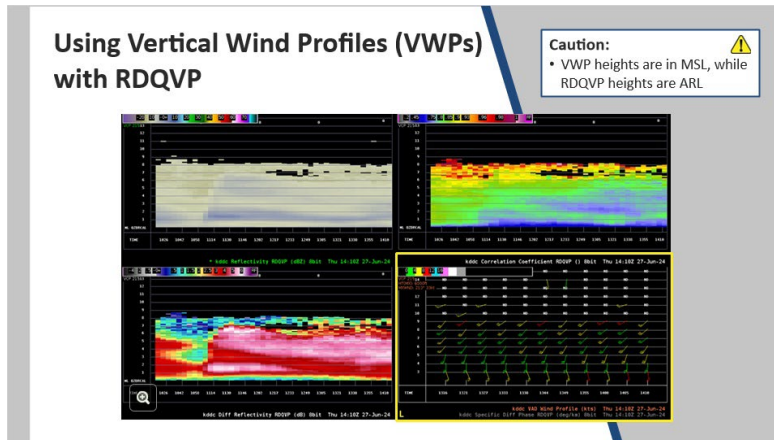
**Convection**



### Notes:

This is an example of how to use RDQVPs in operations. The example here is from a convective event from Louisville, Kentucky. Here's a 4-panel of reflectivity, correlation coefficient, differential reflectivity, and specific differential phase. Velocity and spectrum width can also be displayed. As of right now height, height resolution, and number of volume scans can't be adjusted.

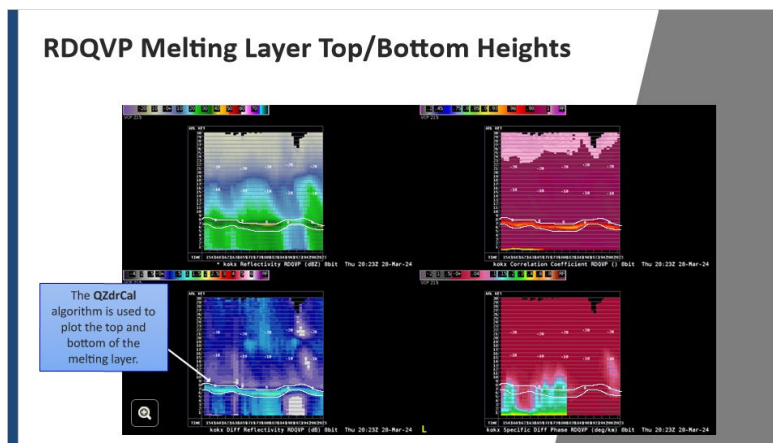
## Using Vertical Wind Profiles (VWPs) with RDQVP



### Notes:

Forecasters have the ability to pair RDQVPs with Vertical Azimuth Display (VAD) wind profiles by loading it to their desired panel. Simply, select a panel and use “load to this panel” to display the VAD Wind Profile. Note, VWP heights are at mean sea level (MSL), while RDQVP are above radar level (ARL).

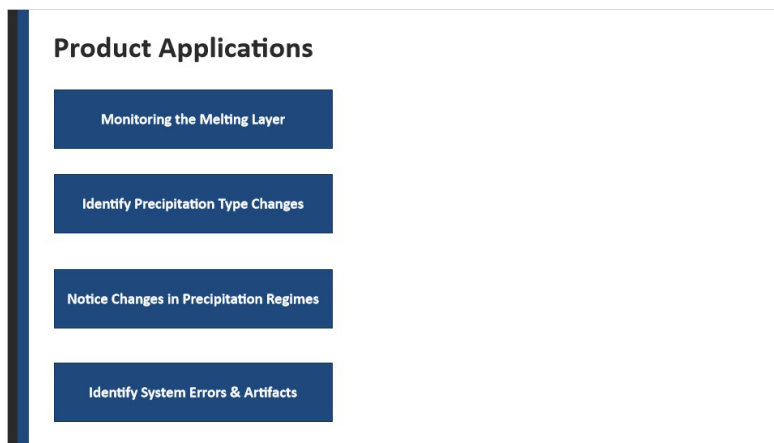
## ***RDQVP Melting Layer Top/Bottom Heights***



### **Notes:**

The RDQVP product plots two lines detecting the top and bottom of the melting layer. It does so using an algorithm called QZdrCal that analyzes the RDQVP data to find the melting layer. The top and bottom of the melting layer is depicted by the two white contours overlaying the time-height plots. If there is not sufficient data to identify a melting layer, these lines will not be plotted.

## ***Product Applications***

A vertical menu titled "Product Applications" with four blue buttons. The buttons are stacked vertically and contain the following text from top to bottom: "Monitoring the Melting Layer", "Identify Precipitation Type Changes", "Notice Changes in Precipitation Regimes", and "Identify System Errors & Artifacts".

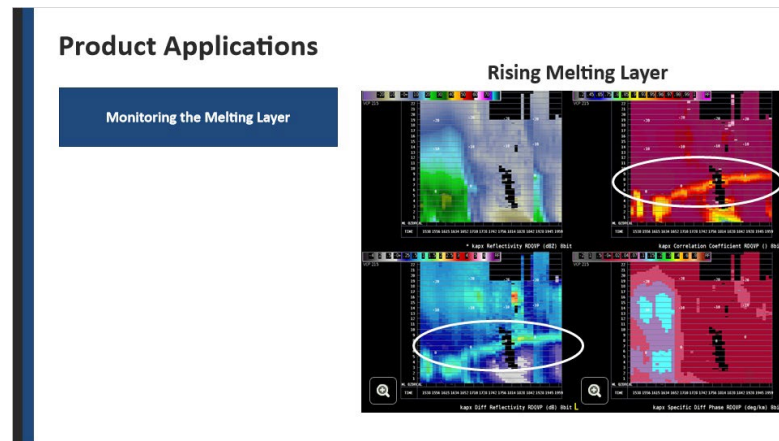
**Product Applications**

- Monitoring the Melting Layer
- Identify Precipitation Type Changes
- Notice Changes in Precipitation Regimes
- Identify System Errors & Artifacts

### **Notes:**

Click through each of the product applications below to learn more. Once you have reviewed each example, click "next".

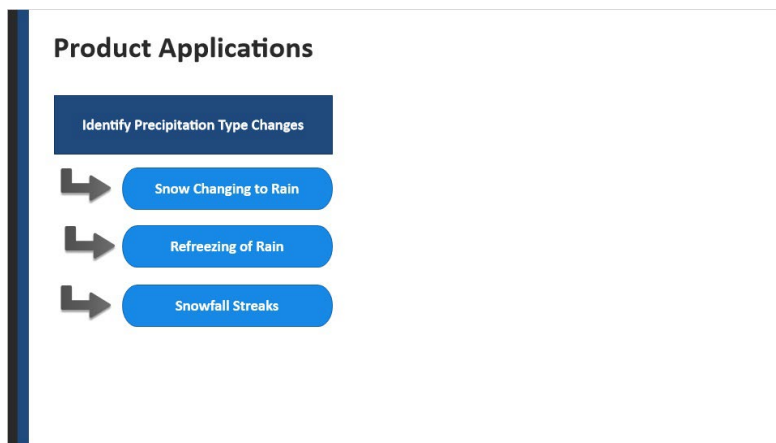
## Monitoring the Melting Layer



### Notes:

Range-Defined Quasi-Vertical Profiles can be useful for monitoring the melting layer. In this example from April 2, 2025 at the KAPX radar, you can see a rising melting layer on both the correlation coefficient and differential reflectivity plots. This rising melting layer coincides with a precipitation transition from snow to rain.

## ***Identify Precipitation Type Changes***

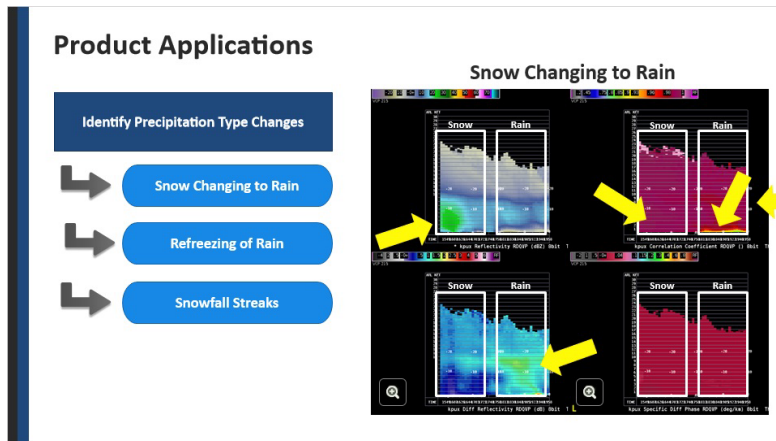


The image shows a user interface for 'Product Applications'. At the top, there is a dark blue header with the text 'Product Applications'. Below this, there is a dark blue button labeled 'Identify Precipitation Type Changes'. Underneath the button, there are three blue buttons, each preceded by a right-pointing arrow icon. The buttons are labeled 'Snow Changing to Rain', 'Refreezing of Rain', and 'Snowfall Streaks' from top to bottom.

### **Notes:**

Click through each of the examples below to learn more. Once you have reviewed each example, click "next".

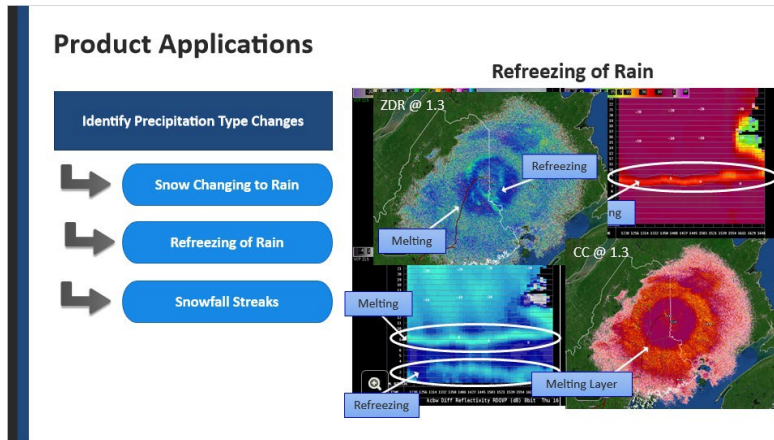
## Snow Changing to Rain (Slide Layer)



### Notes:

Range-Defined Quasi-Vertical Profiles can also be useful for identifying precip changes. In this example from the KPUX radar on March 14, 2024, you can see a transition from snow to rain. On the reflectivity panel, snow shows a stronger radar return. On correlation coefficient, note the lack of a melting layer when the precipitation type is still snow, as it transitions to rain you start to see decreased correlation coefficients near the surface indicating melting near the surface. You can also see this difference in differential reflectivity with rain having a higher differential reflectivity than snow. Higher ZDR values are initially seen around 10 kft (or around -15 C) and that likely corresponds to dendritic growth. If you look closely, a weak drop in CC is visible at the same height.

## Refreezing of Rain (Slide Layer)

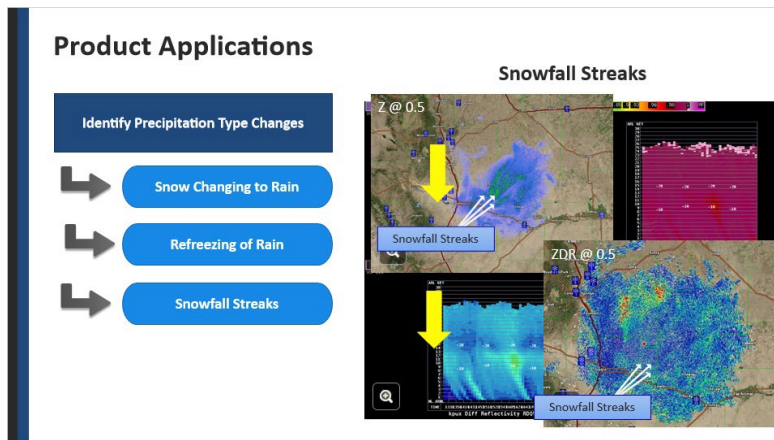


### Notes:

Another example of precipitation changes comes from the KCBW radar on April 3, 2025. In this example, you can see the melting and refreezing of rain by looking at the differential reflectivity panel. The top bright band shows melting, while the bottom bright band shows refreezing of rain before it hits the surface. During this timeframe, sleet was occurring throughout the CWA.

Looking at this same case in plan view, you can again see two rings on ZDR and CC at the 1.3 tilt displaying melting and refreezing of hydrometeors, aligning with what we are seeing on the RDQVP. Reminder, in plan view the radar beam is angled measuring higher altitudes as you move away from the radar.

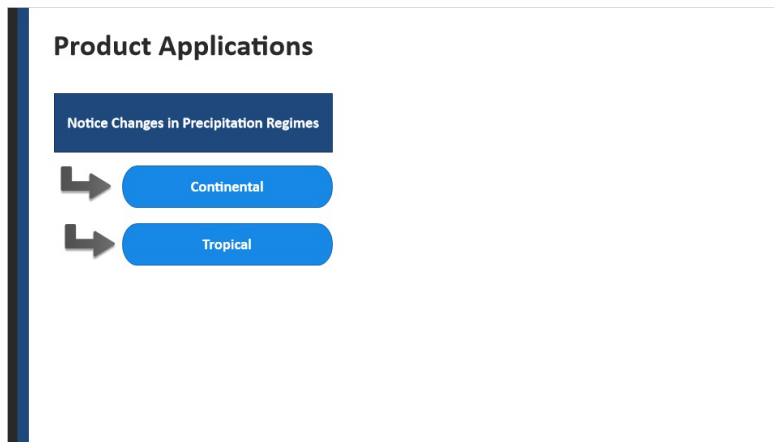
## Snowfall Streaks (Slide Layer)



### Notes:

In this example from KPUX radar on November 7 2024, you can see snowfall streaks as they move through the radar's various scans, stretching from the DGL to the surface. Looking at the plan view from the same example, you can see the snowfall streaks on reflectivity and ZDR as they pass over the RDA.

## ***Precipitation Regimes***

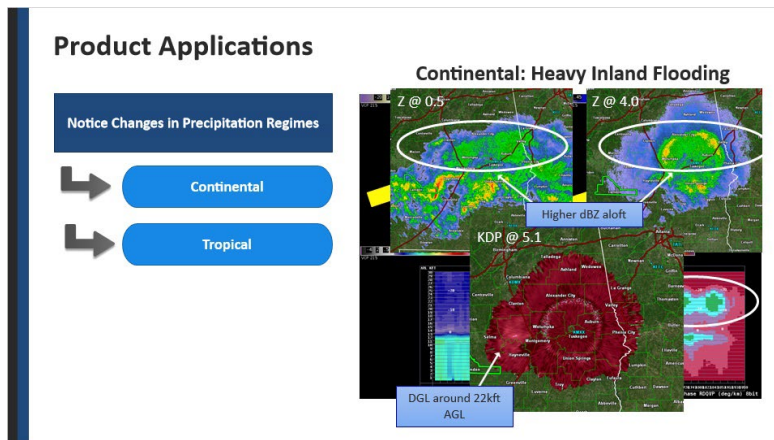


The image shows a user interface titled "Product Applications". At the top, there is a dark blue header with the text "Notice Changes in Precipitation Regimes". Below this header, there are two blue buttons, each preceded by a right-pointing arrow icon. The top button is labeled "Continental" and the bottom button is labeled "Tropical".

### **Notes:**

Range-Defined Quasi-Vertical Profiles can be useful for noticing differences in precipitation regimes. Click through each precipitation regime to learn more. Once you've reviewed both examples, click "next" to continue.

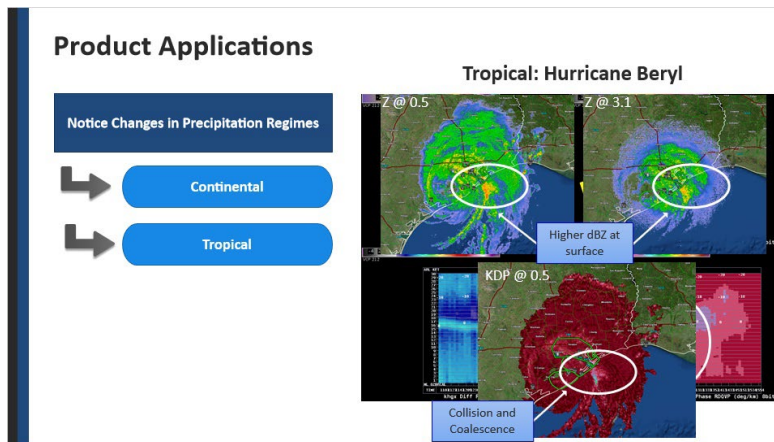
## Continental (Slide Layer)



### Notes:

In this example from the KMXX radar at Maxwell AFB, AL on May 17, 2024, heavy inland flooding was observed. This event provides a good example on continental based precipitation and its associated microphysics. This example includes cold rain processes and exhibits a dendritic growth layer between -10 and -20C as seen in the specific differential phase panel. Also note, in this example, the highest reflectivity returns are co-located with the melting layer, where dendrites are melting into liquid droplets. Looking at the plan view for the same inland flooding case, you can see higher reflectivities on the 4.0 degree scan, compared to the 0.5 degree scan. Looking at a plan view of KDP on the 5.1 degree scan, you can also see the DGL at a height of around 22kft, aligning with what we saw on the RDQVP.

## Tropical (Slide Layer)

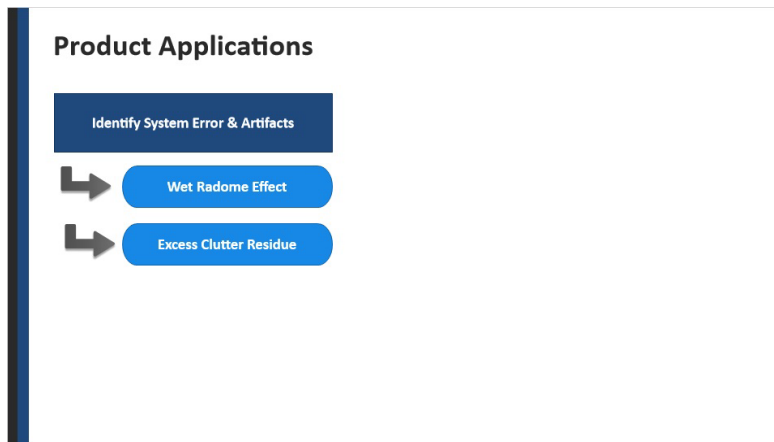


### Notes:

In this example from the KHGX radar during hurricane Beryl landfall on July 8, 2024, we can see warm rain processes at play. In this tropical environment, the melting layer is much higher around 17kft. Looking at the reflectivity panel, we see the highest radar returns closer to the surface, which would be indicative of collision and coalescence creating larger droplets as we approach the surface. We can also see this with increased KDP near the surface.

Looking at the plan view for this tropical rain case, you can see higher reflectivities on the 0.5 degree scan, compared to the 3.1 degree scan. Looking at a plan view of KDP on the 0.5 degree scan, you can also see a region of higher KDP near the surface indicating collision and coalescence, aligning with what we saw on the RDQVP.

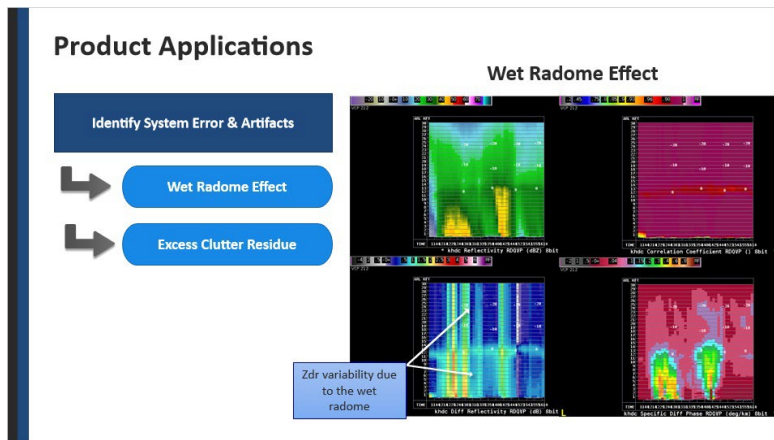
## ***System Errors & Artifacts***



### **Notes:**

Lastly, RDQVPs can be helpful with identifying system errors and radar artifacts. Click through each of the examples below to learn more. Once you have reviewed each example, click "next".

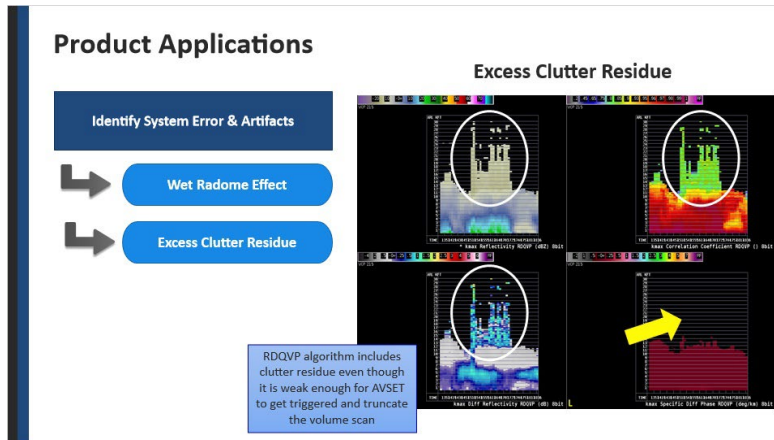
## Wet Radome Effect (Slide Layer)



### Notes:

In this example from New Orleans, rain was observed over the RDA. This rain led to wet radome effect and was captured on the RDQVP. Here you can see ZDR variability in both above and below the melting layer due to a sensitivity response to the wet radome.

## Excess Clutter Residue (Slide Layer)




### Notes:

This is an example of mountain top snow at the Medford, OR radar (KMAX). If AVSET is turned on, like in this case, the only data for these higher altitudes is from a small area of weak returns on the last tilt before it is cut off. The RDQVP algorithm includes this breakthrough clutter data even though it is small enough for AVSET to get triggered and truncate the volume scan. With AVSET on, you may find excess clutter residue at higher tilts like shown here. Note, KDP does not show this clutter as KDP does not get calculated when the corresponding CC values are so low.

## ***Product Limitations***

**Product Limitations**

- Averaging can smooth out the signal
- Biasing from strong returns
- Standard atmosphere assumptions may not be valid
  - May impact height estimates
- Ground clutter may skew results

A yellow triangular warning sign with a black border and a black exclamation mark in the center. A blue line points from the sign towards the text above it.

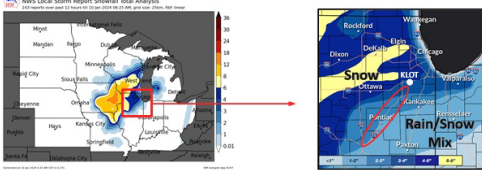
### **Notes:**

With the many applications of RDQVPs, there are also some product limitations. Averaging across the radars line of site can smooth out the signal, and mask smaller features. If precipitation returns are not uniformly distributed around the radar, the averaged height of the melting layer (at least compared to the model temperature heights) may be different. I should also note that standard atmospheric assumptions may not be valid, which can further impact the height estimates. Lastly, ground clutter may skew results of these time-height plots.

## Case Study – A Cautionary Tale

**Case Study – A Cautionary Tale**  
Chicago, IL (KLOT)  
January 9th, 2024

NWS Local Storm Report Snowfall Total Analysis

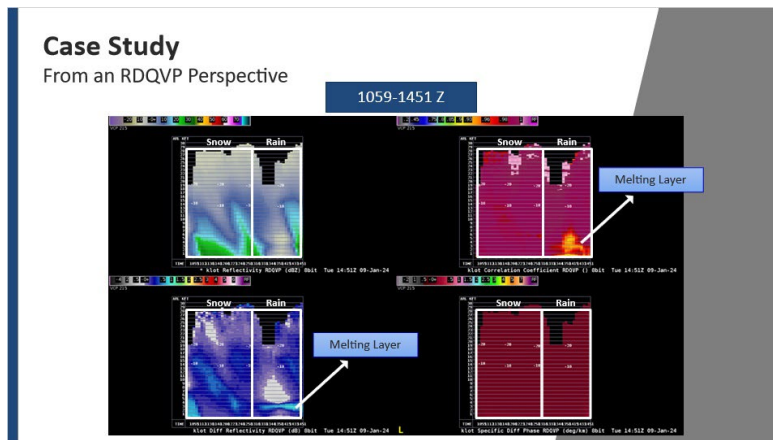


A low pressure system brought a significant winter storm to the Midwest on January 8-9, 2024. The greatest snowfall totals of over a foot were observed in eastern Iowa. Whereas the northern portions of the LOT CWA saw maximum snow totals of 6-8 inches. A sharp gradient in snow totals was along the I-55 corridor so areas to the southeast witnessed mostly rain or a rain/snow mix throughout the event.

### Notes:

Now that we've learned about what a RDQVP is along with some of its applications, system errors, and limitations let's review a case study on how to apply RDQVPs to a past weather event. A low pressure system brought a significant winter storm to the midwest on January 8-9, 2024. The greatest snowfall totals of over a foot were observed in eastern Iowa. Whereas the northern portions of the Chicago CWA saw maximum snow totals of 6-8in. A sharp gradient in snow totals was along the I-55 corridor, with snow to the Northwest and areas to the southeast witnessed mostly rain or a rain/snow mix throughout the event.

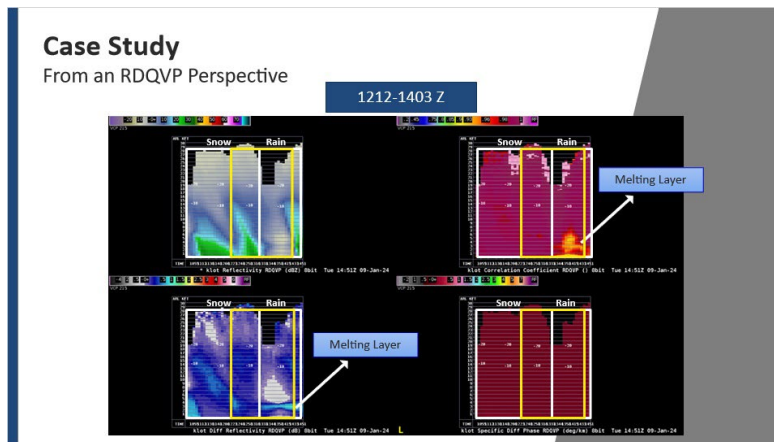
## Case Study



### Notes:

Now that we know what happened let's look at this event from a RDQVP perspective. From around 11Z to 13Z the RDQVP indicates the precip type was snow. However, we can see melting signatures in CC and ZDR from around 13Z to 15Z which would indicate the primary precip type changed over to rain in a portion of the 50km radius around the radar.

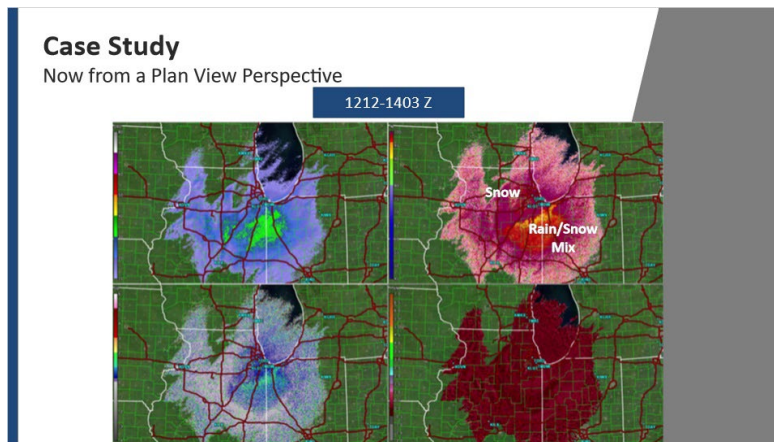
## Case Study



### Notes:

Next we will look at a plan view of this case focusing on the p-type transition period, highlighted in the yellow box. This covers the time period of 1212-1403Z.

## Case Study (Video)



### Notes:

Looking at a plan view, you can see a rain/snow mix in the southeast portion of the CWA and primarily snow in the northwest portion. As the loop progresses, this boundary shifts slightly to the northwest as the warm sector moves northward. However, by the end of the loop there are still areas to the northwest that are predominantly snow and have not yet transitioned over to rain or a mix. So why are the profiles showing predominantly rain at this time? Stronger returns from the rain/snow mix to the southeast are biasing the averages displayed in the RDQVP profiles.

## Case Study Takeaways

### Case Study Takeaways

- Since the RDQVPs are averaged across a 50 km radius at each height, the nuances of the rain/snow transition zones can be smoothed out or biased by stronger returns.

- We see this in our Chicago case:

1212Z - 1315Z

RDQVP: snow

Plan view: rain/snow mix in the SE,  
snow in the NW

1315Z - 1403Z

RDQVP: rain


Plan view: rain in the SE,  
snow in the NW

**Recommendation:** Cross check the RDQVPs with plan view radar data to make sure you are getting the full picture

### Notes:

Finally, let's review some takeaways from this event. We know that the RDQVPs are averaged across a 50 km radius at each height so the nuances of the rain/snow transition zones can be easily smoothed out or biased by stronger returns. We saw this in our Chicago case. At the beginning of the loop the RDQVP indicated snow as the precip type. However, when we looked at the radar planview there was a rain/snow mix in the southeast portion of the CWA and mostly snow in the northwest portion of the CWA. Then as we move into the second half of the loop the RDQVP indicated rain as the precip type. While that was the case in the SE portion of the CWA, the northwest portion of the CWA was predominantly snow. We advise you to cross check the RDQVPs with radar data to make sure you are getting the full picture.

## Contact Info

Contact Information	
RAC Help Email: <a href="mailto:nws.wdtd.rachelp@noaa.gov">nws.wdtd.rachelp@noaa.gov</a>	
Lesson Author Email: <a href="mailto:Jessica.bunker@noaa.gov">Jessica.bunker@noaa.gov</a> and <a href="mailto:Alyssa.woodward@noaa.gov">Alyssa.woodward@noaa.gov</a>	

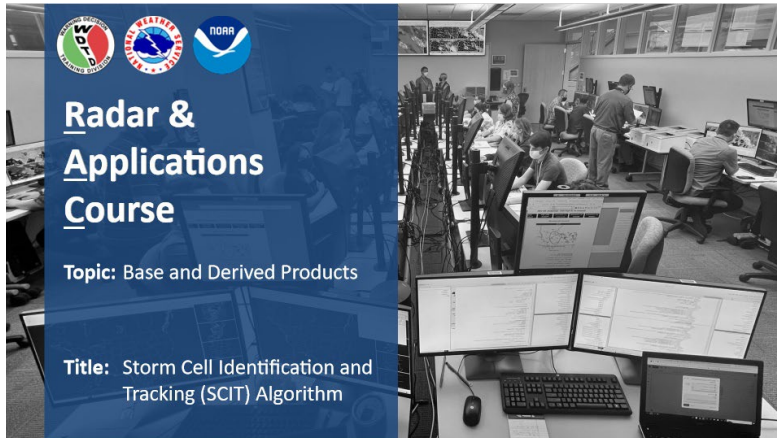
Once you've completed the quiz, hit "Exit" to close out!

### Notes:

If you have any questions, please feel free to contact us directly or the RAC help email.

# Storm Cell Identification and Tracking (SCIT)

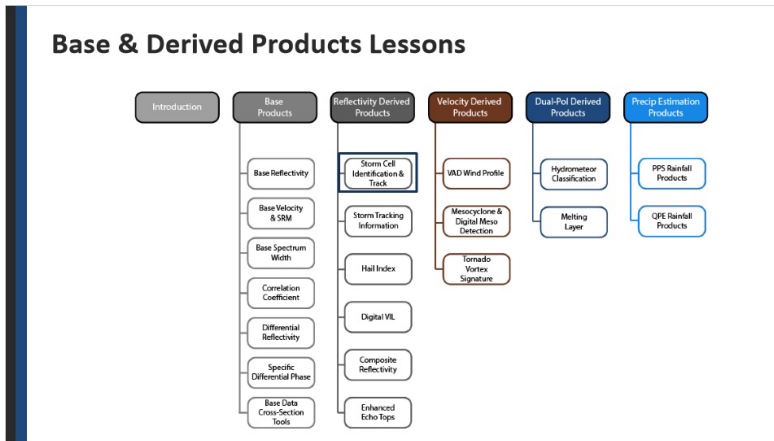
## *Introduction*



### **Notes:**

Welcome to this lesson on the Storm Cell Identification and Tracking (or SCIT) algorithm. This training is part of the Base and Derived Products topic in the Radar and Applications Course. Let's get started.

## Base & Derived Products Lessons



### Notes:

Here is a roadmap for the lessons in this topic. This lesson on the SCIT algorithm, highlighted on the slide, is the first in the Reflectivity Derived Products Section of this topic.

## ***Learning Objectives***

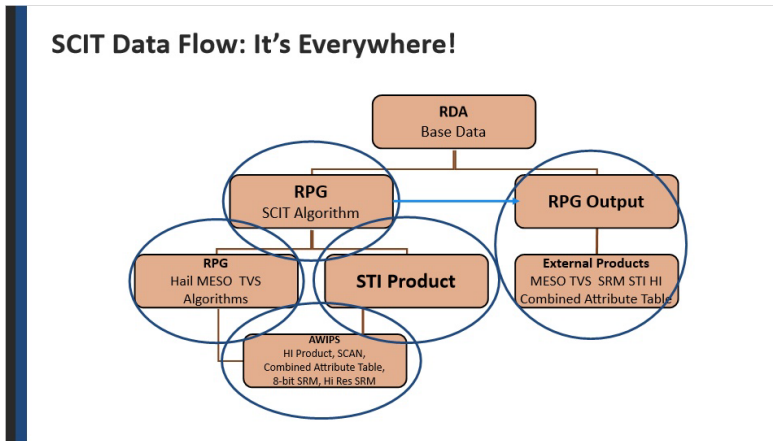
### **Learning Objectives**

1. Identify the primary role of the SCIT algorithm and how it relates to other RPG algorithms
2. Identify the key storm traits the Storm Cell Identification and Tracking (SCIT) algorithm characterizes
3. Identify the outputs of the SCIT algorithm and the other RPG algorithms/products that use these outputs

### **Notes:**

Here are the learning objectives for this lesson. Take a moment to read these and advance to the next slide when you are ready to proceed.

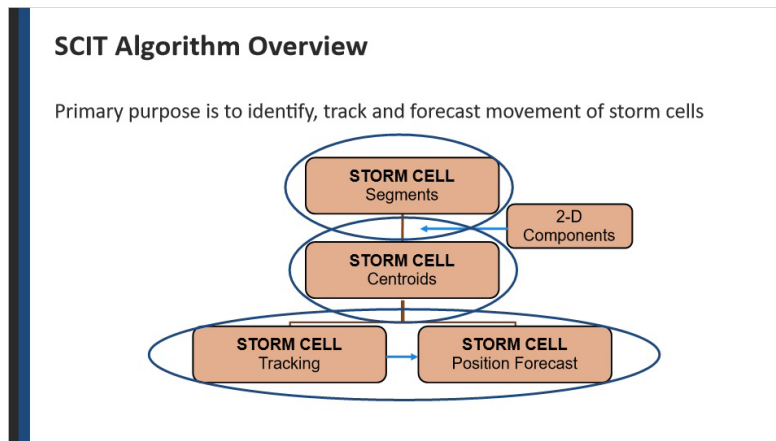
## SCIT Data Flow: It's Everywhere!



### Notes:

We start our discussion on algorithms with SCIT because it plays an important roll in so many other algorithms at the Radar Product Generator (RPG). As base data flows into the RPG, the SCIT algorithm (Johnson et al., 1998) processes the data and produces the Storm Track Information product (which will be discussed in detail in a later lesson). The information in this product is then used as input for other algorithms, such as the Hail, Mesocyclone, and TVS Detection Algorithms. The information are also displayable in overlay products such as Hail Index, SCAN, and Composite Reflectivity (in the Combined Attribute Table). So, SCIT is important because it impacts the performance of several other algorithms and the appearance of several products (including those that are accessible to our customers and partners).

## SCIT Algorithm Overview

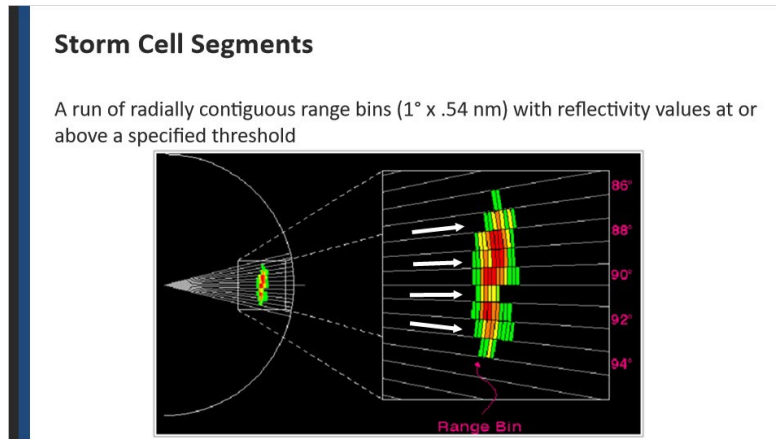


### Notes:

The SCIT algorithm will input Reflectivity data and process it into building blocks called segments. Segments are one-dimensional reflectivity objects of comparable value. Segments, which are oriented radially, are then combined with comparable, adjacent segments into two-dimensional reflectivity objects called components. Once all of the components are defined for each elevation slice, the algorithm compares the components on each tilt to correlate the components with each other and calculate a cell's centroid location. The cell's centroid is key because it will be used to characterize storm traits, track the storm's motion, and even forecast future locations for the storm.

Let's discuss each step in a little more detail so you can better understand how this process works.

## Storm Cell Segments



### Notes:

Storm cell segments are the fundamental traits that the algorithm identifies. A segment is defined as a run of contiguous range bins oriented down a specific radial. The SCIT algorithm uses legacy Reflectivity data resolutions of 1 deg by 0.5 nm for its range bins. As the algorithm processes the data on a radial, it looks for data greater than or equal to a specified threshold.

The graphic on the slide shows Reflectivity data plotted with the individual radials and range bins demarcated for emphasis. The arrows indicate how the algorithm processes the data radial by radial.

## ***Storm Cell Segments: ROC Controlled Adaptable Parameters***

### **Storm Cell Segments: ROC Controlled Adaptable Parameters**

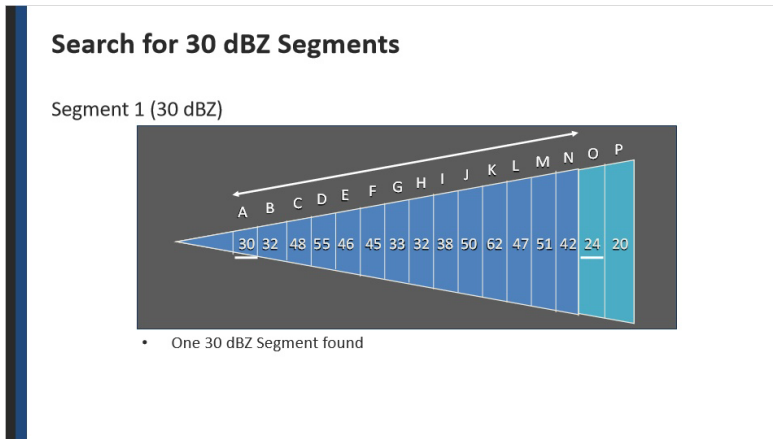
- Segments of up to 7 minimum reflectivity thresholds
  - 30, 35, 40, 45, 50, 55, 60 dBZ
- Minimum segment length
  - 1.9 km/2 bins
- Algorithm has a dropout forgiveness factor:
  - Up to 2 range bins
  - Reflectivity  $\leq$  5 dBZ below minimum reflectivity threshold

### **Notes:**

The SCIT algorithm relies on adaptable parameters that are controlled by the Radar Operations Center. These parameters are: minimum reflectivity thresholds and minimum segment length. The algorithm uses seven minimum reflectivity thresholds from 30 to 60 dBZ in 5 dBZ increments. This means the radar must detect 30 dBZ in a range bin before a segment can start. The minimum segment length is 2 range bins (which is at least 1.9 km). So, you would need two range bins next to each other of at least 30 dBZ for a segment to be identified.

The algorithm can be forgiving at times. In some circumstances, up to 2 contiguous range bins below the minimum threshold can be included in the segment if their value is within 5 dBZ of the threshold.

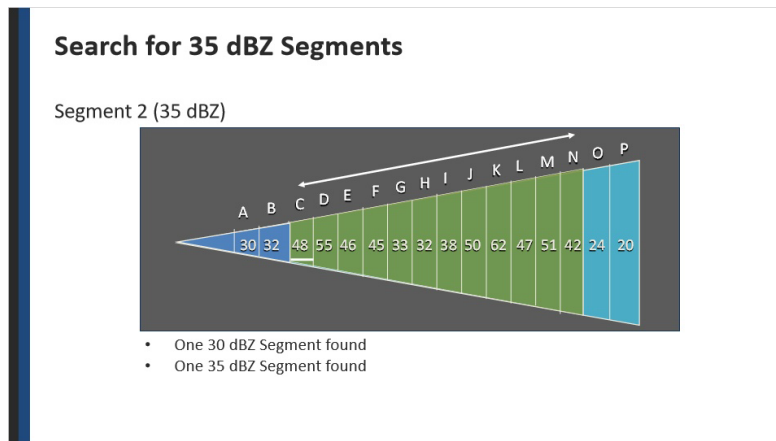
## Search for 30 dBZ Segments



### Notes:

Let's walk through an example just to make sure I am making sense to you. The slide shows you a segment of a single radial of Reflectivity data. Once the algorithm finds a couple of bins at or over 30 dBZ, so it starts identifying a segment. The algorithm proceeds looking at each range bin down radial until it encounters an out of range bin (which in this case is the 24 dBZ value in the location labeled "O"). The initial segment, or 30 dBZ segment, then terminates at this point.

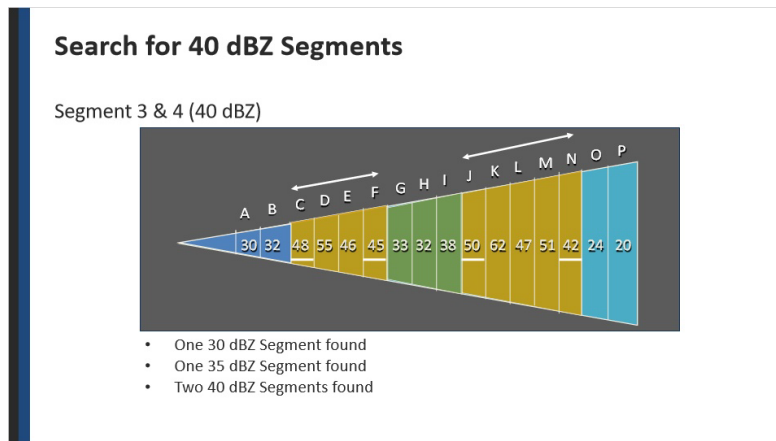
## Search for 35 dBZ Segments



### Notes:

The algorithm proceeds to the next segment threshold by looking at each of the 30 dBZ segments. The algorithm attempts to isolate and identify the higher reflectivity cores in each segment, so it will continue to incrementally increase the minimum reflectivity threshold with each pass. So, using the 35 dBZ threshold, the next segment begins in bin C where we have a 48 dBZ value and ends at the same point as the previous segment.

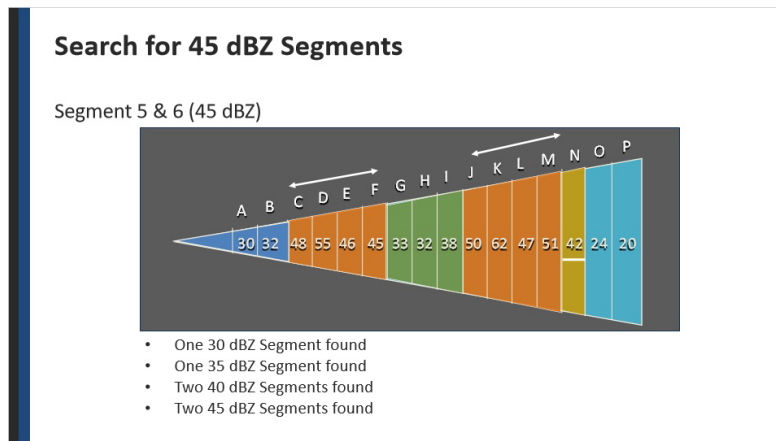
## Search for 40 dBZ Segments



### Notes:

The process gets a little more interesting at the 40 dBZ threshold. A segment starts at bin C again, but now terminates at bin F because of the drop in values in the bin G. However, the algorithm continues down the radial and finds another segment starting in bin J and ending at bin N.

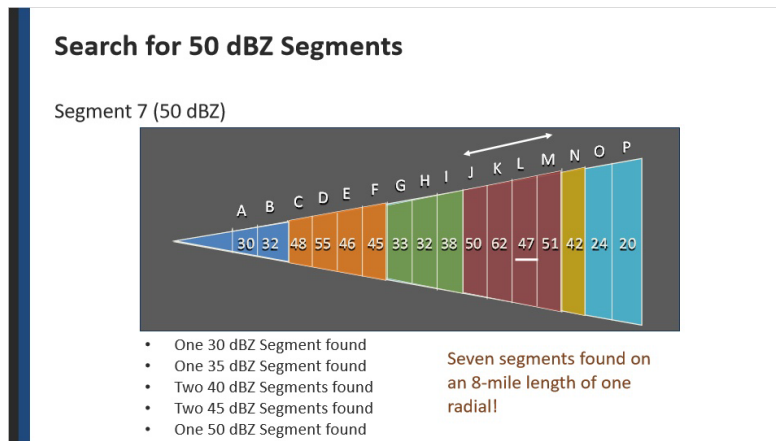
## Search for 45 dBZ Segments



### Notes:

Continuing on at 45 dBZ, the algorithm furthers its attempt to isolate the higher reflectivity cores in these two segments. Note, the value in bin N is within the 5 dBZ dropoff range, but there are more than two range bins between locations of 45 dBZ values. Hence, this range bin is not included in the segment.

## Search for 50 dBZ Segments



### Notes:

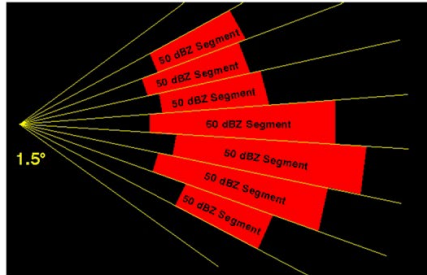
Finally, the algorithm identifies its last segment on this portion of the radial in bins J through M. Notice how bin L is included in the segment with a value 3 dBZ below the threshold because it is located between two 50+ dBZ bins.

The end result is the algorithm found 7 segments on this small part of a single radial!

## Storm Cell Components: Definition

### Storm Cell Components: Definition

A two-dimensional area of combined segments on a single elevation slice



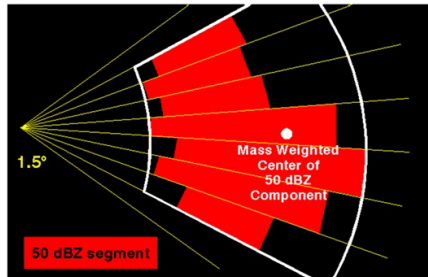
### Notes:

Once all the segments are identified on a particular elevation slice, the algorithm can start associating adjacent segments with the same threshold values into two-dimensional components. These components are traits that indicate the two-dimensional representation of a cell at a particular elevation angle.

## Storm Cell Components: Mass Weighted Center

### Storm Cell Components: Mass Weighted Center

Component defined by two dimensional area of combined segments and mass weighted center



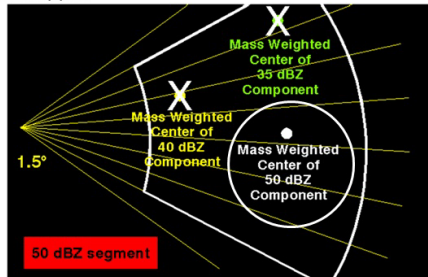
### Notes:

As components are assembled, the algorithm looks for the mass-weighted center of the component. This image shows the 50 dBZ component with its mass weighted center identified. The term "mass-weighted" comes from the reflectivity values "pulling" the storm centroid in that location. This process prevents the algorithm from plotting the storm centroid simply at the geographic center of the component, which could be misleading to the forecaster looking at the algorithm output.

## ***Storm Cell Components: Center Changes Depending on Threshold***

### **Storm Cell Components: Center Changes Depending on Threshold**

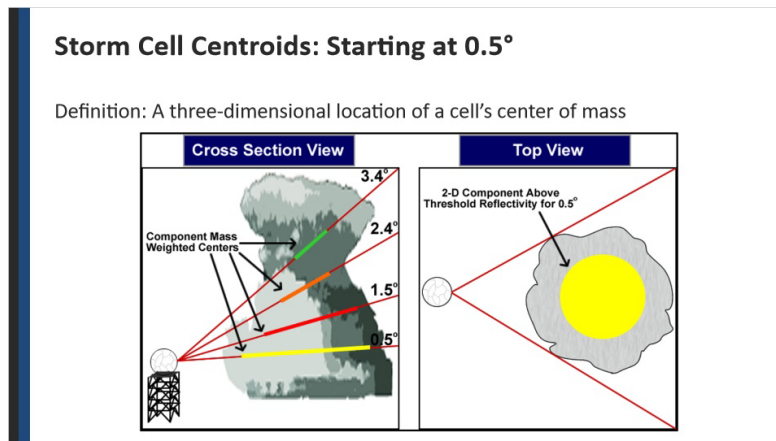
Lower threshold components whose centers fall within area of higher threshold component are dropped



### **Notes:**

Many times, the mass-weighted centers will move as the reflectivity thresholds increase. The mass-weighted center that ultimately leads to identifying the storm centroid will use the location for the highest threshold value for the component. In this case, the component is built out of contiguous 50 dBZ segments. Hence, the 50 dBZ mass-weighted center is used as we proceed to the next step.

## Storm Cell Centroids: Starting at 0.5°

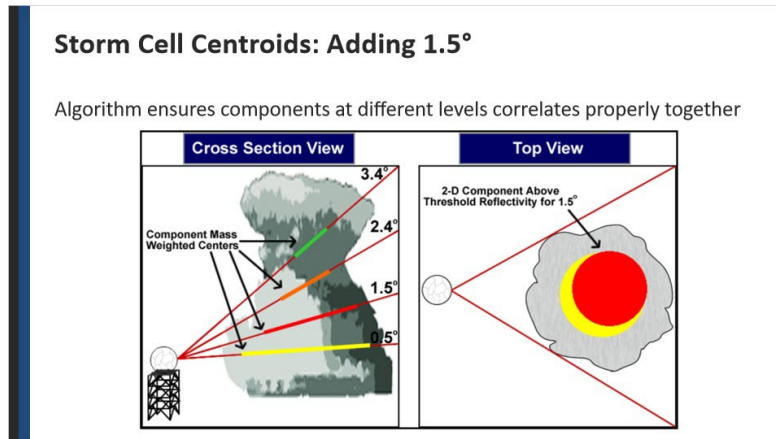


### Notes:

The last trait that the algorithm will identify are centroids. Centroids are identified by looking at the mass-weighted centers of components on each elevation slice and correlating them together vertically to create a three-dimensional object.

Let's walk through this process, by comparing mass-weighted centers from several elevation angles (shown in the graphic on the left). The image on the right shows the component from the 0.5 degree tilt. Let's add components from other slices and see what we come up with.

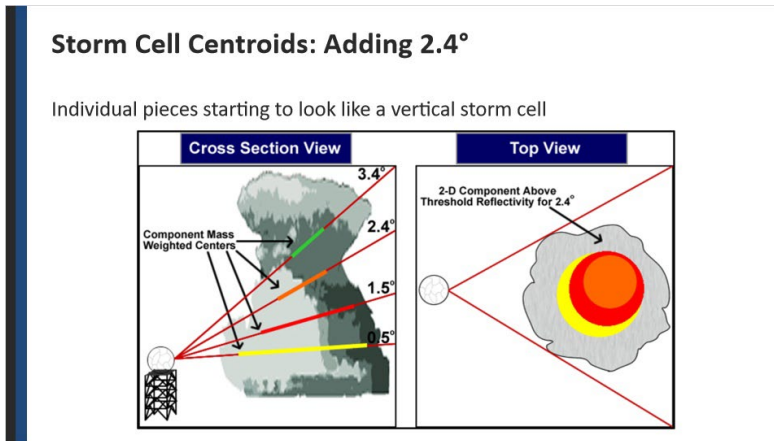
## Storm Cell Centroids: Adding 1.5°



### Notes:

Adding the 1.5 degree component, there appears to be some agreement between the two. The algorithm will perform some checks to make sure that two components are found within a particular search radius of each other. Specifically, the algorithm ensures the upper level component correlates properly with the component(s) below it.

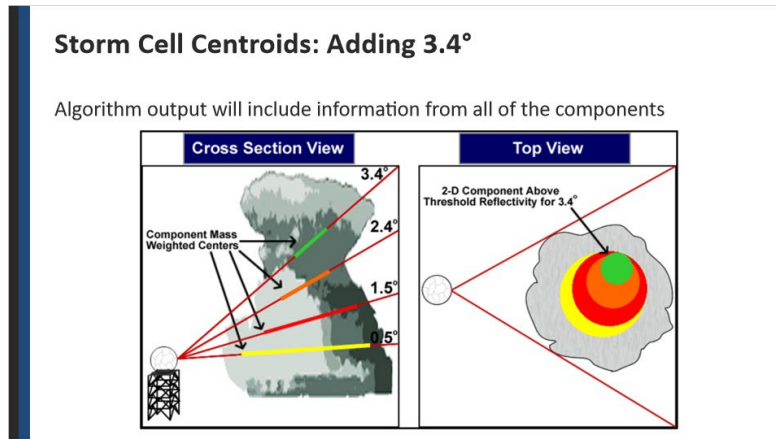
## Storm Cell Centroids: Adding 2.4°



### Notes:

As we move up to 2.4 degrees, we add the next component. You can see how the individual pieces start looking more like a vertical storm cell, algorithmically speaking.

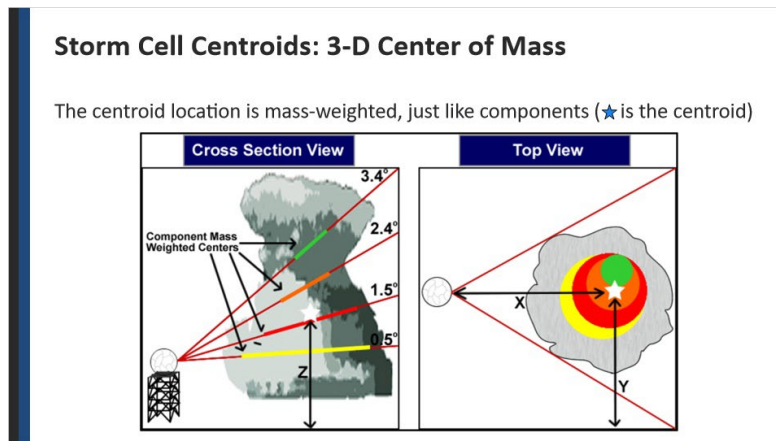
## Storm Cell Centroids: Adding 3.4°



### Notes:

We include the last component, found on the 3.4 degree tilt. The algorithm output for this storm will include the information calculated from all four of these components. If the algorithm found components on higher tilts, it would include those, too.

## Storm Cell Centroids: 3-D Center of Mass



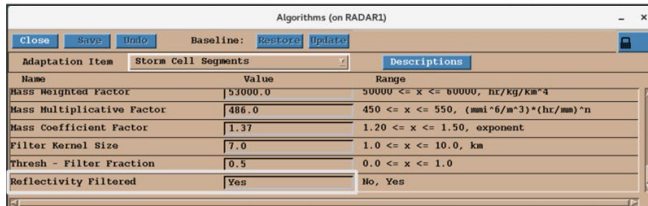
### Notes:

Once the three-dimensional structure of the storm components has been analyzed, the storm centroid is calculated in the much the same way as each component's mass-centered weight. The storm centroid will be influenced by the location of higher reflectivity values. So, don't expect the centroid to be in the three-dimensional geographic center of the cell. The centroid will have an azimuth, range, and height associated with it since it's a three-dimensional feature. The RPG will use the storm centroid to plot the location of the cell in this and other algorithm's outputs you see in AWIPS.

## Adaptable Parameters: Reflectivity Filter

### Adaptable Parameters: Reflectivity Filter

- Does not impact high reflectivity values used in defining cell attributes
- Recommend it be turned on (“yes”)



Name	Value	Range
Mass Weighted Factor	53000.0	30000 <= x <= 60000, hr/kg/km <sup>3</sup>
Mass Multiplicative Factor	486.0	450 <= x <= 550, (mm <sup>6</sup> /m <sup>3</sup> )*(hr/mm) <sup>n</sup>
Mass Coefficient Factor	1.37	1.20 <= x <= 1.50, exponent
Filter Kernel Size	7.0	1.0 <= x <= 10.0, km
Thresh - Filter Fraction	0.5	0.0 <= x <= 1.0
Reflectivity Filtered	Yes	No, Yes

### Notes:

There's one adaptable parameter your office has control over under Storm Cell Segments called "Reflectivity Filtered" that we want to highlight. The purpose of this filter is to eliminate spurious noise in the Reflectivity that might mess up the SCIT algorithm. It only filters the values that go into the algorithm, not what you see on your Reflectivity displays in AWIPS. As a result, we recommend you set this parameter to "Yes" to aid the algorithm's performance.

## ***Storm Cell Centroids Output: Available on Up to 100 Cells***

### **Storm Cell Centroids Output: Available on Up to 100 Cells**

- Centroid (in polar coordinates)
- Height of the centroid (ARL)
- Maximum (3-bin averaged) reflectivity
- Height of the maximum reflectivity (beam center point height - ARL)
- Cell Top and Base (beam center point height - ARL)
- Number of components
- Cell-based Vertically Integrated Liquid (VIL)

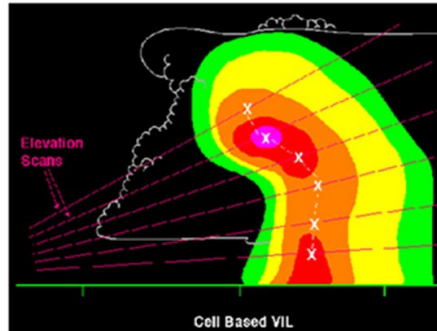
### **Notes:**

Once the algorithm has processed all of the data for the volume scan, it is ready to provide a list of all the storms it identified. The algorithm output can include up to 100 different cells. Each identified cell will have an azimuth, range, height (above radar level), the maximum reflectivity value and height, plus the cell base and top heights. The algorithm will also document the number of components identified in a cell, along with a cell-based Vertically Integrated Liquid, or VIL, value.

## Cell-Based VIL

### Cell-Based VIL

- VIL gives a sense of storm intensity
- Same equation as Grid-based VIL (not DVIL)
- VIL values used to:
  - Rank storms by intensity
  - Order attribute info in tables



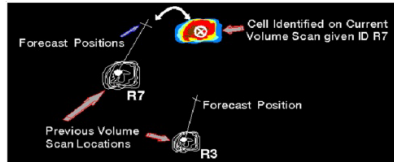
### Notes:

If you are taking the Base and Derived Products lessons in the order prescribed in the RAC curriculum, then you haven't seen a discussion of VIL (actually Digital VIL) yet. So, I want to take a moment to discuss it here.

Cell-based VIL integrates the maximum reflectivity values throughout the vertical extent of the cell to give you a sense of the storm's intensity. It's important to note the SCIT algorithm uses the same equation as the original VIL product, not digital VIL. These VIL values are important because the algorithm will use VIL to rank the storms it identifies. Storms with higher VIL values will generally appear before lower VIL storms in the various tables where storm cell information is displayed.

## Storm Cell Tracking Process

### Storm Cell Tracking Process



- Start with highest Cell-Based VIL
- Compare current location of centroid with forecast locations from previous volume scan
- The **closest projected centroid** within a threshold distance is considered the same cell, and the direction and speed of movement is computed.

### Notes:

Once all of the cells surrounding the radar have been identified, the SCIT algorithm attempts to correlate them with storms from the previous volume scan. This process is called storm cell tracking. The algorithm processes each cell in order by cell-based VIL values, starting with the highest.

The image on the slide shows an example of this process. We see one cell (shown in color) for the current volume scan, along with two nearby cells from the previous volume scan. The algorithm will attempt to correlate the current cell with one of the previous ones. How you might ask? Well, the algorithm will compare the cells current location with forecast positions (calculated during the previous volume scan) of the old storms. The two older storms have the IDs R7 and R3, respectively, and their forecast positions are indicated on the graphic. While the current storm is not at either of these locations, the algorithm will see if the distance between the forecast position and current location falls within a threshold value. In this case, R7 falls within that threshold. As a result, the current storm is given the ID R7 and the storm motion and forecast position are updated based on the new information.

## More on Storm Cell Identification Process

### More on Storm Cell Identification Process

- What if cell isn't correlated: Cell is given a new ID
- The letter-number combination assigned a new cell is determined by the following order: A0, B0,...,Z0, A1, B1,..., Z1, A2, B2,..., Z9, A0...
- The list of IDs will reset with A0 when:
  - The RPG is rebooted
  - 20 minutes (default) lapses without a cell

### Notes:

So, what happens if a storm doesn't correlate with any previously existing cells? Well, the cell will be considered a new storm and given a new ID based on a simple letter/number convention. The first identified storm is given the ID of A0. The next storm is given the ID B0, and so on, until the algorithm labels a storm Z0. From there, the IDs roll over to A1, B1, etc. During an active weather event, the storm IDs don't really tell you much about a storm's strength, just how long a particular storm centroid has been tracked by the algorithm. The lower the number, the longer the storm has been around. The IDs are eventually reset when the RPG is either rebooted, or when there have been 20 minutes or more without an identified storm.

## ***Storm Position Forecast***

### **Storm Position Forecast**

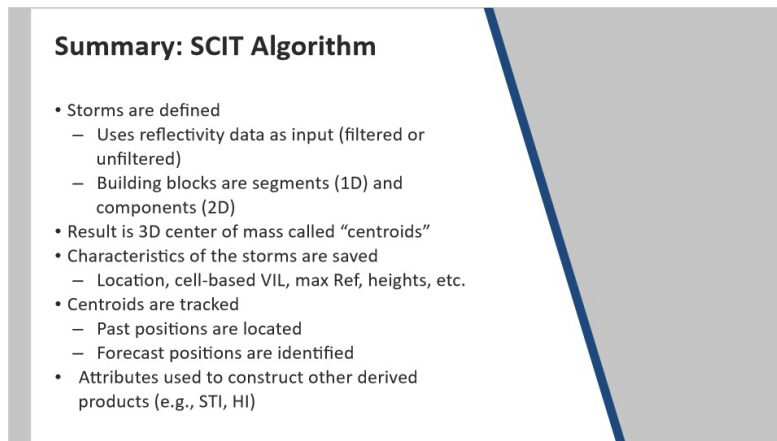
- Objective: Predict the future centroid location
- Forecast location: Linear least square fit of cell's previous movement over cell's lifetime
- Forecast duration (15, 30, 45, or 60 min): Dependent on error in the previous volume scan's forecast
- Process: Forecast movement of a "NEW" cell is:
  - The average movement of all identified cells, or
  - Default speed & direction as set at the RPG HCI if no cells detected

### **Notes:**

We talked previously about the storm position forecast. Let's look at this process in more detail. This part of the SCIT algorithm attempts to predict the future location of the storm centroid. This forecast is based on a linear least square fit of the storm's previous movement over its lifetime. If a storm has been tracked by the algorithm for several volume scans, this forecast track can be fairly good and can extend out for 15 to 60 minutes, depending upon the error calculated during the least square fit process. Basically, the higher the error, the shorter the forecast duration.

So, you might be asking yourself what happens with cells identified in the last volume scan? Well, new cells are given one of two forecast movements. Most of the time, it will use an average speed from all of the identified cells as a first guess. If the storm in question is A0 (or identified in the same volume scan as A0), then it will use the default speed and direction set at the RPG.

## Summary: SCIT Algorithm



**Summary: SCIT Algorithm**

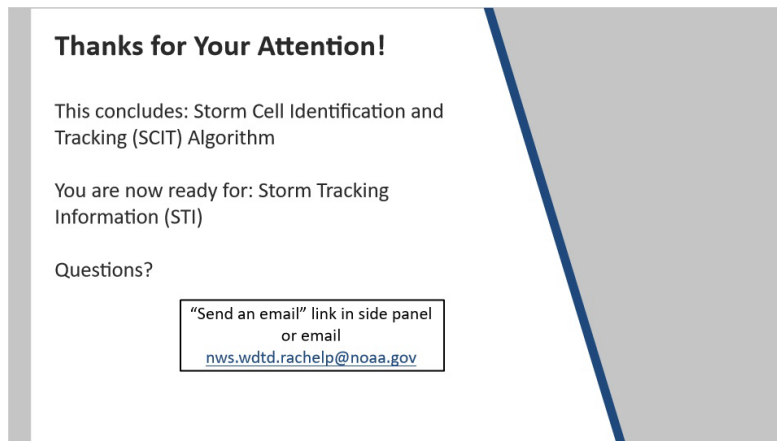
- Storms are defined
  - Uses reflectivity data as input (filtered or unfiltered)
  - Building blocks are segments (1D) and components (2D)
- Result is 3D center of mass called “centroids”
- Characteristics of the storms are saved
  - Location, cell-based VIL, max Ref, heights, etc.
- Centroids are tracked
  - Past positions are located
  - Forecast positions are identified
- Attributes used to construct other derived products (e.g., STI, HI)

### Notes:

Let's summarize the SCIT algorithm and how it will impact the algorithms and derived products that will be discussed in later lessons. The purpose of this algorithm is to identify storms. It uses reflectivity (which we recommend filtering via your adaptable parameters) as its primary input. The reflectivity data are used to identify one-dimensional, radially aligned segments. Contiguous segments are used to build two-dimensional components that fall on a single elevation angle. Components are then stacked on top of each other to build a three-dimensional centroid. Centroids have a center of mass that is used to locate and track the storm's position. Various characteristics of the storm (including location, cell-based VIL, maximum reflectivity, and centroid height) are saved by the algorithm. Storm centroids are then tracked by comparing these data to data (specifically forecast position) from storms identified in the previous volume scan and correlating the storms when they appear to be the same. This information is then passed along to other algorithms and derived products (such as the Storm Tracking Information and Hail Index products).

Please take a few moments to complete the quiz on the next slide.

## ***Thanks for Your Attention!***



**Thanks for Your Attention!**

This concludes: Storm Cell Identification and Tracking (SCIT) Algorithm

You are now ready for: Storm Tracking Information (STI)

Questions?

"Send an email" link in side panel  
or email  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

### **Notes:**

If you have passed the quiz, then you have successfully completed this lesson. You are now ready to proceed to the next lesson on the Storm Tracking Information (STI) product. If you have any questions, feel free to e-mail the contacts listed below.

# Storm Tracking Information (STI)

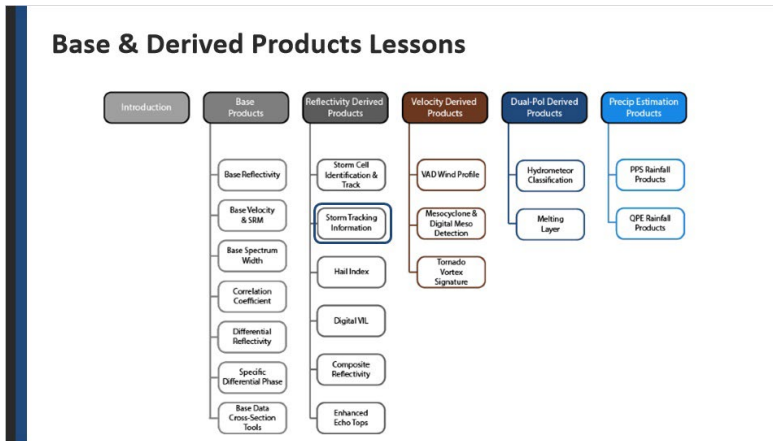
## *Introduction*



### **Notes:**

Welcome to this lesson on the Storm Tracking Information (STI) product. This training is part of the Base and Derived Products topic in the Radar and Applications Course. Let's get started.

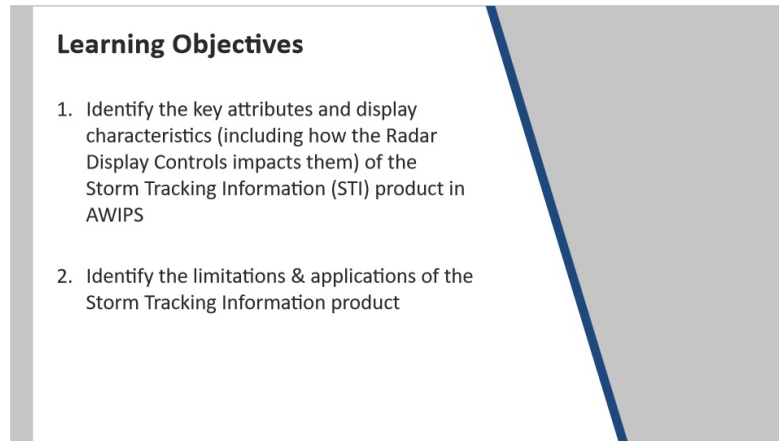
## Base & Derived Products Lessons



### Notes:

Here is a roadmap for the lessons in this topic. This lesson on the STI product, highlighted on the slide, is part of the Reflectivity Derived Products Section of this topic.

## ***Learning Objectives***



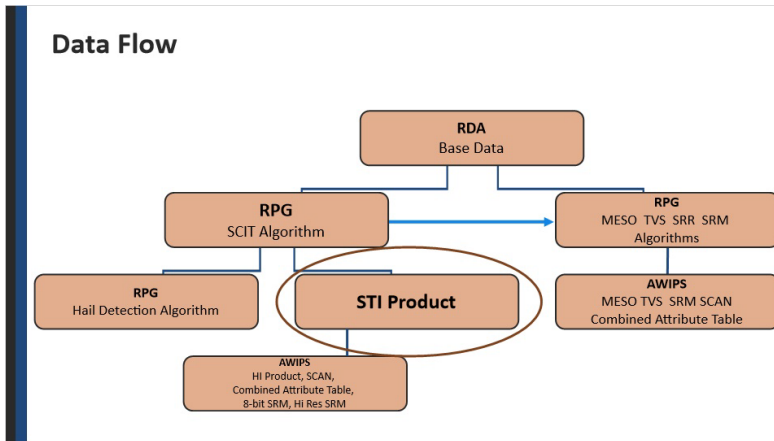
**Learning Objectives**

1. Identify the key attributes and display characteristics (including how the Radar Display Controls impacts them) of the Storm Tracking Information (STI) product in AWIPS
2. Identify the limitations & applications of the Storm Tracking Information product

### **Notes:**

Here are the learning objectives. Take a moment read them and advance the slide when you are ready.

## Data Flow







### Notes:

The Storm Cell Identification and Track algorithm (or SCIT) lesson discussed how the WSR-88D RPG identifies storms as a three-dimensional object. This lesson will talk about one product that is produced from that algorithm's output: the Storm Tracking Information, or STI, product.

## Product Description

### Product Description

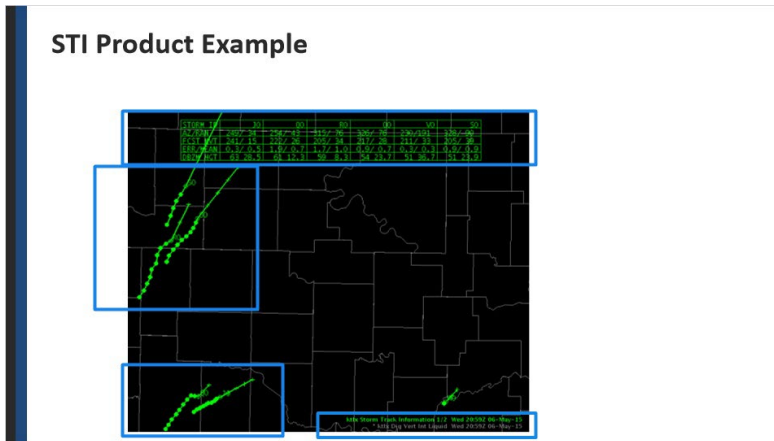
Displays up to 100 cells identified by the SCIT Algorithm along with actual past positions and forecast positions with the following symbols:

-  Centroid location
-  Past position (volume scan increments with a line between each symbol)
-  Forecast position (15 minute increments with a straight line connecting all forecast positions)
-  Cell moving less than 5 knots

### Notes:

The STI product allows you to see the output of the work done by the SCIT algorithm. The product will display data on up to 100 cells identified by the SCIT algorithm, including the past, current, and forecast locations. Each of these items are identified using different symbols. The current centroid location is marked by a circle with an x in it. Positions from previous volume scans are marked by a filled circle connected by lines. Forecast positions will appear with a plus symbol (spaced out in 15 minute increments) with a straight line connecting locations. Cells moving at less than 5 knots will have an additional circle around the centroid location marker, similar to how a ASOS site would report calm winds on a surface map.

## STI Product Example



### Notes:

Here is what the Storm Track Information product looks like. We see several storms with various amounts of past and forecast positions. There is also an attribute table which gives additional information about each cell. More on that info in a little bit. Lastly, you can see in the product legend that the STI product will have pagination info about the table. In this case, page 1 of a two-page table is visible.

## STI Attribute Table

STI Attribute Table

STORM ID	J0	00	R0	00	W0	S0
0Z/RAN	249/ 34	254/ 43	315/ 76	326/ 76	230/191	328/ 90
FCST MVT	241/ 15	222/ 26	205/ 34	217/ 28	211/ 33	205/ 39
ERR/MEAN	0.3/ 0.5	1.9/ 0.7	1.7/ 1.0	0.9/ 0.7	0.3/ 0.3	0.9/ 0.9
DBZM HGT	63 28.5	61 12.3	59 8.3	54 23.7	51 36.7	51 23.9

- **STORM ID:** Cells in order of Cell-based VIL
- **NEW:** Appears on FCST MVT line for 1st scan of new cell
- **ERR:** Distance (nm) from forecast position to actual position
- **MEAN:** Mean error (ERR) during the cell's lifetime
- **DBZM:** Maximum reflectivity
- **HGT:** Height of the maximum reflectivity in kft ARL

### Notes:


Let's take a look at the Storm Track Information attributes table. Each storm that has been identified will be listed on one of the pages of this table. The Storm ID is the letter/number combination discussed in detail during the SCIT lesson. Cells will be listed in order of cell-based VIL. In this example, J0 has the largest cell-based VIL and gets listed first.

The azimuth and range listed is for the current centroid location. It's not the location of the largest hail, high winds or heavy rain, but rather the storm's 3-D center of mass. Forecast movement shows the expected direction and speed for a particular cell. If it's a brand new storm, you will see the word "NEW". The next line, "ERR/MEAN", is a measure of how well the algorithm thinks it's doing tracking that particular storm. The error number indicates the distance of current position from previous forecast positions. The mean number is the average of all the errors during the lifetime of the storm. The last line shows the maximum reflectivity for that storm centroid, and the height (in thousands of feet) where that value is located.

## Radar Display Controls: Displays Can Be a Mess!

**Radar Display Controls: Displays Can Be a Mess!**

- Display can be cluttered if numerous cells present
- Limit number of cells displayed on product
  - Sorted by cell-based VIL
- AWIPS doesn't annotate display with this setting!
- Can select to display (or not display) past tracks or future positions

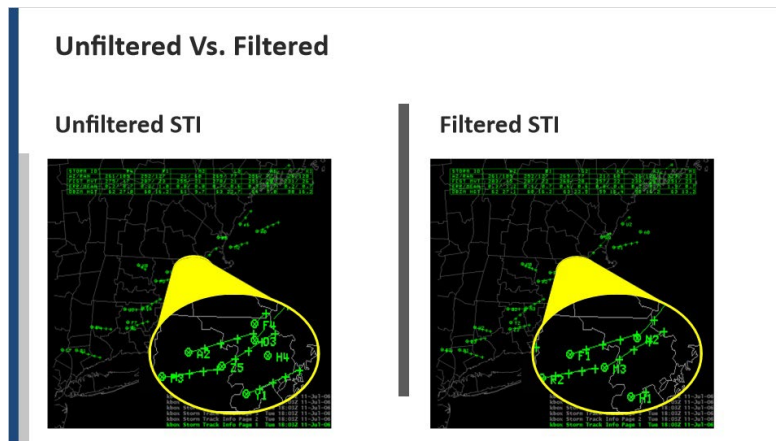


### Notes:

If the RPG identifies numerous, persistent storm centroids, the STI product can become very cluttered. Users have the ability to control the appearance of the STI product using the Radar Display Control GUI. At the top of the interface, a slider bar limits the number of storm centroids that are displayed. You can choose any number between 0 and 100. Remember that the storm centroids that are displayed will depend on their cell-based VIL. So, if you choose to display only 10 cells, then you will only see the ones with the highest cell-based VIL values. If storms are cycling in intensity on short-time scales, storm centroids could disappear and reappear from volume scan to volume scan if you have the display value set very low. Also, there is no way to tell in AWIPS how many cells are not being displayed because of this cut off value. So, if you set the value to 10, but the SCIT algorithm identified 30 storms, then AWIPS will not tell you that 20 storms are not being displayed.

You can also change how past and future cell tracks are displayed. You can choose to display past & future tracks, each individually, or neither. These settings can further help de-clutter your display.

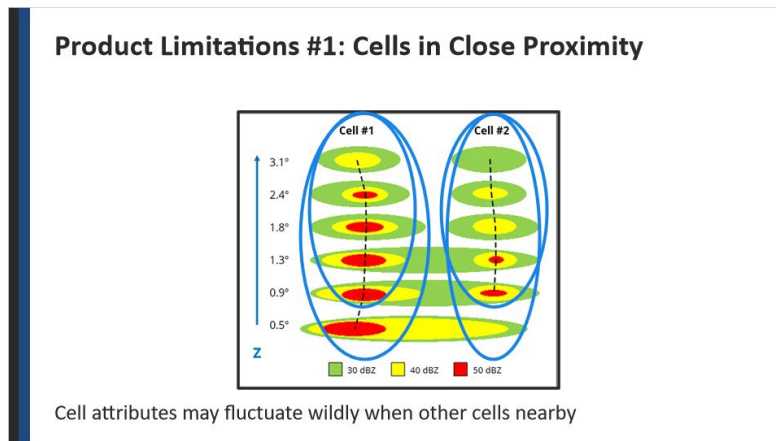
## Unfiltered Vs. Filtered



### Notes:

Recall from the SCIT lesson that users have the option to filter the reflectivity data input to that algorithm. The option that you choose will affect the appearance of the STI display. Let's look at an example with unfiltered data shown on the left and filtered data on the right. We will focus on the areas inside the yellow oval. You can see more centroids have been identified in the unfiltered data. While the unfiltered data gives you more storm centroids, the filtered STI likely shows you better centroid locations, making it a more reliable product.

## Product Limitations #1: Cells in Close Proximity

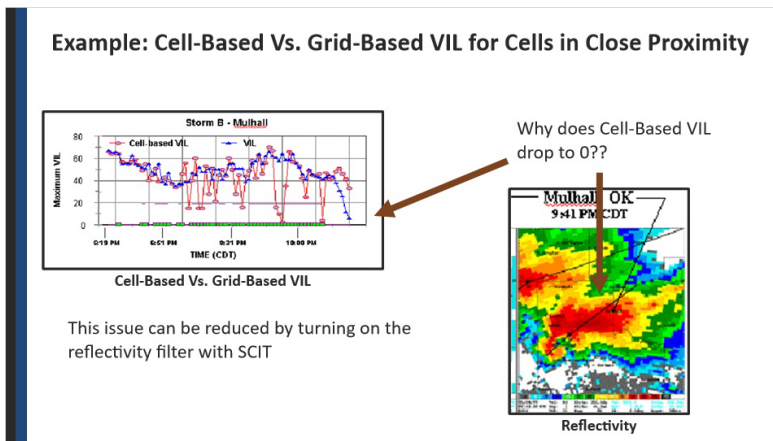


### Notes:

Now that we have covered the basics of the Storm Track Information product, let's talk about its limitations. Errors can sometimes occur in storm centroid trait calculations, or storm centroids could not be identified altogether, if cells are in close proximity to each other. Let's use an example to illustrate this limitation.

We see two cells, Cell 1 and Cell 2, that are made up of storm components, some of which they have in common, on multiple elevation angles. The SCIT algorithm doesn't "share" components between cells in close proximity. So, the large component at 0.5 degree is assigned completely to Cell 1. Even though a human can clearly see an echo at 0.5 degree for Cell 2, the SCIT algorithm truncates the bottom of this cell at 0.9 degrees. This algorithmic truncation will impact the attributes for Cell 2 that you see in STI, such as cell-based VIL. If cell-based VIL is reduced significantly, it would reduce where Cell 2 should fall in the algorithm's ranking system. Worse yet, if the structure of the 0.5 degree component changes significantly in the next volume scan, the algorithm could attach this component to the Cell 2 centroid next. The end result is that storm centroids in close proximity can appear to oscillate abnormally in intensity (and rank) due to this artifact in the SCIT algorithm.

## Example: Cell-Based Vs. Grid-Based VIL for Cells in Close Proximity



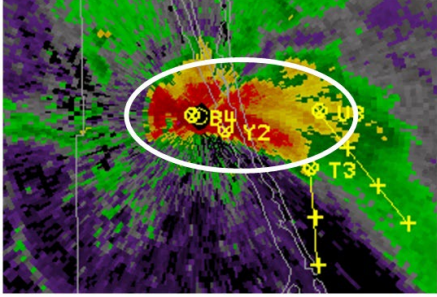
### Notes:

Here is another example of the errors that can occur when cells are in close proximity. This graph shows cell-based and grid-based VIL values for a particular storm over time (shown on the right). The cell-based VIL, shown in red, tends to vary much more than the grid-based VIL for this storm. It even drops all the way to 0  $\text{kg}/\text{m}^2$  a couple of times. One of those dropouts coincides closely with the reflectivity image shown at the right. Now, do you really think that storm should have a cell-based VIL of nearly 0? I don't think so. Clearly there is some storm segment shenanigans going on because two or more centroids are close together.

Some of these issues can be avoided by using filtered reflectivity data. However, using that adaptable parameter will not always prevent this issue from popping up.

## ***Product Limitations #2: Cells in the Cone of Silence***

**Product Limitations #2: Cells in the Cone of Silence**



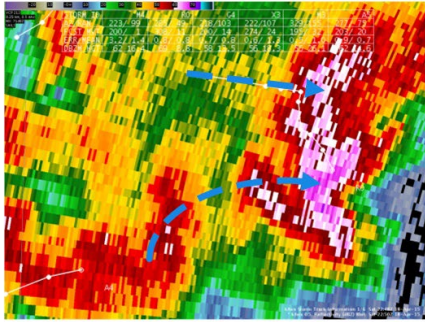
Mitigate errors by looking at data from another radar

### **Notes:**

A second limitation is large errors in cell attributes can occur for cells located in the cone of silence near the RDA. You can mitigate this issue by viewing data from a nearby radar (if one is available). That secondary radar should provide better cell attribute data, even though the storm is located further from the radar.

### ***Product Limitations #3: Errors Due to Storm Splits & Mergers***

**Product Limitations #3: Errors Due to Storm Splits & Mergers**



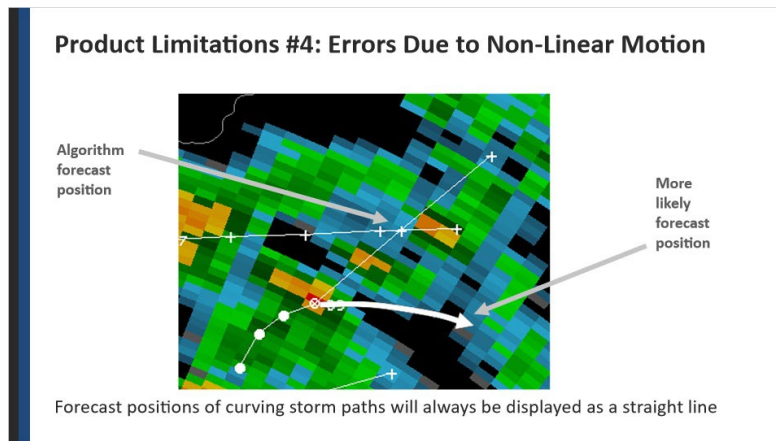
- Algorithm struggles to identify components and centroids
- Non-linear, unpredictable motion compounds issue

#### **Notes:**

A third limitation occurs when you have a large storm that splits or smaller storms that merge. As these processes occur, the algorithm can struggle to identify the storm components and centroids in a manner that makes the most sense to a human forecaster. Combine this issue with the non-linear, and sometimes unpredictable, cell propagation and redevelopment that occurs during these transitions, and you may be left scratching your head at the results.

In the example on the slide, we have two cells (labeled R0 and B4) that are on a collision course. As we move forward in time, you can see that B4 is moving initially to the north, but curving to the right. SCIT starts getting confused as they near each other and treats them as one centroid. As the B4 ID disappears, R0 starts taking a hard jog to the south. The core for this cell still is moving to the east at 0.5 degrees. You can see as we reach the last of the frames that the cores, which started merging aloft several volume scans ago, has now more or less merged at 0.5. The frames during the pre-merger phase may confuse you if you don't realize what is happening. If you use the STI regularly, you will need to catch these spurious identifications as they happen or they can lead you down the wrong path.

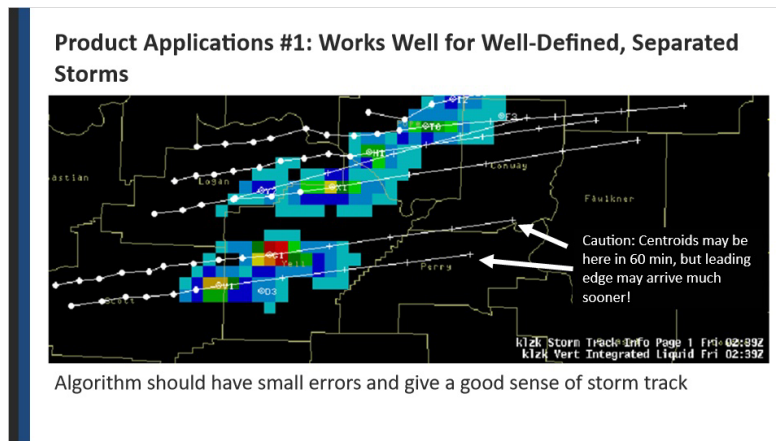
## Product Limitations #4: Errors Due to Non-Linear Motion



### Notes:

A fourth limitation occurs with cells experiencing non-linear motion. For each storm centroid, the SCIT algorithm generates a linear storm motion. So, the forecast positions shown in STI will always be a straight line. In the example on the slide, cell S9 clearly has been following a right-ward curving path. However, SCIT has assigned a linear forecast location for this cell. In reality, the curved arrow overlaid on the image gives a truer sense of the forecast path of this cell.

## ***Product Applications #1: Works Well for Well-Defined, Separated Storms***

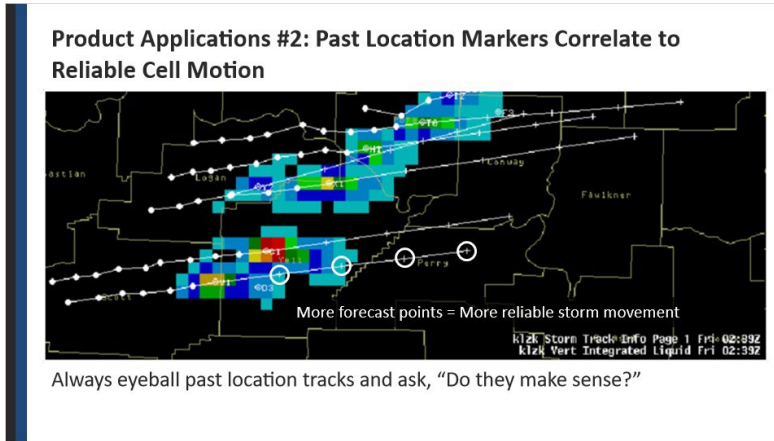


### **Notes:**

STI is most useful when you have well-defined, separated storms in your CWA. In the example shown, we have the STI overlaid on a gridded VIL product. With this display, we can see past storm locations, the current centroid location matching well with local maxima of VIL values, and future cell positions based on linear propagation. In situations like this one, the algorithm should have small errors and give forecasters a good sense of where these storms may track in the next hour.

If you are using STI to give you a sense of future storm positions, there's an important caveat to consider. The future positions just tell you where the algorithm thinks the storm centroid will be located. There's no indication where the leading edge of the cell is located. That location may not be the most important when it comes to tracking potential severe weather threats or, more importantly, drawing any warning polygons that are needed.

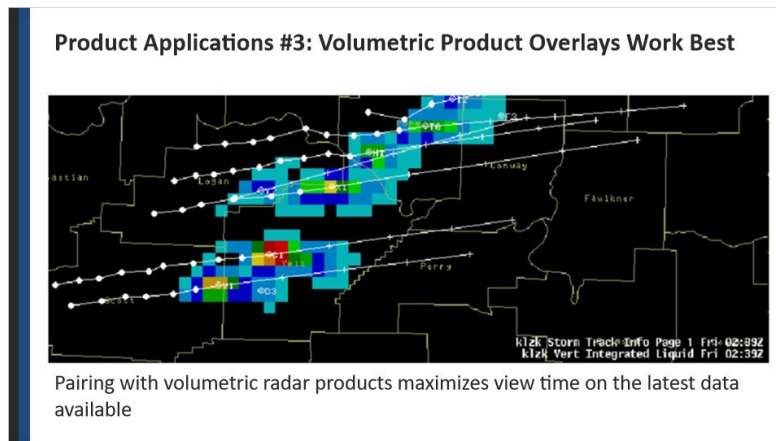
## ***Product Applications #2: Past Location Markers Correlate to Reliable Cell Motion***



### **Notes:**

In most cases, seeing a large number of past centroid locations markers (and preferably 4 forecast position markers) signifies a more reliable storm movement. You should always eye-ball these tracks and see if they make sense. Looking at this example, the algorithm appears to have a good handle on things.

### ***Product Applications #3: Volumetric Product Overlays Work Best***



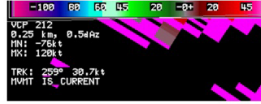
#### **Notes:**

As I mentioned previously, this STI is overlaid on a VIL product. While STI can be matched with any radar graphics product, we think it works best to display with volumetric products for time-matching reasons. If you try to plot STI on 0.5 degree Reflectivity, it will take several minutes for STI to appear on your products since STI is created at the end of the volume scan. That gives you very little time to view both products together before the next reflectivity image comes. Volumetric products are generated at the end of the volume scan, so the STI product will reside on the display longer when paired with them.

## Other Product Applications

### Other Product Applications

4. Cell motion can be used in storm-relative velocity products



5. Attributes are input to other derived products (e.g., Hail Index, Combined Attribute Table, SCAN display)



### Notes:

There are two other product applications you should know about with STI. STI cell-motions are used to determine the average cell motion velocity, which is one of three velocities used to calculate the Storm Relative Mean Radial Velocity Map (SRM) product. This average velocity is often a good first guess estimate for use with SRM. Second, the storm attributes shown in STI are the same critical inputs that go into the Hail Index product and SCAN displays. If you use those products, you may want to have STI available in an AWIPS display so that you look at the data going into them.

## Summary

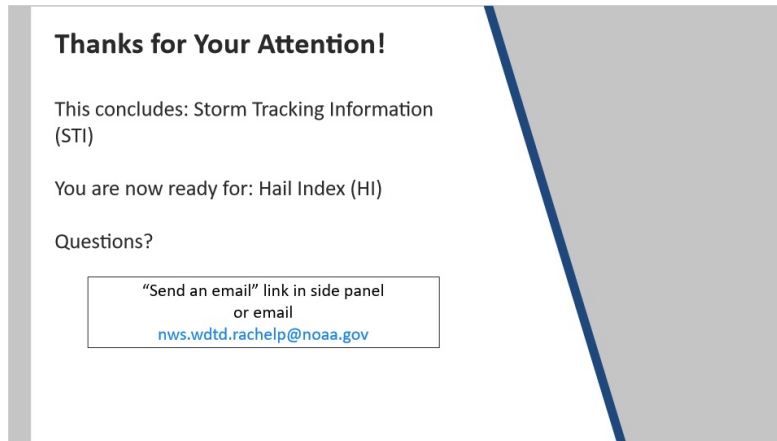
### Summary

- Errors occur in cell identification and tracking when cells are in close proximity
- Cell identification and tracking works best when storms are separated and little development or dissipation is occurring
- A large number of past tracks and/or four forecast positions are indications of reliable tracking

### Notes:

The Storm Tracking Information product provides a graphical display of the storm cell attributes generated by the SCIT algorithm. This product has several limitations. Errors can occur when storms are located close together, fall within the radar's cone of silence, or when they move (or propagate) in a non-linear fashion. Be very suspicious of the attributes in those instances. Likewise, the STI product works best when storms are widely separated, temporally persistent, and move in a linear fashion. When STI shows numerous past storm centroid locations and four forecast positions, the algorithm thinks that the storm motion is quite reliable.

## ***1.27 Thanks for Your Attention!***



**Thanks for Your Attention!**

This concludes: Storm Tracking Information (STI)

You are now ready for: Hail Index (HI)

Questions?

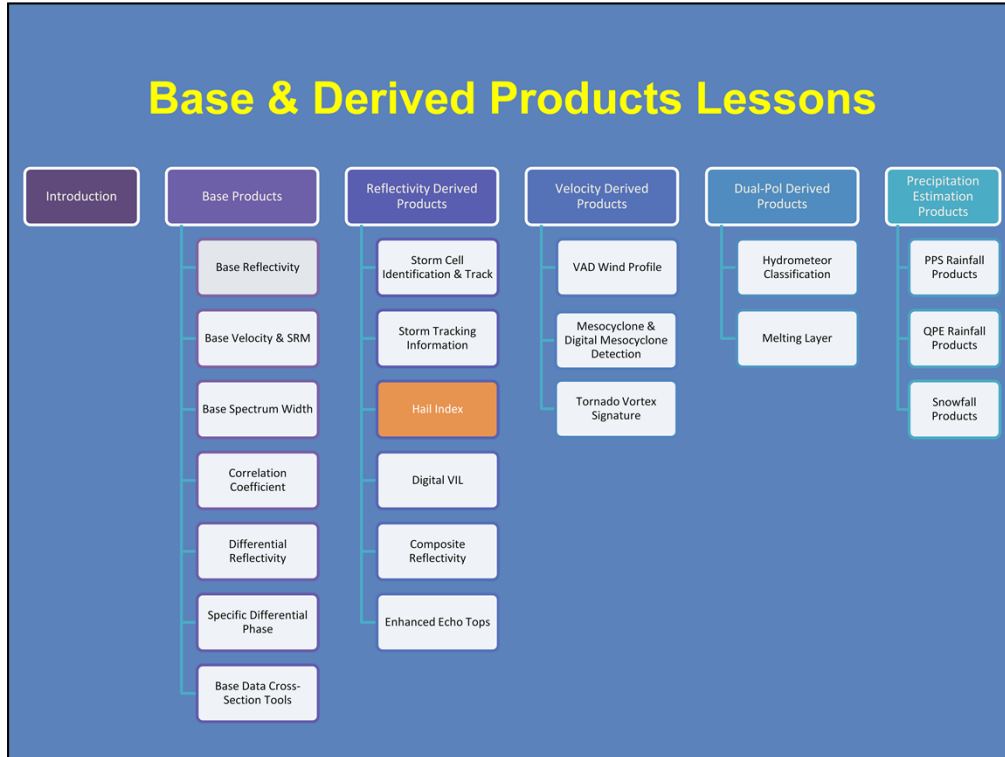
"Send an email" link in side panel  
or email  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

### **Notes:**

If you have passed the quiz, then you have successfully completed this lesson. You are now ready to move onto the next lesson, Hail Index (HI). If you have any questions, please contact us using any of the e-mail addresses listed on the bottom of the slide.



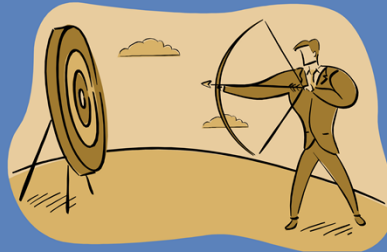
Welcome to the next lesson on Reflectivity-Derived Products. This lesson will cover the Hail Index algorithm.



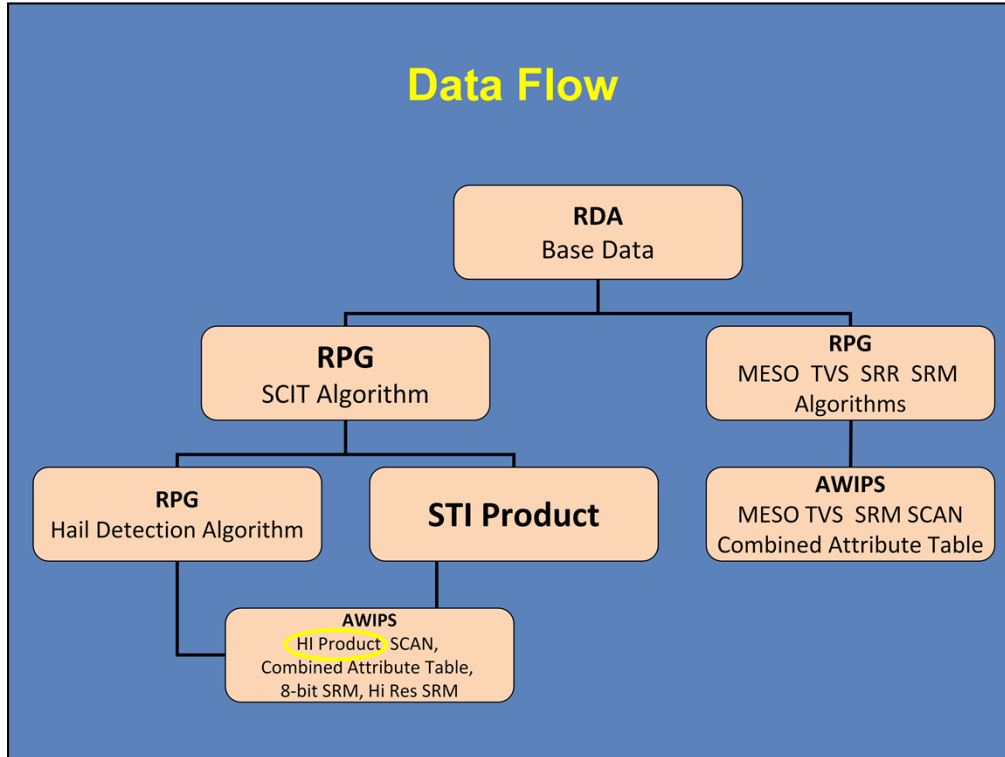
Here is a roadmap for the lessons in this topic. This lesson on the Hail Index algorithm, shaded in orange, is the third in the Reflectivity Derived Products Section of this topic.

## Learning Objectives

Upon completion of this lesson you will be able to identify the characteristics, limitations, and applications (strengths) of the Hail Index (HI) product



Here are the learning objectives for this lesson. When you are ready click advance to start this lesson.



This is the flow of data from the RDA to the RPG and ultimately to your AWIPS-2 workstation. On the right side is velocity derived products that we'll discuss soon, but for this lesson we can see that output from the SCIT algorithm is ingested by the Hail Detection Algorithm which then produces the hail index product. Let's dive deeper into this Hail Index product.

## Hail Detection Algorithm (HDA)

### INPUTS

1. Component and cell attributes from SCIT
2. 0°C and -20°C heights supplied to the RPG

### OUTPUTS

1. Probability of Hail (any size) - 10% increments (POH)
2. Probability of Severe Hail (3/4 in) 10% increments (POSH)
3. Maximum Expected Size of Hail - 1/4 inch increments (MESH)

NOTE: POSH does **not** reflect requirement of 1" hail

Let's go over a summary of the inputs and outputs of the HDA. The Hail Detection Algorithm requires just 2 inputs: Component and cell attributes from SCIT, and the 0 and -20 degree Celsius heights supplied to the RPG. The HDA outputs 3 things that get put into the Hail Index...probability of hail which is any size in 10% increments...probability of severe hail (or POSH) which means hail greater than 3/4" in 10% increments...and finally the maximum expected size of hail in 1/4" increments which we call MESH. One note here...despite the 1" criteria for severe hail, the POSH was never updated to reflect this.

## Hail Detection Algorithm (HDA)

### POH:

- Uses the altitude of the highest component above the 0°C level with a reflectivity > 45 dBZ
- The greater the height, the greater the POH

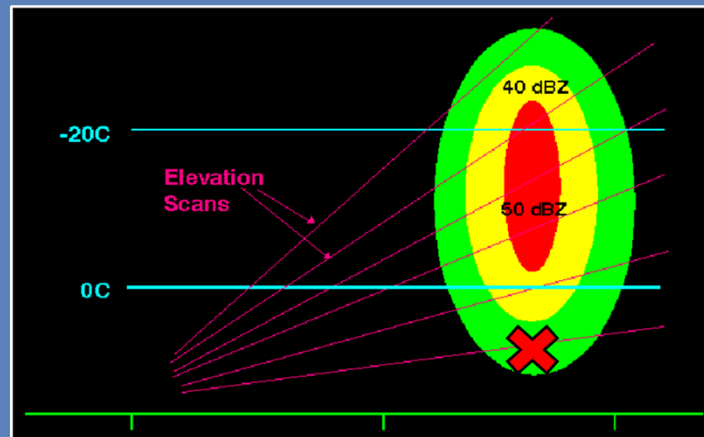
### POSH:

- Uses all components above 0°C level that have maximum reflectivities > 40 dBZ
- The greater the height, the greater the weighting factor
- Reflectivity > 50 dBZ and above -20°C altitude get the highest weighting

Let's learn the details of the HDA output, the probability of hail first. This uses the altitude of the highest component above the 0 degree Celsius level with a reflectivity greater than 45 dBZ. It is a linear relationship. The greater the height, the higher the probability of hail. POSH uses all components above the 0 degree Celsius level that have maximum reflectivity values greater than 40 dBZ. The greater the height, the greater the weighting factor. Reflectivity values greater than 50 dBZ and above the -20 degree Celsius altitude get the highest weighting. We'll explain this a little further on the next slide.

## Hail Detection Algorithm





- > 50 dBZ, higher than -20°C → Full weight
- < 40 dBZ, lower than 0°C → Removed entirely

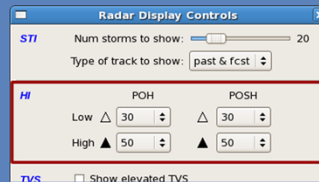


So to recap, the HDA uses 2 weighting function, one is for temperature and the other uses reflectivity values. Reflectivity values greater than 50 dBZ occurring at heights higher than the -20 C level receive full weight. On the flip side, reflectivity values less than 40 dBZ and below the 0 C level are removed entirely. The weighting functions really come into play when reflectivities are between 40 and 50 dBZ or are located between the 0 and -20 C heights.

## Hail Symbols

NOTE: Only one symbol per centroid

- 
  - Minimum POH Threshold  $\leq$  POH < Fill-in Threshold  
 Default = 10 % Default = 50 %
  
- 
  - POH  $\geq$  Fill-in Threshold & POSH < Minimum POSH Threshold  
 Default = 50% Default = 10%
  
- 
  - Minimum POSH Threshold  $\leq$  POSH < Fill-in Threshold  
 Default = 10 % Default = 50 %
  
- 
  - POSH  $\geq$  Fill-in Threshold  
 Default = 50%



There are multiple symbols that can be assigned to a hail centroid, but only 1 is allowed. Let's look at these different symbols and see what they mean. First note that the default minimum threshold is 10% and the default threshold to fill in an icon is 50%. Then, the first icon is a small, open triangle. This means that the POH value is between the minimum POH threshold and the minimum POH fill-in threshold. The next symbol is a small, filled-in triangle which means that the minimum POH fill-in threshold has been met, but the minimum POSH threshold has not been met. A large, open triangle means that the minimum POSH threshold has been reached, but the minimum POSH fill-in threshold has not been met. Finally, a large, filled-in triangle means the minimum POSH fill-in threshold has been met. The numbers listed in the upper right of some of the symbols represent the maximum expected hail sizes in inches. An asterisk means that the maximum expected hail size is less than 3/4 inch. In a warning environment, a forecaster will probably only concern themselves with the large, filled-in triangles. But keep in mind these thresholds are defined at your workstation through the Radar Display Controls GUI. If the triangles are creating too much clutter, raise your thresholds.



## Hail Attribute Table

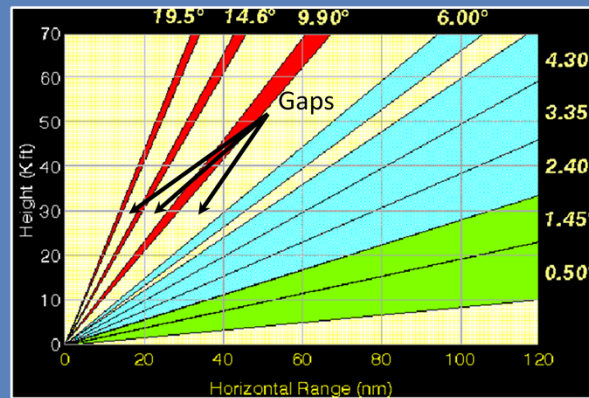
STORM ID	00	00	X3	10	00	00
AZ/RAN	106/104	120/ 96	122/102	135/ 66	127/ 80	124/ 84
POSH/POH	100/100	100/100	100/100	100/100	100/100	100/100
MAX HAIL SIZE	2.00	1.00	1.25	1.00	0.75	0.50
0/-20 C TEMP ALT	13.5/24.0 KFT(MSL) - LAST CHANGED 20:18 02/22/99					

- STORM ID - ordered by POSH then POH
- AZ / RAN - Azimuth and range to centroid (Not Hail)
- POSH / POH - in 10% increments
- MAX HAIL SIZE - in 1/4 inch increments
- 0° & -20° C TEMP ALT - Altitude in KFT (MSL) set by RPG HCI operator and the time/date of the last change

Now let's examine the Hail Attribute Table that can be found toward the top of the HI product. In the first row is Storm ID. The ordering of these IDs is by POSH, then POH. These are just the storm IDs that are assigned by the SCIT algorithm. The next row is the azimuth and range to the centroid of the storm identified which may or may not be the hail core. The next row is the POSH and POH values for the identified storm in 10% increments. The fourth row is the MESH and is listed in 1/4" increments. Finally, the bottom row lists the 0 and -20 C heights in kft MSL as defined in the RPG HCI environmental window. It also tells you the last time these values were updated.

## Product Limitations

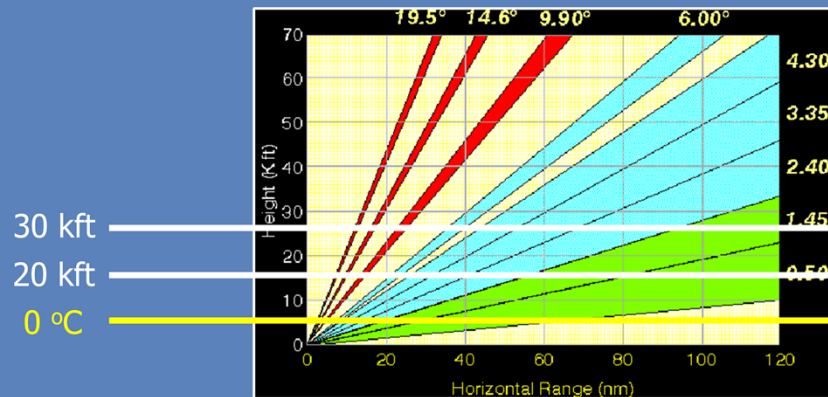
1. Values of POH, POSH, and MESH will fluctuate at close ranges



Now for the limitations. The first one is values of POSH/POH and MESH will fluctuate at close ranges to the radar. The primary reason is the gaps in elevation which are more prominent when storms are close to the radar.

## Product Limitations

2. Values of POH, POSH, MESH may fluctuate at long ranges

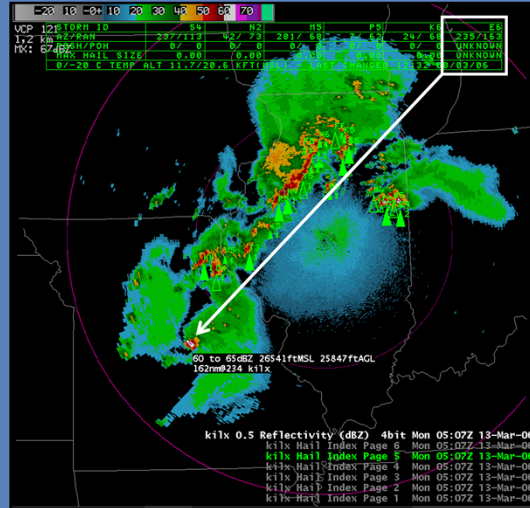


The opposite is also true. At further ranges the values of POSH, POH and MESH may fluctuate. Now, this is not so much tied to VCP choice as it is the earth curvature issue. Recall that at long ranges, the beam is sampling higher and higher into the atmosphere. So at long ranges, only a couple elevations may sample the storm, but as it moves closer more elevations sample the storm and the values of POH, POSH and MESH will fluctuate and this may or may not be representative of what is actually occurring.

## Product Limitations

- Cells beyond 124 nm identified as "UNKNOWN"

NOTE: Cell with POSH = 0 & POH = 0 listed in the Hail Attribute Table **before** cell at ranges > 124 nm (even if it contains large hail)

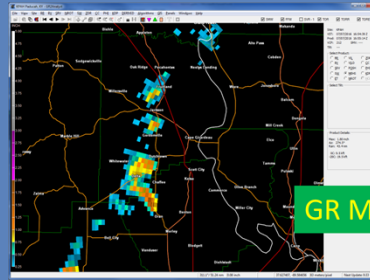
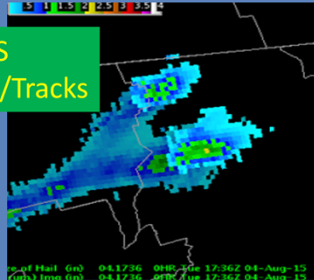


Although storms can be identified out to ranges beyond 124 nm, the HI product does not compute beyond that range. So storms identified at ranges beyond 124 nm will have HI characteristics listed as "Unknown". Something interesting here is that cells with POH and POSH of zero will be listed before a storm at ranges further than 124 nm, even if that storm is severe and producing softball-sized hail! Notice in this example that you have to go all the way to page 5 to see this storm identified. It was at a range greater than 124 nm so its HI characteristics were listed as "Unknown," even though you can clearly see it is severe and you would want to pay attention to it.

## Product Limitations

4. POSH and MESH may be overestimated in weak wind and tropical environments
5. Other products give better geographical representation of hail size (may also be overestimated in weak wind and tropical environments)

MRMS  
MESH/Tracks



GR MEHS

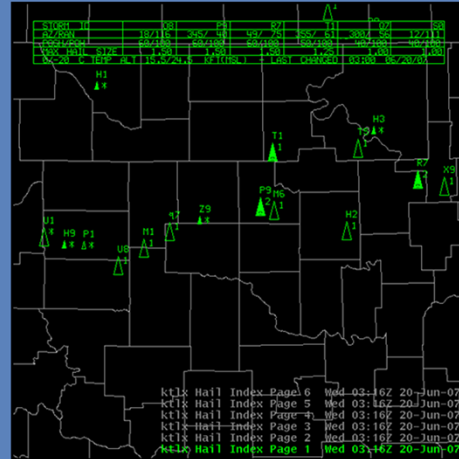
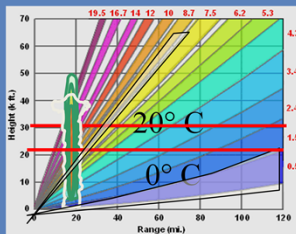
CAUTION: Use only after a thorough base data analysis as a **guide** in the warning decision process, integrating w/spotter reports, etc.

Additionally, several local studies have shown that POSH and MESH may be overestimated in weak wind and tropical environments. Finally, it is worth noting that other hail products can give better spatial representations of hail size and even trends, though they may also exhibit the same overestimation as the HI. Multi-Radar/Multi-Sensor (MRMS) Maximum Estimated Size of Hail (MESH) and its MESH Tracks pinpoint a storm's core and other features such as trends and deviant motion. Studies (Wilson et al. 2009, Cintineo et al. 2012) have shown MESH has utility in determining the presence of severe hail but not to discriminate between severe and giant hail. If you're a GR user, Gibson Ridge's Maximum Expected Hail Size can also give you a hail size estimate and an inferred core location. GR uses the same hail size algorithm as MRMS MESH, one developed at the National Severe Storms Laboratory, but can still give different estimates. Taking into account all these limitations, it is highly recommended that the HI product only be used as a GUIDE in the warning decision process. Do a thorough base data analysis integrated with spotter reports, etc. and then use the HI product as a consistency check with regards to hail threat.

## Product Applications

1. High probability of detection in cells that contain severe hail

NOTE: A POSH of 70% has been related to 1" hail by the Radar Operations Center (modified from Witt et al. 1998)



Let's examine how you'd apply hail index products. Despite the high false alarm rate, the hail index product scores a high probability of detection for severe hail. What this means is that with Hail index it won't often miss severe hail events, but as discussed earlier it false alarms often. If using POSH, the Radar Operations Center found 1" hail corresponds 70% POSH.

## Summary

- Hail Index Product displays three values: POSH, POH, MESH for identified cells
- Uses attributes calculated by the SCIT algorithm and 0°C and -20°C heights (MSL) input at the RPG HCI
- Can be overestimated in weak shear and tropical environments

Summarizing this lesson, HI displays three different values; POH, POSH and MESH for all identified cells. It uses attributes calculated by the SCIT algorithm and the 0 and -20 C heights MSL input at the RPG HCI. Keep in mind it can be overestimated in weak wind and tropical environments. The next slide will be a short quiz on this lesson.

## Thanks for Your Attention!

This concludes:  
Hail Index (HI)

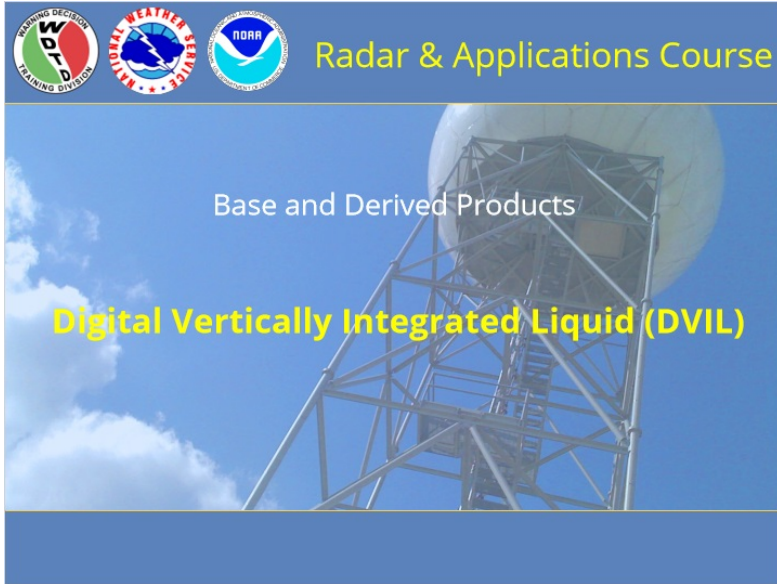
Questions?

“Send an email” link in side panel  
or email  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

This concludes the lesson on the HI product. You can now move onto the next lesson. If you have any questions, feel free to email the contacts listed.

# Digital Vertically Integrated Liquid (DVIL)

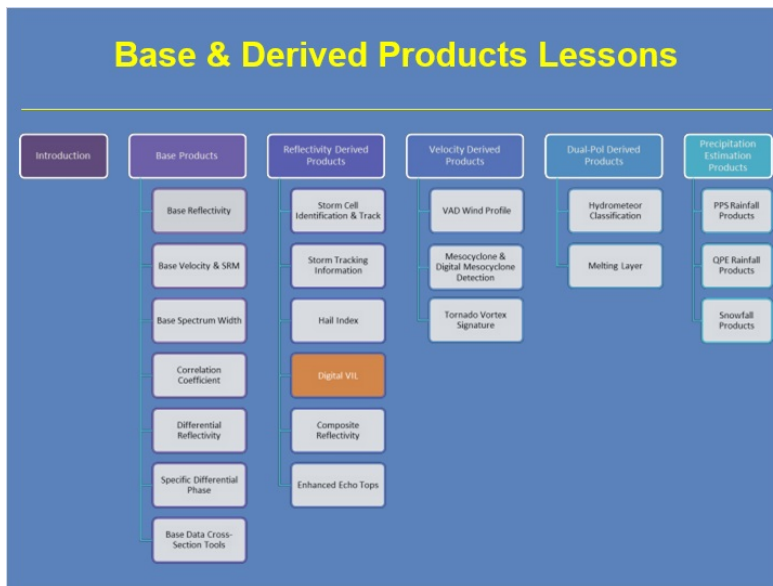
## 1.1 Introduction



### Notes:

Welcome to the next lesson on Reflectivity-Derived Products. This lesson will cover the Digital Vertically Integrated Liquid (DVIL).

## 1.2 Base & Derived Products Lessons




### Notes:

Here is a roadmap for the lessons in this topic. This lesson on the Digital Vertically Integrated Liquid (DVIL), shaded in orange, is the fourth in the Reflectivity Derived Products Section of this topic.

## 1.3 Learning Objectives

**Learning Objectives**

Upon completion of this lesson, you will be able to identify specific characteristics, limitations, and applications (strengths) of the Digital Vertically Integrated Liquid (DVIL) product



**Notes:**

Here are the learning objectives for this lesson. Please advance the slide when you are ready to begin.

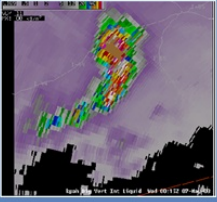
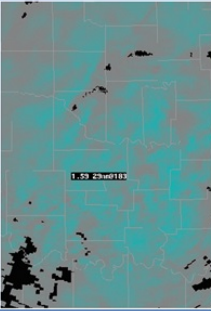
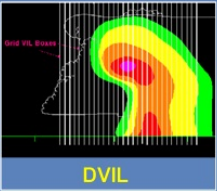
**1.4 Course Completion**

### Course Completion

Review Lesson	<b>Introduction</b> In order for NWS forecasters to receive credit for this course in the NWS Learning Center, you will need to take the following steps
Complete the Quiz	
Technical Problems?	

**2.1 DVIL Menu**

### Digital Vertically Integrated Liquid (DVIL)

Product Characteristics		
Product Applications		
Product Limitations	<b>DVIL</b>	

**QUIZ**

**Notes:**

Welcome to the homepage for this lesson on DVIL. From here, you can click on these three buttons to learn more about DVIL's characteristics, why it is useful, and some of the limitations for using it in operations. Once you feel comfortable with these materials, click here to take the quiz.

## **2.2 Digital Vertically Integrated Liquid (DVIL)**

**Digital Vertically Integrated Liquid (DVIL)**

- Uses same equation as VIL for converting reflectivity values to a liquid water content

$$M = 3.44 \times 10^{-3} Z^{(4/7)}$$

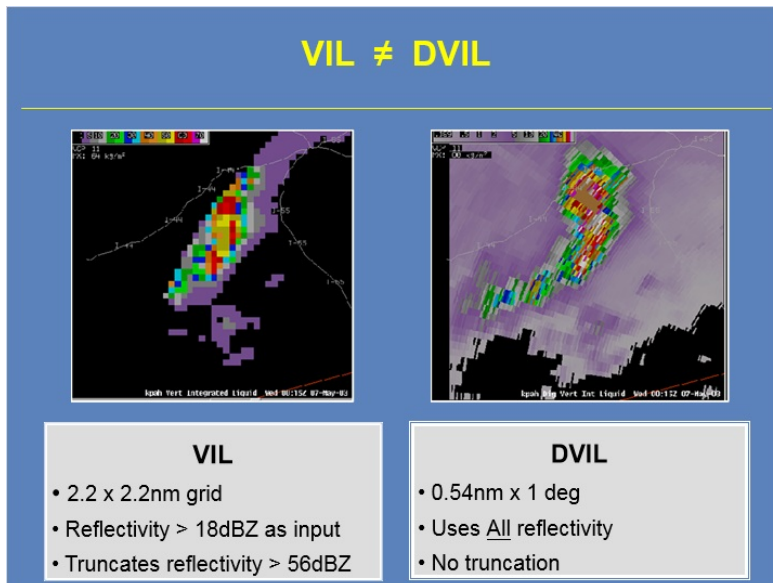
**M = liquid water content (g m<sup>-3</sup>)**  
**Z = radar reflectivity (mm<sup>6</sup> m<sup>-3</sup>)**

See RAC References NOAA Virtual Laboratory (VLab) page for information about VIL

**Notes:**

First, let's note that this lesson only covers the Digital VIL product. If you'd like to learn more about the VIL product, you can refer to the RAC References NOAA Virtual Laboratory (VLab) page for this lesson. What's important here is to note that DVIL uses the same equation as VIL which is shown here, where M = liquid water content (g m<sup>-3</sup>) and Z = radar reflectivity. The values are derived from each 1 km (0.54 nm) x 1 degree range bin, and then vertically integrated. DVIL values are output in kg/m<sup>2</sup>, and displayed in 256 data levels from 0 to 80 kg/m<sup>2</sup> out to a range of 460 km (248 nm). However, DVIL and VIL differ in many ways. We'll see that in the next slide.

## 2.3 VIL $\neq$ DVIL



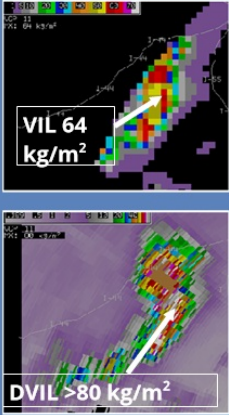
### Notes:

Here are the differences between VIL and DVIL. First VIL is a gridded product that has a resolution of 2.2 nm x 2.2 nm. DVIL is a polar coordinate product that is 0.54 nm by 1 deg. Secondly, VIL does not use reflectivity values below 18 dBZ whereas DVIL uses all reflectivity values. And on the other side, VIL truncates reflectivity values greater than 56 dBZ where as DVIL uses all reflectivity values as mentioned. So, you can see in the example shown that VIL and DVIL are definitely not apples to apples comparisons.

## 2.4 Limitations (DVIL not VIL)

**Product Limitations**

1. Higher resolution and no truncation produces different values when compared to VIL
  - VIL research findings invalid for DVIL
    - VIL Density
    - VIL of the Day



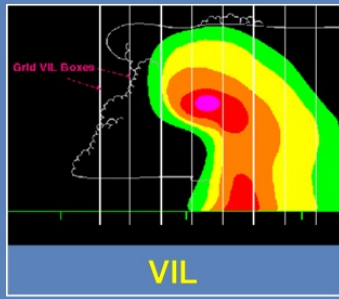
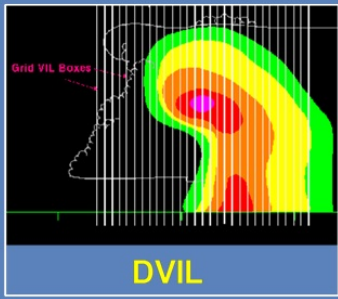
### Notes:

So looking at the limitations of DVIL. The higher resolution and no truncation produces different values when compared to VIL. This difference renders all VIL study findings invalid when using DVIL values. Therefore, you cannot use VIL diagrams when viewing DVIL. You can see this illustrated in the example shown. The VIL and DVIL values are vastly different, so trying to use your “VIL of the Day” while looking at DVIL would not be wise.

## 2.5 Fast Moving / Tilted Storms

### Product Limitations

- Greater impact of fast movement and tilt on DVIL than VIL



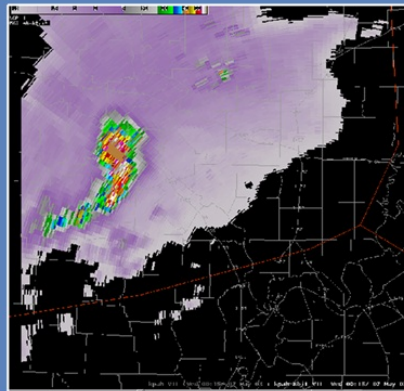
#### Notes:

Because of the higher resolution of the DVIL product, there is greater impact of fast moving storms and tilt on the values of DVIL than you will see on VIL. So, watch for erroneous DVIL values when you have fast storm motion.

## 2.6 Large Area of Max Values

### Product Limitations

- 80 kg/m<sup>2</sup> max value is commonly reached due to lack of truncation



**Notes:**

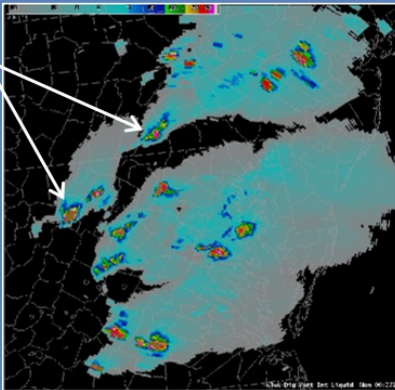
Because we don't truncate reflectivities used in the DVIL algorithm, you tend to get larger areas of high VIL values. In this case, 80 kg/m<sup>2</sup>, which is the maximum value the product will display, can be reached much more easily resulting in large areas of the maximum value. If you'd like to fix this issue, you can raise the maximum threshold of your color scale.

## **2.8 Applications (Quickly Identify Storms)**

**Product Applications**

---

1. Helps locate areas of more significant Z cores



**Notes:**

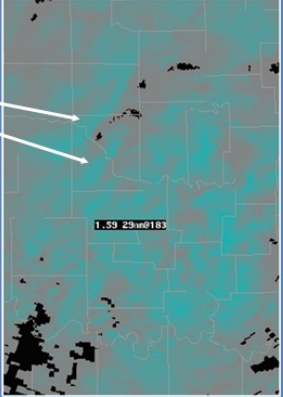
The primary application for the DVIL product is it can help you locate the areas of more significant Z more easily. Notice how in this image, you can quickly identify which areas are experiencing more significant storm. If you were to look at reflectivity, some of the weaker areas may be contaminated by high Z due to ground clutter, but DVIL has not been impacted by it, making it easier to see the strengths of the storms relative to each other in the DVIL product.

## 2.9 Weak Z Features

**Product Applications**

2. Displays low reflectivity features

- Snow bands
- Gust fronts
- Smoke plumes



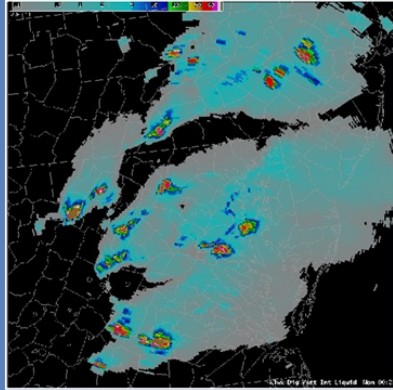
### Notes:

As is often the case with most of these products, sometimes its limitations in one area becomes a strength elsewhere. This is an example we have with DVIL. Because we are including all reflectivities, especially the lower reflectivities, we can see weak features such as snow bands, gust fronts or smoke plumes in the DVIL product. This was actually a surprise when we first fielded the product, but because of the inclusion of lower reflectivities in the integration, we can see these feature more frequently in the DVIL product.

## 2.10 Ground Clutter

### Product Applications

3. Ground clutter has less impact on DVIL than other volume products (e.g. Composite Reflectivity)
  - Used by FAA



#### Notes:

You might be able to better sort out ground clutter on DVIL than you would be able to on certain products such as CZ. When you are looking at high Z in the CZ product, and DVIL is low, you know that that region does not have much vertical extent so you can sort out what is AP more easily. This application is used by the FAA to detect ground clutter.

## 2.7 Summary

### Summary

---

- Values differ from VIL due to different grid size and lack of truncation of high reflectivity values
- Weak reflectivity signatures displayed
- Impact of ground clutter less than on other volume products

#### Notes:

In summary of the digital VIL or DVIL product...the values differ from VIL due to different grid size and the lack of truncation of high reflectivities. You can see very weak reflectivity features displayed, and the impact of ground clutter is less than that of other volume products such as CZ. The next slide will be a short quiz over this lesson.

## 4.1 Conclusion

### Thanks for Your Attention!

---

This concludes:  
Digital Vertically Integrated Liquid (DVIL)

Questions?

"Send an email" link in side panel  
or email  
[nws.wtdt.rachelp@noaa.gov](mailto:nws.wtdt.rachelp@noaa.gov)

#### Notes:

This concludes the lesson on the DVIL product. You can now move onto the next lesson. If you have any questions, feel free to email the contacts listed.

# Composite Reflectivity

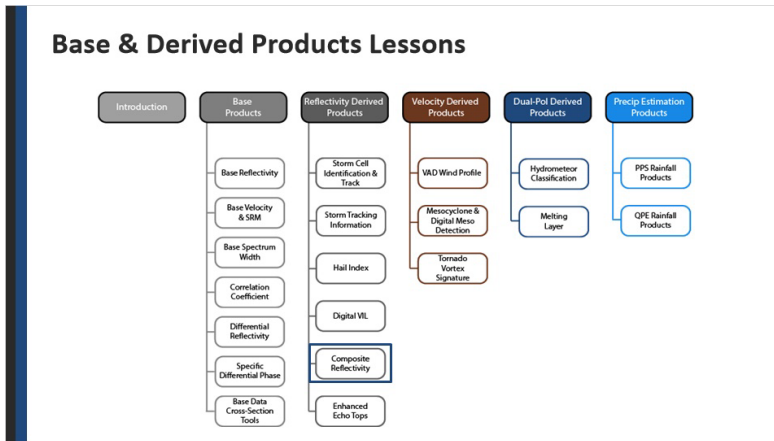
## *Introduction*



### **Notes:**

Welcome to this lesson on the Composite Reflectivity (CZ) product. This training is part of the Base and Derived Products topic in the Radar and Applications Course. Let's get started.

## Base & Derived Products Lessons



### Notes:

Here is a roadmap for the lessons in this topic. This lesson on the Composite Reflectivity product, highlighted in the chart shown on the slide, is part of the Reflectivity Derived Products Section of this topic.

## ***Learning Objectives***

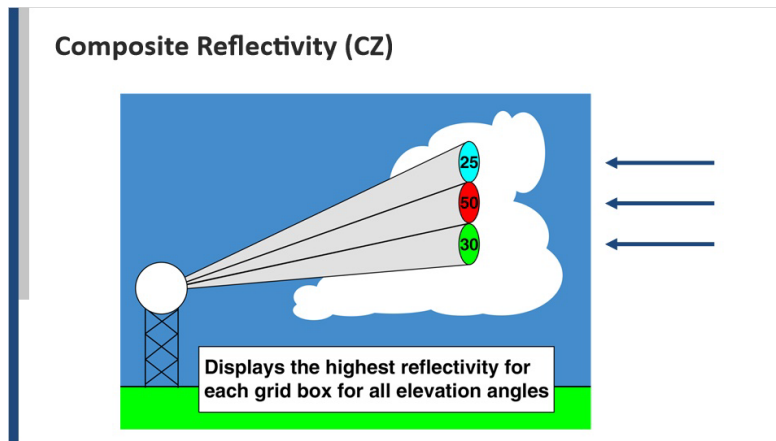
### **Learning Objectives**

1. Identify the definition of composite reflectivity and the specific attributes available for viewing with the Composite Reflectivity (CZ) product
2. Identify the limitations & applications of the Composite Reflectivity product

### **Notes:**

Here are the learning objectives for this lesson. Take a moment to read these and advance the slide when you are ready.

## Composite Reflectivity (CZ)



### Notes:

The composite reflectivity product is based on a straight-forward concept. The purpose of CZ is to indicate the maximum reflectivity at a point for the entire volume scan. The RPG accomplishes this task by picking the highest reflectivity value for that point from each elevation angle scan from that volume.

So, if we look at this example here, we are looking at the reflectivity values above a particular grid box. At 0.5 deg, the radar observes 30 dBZ at that location. At 1.5 deg, 50 dBZ is observed. And, at 2.4 deg, the radar detects 25 dBZ. Composite Reflectivity will pick the highest reflectivity value from these (and any other available) data and display that value for that location.

The key point is this: when we look at the CZ product, we don't know from which elevation angle the displayed value was observed. We just know that was the highest value in the volume above that grid box.

## Composite Reflectivity (CZ): Combined Attribute Table

**Composite Reflectivity (CZ): Combined Attribute Table**

STN ID	AZ/RAN	TVS	MDA	POSH/POH/MX SIZE	VIL	DBZH	HT	TOP	FCST	MVHT
F4	293/106	NONE	6	70/100/ 1.25	46	64	12.7	33.1	212/ 36	
Z4	237/ 76	NONE	5	80/100/ 1.50	52	64	16.2	35.5	231/ 48	
T5	304/104	NONE	5	0/ 60/10.50	21	52	12.3	23.8	NEW	
O3	313/ 97	NONE	3	100/100/ 2.00	59	67	11.1	30.3	240/ 43	

- Contains information from SCIT, HDA, MDA, & TDA Algorithms
- Order of storms:
  1. TVS, ETVS or None
  2. Strength Rank for MDA detected Meso, or None
  3. Probability of Severe Hail (POSH)
  4. Probability of Hail (POH)
  5. Cell based VIL
  6. Max Reflectivity

### Notes:

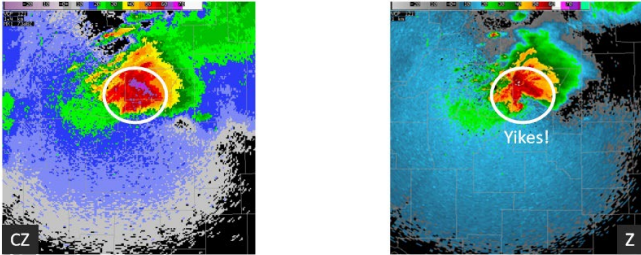
The Composite Reflectivity display is different from other reflectivity products because it displays with the Combined Attributes Table. This table displays information from the SCIT, HDA, MDA and TDA algorithms. The Combined Attribute Table gives you a dashboard view of severe weather likelihood. One way to remember which product this table comes with is Combined and Composite both begin with COM.

Notice that the table is organized with the Storm ID from SCIT on the left. The next column contains the azimuth and range where the SCIT defined storm centroid is located (not necessarily the most significant portion of the storm weatherwise).

The remaining data help determine the order in which the storms are listed. The storm order gives precedence to the most "significant" storm first. Storms with a TVS detected are listed at the top. After that, storms with a MDA detection will be listed next in order of the circulation's strength rank. The next criteria used are the storms POSH and POH values. Then, the algorithm uses the cell-based VIL computed by the SCIT. Lastly, storms are sorted by the highest reflectivity value and the height of that value.

## ***Product Limitations #1: Low-Level Reflectivity Signatures Obscured***

**Product Limitations #1: Low-Level Reflectivity Signatures Obscured**



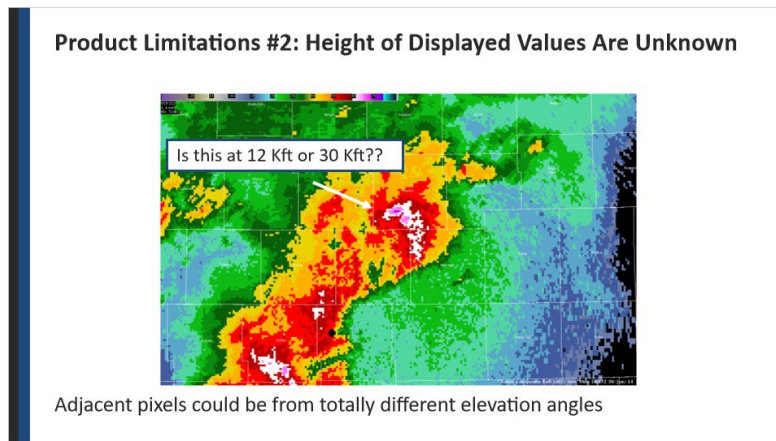
Composite Reflectivity makes it difficult to observe storm structure at low levels useful for warning issuance

### **Notes:**

So, let's talk about the limitations of CZ. Arguably the biggest limitation is the tendency of Composite Reflectivity to obscure low- and midlevel signatures. CZ makes it difficult to observe storm structure at these levels useful for warning issuance.

Let's look at an example. The CZ image on the left shows a big blob of a storm with high Z, approaching 70 dBZ. If you were just using this product, then you would miss the well-defined hook echo seen in the image on the right (the 0.5 deg Z product). The lesson here is make sure you use Base Reflectivity along with CZ when analyzing storm structure.

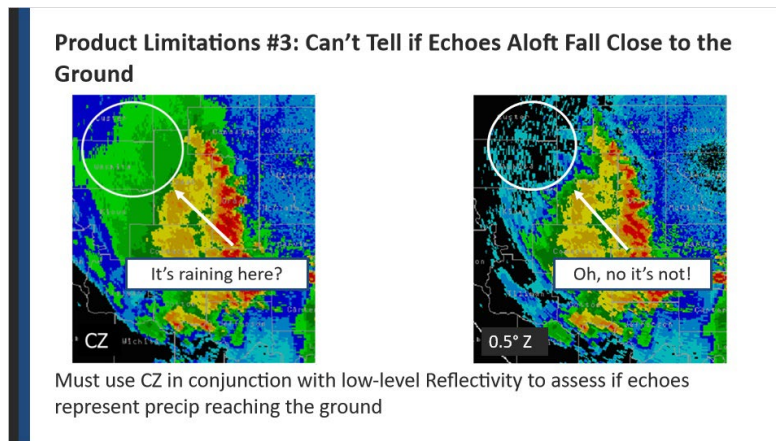
## ***Product Limitations #2: Height of Displayed Values Are Unknown***



### **Notes:**

By design, the CZ product gives us the max reflectivity anywhere in the volume scan. The problem is we don't know where it came from. We have no idea if that max Z is from 0.5 deg or 19.5 deg. In this example, we don't know if the pixel being pointed out displays data collected at 12 kft, 30 kft, or anywhere else. All we know is that it is somewhere in that volume above that particular location. This limitation is another reason not to use CZ for identifying storm features because adjacent pixels could be from totally different elevation angles.

### ***Product Limitations #3: Can't Tell if Echoes Aloft Fall Close to the Ground***

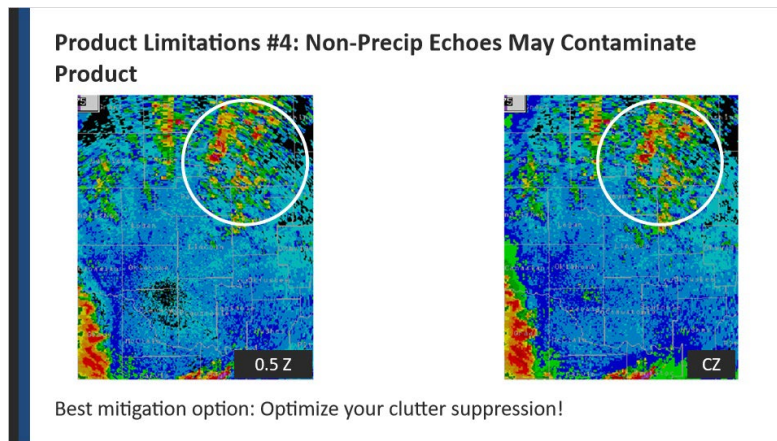


#### **Notes:**

This next limitation is similar to the one we just talked about. Composite Reflectivity doesn't allow you to discriminate whether the reflectivity displayed is precip that actually reaches the ground (i.e., virga).

In this CZ product shown on the left, we have a lot of echo. If you just looked at this product, you might think it was raining at the surface in the circled area. However, one look at the 0.5 deg Z and you'll see that those echoes are not precipitation reaching the ground. So, I continue to beat the broken drum that you must use CZ in conjunction with Z to better assess if echoes represent precipitation reaching the ground.

## ***Product Limitations #4: Non-Precip Echoes May Contaminate Product***

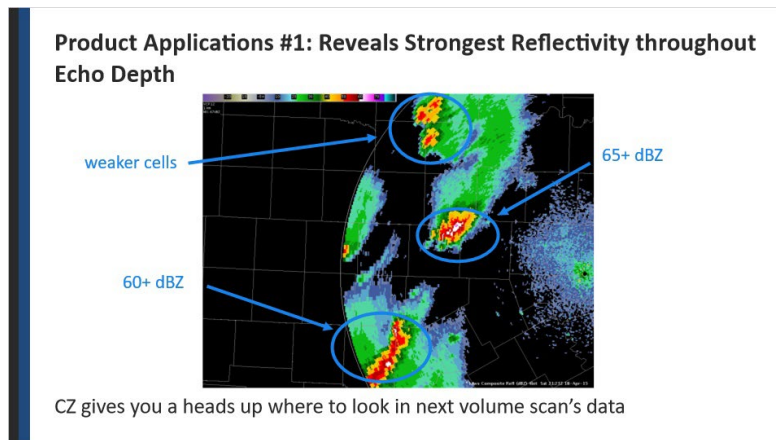


### **Notes:**

The next limitation involves anomalous propagation and ground clutter. The images on this slide are an example of how these returns on low elevation angle scans can contaminate the CZ product. Remember, the values displayed in CZ are not required to have vertical extent to be included in the product.

The best option is to optimize your clutter suppression. However, you need to be aware that these returns may appear in your CZ product regardless of your office's best efforts to mitigate them.

## ***Product Applications #1: Reveals Strongest Reflectivity throughout Echo Depth***



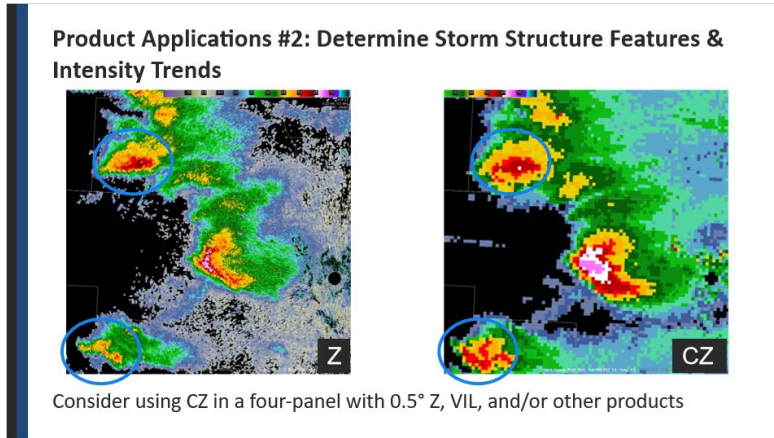
### **Notes:**

Enough with the limitations, let's look at how CZ can be useful to you.

CZ provides a quick look at the highest reflectivity values without having to check each elevation product. I can see in this example that there are three areas with storms to the west of the RDA. The storm in the middle of the display grabs our attention because of its peak reflectivity values exceeding 65 dBZ. The storm to the south appears to be strong, but a little weaker than the first storm. The area of storms to the north appear to be smaller and weaker than the first two. This quick view helps me focus my attention on these areas for a more thorough, base data analysis using the elevation-based products.

I should note that CZ is one of the last products generated during the volume scan, so it will likely give you a heads up on where to look for the next volume scan as that data comes in.

## ***Product Applications #2: Determine Storm Structure Features & Intensity Trends***



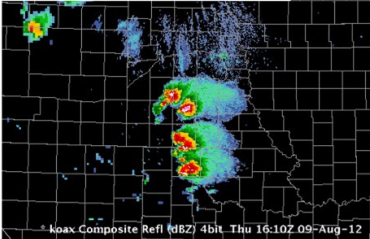
### **Notes:**

You can get around the limitations we mentioned by using other products with CZ. Often, you will want to use CZ in conjunction with Z. In the example, some of the storms have noticeably strong low-level reflectivity values. However, the storm to the southwest is noticeably stronger aloft than it is at low levels. Likewise, the storm to the northwest has a strong echo aloft that suggests a possible WER or BWER with this storm. When analyzing CZ, display the product in a four-panel with Z, VIL, and/or other products for comparison purposes.

### Product Applications #3: Combined Attribute Table

**Product Applications #3: Combined Attribute Table**

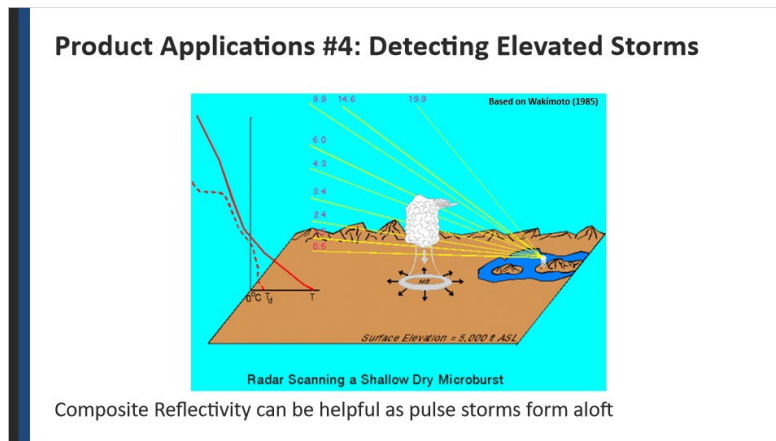
STM ID	AZ/RAN	TWS	MDA	POSH/POH/MX SIZE	VIL	DBZM	HT	TOP	FCST	MVMT
P4	146/ 31	TWS	NONE	10/100/ 0.75	39	57	12.5	50.1	244/ 58	
W7	87/ 92	NONE	19	60/100/ 1.50	61	62	24.4	45.3	287/ 45	
N6	75/ 97	NONE	12	60/100/ 1.50	42	59	26.4	50.2	240/ 35	
V1	104/ 69	NONE	8	40/100/ 1.25	53	60	20.4	31.8	271/ 31	



#### Notes:

Another strength of the CZ product is that we can view the Combined Attributes Table. Much of this information also finds its way into SCAN which is available at your workstation.

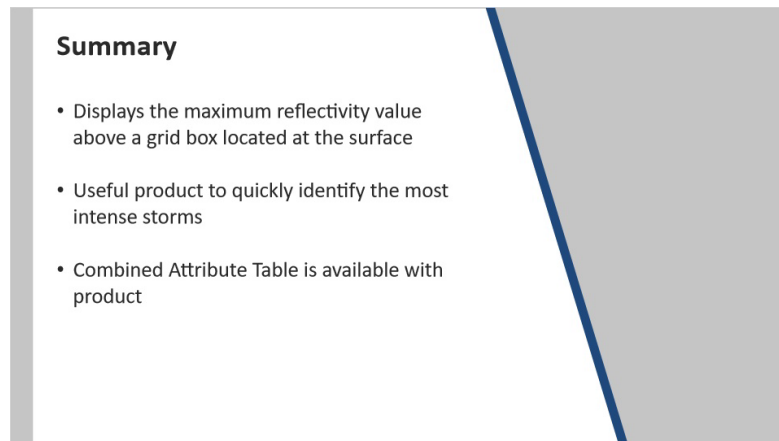
## Product Applications #4: Detecting Elevated Storms



### Notes:

In some regions, like the western U.S., elevated pulse storms may lead to significant downbursts (Wakimoto, 1985). Radar echoes at the lowest elevation tilt may not appear until the downburst is occurring. Composite Reflectivity can be helpful for spotting these storms as they form aloft.

## **Summary**



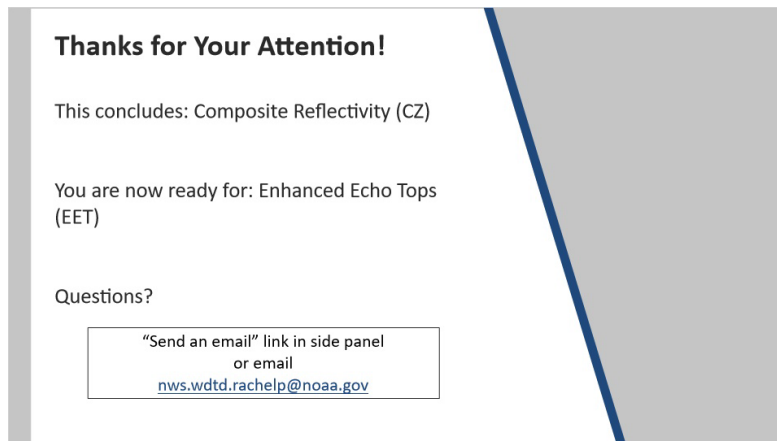
**Summary**

- Displays the maximum reflectivity value above a grid box located at the surface
- Useful product to quickly identify the most intense storms
- Combined Attribute Table is available with product

### **Notes:**

To summarize, the CZ product determines the highest reflectivity value above a grid box at the surface for your radar coverage area using all the elevation scan reflectivity data in the current volume coverage pattern. It is most useful to quickly identify the most intense storms in your local area. CZ also has the Combined Attributes Table.

## ***Thanks for Your Attention!***



**Thanks for Your Attention!**

This concludes: Composite Reflectivity (CZ)

You are now ready for: Enhanced Echo Tops (EET)

Questions?

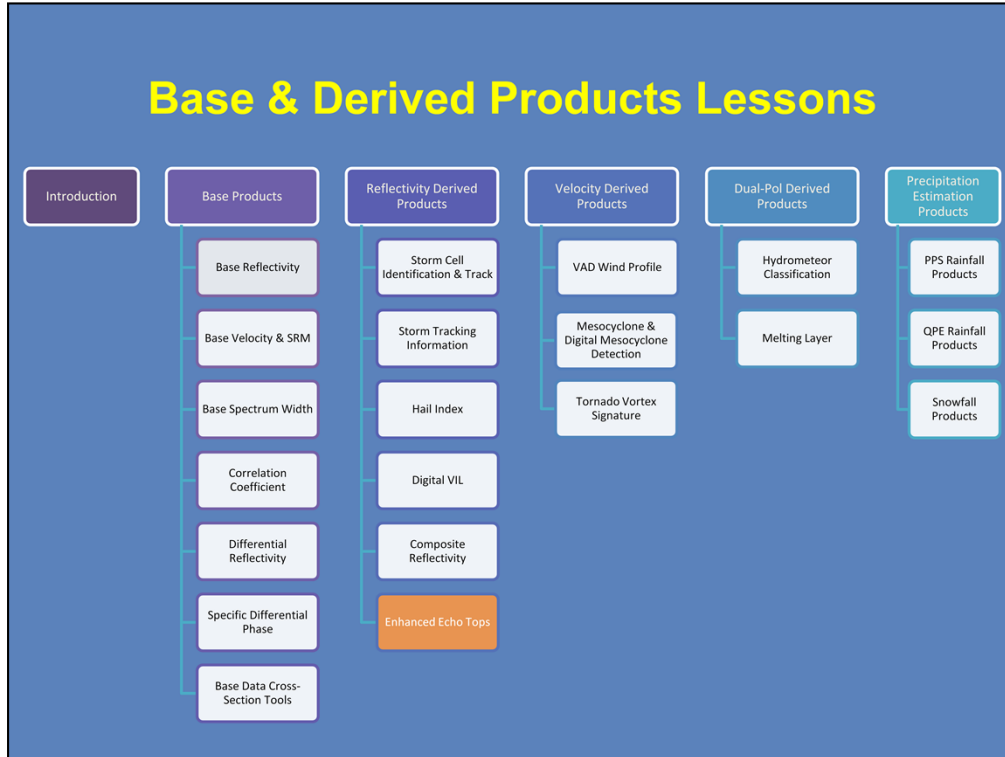
“Send an email” link in side panel  
or email  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

### **Notes:**

If you have passed the quiz, then you have successfully completed this lesson. You are now ready to move onto the next lesson, Enhanced Echo Top (EET). If you have any questions, please contact us using any of the e-mail addresses listed.



Welcome to the last lesson on Reflectivity-Derived Products. This lesson will cover the Enhanced Echo Tops (EETs).



Here is a roadmap for the lessons in this topic. This lesson on the Enhanced Echo Tops (EETs), shaded in orange, is the sixth and last in the Reflectivity Derived Products Section of this topic.

## Learning Objectives

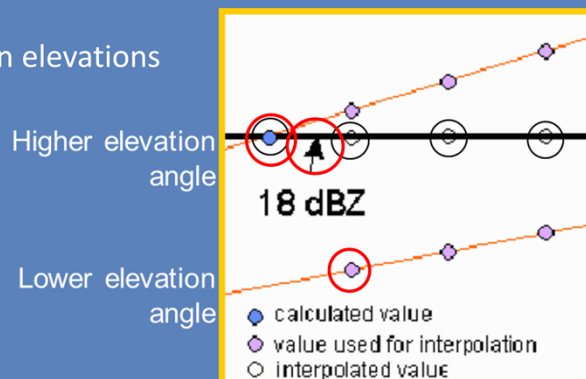
Upon completion of this lesson, you will be able to identify the characteristics, limitations, and applications (strengths) of the Enhanced Echo Tops (EET) product



Here are the learning objectives for this lesson. Please advance the slide when you are ready to begin.

## Definition

- Estimate of the maximum height (MSL) of the 18 dBZ echo for each 1 km x 1 deg range bin
- Interpolates between elevations

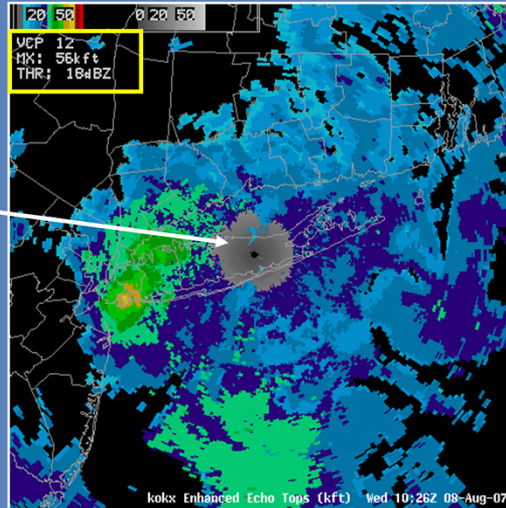


Note: Echo Top heights (18 dBZ-MSL) differ from Storm Cell Tops (30 dBZ-ARL)

Let's start by defining enhanced echo tops. The echo top is defined as the estimate of the highest height of the 18 dBZ echo for each range bin. Heights are given in MSL and interpolation is used to determine the height of the 18 dBZ echo in between elevation angles. Look at the graphic on the right for an illustration. The slanted red lines are the lower and upper elevation angles. The light purple dots represent the reflectivity values at each range bin. Let's say that the upper elevation bins are less than 18 dBZ and the lower elevation bins are greater than 18 dBZ. It will use linear interpolation between these elevations to determine the height of the 18 dBZ interpolation. Recall from the SCIT algorithm that it tries to estimate storm tops. These are not the same thing. SCIT uses height of 30 dBZ ARL and EET uses height of the 18 dBZ MSL.

## Enhanced Echo Tops (EET)

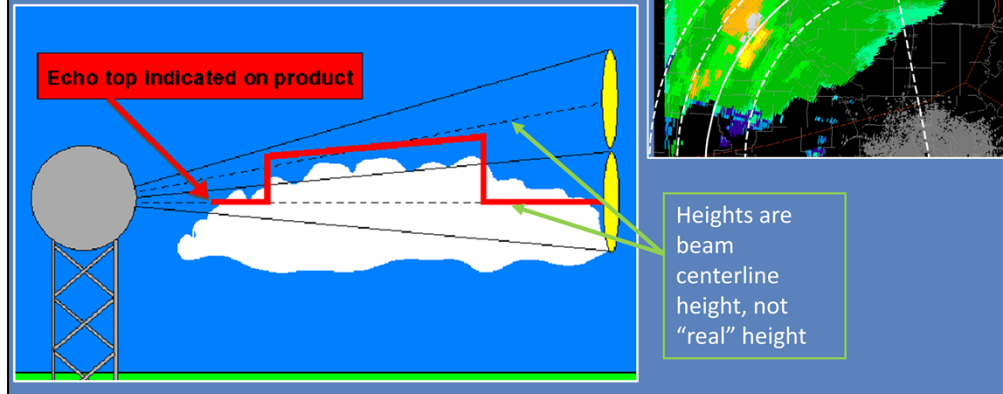
- Range = 187 nm
- Res. = 1 km x 1°
- Data Levels = 256
  - Topped usually grayscale



Here are the characteristics of the EET product. It goes out to a range of 187 nm. The resolution is 1 km x 1 deg and it has 256 data levels, or is 8-bit. It also has a gray scale for something it calls “topped”. Bins are tagged as “topped” for areas where the highest elevation angle has a value of 18 dBZ or higher. The algorithm cannot extrapolate the height in these situations, so it tags that bin as “topped”, or gives a basic estimate of what it thinks it could be. Note the product annotation in the top left.

## Product Limitations

1. A circular stair-stepped appearance will often be evident

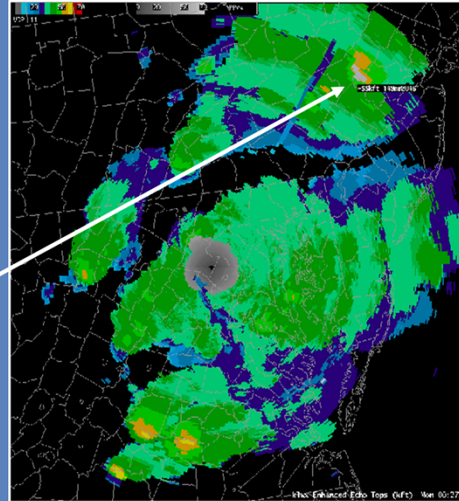


So, for limitations, a circular stair-stepped appearance will often be evident with widespread precipitation. Recall from other reflectivity derived products with stair-stepped appearances, this is due to the gaps in elevations and the fact that beam center point is being used in the calculation of the height. Because the heights along each radar beam use the beam center point, not the actual height, the algorithm thinks that the heights are actually higher in the middle of this area than they actually are. As soon as the higher elevation no longer samples the cloud top, the echo height goes back down to the height of the lower beam.

## Product Limitations

2. Tops will be underestimated close to the radar (coded as "topped")

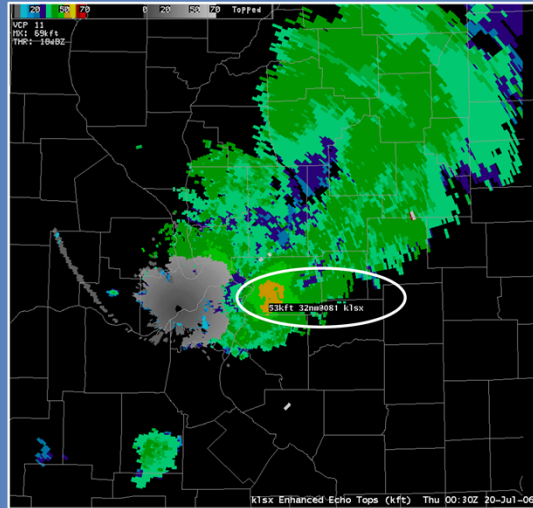
Far range too!



A second limitation is tops will be underestimated close to the radar. Recall that these are coded as topped because the highest elevation angle is showing reflectivity higher than 18 dBZ. Topped can happen at far ranges too, but for a different reason. You may recall that reflectivity data are cut off at 70 thousand feet. Thus with each successive elevation angle, the range for which data are shown gets shorter and shorter. In the example shown, there may be data at lower elevations. However, the 2.5 deg elevation angle at that range is above 70 thousand feet, so it is displayed as no data. Since the 1.5 deg has data and the 2.5 deg has no data, the algorithm tags it as topped just like it would near the radar. This is pretty rare, and most likely will only show up in the most intense storms.

## Product Applications

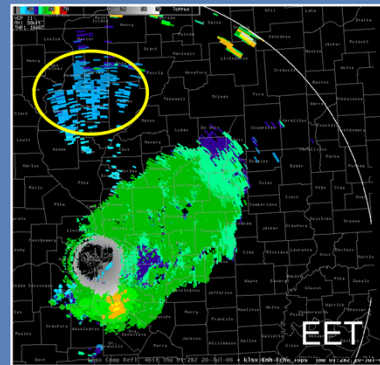
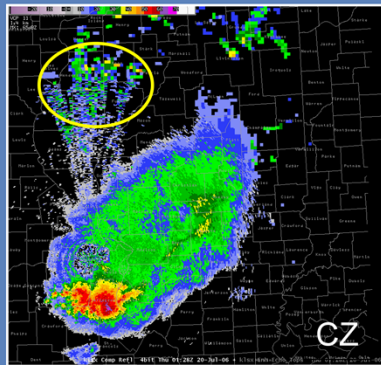
1. Quick estimation of the most intense convection (i.e. higher echo tops)



One of the applications of EET is to get a quick estimation of the most intense convection. Typically the higher the echo tops relative to surrounding storms, the more intense the updraft, and thus more potential for more severe weather. Using cursor readout with EET is particularly useful.

## Product Applications

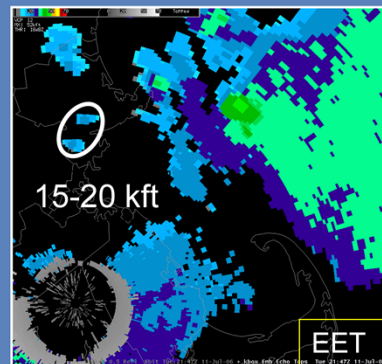
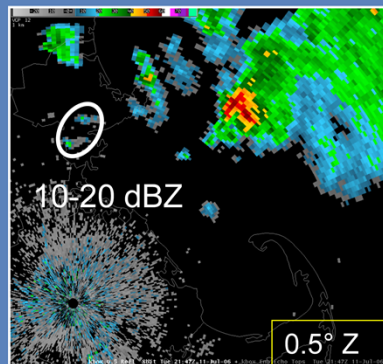
2. Assist in differentiating non-precipitation echoes from real storms



A second application is to assist in differentiating non-precipitation echoes from real storms. Recall that this application applies to many of the reflectivity derived products. In the example below, we have a lot of AP in the CZ product in the area to the north of the radar. Notice in the EET product that the tops are blue which are well below 20 kft which is a good thing since AP is usually very low. So, this product can help you differentiate echoes that are real from those that are artifacts.

## Product Applications

3. May detect mid-level echoes before low-level echoes are detected



Finally, EET can be very useful in detecting mid-level echoes before low-level echoes are detected. In the example below, the 0.5 deg Z is shown on the left and the EET product is shown on the right. The two little blobs of reflectivity in the white circle eventually went on to be mini supercells. Notice that there are some tops to almost 20 kft with the weaker echoes at low levels, but it isn't the greatest example since there are already echoes in the lowest levels, but it does illustrate the point.

## Summary

- Estimate of the maximum height (MSL) of the 18 dBZ echo
- Primary use of the product is to identify storms with greater vertical development
- Can be used in differentiating real echoes from non-precipitation echoes

In summary, the EET product is an estimate of the maximum height, in MSL, of the 18 dBZ echo. It's primary application is to identify storms with greater vertical development and thus could be the most severe. Finally, it can be used in differentiating real echoes from non-precipitation echoes. The following slide is a short quiz on this lesson.

## Thanks for Your Attention!

This concludes:  
Enhanced Echo Tops (EET)

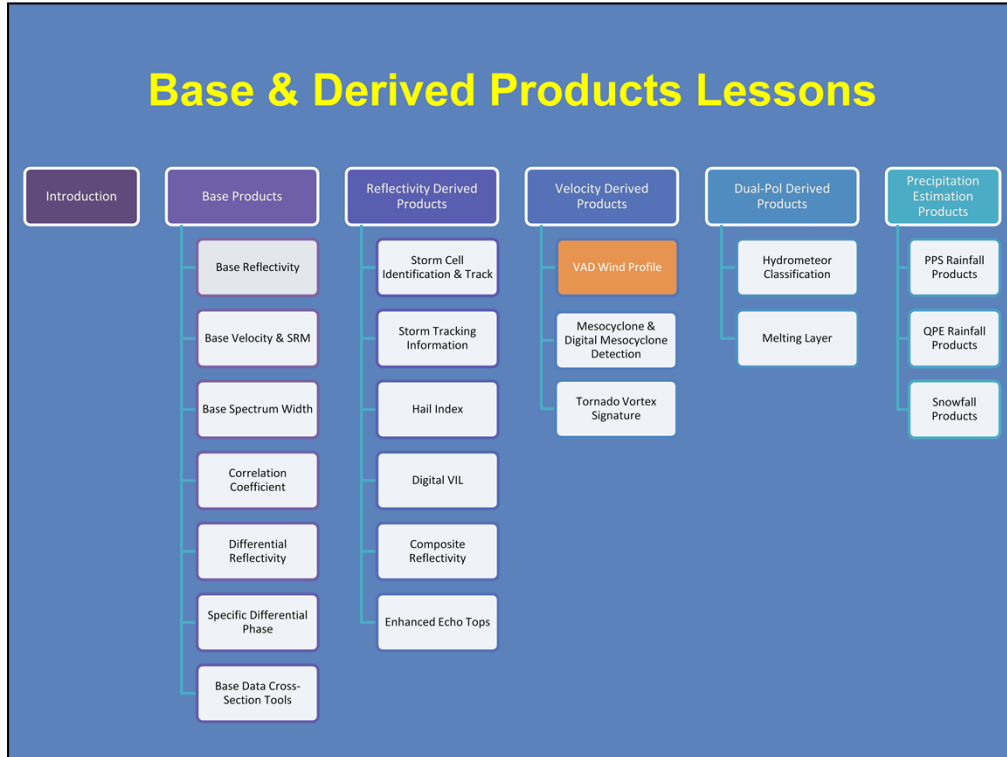
Questions?

“Send an email” link in side panel  
or email  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

This concludes the lesson on the EET product. You can now move onto the next lesson. If you have any questions, feel free to email the contacts listed.



Welcome to the first lesson on velocity-derived products. This lesson will cover the Velocity Azimuth Display Wind Profile, or VWP.



Here is a roadmap for the lessons in this topic. This lesson on the VWP profile, shaded in orange, is the first in the Velocity Derived Products Section of this topic.

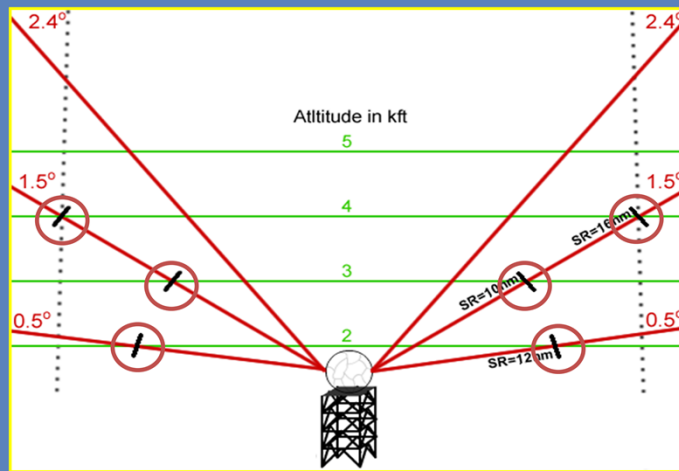
## Learning Objectives

Upon completion of this lesson you will be able to identify the characteristics, limitations, and applications (strengths) of the Velocity Azimuth Display Wind Profile (VWP) product



Here are the learning objectives for this lesson. When you have read them, click next to start.

## Velocity Azimuth Display (VAD) Algorithm

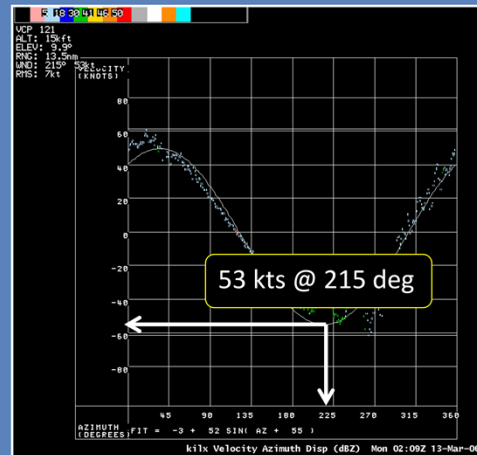


- Calculate winds based on slant ranges and elevations
- Must meet constraints for accuracy

The VWP product is an output of the Velocity Azimuth Display (VAD) algorithm. We'll quickly look at how this algorithm works, and then jump right into the VWP product. For each height requested, the VAD algorithm finds the elevation angle that closely intersects a slant range, at which it computes a wind speed and direction. It then uses multiple slant ranges and elevation angles at that height to compute more winds that are constrained for accuracy. This procedure is repeated for every requested height level. Note that the slant range increases with elevation angle and that the slant ranges are calculated between 10 and 120 km of a radar. In order for any wind from any elevation to be considered, there is an "error test" requirement that ensures that any error in the estimate is sufficiently low. Since VAD calculates more than one possible wind for any given height, a single wind is chosen using a validity weight or validity index to take into account the error, the wind speed, and the number of points used to generate the wind estimate. Note that you can specify the requested heights used to compute the VAD winds in the RPG.

## Velocity Azimuth Display (VAD) Algorithm

- Max inbound = wind speed and direction
  - At least 25 points
- Compute
  - RMS error
  - Symmetry

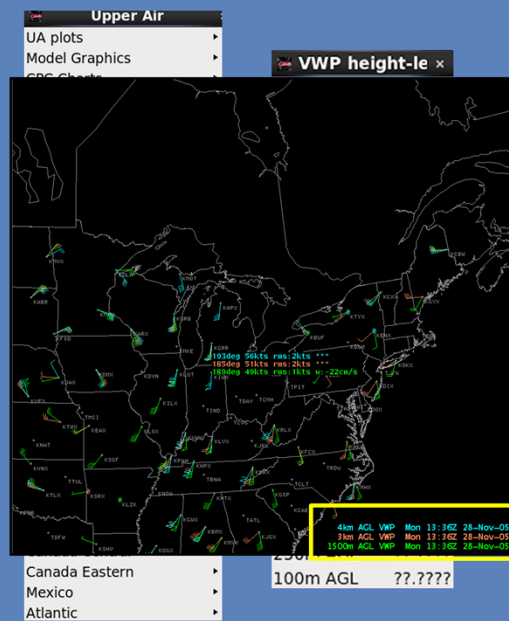


When all the points are plotted, you get this graph. Notice that it looks like a sine wave—the algorithm fits a sine wave to the plotted data. From the fitted sine wave, the maximum inbound velocity, or maximum negative velocity value, is recorded as the wind speed at that height. The direction of the wind is the azimuth that velocity value occurs. And, to fit a sine wave, there needs to be at least 25 points. So in this example, see there are plenty of points and the wind at 15 kft from this fitted sine wave would be approximately 53 knots from 215 degrees. The algorithm then computes RMS error and symmetry, basically telling us how close the data fit the sine wave.



## VWP Planview

- Plot of VWP data nationwide called Planview
  - Height- and pressure-level plots
- Analyze low-mid level wind shear
- Updated 4-10 minutes
- Single height display of VWPs
  - mb or km

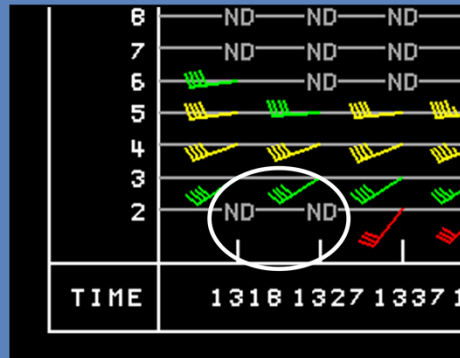


You can also plot the VWP winds in Planview to get a spatial feel for the wind patterns when upper air plots from RAOBs are not available. You can find these plots in the Upper Air menu in CAVE. These winds are updated every 4-10 minutes, or whenever new volume scans are available. Here's an example. Notice you can plot multiple heights. This is great for getting a feel for the magnitude and direction of horizontal shear evolving throughout the day if you are anticipating severe weather.



## Product Limitations

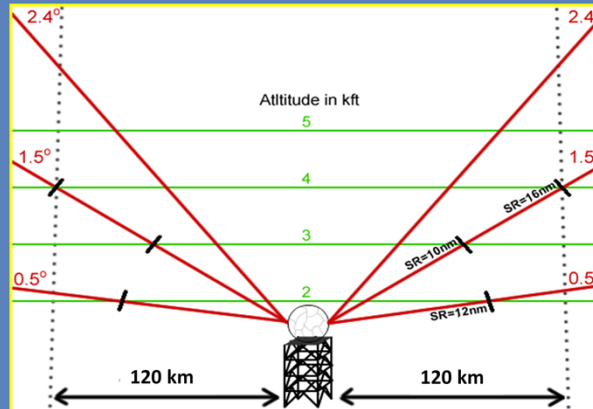
2. Winds are not encoded if RMS error or symmetry thresholds are exceeded. (“ND” will be plotted)
  - RMS error exceeds 9.7 kts
  - Symmetry exceeds 13.6 kts



There is another way “ND” is plotted, and that has to do with our second limitation. Winds will not be plotted if the RMS error or symmetry thresholds are exceeded. Those values are 9.7 kts for RMS error, which is a measure of how well the plots fit the sine curve, and 13.6 kts for symmetry, which is the measure of how homogeneous the wind flow is around the radar. If either of these thresholds are exceeded, then “ND” will be plotted.

## Product Limitations

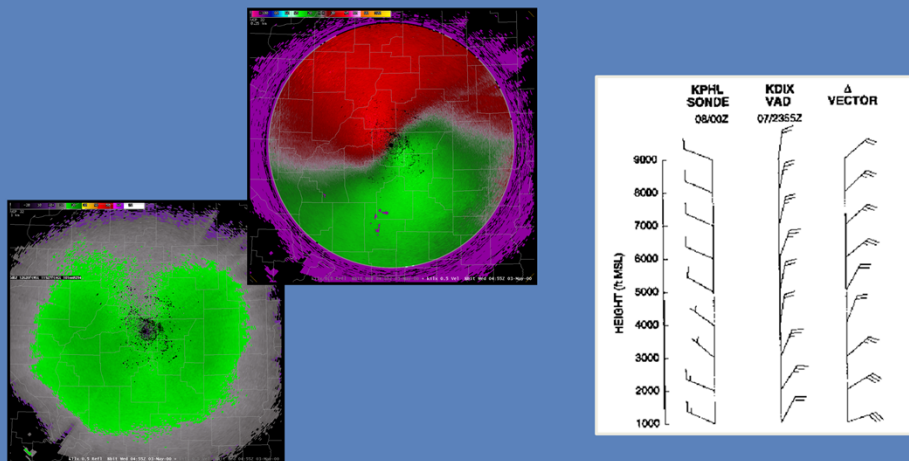
3. Generally representative of winds within 120 km of the RDA



Our third limitation to keep in mind is that the VAD winds plotted on the VWP are only representative of the winds within 120 km of the radar. If you've got storms developing 150 km from the radar, you will want to use other sources of data to assess the wind profile in that area.

## Product Limitations

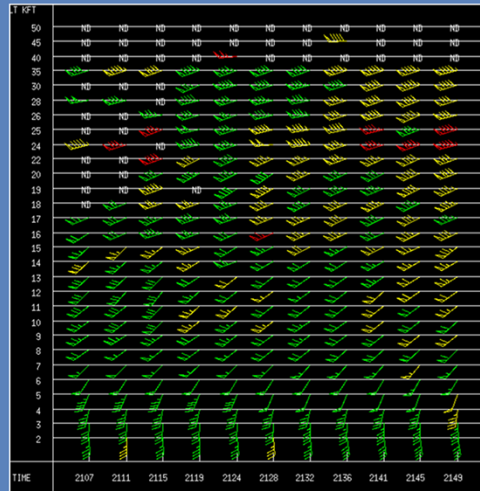
### 4. Birds can produce anomalous wind patterns



One last limitation to consider. Flocks of migrating birds can affect the correctness of the VAD winds which are passed to the VWP. This can make you think you are developing a low level jet at night when in reality it is just the migrating birds.

## Product Applications

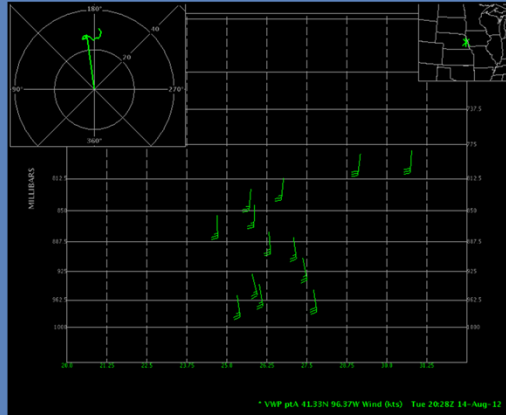
1. The VAD Wind Profile (VWP) will aid in the following operations:
  - Severe Weather
  - Aviation
  - Hydrology
  - Forecasting



The VWP product is useful in the severe weather, aviation, and hydrology sectors and forecasting in general. You can use the VWP to see how winds change with height in both direction and speed, plus you can analyze changes in time. You can also use it to estimate the depth of a cold air mass. For instance in the winter time, if you have a cold air mass moving in and you want to determine if it is dissipating or moving back north with time, you can use the VWP to see that. That can help you decide what type of precip you are going to anticipate.

## Product Applications

2. The VAD Wind Profile (VWP) can be used to create or adjust hodographs and soundings

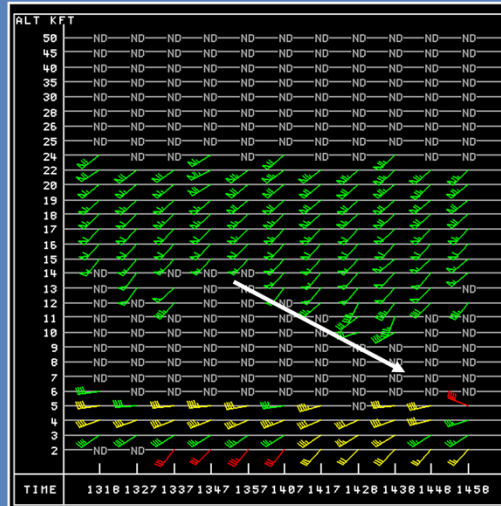


See RAC References VLab page for display instructions

The VWP can also be used to update hodographs for times in between upper air soundings.

## Product Applications

3. Can indicate cloud depths and/or virga lowering with time
4. Can be used to estimate expected low-level trajectories for balloon launches



A surprising application of the VWP is the estimation of cloud depths or virga lowering with time. This is what virga descending will look like, denoted by the white arrow. As it descends it saturates the lower levels, in turn providing more data points, allowing the VWP to plot the data at those lower and lower heights. You can also use the VWP to estimate the expected low-level trajectories for balloon launches.

## Summary

- A **composite vertical profile** of VAD derived winds
- Excellent tool for forecasting, severe weather, hydrology, and aviation
- The VAD Wind Profile will display "ND" (no data) at a given height, if fewer than 25 data points exist, or if the symmetry or RMS error thresholds are exceeded

In summary, the VWP is a composite vertical profile of the VAD derived winds. It's a great tool for forecasting, severe weather, hydrology and aviation. The VWP will display "ND" at heights where there are fewer than 25 data points for the VAD algorithm or if symmetry or RMS error thresholds are exceeded. The next slide will be a short quiz on this lesson.

## Thanks for Your Attention!

This concludes:  
VAD Wind Profile (VWP)

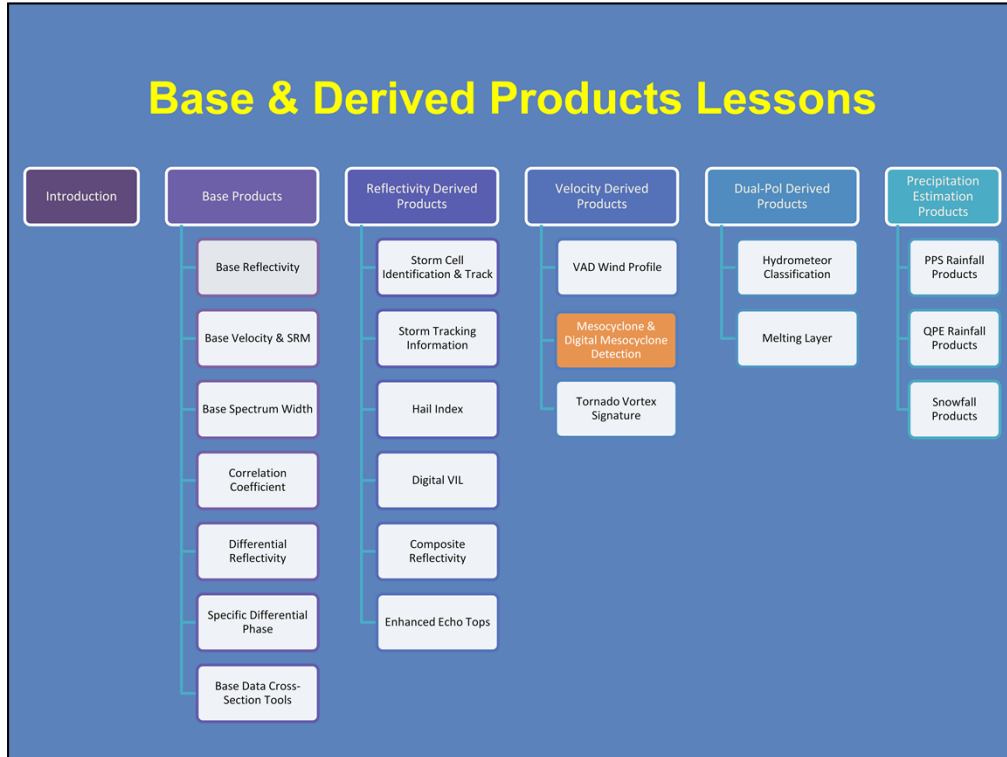
Questions?

“Send an email” link in side panel  
or email  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

This concludes the lesson on the VWP product. You can now move onto the next lesson. If you have any questions, feel free to email the contacts listed.



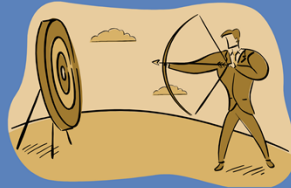
Welcome to the next lesson on Velocity-Derived Products. This lesson will cover the Mesocyclone (MD) & Digital Mesocyclone (DMD) products.



Here is a roadmap for the lessons in this topic. This lesson on the Mesocyclone (MD) & Digital Mesocyclone (DMD) products, shaded in orange, is the second in the Velocity Derived Products Section of this topic.

## Learning Objectives

Upon completion of this lesson you will be able to identify specific characteristics, limitations, and applications (strengths) of the Mesocyclone (MD) and Digital Mesocyclone (DMD) products



Note: Strengths and limits for both products are the same and will be presented after discussion of both MD and DMD

Here are the learning objectives for this lesson. Notice the strengths and limitations are pretty much the same for both products. Advance the slide when you are ready.

## Operator Defined Mesocyclone

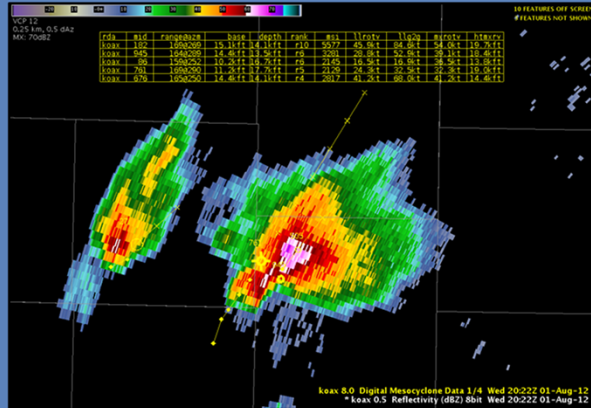
- Small scale rotation closely associated with a convective updraft that meets or exceeds established thresholds for:
  - **Persistence** (Minimum of two volume scans)
  - **Vertical extent** (Depth of at least 10,000 ft)
  - **Shear**
    - Core diameter < 5 nm
    - rotational velocity  $\geq$  minimal mesocyclone strength in the table

Modified from original NSSL  
Mesocyclone definition

Let's make a distinction between what you as an operator would define as a mesocyclone versus what the algorithm will define as a mesocyclone. This definition comes from the original work done by NSSL done back in the 70s and 80s. An operator defined mesocyclone is defined as a small-scale rotation closely associated with a convective updraft that meets or exceeds established thresholds. One, it must be persistent, so it can't just show up and then disappear as will be the case often when viewing velocity data. Persistence in this case is going to be a minimum of 2 volume scans, but may need adjusting depending on the situation. Secondly, it needs to have vertical extent. By definition it needs to be at least 10,000 ft deep, but this again may be dependent upon the situation (like mini supercells). And it has to have a certain amount of strength, which is measured by shear. The core diameter must be less than 5 nm and the rotational velocity must equal or exceed a minimal mesocyclone strength that we'll see in a moment. So it has to be around for a while, have vertical extent and have some amount of strength.

## Mesocyclone Detection Algorithm (MDA)

1. 1-D shear segments
2. 2-D features
3. 3-D features
4. Strength rank
5. Tracking
6. Feature parameters

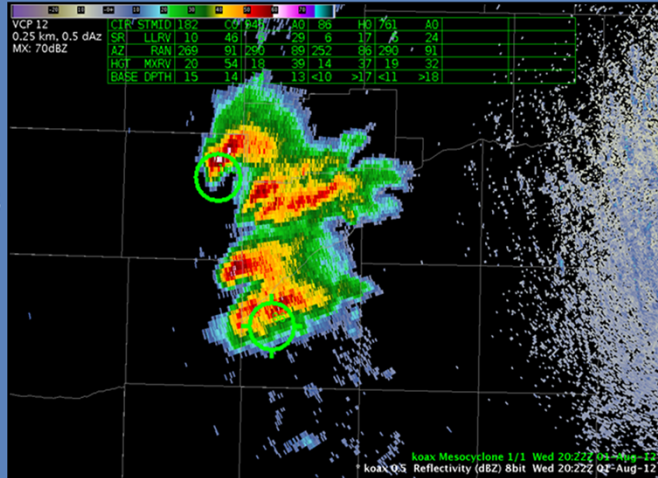


For more detailed information on how the algorithm works and adaptable parameters, see the RAC References VLab page

The mesocyclone detection algorithm will follow a similar path to the SCIT algorithm. Recall the SCIT used reflectivity as input and used building blocks to identify storms or centroids. The MDA will do a similar thing except use velocity as input. It will first identify what it calls 1-dimensional shear segments. It will combine those into 2-D features. It will then look vertically and build a 3-D feature we'll call a circulation. A strength rank will then be assigned to that circulation, and depending on the strength, you may call it a mesocyclone. It will then track the feature and give you a whole bunch of information on that circulation. For more detailed information on how the algorithm works, as well as information about the adaptable parameters associated with this algorithm, see the RAC References VLab page for this lesson.

## Mesocyclone (MD) Characteristics

- Available at end of volume scan
- Icons
  - Thin circles = SR 1-4
  - Thick circles = SR  $\geq 5$
- Four spikes if found at lowest tilt or  $< 1$  km ARL
- Attribute table available



Now, let's get to the products. First, we'll talk about some of the characteristics of the mesocyclone detection product. It is available at the end of a volume scan and you'll see a few different icons with it. You'll see thin circles if the strength rank is 1 to 4, and thick circles for strength ranks greater than or equal to 5. If you see four spikes on these circles, then that tells you that the circulation was found on the lowest tilt or less than 1 km ARL. And, there's an attribute table that is available.

## MD Attribute Table

CIR	STMID	353	14	29	14	644	W7
SR	LLRV	10	26	9L	53	9L	41
AZ	RAN	128	81	127	78	123	84
HGT	MXRV	14	68	16	61	10	41
BASE	DPTH	< 9	>17	< 9	>15	<10	>13

- CIR STMID = Circulation ID Number and ID of closest SCIT storm
- SR = 3-D strength rank
- LLRV = Lowest level rotational velocity (kts)
- AZ = Azimuth of lowest 2D Feature
- RAN = Range of lowest 2D Feature
- HGT = Height of maximum rotational velocity (Kft)
- MXRV = Max Rotational Velocity in the feature (kts)
- BASE = Altitude of lowest 2D Feature (Kft) (" $<$ " shown if Base on 0.5° slice)
- DPTH = Depth of 3D Feature (Kft) (" $>$ " shown if base on 0.5° slice)

Let's take a moment to go through the MD attribute table. First you'll have a circulation identification number and this is an individual mesocyclone identification number, in this case 353. Next to that is the ID of the closest identified storm output by SCIT. Next, you have a strength rank, and it's a 3D strength rank, and then the low level rotation velocity associated with the feature. Next is the azimuth and range to the lowest 2D feature. The height is the height of the maximum rotational velocity. And finally you have the base of the feature which is the height of the lowest 2D feature, and you'll see the less than sign if the base is on the 0.5 deg slice indicating it could be lower than that. And, depth of the 3D feature with a greater than sign if the base is on the 0.5 deg slice since the depth could be greater than what is depicted.

## Digital MD (DMD) Characteristics



- Updated every elevation slice
  - Includes extrapolated features and SAILS cuts
- Available in SCAN and volume browser
- Dynamic progressive disclosure
  - The more you zoom, the more you see
- Cursor readout of attributes
  - See RAC References VLab page for more details
- Attribute table

Here is the Digital Mesocyclone Detection product, or DMD. It gives you a little more information. First, it is updated every elevation slice. That way, you don't have to wait until the end of the volume scan. Therefore, this product will have extrapolated features which appear as broken circles on the display. Those show you where the algorithm thinks the new update will be, and will become a full solid circle when the feature is correlated. Data are available in SCAN as well as the volume browser. There is dynamic disclosure with this product which means the more you zoom, the more detail you will see. Finally, cursor readout has a lot of the attributes available. For more details on these characteristics, see the RAC References VLab page.

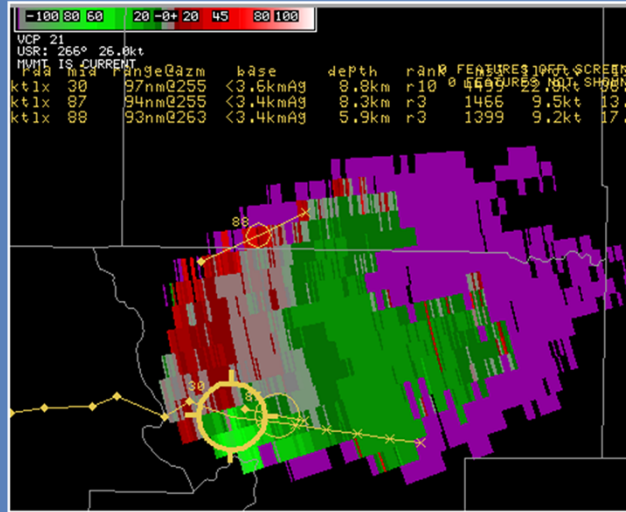
## DMD Attribute Table

rad	mid	range@azm	base	depth	rank	msi	llrotv	llg2g	mxrotv	htmxrotv
kddc	211	44nm@093	1.1kmAg	4.2km	r11	6764	26.6kt	38.7kt	34.6kt	3.1kmAg
kddc	857	40nm@087	1.0kmAg	9.1km	r11	6521	31.6kt	42.2kt	38.5kt	4.5kmAg
kddc	96	46nm@092	4.0kmAg	7.8km	r7	4066	22.9kt	30.2kt	27.4kt	5.0kmAg
kddc	394	116nm@016	4.9kmAg	10.8km	r6	2941	14.6kt	26.5kt	20.2kt	9.9kmAg
kddc	281	36nm@083	1.3kmAg	3.1km	r5	3444	8.8kt	21.7kt	22.1kt	2.5kmAg

- Radar ID
- Meso ID
- Range/Azimuth
- Base of lowest 2D feature
- Depth of feature
- Strength rank
- Mesocyclone strength Index
- Low level rotational velocity
- Low level gate-gate shear
- Max rotational velocity
- Height of max rot velocity

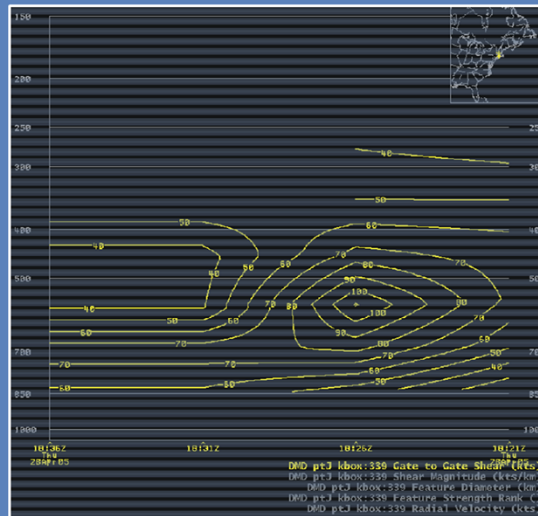
The DMD product has its own attribute table. On the left side we see information related to the radar ID, meso ID, azimuth and range, the base of the lowest 2D feature, the depth of that feature as well as the strength rank. On the right side we see a mesocyclone strength index, a low level rotational velocity, low level gate to gate shear, max rotational velocity and the height of the max rotational velocity.

## Digital MD (DMD)



This is what the DMD product looks like and we have overlaid on top of a base velocity image.

## DMD Time Height Display

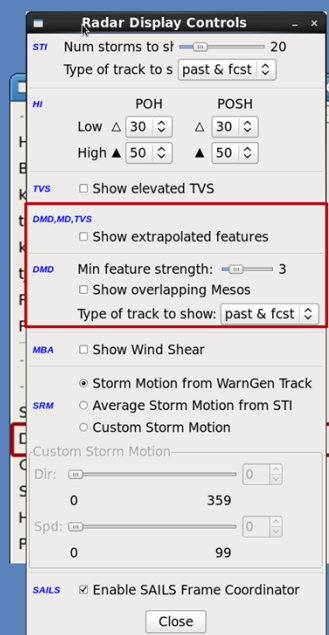


- See RAC Reference VLab page for Volume Browser instructions

This is what you get when you send of a request for this data from the volume browser. You can see the time height series for the gate to gate shear and you can see the time characteristics and if it is strengthening with time. All of this is dependent of course on how well the algorithm has identified and maintained this feature. For more information on how to access the DMD product from the Volume Browser, see the RAC References VLab page for this lesson.

## MD/DMD Menus

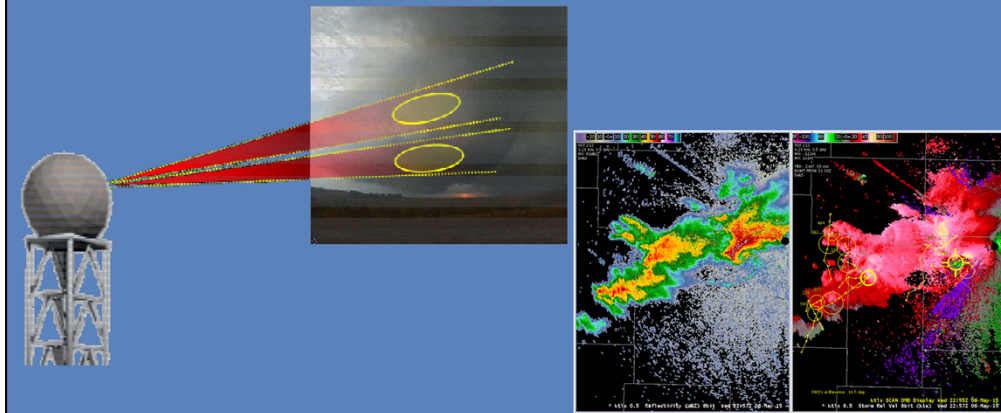
- DMD Output via SCAN
  - More effective at viewing time/height series
  - Easier to read
  - Must start SCAN DMD Application
- Radar Display Controls Menu
  - Determine display attributes:
    - Extrapolated features
    - Minimum strength rank
    - Past & forecast tracks



Using the volume browser time-height option can be cumbersome. Another option is the DMD Icons and Table via the SCAN menu. This is a more effective way of viewing the time-height series. It requires you to start the SCAN application. As with many other algorithms, you can affect how the DMD data are displayed by using the radar display controls menu. Here you can decide if you want to see extrapolated features, what DMD features to see, what strength rank to filter, and whether to see past or forecast positions.

## Products' Limitations

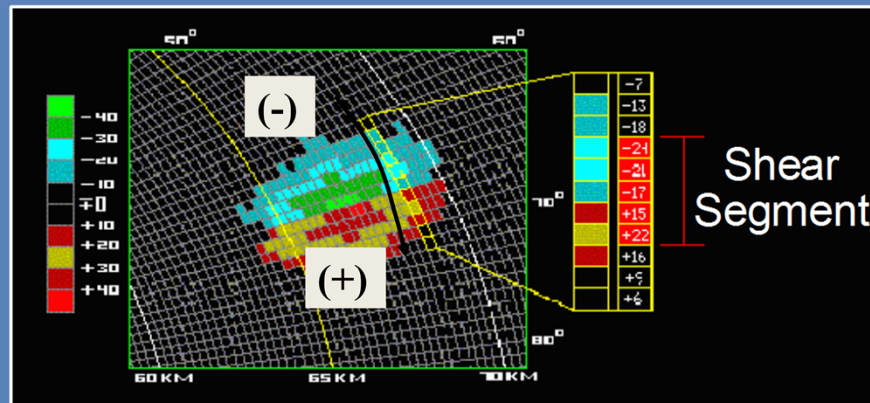
1. Detects numerous false detections and weak, shallow, insignificant circulations
  - Doesn't require 10Kft depth



So let's look at the limitations of the MD/DMD products since they are pretty similar. The first is that we do not need a 10kft depth for the circulation but rather only 2 elevation cuts, which is different from the original operator defined mesocyclone. This means that you can get some weak, shallow features identified by the algorithm.

## Products' Limitations

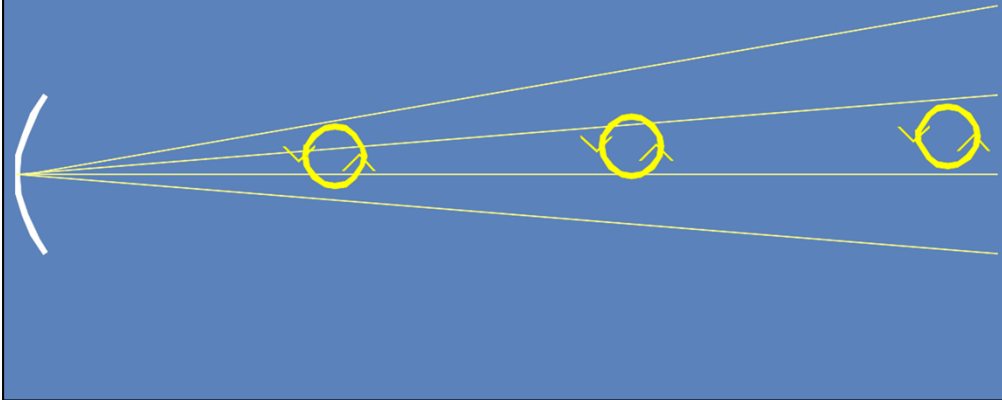
2. The algorithm only detects cyclonic rotations



Because we are searching for increasing velocities as the radar rotates clockwise, we are only searching for cyclonic rotations. We are currently not able to detect anticyclonic rotations.

## Products' Limitations

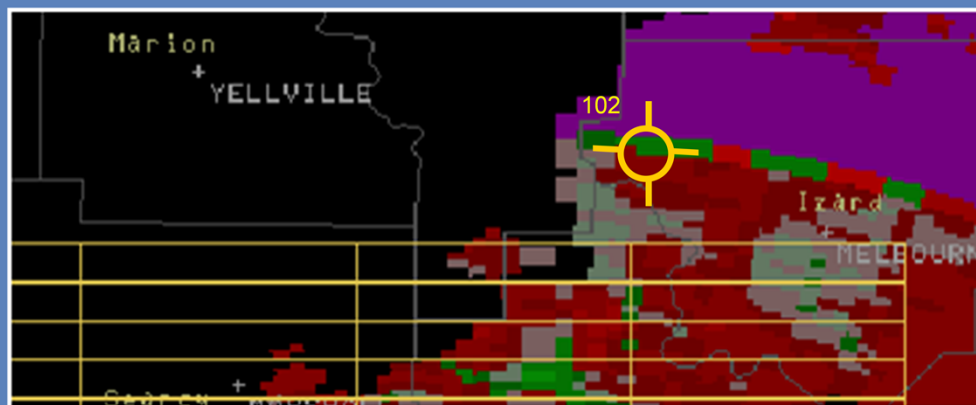
3. Identification is influenced by aspect ratio
  - Especially impacts small features at further ranges



Whether a feature is identified is influenced by aspect ratio. And by this, we mean the relationship between the size of the feature relative to the size of the beam. This primarily affects small features at small ranges where the feature can be contained solely within one beam.

## Products' Limitations

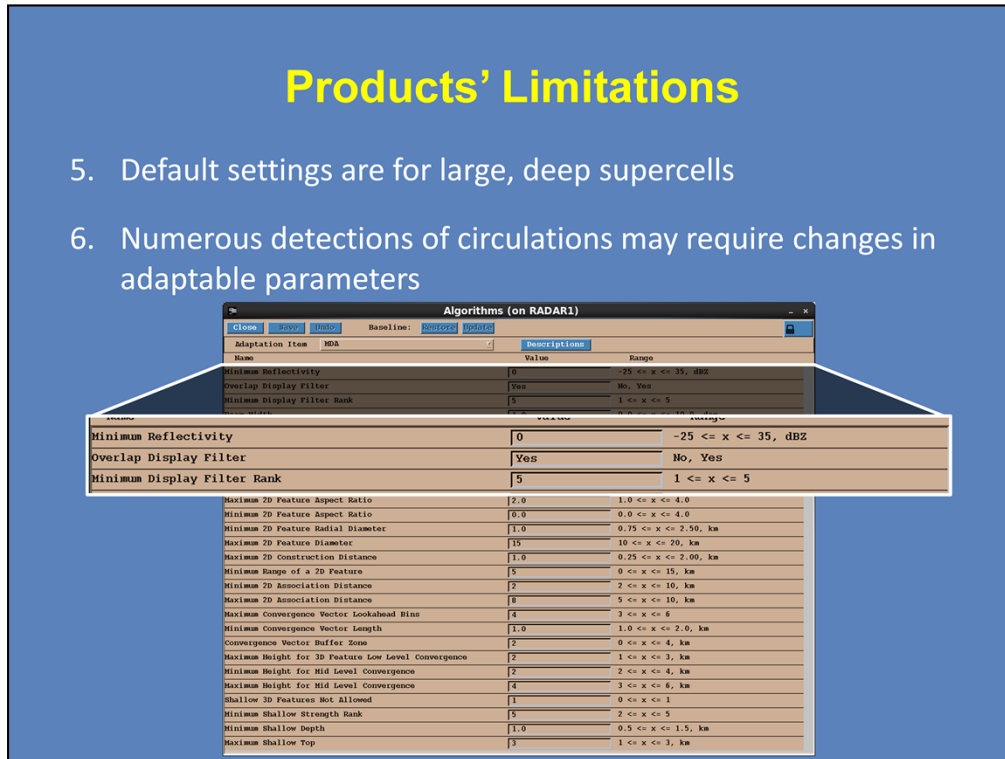
4. Improper dealiasing may generate false mesocyclones



If you get improper dealiasing that has vertical continuity, you can get some false detection. This can really be an issue at far ranges where you only need one elevation angle. That is why it is important that you always go back to the base data to verify features in the derived products.

## Products' Limitations

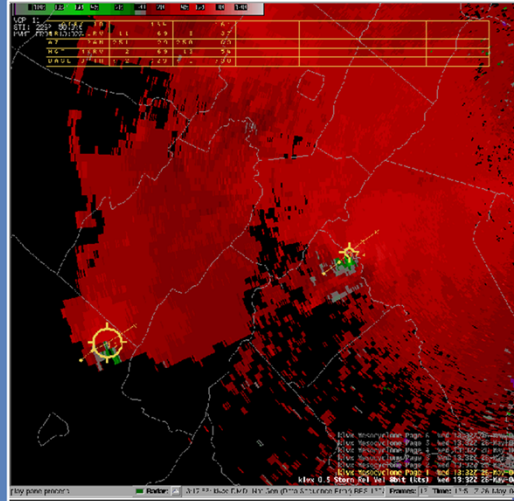
5. Default settings are for large, deep supercells
6. Numerous detections of circulations may require changes in adaptable parameters



Limitations 5 and 6 have something to do with the adaptable parameters for the algorithm. First, the default setting is for large, deep supercells and this is fine if that's what you have, but it may not be fine on other occasions. If you get a lot of detections, you may need to tweak these parameters such as increase min reflectivity, or change the values for what is displayed on your workstation. With all the limitations and increased base data products coverage with SAILS, the MD/DMD aren't used as often anymore.

## Products' Applications

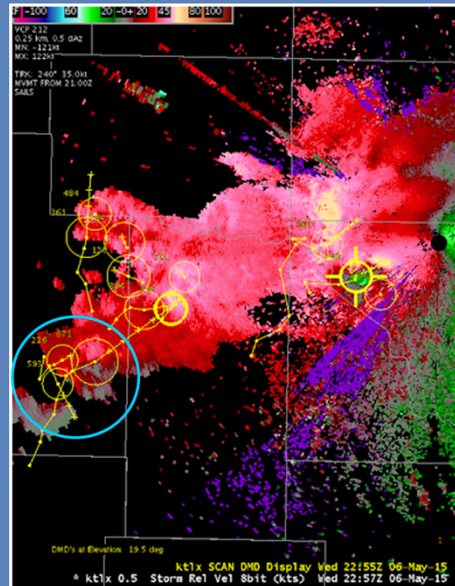
1. Identify mesocyclones, even those that are shallow



The strength of these products is that they can identify mesocyclones, even those that are shallow. It is good practice to always overlay the MD/DMD products on top of base velocity or SRM that way you can verify their existence. In this image, you can see there is good correlation between the algorithm and the base data.

## Products' Applications

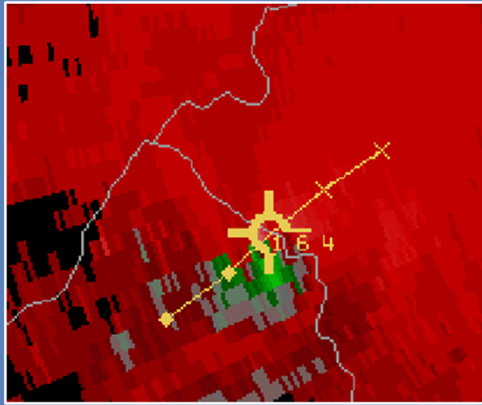
- Weak circulations detected
  - Display by lowering minimum strength rank



You can see weak circulations but only if you have the minimum display threshold set low enough. By default, 5 is the minimum strength rank displayable, so to see the thin circles, you have to set your display threshold to strength rank 1-4.

## Products' Applications

3. Tracking attempts to account for time continuity



This product does attempt to give you time continuity by showing you the past and forecast positions.

## Summary

- A signature from the MD or DMD product must be investigated for validity
- Tracks identified features and provides numerous attributes
- Provides tracking and forecast positions
- Adaptable parameters will need to be adjusted to various environments

To summarize these products, the DMD or MD products must be validated by looking at velocity or SRM displays, correlate it with reflectivity and understand the environment the feature is located in. We track these identified features and provide numerous attributes as well as past and future positions. And, there are adaptable parameters that you can adjust, and probably should adjust, based on various environments. The next slide will be a short quiz on the DMD/MD products.

## Thanks for Your Attention!

This concludes:  
Mesocyclone (MD) &  
Digital Mesocyclone (DMD)

Questions?

“Send an email” link in side panel  
or email  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

This concludes the lesson on the MD/DMD products. You can now move onto the next lesson on the Tornado Vortex Signature. If you have any questions, feel free to email the contacts listed below.

# Tornadic Vortex Signature (TVS)

## *Introduction*



### **Notes:**

Welcome to the next lesson on Velocity-Derived Products. This lesson will cover the Tornadic Vortex Signature.

## ***Learning Objective***

### **Learning Objectives**

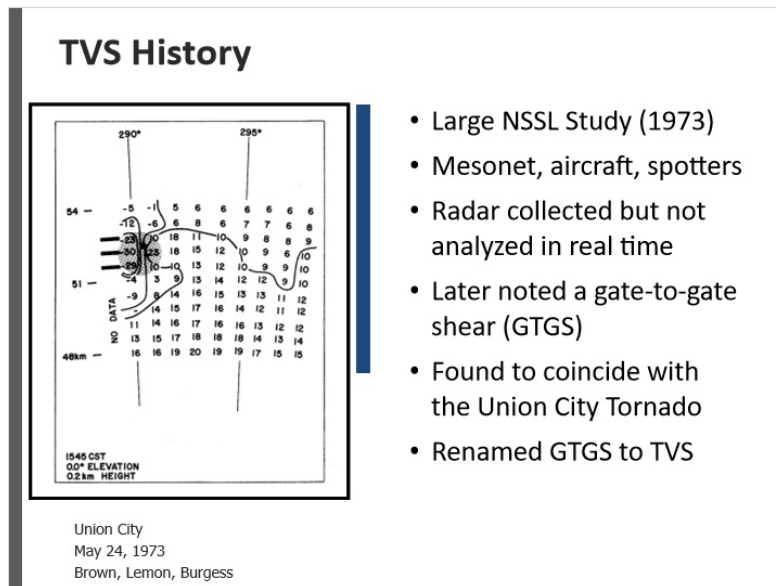
Upon completion of this lesson you will be able to identify specific characteristics, limitations, and applications (strengths) of the Tornadic Vortex Signature (TVS) product



#### **Notes:**

Here are the learning objectives for this lesson. The next slide will feature Les Lemon telling his account of the history of the TVS. Advance the slide when you are ready to get started.

## Tornadic Vortex Signature (TVS) History



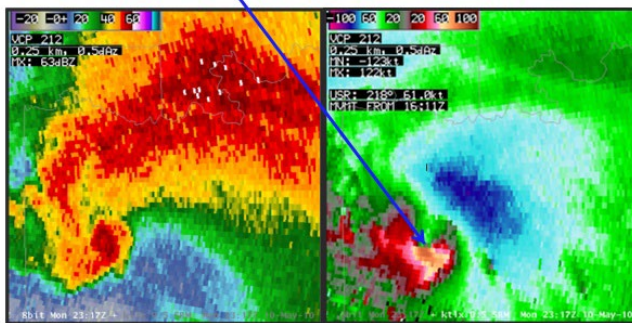
### Notes:

Back in the early days of NSSL, we had a spring data collection (1973). We were trying to sample storms with radar from inception to decay, and we were lucky to see the storm that passed over Union City, OK. We collected data on the storm and one thing to note is we could not see the data in real time. The processors were just not fast enough. So, after data collection, in fact during the winter after that event, we were analyzing the B-scans. In looking at them we started seeing what you can see in the image of intense gate-to-gate velocity differences. We thought it was a problem with the radar. Nobody anticipated seeing this signature. When we looked at higher elevations we saw something similar, so we knew this was something unique here and not something caused by an artifact or bad radar measurement. We called this a gate-to-gate shear (GTGS). We knew it was associated with a tornado when we launched a rocket from the damage path from a point where we collected data and where we saw the TVS on the ground and this rocket echo was in the exact same spot. We realized then this was a tornadic signature. But we only called it a gate-to-gate shear because we didn't know how prevalent it would be. Later we started seeing it in more situations but sometimes it was only aloft, never touching the ground. So, this is the origin of the TVS or tornadic vortex signature.

## TVS and Tornadic Signatures (TS)

### TVS and Tornadic Signatures (TS)

- Radar may see tornadoes with a shear signature that is not gate to gate
  - Tornadic Signature (TS)



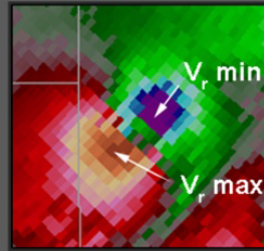
#### Notes:

For many years the term tornadic vortex signature has been used to indicate gate to gate shear associated with tornadoes. Since 2008, WSR-88D's have been able to display super-resolution base products. As a result, the radar has been able to sample the actual tornado, and the shear signature associated with some tornadoes has not been gate-to-gate. Notice in this example in the lower right that there are a few very weak super-res velocity gates in between the maximum inbound and outbound velocities, yet that is an EF4 tornado from a range of 28 nm. These types of rotational signatures are called tornadic signatures and will be covered in depth in the topic on convective storms. The tornado detection algorithm, which is what this lesson is based on, only searched for gate to gate signatures and did not detect a TVS with this tornado.

## Operator Identified Tornadic Shear

### Operator Identified Tornadic Shear

- An intense, roughly azimuthal shear associated with tornadic-scale rotation
  - Not necessarily gate to gate
- Low-level azimuthal velocity difference of 50 kts
  - $\sim < 50$  nm range



$$\Delta V = |\text{Max } V \text{ inbound}| + \text{Max } V \text{ outbound}$$

$$\text{Rotational Velocity } V_r = \Delta V / 2$$

$$\text{Shear} = \Delta V / (\text{Distance})$$

### Notes:

With the previous 2 slides in mind, I'd like to define operator identified tornadic shear...which is what you the forecaster will be looking for in the base products. Tornadic shear is an intense, roughly azimuthal shear associated with tornadic-scale rotation. It does not have to be gate-to-gate but should be at nearly the same range and the max inbound and outbound velocities shouldn't be separated by more than a radial or two in super-res velocity. The low-level azimuthal velocity difference should be at least 50 kts. Because of beam height increasing with range from radar, and beam width increasing, you normally cannot sample tornadic scale winds outside of about 50 nm. To avoid confusion with terms, Delta V is the velocity difference, and it just the addition of the absolute value of the maximum inbound and outbound velocities. Rotational velocity,  $V_r$ , is delta-V over 2. Finally, shear is delta-V divided by the distance between the maximum inbound and outbound velocities. Topic 7 will cover these topics at great length. The rest of this lesson focuses on how the algorithm identifies tornadic vortex signatures.

## Tornado Detection Algorithm (TDA)

### Tornado Detection Algorithm (TDA)

1. Search for increasing velocity values with increasing azimuth (shaded in blue)

	rad #1	rad #2	rad #3	rad #4	rad #5	rad #6	rad #7
33.00	-7	-10	-10	-7	1	2	1
32.75	-10	-15	-13	-11	4	3	0
32.50	-4	-11	-14	-18	12	22	13
32.25	-11	-19	-22	13	18	11	-1
32.00	-4	-9	-19	3	13	17	12
31.75	-10	-14	-22	1	21	9	9
31.50	-10	-25	-19	-6	4	2	1
31.25	-7	-3	-5	-6	4	13	10
31.00	-1	2	1	-3	-4	-4	-6

RDA

#### Notes:

We will now dig into the Tornado Detection Algorithm (TDA). Because the radar spins in a clockwise direction, it looks for increasing velocities along adjacent azimuths in a clockwise direction. The data in this table are velocity values and anything that is increasing from left to right, that's increasing azimuth, is shaded blue. Searching in a clockwise direction for increasing velocities means that the TDA only looks for cyclonic circulations which in the northern hemisphere is counterclockwise. The vast majority of tornadoes in the northern hemisphere spin counterclockwise.

## Gate-to-Gate Shears

### Tornado Detection Algorithm (TDA)

2. Search for gate-to-gate shear (GTG) > 11 ms<sup>-1</sup> (shaded in red)

	rad #1	rad #2	rad #3	rad #4	rad #5	rad #6	rad #7
33.00	-7	-10	-10	-7	1	2	1
32.75	-10	-15	-13	-11	4	3	0
32.50	-4	-11	-14	-18	12	22	13
32.25	-11	-19	-22	13	18	11	-1
32.00	-4	-9	-19	3	13	17	12
31.75	-10	-14	-22	1	21	9	9
31.50	-10	-25	-19	-6	4	2	1
31.25	-7	-3	-5	-6	4	13	10
31.00	-1	2	1	-3	-4	-4	-6

RDA

#### Notes:

It then calculates the actual values of shear greater than 11 m/s, or 22 knots. The values of shear greater than 11 m/s, or 22 knots, are shaded in a reddish color.

## Drop Adjacent Shears

### Tornado Detection Algorithm (TDA)

#### 3. Drop adjacent shears

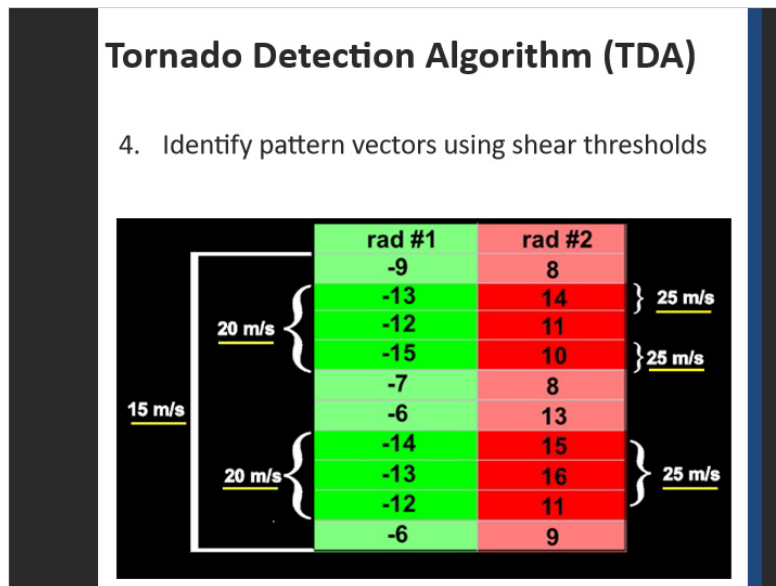
	rad #1	rad #2	rad #3	rad #4	rad #5	rad #6	rad #7
33.00	-7	-10	-10	-7	1	2	1
32.75	-10	-15	-13	-11	4	3	0
32.50	-4	-11	-14	-18	12	22	13
32.25	-11	-19	-22	13	18	11	-1
32.00	-4	-9	-19	3	13	17	12
31.75	-10	-14	-22	1	21	9	9
31.50	-10	-25	-19	-6	4	2	1
31.25	-7	-3	-5	-6	4	13	10
31.00	-1	2	1	-3	-4	-4	-6

RDA      Not Included

#### Notes:

The TDA then uses a pattern matching scheme. Notice that everything colored red in this table has fairly strong negative, or inbound velocities on the left, and positive, or outbound velocities on the right. The 21 m/s outbound velocity which is colored yellow, is not included in this 2D feature because it does not fit the pattern of the rest of the signature.

## Pattern Vector Thresholds



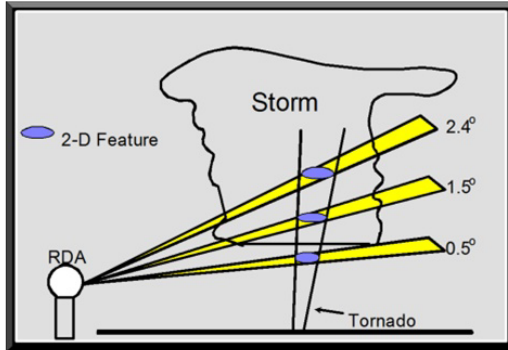
### Notes:

So, at this point, the algorithm has its 2D feature containing all gate to gate shears greater than 11 m/s, or 22 knots. The next step is to apply shear thresholds to all of the 2D features. Again, the velocities here are in meters per second. So, it first applies a 15 m/s threshold which includes the entire 2D feature. When a threshold of 20 m/s is applied, two features containing 3 gates each are identified. Finally, a 25 m/s threshold comes about, and three separate features are identified. The algorithm starts with the higher thresholds first in order to find a match with higher elevation angles first, which then helps to determine if it's a TVS signature or not. We'll talk about how it tries to correlate vertically next.

## Building 3D circulations

### Tornado Detection Algorithm (TDA)

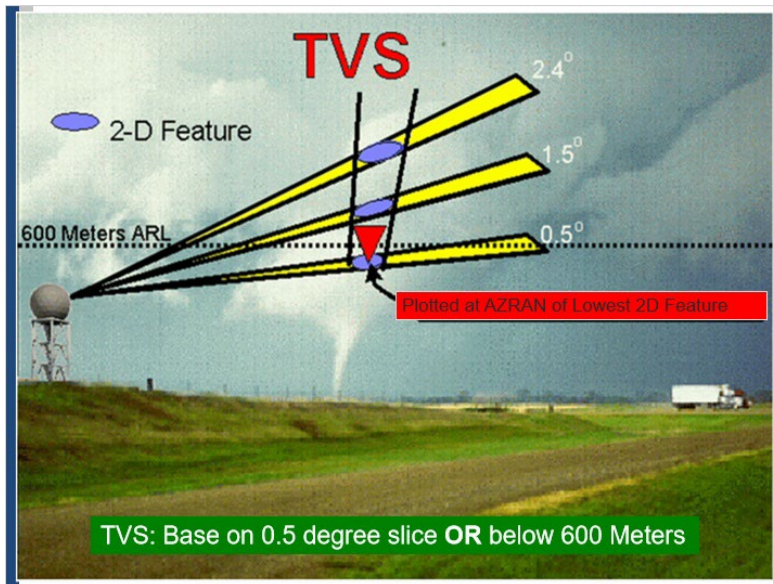
5. Feature identification – requires at least 3 2-D features



#### Notes:

The final step in determining at TVS (starting with the strongest 2D circulations first) it tries to match at least 3 vertically correlated 2D circulations, and that would declare it a 3D circulation. Ideally, there will be no gaps in the elevation angles between the vertically correlated 2D circulations. However, a one elevation gap is allowed to account for base data issues such as range folding and velocity dealiasing. In the graphic shown here, 3 successive elevation angles have 2D features that match, therefore this is a TVS.

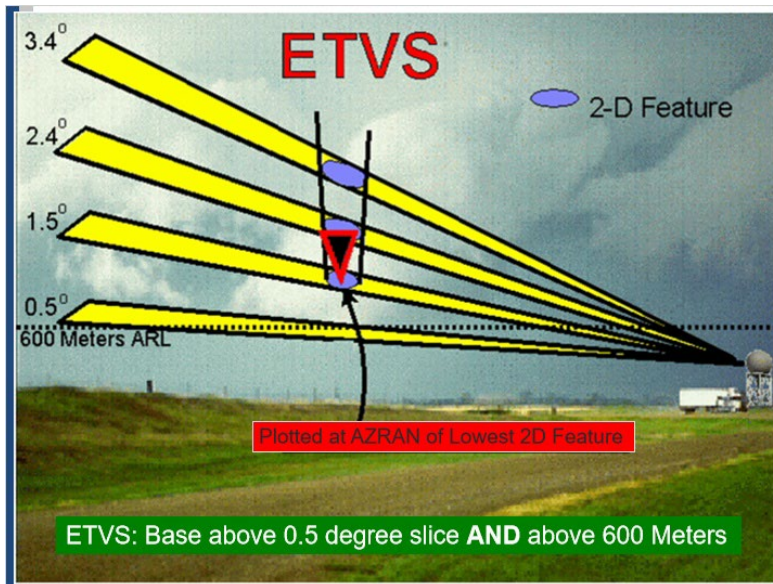
## TVS Identification



### Notes:

We saw just a few slides ago that for a TVS to be identified, there needs to be at least 3 vertically correlated 2D circulations identified and ideally these vertical correlations will have no gaps, but a one elevation gap is permitted for unforeseen data quality issues like range folding. Anyhow, one additional criteria is the lowest 2D feature must be on the 0.5 deg slice or below 600 meters ARL, which is around 2000 feet ARL. Provided that the TVS is on the 0.5 deg elevation angle or below 600 m, or less than 2000 feet ARL, the TVS symbol, which is a red, isosceles triangle will be plotted at the azimuth and range of the lowest 2D feature.

## ETVS Identification



### Notes:

Even though these are turned off by default, we do need to examine how the ETVS is identified. As with the TVS, it needs at least 3 vertically correlated 2-D features. However, the constraint of this feature is the lowest 2D circulation needs to be above the 0.5 deg slice AND above 600 meters, 2000 feet ARL. An ETVs icon is plotted at the azimuth/range of the lowest 2D feature identified. The icon is an OPEN, red isocolese triangle.

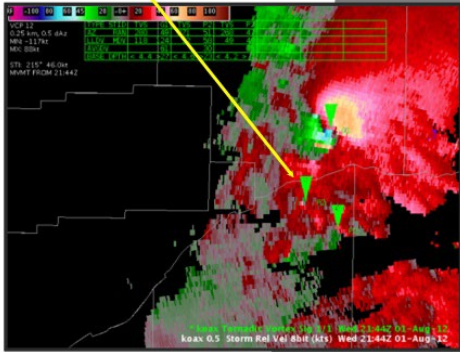
## TVS Characteristics

### Tornado Vortex Signature (TVS)

- Updated after each full volume scan

TVS icons = upside down triangles

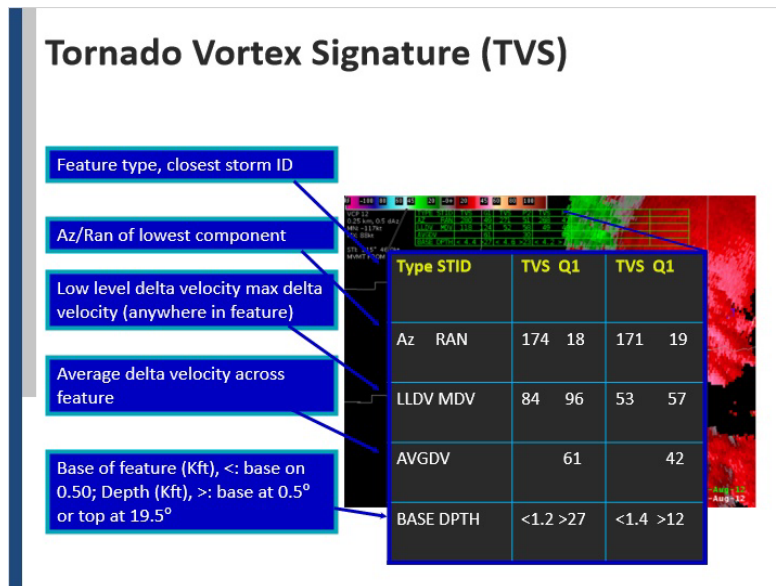
NOTE: The product's color can be customized the same way as other products'



### Notes:

Here is what the TVS product looks like in CAVE. In this graphic I have the TVS overlaid on top of the base SRM product. The closest storm ID from SCIT is plotted next to each TVS icon symbol. The TVS updates after each full volume scan.

## Attributes Table



### Notes:

Notice there is also an attributes table. The first row gives you the circulation type and the closest storm ID to that circulation feature. The second row is the azimuth and range of the lowest 2D feature. The third row gives you the low-level delta velocity in knots, and the max delta velocity in knots, anywhere associated with that feature. The fourth row gives you the average delta velocity of the feature. And, finally, the bottom row gives you the base of the feature in thousands of feet. Anytime you see a less than sign associated with the base, this tells you that the lowest 2D feature is on the 0.5 deg scan. The other part of the bottom row is depth, in thousands of feet. If you see a greater than symbol, that means that the base is at 0.5 deg or the highest 2D feature is on the 19.5 deg scan.

## TVS Characteristics

**Tornadic Vortex Signature Rapid Update (TRU)**

- Generated from TDA
- Updated each elevation scan, including during SAILS and MRLE tilts
- Contains tracking info from SCIT for time continuity

TYPE	STID	TVS	00	TVS	A	S1		
AZ	RAN	254	22	250	^	50		
LLDV	MDV	157	157	^	49	^	49	
STA	AV	PER	99	NEW	^	26		
BASE	DEPTH	<	1.5	>	26	6.4	^	22

\*Product color changed for visibility

### Notes:

A useful TDA-derived product is the TVS Rapid Update, or TRU, product. Instead of only updating once a volume scan like the TVS, TRU updates after every elevation scan, including during SAILS and MRLE tilts. Additionally, it contains SCIT cell-tracking information to account for time longevity. TRU's attribute table is similar to TVS', with the addition of feature status levels and a carat (^) symbol to denote attributes computed from the current volume scan. Also note the attribute table contains information from both previous and current volume scans.

## Radar Display Controls

### Radar Display Controls

- Change AWIPS-2 workstation display to not view ETVS symbols
- CAUTION!
  - Only changes AWIPS-2 display!
  - You will not see ETVS
    - Outside users will see ETVS
- Choose whether to show extrapolated features

The screenshot shows the 'Radar Display Controls' window with the following settings:

- STI**: Num storms to show: 20; Type of track to show: past & fcst
- NI**: POH: Low 30, High 50; POSH: 30, 50
- TVS**:  Show elevated TVS (highlighted with a red box)
- DMD, MD, TVS**:  Show extrapolated features
- DMD**: Min feature strength: 3;  Show overlapping Mesos; Type of track to show: past & fcst
- MBA**:  Show Wind Shear
- SRM**:  Storm Motion from WarnGen Track;  Average Storm Motion from STI;  Custom Storm Motion
- Custom Storm Motion**: Dir: 0, Spd: 0
- SAILS**:  Enable SAILS Frame Coordinator

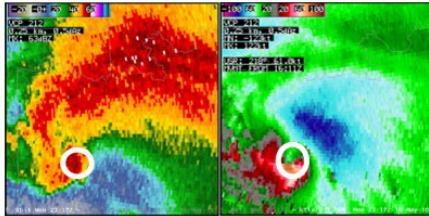
### Notes:

Though by default ETVSs are turned off at the RPG, let's say you are using them. In AWIPS-2, you can control whether they are displayed or not using the radar display controls window. However, this only changes the AWIPS-2 display, so outside users will see them despite you not seeing them. The only way to prevent outside users from having their display cluttered with ETVSs is to have them turned off at the RPG. You can also choose whether to show extrapolated features from the SCIT algorithm.

## ***TVS Operational Considerations***

### **TVS Operational Considerations**

- For TVS detection, consider:
  - Low-level wind shear and thermal profile
  - Signature's position in relation to reflectivity storm structure
  - Time continuity and range
- Beyond ~60 km (~45 nm), TVS most likely triggered by strong mesocyclone
  - TDA independent of MDA



#### **Notes:**

The next several slides deal with operational considerations for incorporating TVS into the warning decision process. If you see a TVS consider the following: What is the low level wind shear and thermal profile in the near storm environment? Are they both favorable for tornadoes? Next, look at the TVS in relation to the reflectivity structure. Does it make sense where this TVS is located relative to the storm? Finally, is there time continuity and how far from the radar is this feature? Is the TVS associated with a mesocyclone that has been around a while? That is good time continuity. The problem with range, is that beyond 60 km, or 45 nm, the TVS is most likely triggered by strong mesocyclones, and not necessarily indicative of an impending tornado. Recall that the TDA is independent of the MDA, so at far ranges, they most likely will be identifying the same feature.

## ***More Operational Considerations***

### **TVS Operational Considerations**

TDA shows time and space continuity

TDA identifies TVSs nearly continuously on supercells

TDA has poor performance in squall lines

TDA tends to identify TVSs near the bend in a LEWP

#### **Notes:**

Continuing on with operational considerations, the TDA does show some time and space continuity allowing you to track features. Also, the TDA nearly continuously identifies TVSs on supercells which could be a good or a bad thing. It's bad in that the false alarm is very high in these supercells. But it could be a good thing in maintaining your situational awareness that the storm you are looking at is still a supercell and still warrants a continuous and thorough base data analysis. TDA also performs very poorly in the squall lines depending on how the leading edge of the squall line oriented relative to the radar. You can have large areas of shear show up that aren't really tornadic by any means, but still they show up because they are areas of shear. This is especially true near the bends in LEWPs.

## More Operational Considerations

### TVS Operational Considerations

- Elevated TVVs correlation worse than TVVs
  - Recommend keeping them turned **off** at the RPG
- Remember that algorithms serve to provide users with **guidance**

**DO NOT** issue tornado warnings solely on TVV/ETVVs!



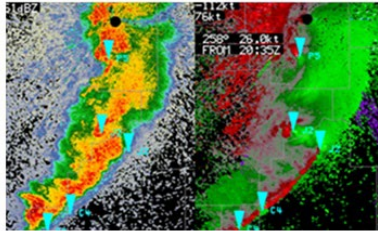
### Notes:

Some final operational considerations. The elevated TVV has worse correlations than TVVs relative to tornado occurrence. Therefore, it is recommended that you keep the ETVV turned off at the RPG until evidence says otherwise. We would be doing our customers a great disservice if we issued tornado warnings based solely on the TVV signature. Remember that these algorithm serve to provide users with guidance only. A thorough base data analysis coupled with near storm environmental analysis is critical in any tornado warning decision. Do not issue a tornado warning based solely on a TVV or ETVV!

## ***Limitations***

### **TVS Limitations**

1. Adaptable parameters need more research
2. High false alarm ratio, especially in squall lines and tropical cyclones
3. Little research has been done to date relating the occurrence of tornadoes to Elevated TVSs



### **Notes:**

Let's examine the limitations. First, adaptable parameters need more research. Second, high false alarm ratios occur especially with squall lines and tropical cyclones. And finally, there has been little research done to date, relating the occurrence of tornadoes to ETVs.

## ***Applications (Strengths)***



**Product Applications**

Application #1

Application #2

Application #3

Application #4

Please click the buttons along the left to view the applications of the TVS products.

### **Notes:**

Here are the applications of the TVS. Please click on each blue button along the left to see all the applications. First, it searches for all gate-to-gate shears. So, after doing a thorough base data analysis, you can use the TVS product to see if you missed anything. Second, it does use multiple velocity difference thresholds. The product is displayed with an attributes table which provides information on the base and the depths of the circulations. And, finally, it allows for performance tuning through adaptable parameter changes based on the meteorological conditions you anticipate for an event.

## Summary: TVS

### Summary

- TVS product can alert operator of significant and possibly tornadic circulations
- TDA performance within squall lines and tropical cyclones is significantly worse than supercells




Image courtesy WFO ILX website

### Notes:

Summarizing this lesson, the TVS can alert the operator of significant and possibly tornadic circulations. Be careful using TVS products in squall line and tropical cyclone events as the TDA performance in these situations is significantly worse than in the supercells. The next slide will be a short quiz.

## ***Conclusion***

<p><b>Contact Information</b></p> <p>RAC Help Email: <a href="mailto:nws.wdtd.rachelp@noaa.gov">nws.wdtd.rachelp@noaa.gov</a></p> <p>Lesson Author Email: <a href="mailto:alyssa.bates@noaa.gov">alyssa.bates@noaa.gov</a></p>	 <p>Once you've completed the quiz, hit "Exit" to close out!</p>
--	--

### **Notes:**

This concludes the lesson on the TVS/TS products. You can now move onto the next lesson. If you have any questions, feel free to email the contacts listed.



# Radar & Applications Course (RAC)

Topic 4- Base and Derived Products

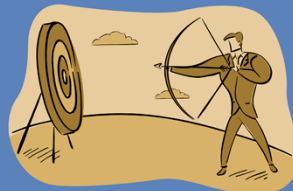
Hydrometeor Classification (HC)

Warning Decision Training Division (WDTD)

This Topic 4 lesson will be on Hydrometeor Classification. I'm Justin Gibbs of the Warning Decision Training Division.

## Learning Objectives

Upon completion of this lesson you will be able to identify specific characteristics, limitations, and applications (strengths) of the Hydrometeor Classification (HC) product

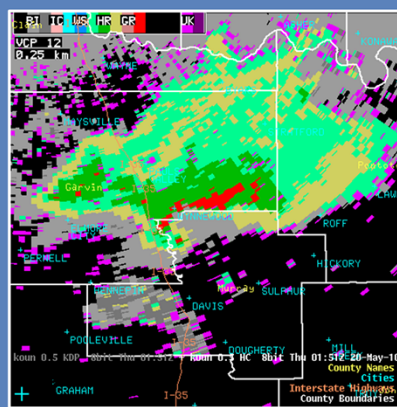
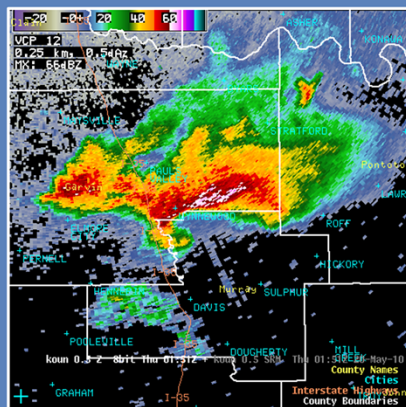


Here are the learning objectives for this lesson. Please advance the slide when you are ready to begin.

# Hydrometeor Classification Algorithm (HCA)

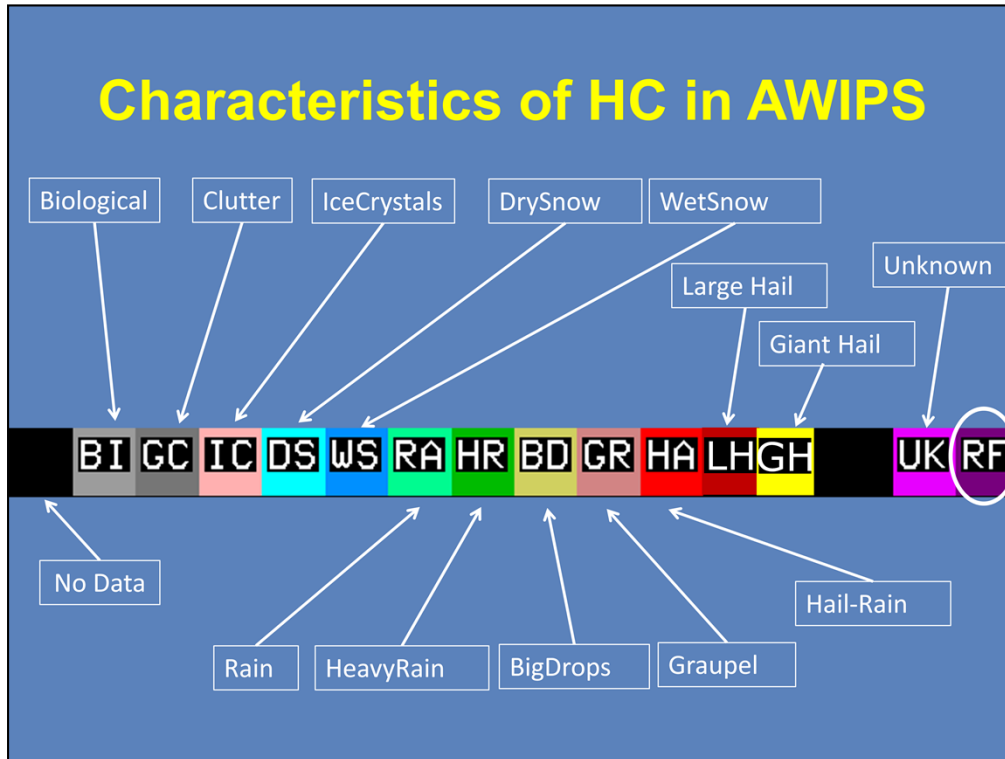
Determine most likely classification:

- Pre-defined list of echo classes
- Base moments and polarimetric variables



Straka et al. (2000)

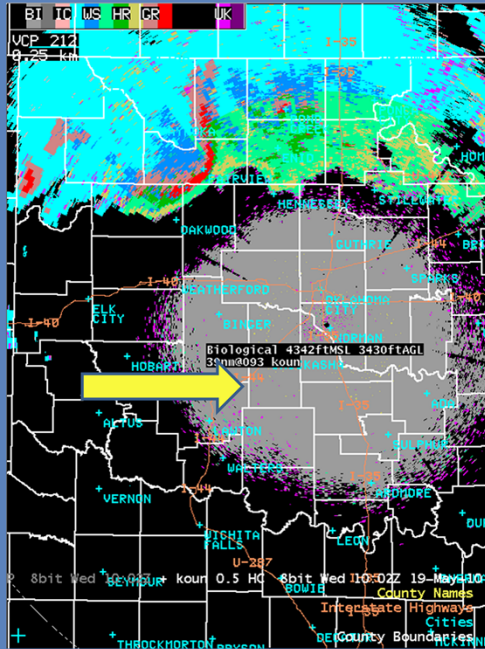
The purpose of the hydrometeor classification algorithm, or HCA, is to determine the most likely classification of all the range bins that the radar detects at all elevation angles. What most likely is what the radar is sensing in each bin. It attempts to put all the echoes into a predefined list of echo classes, and uses base data and polarimetric variables to reach its estimate.



The bins that the HCA attempts to place echoes into are , No Data (ND), biological scatterers (BI), ground clutter / anomalous propagation (GC), ice crystals (IC), dry snow (DS), wet snow (WS), light/moderate rain (RA), heavy rain (HR), big drops (BD), graupel (GR) hail possibly mixed with rain (HA), Large Hail (LH), Giant Hail (GH) , and Unknown (UK).

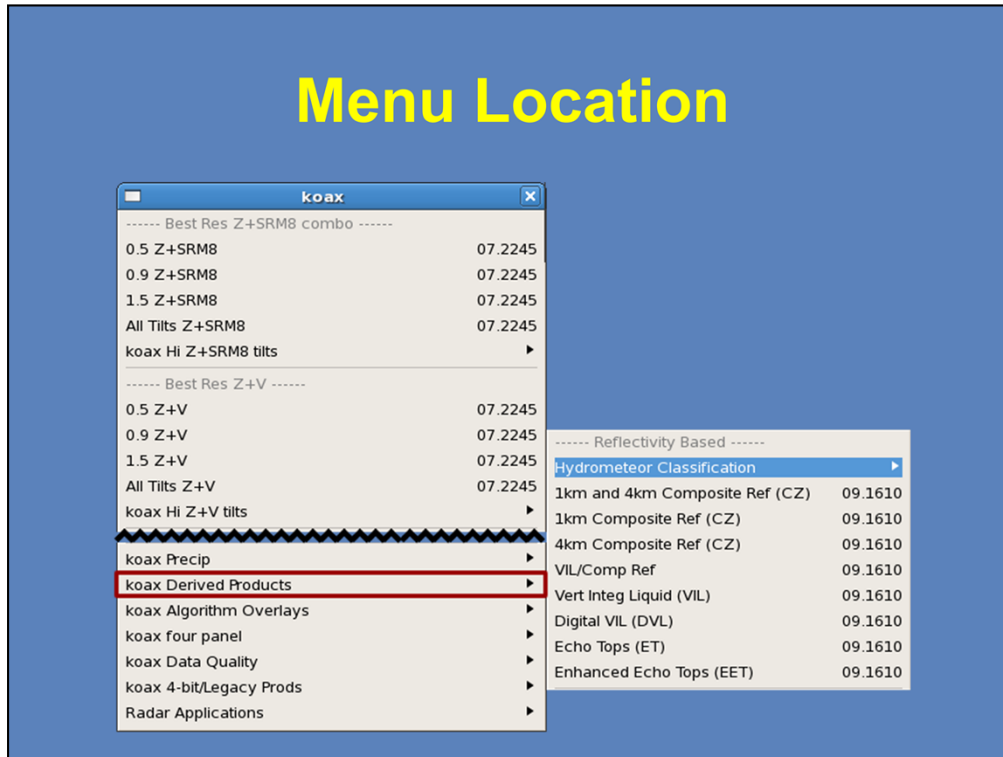
## Cursor Readout

- No Data
- Biological
- Clutter
- IceCrystals
- WetSnow
- DrySnow
- Rain
- HeavyRain
- BigDrops
- Graupel
- Hail-Rain
- Large Hail
- Giant Hail
- Unknown



You can enable sampling and do a mouse over of each target in plan view. In this case the target was biological scatterers at 4,342 MSL, and it will give you any of the returns we mentioned before.

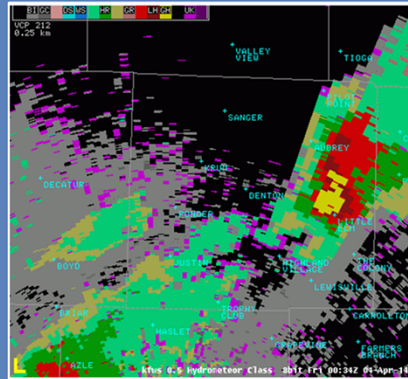
# Menu Location



To pull up the Hydrometeor classification algorithms output, go to your radars pulldown menu, select derived products, and Hydrometeor classification and you will get a pulldown menu that will allow you to select any individual, or all of the tilts of the HCA output.

## Hail Size Discrimination Algorithm

- **Two Hydrometeor Classifications:**
  - Large Hail: 1-2 in
  - Giant Hail:  $\geq 2$  in
- **Requires height of 0° C & -25° C wet bulb temp**
- **Can be turned “off”**
- **Has relatively low FAR, modest POD**



Ortega, et al. (2016)

A relatively new addition to the HCAs is the hail size discrimination algorithm. This gives you your LH and GH outputs in the HCA. Which signals large hail, and giant hail. Large hail being severe hail between 1-2 inches, and giant hail, greater than 2 inches.

The HSDA requires a 0 and -25 degree C wet bulb temperature which should populate in the RPG.

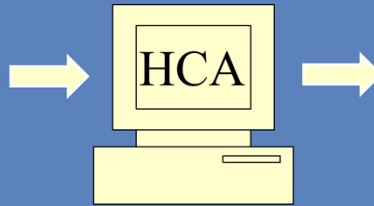
It CAN be turned off if for some reason you need to, and then you would just get the standard rain hail mixed HCA output.

In validation testing it showed some promising skill, with a relatively low FAR, the probability of detection was a little low, so keep that in mind but it may have sufficient skill to be a useful alerting tool given its low FAR, meaning if its showing Giant hail and you don't think hail is falling, take another good look at your data because you may be missing something.

# Product Limitations

1. Overlapping polarimetric characteristics (they look the same to the radar)

Inputs
Z = 50 dBZ
ZDR = 1.0 dB
CC = 0.95
KDP = 0.05 deg/km
SD (Z) = 1.5 dBZ
SD (Phi) = 5 deg



Type	Value
GC	0.2
BI	0.194
DS	0
WS	0
IC	0
GR	0
BD	0.357
RA	0.143
HR	0.789
HA	0.737

One of the key limitations of the hydrometeor classification algorithm are overlapping polarimetric characteristics. Basically two different bins of possible answers that look the same to the radar. In this example the input has 50dbz a zdr of 1db, CC of 0.95 an SD Z of 1.5 dBZ and an SD Phi of 5 degrees. When it runs through the algorithm the output says theres a 79% chance that its heavy rain and a 74% chance its large hail, so it can't tell if its hail mixed with rain, or just heavy rain.

# Product Limitations

## 2. Uncertainty not portrayed

Example  
Inputs

- Z = 50 dBZ,
- ZDR = 1.0 dB,
- CC = 0.95,
- KDP = 0.05,
- SD (Z) = 1.5 dBZ,
- SD(Phi) = 5 deg



HR = 0.789  
HA = 0.737

Heavy Rain (HR) will be displayed in AWIPS:

- Will not see that HA was very close in likelihood value

And its important to understand that uncertainty is not portrayed in the HCA output. It just takes the most likely answer and spits that out to you. So in our situation we had in the previous slide where its about 79% chance its heavy rain and 74% chance its hail, AWIPS is only going to display heavy rain. You wont see that hail was a very close in likelihood value, only about 5% difference. So when you have those overlapping characteristics where maybe its graupel or hail or rain, you wont know what those other options are other than what is displayed in the HCA.

## Product Limitations

### 3. Available classifications are limited



No classification categories for scatterers such as ash or sleet

The available classifications are also limited, there is no classification categories for scatterers such as ash or sleet, or debris both from weather related phenomena or a rocket explosion, weve seen a couple of those in the last few years where debris shows up on the radar, its got low CC so humans can tell what it is, but the algorithm cant pick up on it.

# Product Limitations

## 4. Thresholds are empirical and/or subjective

Fuzzy-Logic Membership Function  
(Dry Snow)

Weighting  
(Dry Snow)

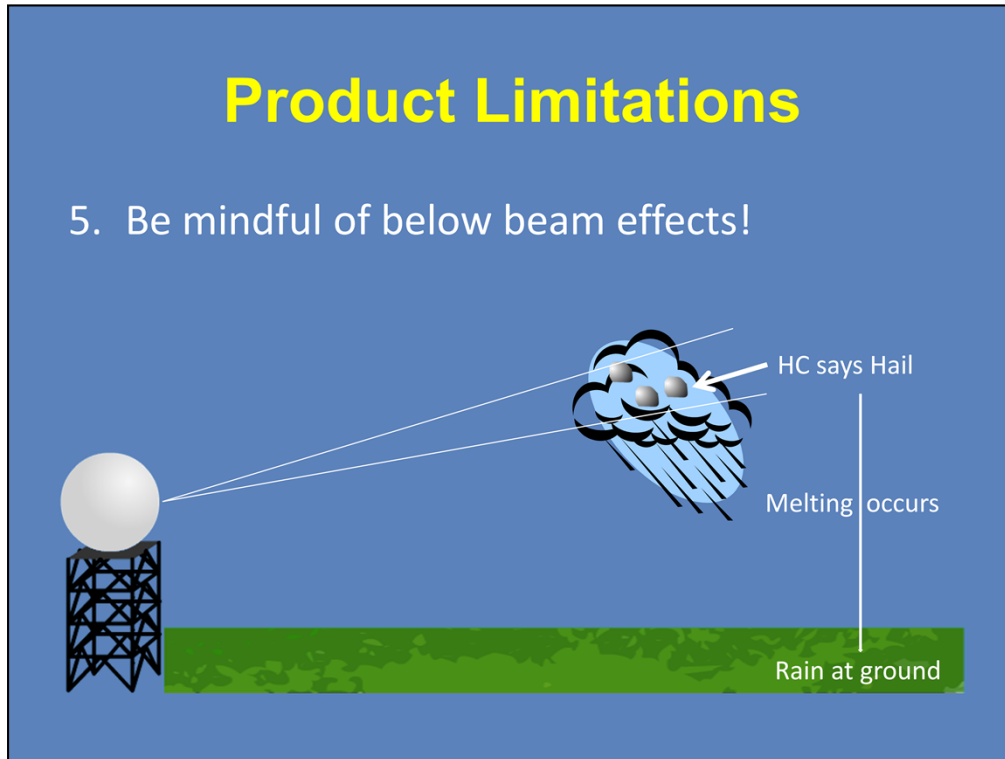
	X1	X2	X3	X4	Weight
Z	5	10	35	40	1.0
ZDR	-0.3	0.0	1.3	1.6	0.8
CC	0.95	0.98	1.0	1.01	0.6
KDP	0.001	0.003	10	100	1.0
SD(Z)	0	0.5	3.0	6.0	0.2
SD(Phi)	0	1	15	30	0.2

Values may not be representative for all regions of U.S.

Another limitation is that the thresholds are empirical or subjective. What that means is a mathematical theory doesn't exist that says the Zdr of heavy rain should be say, 1.5 and the CC should be 0.95. There's no theory that we can go to to say this is what we are expecting like there are with other variables in meteorology. So a fuzzy logic membership function was derived from a series of studies where they said "this is heavy rain falling, were going to point the radar at it" and these are the values that came out, so were going to say when we see these values in the future it must be heavy rain. The problem with that is that these values may not be representative for all regions of the US, so the algorithm will have that limitation as well.

## Product Limitations

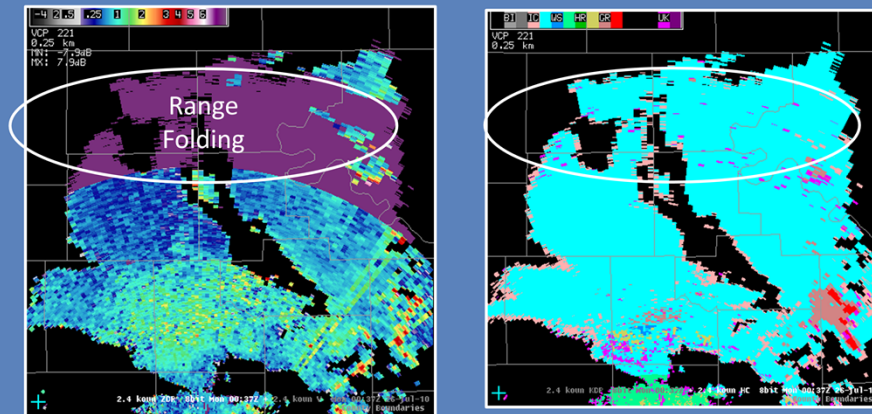
### 5. Be mindful of below beam effects!



You also have to be mindful of below beam effects. The HCA is going to give you the output where the beam intersects the target, and whatever happens below the target the radar is not able to account for. So in this illustration the HCA is detecting hail and lets say 15,000 ft. Well that hail melts before it reaches the ground and produces rain at the ground. Its also a problem if its snow, heavy rain, hail you can imagine the possibilities where you could have a target at 8 or 10 thousand feet above the ground and how it could change before it reaches the ground.

## Product Limitations

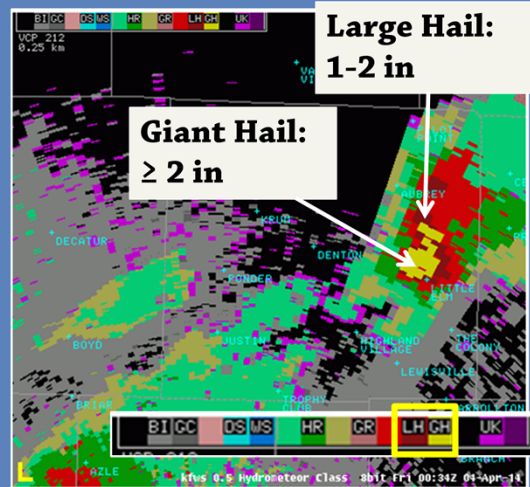
6. HC provided in range folding in batch cuts (1.65 to 6.5 degree elevation) despite DP variables unavailable



The sixth limitation, the HCA, part of what makes it work is the dual pol moments. The dual pol moments however aren't available in batch cuts, between 1.65 and 6.5 degrees elevation in range folding so this area of range folding that exists on the left hand image, there is no ZDR there is no KDP there is no CC but the HCA is going to make a guess anyway, and its not going to have nearly as much information as it would otherwise have to make a guess at what the p-type is and theres no indication in the HCA that, hey I don't have as much information as I normally have I don't have any ZDR or CC so the user has to be aware of that. Again thats where your meteorology comes in handy and your ability to know what is the most likely outcome based on the science that exists away from what the HCA is showing you.

# Product Limitations

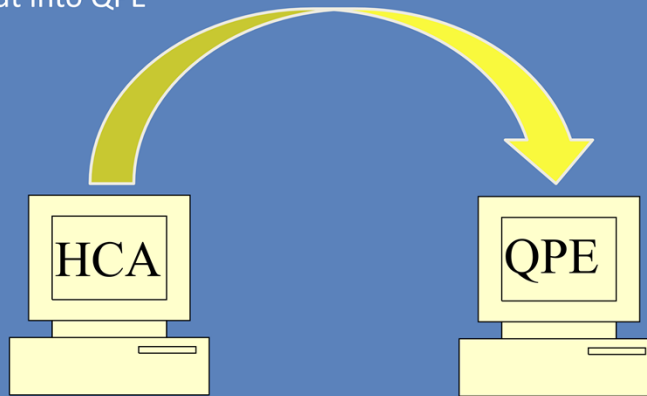
7. Hail Size Discrimination is especially sensitive to ZDR calibration, and has about a 50% probability of detection.



The hail size discrimination algorithm is still pretty new, so we don't know too much about how it will perform in the field. It also has a relatively low POD, and is particularly sensitive to ZDR calibration issues.

# Product Applications

1. Input into QPE

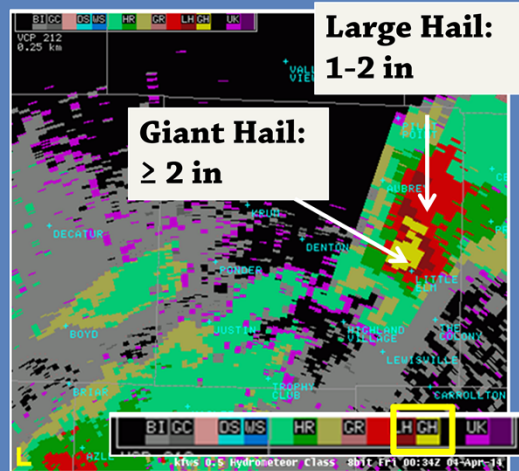


HCA designed to provide best QPE possible, not to help forecasters interpret hydrometeors

One of the main applications of the HCA is that it is used to improve the QPE output. The HCA is really designed to provide the best QPE possible, and its not really there to help forecasters interpret hydrometeors. Its just a nice by product that is available, so might as well have it. So its going to provide you better rainfall rates, and if its not working correctly its going to introduce potential errors into your QPE and that is why you can see the output so you can be like "whoa, I've got a lot of hail I know there is so I'm going to be a little more questionable to my QPE for example" But it isn't really there to help you interpret hydrometeors, thats why youre a meteorologist and you're a forecaster you make those determinations and provide that value added service to our customers.

# Product Applications

2. Hail Size Discrimination appears reasonably skillful

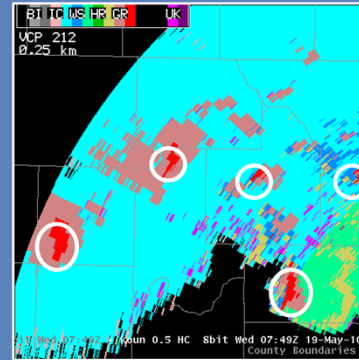
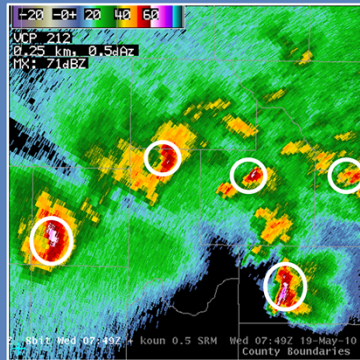


10-12% FAR in validation tests

The hail size discrimination algorithm shows promise, and appears reasonably skillful. It may be useful as a situational awareness tool, and particularly as an alerting tool given its apparently low false alarm rate, 10-12% in validation tests

## Product Applications

3. Provides quick look at regions of interest
  - Aviation nowcasting of hail



It also can be used to provide a quick look at regions of interest, perhaps aviation nowcasting of hail. You look at the image on the lower left and there is some 60 to 65 dBZ output and that correlates pretty well to where the algorithm is showing hail. The image on the right center looks a little more suspect but I don't know what's going on aloft in this image. So it gives you a quick first glance if you want to use it, but again base data analysis all the methods that you are being taught through this course and the courses to come are going to provide a superior service to the HCA.

## Summary: HC

- Provides guess for echo type, HSDA appears skillful
- Input is used in QPE
- Thresholds/parameters are empirical and overlap
  - Uncertainty is not portrayed
- Below beam effects
- Not designed for deterministic operational use!

So in summary the HCA provides a guess for echo type, the new HSDA appears skillful but the algorithms

primarily used to improve QPE.

The thresholds are empirical they are not mathematically derived, and they can overlap and that uncertainty is not portrayed, there is a lot of fuzzy logic that goes into the developing the HCAs output.

Below beam effects what is going on at the ground may not be in any way representative as to what the radar beam is detecting.

It is not designed for deterministic operational use and should not be used that way. If you're relying on your HCA output you are probably not going to be providing the best service, look at the other aspects of what the radar can do and meteorology to get that level of service up to the standards that we want it.

**Thanks for Your Attention!**

Questions?

[justin.gibbs@noaa.gov](mailto:justin.gibbs@noaa.gov) or  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

That concludes this lesson on hydrometeor classification. If you have any questions, email myself or any member of the team responsible for putting this course together. Thanks for listening!



# Radar & Applications Course (RAC)

Topic 4: Base and Derived Products

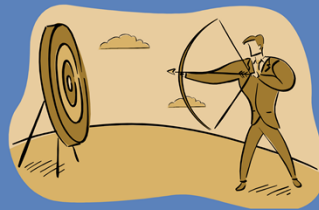
Melting Layer (ML)

Warning Decision Training Division (WDTD)

Welcome to this Topic 4 lesson on the Melting Layer.

## Learning Objectives

Upon completion of this lesson you will be able to identify specific characteristics, limitations, and applications (strengths) of the Melting Layer (ML) product

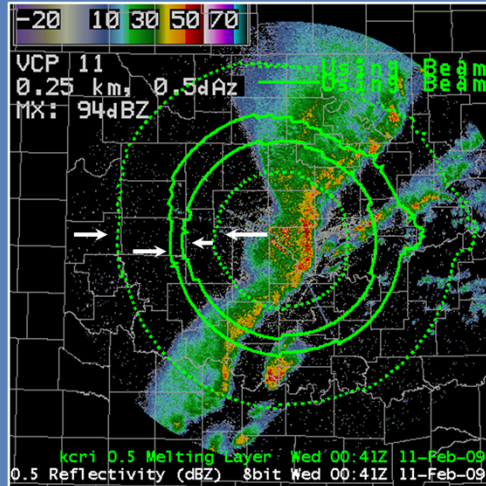


Here are the learning objectives for this lesson. Advance to the next slide when you are ready to begin.

# Melting Layer Detection Algorithm (MLDA)

Overlay graphic:

- Every volume scan
- Every elevation angle



Giangrande, Krause and Ryzhkov, 2008

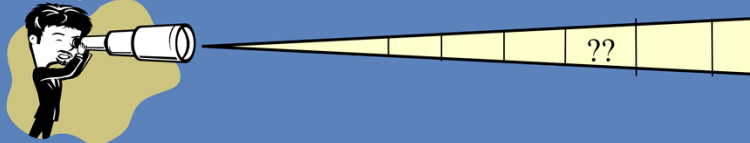
As we mentioned earlier, the melting layer has a distinct signature in both ZDR and CC. This fact is by the Melting Layer Detection Algorithm (MLDA) to automatically detect a melting layer from the radar data and then display it as an overlay on other radar products. The green solid and dotted lines in the graphic shown represent the melting layer product. This graphic is available every volume scan for every elevation angle. The next few slides will briefly describe how the MLDA works.

## Step 1: Identify Wet Snow Bins

Along each radial from 4 through 10 degrees

Z is between 30 and 47 dBZ  
ZDR is between 0.8 and 2.2 dB  
CC is between 0.9 and 0.97

AHA! We have Wet Snow!

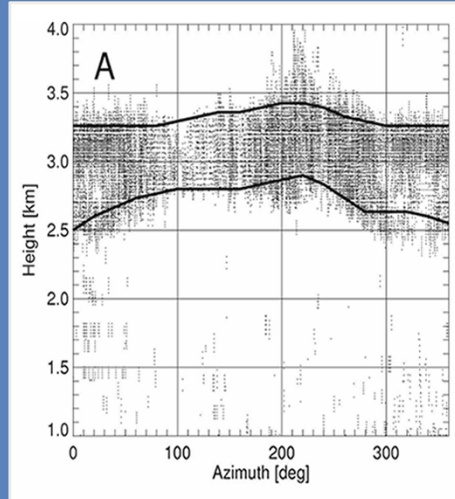


The algorithm starts by looking down each radial between the elevations of 4 and 10 degrees and identifies the total number of wet snow bins. A wet snow bin is identified in regions where there is a combination of high Z and ZDR and lower CC. For a bin to be “wet snow”, Z must be between 30 and 47 dBZ, ZDR between 0.8 and 2.2 dB, and CC between 0.9 and 0.97. It's important to note that “wet snow” in the MLDA is not the same as wet snow in the HC product.

## Step 2: Construct Height Vs. Azimuth Array

Contains all wet snow bins from current volume scan plus:

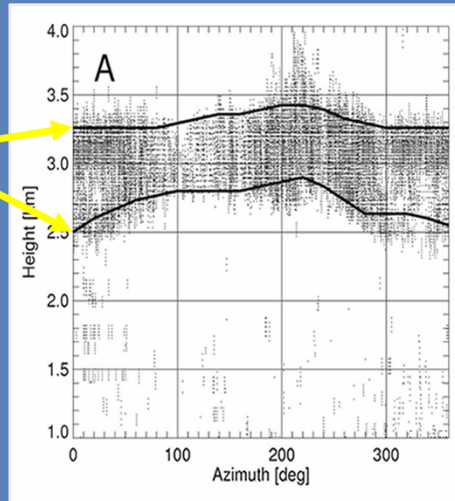
- Previous 2 volume scans for precip VCPs
- Previous 5 volume scans for clear-air VCPs



The next step in the algorithm is to construct a height versus azimuth array (like the one shown here on the right) for all bins identified as wet snow from step 1. This array includes all wet snow bins from the current volume scan, plus the previous two volume scans in precip mode or the previous five volume scans for clear-air mode.

## Step 3: Compute Top and Bottom of ML

- Bottom
  - 20% wet snow bins below this height
- Top
  - 80% wet snow bins below this height
- Done for each azimuth and smoothed



If a sufficient number of wet snow bins are identified, the top and the bottom of the melting layer are then computed using the height versus azimuth array. The top and bottom are determined using a percentage of wet snow bins along each azimuth of the array. The bottom of the melting layer is placed at the 20<sup>th</sup> percentile location (bottom black line) while the top of the melting layer is identified at the 80<sup>th</sup> percentile location (top black line). Once these height designations are identified for each azimuth, they are smoothed to maintain time and space consistency between radials.

## Step 4: Not Enough Wet Snow Bins?

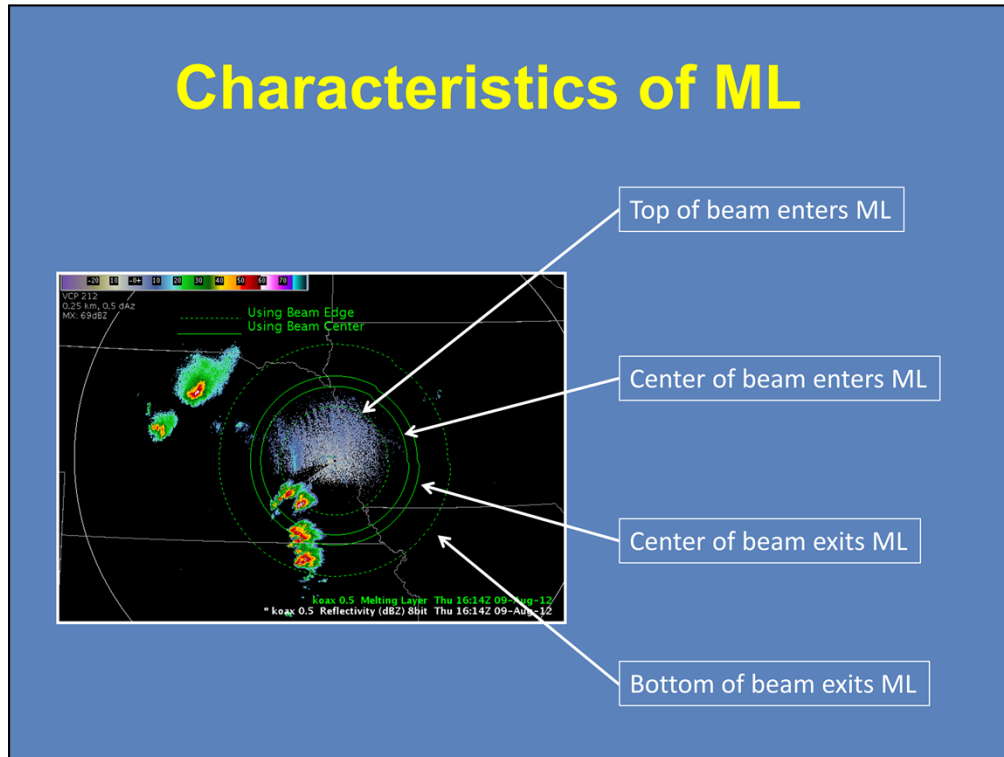
- Use average of ML heights from valid radials
- Use the RPG-defined 0° C height
  - Top = 0° C height
  - Bottom = 500 m below top



So what happens if the MLDA doesn't identify enough wet snow bins to locate the melting layer? Well, the algorithm still identifies a melting layer height using one of two methods.

The first method interpolates the melting layer top and bottom from nearby radials in the current volume scan where there were valid detections. If the gap between radials where the melting layer was identified is too large, then the second method uses the 0 Celsius height in the gap as defined in the RPG. It will set the 0 Celsius height as the top of the melting layer, and the bottom of the melting layer will be 500-m below that height. This 0 Celsius height can be defined automatically if you have "Model Input" turned on at the RPG, or you can manually enter it if you think the model is out to lunch. Either way, just make sure you have an accurate 0 Celsius height defined in the RPG.

## Characteristics of ML

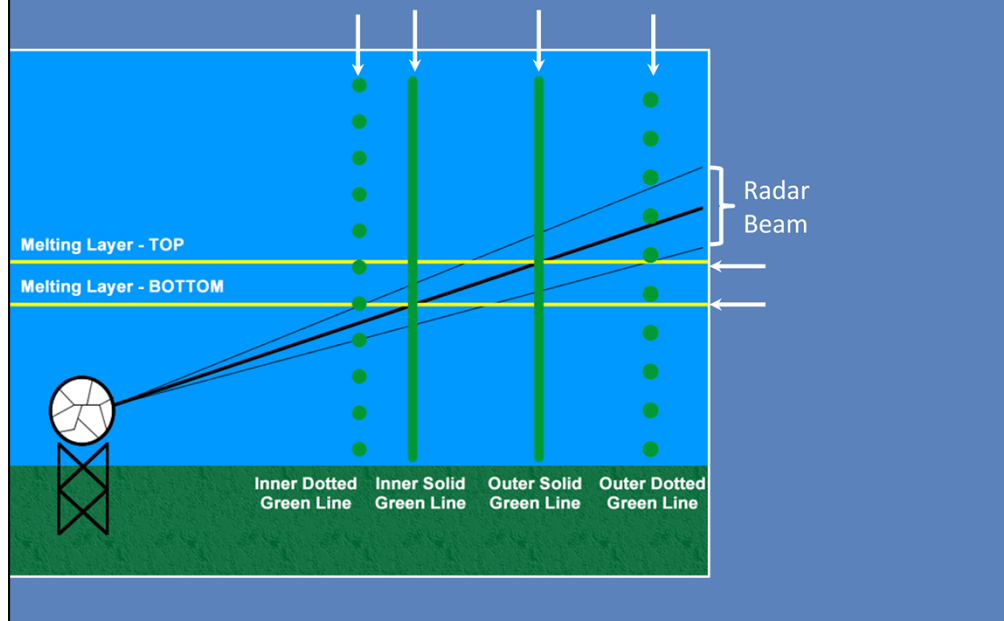


The heights determined by the MLDA are then used to construct the Melting Layer (ML) product. This example shows the 0.5 deg ML overlaid on top of the 0.5 deg Reflectivity. I should note that, although the algorithm only uses tilts between 4 and 10 degrees to identify the melting layer, the ML product is available for every elevation angle in the volume scan.

So let's look at this display and see what the ML product tells us. There are four different green lines displayed: Two are solid lines and two are dashed. We'll start closest to the radar and work our way down the radial. The innermost dotted line indicates where the top of the radar beam intersects the bottom of the melting layer. The innermost solid line indicates where the radar beam center intersects the bottom of the melting layer. The outermost solid line indicates where the center of the beam intersects the top of the melting layer. Lastly, the outermost dotted line indicates where the bottom of the beam intersects the top of the melting layer.

So, the region between the two solid lines is where the radar primarily samples the melting layer. However, the melting layer affects in some way all data collected between the two dashed lines.

## Conceptualizing the ML Product



We provide this graphic to conceptualize the ML display further and aid your understanding further. In this graphic, the radar beam is illustrated with a thick black line for the center of the beam and two thin black lines for the radar beam edges. The two yellow lines represent the identified melting layer top and bottom.

Following the discussion from the previous slide, the first dashed line is displayed where the top of the beam intersects the bottom of the melting layer. The innermost solid line is plotted at the height where the center of the beam intersects the bottom of the melting layer. The outermost solid line represents where the beam center intersects the top of the melting layer. Finally, the outermost dashed green line is plotted at the height where the bottom of the beam intersects the top of the melting layer.

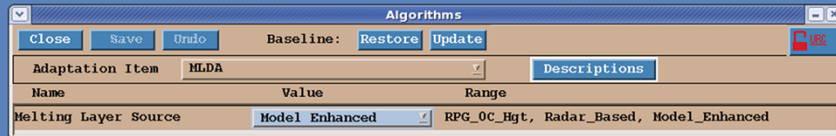
## Menu Location



The ML product graphic can be found in two places in the radar's drop-down menu. You can load the ML product by itself for any elevation angle available using the "Algorithm Overlays" menu in your radar's menu.

We recommend displaying the ML product only on other elevation-based radar products like 0.5 or 0.9 degree radar products. And when you do, make sure the elevation angles for the ML and other products you have loaded match.

# Adaptable Parameters



## Melting Layer Source:

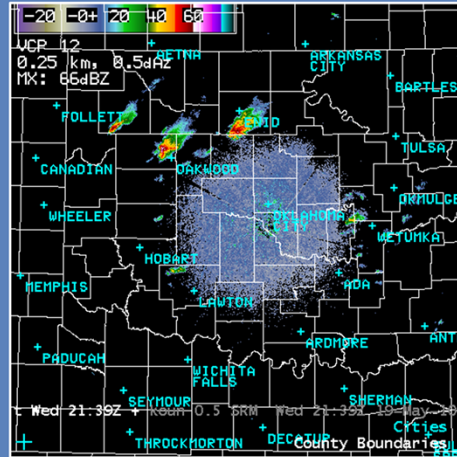
- Model Enhanced (Default)
  - Use the dual-pol data to compute melting layer heights
  - Model data helps fill in gaps
- Radar Based
  - Uses radar data exclusively
- RPG 0C Height
  - Uses current value for 0°C from RPG

In the RPG window, you will see one adaptable parameter, entitled Melting Layer Source, with three possible options. “Model Enhanced” is the default option shown on the slide. When “Model Enhanced” is selected, the MLDA will look at the data available radial by radial. When sufficient data exists, the methodology discussed previously is used. Azimuths lacking sufficient coverage are addressed in two ways. If the data gap is less than 15 deg of azimuth, the RPG interpolates to fill the gap using radar-based heights only. If the data gap is greater than 15 deg of azimuth, the RPG interpolates using a blend of the radar-based heights and model data. If no radar-based estimate is possible at any azimuth, model data are used at all azimuths.

The other two options are “Radar Based” and “RPG 0C Height”. When “Radar Based” is selected, the algorithm will use radar data exclusively. When “RPG 0C Height” is selected, a 500 m thick melting layer is assigned at all azimuths using the current value for 0 C in the RPG Environmental Data window.

# Product Limitations

1. Situations with unlikely ML detections
  - Fast moving cold fronts
  - Small stratiform regions
  - Majority of area below freezing
  - Isolated storms



Let's talk about the limitations of the ML product. The algorithm requires the radar to detect the melting layer with a certain amount of spatial and temporal continuity. So, if there are not enough wet snow detections are made in a 3-6 volume scan period, depending on VCP, then the algorithm will fail. So, when will failures most likely occur during non-quiet weather?

The first situation is when there are fast moving cold fronts. During quick frontal passages, the algorithm can have difficulty maintaining temporal continuity unless there is a lot of precipitation present. A second difficult situation occurs during small-scale stratiform rain events where there is not enough wet snow sampled to identify the melting layer heights. Problems can also occur when the majority of the local area is below freezing, especially if the 0 degree height listed in the RPG is incorrect. Lastly, issues can arise with the ML product when there are only isolated storms in the area, as in the example shown.

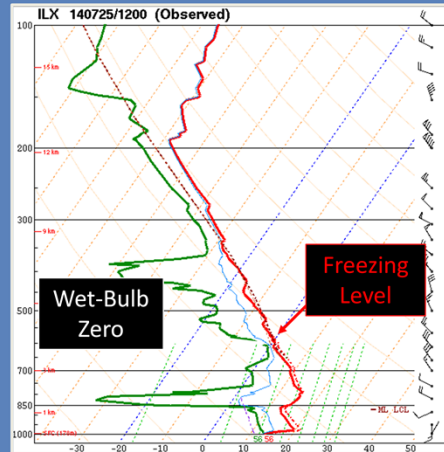
# Product Limitations

## 2. Wet-bulb zero vs. 0° C

PARCEL	CAPE	CINH	LCL	LI	LFC	EL
SURFACE	0	0	38m	12	M	125'
MIXED LAYER	0	0	1131m	8	M	3709'
FCST SURFACE	0	0	1721m	5	M	5645'
MU (651 mb)	85	-18	4009m	-0.7372m	28128'	

PW = 1.06 in	3CAPE = 0 J/kg	WBZ = 13569'	WNDG = 0.0
K = -2	DCAPE = 547 J/kg	FZL = 14259'	ESF = 0.0
MidRH = 21%	DwnT = 52 F	CovT = 11	MMP = 0.37
LowRH = 45%	MeanW = 8.8 g/kg	MaxT = 78F	NCAPE = 0.07
SigSevere = 0 m3/s3			
Sfc-3km Agl Lapse Rate = 1.7 C/km		Supercell = 0.0	
3-6km Agl Lapse Rate = 7.0 C/km		Left Supercell = 0.0	
650-500mb Lapse Rate = 5.3 C/km		STP (eff layer) = 0.0	
700-500mb Lapse Rate = 6.7 C/km		STP (fix layer) = 0.0	
		Sig Hail = 0.0	



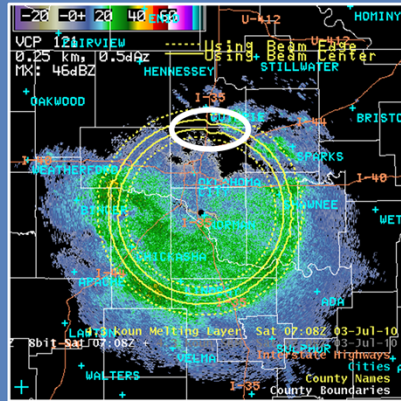
The top of the melting layer is considered synonymous to the 0° C height. While this is true in some cases, the top of the melting layer is actually the wet-bulb zero height. In some environments, there may be a significant difference (~1000 ft or more) between the two heights. If the algorithm has to switch between algorithm output and the environmental data values, noticeable differences may occur due to the difference in what is measured, not because the algorithm isn't working properly.



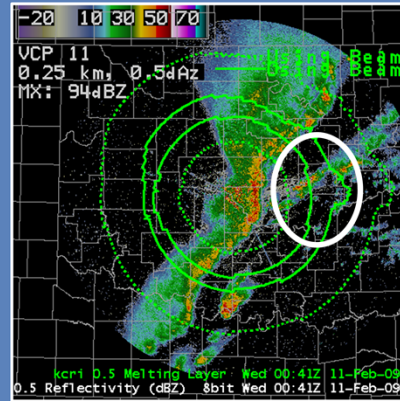
# Product Limitations

## 4. Unrealistic discontinuities

Antenna Wobble



Algorithm Error



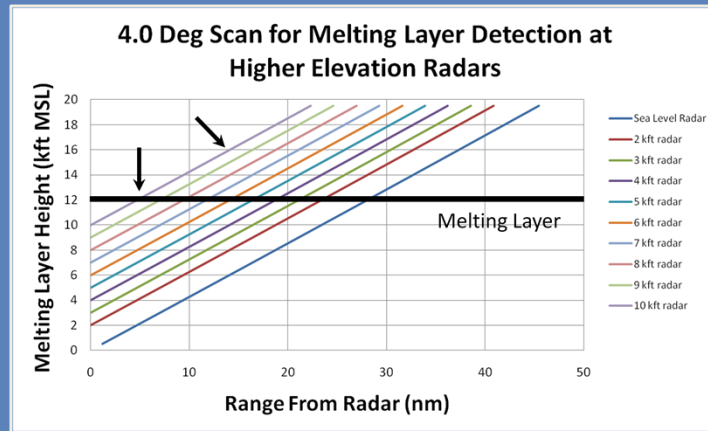
Another limitation to be aware of occurs when there are unrealistic discontinuities in the melting layer display. When this situation occurs, there are two likely causes: antenna wobble and algorithm error.

Antenna wobble typically occurs at the beginning of an elevation scan. When the antenna changes elevation angles, sometimes the dish has not finished moving vertically before data collection begins. As a result, you may see an odd, smooth discontinuity (such as in the example on the left) because the beam is under- or over-shooting at the beginning of the elevation scan. These discontinuities should only appear on elevation angles where the wobble occurs.

While antenna wobble discontinuities appear smooth, algorithm errors usually appear spiky and are visible on every elevation angle at the same azimuth. An example of algorithm error is shown on the right.

# Product Limitations

## 5. Performance in mountain regions



The higher the surface elevation of the radar, the greater the likelihood the radar beam will start in the melting layer or completely overshoot it.. Recall that the MLDA computes the ML product using data between 4 and 10 degrees. At lower elevation regions, using these scans will rarely be a problem. However, radars in mountainous regions are another story.

Say, for example, your radar is located at 10 kft above MSL. The purple line at the top of the graph represents the center beam height for your radar in a standard atmosphere. If the top of the melting layer is 12 kft MSL, then the center of the beam will already be sampling above the melting layer in the first 10 nm. Unless there is precipitation all around the RDA, it's unlikely the MLDA algorithm will work well in these conditions.

# Product Applications

1. Updates every volume scan
  - Polarimetric data is not sufficient?
  - Uses 0° C height from RPG adaptation data -or- RAP

Lvl	Dir	Spd
kft	deg	kts
1.3	186	11.5
2.3	188	15.3
3.3	194	17.2
4.3	199	17.2
5.3	199	21.1
6.3	199	21.1
7.3	199	22.0

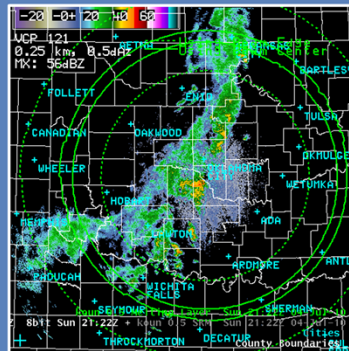
Enough with the limitations...let's move on to the ML applications.

With the ML product, you have the potential for measured melting layer heights updated every volume scan. Even if the radar cannot sample enough “wet snow” to compute the melting layer height, the algorithm can still provide melting layer heights (using the RPG 0 Celsius height from the RPG adaptation data) as an overlay for base data products.

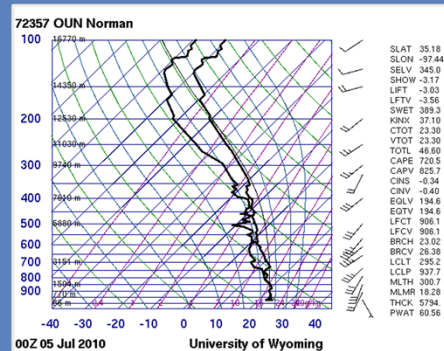
# Product Applications

## 2. Aids in interpreting base data

0.5° Z w/Melting Layer



Nearby Sounding



ML = 15,500 ft MSL / Skew-T = 16,200 ft MSL

By overlaying the ML product on base data products, you can more quickly tell where echoes are being sampled thermodynamically in the atmosphere, which can help you more quickly analyze precipitation type. This application can be very helpful because the melting level is not always uniform nor is the nearest sounding always representative of the area you are investigating.

Having said that, don't ignore sounding data. Use soundings for confirmation if the ML product look fishy.

## Summary: ML

- Provides ML height for each radial determined from base data
  - Updates every volume scan!
  - Uses model data if not enough data
- Many situations with unlikely ML detections
- Two melting level events are tricky
- Unrealistic discontinuities
- Poor performance during:
  - Fast moving cold fronts
  - Poor echo coverage
  - Mostly below freezing temperatures

In summary, the ML product provides an updated melting layer height for every elevation, each volume scan based on the base data and/or environmental input at the RPG! There will be many situations where the algorithm cannot identify the melting layer based on radar data alone. The algorithm can only identify one melting layer, so the algorithm doesn't handle refreezing events well. Also, watch out for unrealistic discontinuities due to antenna wobble or algorithm errors. Lastly, be cautious when using the melting layer product with fast-moving cold fronts, precipitation is occurring in only a small area, or below freezing temperatures are occurring throughout the air mass over most of your area.

**Thanks for Your Attention!**

Questions?

[justin.gibbs@noaa.gov](mailto:justin.gibbs@noaa.gov) or  
[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

If you have any questions, feel free to contact us using any of the e-mails listed below.



# Radar & Applications Course (RAC)

Topic 4: Base and Derived Products

PPS Rainfall Products

Warning Decision Training Division (WDTD)

Welcome to this Topic 4 lesson on PPS rainfall products.

# Learning Objectives

Upon completion of this lesson, you will be able to identify specific characteristics, limitations, and applications (strengths) of the following Precipitation Processing Subsystem (PPS) rainfall products:

Product	ID
Hybrid Scan Reflectivity	HSR
Digital Hybrid Scan Reflectivity	DHR
One Hour Precip	OHP
One Hour Digital Precip Array	DPA
Three Hour Precip	THP
Storm Total Precip	STP
Digital Storm Total Precip	DSP
User Selectable Precip	USP
Supplemental Precip Data	SPD

Here are the learning objectives for this lesson, and the chart on the right shows all the PPS products we'll discuss in this lesson. When you are ready, click next to continue.

## Precipitation Processing Subsystem (PPS)

- PPS products do NOT use any dual polarimetric moments in their calculation.
- They are more frequently referred to as “legacy” precipitation products.

Klazura and Imy (1993)  
Fulton, et al. (1998)

PPS stands for the precipitation processing subsystem. PPS products are the original estimation of precipitation algorithms that came with the WSR-88D and we're last updated in 2004. These predate dual pol and as a result do not have any dual polarimetric moments included in the calculations. Operationally, you most frequently hear these referred to as the legacy precipitation products. At your office when folks are referring to legacy products, legacy precip, 1 hour precip, that is the PPS products. We kept them because they're still somewhat skillful.

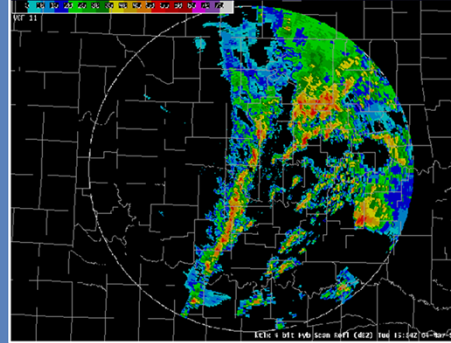
# Menu Location



Products are all located under your precipitation menu on your radar under the legacy precip accumulation products

## Hybrid Scan Reflectivity (HSR)

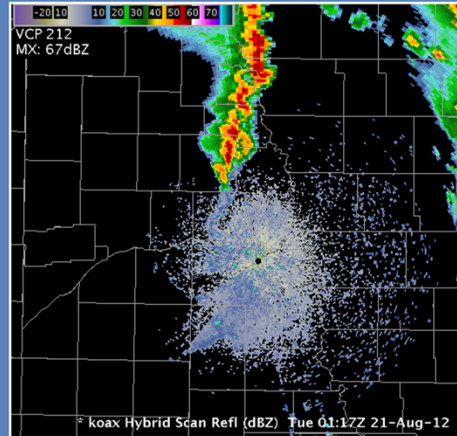
- Available every volume scan (after 99.7% bins out to 124 nm filled)
- 4-bit (16 data levels)
- 1 km x 1 deg
- Used internally by RPG to produce most other precip products



First, we will discuss a hybrid scan reflectivity or HSR. That is available every volume scan after 99.7% of the beams are filled out to 124 nautical miles. Its called hybrid scan because it combines data from multiple elevation angles to produce the best reflectivity to estimate ground rainfall accumulations. It's trying to account for ground clutter, beam blockage and the data quality issues with this product. It is a 4-bit products with 16 different data levels, and it's available in one kilometer by 1 degree resolution. Its primarily used internally by the RPG to produce most of the other precip products.

## Digital Hybrid Scan Reflectivity (DHR)

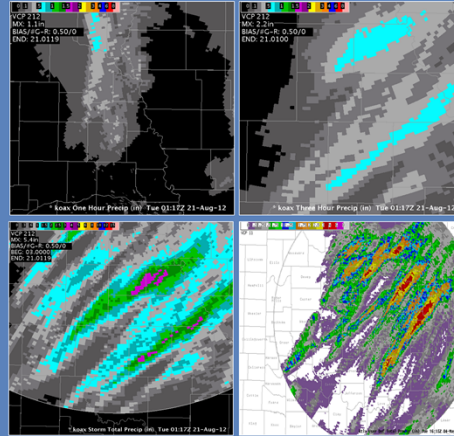
- 8-bit (256 data levels)
- 1 deg x 1 km
- 124 nm range
- Used primarily for FFMP and HPE
- Useful when working hydro events



Next the digital hybrid scan reflectivity or DHR. that's an 8-bit/256 data level product in 1 degree by 1 kilometer resolution and 124 nautical mile range. Its used primarily for input into FFMP, but I've also find it's got some operational use when you're working hydro, to determine intensity and location of rainfall. It is also a decent option when you're making Facebook or Twitter graphics or other public facing graphics as it gives a better idea for rainfall than just a 0.5 degree reflectivity image but its not as course it's a composite reflectivity which is in a much lower resolution.

## Common Characteristics of All PPS Rainfall Accumulation Products

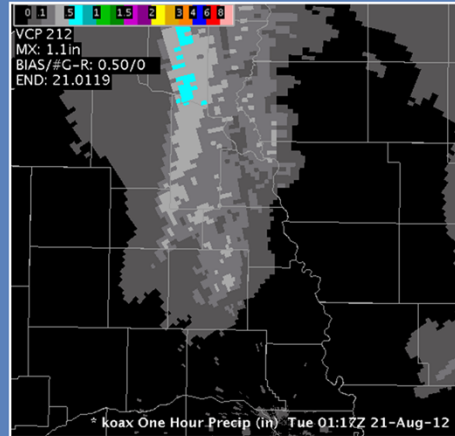
- Built from HSR
- 2 km (1.1 nm) x 1 deg
- 4-bit (one exception)
- 124 nm range



Characteristics of all the legacy rainfall accumulation products. They are built from hybrid scan reflectivity. They are in two kilometer by 1 degree resolution. They are 4-bit products with one exception, and have a range of 124 nautical miles. So if you get targets further away than 124 nautical miles you won't have any PPS rainfall accumulation products

## One Hour Precipitation (OHP)

- Accumulations for past hour
- Moving one hour window
- Uses scan-to-scan accumulations
- Available from the first volume scan with detected rainfall



The one hour precipitation product is one you will probably be accessing most frequently. It produces accumulations from the past hour although it is a one hour moving window so if the radar goes down or there's missing data, it could be more like a 1 hour 10 minute window. Normally though it will be one hour. It uses scan to scan accumulations and is available from the first volume scan precip is detected.

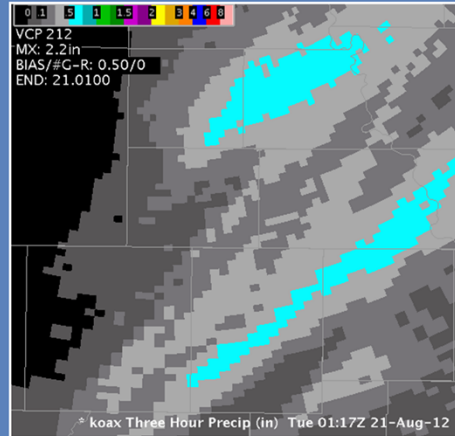
## Digital Precipitation Array (DPA)

- Used by exterior systems
  - RFCs for NWSRFS
  - AWIPS Multisensor Precipitation Estimator (MPE) for bias calculation
  - FFMP - Note: DHR is preferable
- Moving one hour accumulation
  - Scan-to-scan accumulations
- 2.2nm x 2.2nm gridded product (easier to mosaic several radars)
- 8-bit (256 data levels)
- Not displayable

The digital precipitation array or DPA is mainly going to be used by external systems, like River forecast systems, the AWIPS multi-sensor precipitation estimator or MPE which is what goes into FFMP for bias calculation. It's a moving one hour accumulations calculator. DPA is a scan to scan accumulation similar to the one hour precip and is in 2.2 nautical mile x 2.2 nautical mile gridded product which is easier to mosaic several different radars, similar to concept that we see with the multi radar multi sensor project except at a much coarser resolution. Its an 8-bit 256 data level product and it is not displayed at your AWIPS workstations, it is sort of a behind-the-scenes product.

## Three Hour Precipitation (THP)

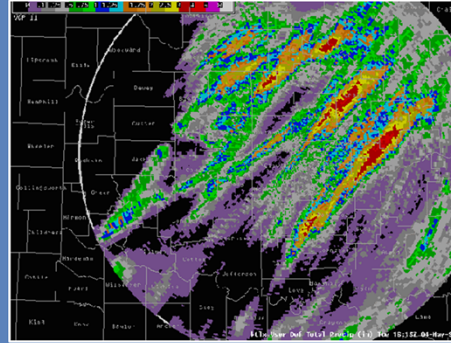
- Updated once per hour (after top of the hour)
- Uses top-of-the-hour accumulations
- Require 2 out of 3 top-of-the-hour accumulations (zero or nonzero)
- Not recommended for RPS list



The three hour precipitation product or THP is updated once per hour at the top of the hour. It uses top of the hour accumulations and requires two out of the three top of the hour accumulations. Its not recommended for your RPS list because it only comes in at the top of the hour so it isn't as useful operationally as some of the other products.

## User Selectable Precipitation (USP)

- Accumulations for user specified time
- Top-of-the-hour accumulations
- Past 30 hours are available
- User selects duration (up to 24 hours) & end time
- Default USP:
  - 24 hours ending 12Z



If you don't want a one or three hour term. You can use the user selectable precipitation product or USP. This gives accumulations for user-specified time and uses top of the hour accumulations. Up to the past 30 hours of accumulations are available. The user selects the duration this can be up to 24 hours then choose the time you want the 24 hours ending at. The default is 12z.

# USP One-Time-Request

One Time Request

Repeat count: 1 RPG: KOAX

Product: User Select Precip (USP)

Priority: Normal

Request interval: 1

End Hour:  Most Recent 12  Selected

Time Span (Hours): 6

Time:  Current  Latest  Selected

Selected Time: Change...

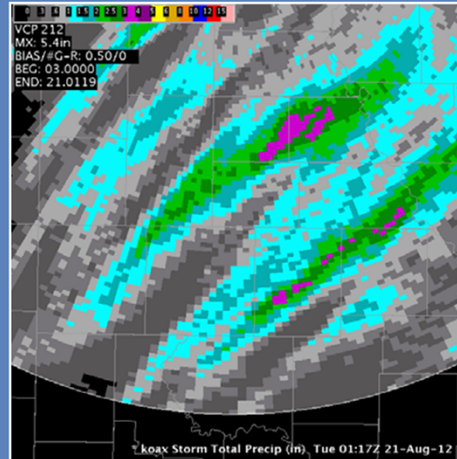
Send Close

Rainfall for the 6 hour period ending at 12 Z

If you're interested in doing a USP one time request you can go to the one time request option on your radars menu, then select the end hour, you can choose the most recent or whichever hour that you would like. You can select a time span up to 24 hours. In this case you would get an accumulated rainfall for six hour period ending at 12Z.

## Storm Total Precipitation (STP)

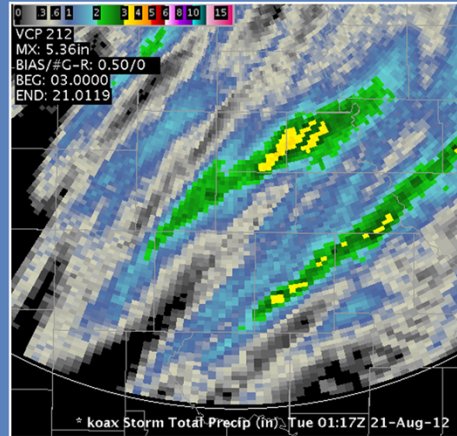
- Total accumulation since precipitation detected (EPRE)
- Uses scan-to-scan accumulations
- Updated every volume scan
- Reset to zero after one hour of no precipitation, or manual reset



Next product is the storm total precipitation product or STP. This is the total accumulation since precipitation was detected using the enhanced preprocessing algorithm which was last updated in 2004. It uses scan to scan accumulations and it's updated every volume scan. it's reset to 0 after 1 hour of no precipitation or can be manually reset which some offices do a daily part of their radar shift checklist.

## Digital Storm Total Precip (DSP)

- 8-bit (256 data levels) allows for higher precision in estimates
- Produced same way as 4-bit STP product
- Preferred storm total product



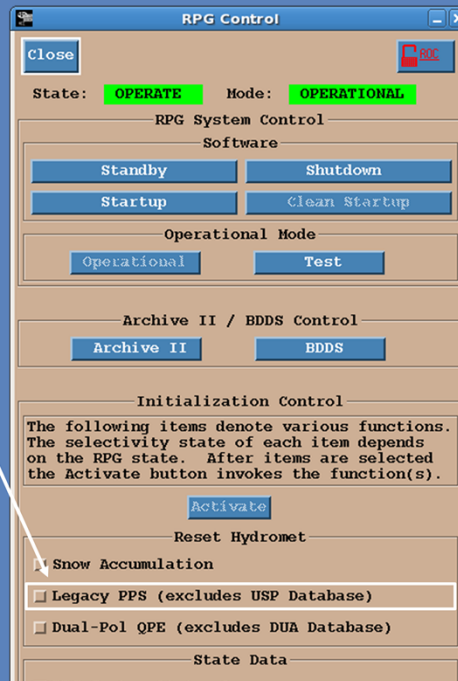
This is the one exception that I mentioned earlier with respect to 4-bit being the standard resolution. That is this product, the high resolution storm total precipitation product, or DSP. It is 8-bit allowing for higher precision in estimates and is produced in the same way the 4-bit STP product is generated. By far, this is the preferred storm total product to request.

## Manual Reset of STP/DSP

### RPG Control Menu:

- Select Legacy PPS
- Click "Activate"
- No Restart required

**Note: Will not reset User Selectable Precipitation**



Manual reset of your STP and DSP can be conducted through your RPG control window on your HCI. It will not reset user selectable precipitations if you have a one-time request there that will continue to keep going. Just go to your RPG control, enter your URC password and then select legacy PPS and click Activate. A restart of your RPG is not required. This may be in in many cases part of your daily radar our check list. So you may have done this before this course but that is the way that you do it in case you're unfamiliar.

# Supplemental Precipitation Data (SPD)

- Alphanumeric product
- Available every volume scan
- Bias computation
- PPS output
  - Gage-radar pairs
  - Missing data

```

Text Display: WSRSPDOAX
File Edit Options Version Tools Scripts Products Help
AFOS Browser Load History WMO Search Enter Editor Accum Update Obs Clear
AFOS Cmd: WMO TTAAl CCCC: AWPS ID:
Message Date: Aug 21 2012 01:19:24

SUPPLEMENTAL PRECIPITATION DATA - RDA ID 519 08/21/12 01:17
VOLUME COVERAGE PATTERN = 212 MODE = A
GAGE BIAS APPLIED - YES
BIAS ESTIMATE - 0.50
EFFECTIVE # G/R PAIRS - 0.00
MEMORY SPAN (HOURS) - 0.00
DATE/TIME LAST BIAS UPDATE - 12/31/** 00:00
TOTAL NO. OF BLOCKAGE BINS REJECTED - 0
CLUTTER BINS REJECTED - 7275
FINAL BINS SMOOTHED - 0
HYBRID SCAN PERCENT BINS FILLED - 99.80
HIGHEST ELEV. USED (DEG) - 1.30
TOTAL RAIN AREA (KM^2) - 29768.1

MISSING PERIOD: 08/16/12 00:10 08/20/12 19:37

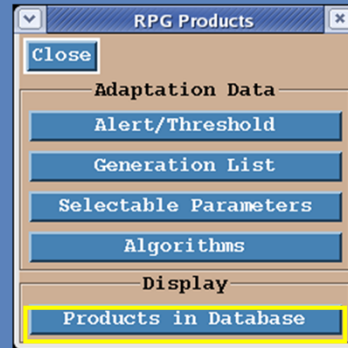
GAGE-RADAR MEAN FIELD BIAS TABLE
LAST BIAS UPDATE TIME: 12/31/** 00:00 BIAS APPLIED ?
MEMORY SPAN | EFFECTIVE NO. | AVG. GAGE | AVG. RADAR | MEAN FIEL
(HOURS) | G-R PAIRS | VALUE (HH) | VALUE (HH) | BIAS
0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000

```

The final product we will talk about is the supplemental precipitation data product or SPD. Its an alpha numeric product and you can pull up the text workstations. Its available every volume scan and it contains a bias computation that was chosen for the other precipitation accumulation products. That also would typically show up on the product in your left hand corner, but this is another place you can see it. You should have access to that product again from any window on your text workstation and it will give you information about your gauge radar pairs and any missing data.

## Adjusting Data Levels

- Data levels on OHP, THP, and STP are editable (URC LOCA)
- Change for:
  - Climate
  - Topography
  - Expected weather



An important consideration of the precipitation accumulation product is at the data levels, like 1 inch 2 inch 3 inch half inch are editable, on the one hour, 3 hour, and storm total precipitation products. You need the URC password to go into the “products in database” display under your RPG products window. This might be useful depending on your climate where forecasting in Miami is going to be different than Bozeman far as what type of rainfall that you might be expecting. Your topography where say in Death Valley a quarter of an inch of rain can cause flash flooding versus New York City maybe an inch or two of rain this allows you to make calls on if you want to see a different level to account for those higher or lower values.



Welcome to the Topic 4 lesson on Dual-Pol QPE rainfall products.

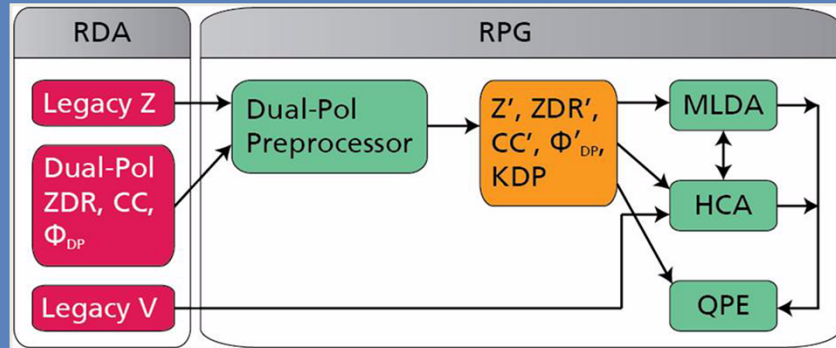
# Learning Objectives

Upon completion of this lesson, you will be able to identify specific characteristics, limitations, and applications (strengths) of the following Quantitative Precipitation Estimation (QPE) rainfall products

Product	ID
Hybrid Hydrometeor Classification	HHC
Digital Precipitation Rate	DPR
One Hour Accumulation	OHA
Digital Accumulation Array	DAA
Storm Total Accumulation	STA
Digital Storm Total Accumulation	DSA
Digital User Selectable Accumulation	DUA
Digital One Hour Difference	DOD
Digital Storm Total Difference	DSD

Here are the products we'll discuss in this lesson, and what you should get out of learning about these products. Take a few moments to look at these products and the learning objectives for each. Advance the slide when you are ready.

# Quantitative Precipitation Estimation (QPE) Algorithm



Very complex!

- Uses 3 different equations (instead of 1)
- Dependent upon HCA/MLDA output

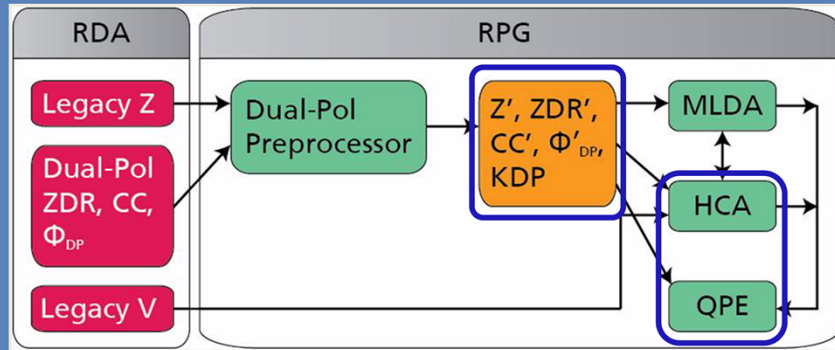
Giangrande, et al. (2008)

Here is the algorithm that outputs the QPE rainfall products. As the name implies, the algorithm is the Quantitative Precipitation Estimation algorithm, or QPE. This graphic should look familiar from Topic 3. The QPE is much more complex than the PPS. It uses 3 different rainfall rate equations and that is dependent upon the hydrometeor classification for a given bin and where that bin lies relative to the melting layer. Comparing this to PPS, you can see how much more complex this algorithm is. I'll try to only hit the main points of this algorithm, so you can stay awake 😊

# Quantitative Precipitation Estimation (QPE) Algorithm

Step 1: Build the HHC product

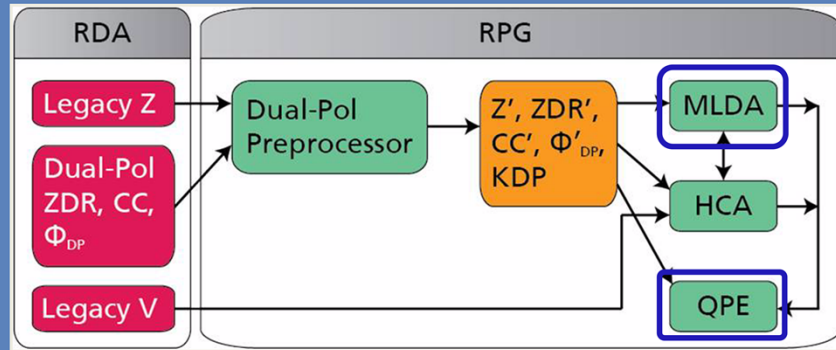
- Lowest unblocked (i.e. mountains/clutter)
- Not unknown



Step 1 in QPE is to build the hybrid hydroclass product, or HHC. It is the basis for what precipitation equation is used for each bin. This product is built by the base data first going into the HCA. From there, the HCA outputs the hydrometeor classification product, as we learned a few lessons ago. The HC product is input into the QPE algorithm where it is processed into the HHC product. Basically, the QPE smoothes the HC product to make the HHC. We'll look at this product shortly. Just know that the HHC in the QPE algorithm is analogous to the HSR/DHR product in the PPS. It is the building block for the QPE accumulation products.

# Quantitative Precipitation Estimation (QPE) Algorithm

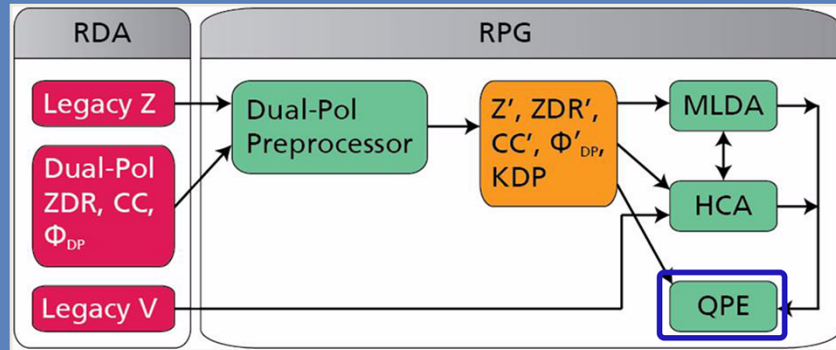
Step 2: Grab the melting layer information



Next, the QPE inputs the melting layer height information. This basically is used as a quality control check for what precipitation types are allowed in the HHC. For instance, rain above the melting layer does not make sense. Secondly, different rain rates are applied depending on the height of the bin relative to the melting layer.

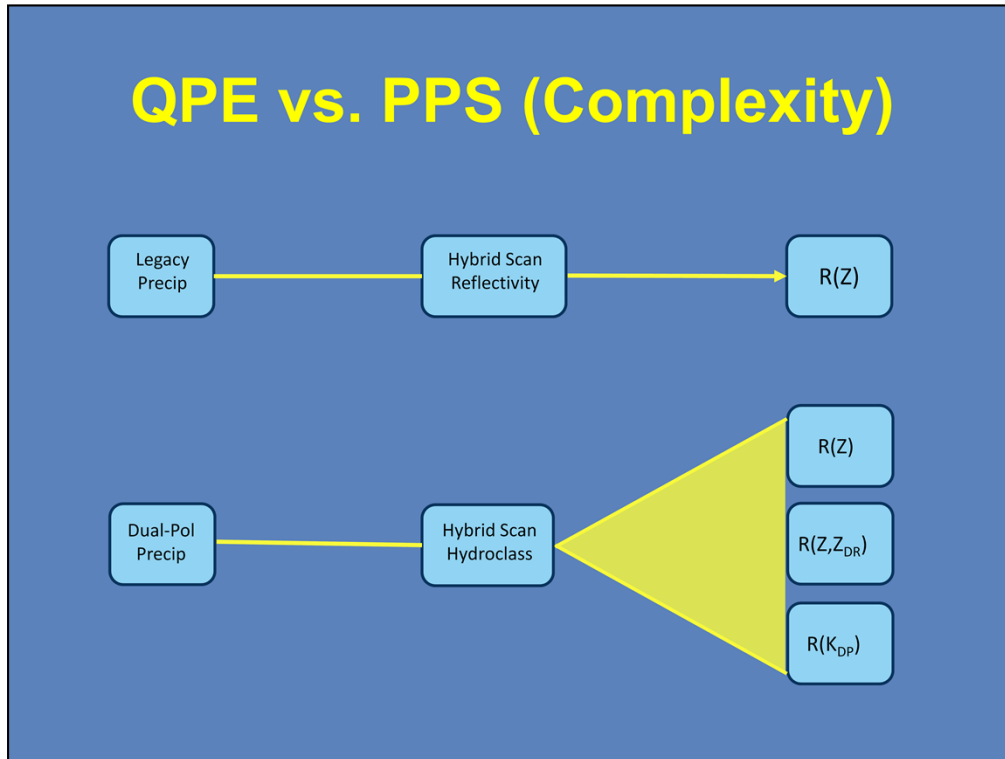
# Quantitative Precipitation Estimation (QPE) Algorithm

Step 3: Assign rain rate equation using HHC and melting layer information



Finally, based on the HHC value for a bin, and its height relative to the melting layer, the QPE algorithm applies the appropriate rain rate equation to that bin and computes the accumulation products.

## QPE vs. PPS (Complexity)

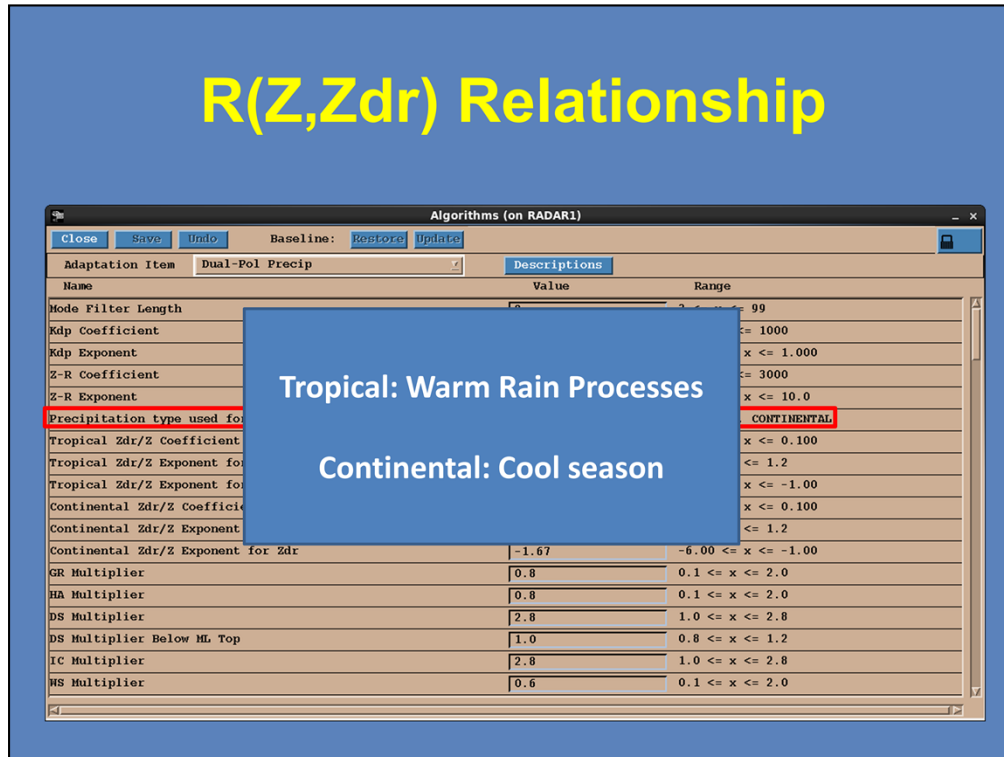


Here is just a graphic to show you the complexity of the QPE compared to the PPS. See how the PPS has only one rainfall accumulation equation, whereas the QPE has 3.

Conditions/Classifications	R method (mm/hr)
Ground Clutter (GC) or Unknown (UK)	Not computed
No Echo (ND) or Biological (BI)	0
Light/Moderate Rain (RA) or Big Drops (BD)	R(Z, Zdr)
Heavy Rain (HR) and blockage < 20% and $\leq 45$ dBZ	R(Z, Zdr)
Heavy Rain (HR) and blockage $\geq 20\%$ or $Z > 45$ dBZ	R(Kdp)
Rain/Hail (HA) and blockage $\geq 5\%$	R(Kdp)
Rain/Hail (HA) and echo is <i>at or below</i> the top of the melting layer (ML) and blockage < 5%	R(Kdp)
Rain/Hail (HA) and echo is <i>above</i> the top of the ML and blockage < 5%	$0.8 * R(Z)$
Graupel (GR)	$0.8 * R(Z)$
Wet Snow (WS)	$0.6 * R(Z)$
Dry Snow (DS) and echo is <i>at or below</i> the top of the ML	R(Z)
Dry Snow (DS) and echo is <i>above</i> the top of the ML	$2.8 * R(Z)$
Ice Crystals (IC)	$2.8 * R(Z)$

and you don't need to have this table committed to memory but I wanted to share it so you can see the concepts behind how the rainfall rates are calculated, just to give you some understanding of the complexity, and how everything is pieced together, when we talk about three different equations this is what we mean. Objects on the left are what the radar is seeing, dry snow, wet snow, heavy rain. Rain and hail, as the HCA identifies them and the HHC detects them, on the right is the R method the rainfall method, basically this is how hard it's raining based on what the radar is returning. Some of the key differences, for reflectivity greater than 45 dbz it uses KDP when calculating it with the value to get your QPE so higher KDP would be a higher QPE, where at lower dbzs you would just use Z and ZDR to give you say, 3/4 inch per hour rainfall rate, where with the KDP you might be looking at 3 inch per hour rainfall rates and the radar operations center has found that KDP works better at that level so they made that change, and then the same is true that dry snow and ice crystals use a standard R to Z, which means reflectivity means this amount of snowfall but that's customizable and the ROC suggests that you attempt to do that, to try to add some skill.

# R(Z,Zdr) Relationship



And the way those relationships are calculated as was mentioned earlier in the course is by modifying the R(Z,Zdr) relationship, which can be done in the algorithms tab on the radar MSCF HCI.

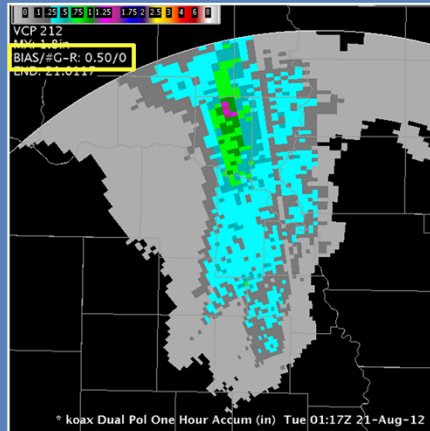
The tropical relationship is recommended during the warm season and events involving warm rain processes. Southern and coastal locations may find this equation works best during the majority of events, and of course during hurricanes and tropical systems. During the cool season however this equation can lead to overestimates.

The continental equation is recommended for the cool season or events in which the tropical relationship is overestimating.

The equations for dual pol QPE and legacy PPS are adjusted separately.

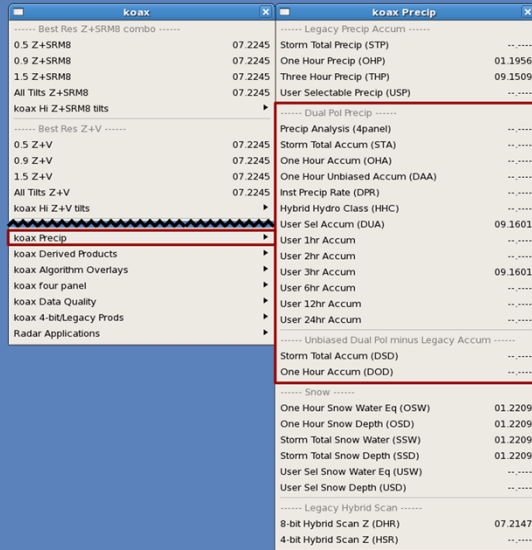
## First!

- The “BIAS” shown on Dual Pol Products are only applied to legacy precip
- Even if its shown, it’s not being applied to Dual Pol QPE products.



First, the “bias” shown, normally on the upper left hand side of the window is not being applied. This is the legacy bias and it is not being applied to the dual pol products.

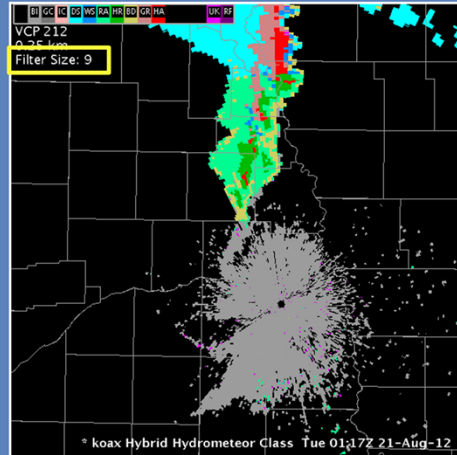
# Menu Location



The QPE products can be found in the dedicated radar drop down menu inside the Precip submenu shown here.

## Hybrid Hydroclass (HHC)

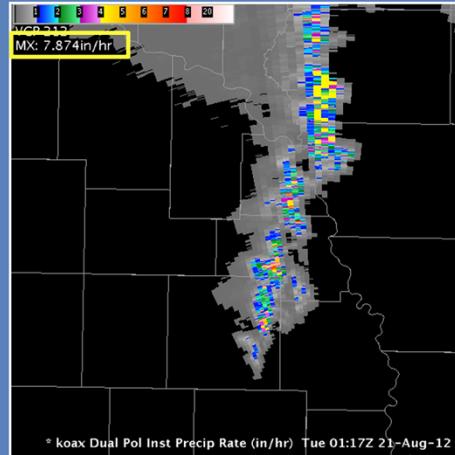
- Classification used to choose rain rate relationship
- 8-bit (256 data levels)
- 250-m resolution



The first product, Hybrid Hydroclass (HHC), shows the hydrometeor classification that is used as an input to the dual-pol precipitation algorithm. The idea here is similar to that of the legacy DHR, and HHC has similar applications and limitations to DHR. The HHC product represents the radar's best guess of echo type to be used in the dual-pol QPE algorithm. It is an 8-bit product, meaning it has 256 data levels, but only 12 of these levels are used at this time. It has the highest available radial resolution of 250 m. The product legend here is indicating that the data have been filtered to remove speckling. The filter is not adaptable, so the filter size in the upper left of the product will always be 9. This is that smoothing referred to a few slides ago.

## Digital Precipitation Rate (DPR)

- Displays instantaneous precipitation rate!
- 250-m resolution
- 16-bit product (65536 data levels)

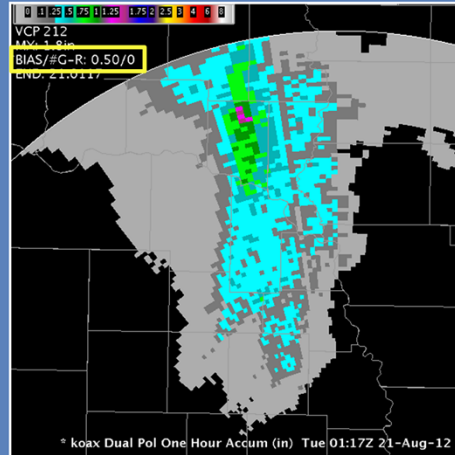


You can also view the instantaneous precipitation rate using the Digital Precipitation Rate (DPR) product. One advantage of this product is that it can give you a good idea of where there may be heavy rain right now. DPR is also a 250 m resolution product, but is a **16 bit** product, meaning it has quite a few data levels: 65536 to be exact! The legend in the upper left lists the maximum precipitation rate anywhere in the product.

## One Hour Accumulation (OHA)

- 1 hour accumulation
- 4-bit (16 data levels)
- 2-km resolution

No bias applied, but may be shown

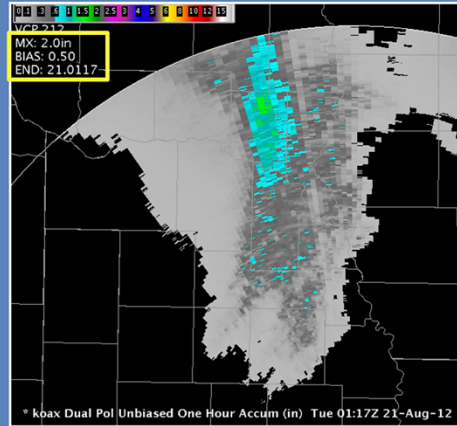


One Hour Accumulation, or OHA, is a 2 km, 4-bit, 1 hour accumulation product. This product is analogous to the legacy One Hour Precipitation (OHP) product. The legend in the upper left lists the maximum accumulation, the bias, and the product end time. Note, there is no bias applied to the QPE products at this time.

# Digital Accumulation Array (DAA)

- 1 hour accumulation
- 250-m resolution
- 8-bit (256 data levels)

No bias applied, but may be shown



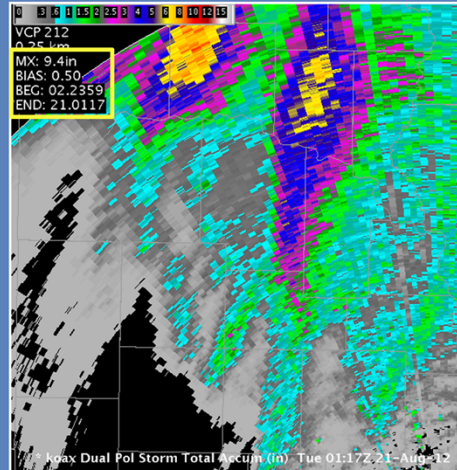
The Digital Accumulation Array (DAA) is also a 1 hour accumulation with no bias applied. However it is a 250 m, 8-bit (256 data level) product similar to the legacy Digital Precipitation Array (DPA). The legend in the corner lists the maximum accumulation in inches, the bias, and the product end time. The first 2 digits of the end time represent the day of the month and the last 4 digits are the time in UTC. Again, a bias may be shown, but it is not applied to this product.

# Storm Total Accumulation Products (STA / DSA)

## Digital Storm-total Accumulation (DSA):

- Accumulated rainfall since start of event
- 8-bit (256 data levels)
- 1 degree by 0.25-km

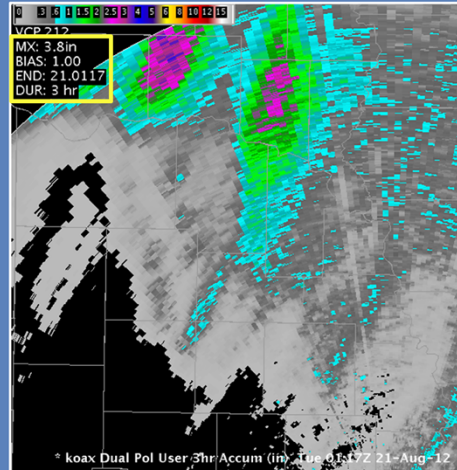
2-km resolution, 4-bit version:  
Storm Total Accumulation (STA)



This is Digital Storm-Total Accumulation, or DSA. DSA, like the legacy Digital Storm Total Precipitation (DSP), shows total accumulated rainfall since the beginning of an event. This is an 8-bit product with a resolution of 1 degree by 0.25 km. In the legend you will find the value of the maximum accumulation (anywhere in the product), the bias, which is not applied, and the beginning and ending times in the same format as in DAA. As with the legacy storm total products, one disadvantage is DSA may need to be reset manually at times. DSA may also include missing data. There is also a 2 km resolution, 4-bit version of this product, Storm Total Accumulation, which is not shown here but matches the resolution and data levels of the legacy Storm Total Precipitation (STP) product.

## Digital User-Selectable Accumulation (DUA)

- Precipitation accumulated over a user-selected time period
  - Min 15 minutes
  - Max 24 hours
- 8-bit (256 data levels)
- 1 degree by 0.25 km



Digital User-selectable Accumulation (DUA) is accumulated precipitation over a time period chosen by the user. This time period can be as short as 15 minutes, or up to 24 hours. One advantage of this is that a precipitation product that most suits the situation can be requested, and in the following slides I'll show you how to set up customized DUA products for your office. This is an 8-bit product with a resolution of 1 deg x 0.25 km. The product legend in the upper left displays the maximum accumulation anywhere in the product, the bias (which again is not applied, even if it is not 1.0), the product end time, and the duration. As with the USP from the PPS, caution is advised because DUA may contain missing data.

## DUA on the RPS list!

- Automatically generated:
  - 3 hour DUA each hour
  - 24 hour DUA at 12Z
- Can have up to 10 DUA products on RPS list

The screenshot shows a dialog box titled 'User Select Accum (DUA)'. The 'Product' field is set to 'User Select Accum (DUA)'. The 'Priority' is set to 'Normal'. The 'Request interval' is set to 1. The 'End Time' is set to 'Selected' with 'Hour' and 'Min' both at 0. The 'Time Span' is set to 'Hour' at 0 and 'Min' at 15. The 'OK' and 'Cancel' buttons are at the bottom.

You can request DUA for other durations by adding them to the RPS list. Open the RPS list editor and choose “User Select Accum (DUA)” from the product dropdown menu. Use the two slider bars to choose the desired duration of the product in hours and minutes. Remember, the lowest duration you can choose is 15 minutes and the highest is 24 hours. Up to 10 additional DUA products can be on the RPS list at once.

# Viewing DUA in AWIPS

----- Best Res Z+V -----		Precip Analysis (4panel)	-----
0.5 Z+V	07.2245	Storm Total Accum (STA)	-----
0.9 Z+V	07.2245	One Hour Accum (OHA)	-----
1.5 Z+V	07.2245	One Hour Unbiased Accum (DAA)	-----
All Tilts Z+V	07.2245	Inst Precip Rate (DPR)	-----
koax Hi Z+V tilts	▶	Hybrid Hydro Class (HHC)	-----
<b>koax Precip</b>	▶	<b>User Sel Accum (DUA)</b>	<b>09.1601</b>
koax Derived Products	▶	User 1hr Accum	-----
koax Algorithm Overlays	▶	User 2hr Accum	-----
koax four panel	▶	User 3hr Accum	09.1601
koax Data Quality	▶	User 6hr Accum	-----
koax 4-bit/Legacy Prods	▶	User 12hr Accum	-----
Radar Applications	▶	User 24hr Accum	-----
		----- Unbiased Dual Poi minus Legacy Accum -----	
		Storm Total Accum (DSD)	-----
		One Hour Accum (DOD)	-----
		----- Snow -----	

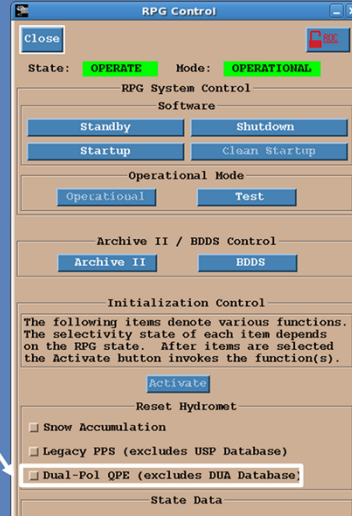
Stick to whole hour accumulations for durations longer than 1-2 hours

You will notice on the precip submenu that there are a number of entries for DUA. These 6 entries, seen inside the red box, will load any DUA product exactly matching the duration given in the menu, if that product is on the RPS list. Any off-hour products will be under the “User Sel Accum (DUA)” menu entry. A word of caution: if you request more than 1 off-hour product, for example, a 30 minute accumulation and a 90 minute accumulation, both products will be loaded from this menu entry. To view both of these products, use the arrow keys to step through them. It is recommended that for accumulations longer than 1 to 2 hours you request whole hour accumulations to make loading and viewing the products in in AWIPS straightforward.

# Resetting STA/DSA

RPG Control menu:

- Select “Dual-Pol QPE”
- Click “Activate”
- No restart required



As mentioned, there may be times when the RPG does not automatically reset accumulations and you think it is warranted. Thus you are allowed to manually reset the storm total accumulation products at the RPG. Note that this will not reset the DUA products. From the main RPG HCI window, go to the “Control” button. Towards the bottom of the RPG control window are the options for resetting the Hydromet products. Look for the “Dual-Pol QPE (excludes DUA database)” option, and check that box. Now, just click the “Activate” button and this will not require an RPG restart.

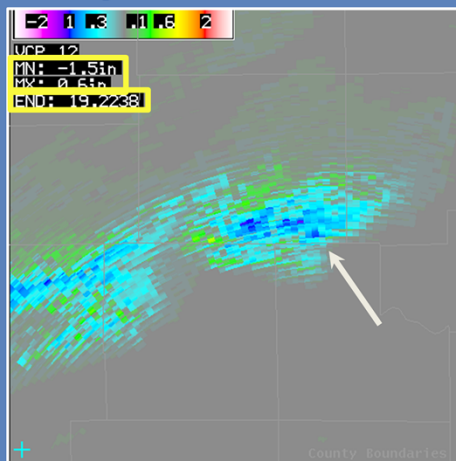
## Difference Products (DOD/DSD)

- Digital One-hour Difference (DOD)
  - Difference between 1 hour accumulations
- Digital Storm-total Difference (DSD)
  - Difference between storm total accumulations
- Both
  - Represent dual-pol minus legacy
  - Differences taken with no bias applied

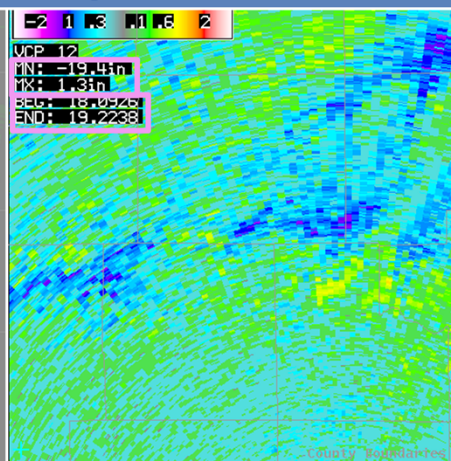
There are also two difference products to help compare legacy precip products to dual-pol precip products. They are: Digital One-hour Difference (DOD) and Digital Storm-total Difference (DSD). DOD is the difference between dual-pol and legacy one hour accumulations while DSD is the difference between dual-pol and legacy storm total accumulations. Both difference products represent the dual-pol minus the legacy accumulations. These differences are taken with no bias applied. Again the product is dual-pol minus legacy meaning positive values indicate dual-pol was higher, and negative values indicate PPS was higher, in general. Also, these products will not tell you which product is correct. It only gives you a relative measure of their differences.

# Difference Product Examples

Digital One-Hour Difference



Digital Storm-Total Difference



- Application: can see differences at a glance
- Caution: differences say nothing about accuracy of legacy or dual-pol QPE

Here is how the difference products look when displayed in AWIPS. Warmer colors, like the yellows and reds, indicate positive values, meaning the dual-pol precipitation estimate exceeds the legacy estimate, while cooler colors (blues) indicate negative values, meaning the dual-pol precipitation estimation is lower than the legacy precipitation estimation. In both DOD and DSD, maximum and minimum differences are listed in the legend in the upper left. DOD also lists the product end time, while DSD lists both the beginning and ending times. It is worth noting that while these products provide a way to see how the dual-pol and legacy precipitation estimates compare at a glance, they say nothing about which estimate is “right” or “wrong”. Also, as with STA, DSD may need to be reset manually at times and may include missing data. Finally, both of these products will often have a “stair stepped” appearance, as seen here. This structure is due to the differences in range resolution between legacy and dual-pol.

## Products' Limitations

- Dependency on hydrometeor classification
- No biases are applied
- QPE is still under development
- Rain rate equations are empirically derived (imperfect)

With the QPE, a few unique limitations arise. First, the accumulations are only as good as the accuracy of the hydrometeor output, or HHC product. If that is off, then the QPE products will be off. Also, no bias is ever applied to any of the products at this point, even though a bias may be listed in the product. QPE is still under development, through time, the QPE will begin to mature and become more robust. Finally, the new rain rate equations used are empirically derived, meaning these relationships may need tweaking in your local area, but that is part of the development process just mentioned.

## Products' Limitations

- Standard radar limitations apply
- Missing data aren't highlighted (STA/DSA, and DUA)
- Data can span multiple days (STA/DSA)

Outside of the limitations unique to QPE, QPE is also subject to all standard radar limitations discussed to this point. Missing data affects STA/DSA and DUA. Plus, data can span multiple days for the STA and DSA products requiring a manual reset.

## Products' Applications

- Assessing flash flooding events
- Flexible Time Intervals
- Tracking Rainfall Paths
- Post storm analysis

As for applications, these QPE products are useful for assessing flash flooding events...they have flexible time intervals with the DUA products. And, they can be used for tracking rainfall paths and for doing post storm analysis. These are applications identical to the PPS products.

## Products' Applications

- Precipitation estimation is hydrometeor based
  - Less bright band sensitivity
  - Non-meteorological echoes don't contribute
- DPR is used as input into FFMP

Unique applications to the QPE products include precipitation is based on hydrometeor type which should result in better precipitation estimations, especially in regions of bright banding because the QPE is suppose to have less sensitivity to the bright band. Also, because the QPE is hydrometeor bases, non-precipitation echoes are not converted to rainfall! Finally, like DHR is used as input into the FFMP applications, so is DPR.

## Summary

- All products are analogous to PPS
  - Except for new DPR!
  - No bias is applied
- Difference products aren't truth tellers
- QPE has shown to be better than PPS in certain situations
  - Still an algorithm under development

In summary, we saw that many QPE products have an analogous PPS product except for the new DPR product. Also, no bias is applied to any of the QPE products despite it being shown in the product annotations. The difference products are not truth tellers. They only give you a sense of the relative differences between the PPS and QPE. Finally QPE has shown to be better than PPS in certain situations (like hail contamination areas) but it is still an algorithm under development.

**Thanks for Your Attention!**

Questions?

[justin.gibbs@noaa.gov](mailto:justin.gibbs@noaa.gov) or

[nws.wdtd.rachelp@noaa.gov](mailto:nws.wdtd.rachelp@noaa.gov)

That concludes this module if you have any questions email myself or anyone on the team associated with putting this lesson together, thanks for listening!