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Topic: Base and Derived Products

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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.

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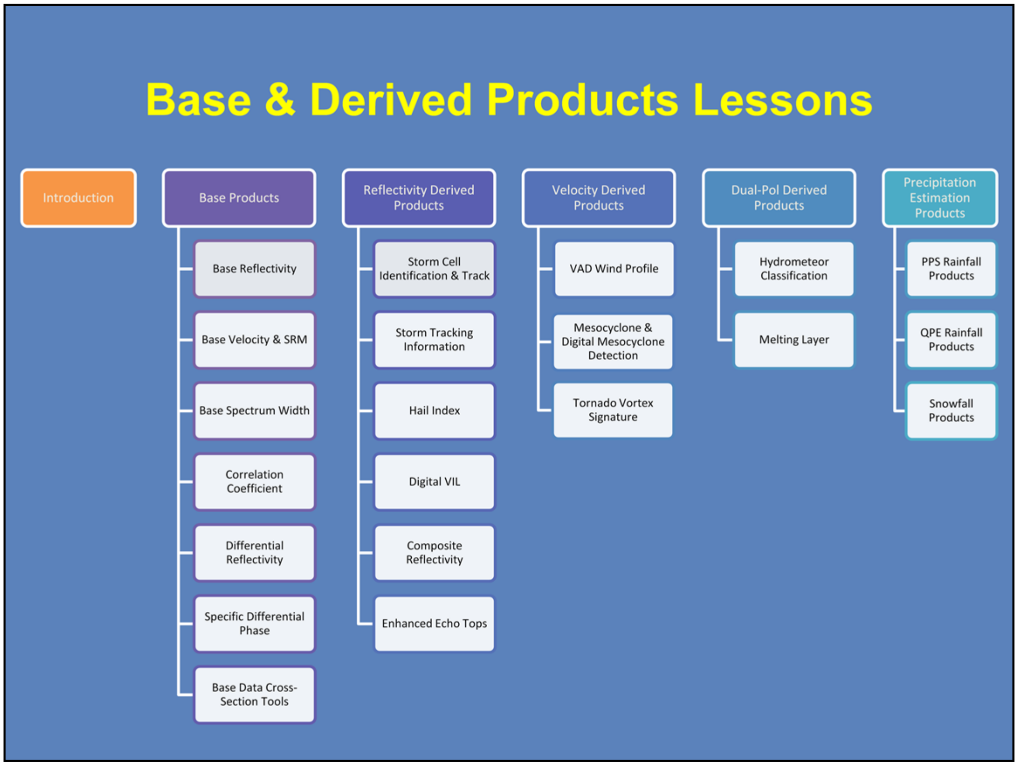

Here is a roadmap for the lessons in this topic. This lesson is the Introduction, shown shaded in orange, that provides an overview of the entire topic. As you take each lesson in this topic, we will highlight “where you are” with respect to the topic as a whole.

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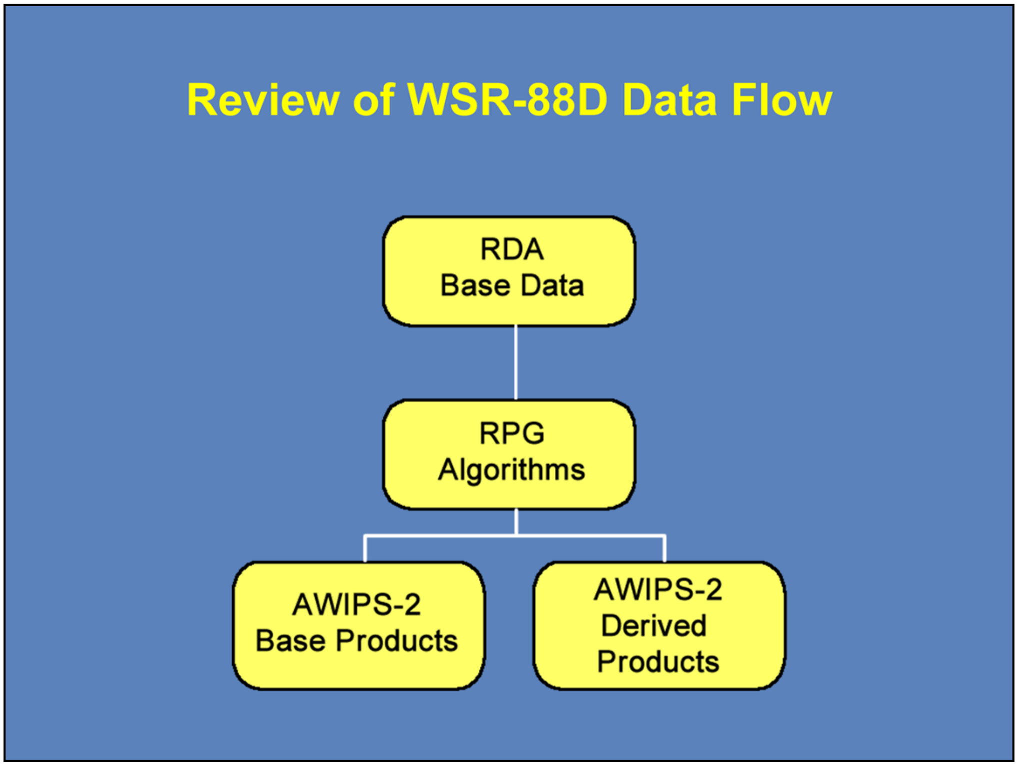
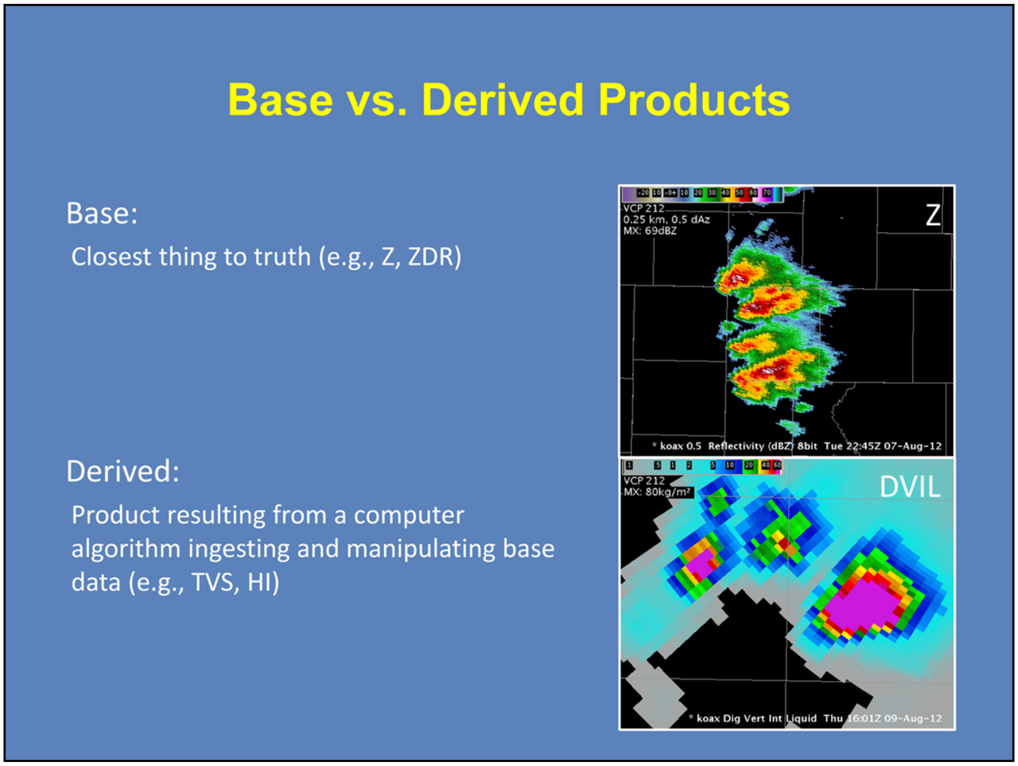
Learning Objectives

1. Identify the general applications and limitations of base and 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

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.



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.



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.

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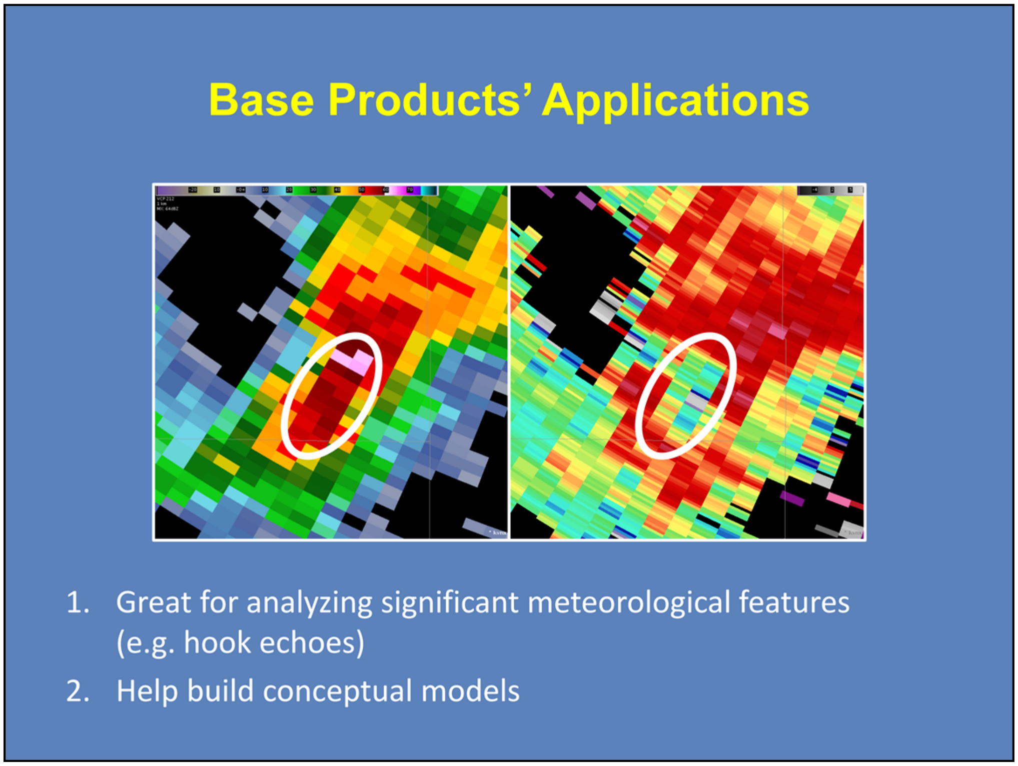
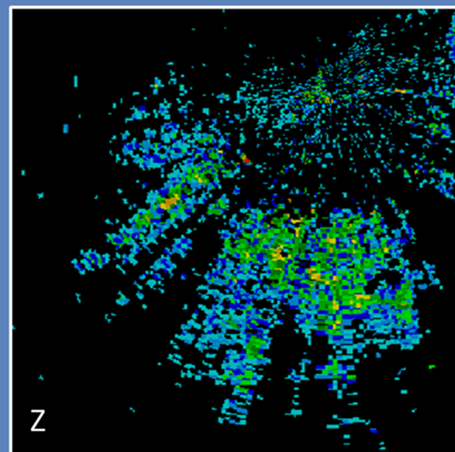


In general, base products are great for recognizing and analyzing significant meteorological features such as hook echoes, hail cores, etc. Base products also help you develop and apply conceptual models that make storm analysis and warning issuance quicker and more efficient.

Base Products' Limitations #1: Ground Clutter

Ground clutter contamination mitigation:

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



Ground clutter contamination near RDA site

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.

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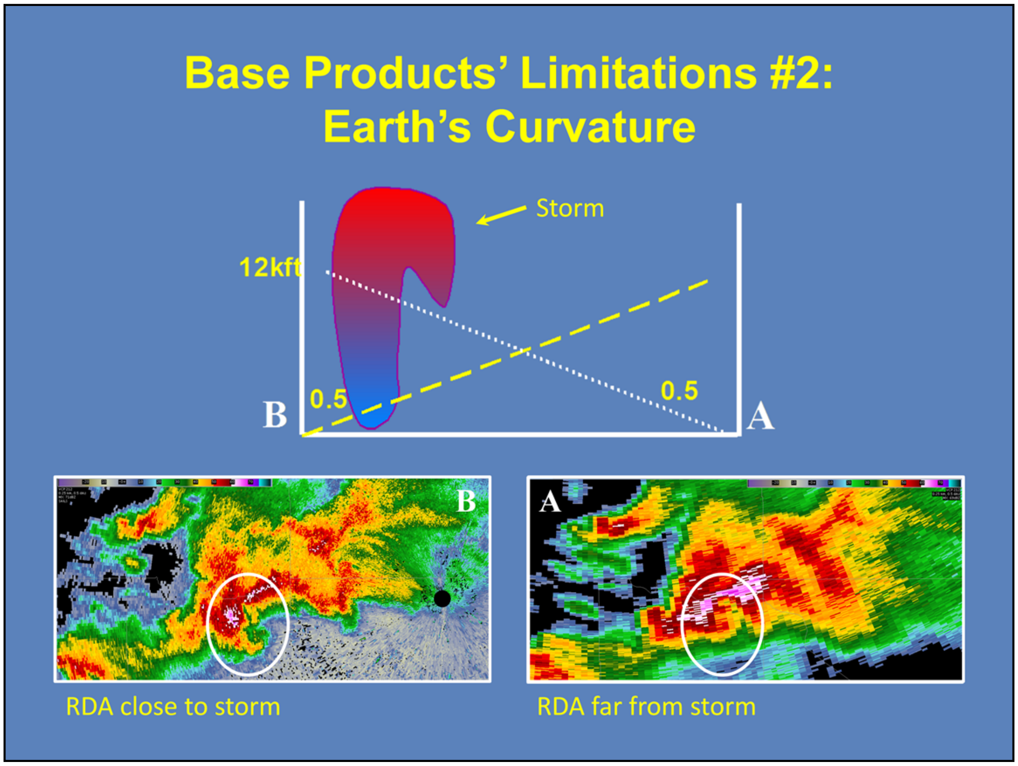


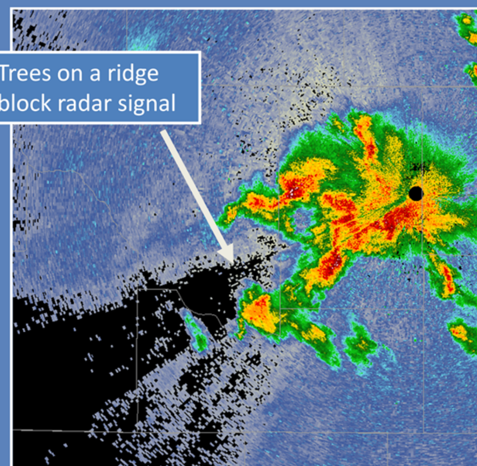
As you know…the earth is round! While this is hardly a shocking revelation, it does play an important role in our next limitation.

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

Beam blockage mitigation:

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



Beam blockage evident WSW of RDA site

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 KVNX 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.

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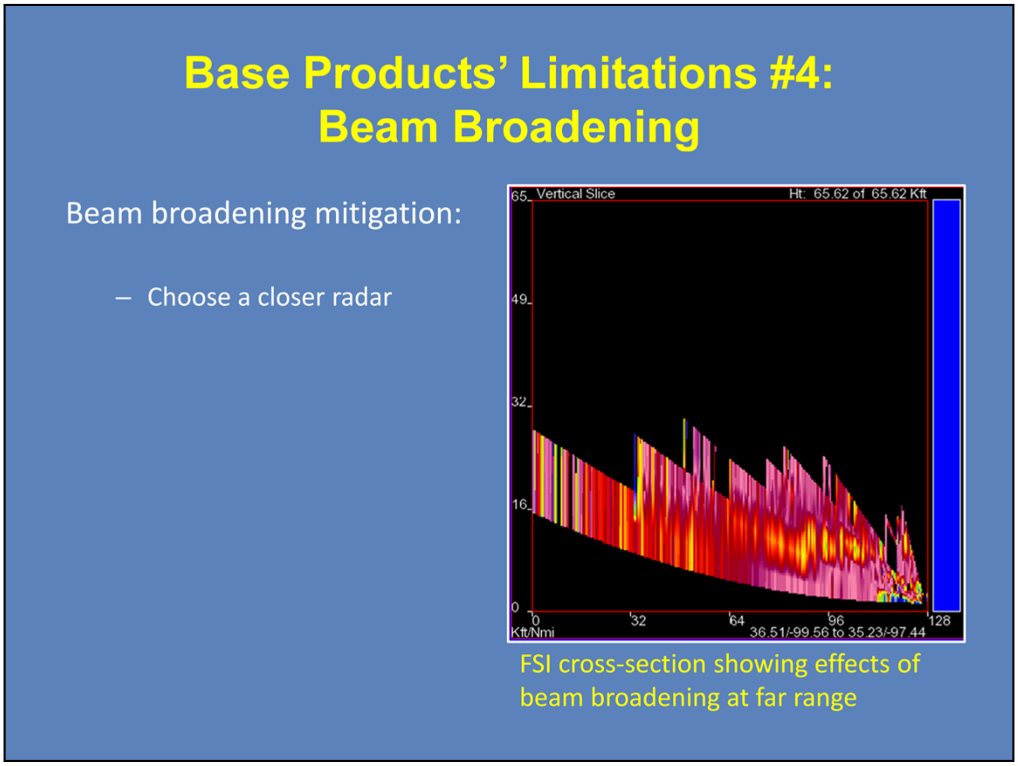
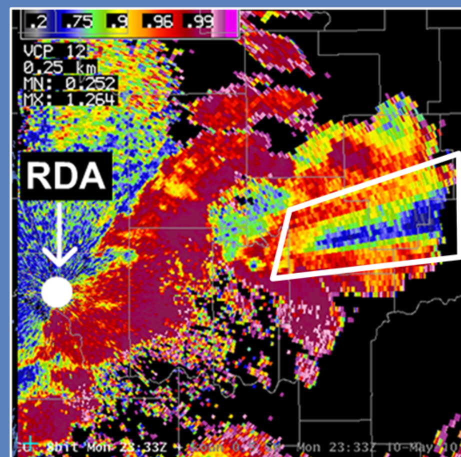


As the radar beam propagates away from the radar, it broadens. In fact at 60 km from the radar, the beam is roughly 1 km wide! This broadening effectively smears all radar signatures. For example, the melting layer, shown by the yellowish/orange colors in the image, becomes broader the farther away from 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

Non-uniform beam filling (NBF) mitigation:

– Choose a different radar



NBF visible at farther ranges ENE of RDA site

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 Zrnic, 1998; Gosset 2004). When NBF impacts your storm analysis, you need to use data from a different radar to mitigate the issue.

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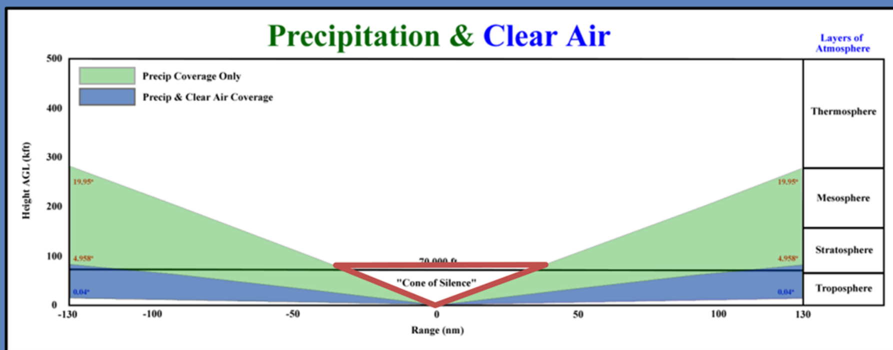
Base Products' Limitations #6: Cone of Silence

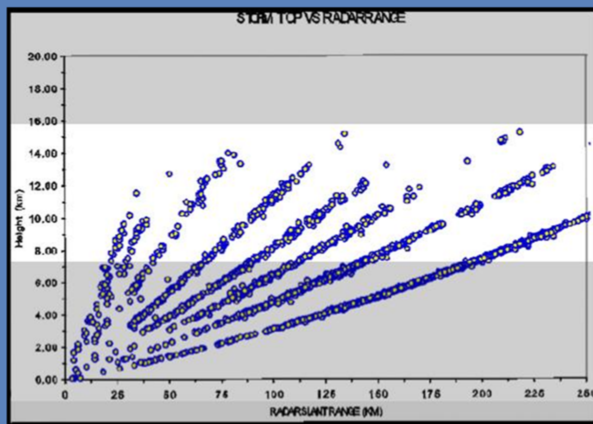


Cone of silence mitigation:

– Choose another radar nearby (if possible)

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

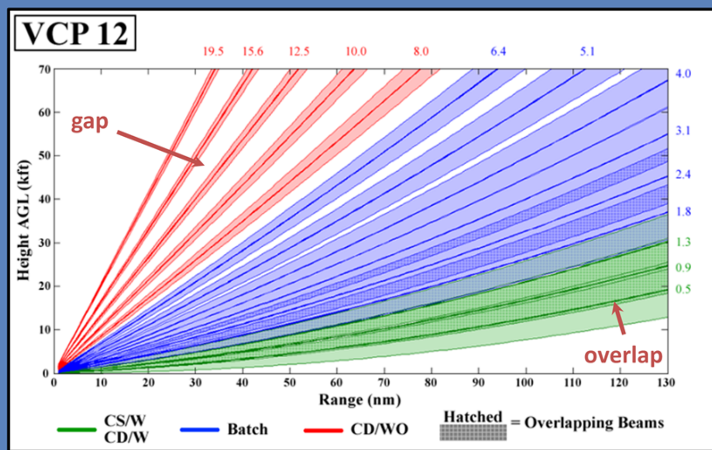


Plot of estimated storm top heights as a function of range

Remember that displayed beam heights are only estimates!

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.

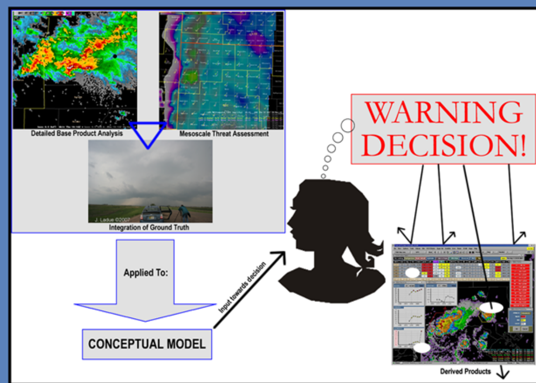
Base Products' Limitations #8: Discrete Sampling



Gaps between elevation angles affect forecaster interpretation & introduce algorithm artifacts

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



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

Never use for warning decision alone!

Now that we have covered base products, lets 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!

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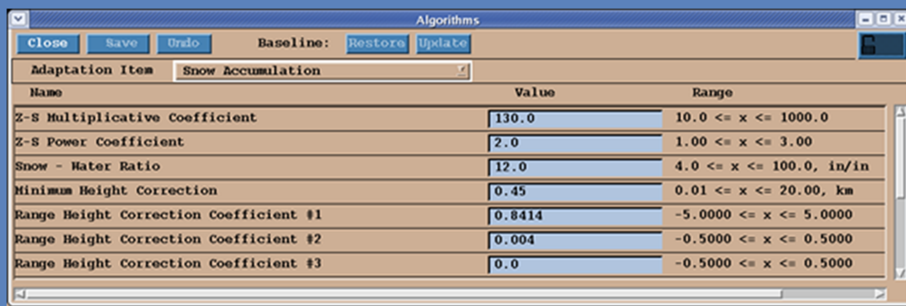
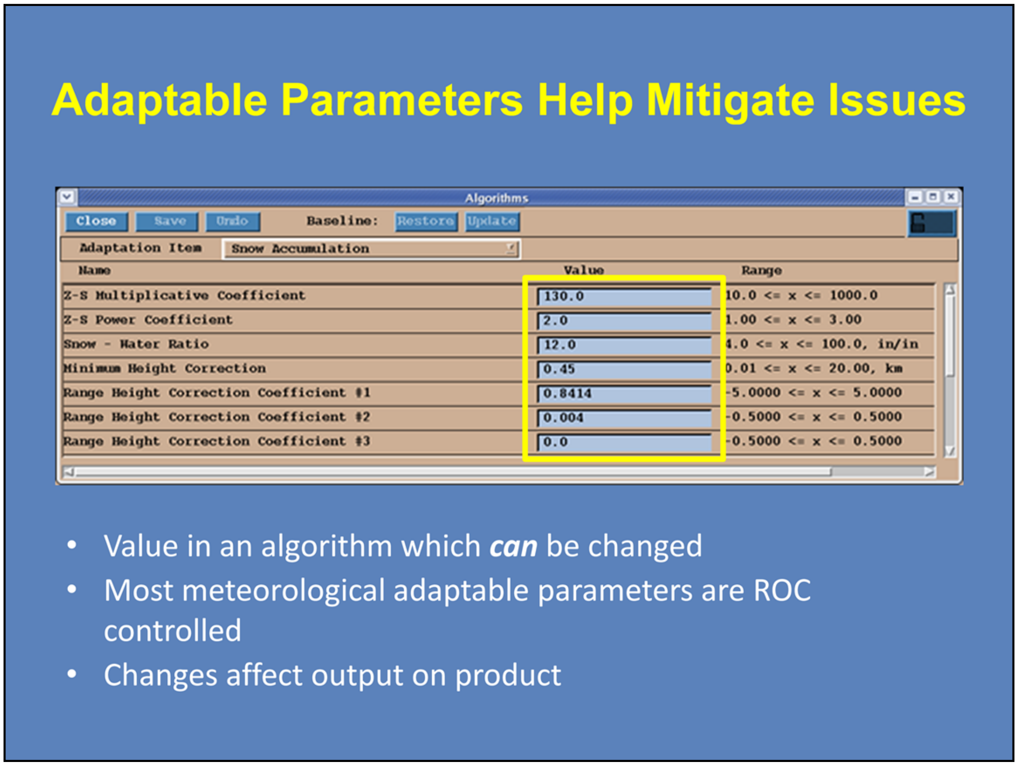
Derived Products' Limitations



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

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.



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.

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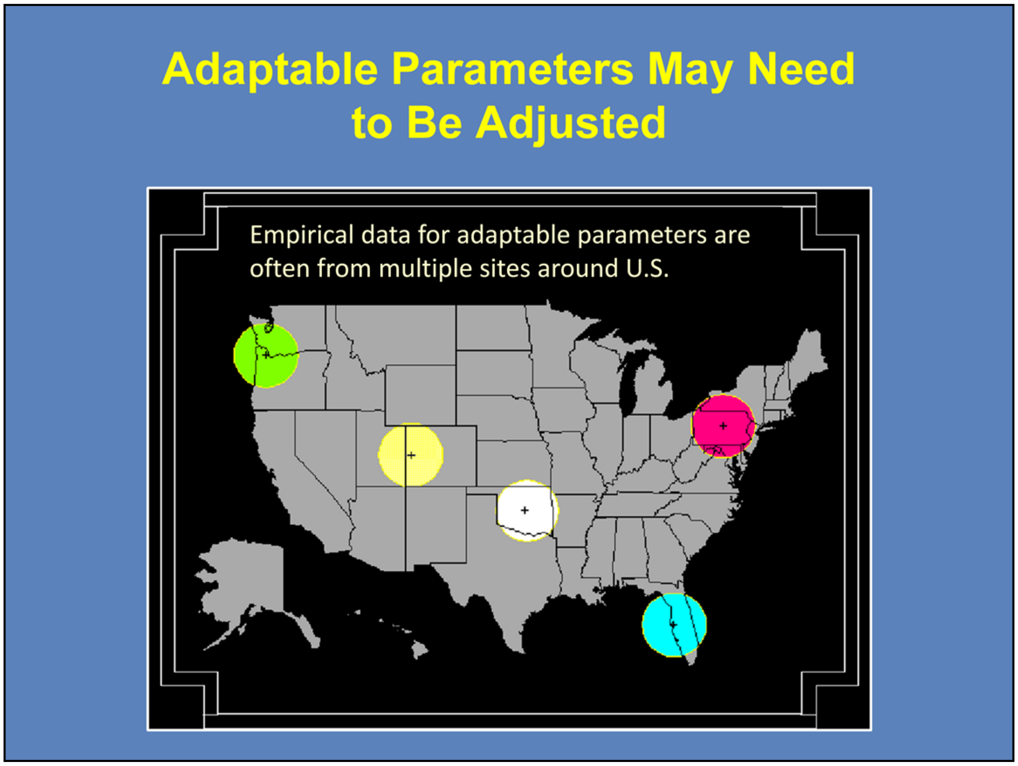
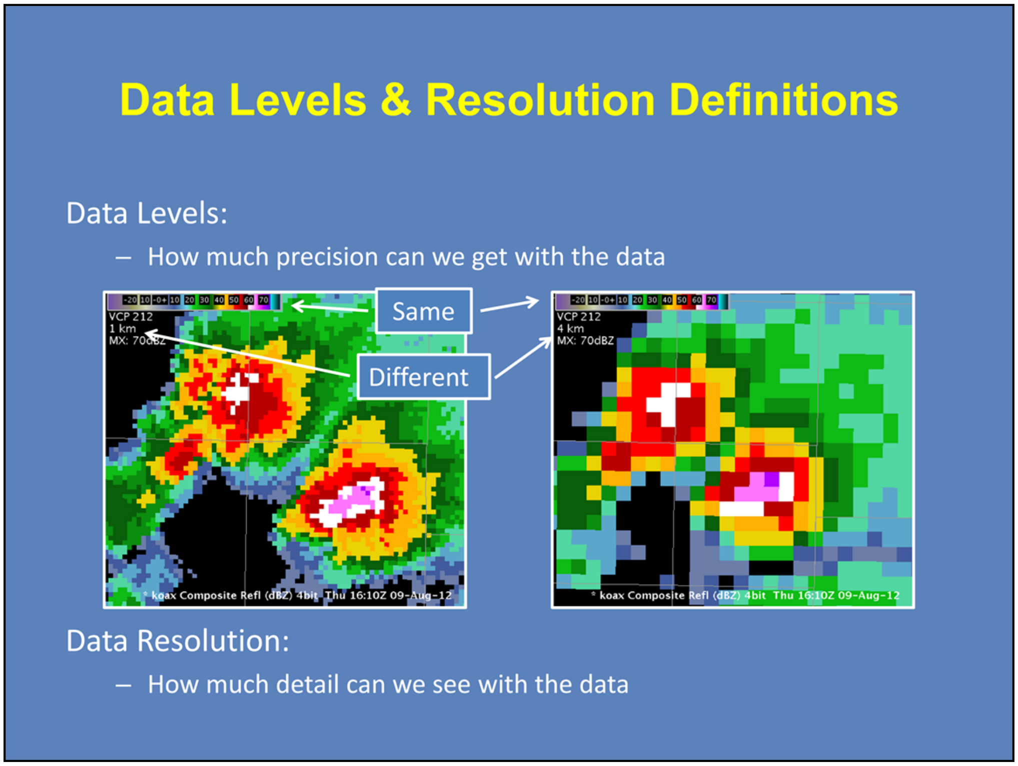


Most algorithms were optimized empirically using a series of datasets. However, to perform best in your area at different times of the year, the adaptable parameters for a particular algorithm may need to be modified. This process takes both research and coordination with the Radar Operations Center.



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.

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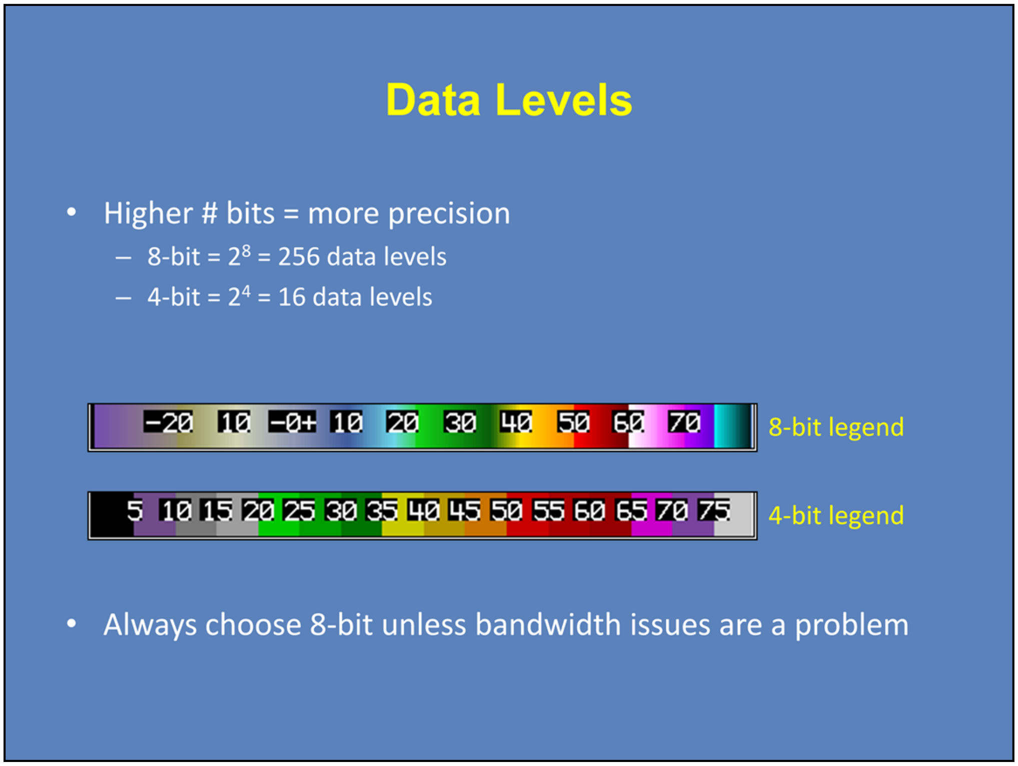

Data levels are characterized by how many bits are available to record them. The more bits available, the more precise the data are. For example, 8-bit products have 256 data levels while 4-bit products only have 16 data levels. To figure out exactly how many data levels are available, just raise 2 to 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. Operationally, higher bit products are always preferable unless you are experiencing significant connectivity issues in your office.

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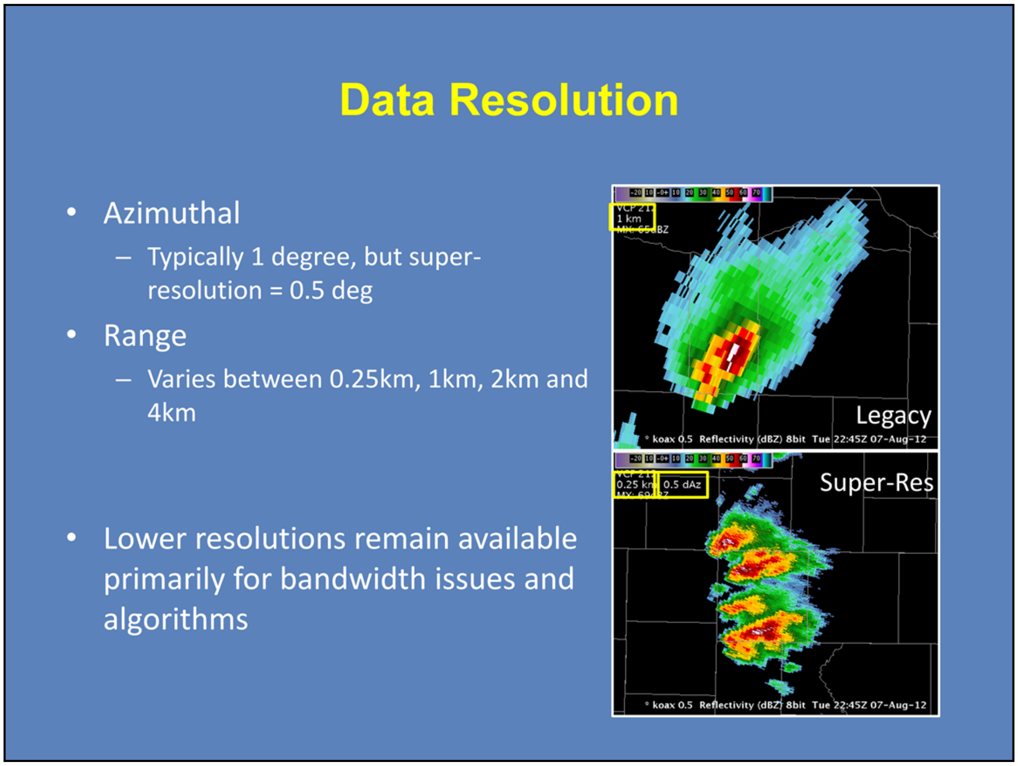

Radar data resolution can be broken out into two categories: azimuthal and range resolution. For WSR-88D products, most products will have an azimuthal resolution of 1 degree, except for super-resolution products which will be 0.5 degree azimuthal resolution. Most WSR-88D products have a range resolution of 0.25 km, but coarser resolution products are still available (i.e. 1, 2 and 4 km). It is highly recommended to use the highest resolution data available unless you experience performance issues with your workstation or your office experiences significant connectivity issues.

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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 only transmits 300 total products per volume scan
  - Each elevation angle is a separate product
- AWIPS will only let you request 150 total products
  - All elevation angles count as one product

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 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, and the number of products you request varies between AWIPS and the RPG. The RPG counts every single product separately and will only transfer up to 300 total products. AWIPS groups separate elevation angles of the same product ID as a single product. As a result, AWIPS will only let you include 150 products (by its count) in a RPS list.

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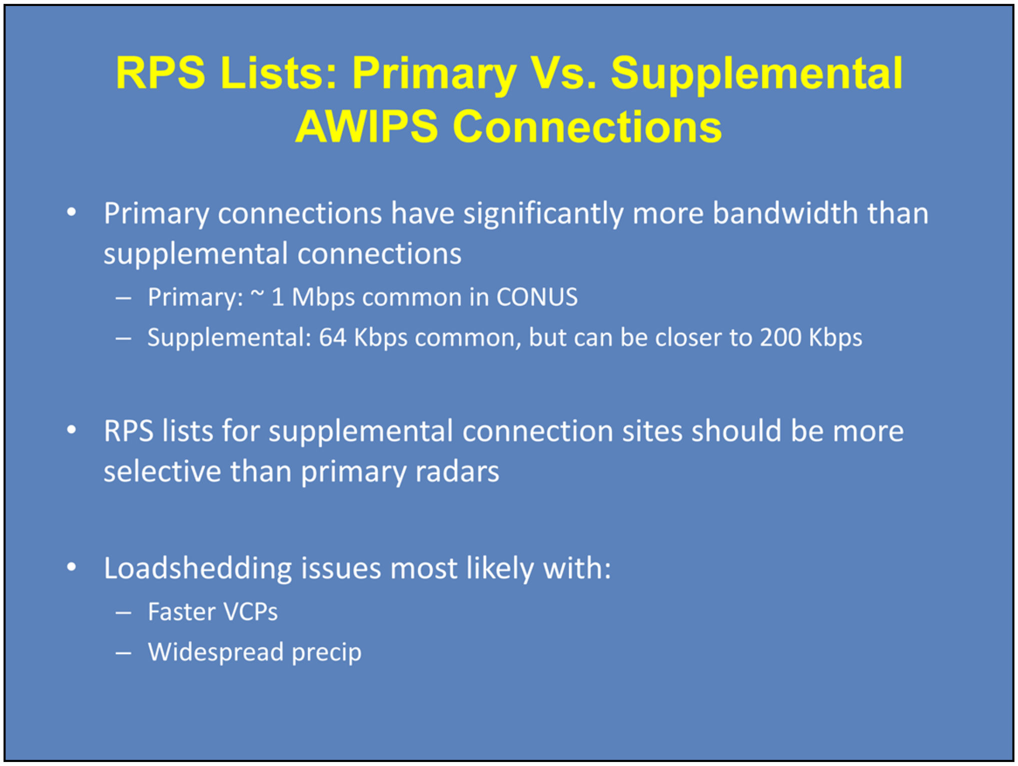
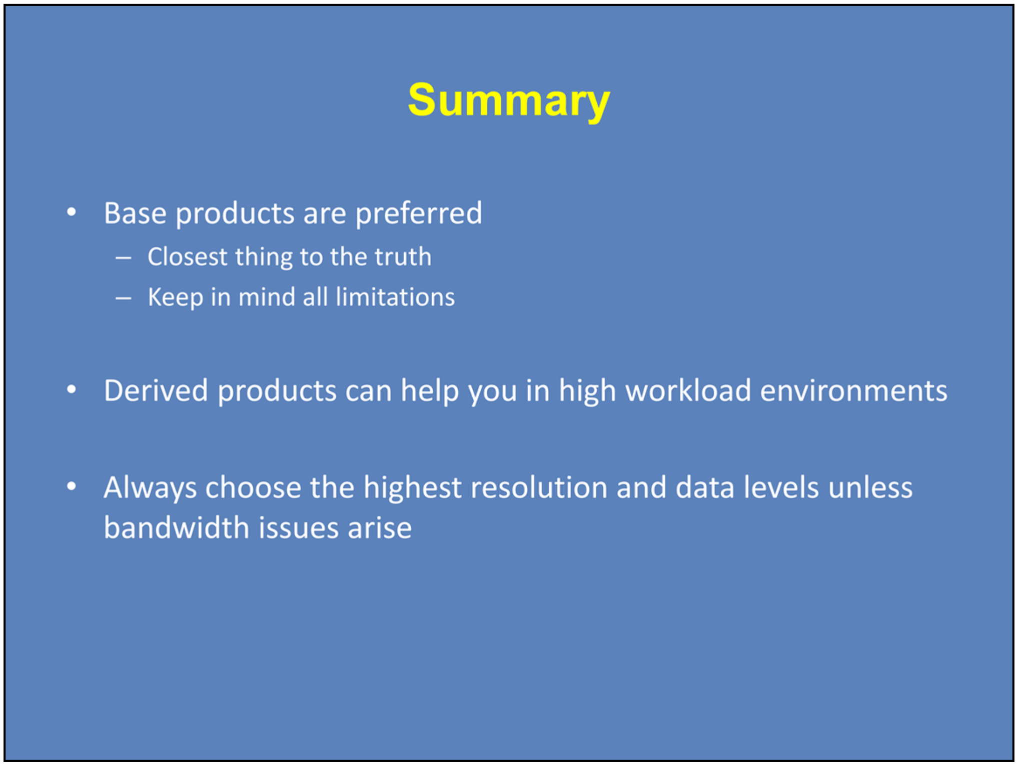


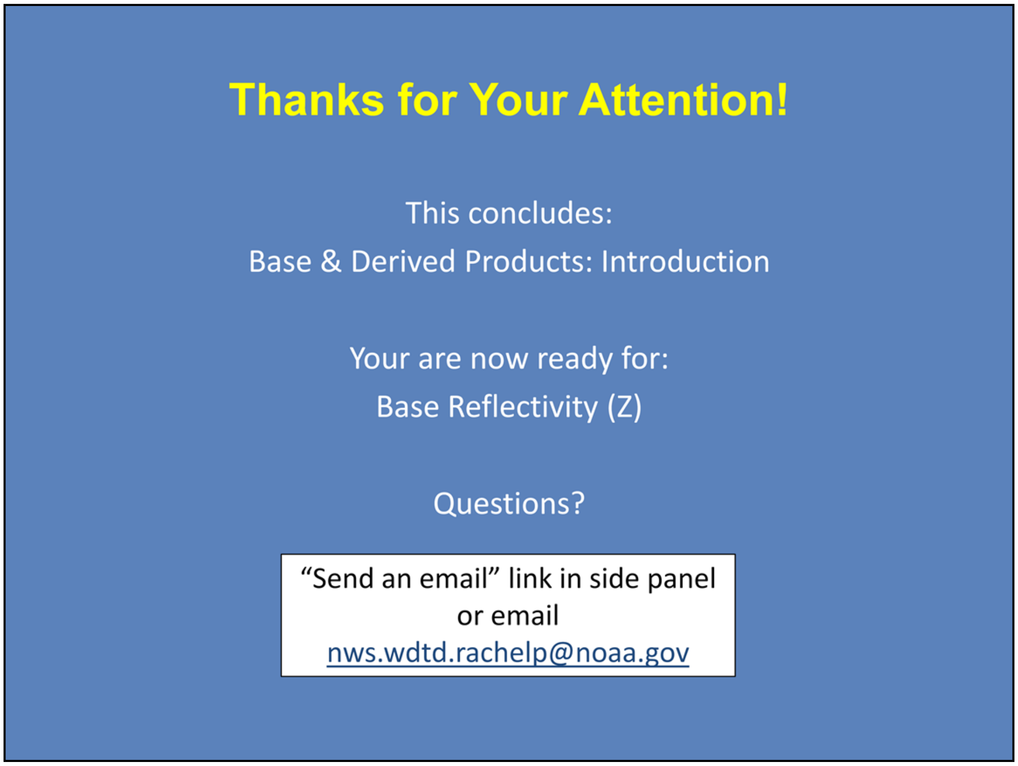
When building RPS Lists, it’s important to know whether the products you request are from your dedicated radar (through a primary AWIPS connection) or a non-dedicated radar (through a supplemental AWIPS connection). Primary AWIPS connections have significantly more bandwidth than supplemental connections. 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.



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.



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.

Welcome to Topic 4, Base and Derived Products. In this first lesson, we will start to build a foundation of understanding with the best known and most widely used base product – Base Reflectivity. So, let's get started!

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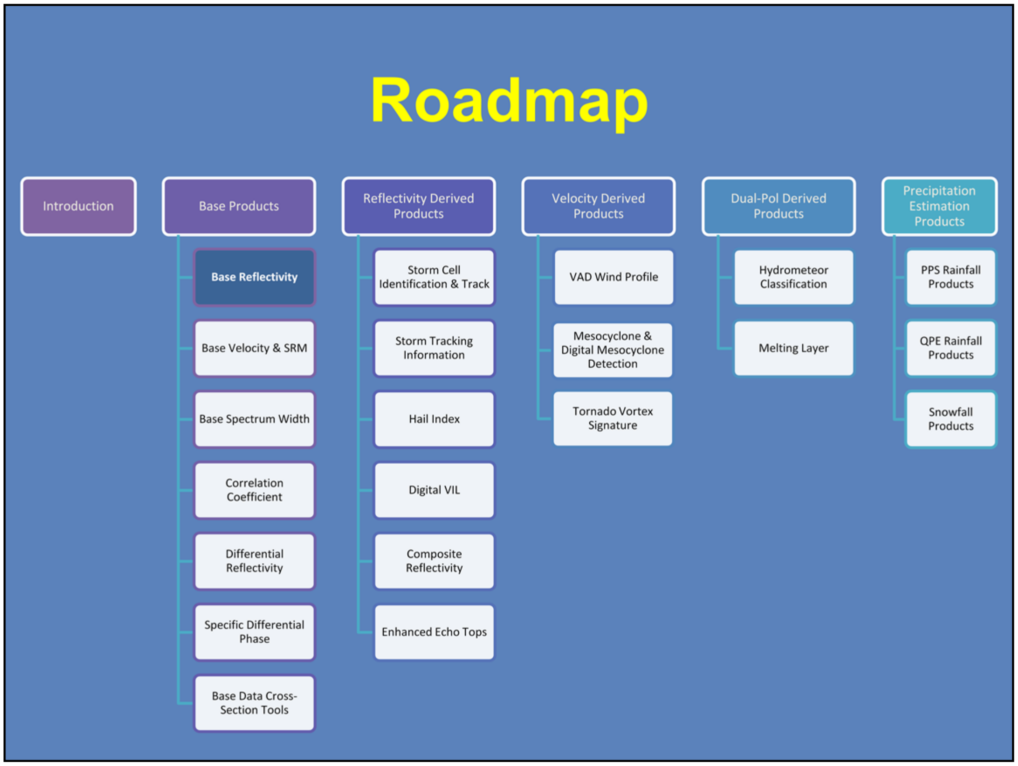

So this is the first lesson for the base products – along with the rest of the lessons in this topic. Also note the additional products to the right, which are derived from the base products coming up in following lessons.

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Learning Objective

Identify the *characteristics, limitations,* and *applications (strengths)* of the Base Reflectivity (Z) product.

Here is the learning objective for this lesson. Please advance the slide when you are ready.

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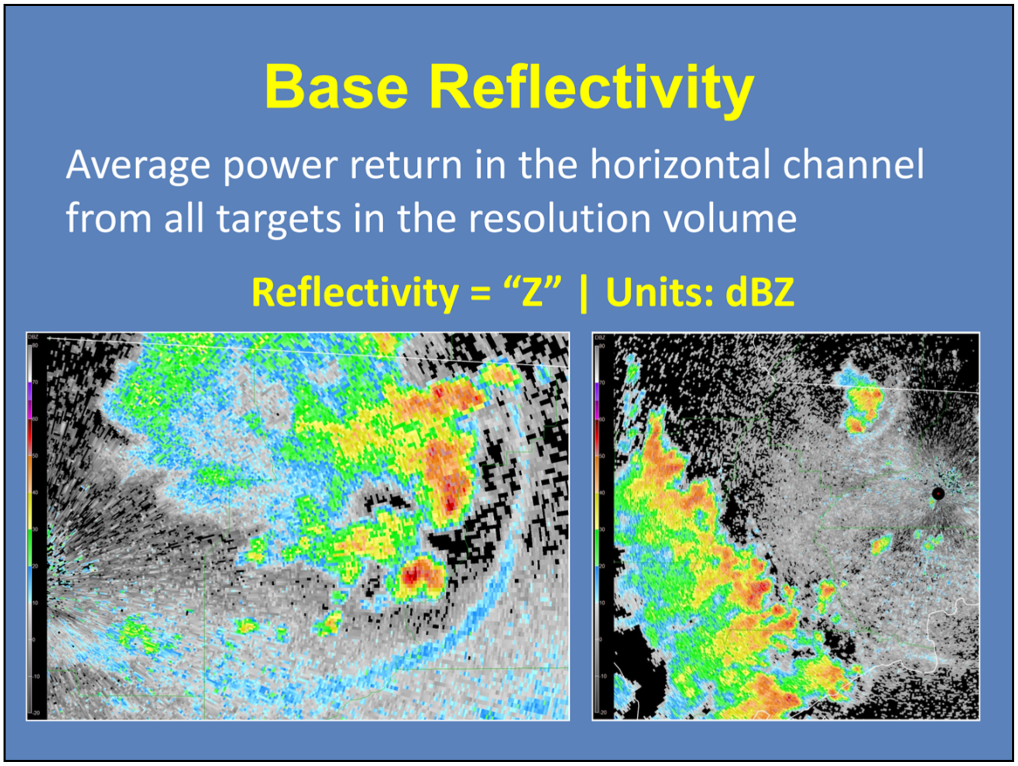
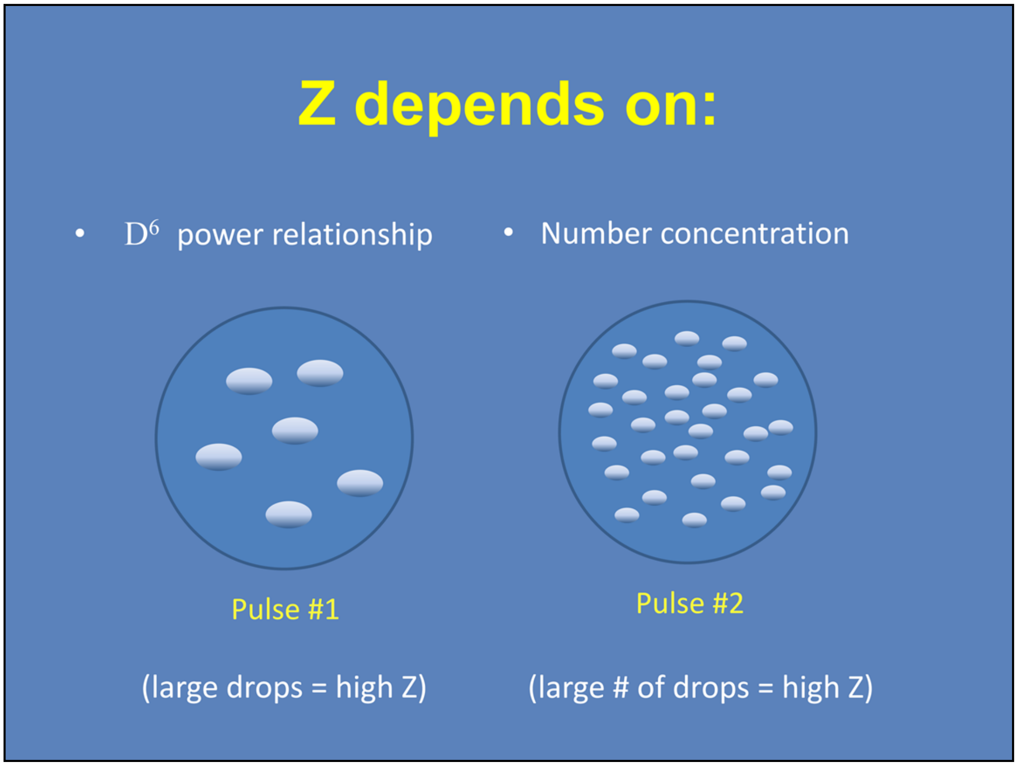


Base Reflectivity is defined as the average power return in the horizontal from all targets within the resolution volume. In terms of the product ID, we call this value “Z”. The average power return that comes back to the RDA is filtered and converted to a form of a decibels with the units of dB or decibels – of – Z, or reflectivity.



This power return, or reflectivity, is essentially how reflective the targets are. It has a diameter to the sixth power relationship meaning larger drops result in substantially larger Z. Also, Z has a number concentration relationship. The more drops per unit volume that are present, the higher the Z. In the example shown, it is possible that even though pulse 1 has larger drops, pulse 2 may have higher Z because of the larger number of drops present.

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Products Available from the RPG

Product Name	Units	AWIPS ID	RPG ID	RPG Code	Data Levels	Range Res	Az Res	Max Range
Base Reflectivity	dBZ	Z	R	19	4-bit (16)	1 km	1 deg	230 km
Base Reflectivity	dBZ	Z	R	20	4-bit (16)	2 km	1 deg	460 km
Base Reflectivity	dBZ	Z	R	21	4-bit (16)	4 km	1 deg	460 km
Base Reflectivity Data Array Product	*dBZ*	*Z*	*DR*	*94*	*8-bit (256)*	*1 km*	*1 deg*	*460 km*
Super Res Reflectivity Data Array Product	*dBZ*	*Z*	*SDR*	*153*	*8-bit (256)*	*0.25 km*	*0.5 deg*	*460 km*

**** Only the white products will be discussed in this lesson*

Here is a table listing all the Reflectivity products available from the RPG. In this lesson we will only focus on the ones in white. The other products are lower resolution products that are primarily available for bandwidth reasons only.

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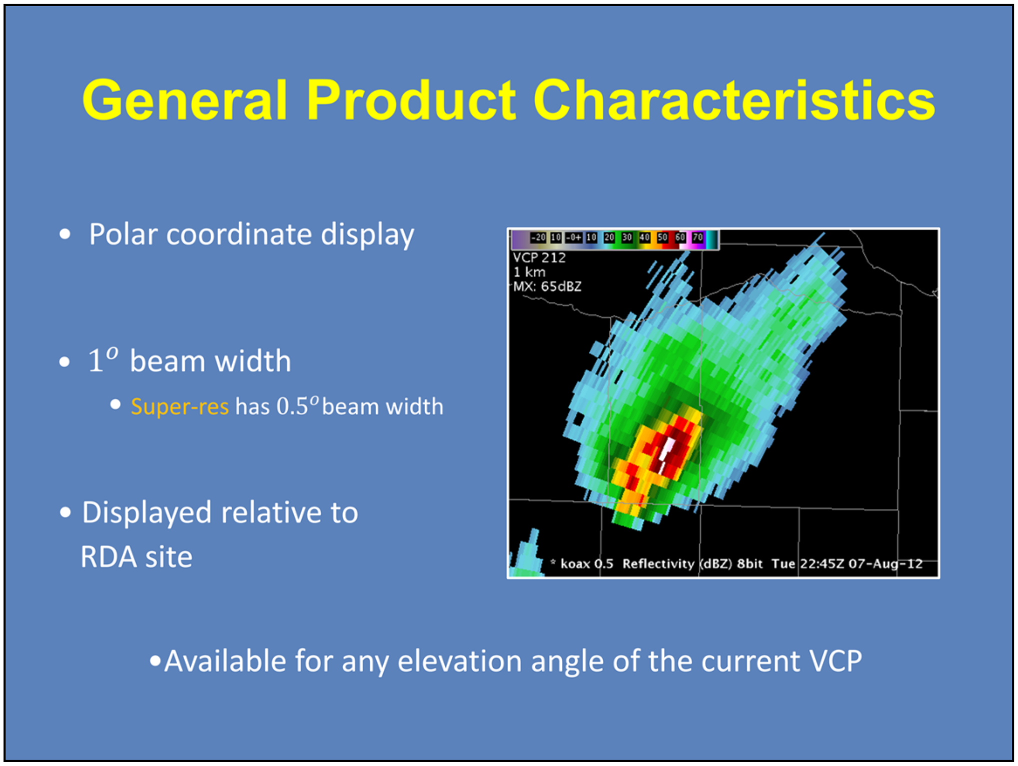

Here are the general characteristics for Reflectivity. It is displayed in polar coordinates with a 1 degree beam width, except for super-res products which have a 0.5 deg beam width. All pixels are relative to the RDA site and the data are available for all elevations for the current VCP.

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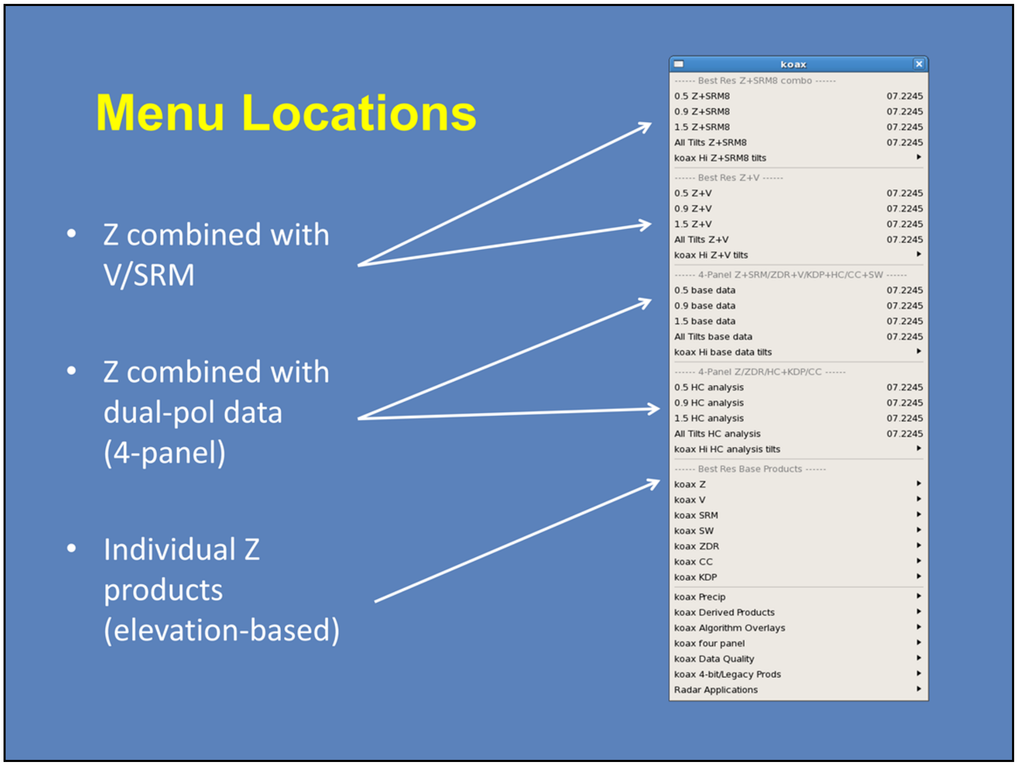

In your dedicated radar's drop-down menu, you can find Z products in these locations. The top four listed are Z combined with the various other base products, like velocity or SRM, so you can switch back and forth quickly, at different levels. If you'd like to just load Z by itself, it can be found toward the bottom of this list, shown here by the last white arrow.

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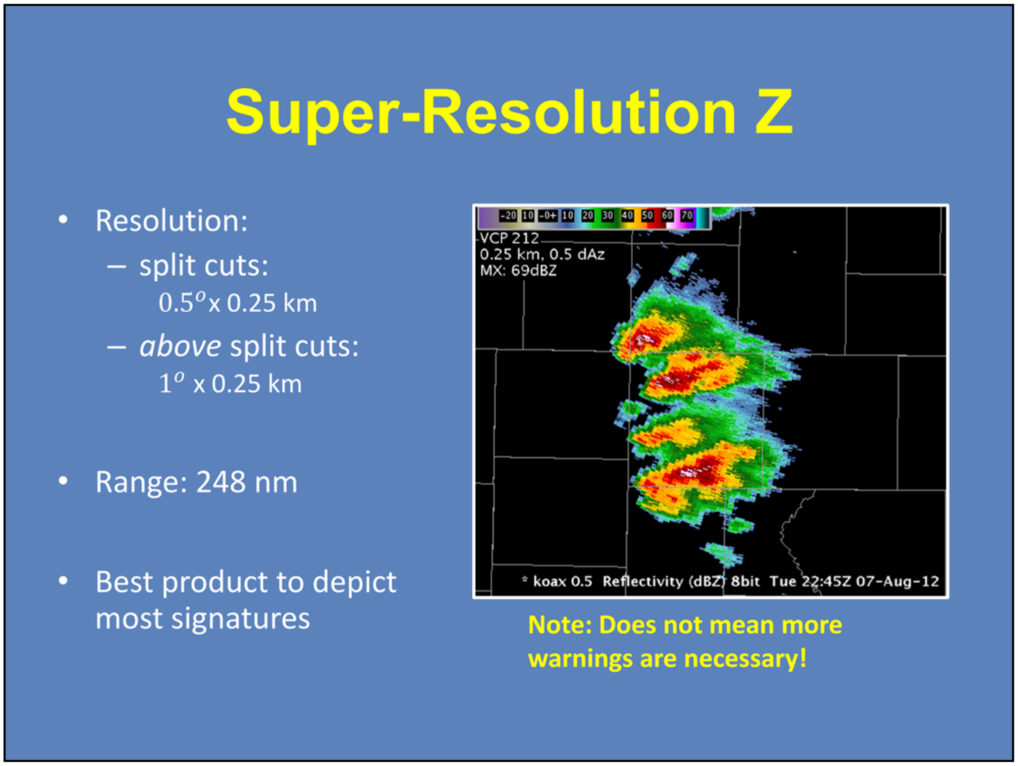
Order of Display Priority

	Beam width	Range resolution	Data levels
1) Super-res	$1^o, 0.5^o$	250m	256
2) 8-bit	1^o	1 km	256
3) 4-bit, 3-bit	1^o	1, 2, 4 km	16

Just a quick reference to the order of products, which is important with regard to how AWIPS-2 loads products. It starts by looking for the highest resolution possible, and then works its way down the list. Here is a table showing the order of loading for Z in AWIPS-2. The same will be true for the velocity products.



The first Reflectivity product we'll discuss is super-resolution reflectivity, which has been around since the late 2000s. It has a resolution of 0.5 deg by 0.25 km in the split cut elevations, and 1 deg by 0.25 km ABOVE the split cut elevations. It extends to a range of 248 nm (or 460 km) and is the best product to use for identifying most meteorological signatures.

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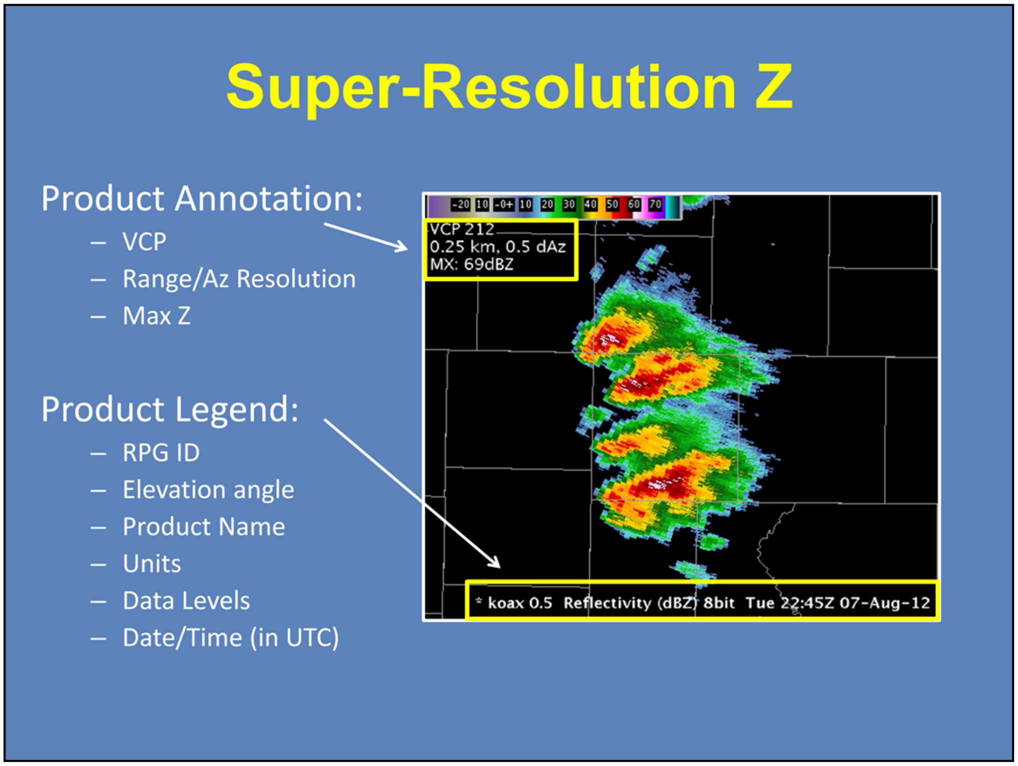
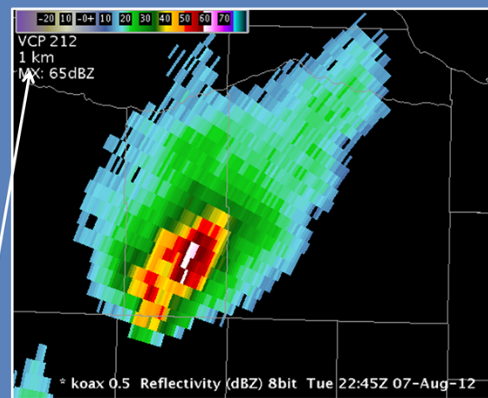


In the upper left corner of the super-res Z product, you will find the product annotation information. This is shown in the example image on the right. Here you will find what VCP the radar is operating in, the range and azimuthal resolutions of the product, and the maximum Z anywhere in the radar umbrella. Note that it does not tell you where that max reflectivity occurs. This doesn't typically matter if you know where that max should occur. But occasionally there is terrain within the radar's reach, and it may flag a pixel or two of the top of a hill or mountain with a very high DBZ value, so keep that in mind.

On this example image, note the product legend on the bottom right. The legend tells what radar it is, the elevation angle being displayed, the product name along with the units, how many data levels are in the product and the date/time in UTC.

8-Bit Reflectivity

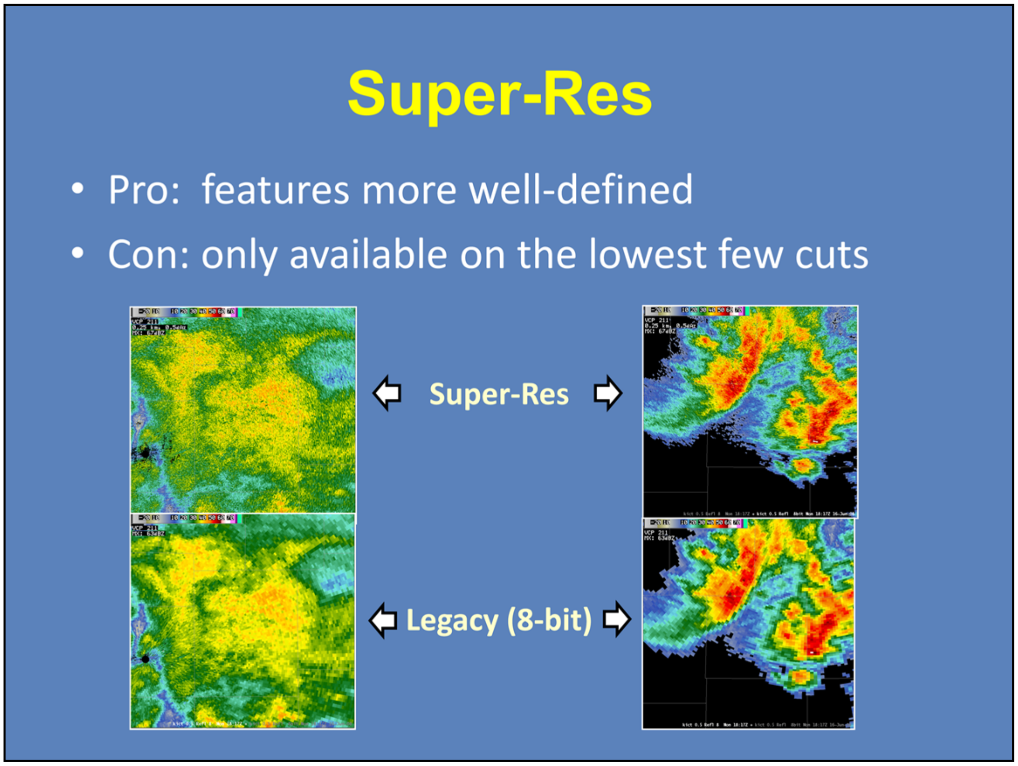
- Resolution: 1^{o} x 1 km
- Range: 248 nm
- **Primarily used for algorithms**



- Product annotations reads "1 km"

The 8-bit Reflectivity product is much like the super-res Z product except it is 1 deg by 1 km in resolution. But it does have it uses, mainly for some of the algorithms in derived products. When Super-Res came about algorithms were not been modified to ingest super-res Z data. It is generated at the RPG by taking the average power of the 8 super-res bins that comprise one 8-bit bin and then converts that average power to a Z value.

The product legend and annotations are identical to the super-res Z product except the resolution just reads 1 km.



In general, super-res Z is much preferred over the 8-bit counterpart because it tends to show features much more easily. However, one thing to note is that super-res Z is noisier than the 8-bit product due to the way super-res Z is computed. But this should not hinder interpretation. Also the super-res is only available on the lowest few cuts.

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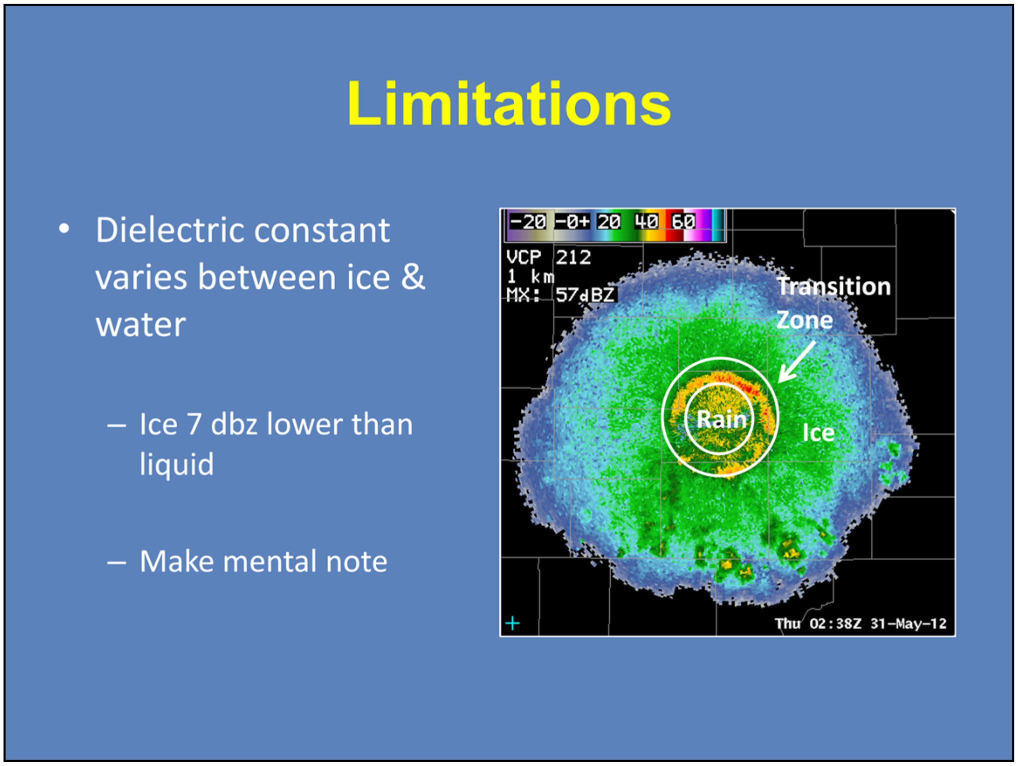

So, believe it or not, there are some limitations to reflectivity, or maybe you could see it as – things to watch out for. First, let's look at this aspect of the dielectric constant, which can and usually does affect the values of Z. Ice has a roughly 0.2 dielectric constant, whereas liquid water has nearly 1.0. This means for the same size particle, ice will be roughly 7 dB lower than the liquid particle.

In the image on the right, near the radar and scanning at a relatively higher elevation, the beam is heading up into the cloud a steep angle, where liquid water, rain, is detected close to the radar but then the beam encounters the melting layer, inside the two white circles, where you see the ring of red and yellows which is the transition zone between liquid water and ice. Then, as the beam continues on up into the cloud, to the right of the outside white circle, it is all ice. Notice how the reflectivities are generally lower in ice than in liquid. This is due to the dielectric constant difference in ice and water.

And even though this is technically a feature-detection – of the melting layer – it is a limitation for precipitation estimation. The radar tends to add up values pretty quickly over the area where the melting layer resides, which obviously is not reality at the surface, just a feature hanging several thousand feet or more up in the cloud, depending on the time of year. (Reference: Gunn and East, 1954)

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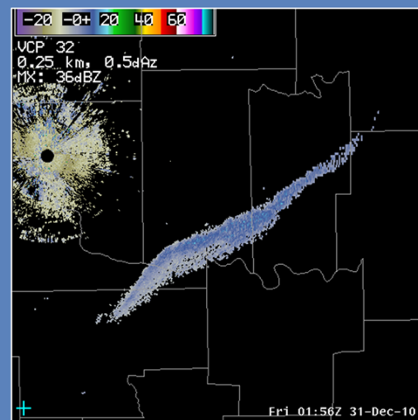
Limitations

- Chaff looks similar to precipitation in Z
  - Military ops
  - High dBZ initially, gradual decrease
  - *Review all observation systems*



Chaff, is pretty rare to see, but does happen on occasion and will appear on the scope as a long, thin stripe, like in the example image. Chaff is made up of very tiny long and thin fibers that are released by military aircraft for military training purposes, which is not an incredibly common thing but something to be aware of. It usually shows up as light to moderate Z during initial release and then decreases in intensity as the chaff disperses down wind. There are ways to figure out that this is not precipitation, mainly using Dual-Pol products, but also, you can tell with various satellite data whether this is actually a dense precipitation-bearing cloud there, and the military normally choses not to release this stuff when there is precipitation, because it would kind of defeat the purpose of detecting it.

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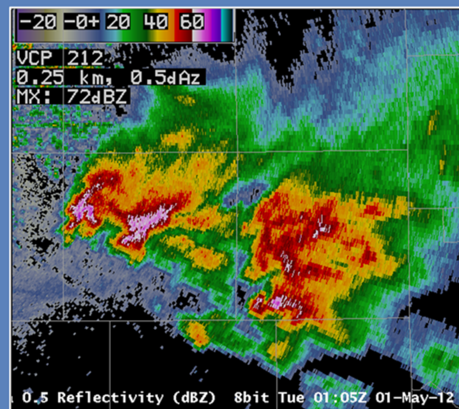
Applications

- Observe precipitation intensity, movements & trends
  - Time lapse feature important
  - Clear air mode for light precipitation



The number one application of reflectivity is to observe precipitation intensity, movements, and trends. Setting a time lapse of reflectivity is invaluable. This allows you to see the morphology of an event and anticipate future development. Additionally, in light precipitation events, clear-air mode is preferred for the same reasons.

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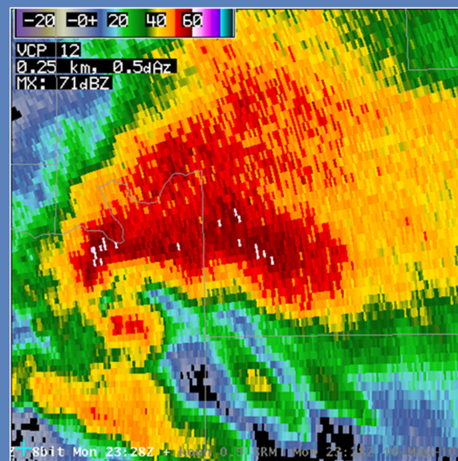
Applications

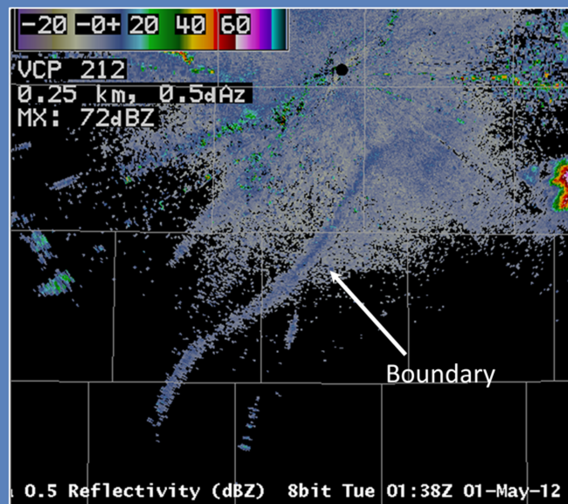
- Determine significant storm structure features
  - WERs, BWERs, Hooks, Weak Echo Channels, TBSS, etc.
  - Use All-Tilts, 4-panels or FSI



When interrogating storms, reflectivity can be used for identifying significant storm structure features that indicate potential for a severe thunderstorm. Some of these features include weak echo regions (WERs), bounded weak echo regions (BWERs), Three body scatter spikes (TBSS), etc. It is highly recommended that you display different levels of reflectivity in either 4-panel or All-Tilts views and utilize FSI – which is the 4-D Storm Interrogation tool, which is a separate window you can use in AWIPS-2 (which we'll discuss in a later lesson) to observe these features.

Applications

Determine location and motion of fronts and other boundaries



Along the lines of the first application, reflectivity can be useful in identifying the motion and trends of fronts and boundaries. The image on the right shows an example of a boundary approaching the radar from the southwest. Most of these detected boundaries show very low reflectivity values and appear because they are carrying non-meteorological particulates in the air as they progress forward.

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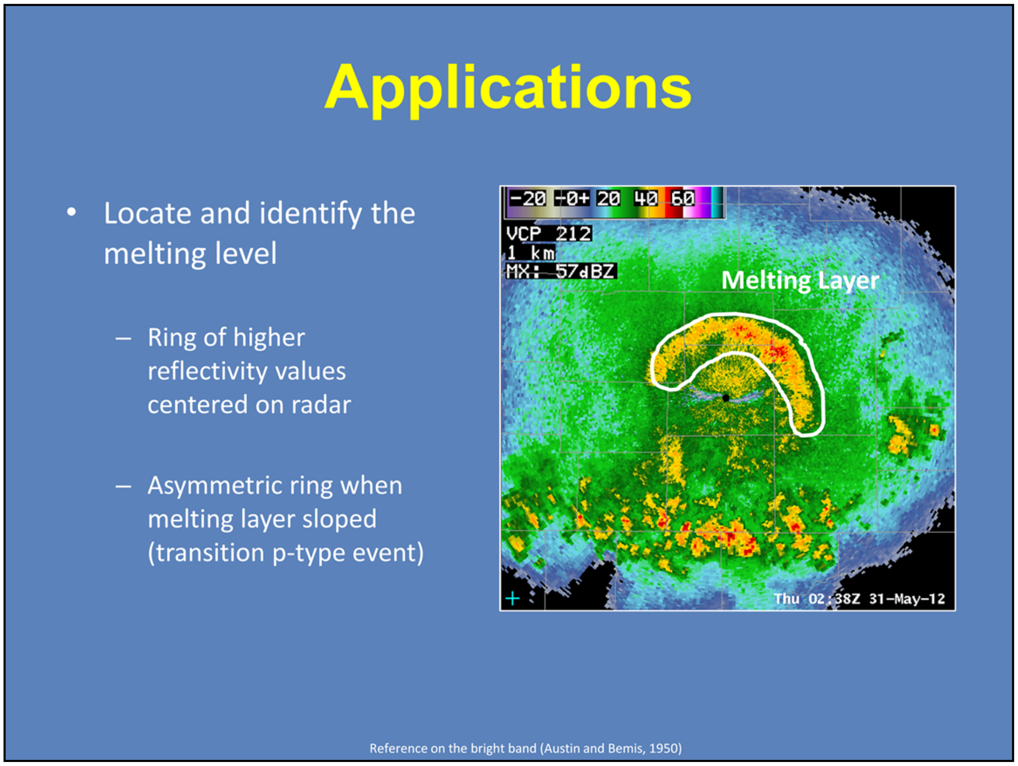
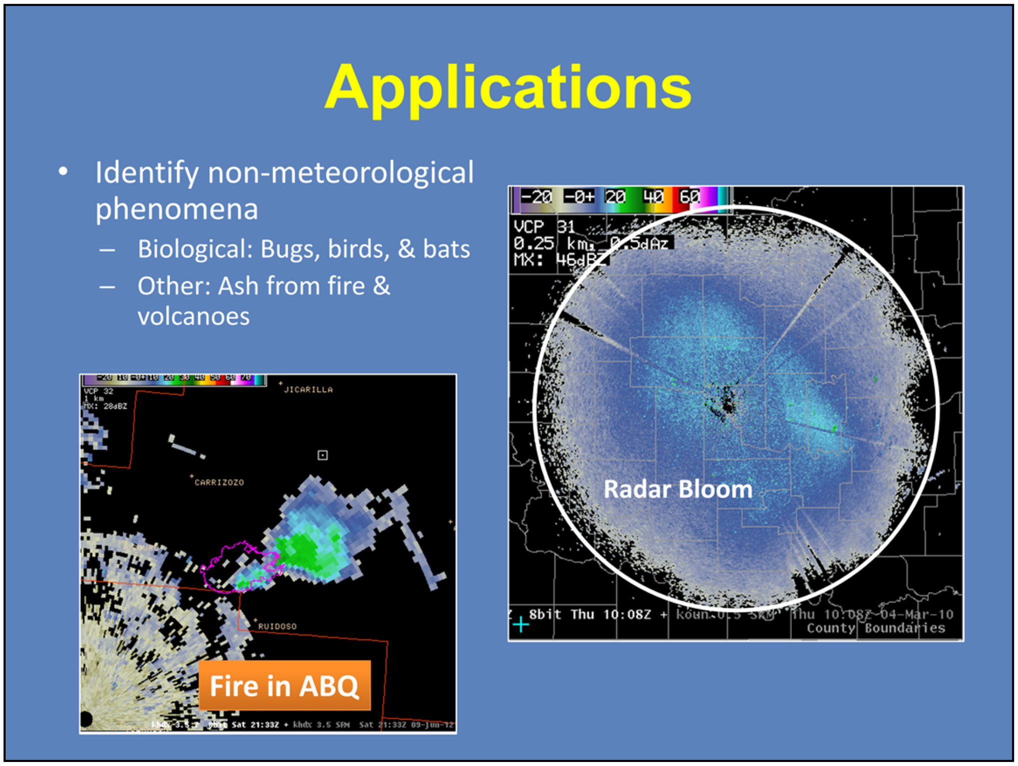


Back to the melting layer, which we noted for its limitations due to the overestimation of precipitation in that zone. However, this is also an application of reflectivity, because it does show the melting layer and when you have sampling turned-on, you can see both where it is above the surface, if there is a melting layer, and what the general thickness is of that layer. If the melting layer shows up as an arc – as you can see in this image, you most likely have a transition precipitation event. Reference: (Austin and Bemis, 1950)



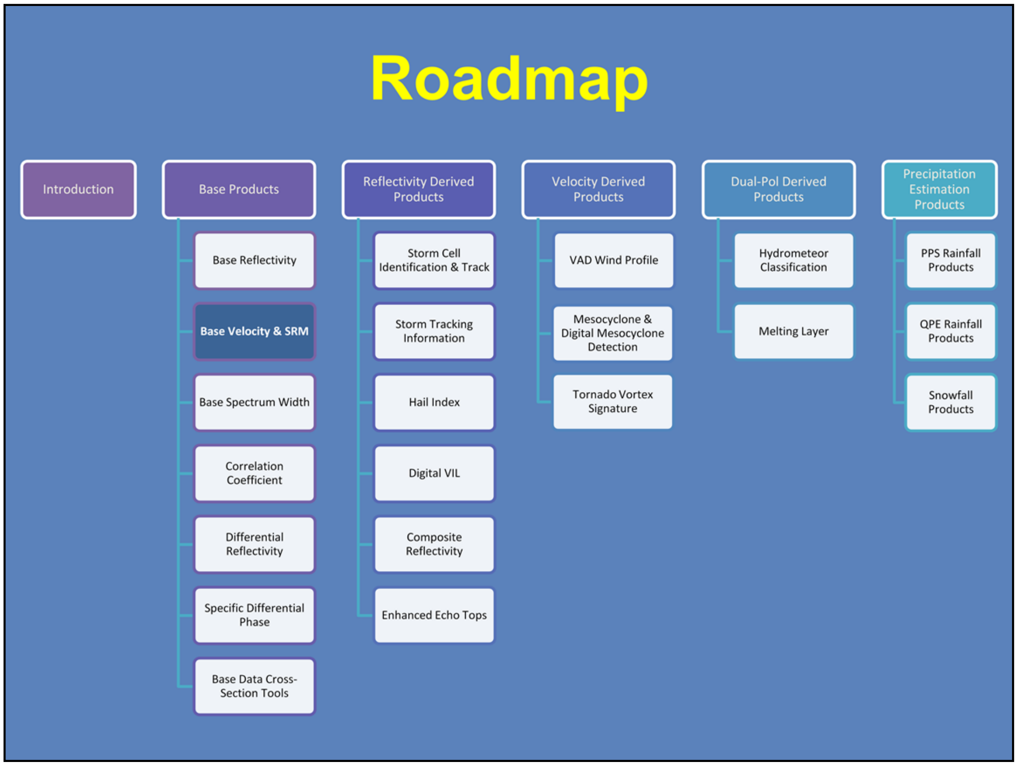
Finally, reflectivity can identify non-meteorological echoes, and even though fronts and boundaries fall into this category, here are some additional features. Typically, during the evening and morning hours, you will note an increase in the coverage of reflectivity in clear-air situations. This is often called the “radar bloom”. This is prime time for bird migrations, insect feeding, etc. So, what you are actually seeing is biological patterns. Over time, this can be helpful in interpreting radar signatures during different times of the year. Also, sometimes you can detect fires or wildfires, and even volcanic ash.

Summary

- Average power return *in horizontal*
- Applications: general motion, intensity, trends, and structure
- Standard radar limitations apply, plus:
  - Chaff
  - Dielectric constant
  - Non-precipitation echoes

To summarize our lesson on reflectivity, recall that it is the average power return in the horizontal channel. The resultant power amount returned to the radar can show the general motion of echoes, intensity, trends, and structure of precipitation within a cloud, whether you're looking at convection or non-convective activity. As always, standard limitations apply in addition to chaff appearing as precipitation and the dielectric constant being different between ice and water, as well as other non-precipitation type features, such as terrain and other features such as fronts.

Welcome to the Base and Derived Products' Lesson on Base Velocity and Storm-Relative Velocity Mean Radial Map (or SRM). In previous years, these lessons were separate. However, these products are essentially the same in terms of their fundamental specs, and so we've combined them in order to draw on their similarities and their differences. So, let's get started!



We're now into the second lesson on base products with 5 more to go after this. Additional products derived from these base products will be discussed in later lessons.

Learning Objectives

Identify the characteristics, limitations, and applications (strengths) of the base velocity (V) and Storm-Relative Mean Radial Velocity Map (SRM) product.

Similar to the last lesson, we will discuss the characteristics, limitations, and applications of these products. However, this lesson will also be a comparison of the V and SRM products with comparisons made. Advance to the slide when you are ready.

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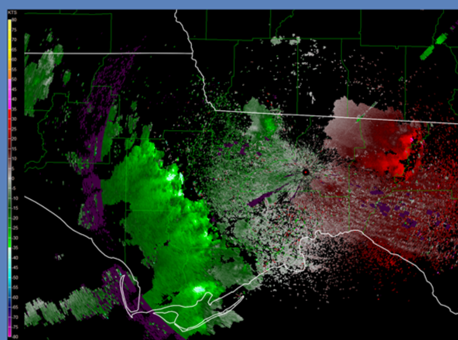
Definitions

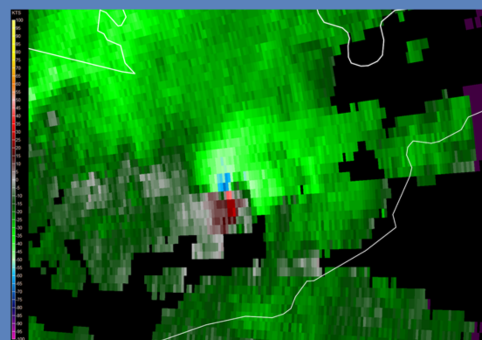
Velocity (V)

- Power-weighted, mean radial velocity of all targets within a resolution volume

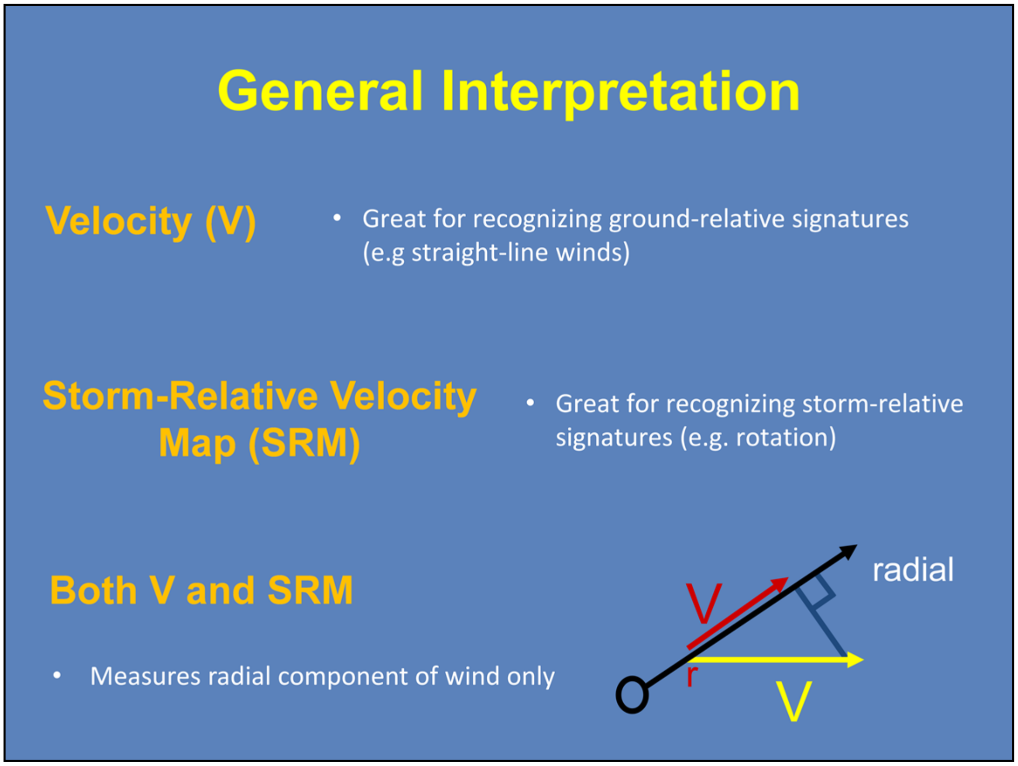
Storm-Relative Velocity Map (SRM)

- Velocity field with the storm motion subtracted out

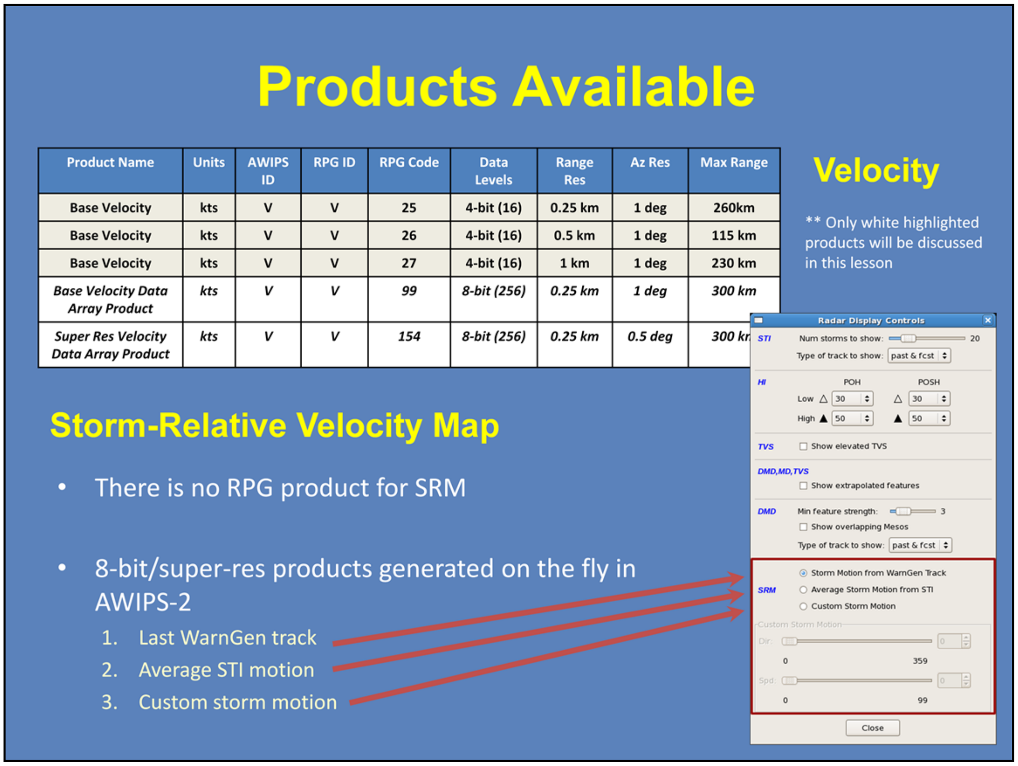




What is velocity? Well actually, it is technically called radial velocity, and it is the power-weighted, mean radial velocity of all targets within a resolution volume. On the other hand, Storm-Relative Velocity Map, or SRM, is really just velocity with a storm motion subtracted out.



The main difference between V and SRM is that V is great for recognizing ground relative signatures, like straight line winds or microbursts, while SRM is great for recognizing storm-relative signatures like rotation. Of course with both of these products you must keep in mind that we are only measuring the radial component of the wind. In other words, V and SRM are not the measure of the true wind unless the wind is oriented along a radial. Any component perpendicular to the radar is not measured, so keep that in mind when using both products.



Just like with the last lesson on Z, we will only focus on the 8-bit and the super-res VELOCITY products for this lesson. The 4-bit products (in grey) are only really needed if there are bandwidth issues.

There are no RPG product for SRM, except for the 4-bit RPG generated SRM – but that is probably not a widely used product and we wont talk about it here. The 8-bit and super-res versions of SRM are actually generated on the fly in AWIPS-2 via one of the three options available from the Radar Display Controls window, shown here on the right. Those three options are: the latest WarnGen storm motion, the average motion of all SCIT identified storms, or a custom storm motion. Which option you choose is totally up to you, but make sure whatever option you do choose best fits the storm motion of the storm you ‘re interrogating.

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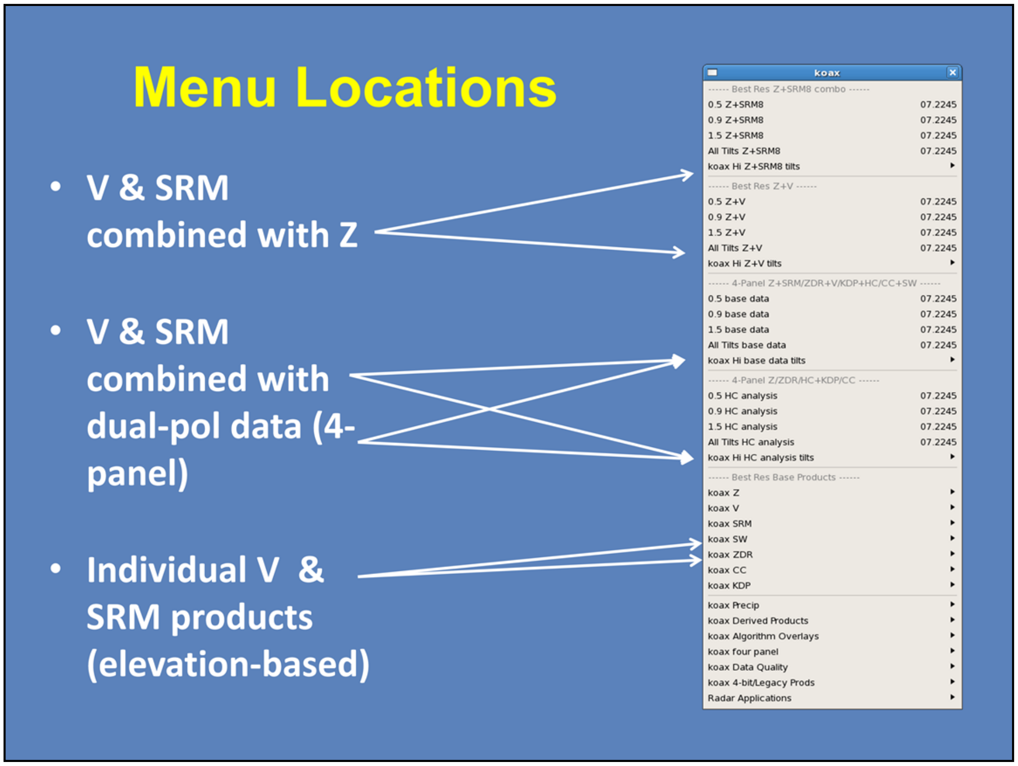

Take moment to see where in the menu the velocity and SRM products are located. Unlike most products, velocity and SRM are unique in-that they are combined with reflectivity in a number of angles. So, velocity products are all over this menu, whether in their standalone versions or in combos of 4-panel and all-tilts.

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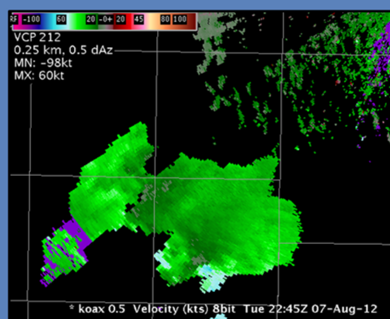
For both V and SRM

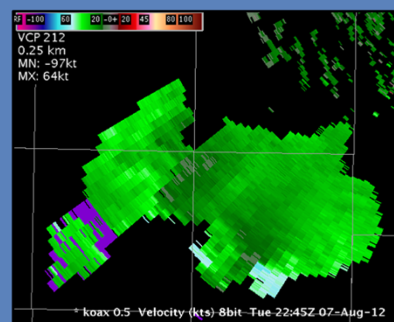
Super-Resolution

- Resolution: 0.5 deg x 0.25 km
  - Split cuts only
- Range: 162 nm

8-Bit

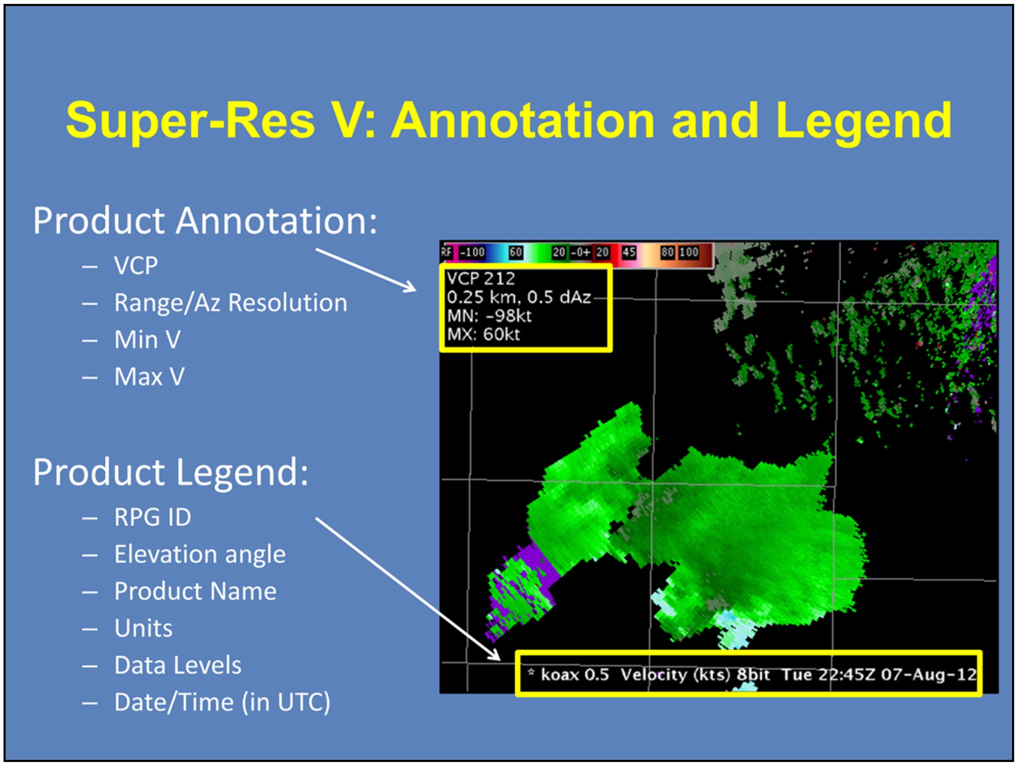
- Resolution: 1.0 deg x 0.25 km
- Range: 162 nm





For both V and SRM, the characteristics of the super-res and the 8-bit velocity products are similar to that of reflectivity. In the split cuts, the super res is 0.5 deg x 0.25 km resolution, and above the split cuts the azimuthal resolution goes to 1 deg. Meanwhile, both of the ranges are at 162 nm. Like reflectivity, super-res velocity is best for identifying most meteorological signatures.

As you can see from the two images, the one of the left, the super-res have much more detail for the same region of sampled velocities than the one on the right. However, super-res velocity can be noisier than 8-bit, but that should not hinder any interpretation.



In the upper left corner of the velocity product is the product annotation information. This tells you the current VCP mode, the range and azimuthal resolution and the min/max velocity values anywhere in the radar domain. Note, that the location of these min/max values are not known. In the lower right is the product legend. This tells you what radar you are viewing, the elevation angle, product name (in this case Velocity), the units, how many data levels and the date in UTC.

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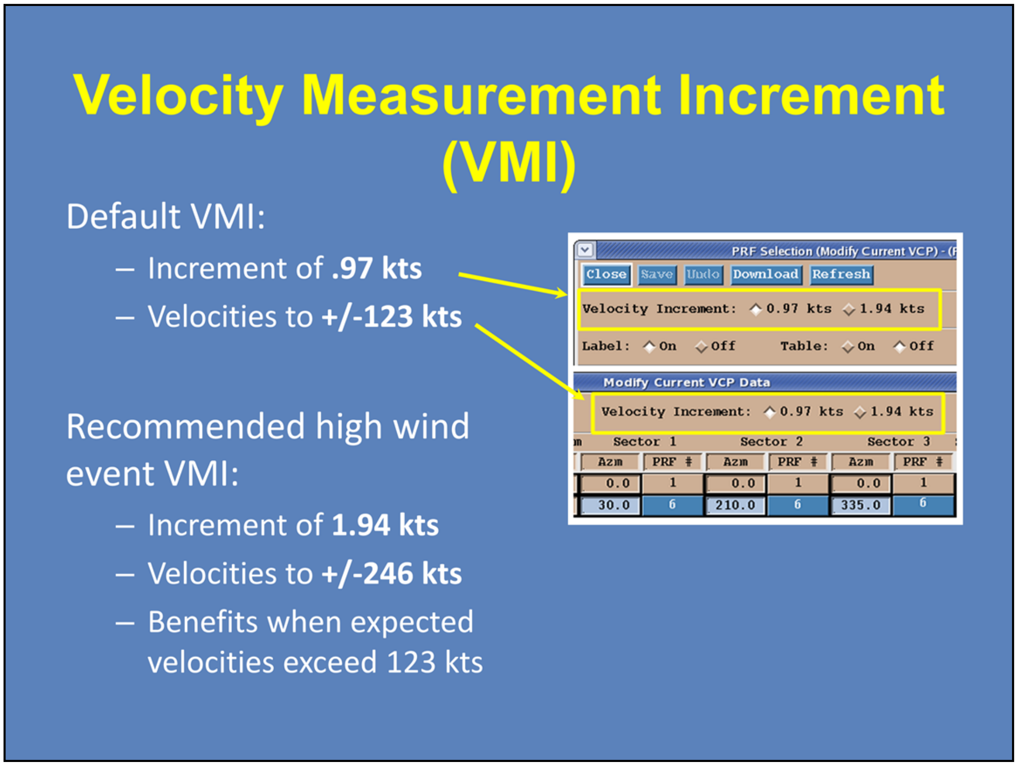

There is a unique element to velocity measurement that we need to briefly cover. Recall with data levels that for a given range of values, you can only get a certain precision. Well, with velocity, the default precision is 0.97 knots, which for 8-bit gives you a range of velocities of 123 knots inbound and outbound. In other words, even if there are winds over 123 knots, at that precision, the radar won't be able to sample it and will max-out at 123 knots. This may be an issue if there is a tropical system that is carrying winds above that level.

The only way to increase this range is to add more bits, or change the precision of the data. We can't change the bits, so this is where the Velocity Measurement Increment (VMI) comes into play. By changing the VMI (or precision) from 0.97 knots to 1.94 knots, the range of velocity values increases to 246 knots inbound and outbound (or doubles), which is basically double. The default VMI is 0.97 knots and for most meteorological events, that is sufficient, but in high wind events like hurricanes, changing this value is recommended. You can find the VMI settings in the RPG HCI via the PRF selection window.

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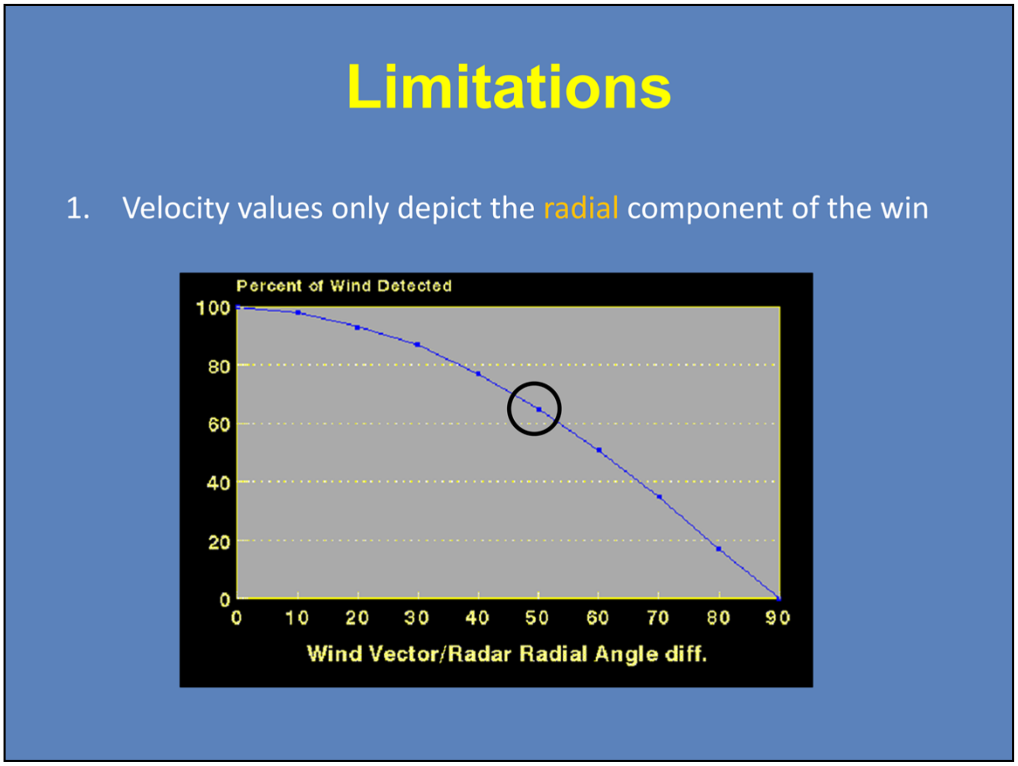

Now we'll look at some issues that may affect velocity interpretation. Note: These limitations apply to both V and SRM.

As mentioned earlier, velocity only depicts the radial component of the wind. Therefore, if the actual wind is blowing perpendicular to the radial, no wind will be detected by the radar just based on the geometry. The graph below shows the percentage of wind that is measured based on the angle it makes to the radial. At an angle of 50 degrees, the radar is only seeing roughly 65% of the actual wind! Remember this and continue to remember it well, that when you are sampling velocity values, keep in mind that angle – relative to the radar – that the data is being sampled it, it may not be a true value to what the velocity actually is at that level and that angle.

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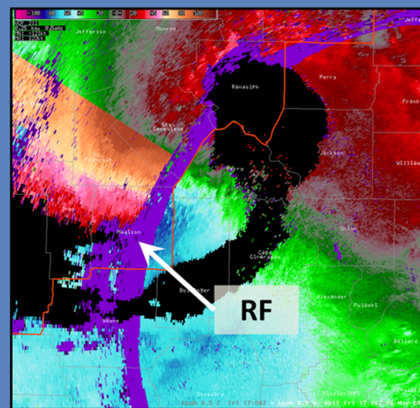
Limitations

2. Mitigate range folding impacts by:
   - Changing PRF
   - Invoking clutter suppression
   - View a higher slice
   - Select another radar



As mentioned in the previous slide, Range folding – or RF – is a major issue with velocity. It can mask features that are crucial to warning decisions (e.g. tornadoes). If RF is an issue, consider the following: Change the PRF, invoke clutter suppression, change to a higher elevation, or choose a different radar.

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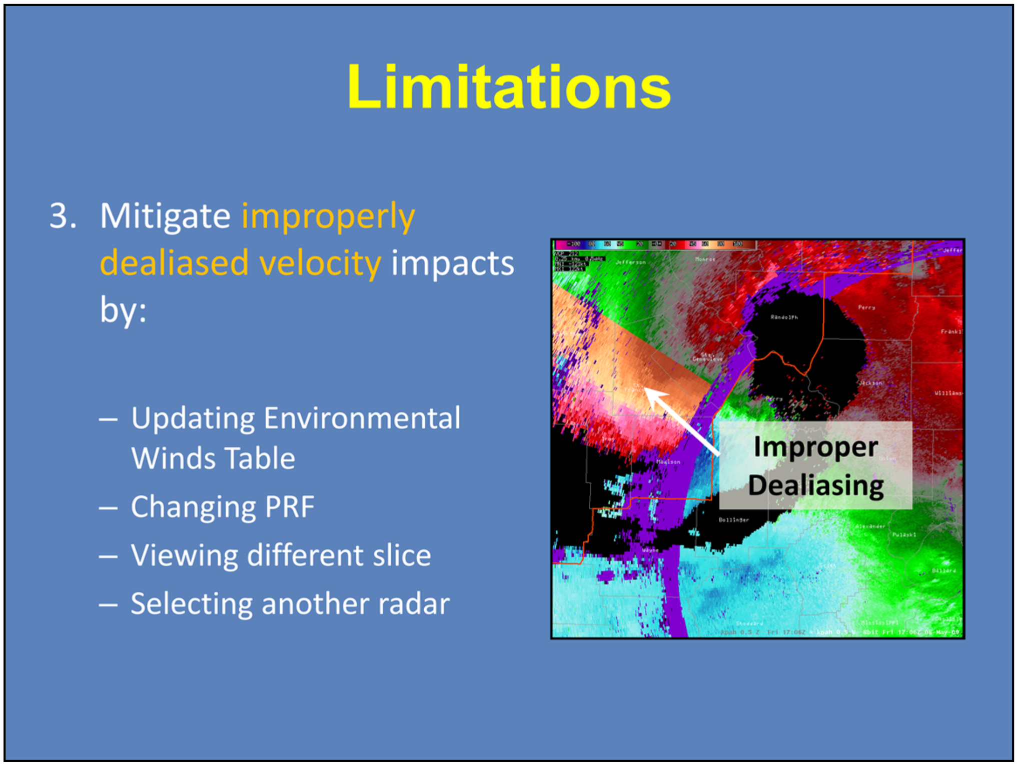

Improper dealiasing can be an issue with velocity although it's mostly been minimized with some recent work to mitigate it through a number of different algorithms. The image on the right is a good example of dealiasing, which is a tough word to say and even more tough to properly extrapolate true values when you see it. In the image, there is a large wedge of dealiased data, mainly the bright orange colors indicated by the black arrow. Here are few things you can do: update the environmental winds table, change the PRF, select a different elevation angle, or change radars.

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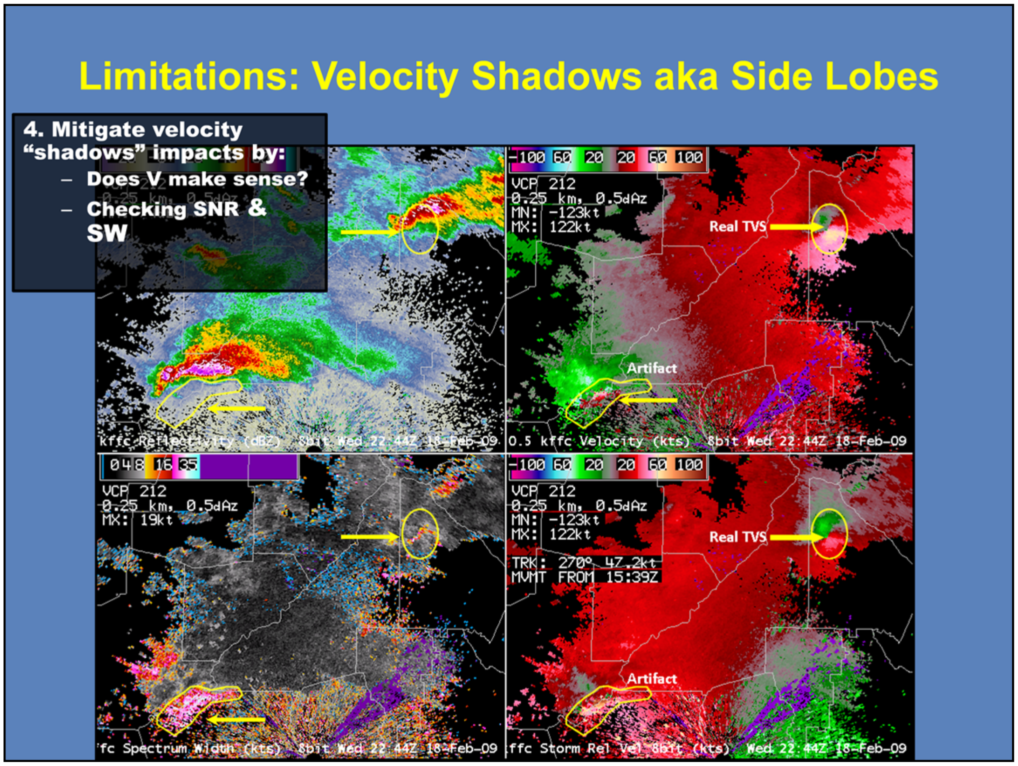

Another velocity limitation loosely termed "velocity shadows" can significantly affect warning decisions, particularly for tornado warnings. Numerous examples exist from the field where tornado warnings were sent out because of this signature. Let's define what they are: Velocity shadows are found in very weak reflectivity returns, normally on the inflow side of storms. You'll typically see them on the lowest elevation angles, and they are likely due to side lobe from very strong echo overhang. Here is an example of two storms at the 0.5 degree elevation angle. Notice that the SW storm has very weak reflectivity returns on the inflow side, and there are very strong rotational signatures in this area. For comparison, the storm to the NE also has very strong rotational signatures, but is a real signature and is far less noisy. For any strong velocity signature, check to see if it makes sense in terms of where in the storm it is located, if there is sufficient reflectivity return associated with it, and if spectrum width and/or general data quality is not overly noisy.

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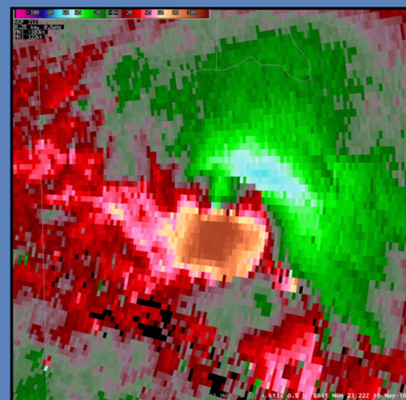
Applications: *Base Velocity*

1. Analyze storm structure
   - Gust fronts
   - Microbursts
   - Straight-line winds, etc.



The primary application of velocity is to identify significant storm-scale structures such as gust fronts, microbursts, straight-line winds, and many other storm-scale signatures.

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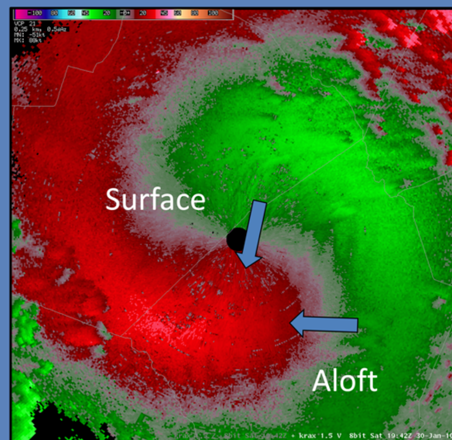
Applications: *Base Velocity*

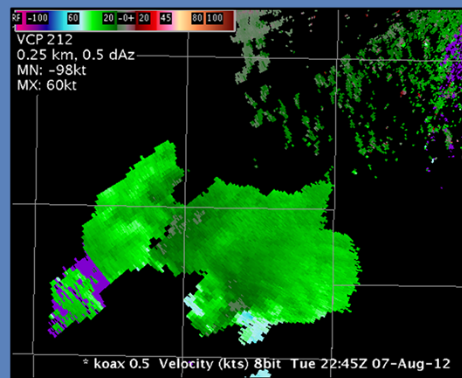
2. Determine atmospheric structure
   - Veering/backing winds
   - Low level jets, etc.



Velocity can also be used to determine synoptic scale wind patterns such as veering or backing winds, and low level jets. In the image on the right, the S-shaped pattern to the velocity indicates that the winds are turning clockwise with height meaning the winds are veering with height. This type of information can be useful for forecasts and anticipating storm mode when combined with other tools.

Applications: *Base Velocity*

3. Estimate velocity magnitudes
   – Use in warnings, statements and forecasts



Velocity can also be used to estimate velocity magnitudes for possible use in warnings, statements and forecasts. But, remember that it is radial velocity and not actual velocity. More on that in the next slide.

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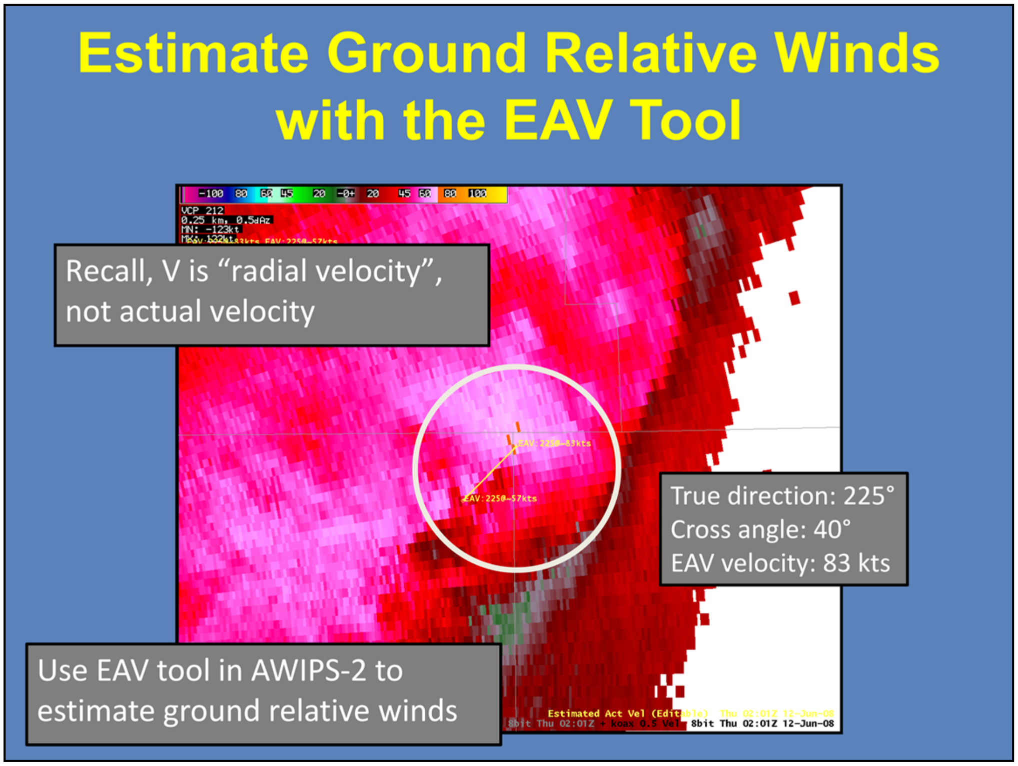

AWIPS-2 has a tool to help you estimate the actual velocity from a base velocity image, known as the estimated actual velocity or EAV tool. It is loaded from the tools menu in CAVE. Here is an example of the EAV tool on a 0.5 degree super-res velocity image of a bow echo. The goal is to orient the line along the direction you think the fastest winds are blowing. Keep in mind that errors of even 10-20 degrees from the true wind direction can result in large errors in the estimated ground relative wind speeds. In this example the gust front was moving from about 225 deg, resulting in a crossing angle of 40 degrees at the northeast tip of the EAV tool. The radial velocity is 70 knots outbound, and the EAV tool estimates 83 knots winds.

Applications: *Base Velocity*

4. Update/adjust hodographs

Finally, velocity information can be used to update and adjust hodographs. This is especially useful since RAOB information is only updated twice, maybe 3 times, per day and radar updates every 5-10 minutes. So in fast evolving cases, this type of updating can be very helpful.

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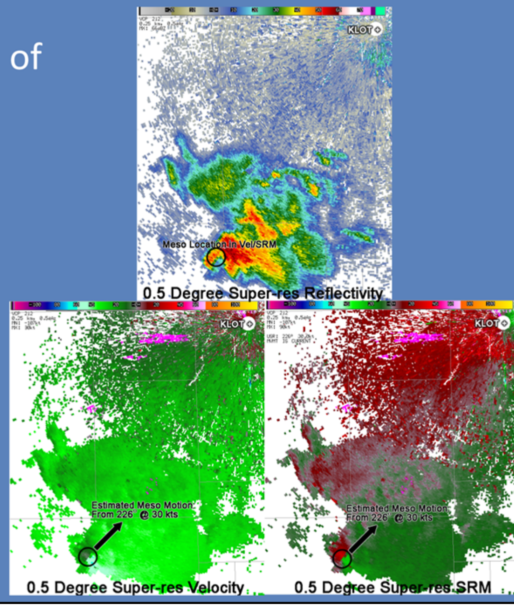
Applications: *SRM*

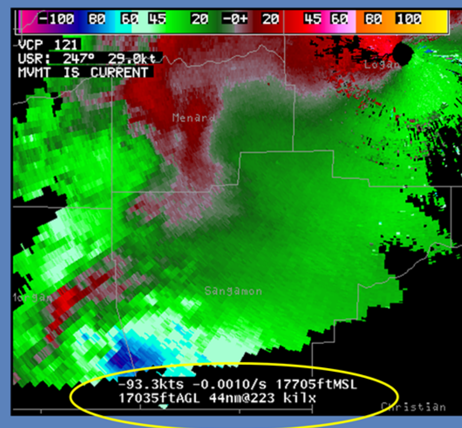
1. Improved detection of velocity signatures:
   - TVSs
   - Mesocyclones
   - Microbursts
   - Boundaries



Now, on to some SRM applications or benefits, to wrap-up this section. The concept behind SRM is to help improve detection of certain velocity signatures. For example, look at the image on the right. In the lower right is SRM and in the lower left is velocity. Notice how the rotational signature shows up in both products, but it is easier to see in SRM. This is the beauty of SRM; improved detection of velocity signatures like rotation.

Applications: *SRM*

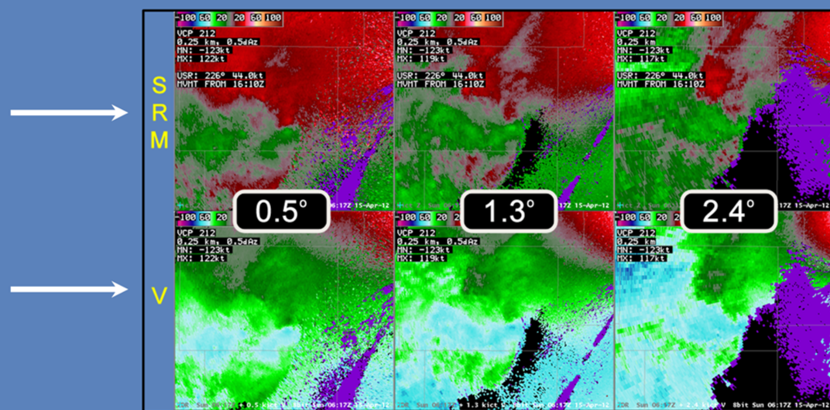
2. High SRM values (up to 248 kts) are displayable and viewable on cursor readout sampling



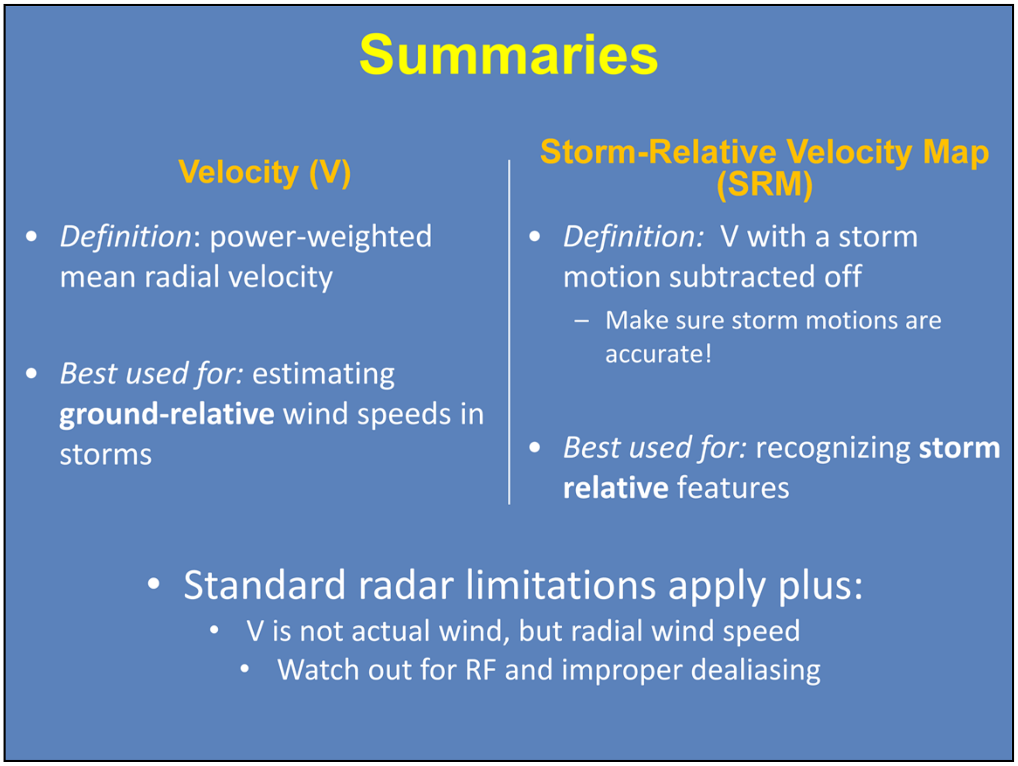
Using cursor readout, the values from the SRM product are displayable, so you can estimate various values such as rotational velocity or delta-V.

Applications: *SRM*

3. Useful for examining the velocity structure of fast moving storms (>10 kts)



In fast moving storms, the velocity field can become saturated by the inbound or outbound colors, making it difficult to see certain signatures. In this example, the lower panel is V and the upper panel is SRM. Notice how both show a velocity couplet, but it is much easier to identify in SRM.

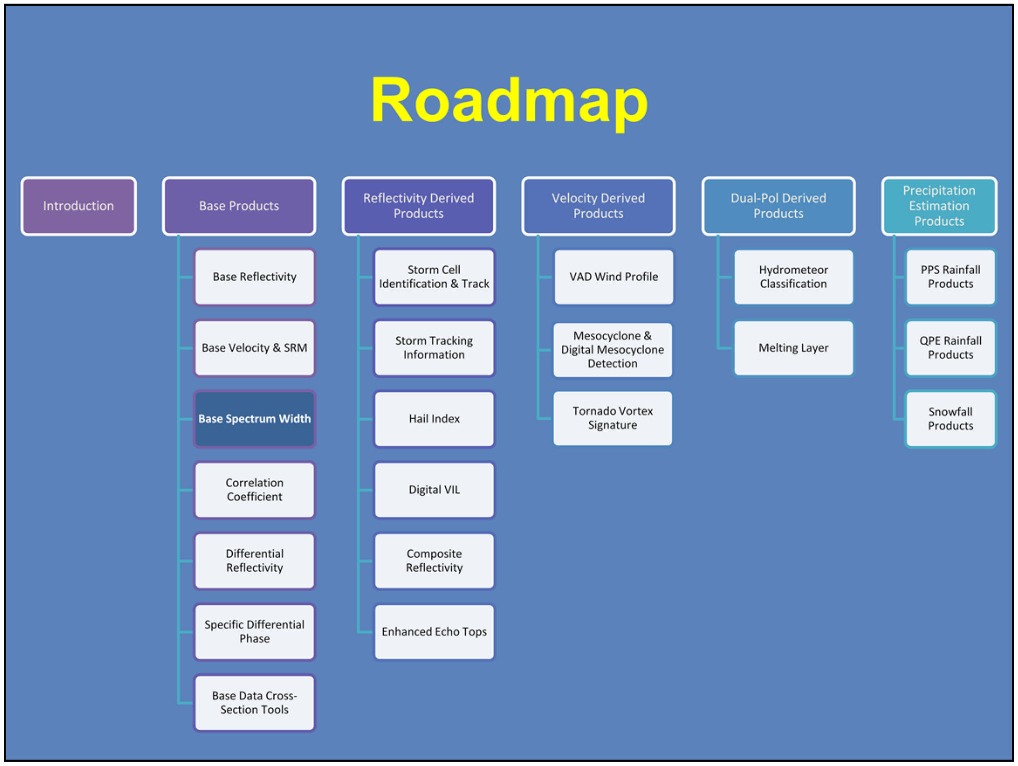


Let's go ahead summarize this lesson. First, velocity is the power-weighted, mean radial velocity of all targets within the resolution volume. It is great for estimating ground-relative winds speeds in storms and determining atmospheric and storm-scale structures.

Meanwhile the SRM is basically the velocity with storm motion subtracted off of it. This aids in recognizing storm-relative features much more easily. However, make sure your storm motions are accurate in addition to other limitations that apply, such as the angle relative to the radar and which you are sampling.

For both of these, standard radar limitations apply, and remember that V is not actual wind, but radial wind speed – so just because you sample of pixel and get a number, like 42.7 kts – that does not necessarily mean that the true velocity or speed of the particulates in that pixel. Also, watch out for RF and improper dealiasing.

Welcome to the much underrated but no less important, Base Spectrum Width. Let's get started.



This is the third lesson for the series of Base Products with four more to go after this. Head to the next slide, when you're ready.

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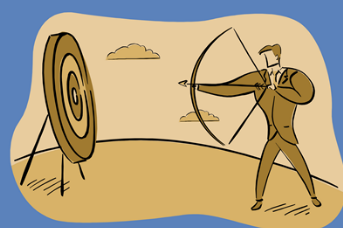
Learning Objectives

Identify the characteristics, limitations, and applications (strengths) of the Spectrum Width (SW) product.



As with the previous base product lessons, the goal of this lesson on Spectrum Width is to provide you with an understanding of the characteristics, strengths, and limitations of the product.

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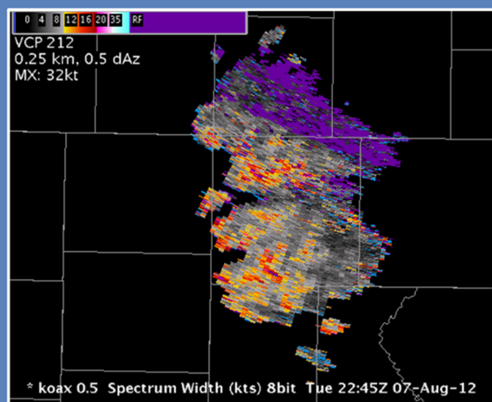
Definition

- **Spectrum Width (SW)** is the amount of velocity dispersion occurring in a resolution volume



- The amount of "chaos" in a range bin

Spectrum Width is defined as the velocity dispersion within a resolution volume. In other words, the product shows the variability of the individual target motions within a resolution volume. Perhaps the easiest way to look it though, is that Spectrum Width is the amount of "chaos" going on within a range bin. The more chaos or turbulence targets are experiencing within that area, the higher the value, and vice versa.

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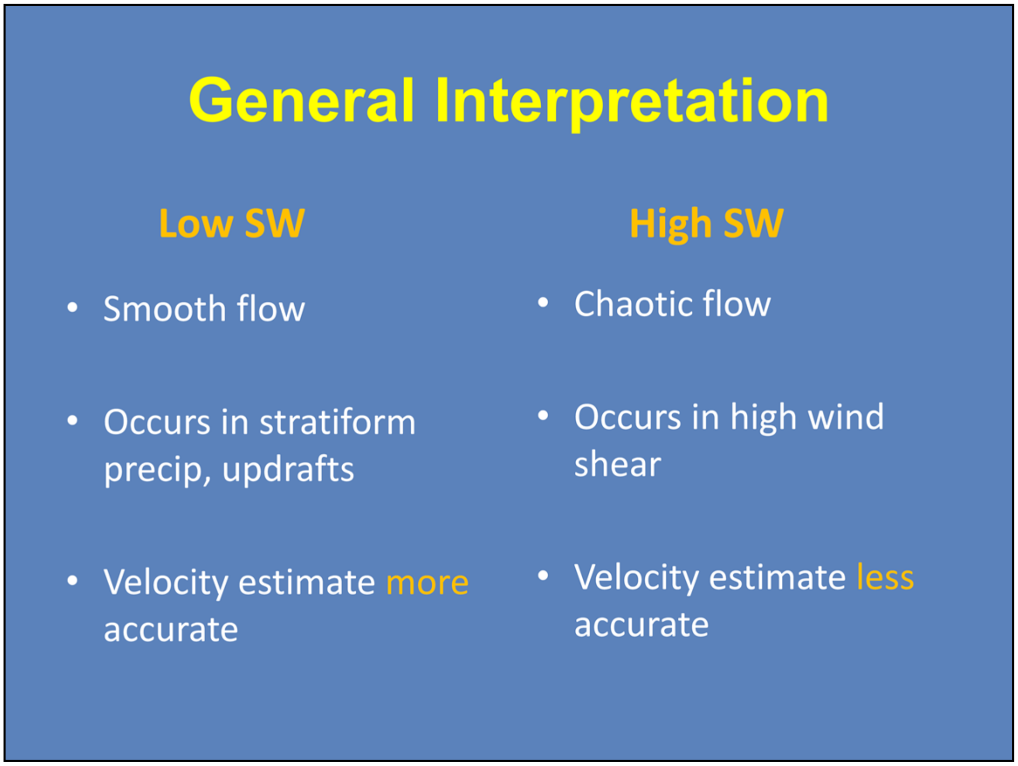


Low spectrum width implies low velocity dispersion, or relatively smooth flow. This most often occurs in regions of quiescent stratiform precipitation, and in regions of uniform flow like you see in thunderstorm updrafts. Perhaps the biggest takeaway or use of the product is that low SW implies that your velocity estimates are more accurate, thus giving you more confidence that the values you're seeing is correct.

High spectrum width on the other hand, suggests chaotic or turbulent flow. This tends to occur in regions of high wind shear. In these areas, the radar velocity estimates tend to be less accurate. This of course is useful to know when working the radar.

Products Available

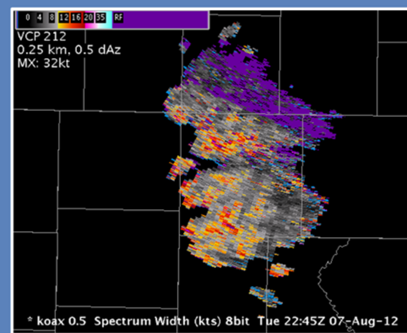
Product Name	Units	AWIPS ID	RPG ID	RPG Code	Data Levels	Range Res	Az Res	Max Range
Base Spectrum Width	kts	SW	SW	28	3-bit (8)	0.25 km	1 deg	60 km
Base Spectrum Width	kts	SW	SW	30	3-bit (8)	1 km	1 deg	230 km
Super Res Spectrum Width Data Array Product	*kts*	*SW*	*SDW*	*155*	*8-bit (256)*	*0.25 km*	*0.5 deg*	*300 km*

Only products highlighted in white will be discussed in this lesson

Here are the SW products available from the RPG. Note there is only one 8-bit, super-res product, which is all we will talk about in this lesson. The 3-bit products are available, but use these only if you are having bandwidth issues in your office.

General Product Characteristics

- Polar coordinate display
- 1° beamwidth, 0.5° for super-res
- Displayed relative to the RDA site



- Available for any elevation angle of the current VCP

The Spectrum Width product is displayed in polar coordinates with a 1 degree beamwidth except for the split cut elevations, where it has a 0.5 degree beam width. All data are displayed relative to the RDA site and are available for any elevation angle of the current VCP.

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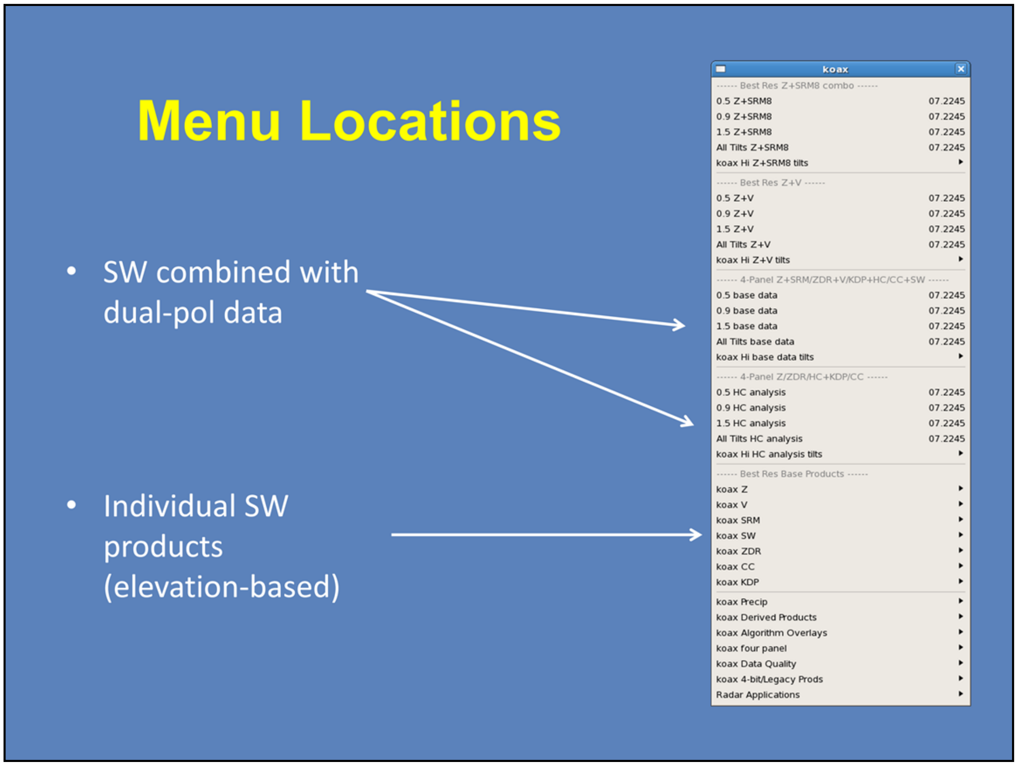

You can find Spectrum Width combined with other base data in the two 4-Panel areas highlighted in the dedicated radar's drop down menu. You can also find individual spectrum width elevation-based products in the Best Res Base Products section.

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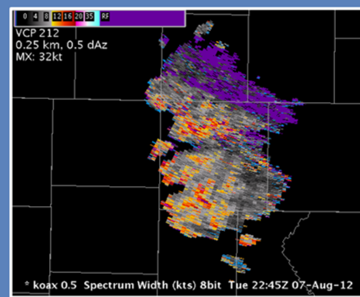
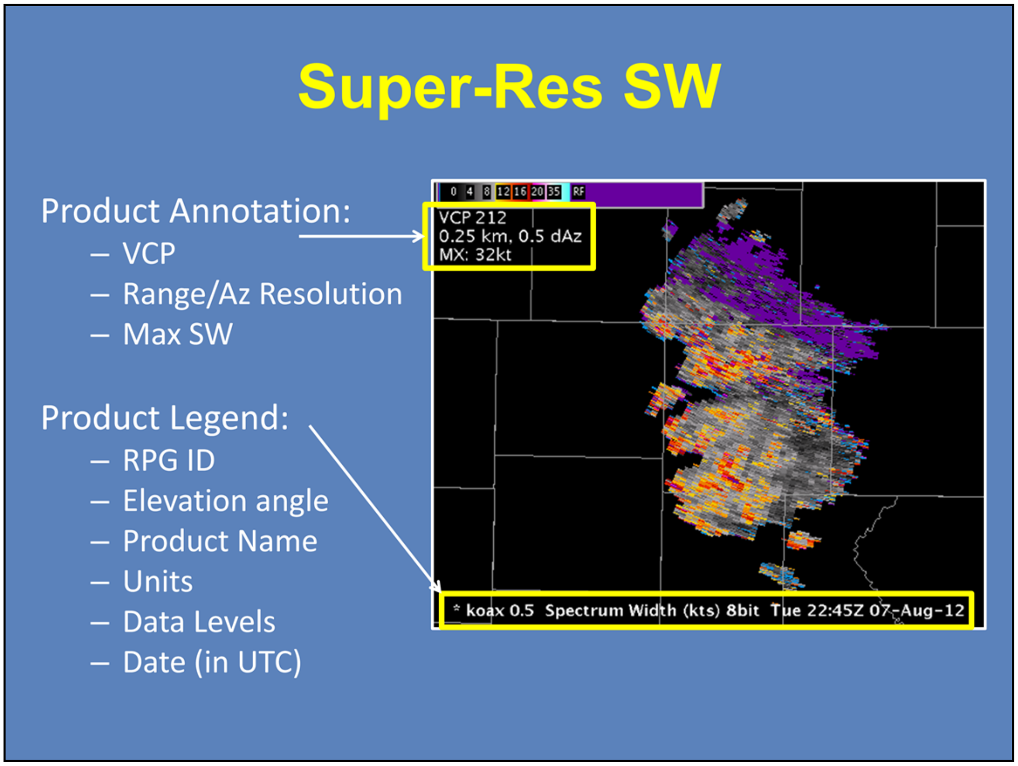
Super-Res SW

- Resolution:
  - Split cuts: 0.5° x 0.25 km
  - Above: 1° x 0.25 km
- Range: 162 nm



- Best depicts most meteorological signatures

Super-res SW has 0.5 deg x 0.25 km resolution in the split cut elevations and 1 deg x 0.25 km resolution above that. The range resolution extends to 162 nm and is the preferred product to help identify most meteorological features.



Here is the product annotation for SW, which is pretty much the same as the base products shown previously.

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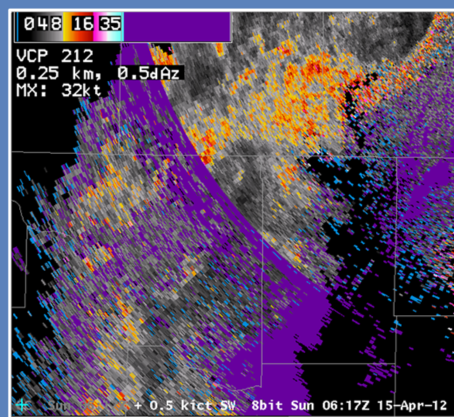
Limitations

- Range folding may obscure some data



So now, some limitations. Since Spectrum Width is just the measure of the velocity dispersion, range folding impacts Spectrum Width just as it does other velocity products. So apply the same solutions you learned previously for mitigating range folding to Spectrum Width.

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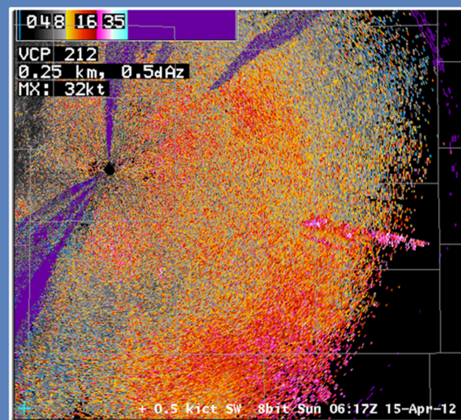
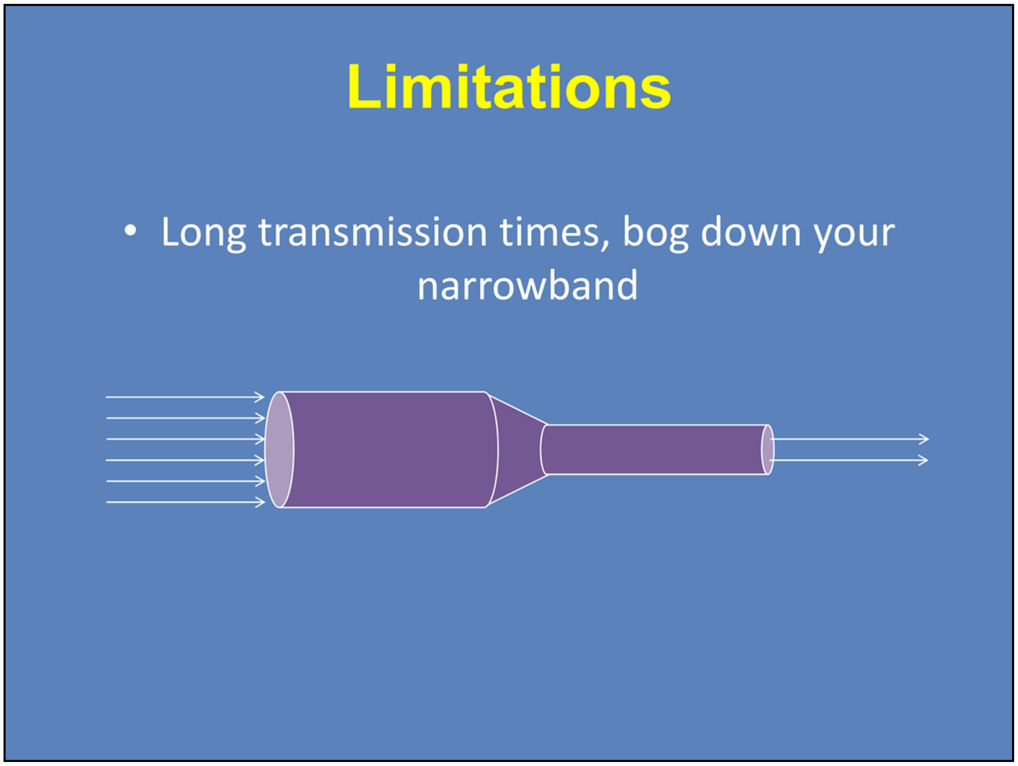
Limitations

- System noise from weak power returns
  - Increases SW
  - Most notable in clear-air returns



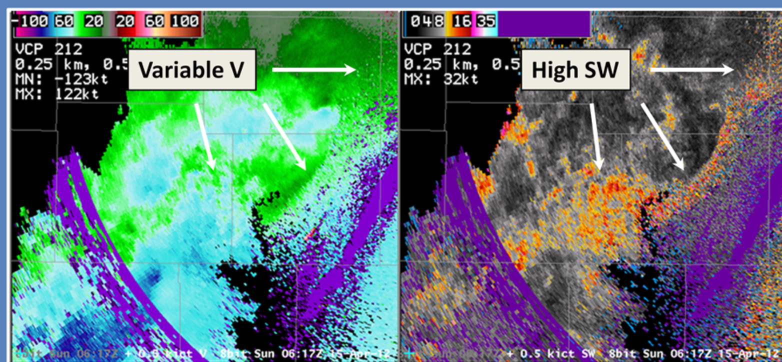
If the power return is very weak and the signal is dominated by system noise, then Spectrum Width values will increase substantially. The most likely region for this to occur is in clear-air.



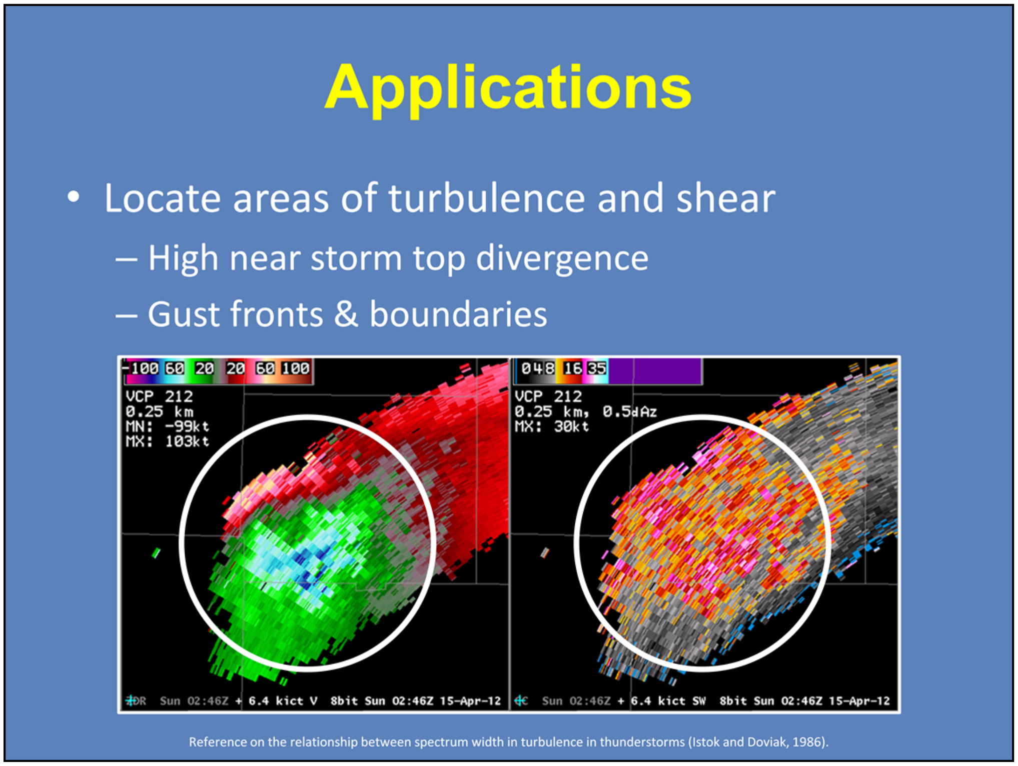
The 8-Bit Spectrum Width has a large file size and thus takes time to transmit over narrowband comms. Thus, it can bog down your system. If you are having issues with your bandwidth, limiting the amount of spectrum width data requested is an option.

Applications

- Evaluate velocity data
  - High (low) SW indicates more (less) certain velocity values



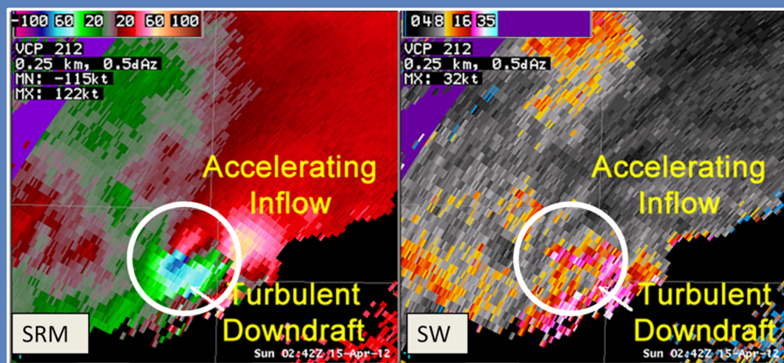
This first and perhaps the most important application of SW is one we alluded to earlier. Spectrum Width helps evaluate the quality of the velocity data. High SW values can indicate a poor estimate of the mean radial velocity values due to turbulence, shear, or a low signal-to-noise ratio within the pulse volume. Recall, that a low signal-to-noise ratio can indicate that reflectivity values are probably too low to obtain good velocity estimates. However, if you check the corresponding reflectivity values and find them to be even modestly high (normally > 5 dBZ but dependent on range to the target) then poor signal-to-noise ratio is probably not the reason for the broad spectrum width. Note that in this example the variability we see in the velocity field is consistent with the Spectrum Width product. Also, it is important to note here that high spectrum width does not imply incorrect velocity estimate, but rather that the estimate is less trustworthy.



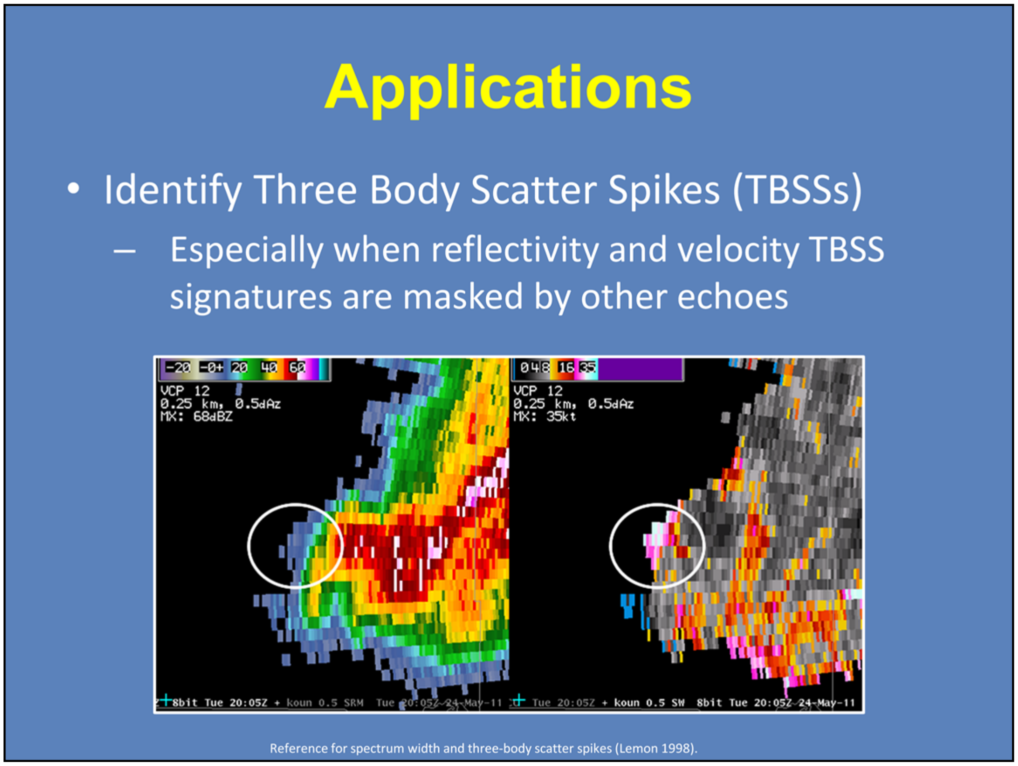
Spectrum Width can be useful for identifying regions of intense turbulence. Some examples where turbulence and shear are high are storm-top divergence and gust fronts. An example of high spectrum width associated with storm-top divergence can be seen in the images shown. Reference on the relationship between spectrum width in turbulence in thunderstorms (Istok and Doviak, 1986).

Applications

- Identify accelerating/decelerating flow
  - Inflow → accelerating → low SW
  - Downdrafts → decelerating → high SW



Spectrum Width can be used to locate areas of accelerating and decelerating flow. Low spectrum width values within the updraft are expected for intense updrafts or updrafts characterized by higher helicity (updraft correlated with high vertical vorticity) values. Thus, the low spectrum width values within the updraft are almost always seen with supercells or with the most intense convective storms. The correlation of low spectrum width with the more intense updrafts (especially in the lowest 1/3 of storm depth) indicates turbulence dampening when flow is undergoing acceleration, as you would expect within an intense updraft. Conversely, flow undergoing deceleration occurs within downdrafts descending near the ground. In this example, the very high spectrum width correlates very well with the presence of a strong mesocyclone with a downdraft at low levels, indicating very turbulent flow.



Spectrum Width can be useful in locating Three Body Scatter Spikes, a feature often associated with severe criteria hail. In fact, many times it is easier and faster (as compared to the use of reflectivity alone) to identify the TBSS by simply scanning two or three SW products that cut through storms in mid-levels where three-body scattering is often more apparent. In the example, the TBSS is not obvious in the reflectivity product, but stands out dramatically in the SW.

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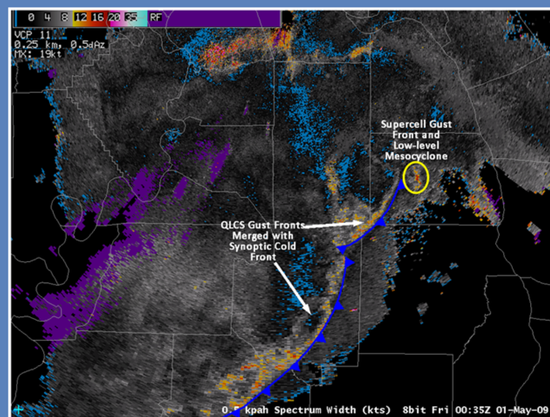
Applications

- Identify important meteorological boundaries

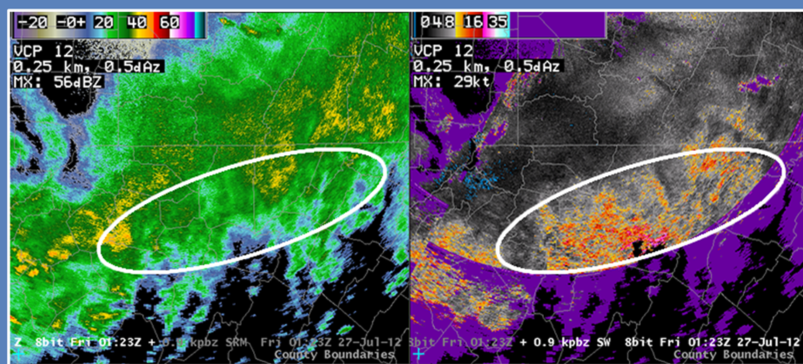
✓ Gust fronts
✓ Synoptic fronts
✓ Outflow boundaries



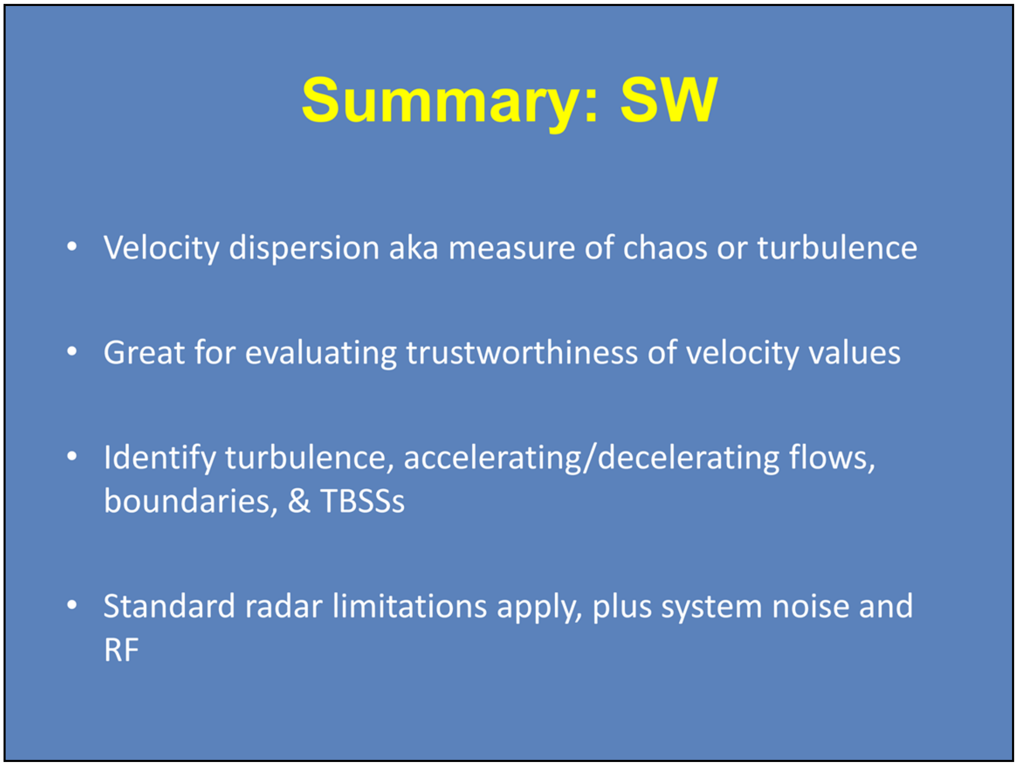
Because many meteorological boundaries create low-level turbulence, particularly boundaries that are moving rapidly, they show up nicely in Spectrum Width. Though Base Reflectivity and Velocity products are used to identify these types of boundaries, Spectrum Width can be used as well. In some cases, the boundary shows up best in Spectrum Width. This application should only be applied with the Super-Res Spectrum Width products available on the split cuts.

Applications

- Locate the melting layer
  - Different fall velocities within layer result in broad spectrum widths

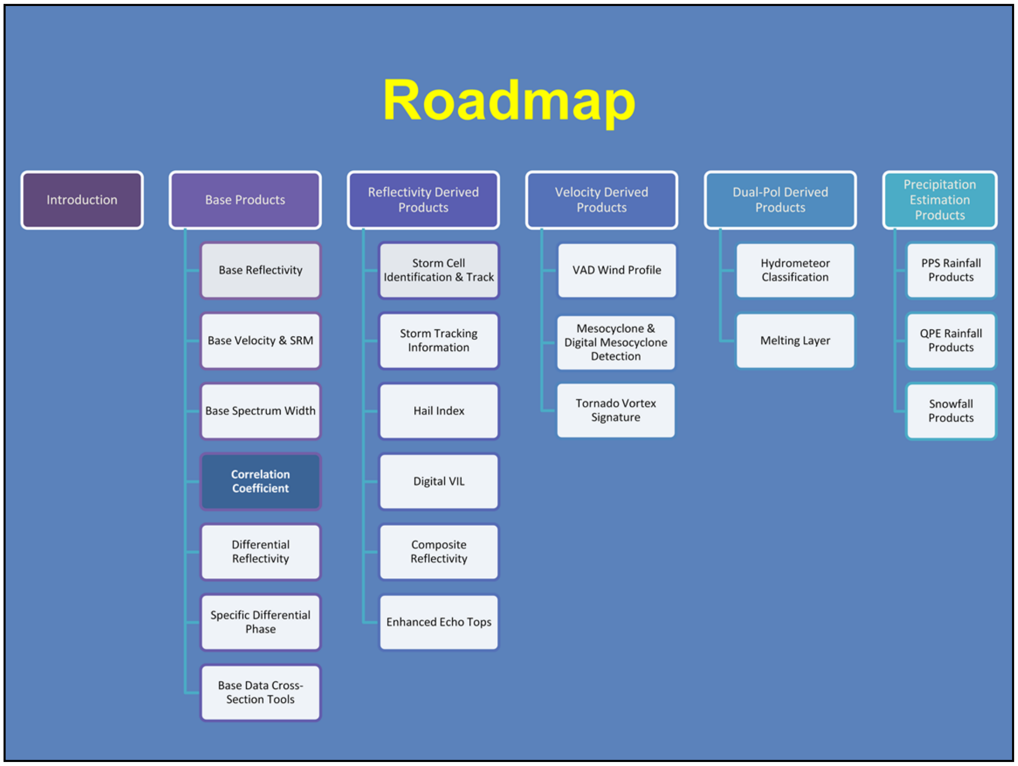


Within the melting layer there are complete ice-phase particles near the top and completely melted liquid-phase particles near the bottom. Liquid particles have faster fall speeds than ice particles, and the melting layer is usually thin compared to the width of the beam. These traits of the melting layer usually result in an observed velocity dispersion, which results in an increase in Spectrum Width values.

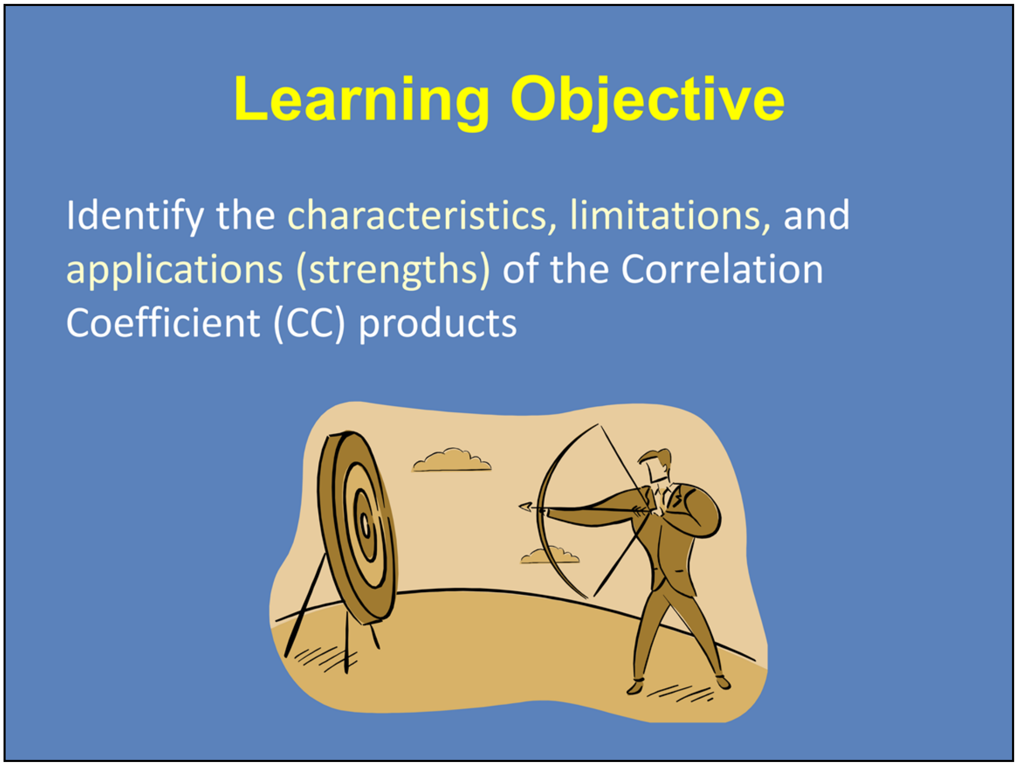


Summarizing this lesson, SW is a measure of the velocity dispersion within a resolution volume. In other words, is a measure of chaos or turbulence in a bin. It is great for evaluating the quality of the velocity values, thus making it useful to monitor next to velocity in your awips display. SW is also good for identifying turbulence, accelerating/decelerating flows, boundaries and TBSSs (which often suggest severe sized hail). As with the other base products, your standard radar limitations apply. Also be careful when interpreting SW in regions of low SNR and range folding.

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.



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

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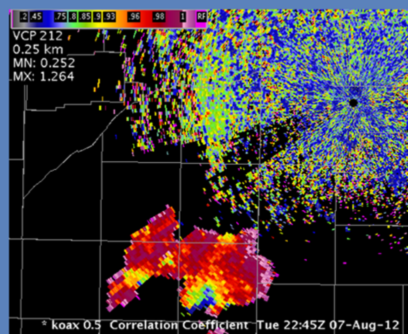
Definition

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.

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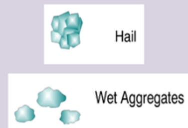
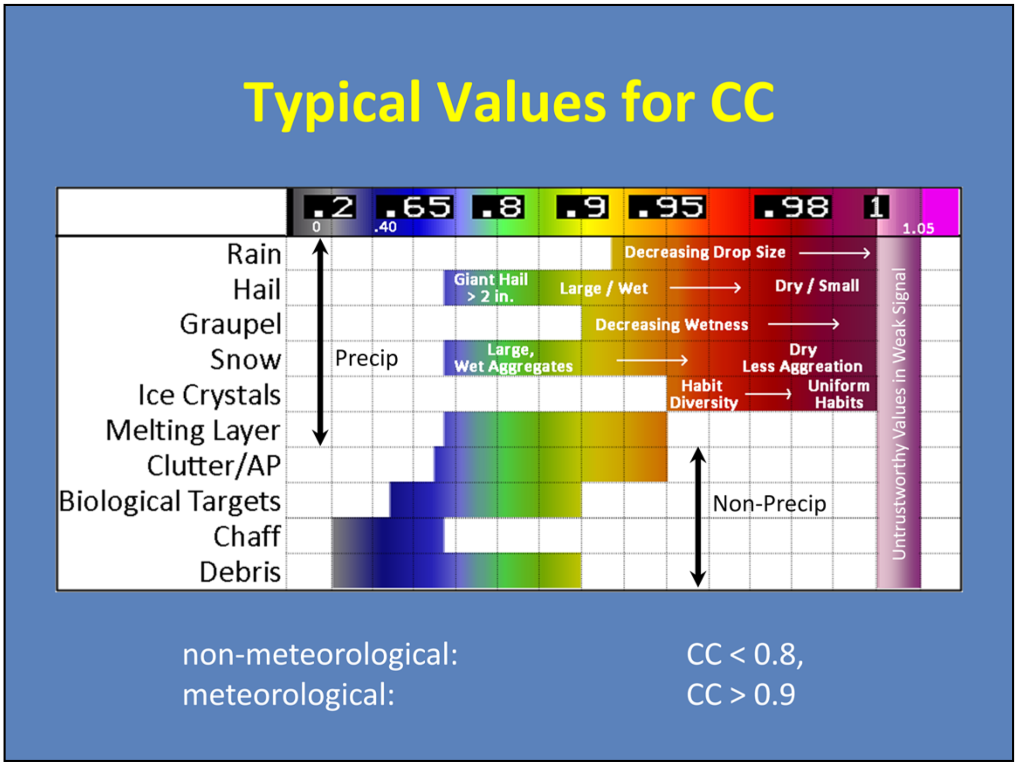
Non-Meteorological (birds, insects, etc.)	Metr (Non-Uniform) (hail, melting snow, etc.)	Metr (Uniform) (rain, snow, etc.)
		
Complex scattering from pulse-to-pulse.	Somewhat complex scattering from pulse-to-pulse.	Well-behaved scattering from pulse-to-pulse.
Low CC (< 0.8)	**Moderate CC (0.80 to 0.97)**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

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.



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.

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Products Available

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

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.

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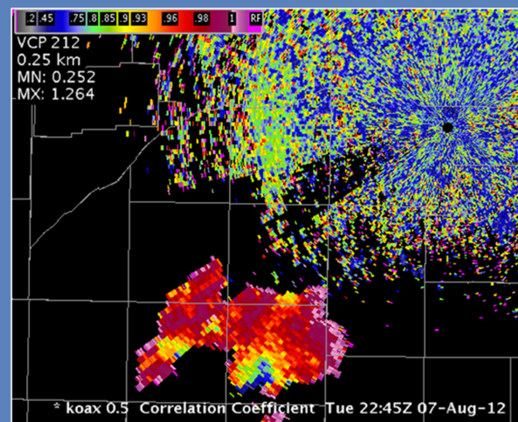
General Product Characteristics

- 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.

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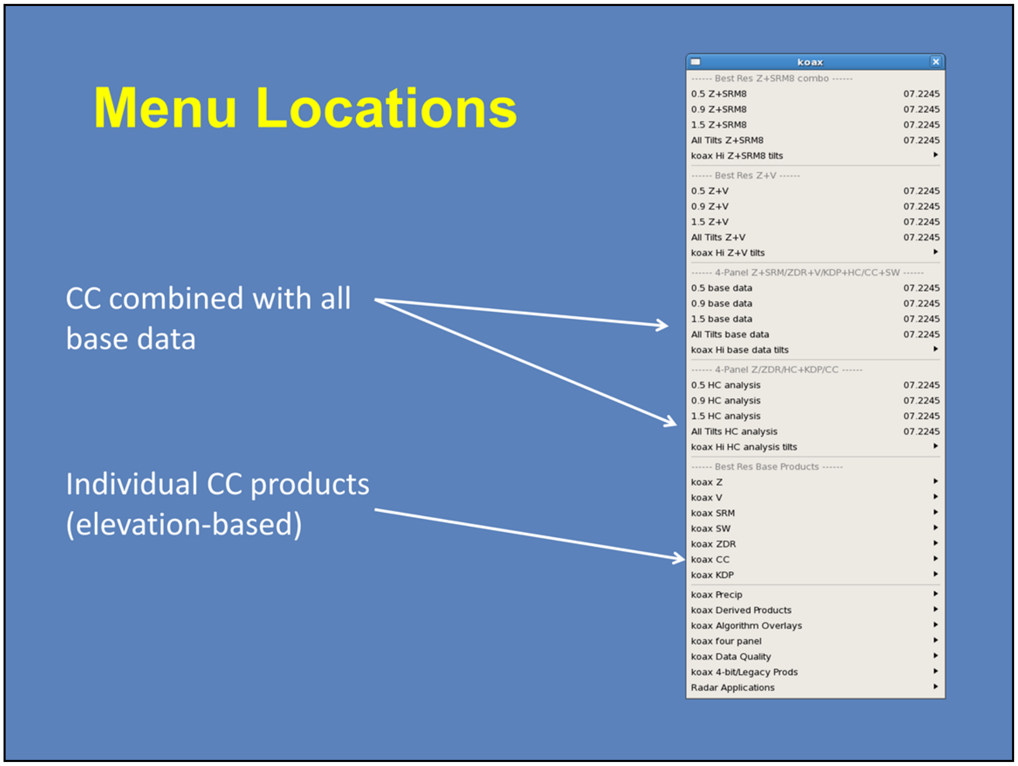

You can find the CC products combined with all base data in your dedicated radar drop-down menu in the first two options highlighted. And, the individual, elevation-based CC products can be found in the third option.

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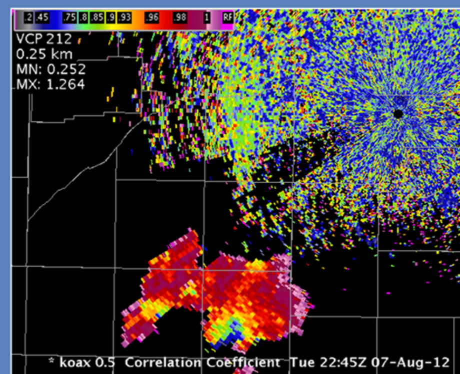
8-Bit Correlation Coefficient

- 1° x 0.25 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 deg x 0.25 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.

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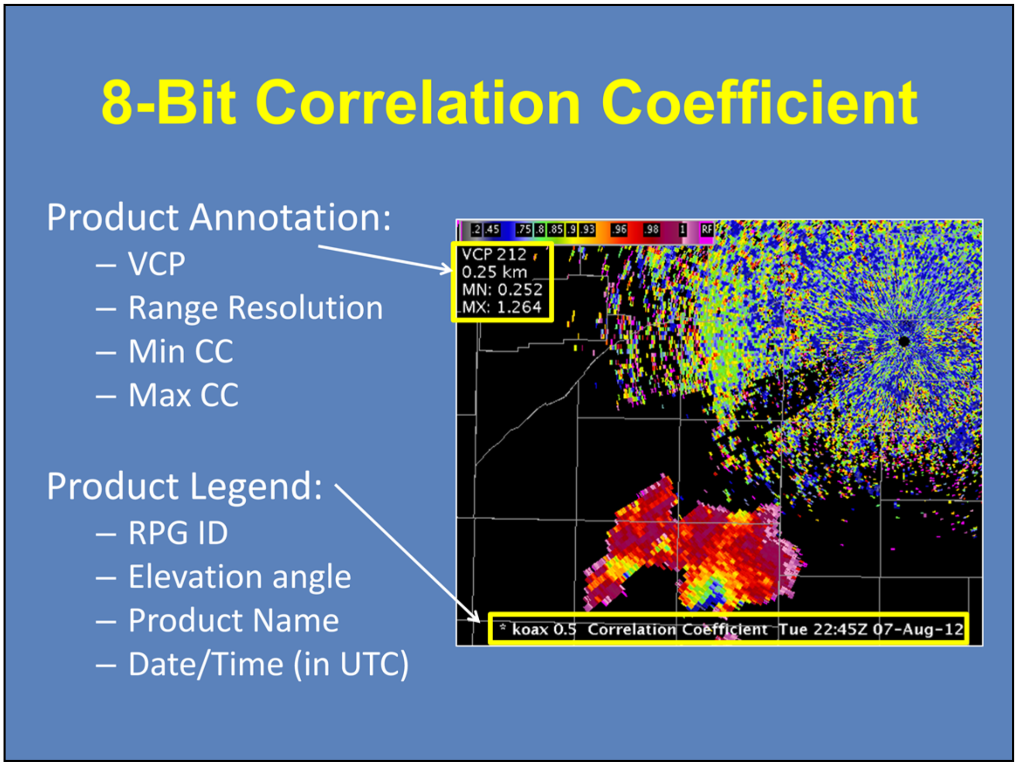
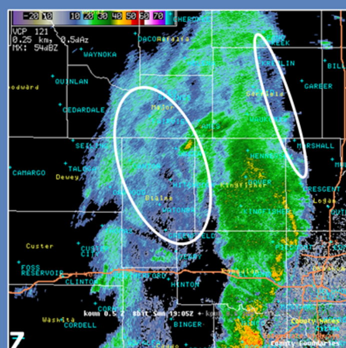
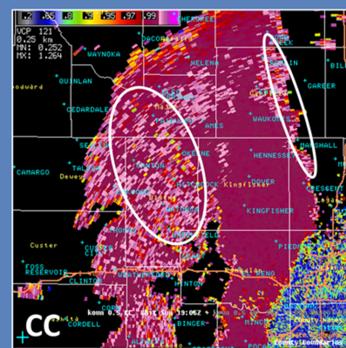


As with the other base products, the product annotation is in the upper-left portion of your display with the legend at the bottom.

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.

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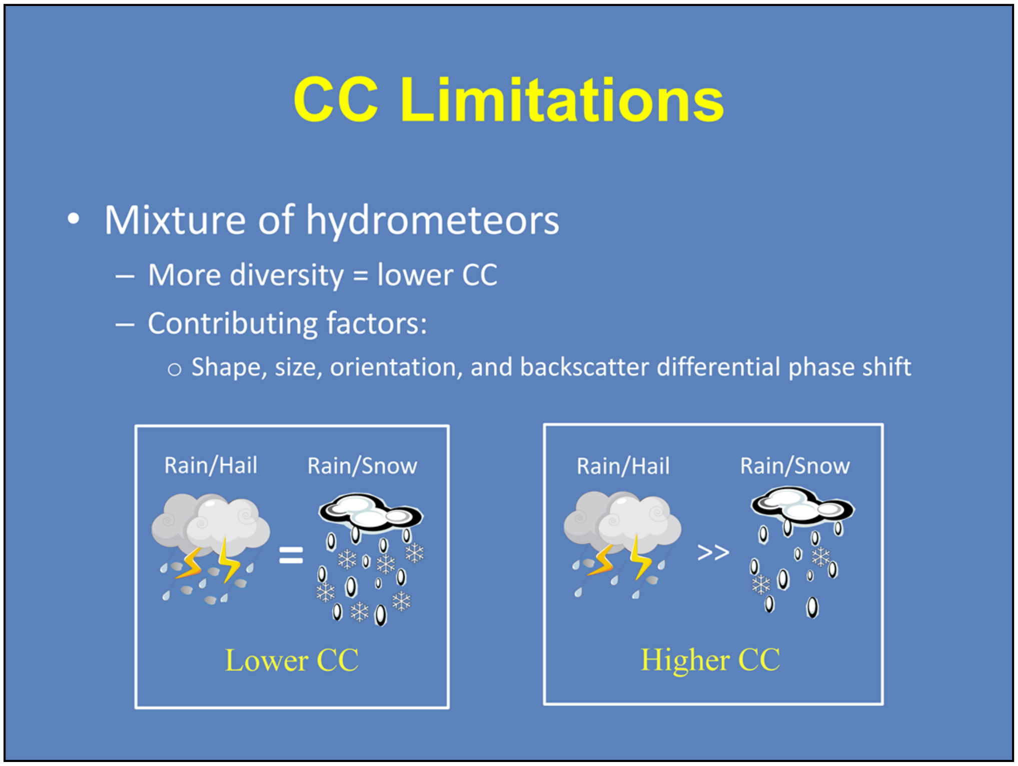
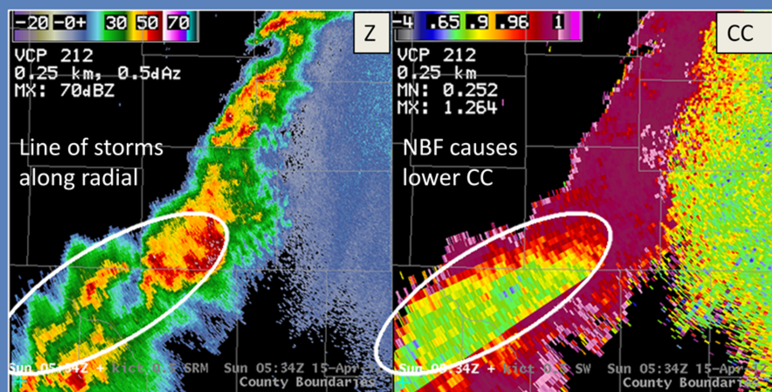


When two or more types of hydrometeors are present within a pulse volume, the correlation coefficient will decrease. The amount of decrease in the correlation coefficient is dependent upon the relative contributions of each hydrometeor type present to the overall signal. The lowest correlation coefficient 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

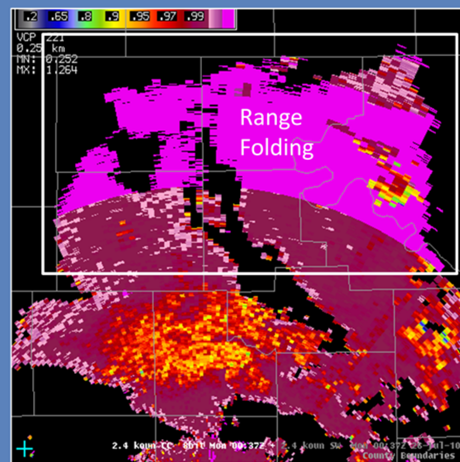


Non-uniform beam filling (NBF) can be detrimental to CC. It occurs when significant gradients of reflectivity and the polarimetric variables exist within the radar beam. The result of these gradients is an increase in the bias of the polarimetric variables, especially for CC. In CC, it is noted by a 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° & 6.5°



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.

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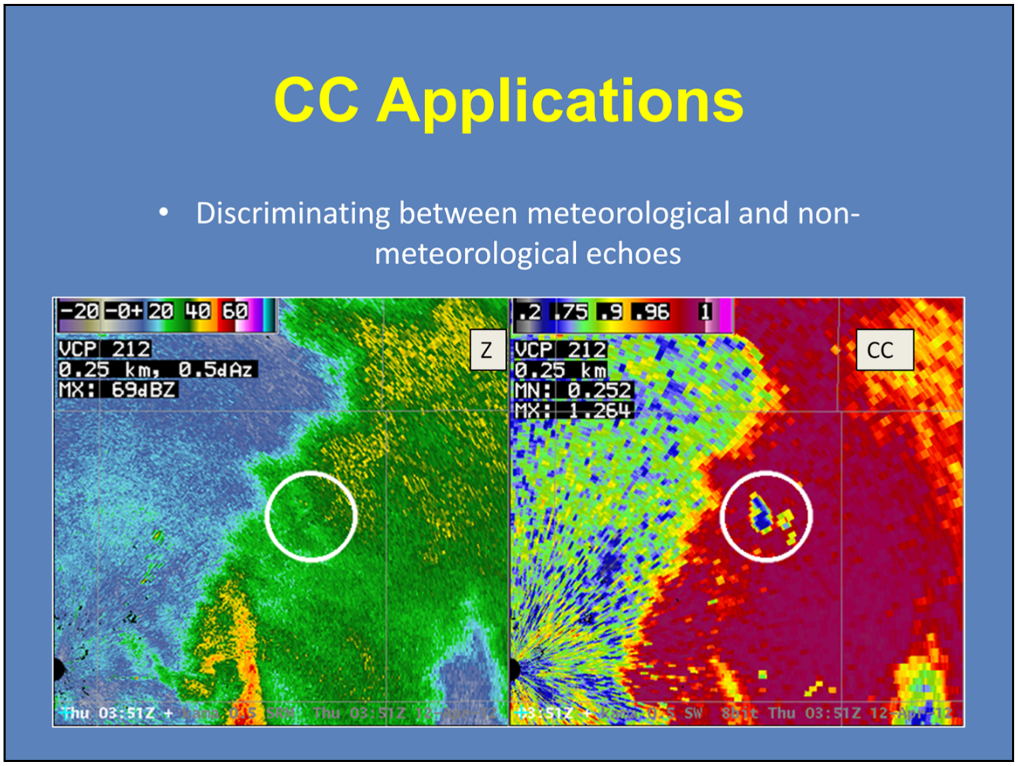
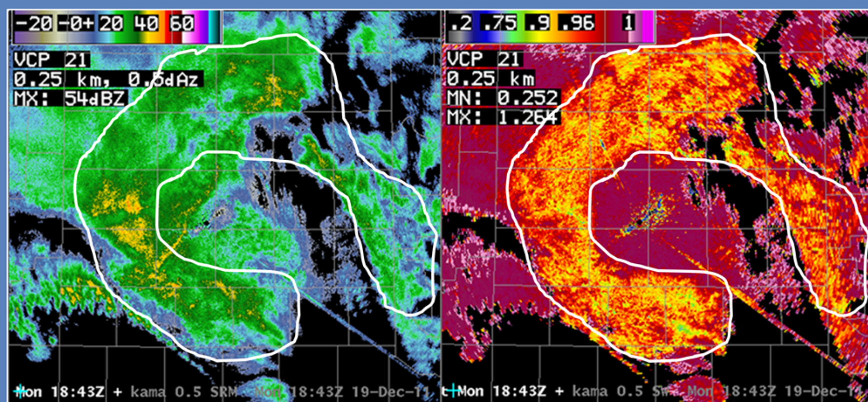


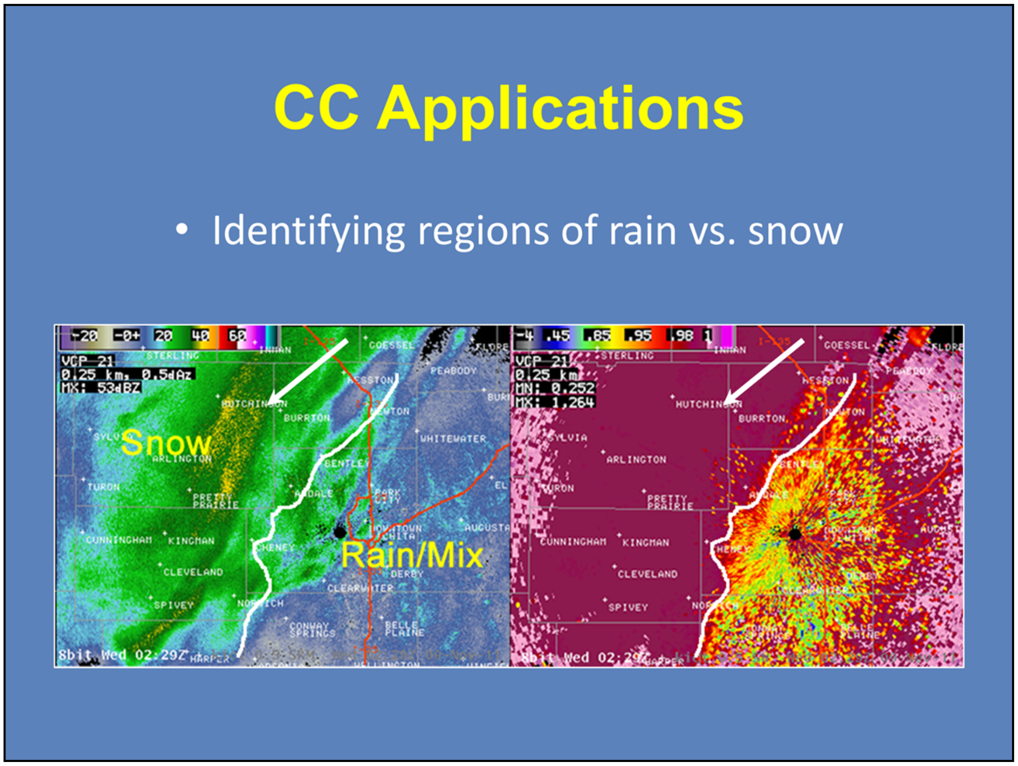
Now, on to the applications of CC. For one, it is best at discriminating between meteorological and non-meteorological echoes – which is why I mentioned that this will probably be – and should be – your first stop on the Dual Pol trail of products. Here is an example where in Z, it is very difficult, 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

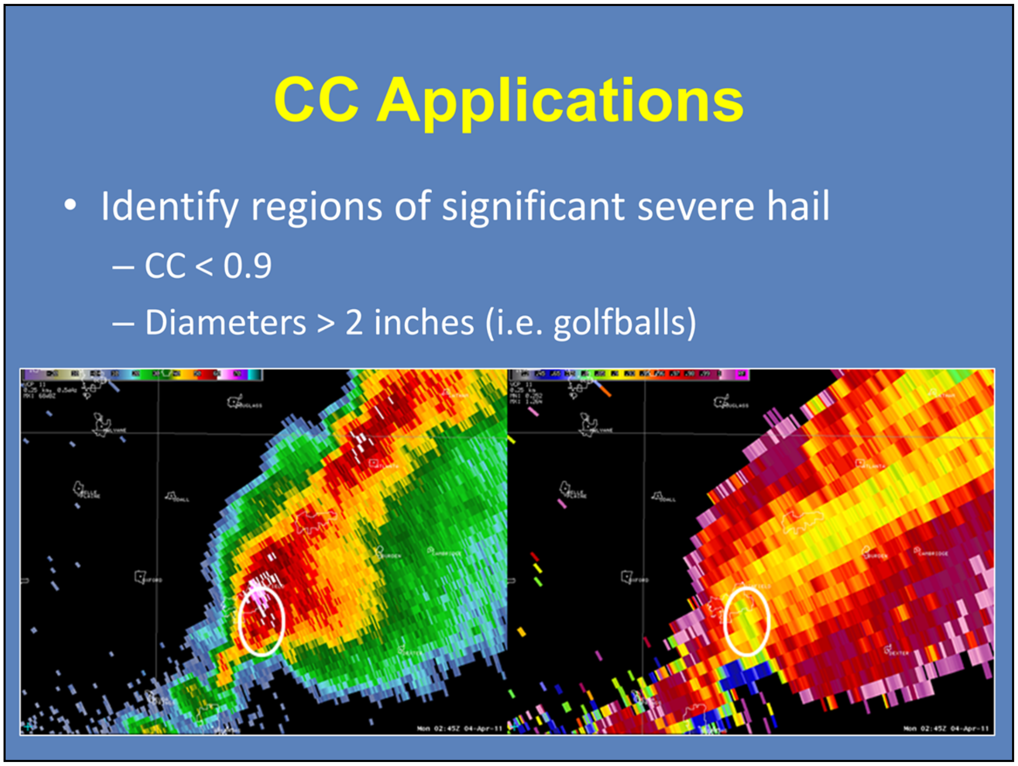
- Identifying the melting layer
  - Ring of lower CC



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.



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.



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.

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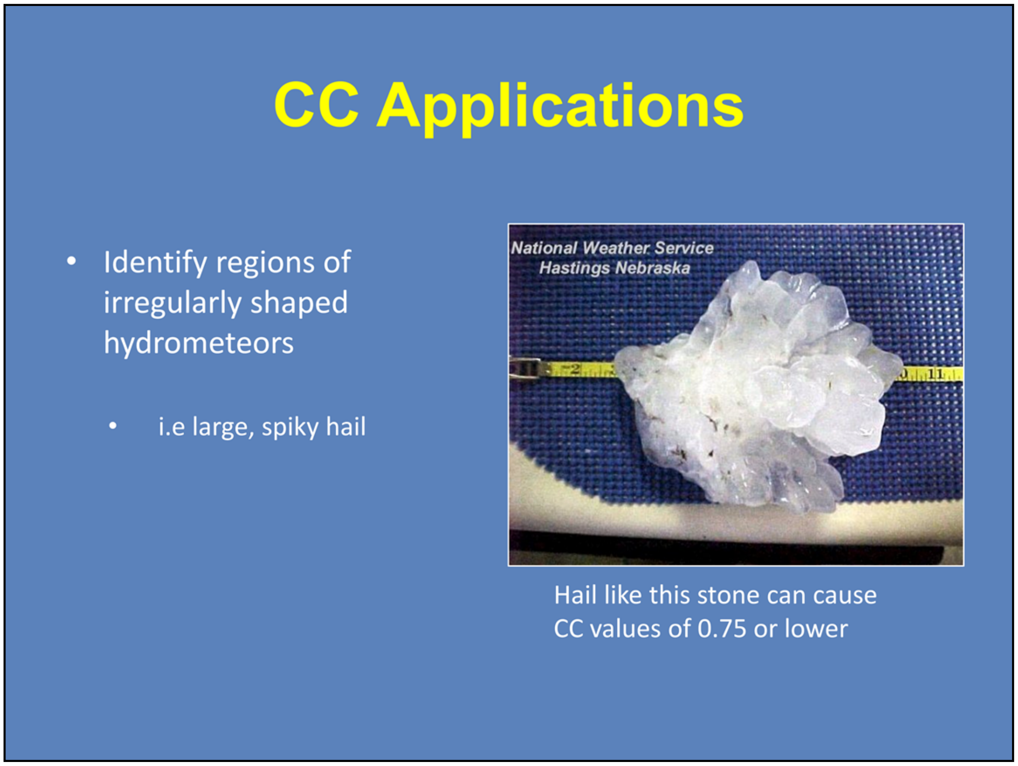
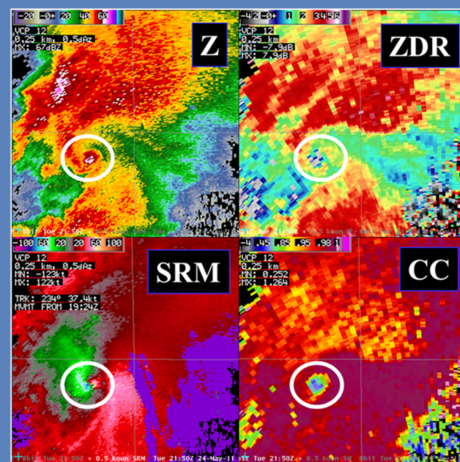


The same logic can be applied to spiky hail. Larger protuberances can cause CC to behave very oddly, reducing CC. There is not as much of a relationship here as with the previous slide. But, if CC are anomalously low, roughly less than 0.75, it is possible that irregularly shaped hail present.

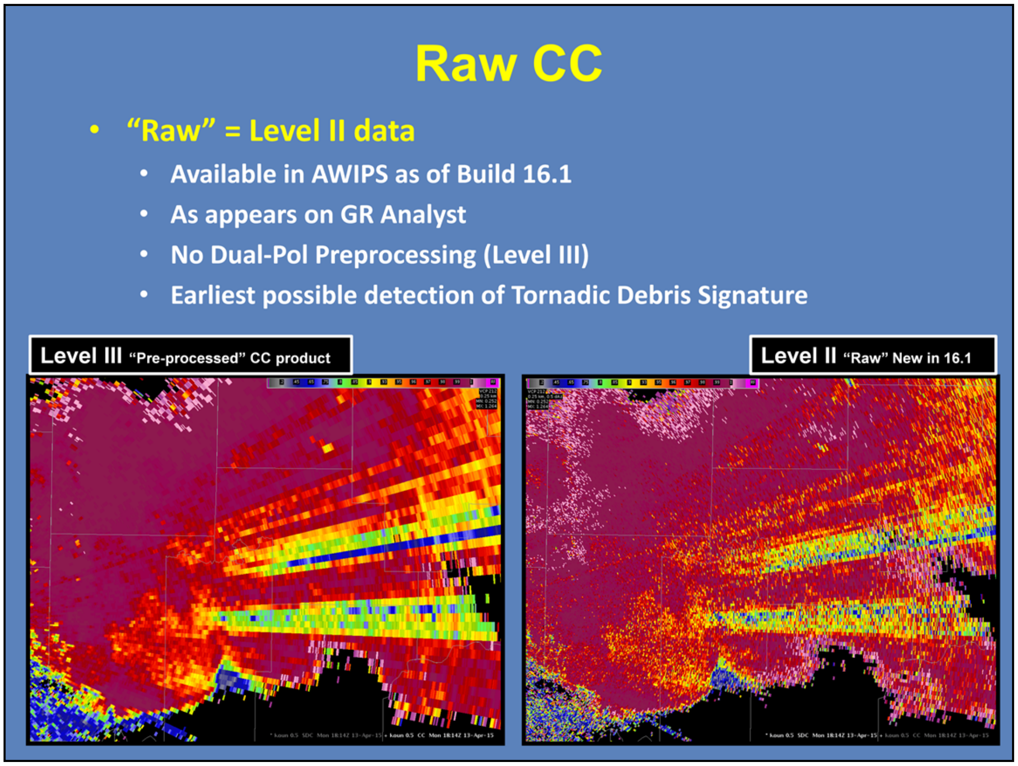
CC Applications

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



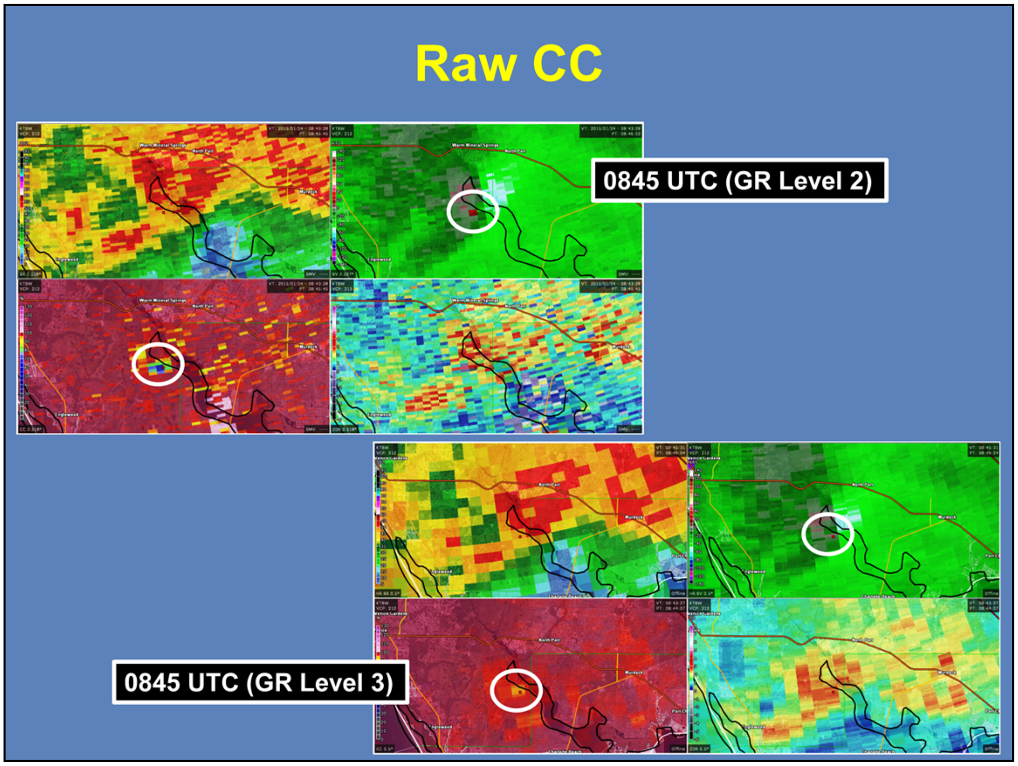
Probably one of the most well known and useful signatures with CC is the tornadic debris signature, or TDS. When you see a storm capable of producing a tornado by first looking at a combination of reflectivity, velocity, and SRM, CC can be used to help confirm the existence of a tornado. If you see CC's 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.

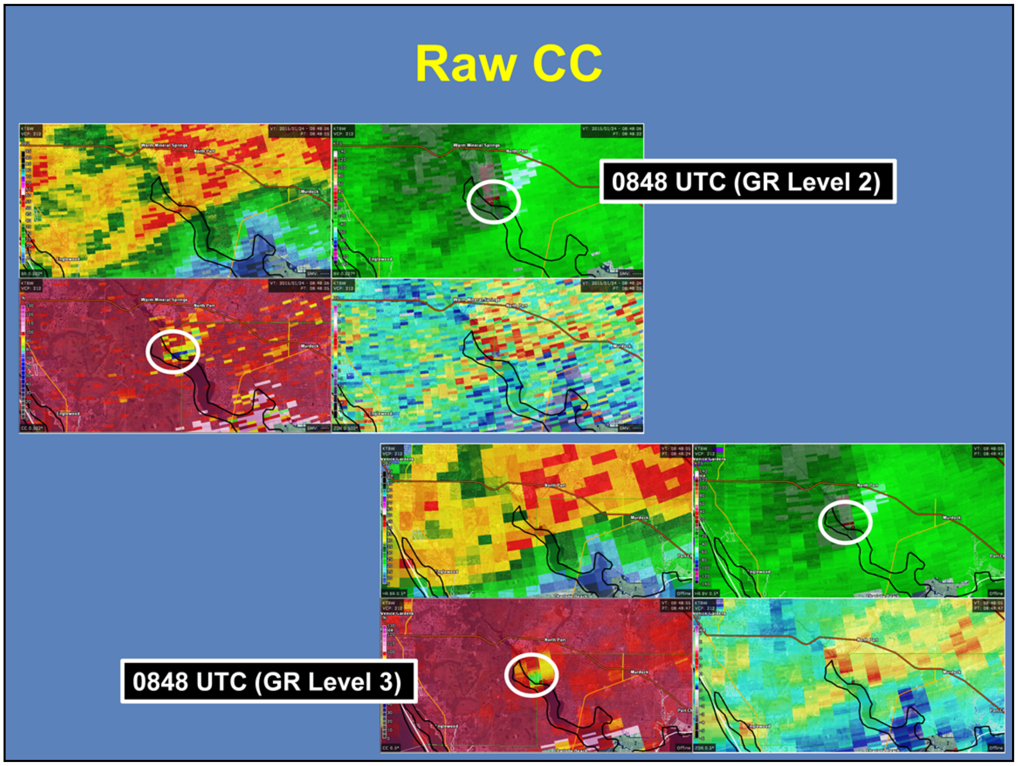


The second significant update with RDA/RPG Build 16.1 is the addition of the Raw CC Product. This product has been added to RPG product suite at the request of numerous WFOs, particularly in the southeastern U.S. Comparisons of the Level II Raw CC data on GR Analyst with the Level III CC product on AWIPS 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 Rae 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.



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.

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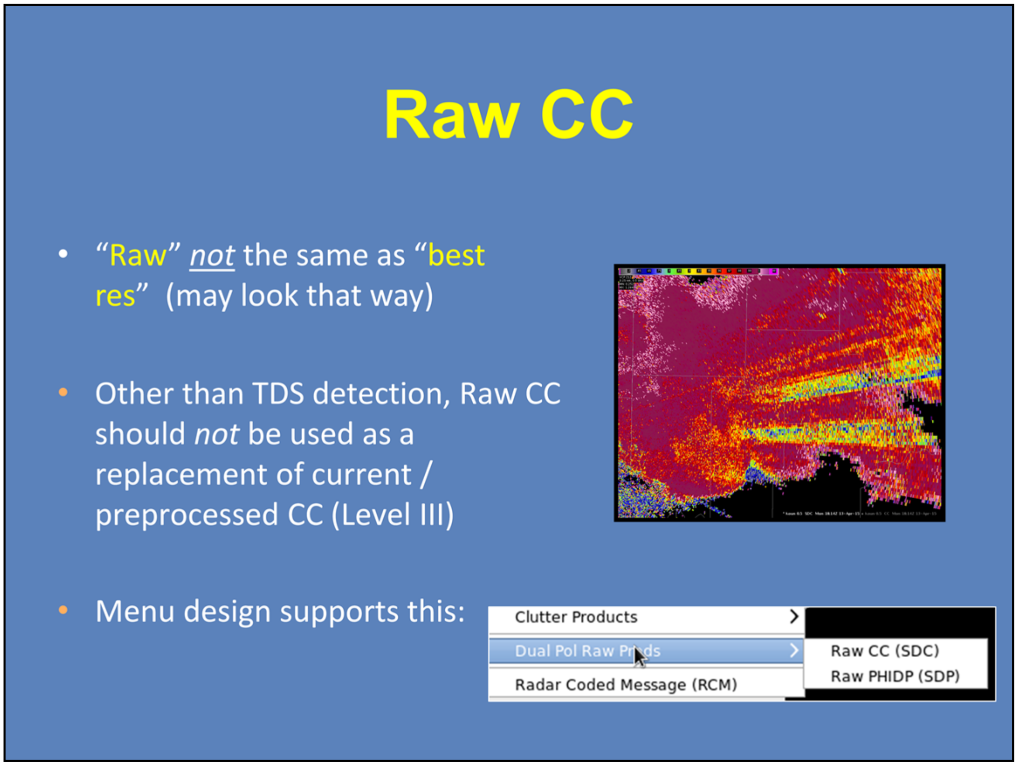

It is important to remember that "Raw" for CC does ***not*** mean the same thing as best res or Super-Res for a product like reflectivity.

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.

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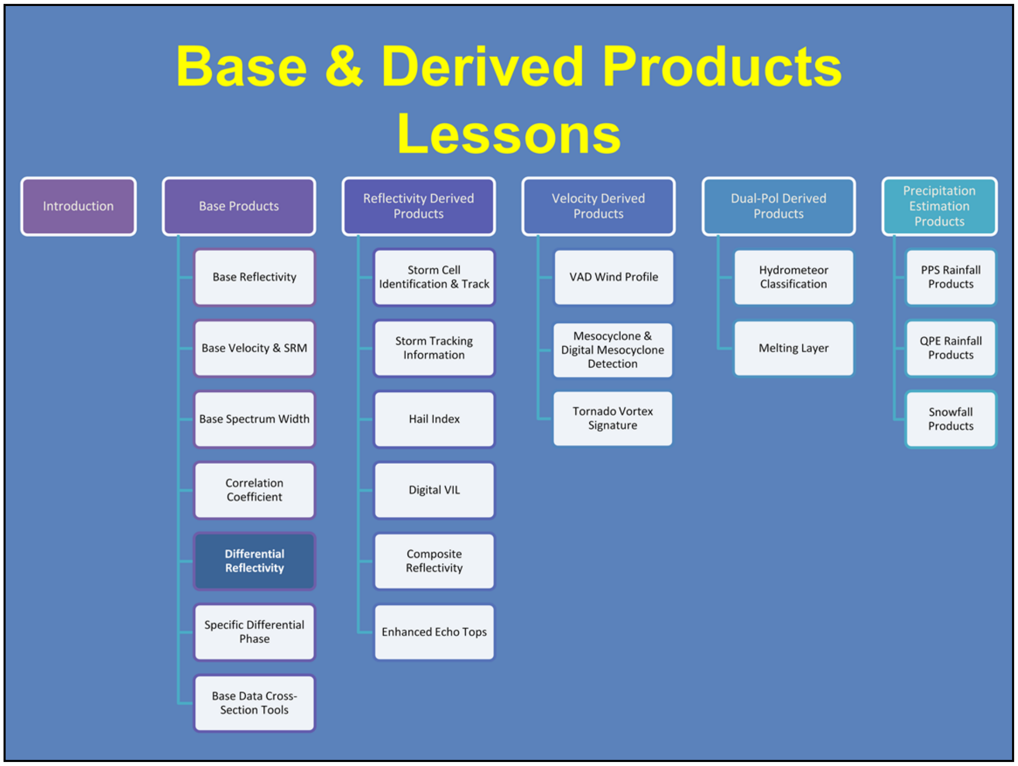
Welcome to RAC Topic 4, on Differential Reflectivity (ZDR).



Now, we’re on to the second of the Dual-Pol products lessons in the base products topic. Only two more to go from here.

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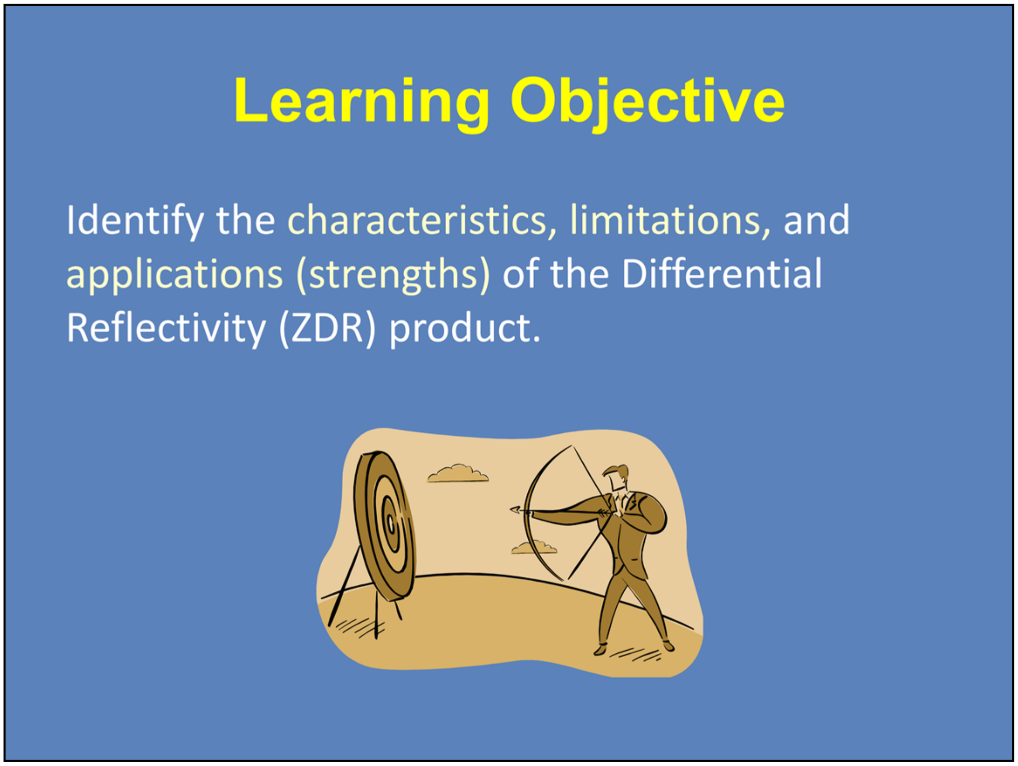
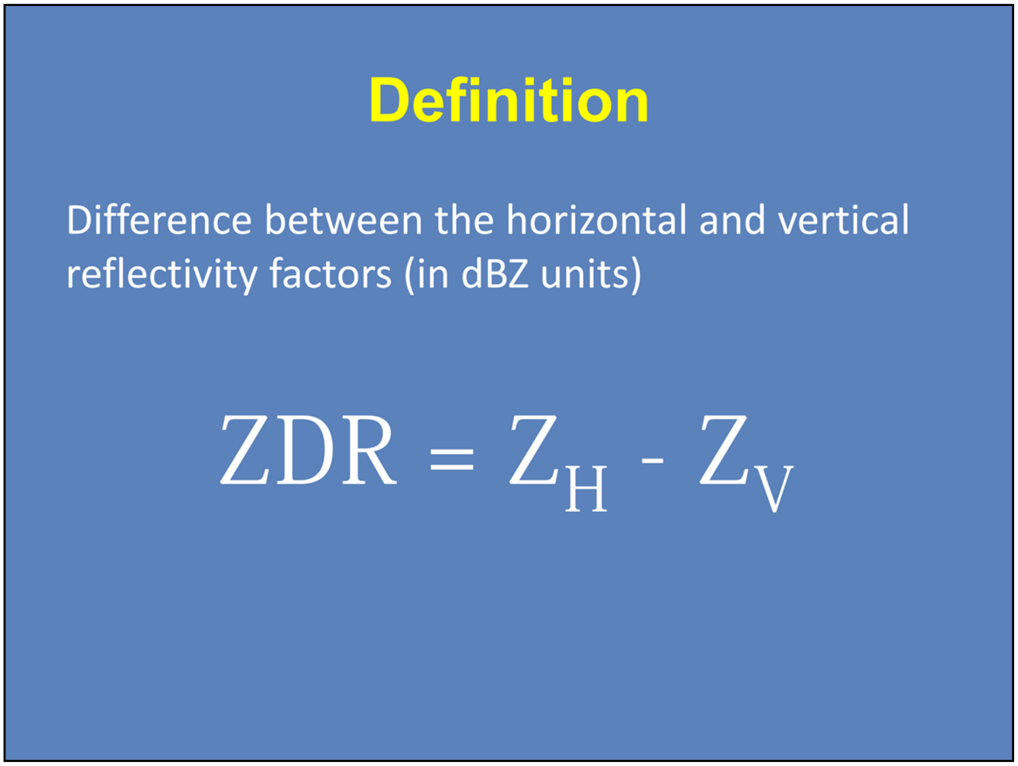


In this lesson we'll discuss the characteristics, limitations, and applications of the ZDR product.



ZDR – or differential reflectivity is just that, it is literally the difference in reflectivity values of a particulate’s horizontal and vertical components - in dBZ units, just like base reflectivity. The equation is seen here.

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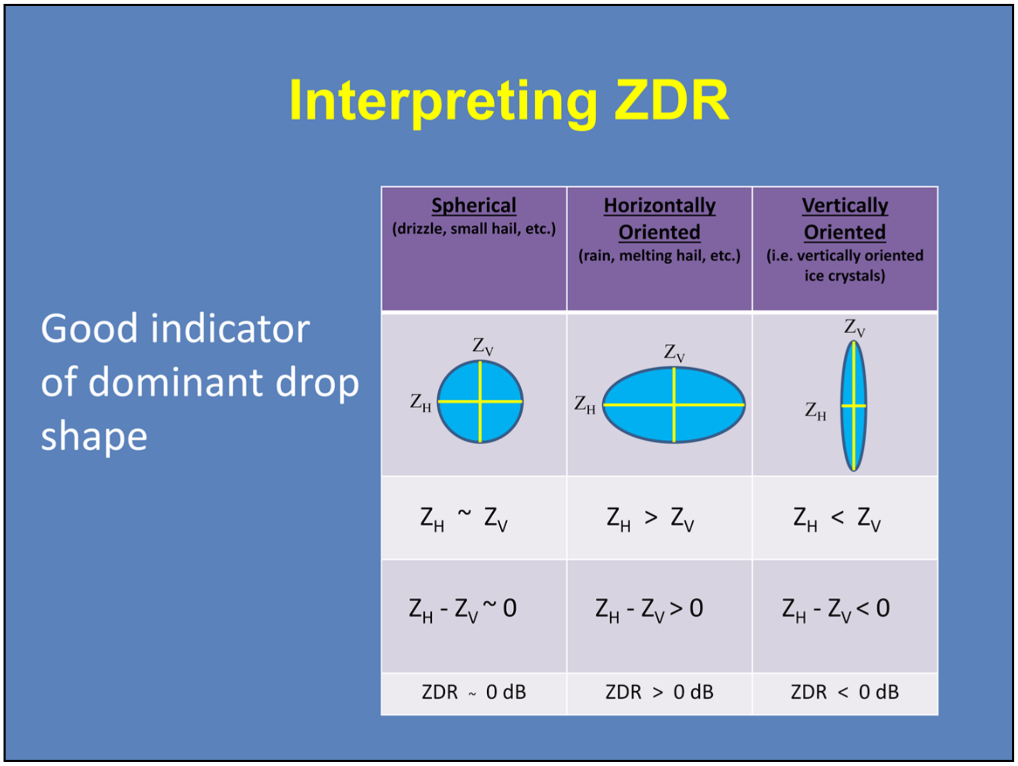
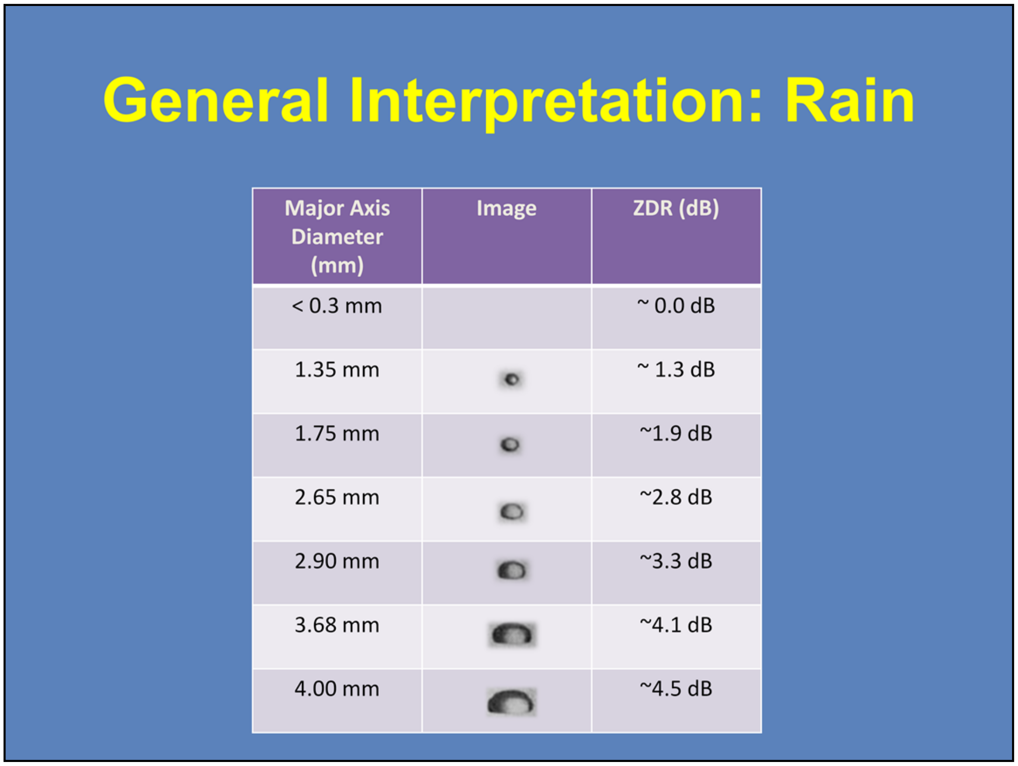
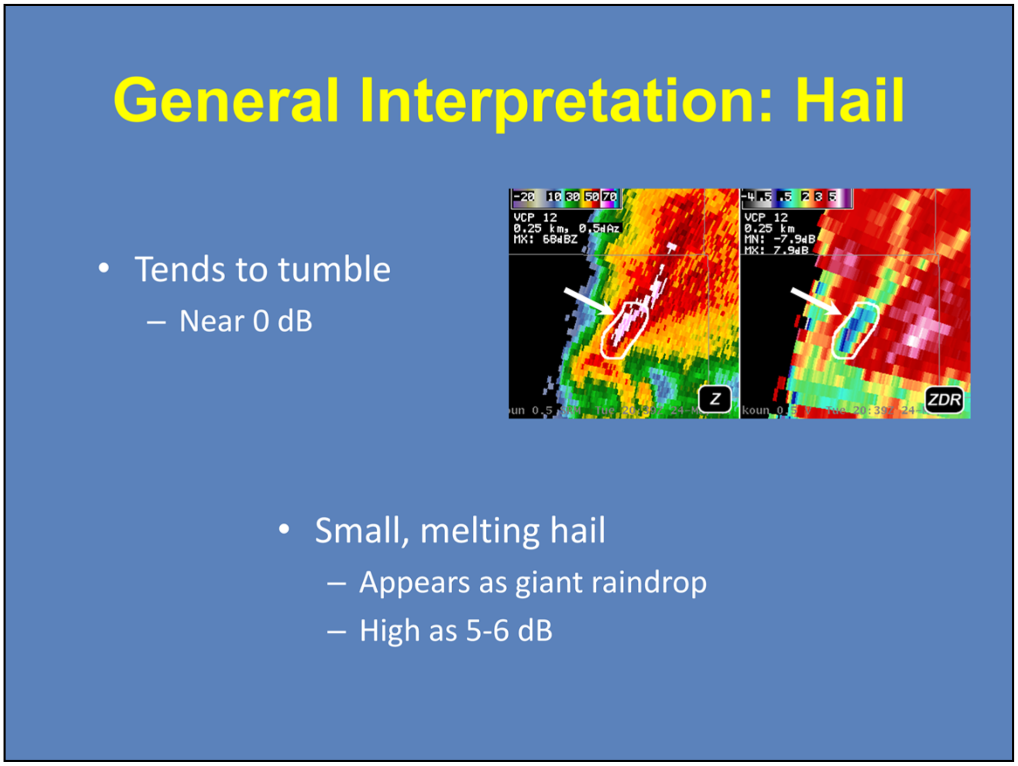


In general, ZDR is great at indicating the dominant drop shape. For example, spherical objects will have near 0 dB because the horizontal and vertical reflectivity factors will be similar. For horizontally oriented objects, the horizontal reflectivity factor will be higher than the vertical reflectivity factor, therefore, ZDR will be positive. The opposite is true for ZDR with vertically oriented objects.



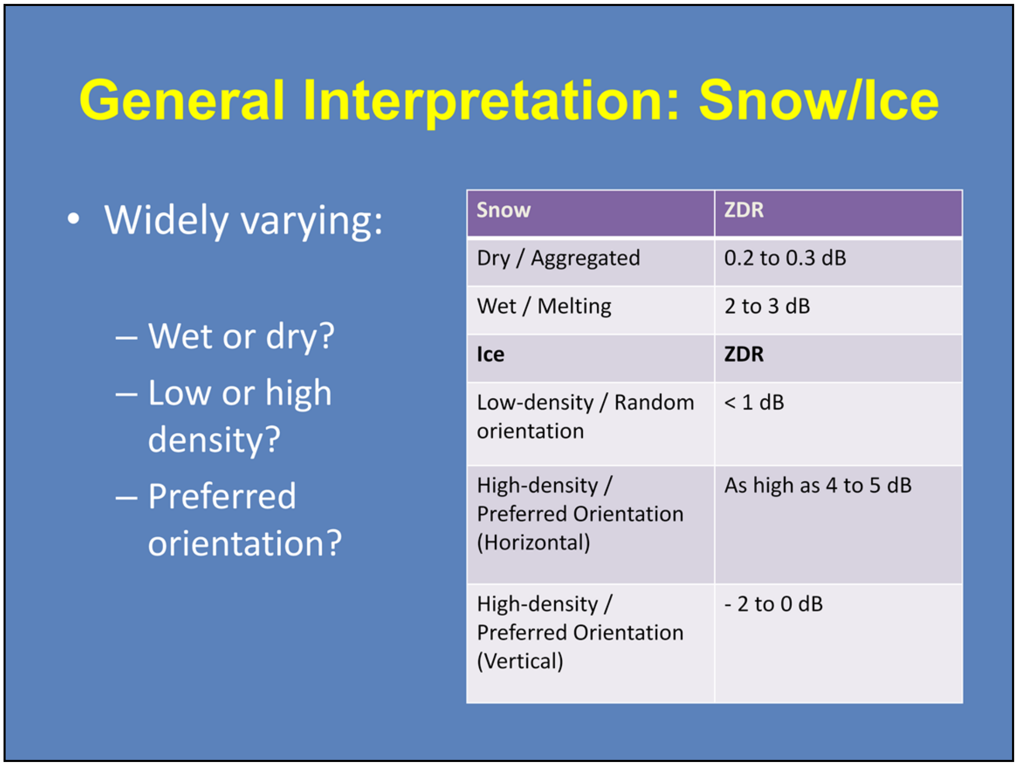
Major Axis Diameter (mm)	Image	ZDR (dB)
< 0.3 mm		~ 0.0 dB
1.35 mm		~ 1.3 dB
1.75 mm		~1.9 dB
2.65 mm		~2.8 dB
2.90 mm		~3.3 dB
3.68 mm		~4.1 dB
4.00 mm		~4.5 dB

Let's dive into ZDR a little deeper by looking at how rain appears in ZDR. As shown in the table, larger rain drops have larger ZDR values.

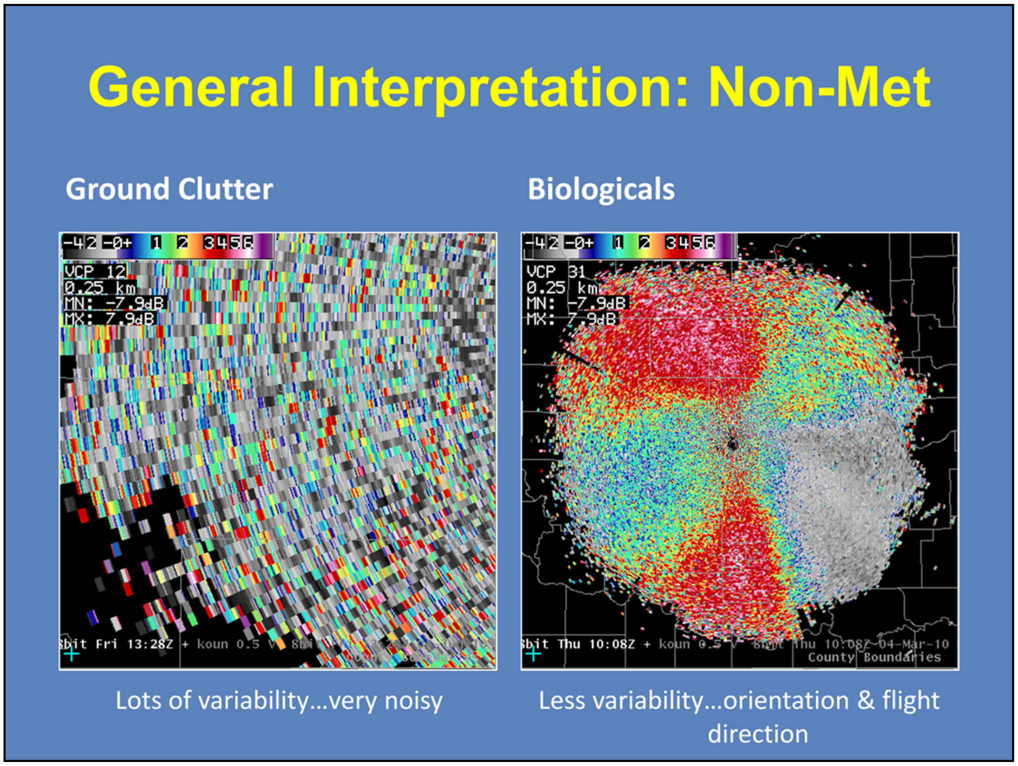


Hail, unlike rain, tends to tumble as it falls making it appear spherical to the radar. This causes a local minimum in ZDR values. The classic hail signature is where high Z and near zero ZDR co-exist. An example of this can be seen in the lower right.

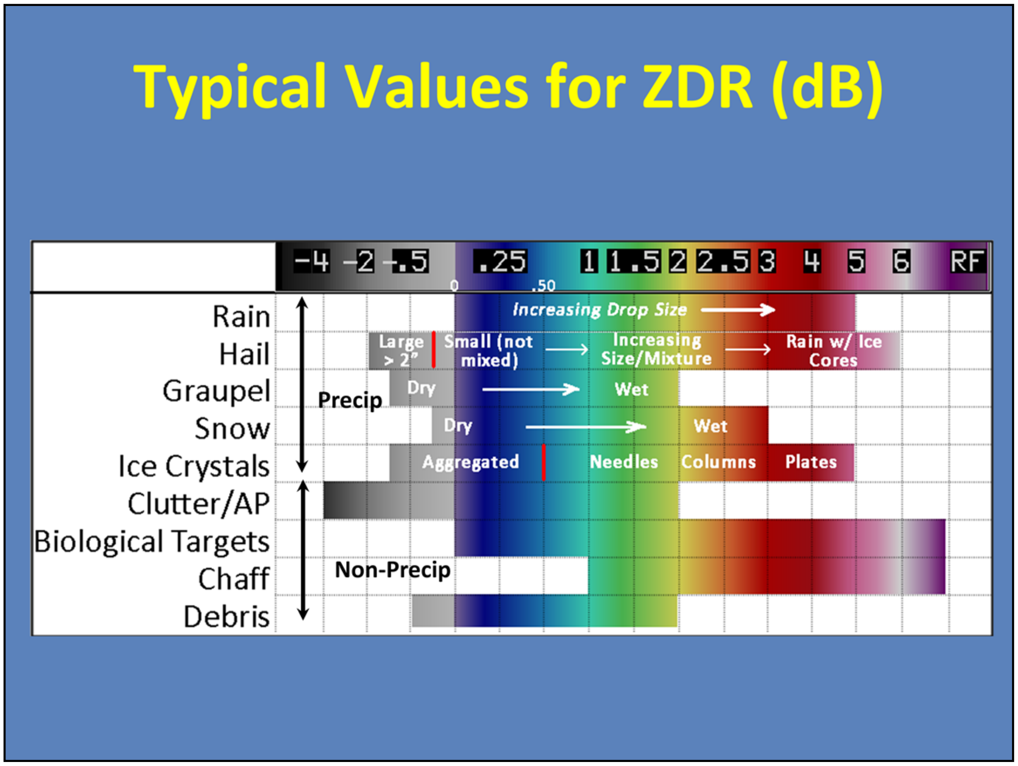
One caveat to this classic signature is small, melting hail. Small, melting hailstones can appear to the radar as large rain drops which can cause ZDR values to become extremely large (as high as 5-6 dB).



For snow and ice, interpreting ZDR values can be very tricky. You have to ask yourself a few questions. Is the snow wet or dry? Low or high density? Do the hydrometeors have any preferred orientation? All these factors play a role in the ZDR value that results. As a general guideline, the table on the right gives various expected values of ZDR for different ice crystal habits.



Non-meteorological echoes have more variability in shapes and sizes than do meteorological echoes, thus increasing the variability of expected ZDR values. The ZDR product is best at distinguishing non-meteorological echoes that are ground clutter (either normal or AP) and biological scatterers. For ground clutter, ZDR will typically appear very noisy and have both high and low values. Birds and insects, however, result in ZDR values that are more predictable and are dependent on the targets shape, orientation, and flight direction.



Here is a table to better illustrate and summarize a lot of the elements were just went over, showing the expected values of ZDR for various hydrometeor types. Notice how there is not as clear of break between non-meteorological and meteorological echoes as there was with CC.

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Products Available

Product Name	Units	AWIPS ID	RPG ID	RPG Code	Data Levels	Range Res	Az Res	Max Range
Differential Reflectivity Data Array Product	*dB*	*ZDR*	*DZD*	*159*	*8-bit (256)*	*0.25 km*	*0.5 deg*	*300 km*

Super-resolution is not available with ZDR at this time

There is only one ZDR product that comes from the RPG, the 8-bit product ZDR and there is no super-res ZDR product available.

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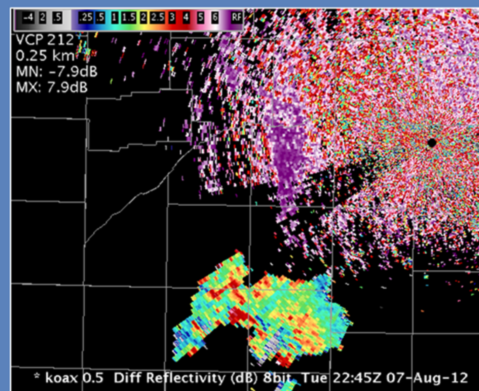
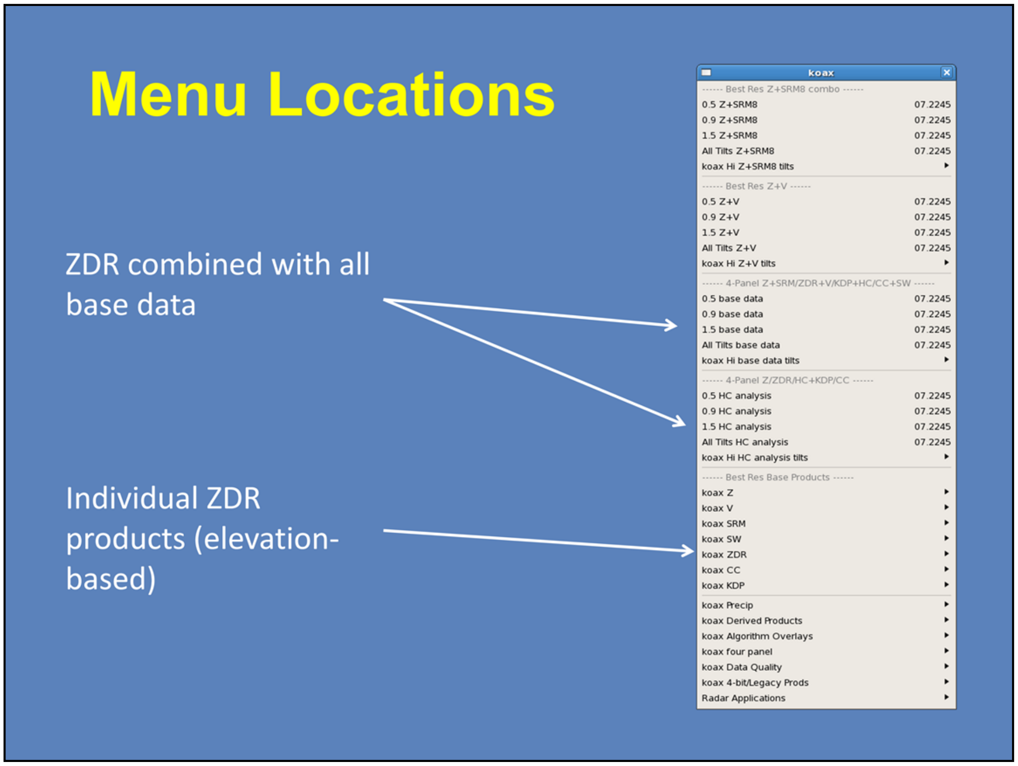
General Product Characteristics

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



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



You can find the ZDR products combined with all base data in the two 4-Panel sections of your dedicated radar drop-down menu. There is also an individual, elevation-based ZDR product available in the Best Res Base Products section of the same menu.

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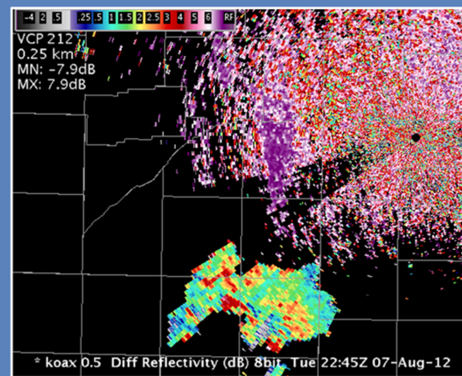
8-Bit ZDR

- 1 deg x 0.25 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 ZDR product is 1 deg x 0.25 km resolution and extends to a range of 162 nm. It is worth noting that while viewing all the base data products on the split cut elevations, you may notice a change in resolution when toggling between ZDR and non-dual-polarization products. While this resolution change may be distracting, it should not change your interpretation of ZDR features.

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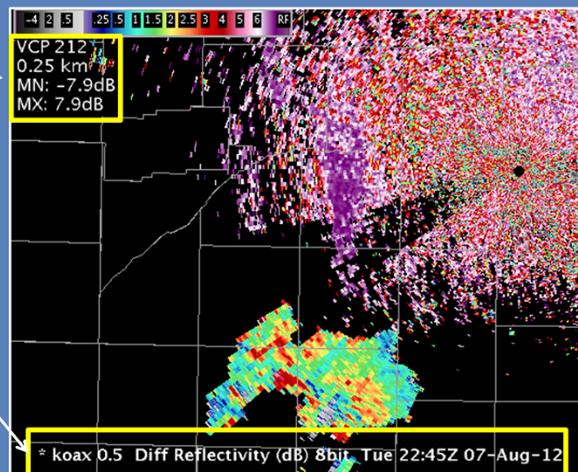
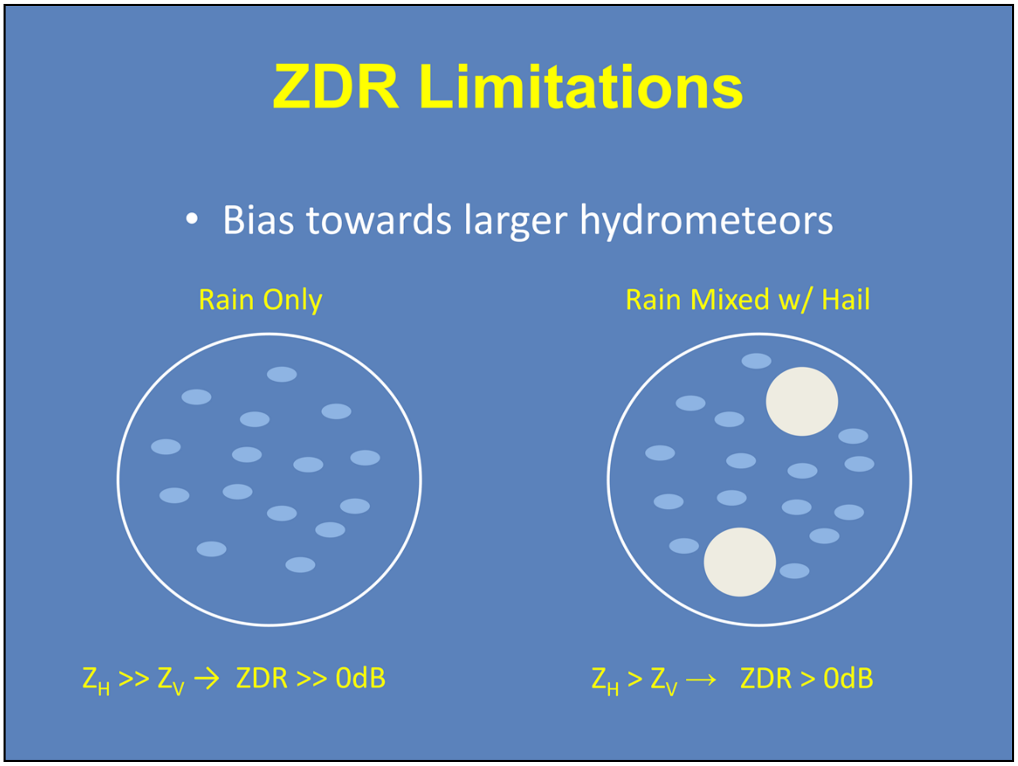
8-Bit ZDR Characteristics

Product Annotation:
- VCP
- Range Resolution
- Min ZDR
- Max ZDR

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



As with the other base products, the product annotation and legend is shown below.



Now let's move on to ZDR's limitations. Since ZDR is just the difference between two reflectivity factors, 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.

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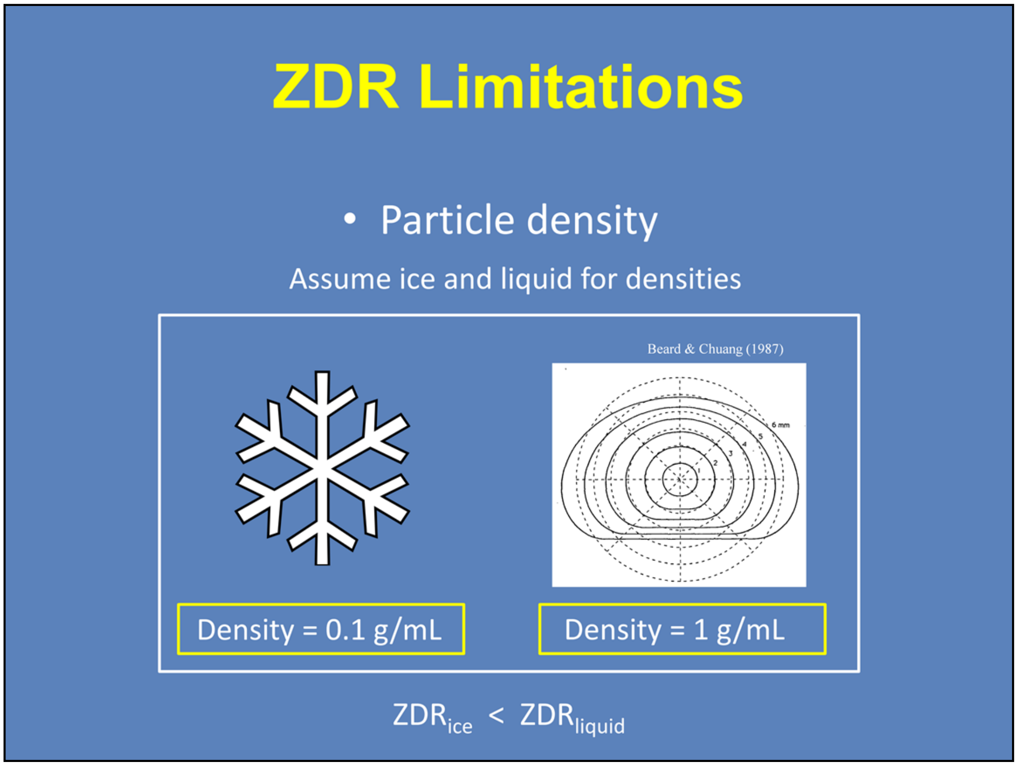
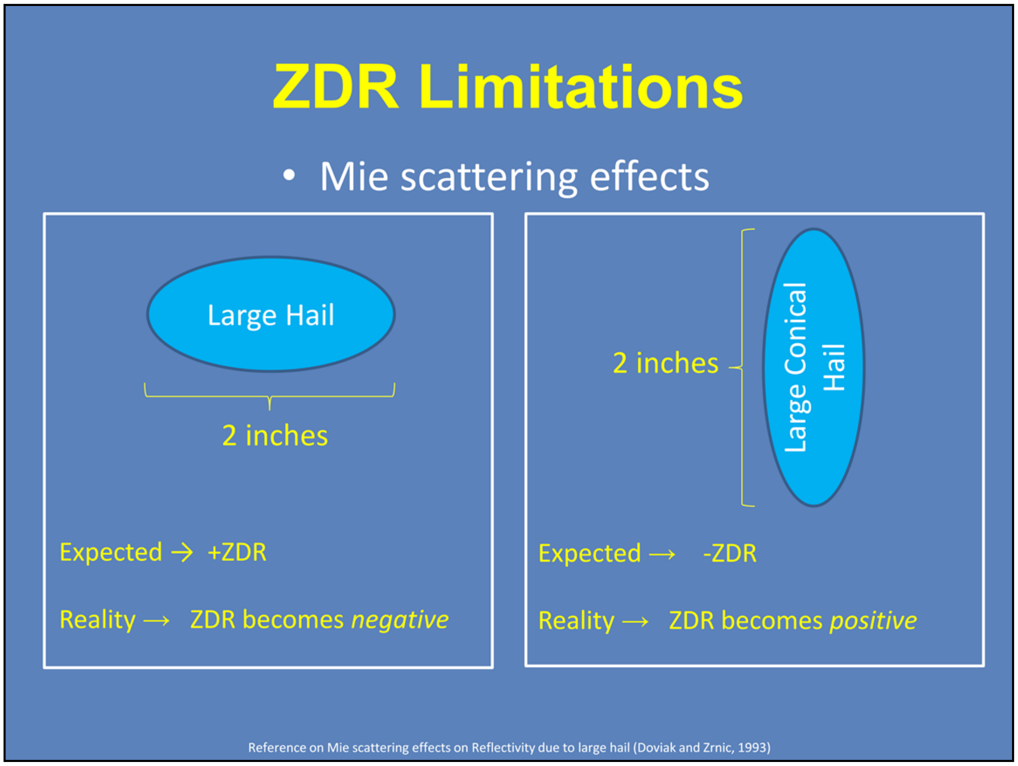


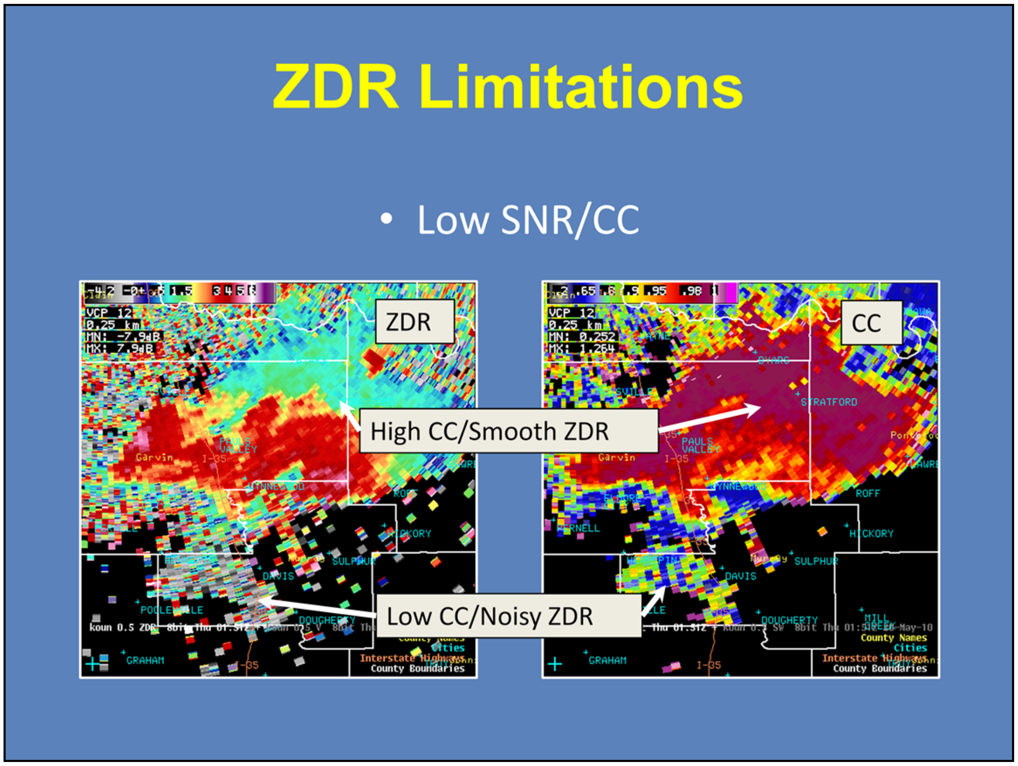
The next factor to consider when viewing ZDR is particle density. The lower the particle density, the lower the ZDR.

For example, if you have one volume filled with ice (with a density of 0.1 g/mL) and another volume filled with raindrops of the same size and concentration (but a density of 1 g/mL), then the ZDR of the ice volume will be lower than the ZDR of the rain. The reason for this difference, despite the shapes being the same, is due to the difference in the dielectric constants of ice and liquid water. The higher the dielectric constant of a radar target, the more power that target returns to the radar, and the higher the reflectivity factor will be.

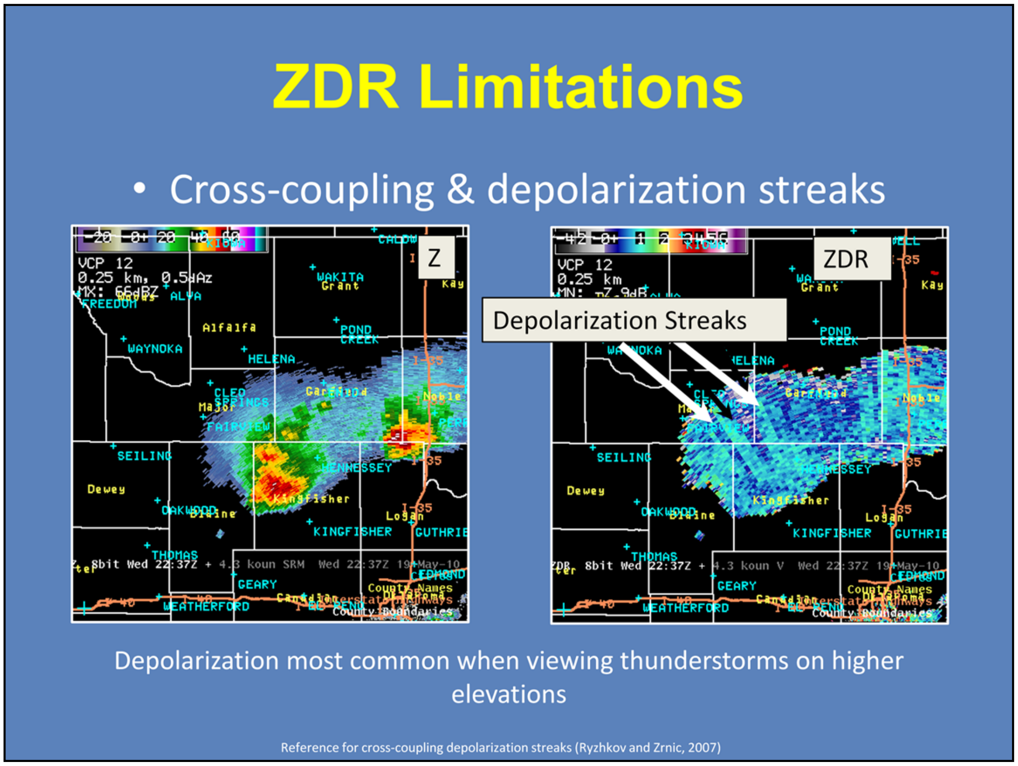
This relationship is why reflectivity values for snow are often lower those for rain. NOTE: High density ice particles (such as needles) that are horizontally oriented can have significantly positive ZDR values even though Z values are generally low.



Recall from the previous lesson that Mie scattering can have some crazy effects on CC. The same issues can be true for ZDR, especially when targets in the radar volume are approximately 2 inches in diameter or larger. Research suggests that when targets are around 2 inches in diameter, Mie scattering effects can cause 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. In regions of hail larger than golf balls, expect more negative ZDR values due to this Mie scattering effect. 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. Reference on Mie scattering effects on Reflectivity due to large hail (Doviak and Zrnic, 1993).



When the correlation coefficient drops below 0.95, the error in ZDR becomes greater than 0.3 dB. When errors are this large, the ZDR product begins to appear noisy. The same result can happen in low signal-to-noise ratio, or SNR, regions because of similar drops in CC. In the example shown, ZDR is on the left and CC is on the right. Where the CCs are a maroon color, greater than 0.98, the ZDR field looks very smooth, but where CCs are yellow and blue in color, less than 0.95, the ZDR fields look much more noisy.



One of the issues that can occur with a radar that simultaneously transmits a horizontally and vertically polarized pulse is an effect called cross-coupling. Cross-coupling occurs when a portion of the transmitted power in one polarization is scattered (forwards and backwards) into the other polarization. Normally, cross-coupling is nominal. However, when a significant number of targets in the radar beam become canted (i.e., preferentially aligned) at an angle between 0 or 90 degrees, cross-coupling can significantly impact the quality of ZDR values down radial from where the cross-coupling began. The end result of this cross-coupling is a streak of enhanced positive or negative ZDR values called depolarization.

Depolarization is most common when ice crystals aloft become preferentially aligned in an electric field inside a thunderstorm. Depolarization streaks are best seen on higher elevation scans. Depolarization only affects ZDR and shows up as radial spikes of high and/or low ZDR based on the type of cross-coupling occurring in the region of depolarization.

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

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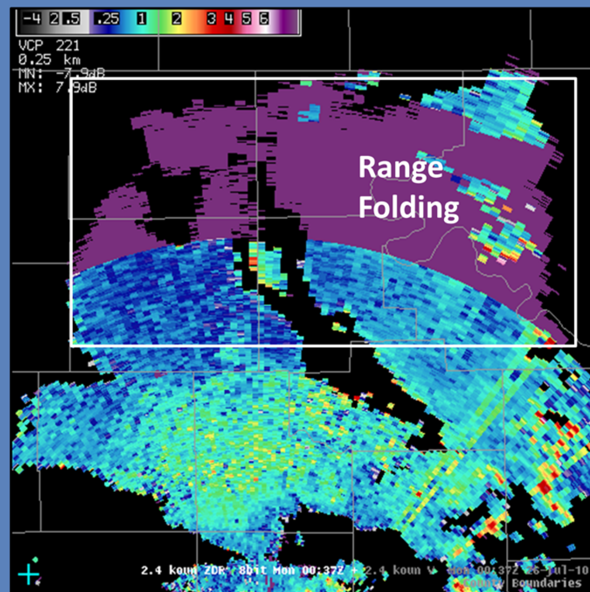
ZDR Limitations

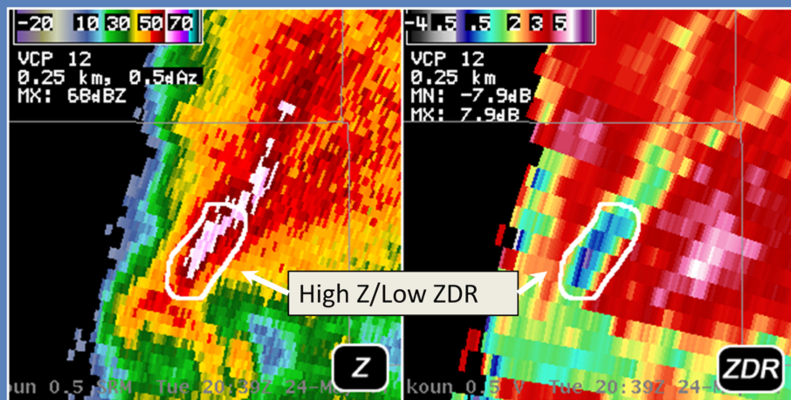
- RF in batch cut elevations
  - Between 1.65 & 6.5 deg



The last limitation we will discuss with ZDR occurs in the batch cuts. On these tilts, range folding may obscure some signatures in ZDR. 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. These pulses are subject to range folding. An example of RF affecting ZDR is shown.

ZDR Applications

- Hail detections



Now let's talk about some applications of ZDR. As mentioned on an earlier slide, hail detection is a major advantage with ZDR. In fact it was one of the first signatures noted with dual-pol data.

The classic signature is characterized by high Z and near zero ZDR, as shown in the example below. It's important to note that small melting hail can cause ZDRs to be very large due to those hydrometeors appearing as giant rain drops to the radar.

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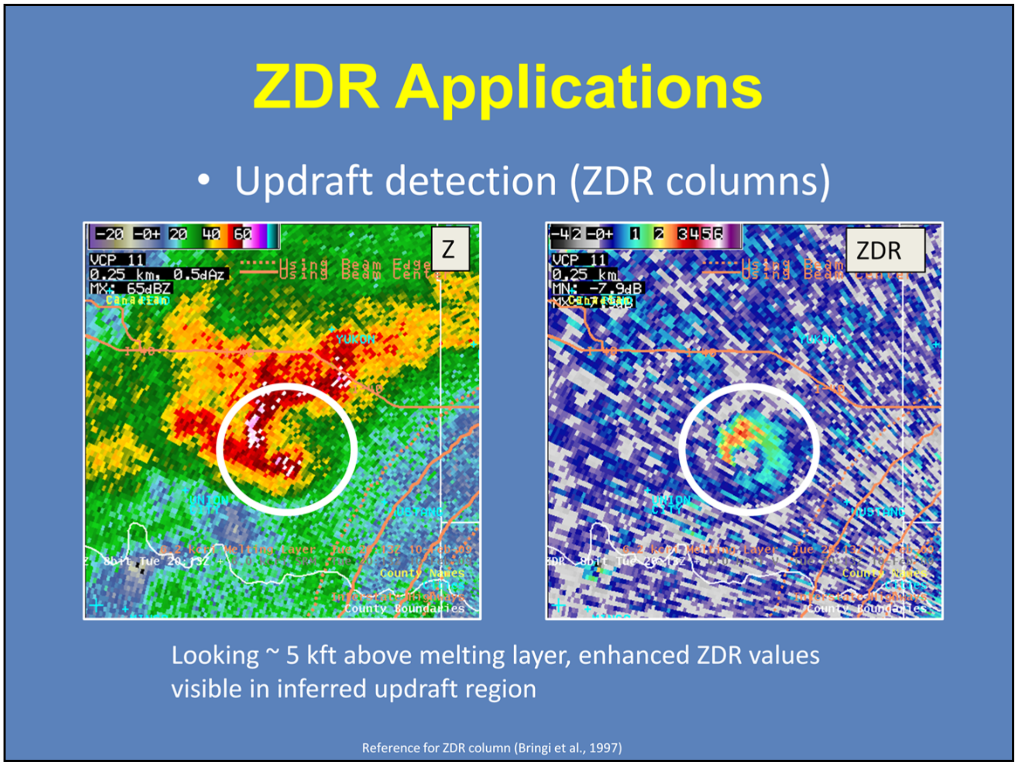

When intense updrafts develop, if enough liquid water is present within them, this liquid water will be lofted well above the environmental 0 degree Celsius level. This process will result in an area of locally enhanced ZDR within an updraft called a ZDR column. A good rule of thumb is look for ZDR > 1 dB above the melting layer height that is connected with higher ZDR below the melting layer. In other words, the column has to have vertical continuity.

Here is an example of a ZDR column. The melting layer height in this example was roughly 10,500 feet and we are looking at 15,700 feet. Looking at reflectivity, we see a supercell with an inflow notch and hook echo. The location of the inflow notch should be roughly the location of the updraft. If we look at ZDR, we see a localized area of enhanced ZDR (> 2 dB) in the inferred updraft region. Due to the ZDR column, we can confidently say this region is where the storm updraft is located. Reference for ZDR column (Bringi et al., 1997).

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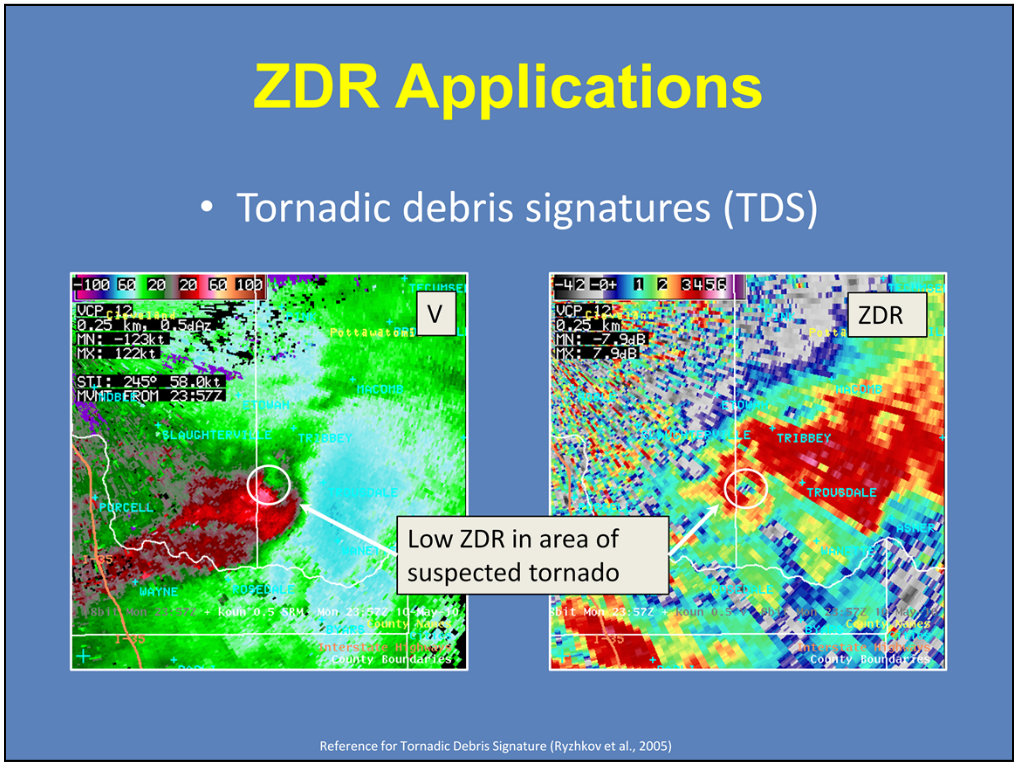

Like CC, ZDR can also be used to verify tornadic debris. Since tornadic debris has no preferred orientation, ZDR is going to be near 0 or slightly negative. So, when looking for tornadic debris in ZDR, first identify the tornadic signature using Z and SRM. Then toggle over to CC to verify it is debris. Then toggle to ZDR. If you see low, or slightly negative, ZDR then that gives you added confidence in a tornado causing damage. However, remember to look at Z, SRM, and CC before ZDR when identifying a TDS. Reference for Tornadic Debris Signature (Ryzhkov et al., 2005).

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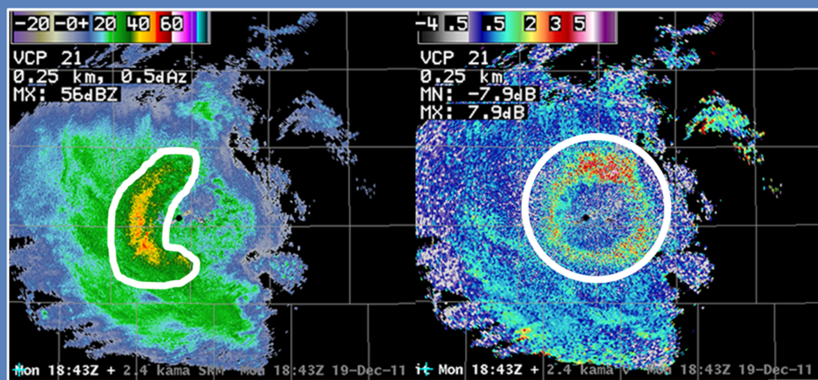
ZDR Applications

- Melting layers appear as a ring of high ZDR values



Within melting layers, ice becomes water coated and melts into a rain drop. During this transition, these particles essentially look like large rain drops. This causes ZDR to increase. Thus, the melting layer will manifest itself as a ring of high ZDR. Here is an example where you can see a partial bright band in Z, but the ring in ZDR is much more noticeable.

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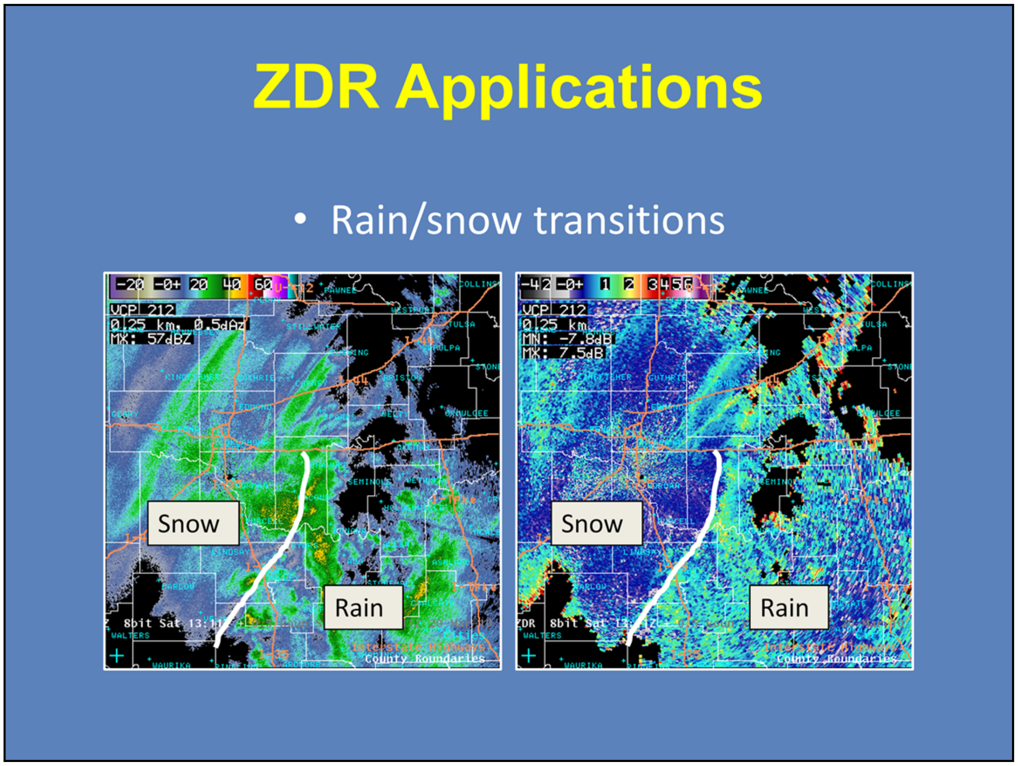

Along the same lines as melting layers, ZDR is great at delineating rain/snow transition regions, but again, always use surface observations to corroborate your evidence.

Here is an example of ZDR delineating the rain/snow transition line (white line). To the east of the white line, ZDR values are generally higher indicating rain. To the west of the white line, ZDR are lower indicating snow. Surface observations confirmed this, but are not shown in the image.

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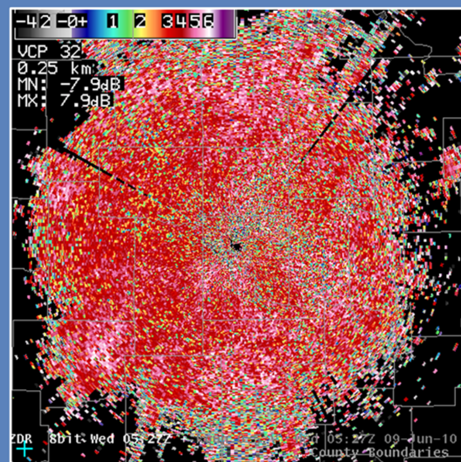
ZDR Applications

- Non-meteorological echoes
  - Local variability exists
  - Knowledge of biological populations helps



Lastly, ZDR can help delineate different types of non-meteorological echoes, especially birds and insects. Migrating birds (and some insects like monarch butterflies) usually will appear with a distinct azimuthal pattern of higher and lower ZDR values based on their body shape and flight orientation. Other insects that do not migrate will generally have high ZDR values at all radials.

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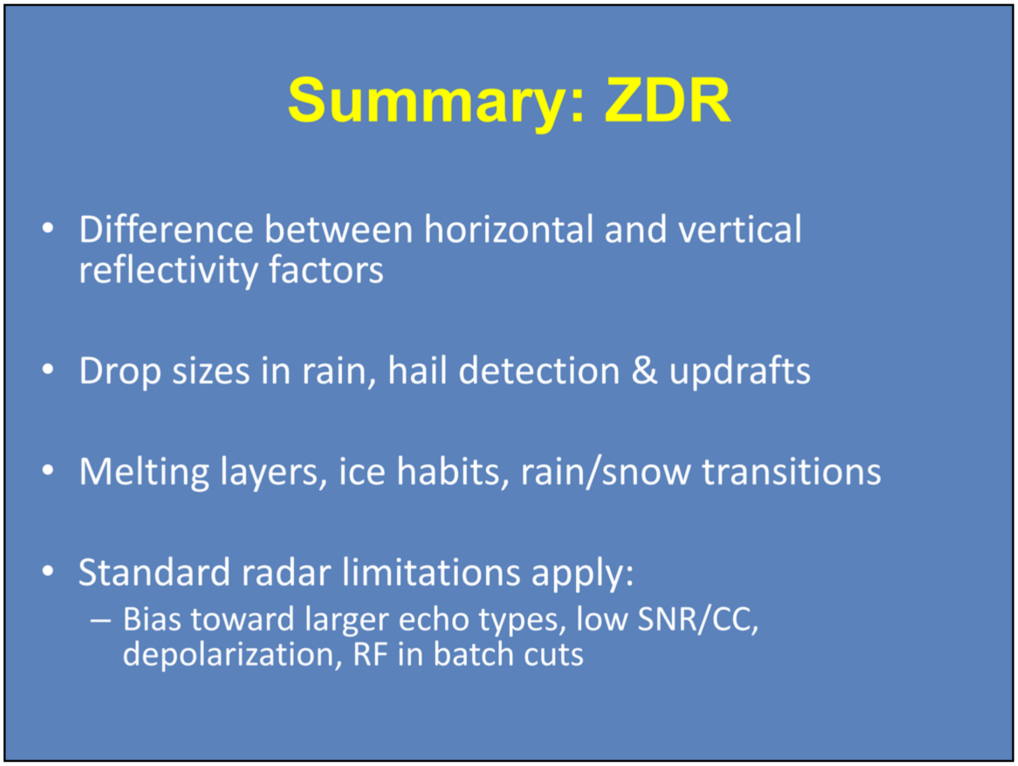
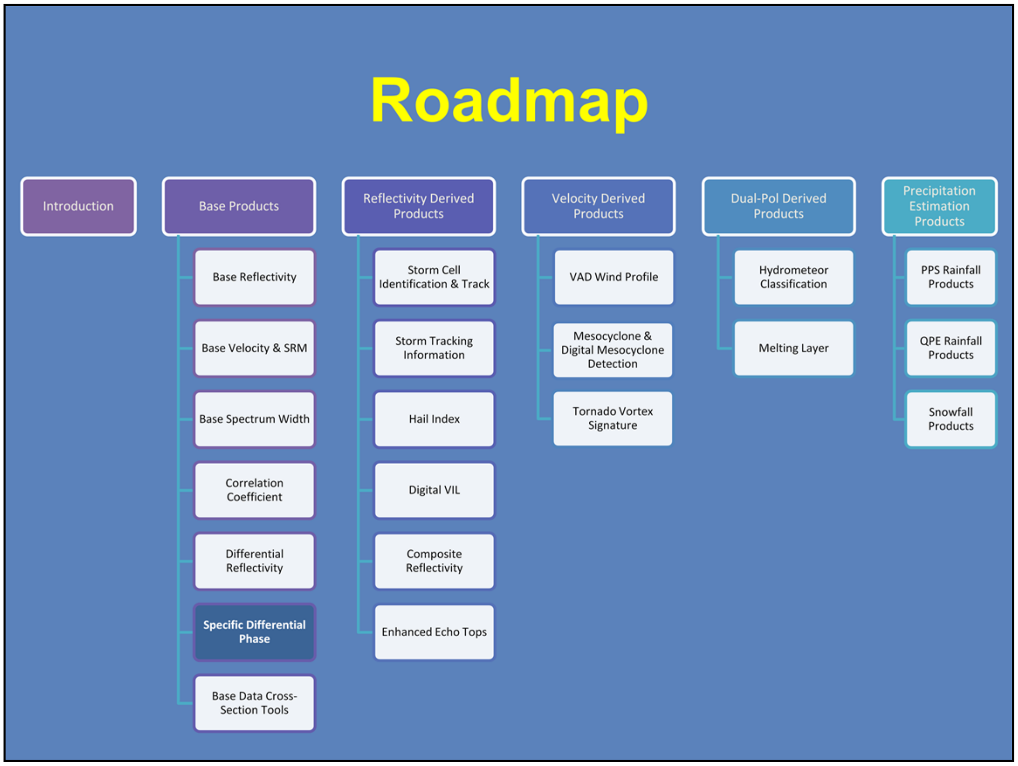


To summarize ZDR, it is the difference in the horizontal and vertical reflectivity factors. It is great for determining drop sizes in rain, detecting hail and updrafts, identifying melting layers, ice habits, and rain/snow transitions. However, ZDR is biased by larger hydrometeors, low SNR & CC, becomes “streaky” in depolarization regions and is masked by RF in the batch cuts.

Welcome to Topic 4 and our lesson on Specific Differential Phase – or KDP.



Almost finished with the base products lessons and we're at the end of the 3 dual-pol products.

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Learning Objective

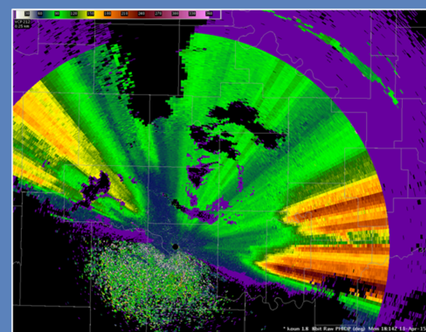
Identify the characteristics, limitations, and applications (strengths) of the Specific Differential Phase (KDP) product.

The purpose of this lesson is to teach you the characteristics, strengths, and limitations of KDP so it can be best used in operations.

Differential Phase Φ_{DP}

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

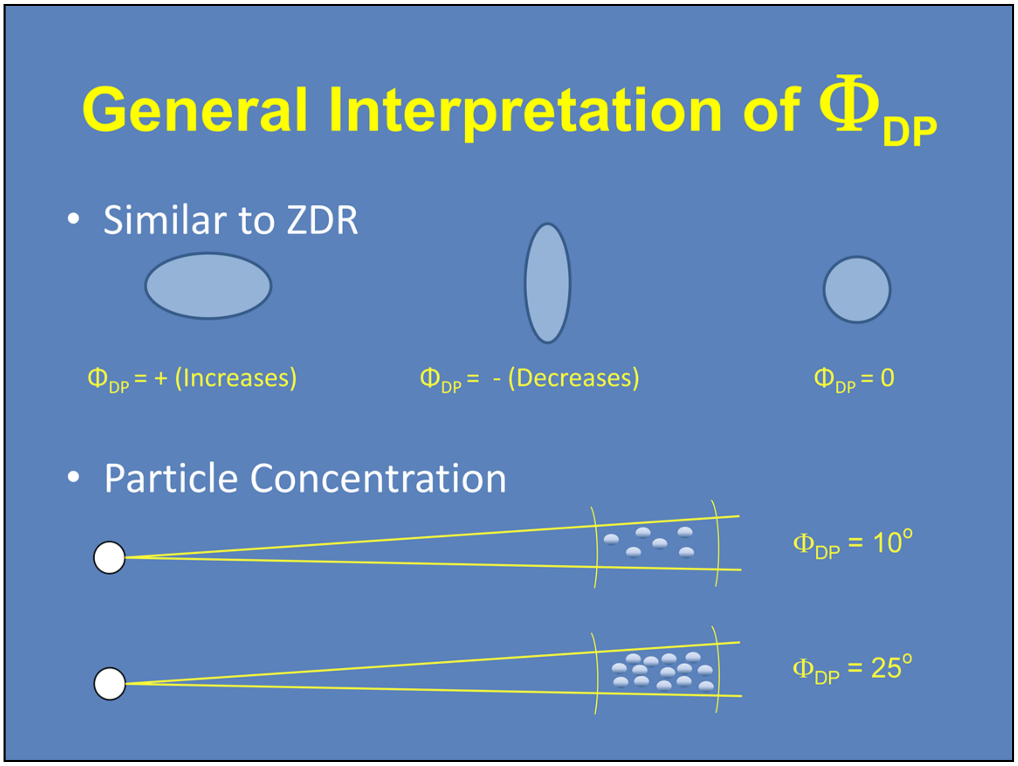
$$\Phi_{DP} = \Phi_H - \Phi_V$$



Before diving into KDP, we need to learn about where it comes from. Back when Dual-Polarization was fielded on the 88Ds, the decision was made to only make the base Dual-Pol products available, and not immerse the field with additional products. This includes a product called Differential Phase.

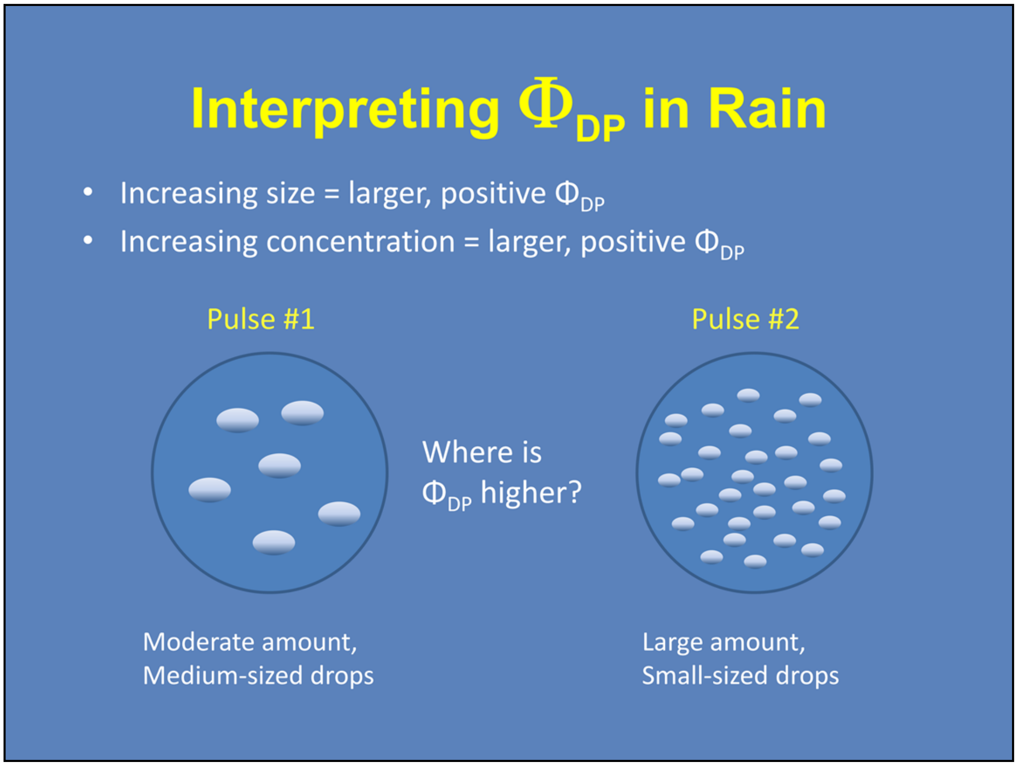
KDP, which is what much of this lesson is about, is actually derived from Differential Phase or Differential Phase Shift to be more precise – which is denoted as Phi DP. Phi DP is the difference between the horizontal and vertical two-way propagation phase shifts. What is a phase shift? That…you will learn in the next several slides on general interpretation. For now, just know that Phi DP is the difference between the horizontal channel – H in this case, and the vertical channel – or V.

Why the strange-looking spikes and increases in the values down radial? Because Phi DP increases with liquid water content down the radial. In this image, gradients increase as the beam enters rainfall along the radial and elicits higher values with higher reflectivity. The product is also cumulative, so it is very difficult to tell where the important areas are, especially way down the radial once values are already high.



Much like differential reflectivity, the shape of the target affects the differential phase shift. Horizontally oriented targets will produce an increasing, positive differential phase shift with range. Vertically oriented targets will produce a decreasing, negative differential phase shift with range. And, spherical targets will produce near zero differential phase shift with range.

Unlike ZDR, differential phase shift is dependent on particle concentration. The more particles there are in a pulse volume, the more differential phase shifting will occur. For example, the more horizontally oriented targets there are within a pulse volume, the higher the positive differential phase shifting.



Larger raindrops are more oblate than smaller raindrops. So, from the last slide we would expect small raindrops, such as drizzle, to have near zero differential phase shifting and larger raindrops to have larger, positive differential phase shifting. This is very analogous to the concept of ZDR.

The caveat here is particle concentration. Let's say one pulse volume has a moderate amount of medium-sized raindrops and a second pulse volume has a large amount of smaller-sized raindrops. Even though the pulse volume with the medium-sized raindrops should have higher differential phase shift according to the size differences, the larger amount of smaller-sized particles could actually make the differential phase shifting in the second pulse volume higher than the first pulse volume.

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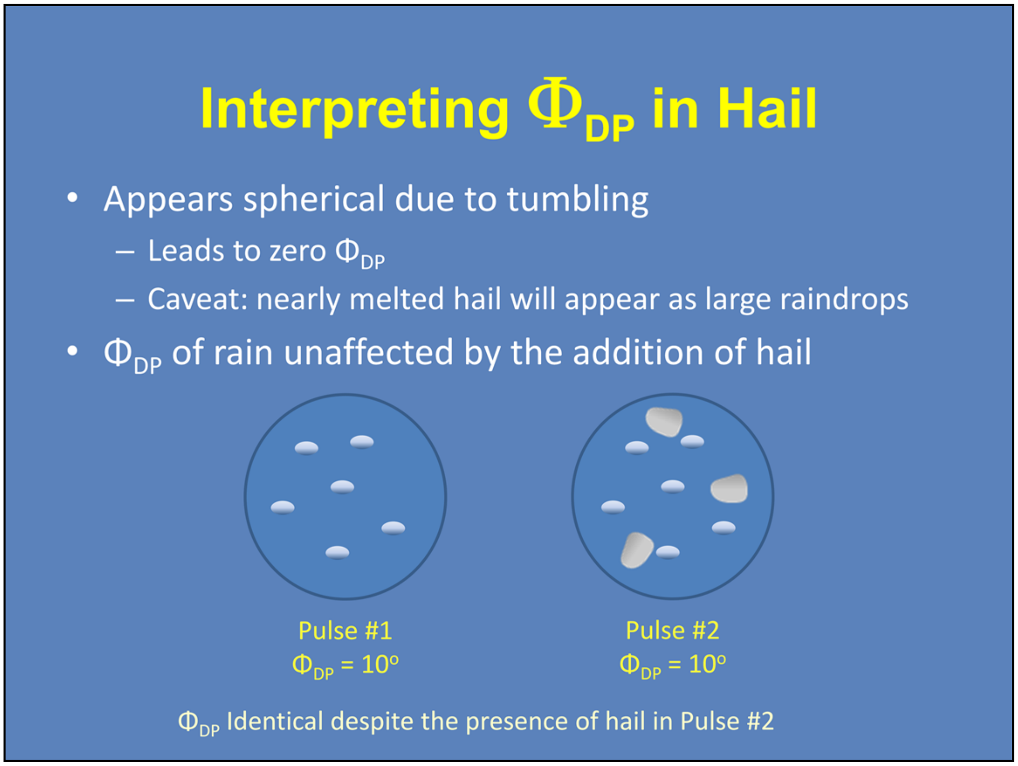
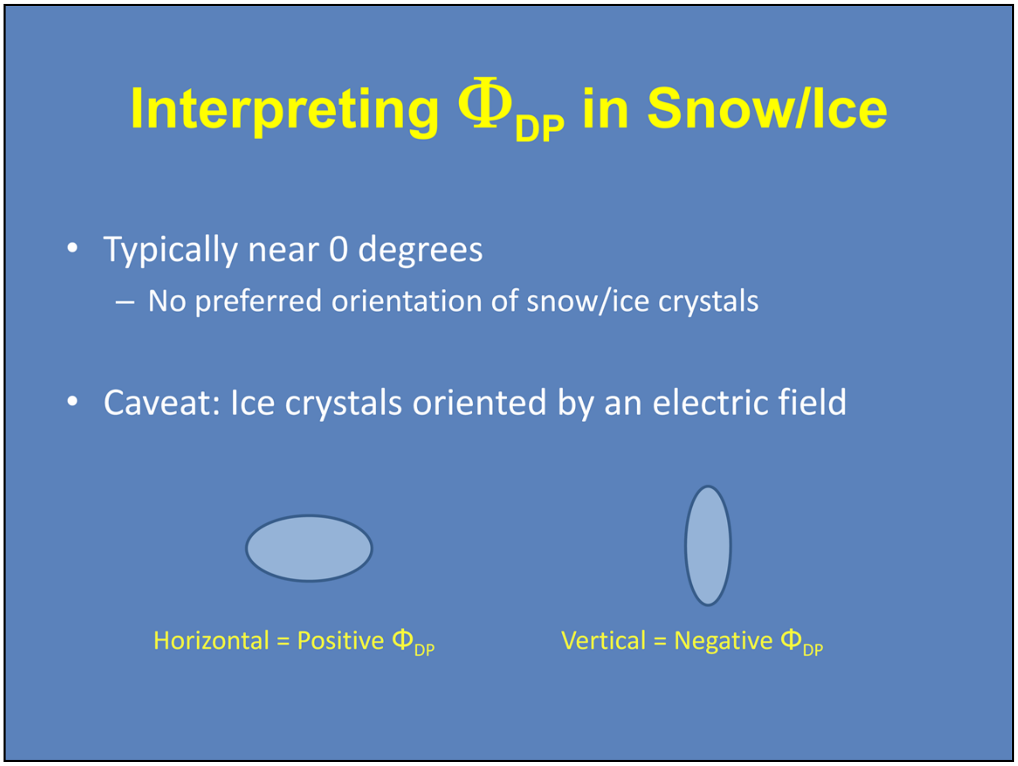


Since hail tends to tumble as it falls, it appears on radar to be spherical. This means hail will typically have near 0 degrees of differential phase shifting. The one caveat to this is that when small, sub-severe hail is nearly melted, it appears on radar as large raindrops which can cause differential phase shifts to be very high. Another important point is the low dielectric constant of ice. Part of the reason that a melting hail stone produces unusually large KDP values is that the hail is wet.

For the most part, differential phase shifting 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, the differential phase shifts will be identical despite the presence of hail.



Since most ice and snow crystals do not fall with a preferred orientation, differential phase shifts in snow and ice crystal regions are typically near 0 degrees. 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 external forcing leading to crystal alignment can cause significant non-zero differential phase shifting, and depending on the orientation of the alignment, the differential phase shifting can be positive or negative. It is positive when the alignment is in the horizontal, and negative when the alignment is in the vertical.

The difference in dielectric constant between ice and snow is also an important factor. For example, you may see a preferential orientation of frozen hydrometeors in dendritic growth zones. Even when the hydrometeor concentration and shape are similar to heavy rain, the difference in Phi DP will be much smaller – but still greater than zero – with dendrites, because they are frozen.

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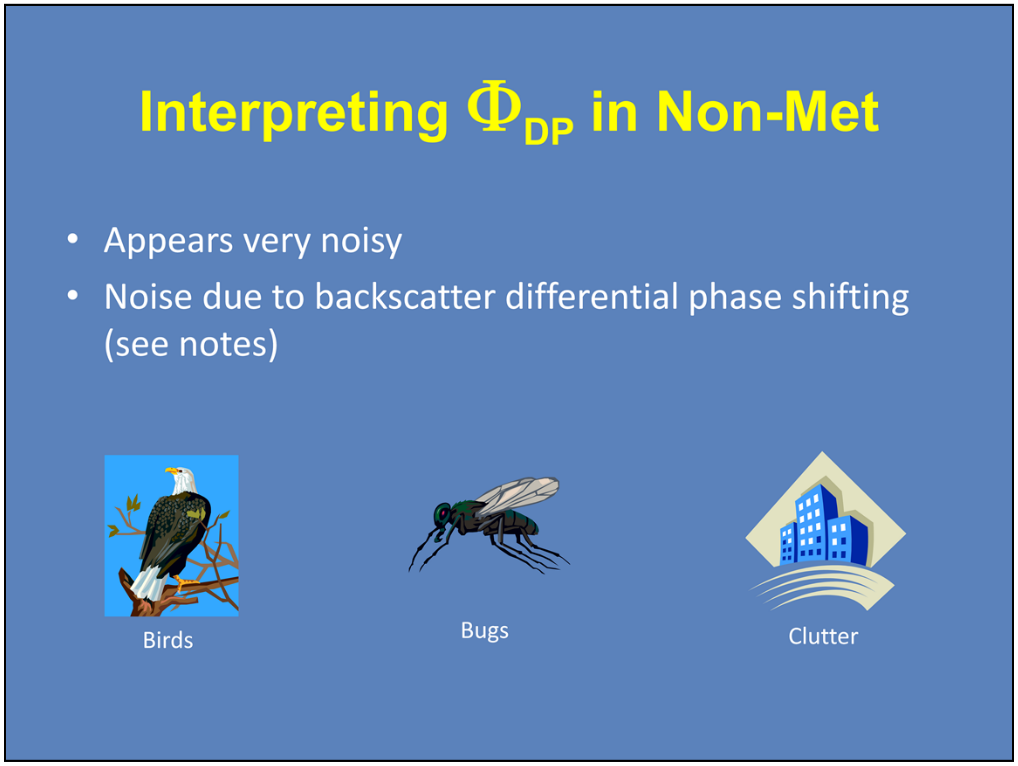

In non-meteorological echoes, differential phase shifting is very noisy. This is primarily due to the effects of something called backscatter differential phase shifting, which we will skip in this lesson for times-sake. If you're curious, feel free to check out the explanation in the notes tab.

Backscatter differential phase shifting is slightly different from what we have discussed so far. To this point we have only looked at what is called propagation differential phase shift. It is the amount of differential phase shifting that occurs solely as a result of forward propagation (i.e. how much differential phase shift has occurred as the pulse has gone forward in space). Backscatter differential phase shifting is the amount of differential phase shifting that occurs once the pulse scatters off of an object. In short, meteorological echoes typically experience no backscatter differential phase shifting, where as non-meteorological echoes such as birds and ground clutter experience significant backscatter differential phase shifting. The amount of backscatter differential phase shifting is highly variable depending on the object shape and size, hence why in non-meteorological echoes differential phase shifting appears very noisy.

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Web Object

Address:
http://training.weather.gov/wdtd/courses/rac/principles/interactions/phidp-gbu/

An interaction should pop up in a separate window, so make sure your browser settings allow for it. This interaction will take you through the good, the bad, and the ugly in terms of Differential Phase. If the interaction does not appear, you can also go to this link on the bottom of the screen.

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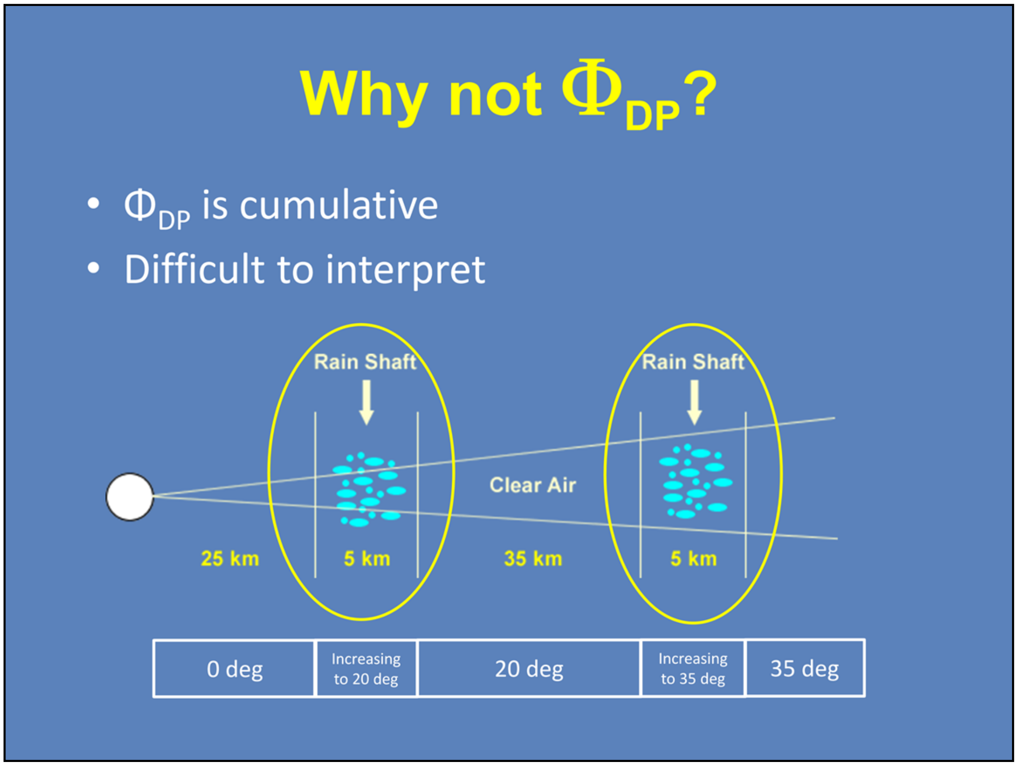

First of all, why can't we just used Phi DP operationally? After all, Phi DP certainly has discernable characteristics in rain versus hail versus snow/ice crystals. In short, the issue is that Phi DP is cumulative, thus making it quite difficult to interpret. You can see what I mean when shown an image later on. If you're interested in the math behind the issue, check out the notes for an explanation corresponding to 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.

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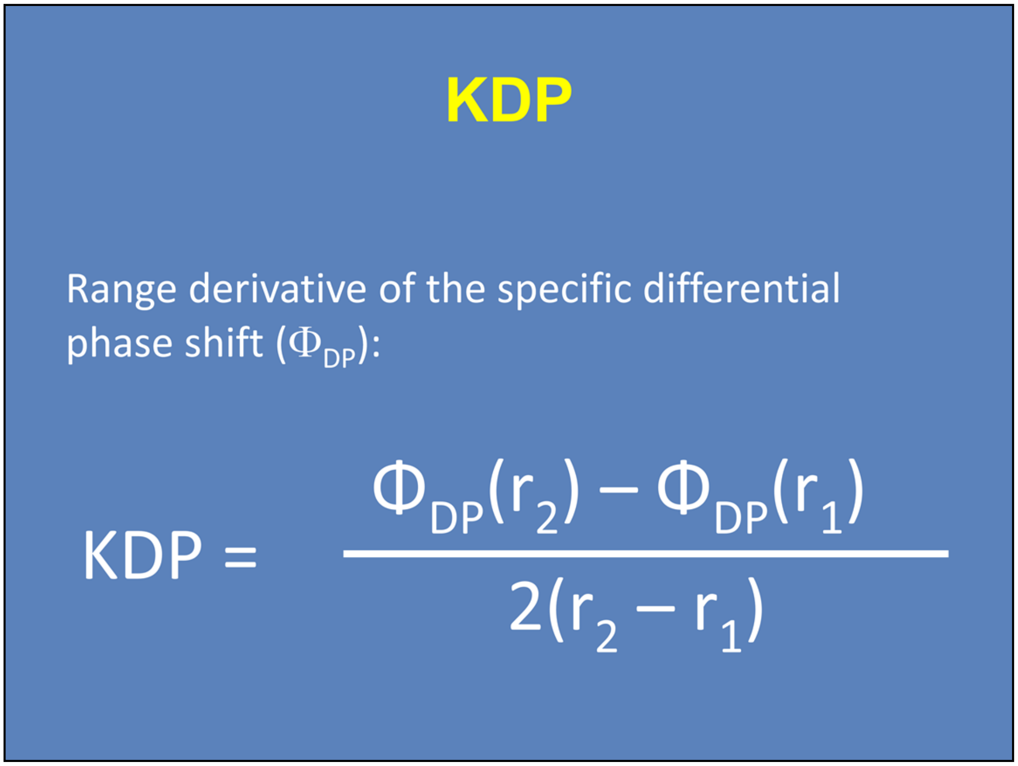

Because of these limitations, Phi is not an operational Dual-Pol product. However, it does factor in to one that is, the Specific Differential Phase or KDP. So what is KDP? It is the range derivative of the differential phase shift between the horizontal and vertical pulse phases. The next several slides will examine in detail the physical characteristics of KDP.

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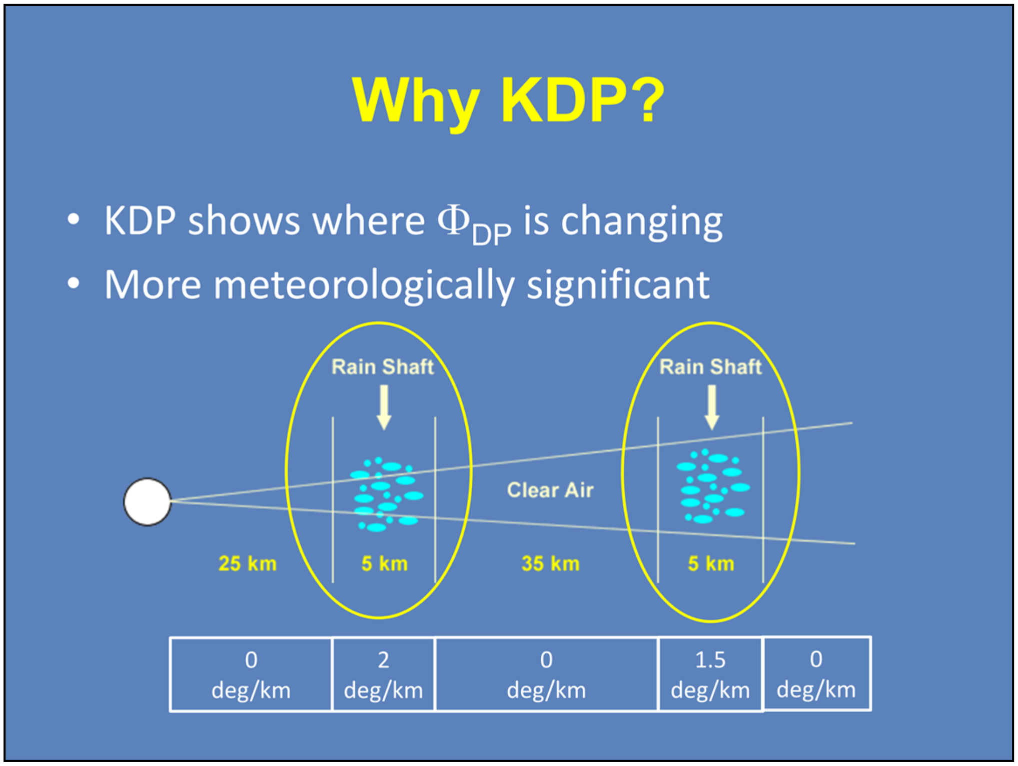

Being the range derivative of Phi DP, KDP shows where the Phi DP is changing, which is more meteorologically significant and easier to interpret. If you would like more details and an explanation of the graphic, check out the notes section.

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.

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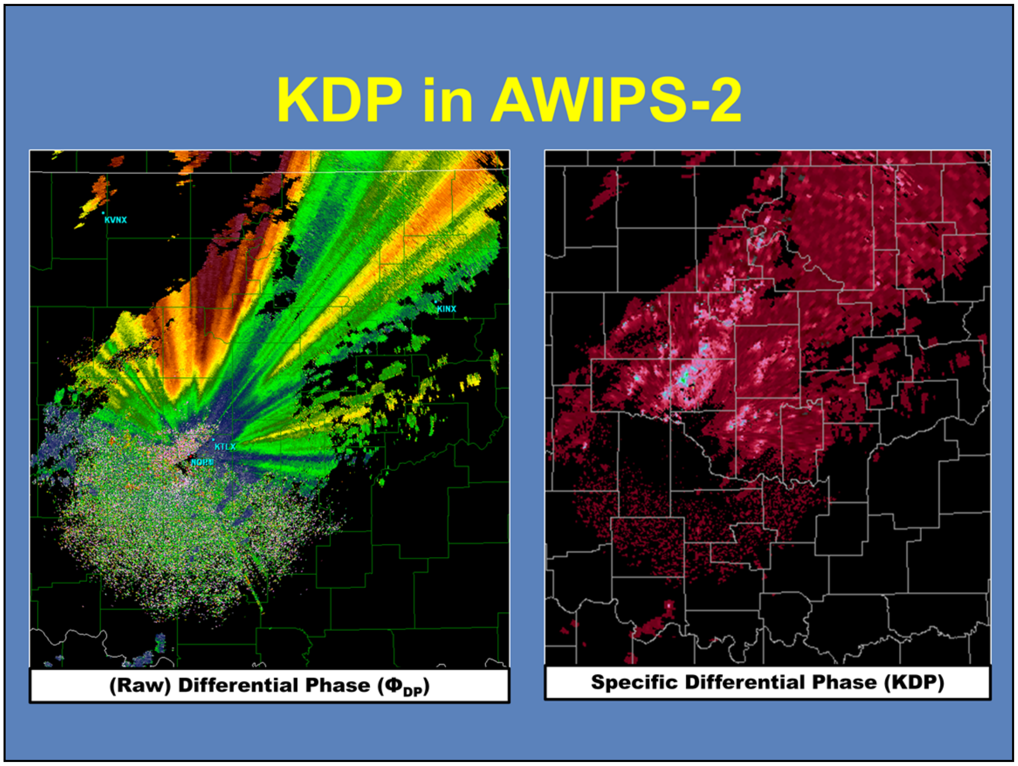
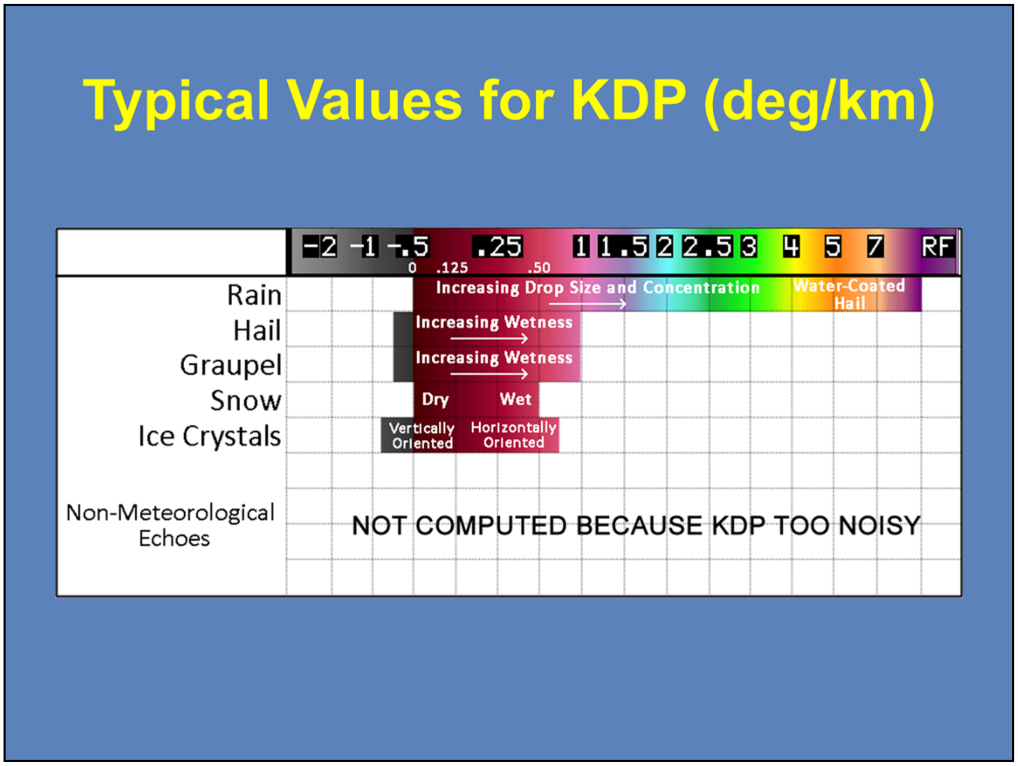


Here is an example of KDP in AWIPS-2. Notice how it is easier to discern regions of interest in KDP rather than Phi DP.



Here are the typical values for KDP given the various types of echoes listed on the left. Notice first how rain is the only meteorological echo that has a wide range of KDP values possible. All other meteorological targets are less than 1 deg/km. The one exception being small, melting hail, which we'll discuss later.

The other note to make is for non-meteorological echoes, KDP is not displayed because KDP is too noisy due to the low CC.

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Products Available

Product Name	Units	AWIPS ID	RPG ID	RPG Code	Data Levels	Range Res	Az Res	Max Range
Specific Differential Phase Data Array Product	*deg/km*	*KDP*	*DKD*	*163*	*8-bit (256)*	*0.25 km*	*0.5 deg*	*300 km*
Super Res Specific Differential Phase Data Array Product	*deg/km*	*SDP*	*SDP*	*168*	*8-bit (256)*	*0.25 km*	*0.5 deg*	*300 km*

There are two 8-bit KDP products from the RPG. The second one is the Super Res product which is better known as Raw Phi DP.

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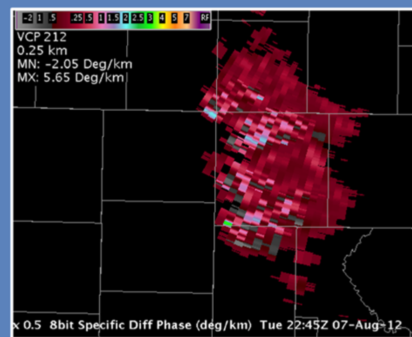
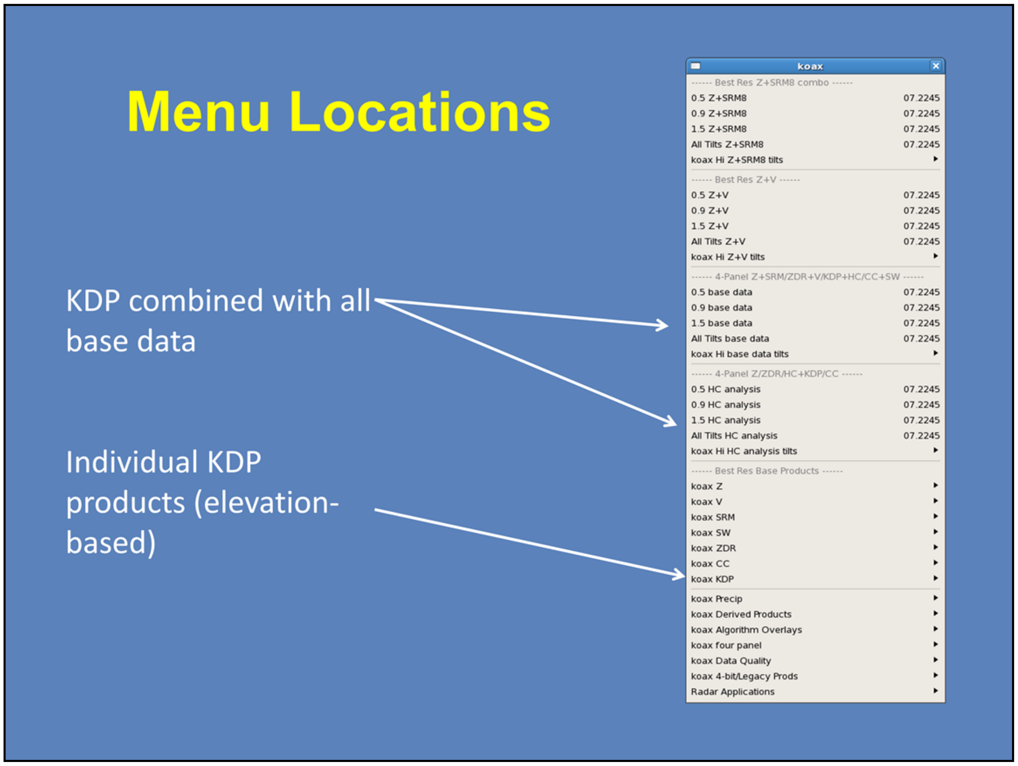
General Product Characteristics

- Displayed in a polar coordinate
- 1° beamwidth
- Displayed relative to the RDA site
- Available for any elevation angle of the current VCP



Just like the other products, KDP is displayed in polar coordinates with a 1 degree beam width and data are displayed relative to the RDA site. KDP is available for all elevation angles for the current VCP.



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

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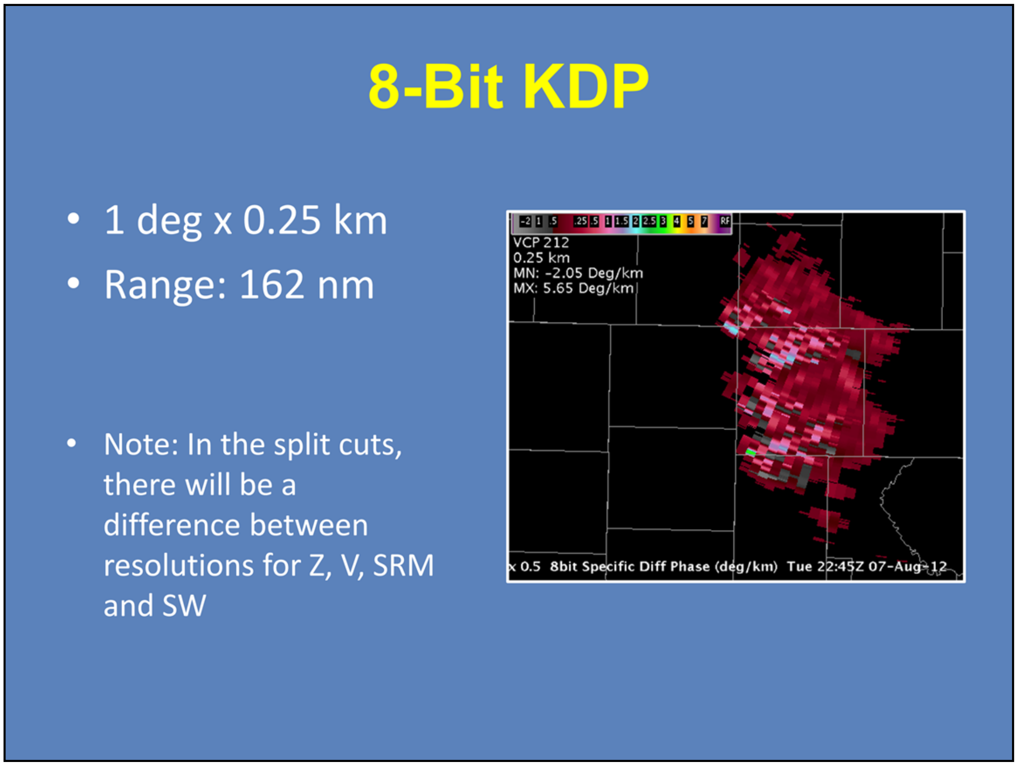

The 8-bit KDP product is 1 deg x 0.25 km resolution and extends to a range of 162 nm. It is worth noting here when viewing products in the split cut elevations, toggling between KDP and Z,V, SRM or SW there will be a difference in resolutions. This should not change your interpretation though.

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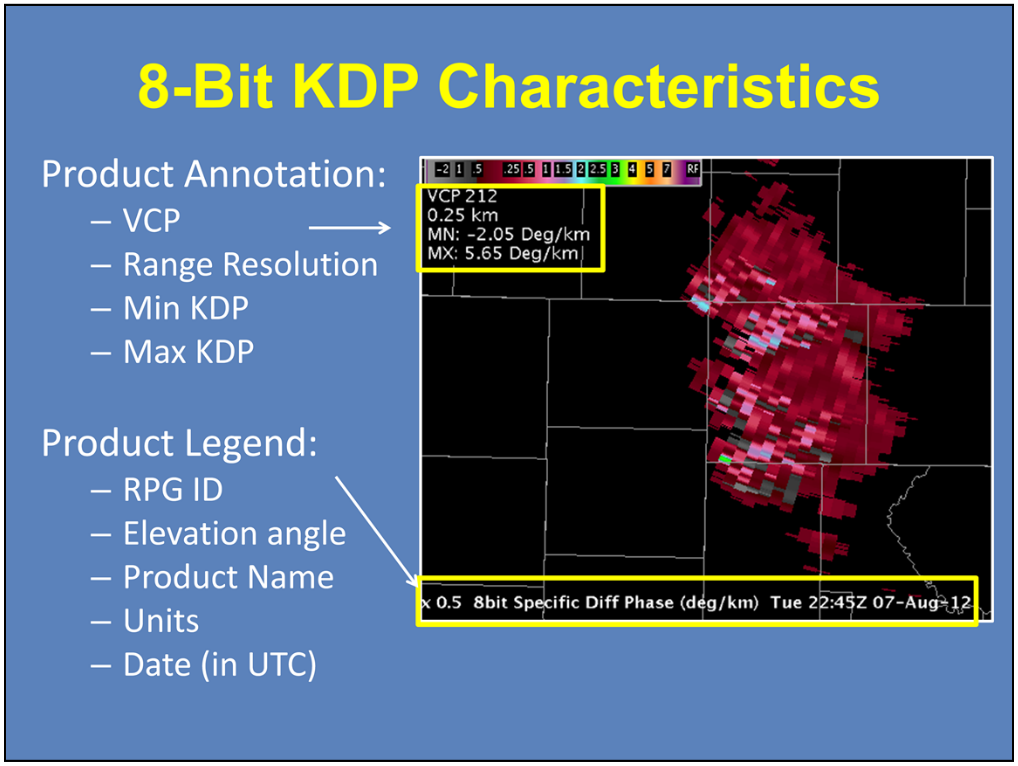

The annotation and legend can be found in the usual spots as well.

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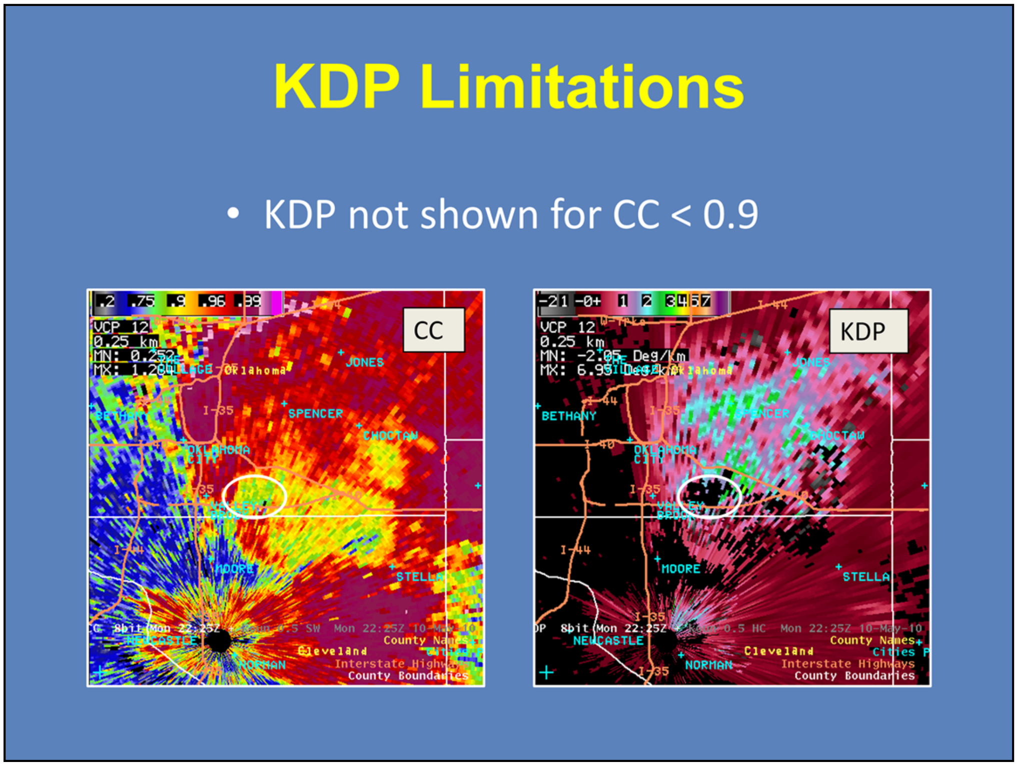
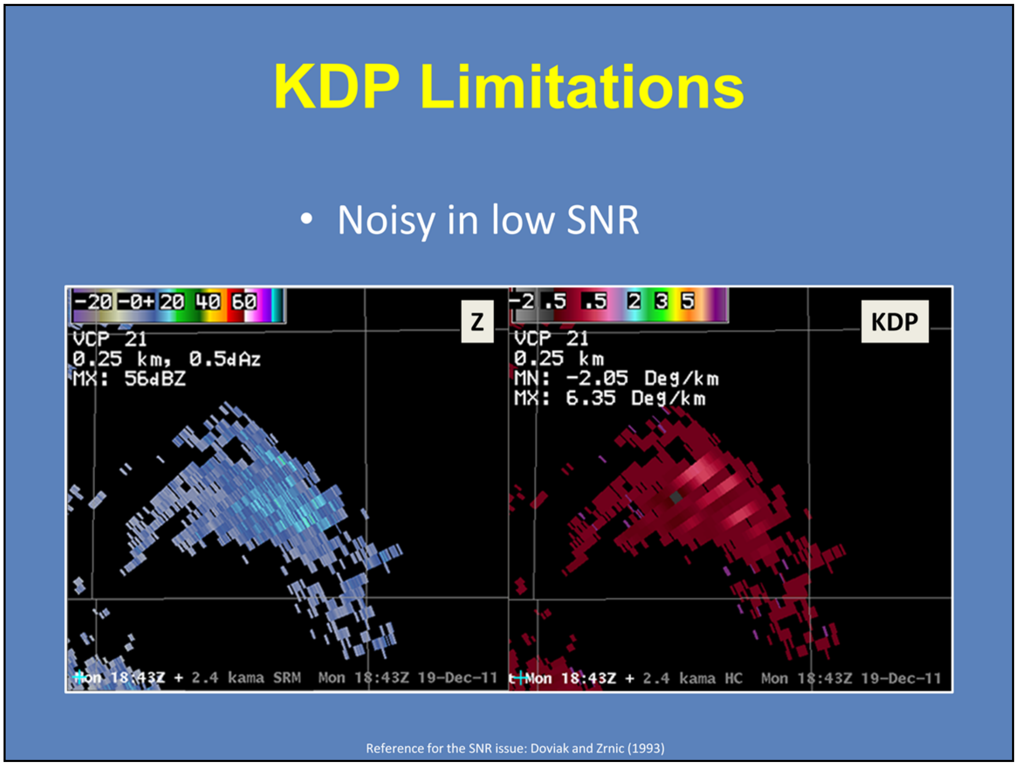


When the CC is below 0.9, Phi DP accumulates significant errors making it appear very noisy. This noisy Phi DP makes it useless to compute KDP. Therefore, in bins with CC less than 0.9, KDP will not be plotted, so it will appear as black holes in the data. Here is an example where KDP is “blacked-out” because CC was less than 0.9.



In regions of very low signal where the signal-to-noise ratio (SNR) is very low, KDP will look noisy. Note in the example how KDP is some what chaotic in the low Z regions far from the radar.

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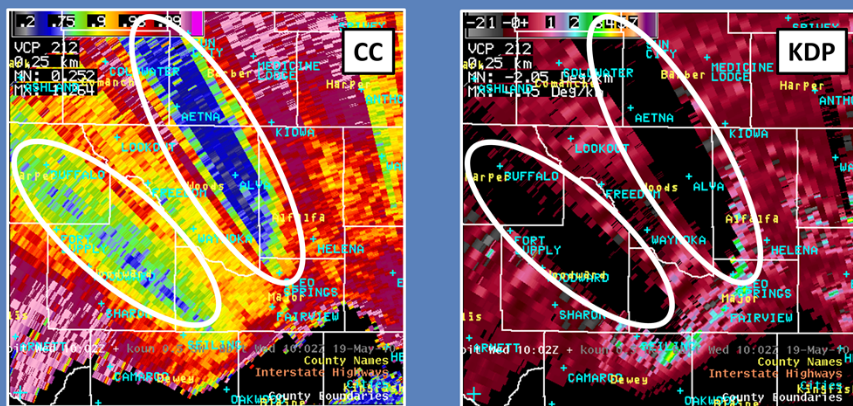
KDP Limitations

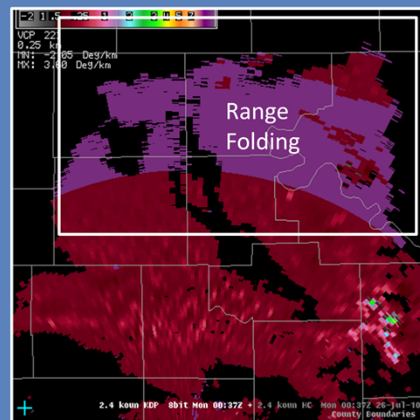
- Not available in areas of non-uniform beam filling (NBF)



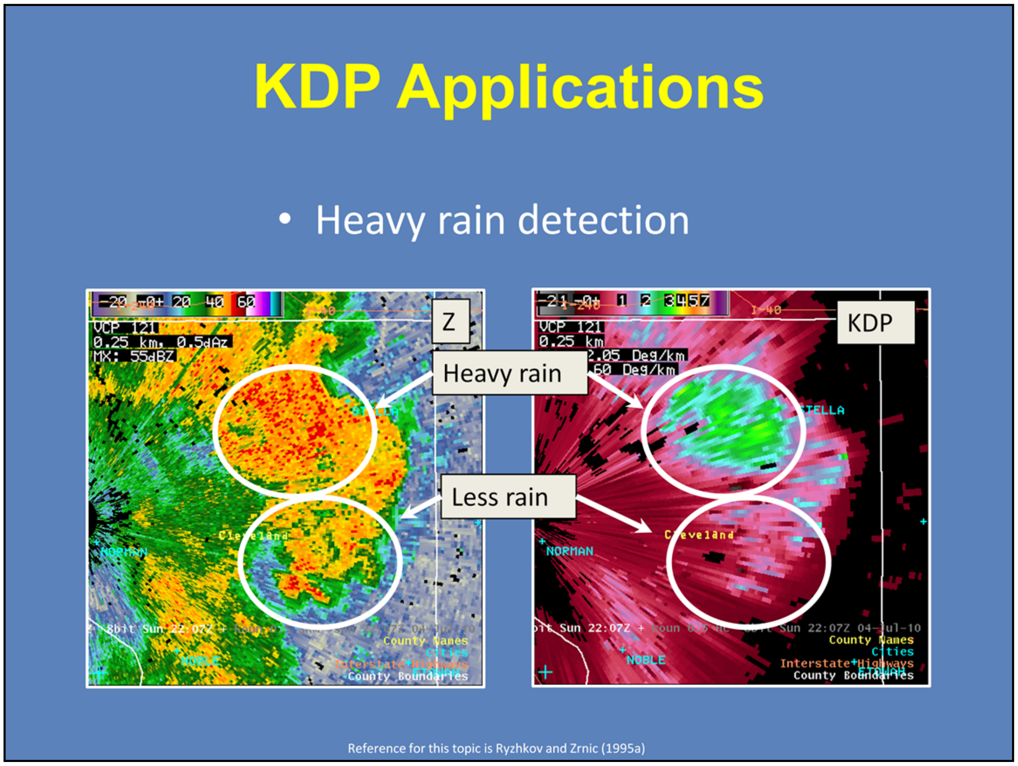
We saw in the CC lesson that non-uniform beam filling causes CC to dramatically decrease along the radials that experience NBF. And, as we just saw a couple of slides ago, if CC less than 0.9, then KDP does not get computed. Therefore, in regions of NBF, especially when CC less than 0.9, KDP will be “blacked-out”. Here is an example of extreme NBF that caused large areas of KDP not to be displayed.

KDP Limitations

- RF in the batch cuts
  - Between 1.65 & 6.5°



The last limitation with KDP that we'll look at is in the batch cuts, range folding may obscure some signatures in KDP. 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 KDP.



The primary advantage of KDP is its ability to detect heavy rain situations. Here is an example where we have a modest area of greater than 40 dBZ echoes that is fairly uniform in intensity. Looking at KDP, we see higher KDP values to the north, and lower KDP values to the south despite reflectivity values being almost identical. This tells us that there is heavy rain falling where the KDP values are higher and not as much rain where KDP is lower. We'll talk more about this example in a few slides.

A reference for this topic is Ryzhkov and Zrnic (1995a), focusing more on R(KDP) vs. R(Z), but it highlights the utility of KDP as a useful tool for identifying areas of moderate to heavy rain.

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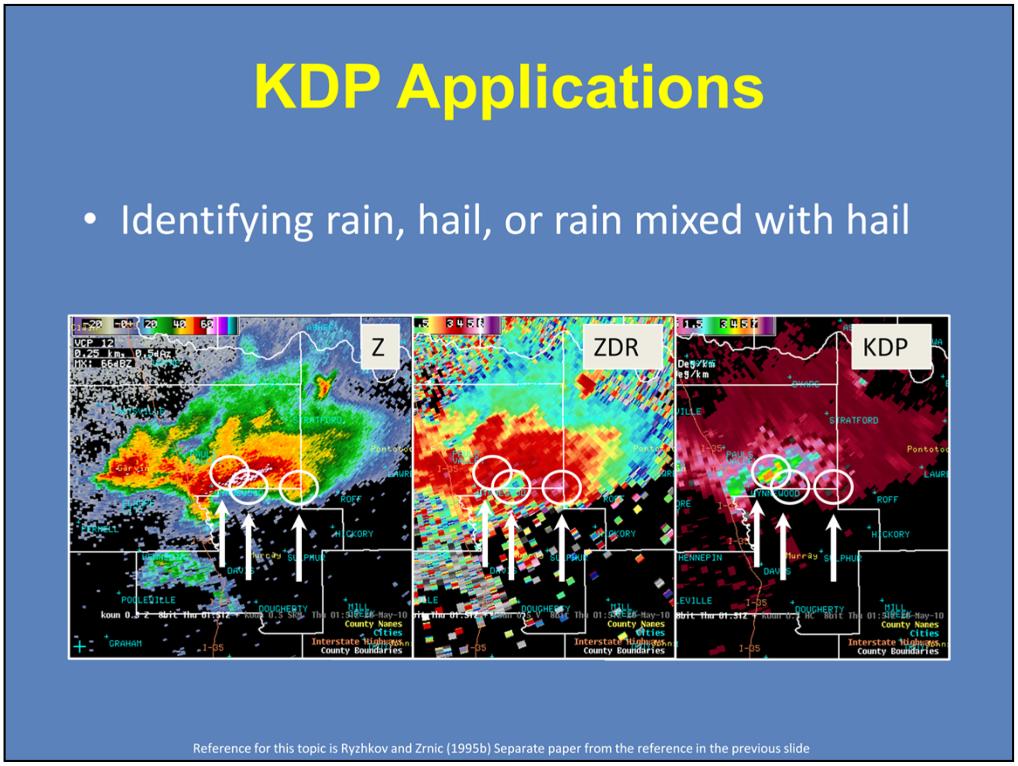

KDP is mostly immune to hail contamination. Here is an example to illustrate. Looking at the white circle farthest to the east, we see Z is moderately high and ZDR is very high. However, KDP is very low, barely reaching 1 deg/km. This tells us we have large rain drops, but in low concentrations in this region, so rainfall is going to be minimal.

Nearer the core (middle white circle), we see that Z is higher, so we might be thinking increased rain. However, ZDR tells us that this is likely hail because ZDR is a local minima (less than 2 dB) and KDP is very near 0 deg/km. So, this area is mainly hail, with very little rain mixed in.

The last area to investigate is the farthest west white circle. Z is roughly the same as the last example, but now ZDR is moderately large (around 4 dB) telling us we have good-sized drops in this region. Looking at KDP, values are approaching 5 deg/km. This tells us there is a lot of liquid water in this region, so flash flooding could be an issue.

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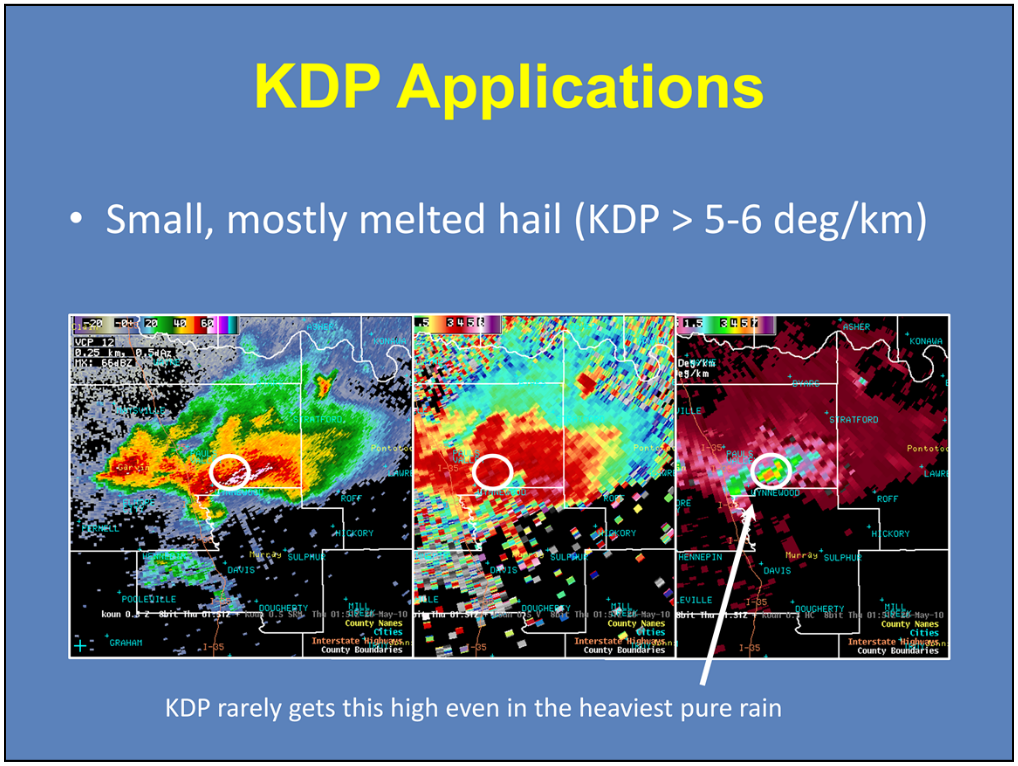

One caveat to point out here is small, mostly melted hail. In these situations, flash flooding may not be a threat but KDP could become very large. This is because in regions of very small, mostly-melted hail, the radar sees these particles as very large rain drops, and if there are a lot of these particles present, KDP sky rockets to values as high as 10 deg/km! A good rule of thumb here is that in pure rain situations, KDP will rarely get above 4-5 deg/km even in the heaviest of rains. So, if KDP are greater than 5-6 deg/km, you can bet that there is some small, melting hail present and you will need to mentally adjust your estimates of rainfall based on KDP, or rely on other means of estimating rainfall.

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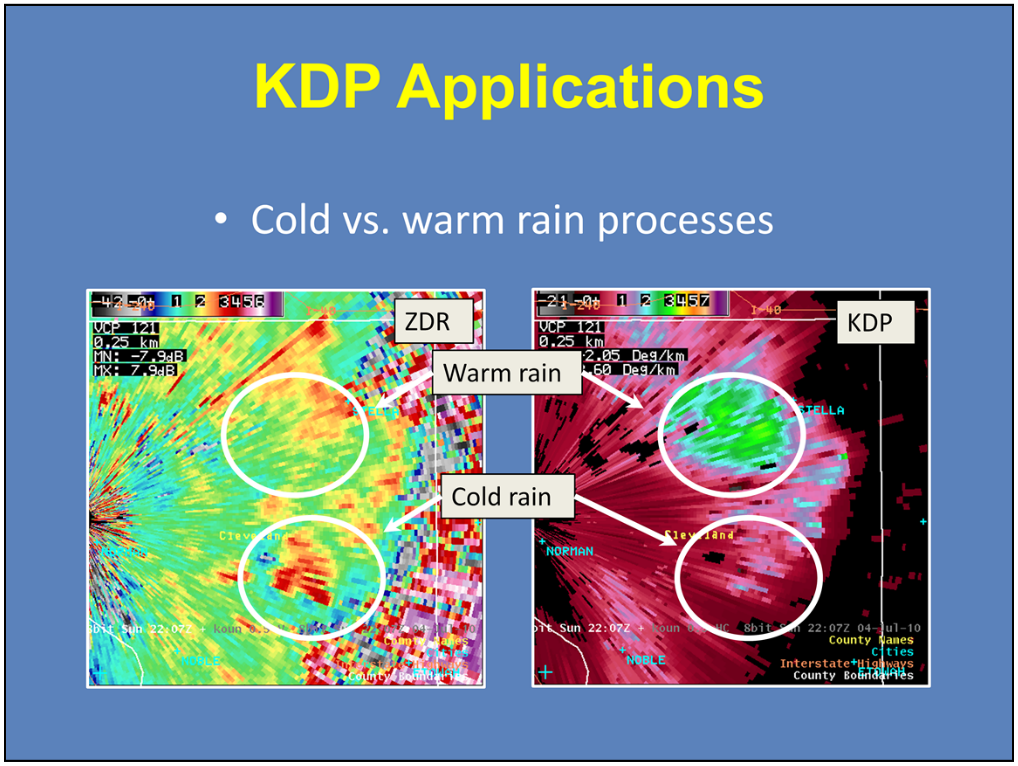

Here is the example from 2 slides ago, except now we are showing ZDR and KDP together. Recall that Z was similar in both areas highlighted here. Note, to the north, ZDR are moderately high but don't really exceed 3 dB. However, to the south, ZDR are approaching 4-5 dB. This tells us that larger drops 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 and might warrant a flash flood warning soon given all other factors are in place.

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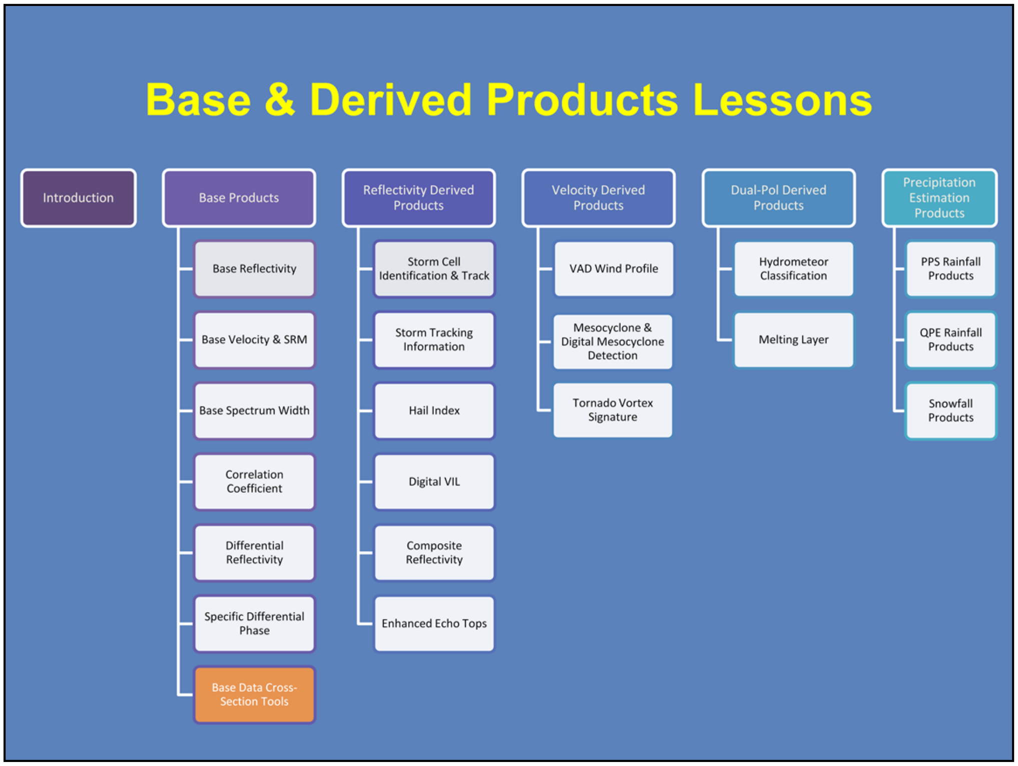
Summary: KDP

- Range derivative of differential phase shift
  - Great for identifying areas of high liquid water content
- Standard radar limitations apply, plus:
  - Data voids where CC < 0.9, areas of NBF
  - Noisy in low SNR
  - RF in batch cuts

In summary, KDP is the range derivative of the differential phase shift, and is primarily good for identifying regions of heavy rain, even in hail contamination cases. However, KDP is not computed where CC less than 0.9, is noisy in low SNR regions and is RF in the batch cuts.

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.



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

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Learning Objectives

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

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

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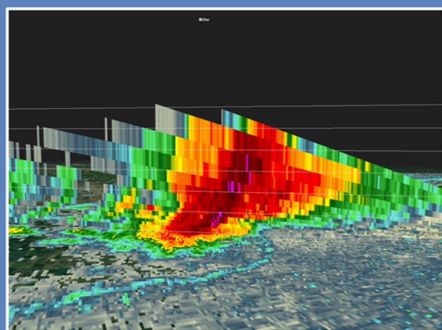
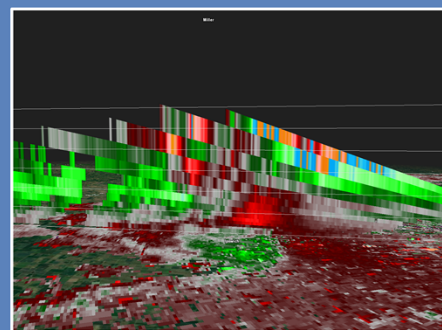
Cross-Sectional Analysis

Great way to assess severity of storms

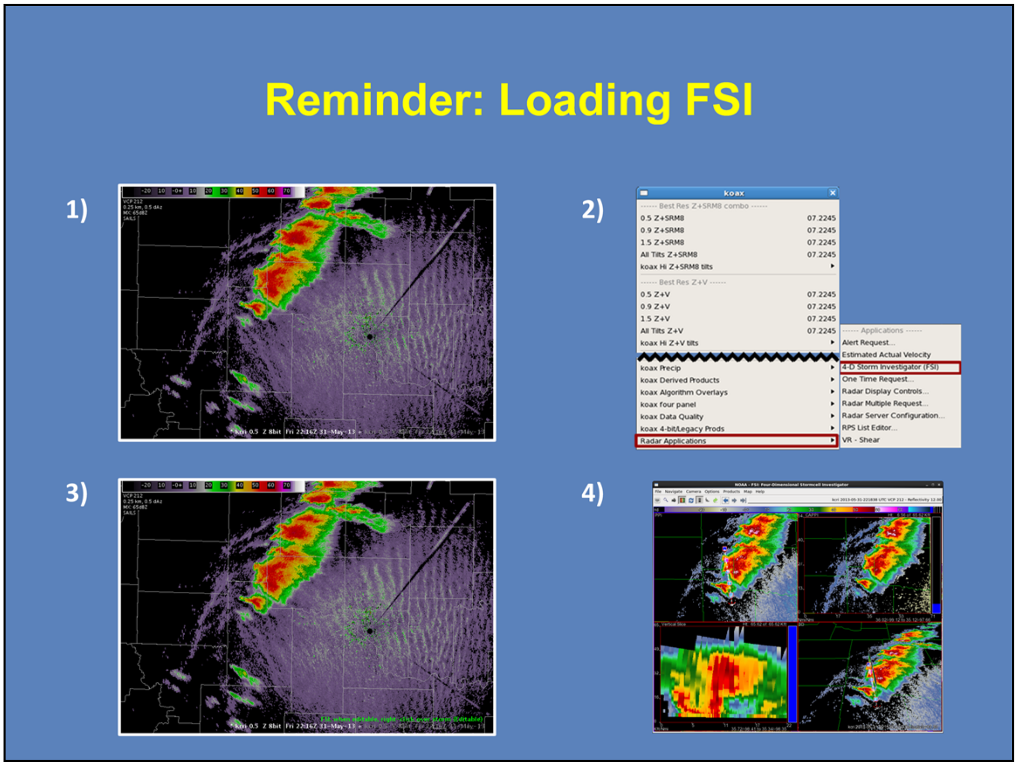


Reflectivity Cross-Section



Velocity Cross-Section

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 three tools 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.



We will start with FSI. In case you need a reminder, here are the steps for loading FSI from the AWIPS Fundamentals training:

- First, load a 0.5 deg base data display with Reflectivity;
- Choose “4-D Storm Investigator” from either a specific radar menu or the Tools menu;
- Right click on the storm you want to investigate; and
- The FSI will appear momentarily in a separate window.

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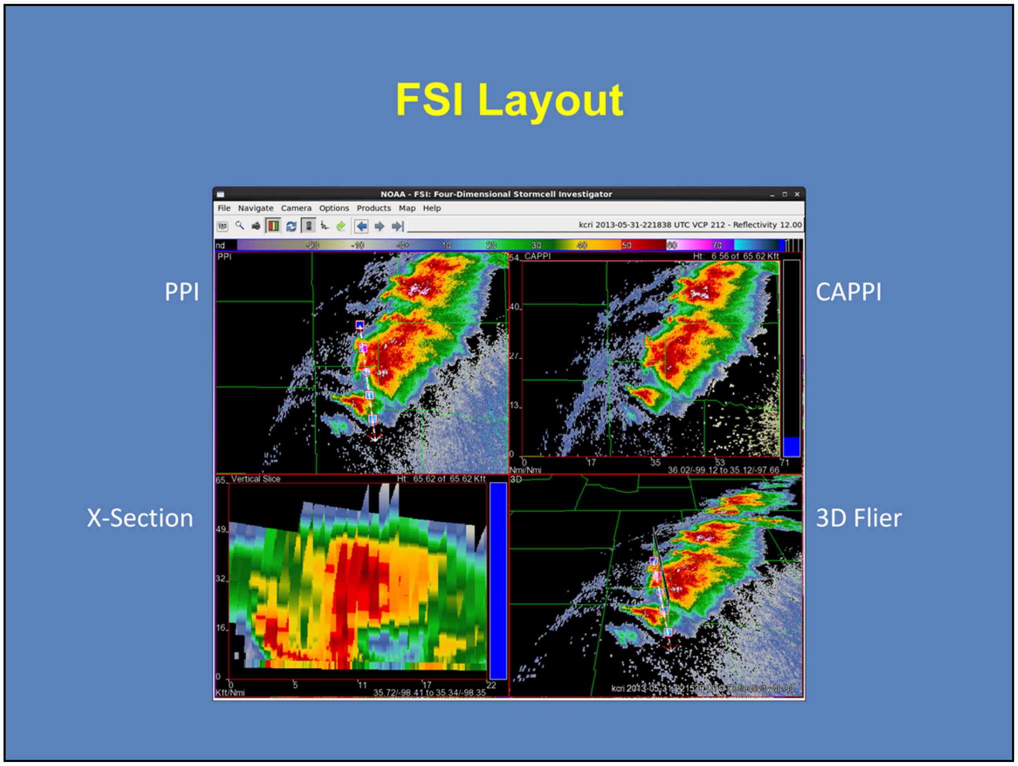

Here is an example of the FSI window. In the top left is the PPI, or what you normally see in AWIPS-2. The top right is the CAPPI panel, which stands for constant-altitude PPI. Here you can define a constant height, and see how the different base data look at that height. The bottom left is the vertical cross-section window. Here you can see vertical cross-sections of the base data, which will be the main focus of this lesson. Finally, the lower right is the 3D flier window. This is where you can get as close to a 3D look as possible by combining a perspective view with the CAPPI and vertical cross-section views.

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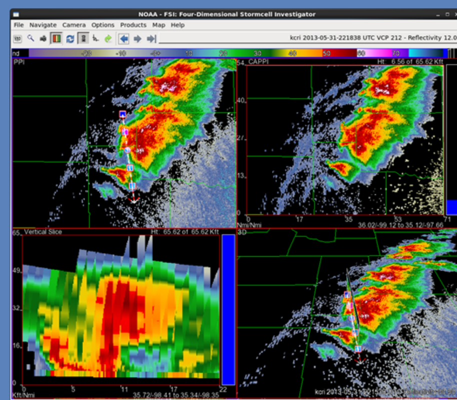
Reminder: Navigating FSI

Keyboard shortcuts:

- "1" or "Z" = Reflectivity
- "2" or "V" = Velocity
- "3" or "S" = SRM
- "4" or "W" = SW
- "5" or "D" = ZDR
- "6" or "O" = CC
- "7" or "K" = KDP



Just to remind you, all base data are available for viewing in FSI. Use the alphanumeric shortcut keys shown in order to toggle between each of the base products. Look over the display and, when you are ready to proceed, click "Next" to go to the next slide.

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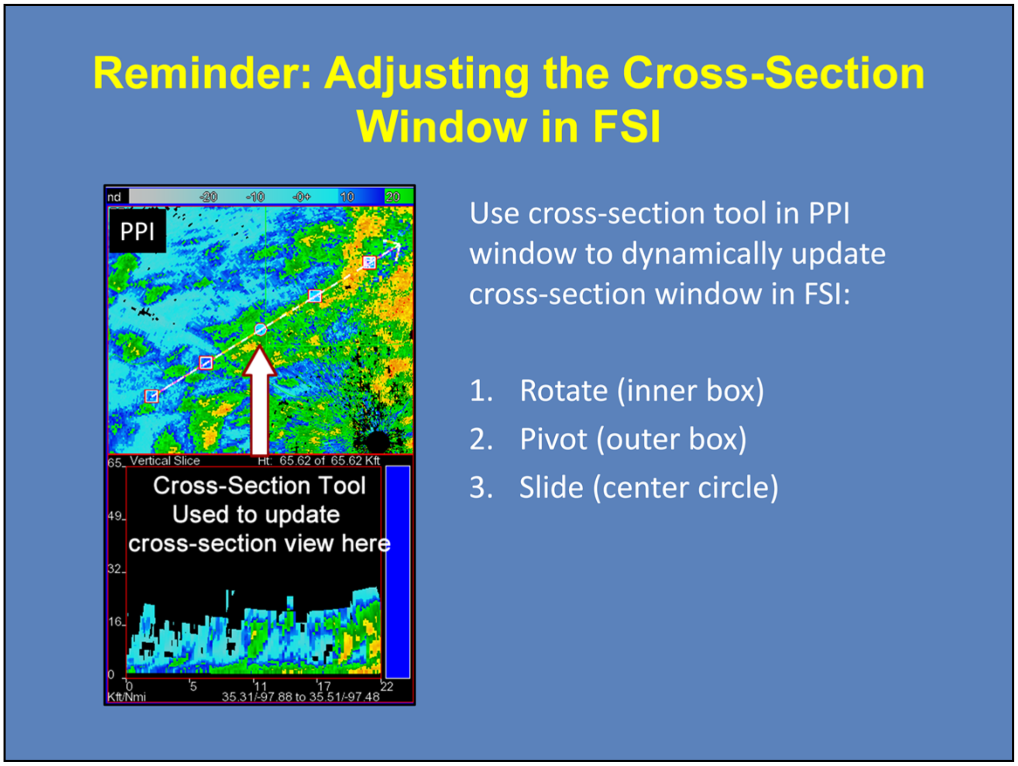
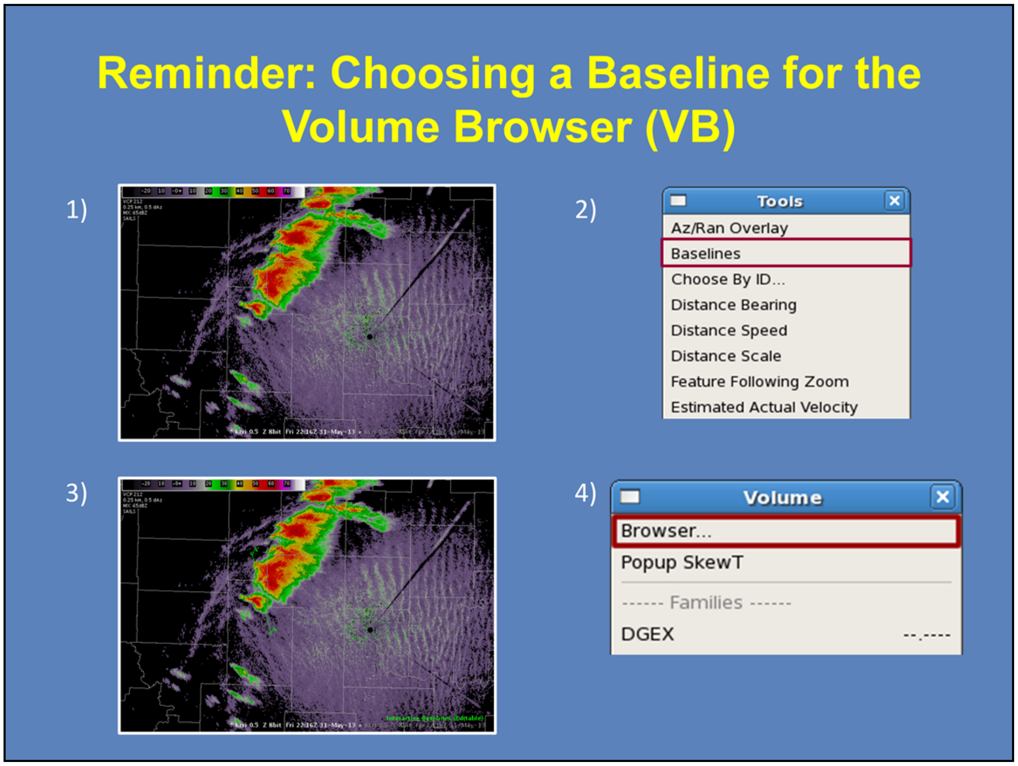


More than likely, you will want to adjust the cross-section baseline that FSI provides when it opens. There are three ways to manipulate the baseline provided by dragging different objects on the feature. You can:

1) Rotate the line (using the inner boxes);
2) Pivot the line (using the outer boxes); and
3) Slide the line (using the center circle).

That covers the basics of FSI.



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.

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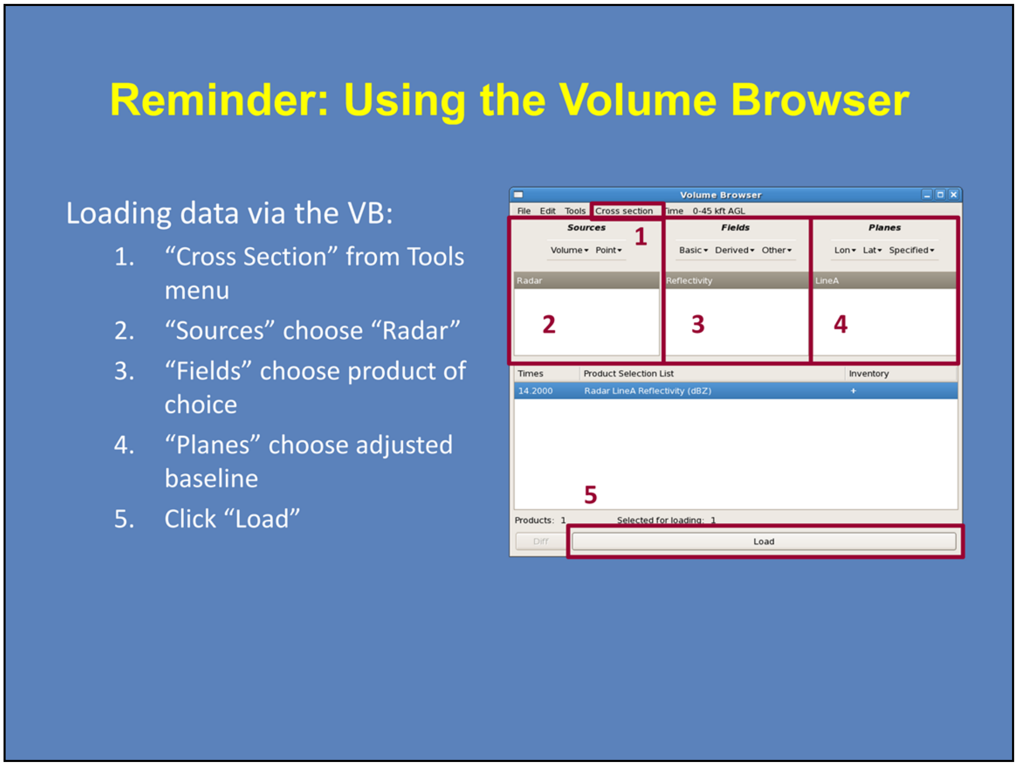

Once the Volume Browser window appears, follow these steps:

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”.

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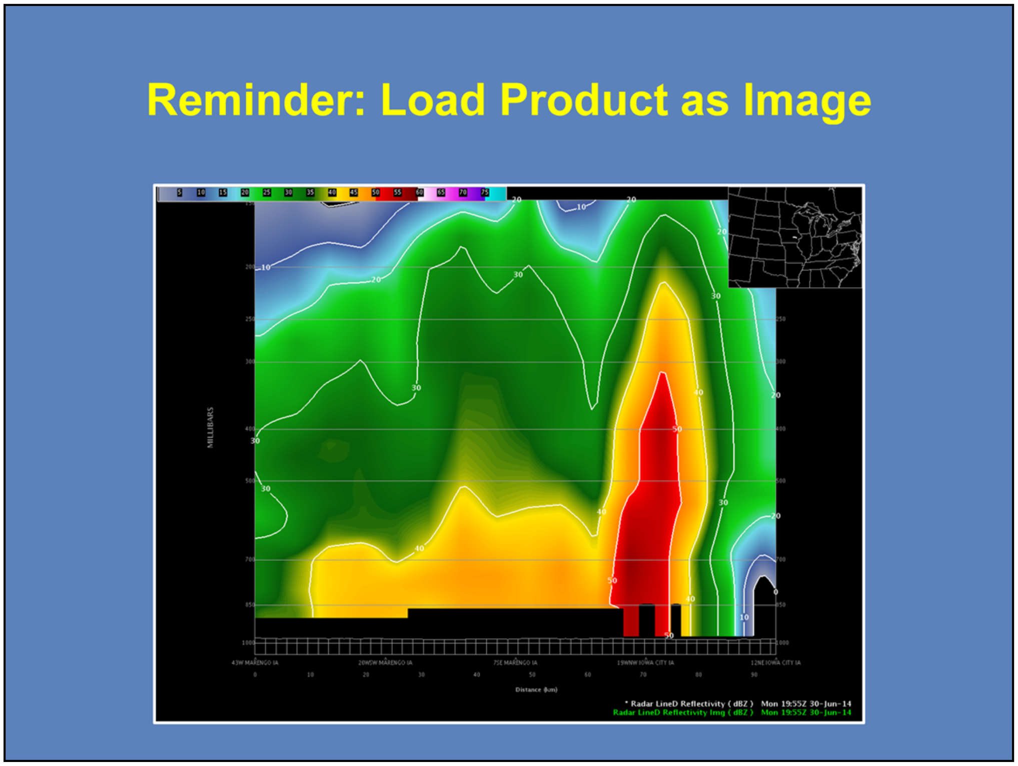

When your cross-section first loads, it appears initially as just contours. You will likely want to make your radar product cross-section an image product instead. To make that change, right-click over the product legend info and choose “Load as Image” from the menu that appears. Here’s an important 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.

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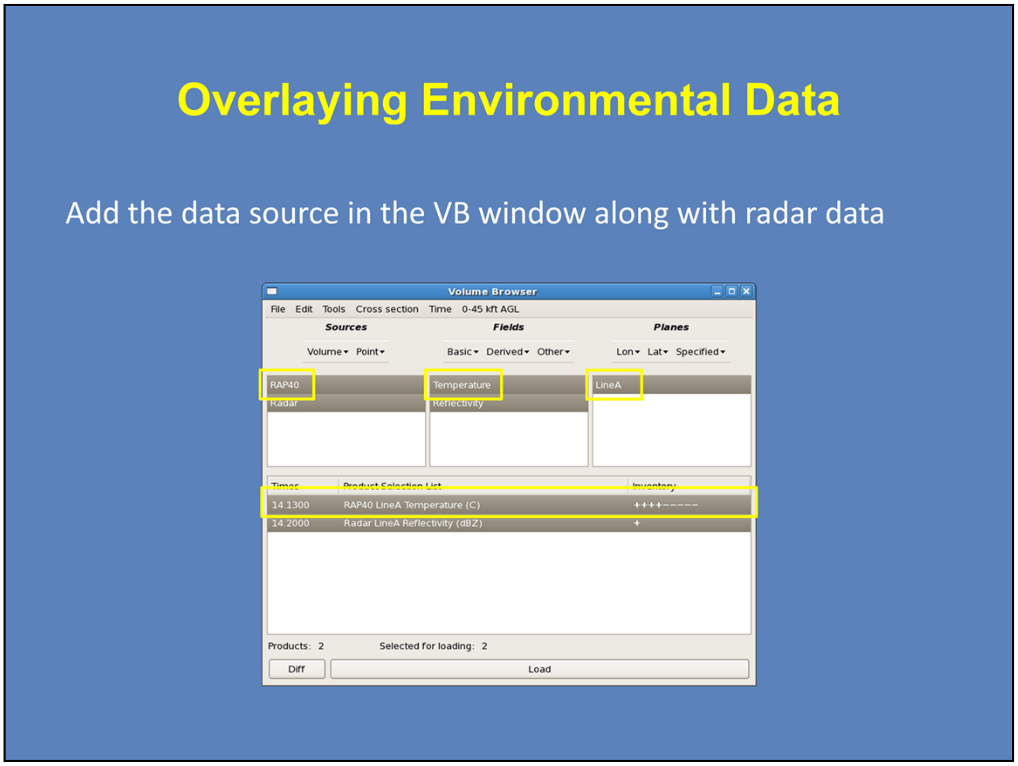

With Volume Browser product cross-sections, you can overlay environmental data such as temperature directly on your image. Just choose the data source and field for the parameter you want to overlay, then use same baseline for your Plane, and AWIPS will plot the parameter on top of the original cross-section.

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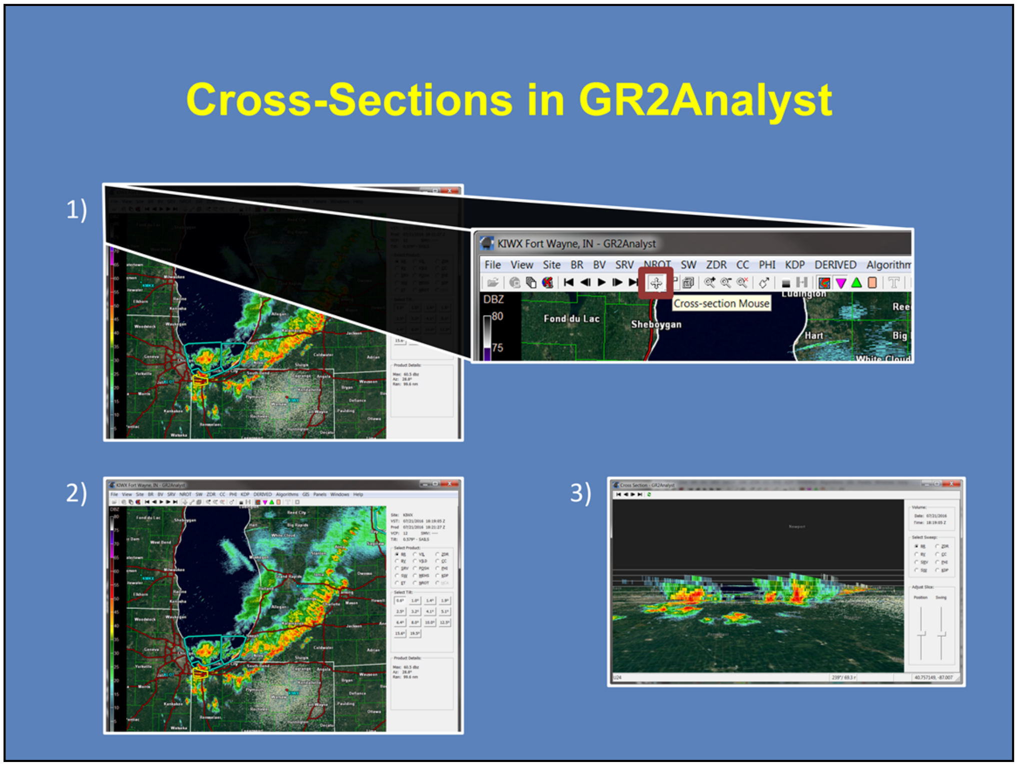

Lastly, let's talk about GR2Analyst. Unlike the previous two methods of generating cross-sections, we have not been training you on how to use this application in previous lessons. However, for the sake of time, I'm just going to assume that most NWS forecasters have an elementary knowledge of GR2Analyst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

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

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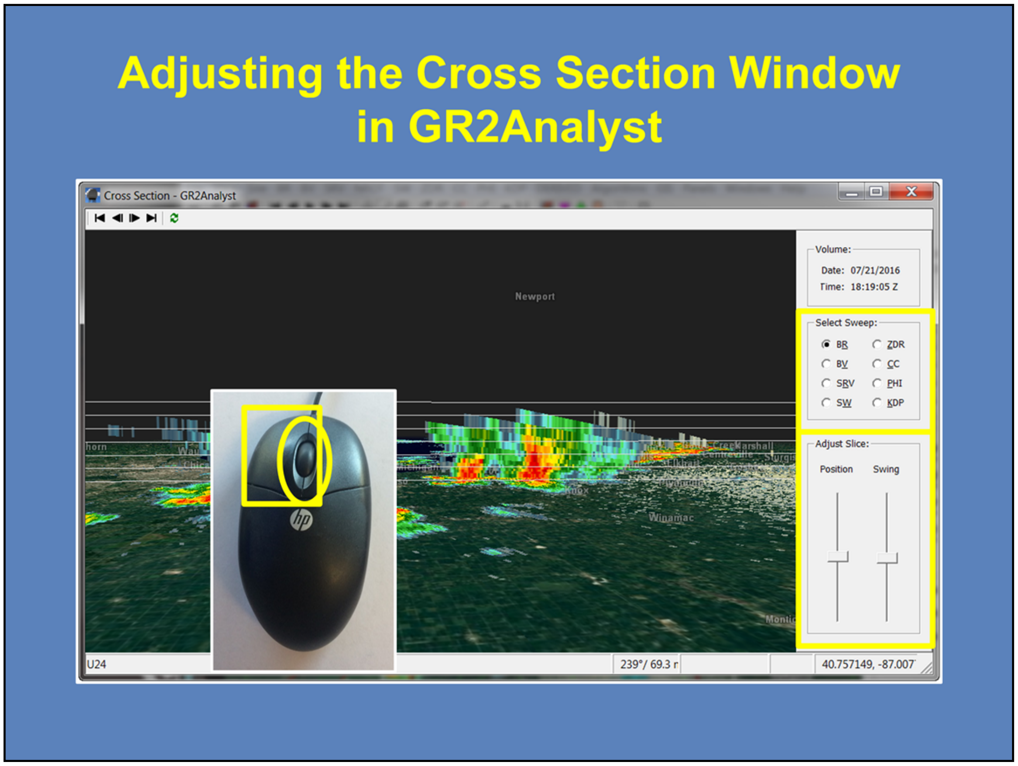
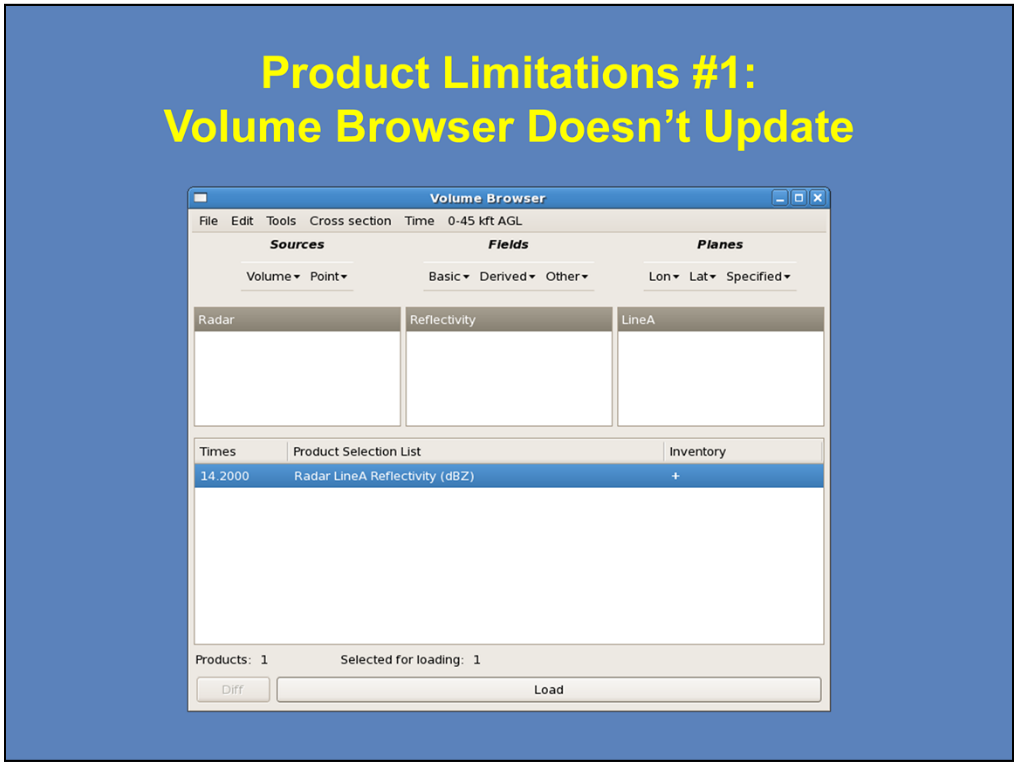


You have several options available to adjust the cross-section display in GR2Analyst:

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 find tune the location of your cross-section baseline.



So let's start with the limitations of these cross-section tools. Volume Browser cross-sections do not update as new data become available. This is a bug in AWIPS-2 and should be fixed soon, but until then, if you notice the cross-section not updating as new data come in, just re-load the product (adjusting the cross-section orientation if necessary).

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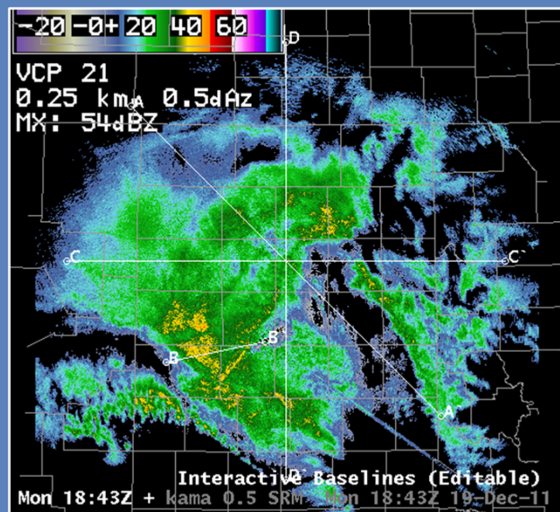
Product Limitations #2:
Baselines Don't Dynamically Update (VB)



Unlike in FSI and 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.

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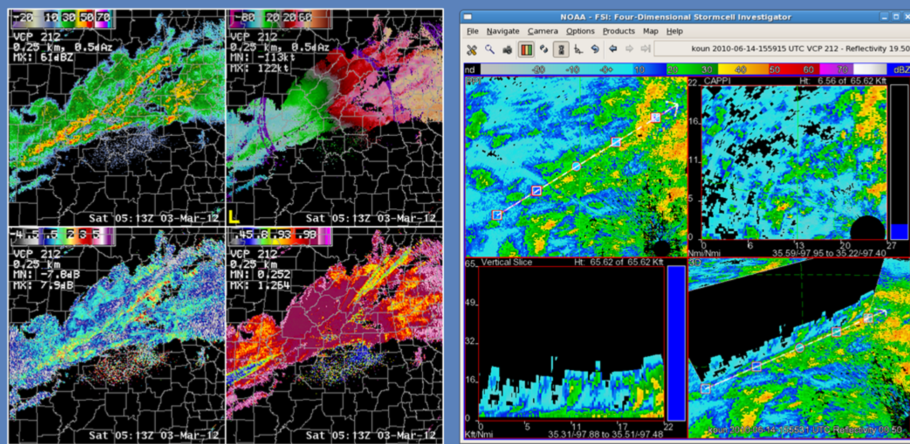
Product Limitations #3: Can Be Resource Intensive (FSI)



1 64-Frame All-Tilts + 1 FSI Window

The downside to FSI's dynamic updates is that it requires a lot of computer resources to do it. Depending on what you have running, FSI can negatively impact performance by significantly slowing your system down. We recommended limiting yourself to only one 64-frame, radar all-tilts display and one FSI window running on the same monitor. If you notice slow system performance even with these restrictions, try closing your FSI window and see if any improvement occurs.

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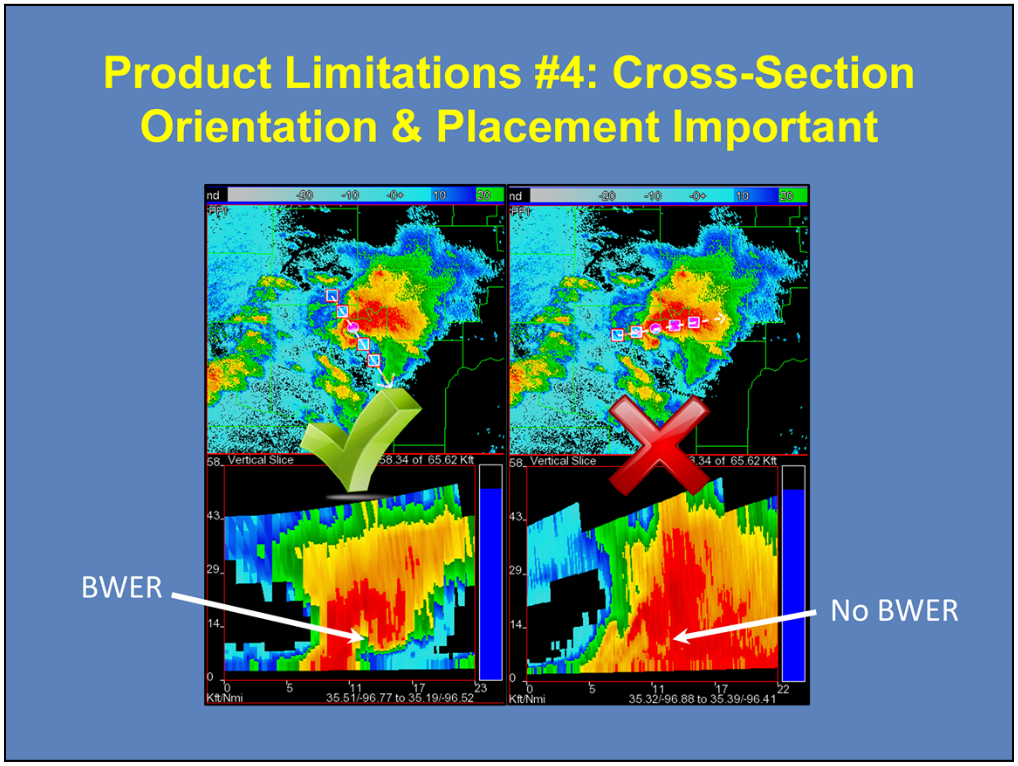

The last limitation we will mention regards the orientation of the cross-section. Improper orientation of your cross-section baseline can result in you missing important storm features. Let's use the example we show on the slide.

Here is a supercell thunderstorm that I suspect has a Bounded Weak Echo Region (BWER) that I want to analyze using a cross-section. The baseline on the left properly dissects the inflow notch, allowing me to clearly see the BWER and reflectivity overhang. The baseline on the right misses this critical part of the storm's structure and, instead, cuts through the storm's core. The end result: No BWER or nice updraft structure like I was suspecting in this second baseline. So, you can see how the orientation and placement of the baseline is crucial when searching for specific features.

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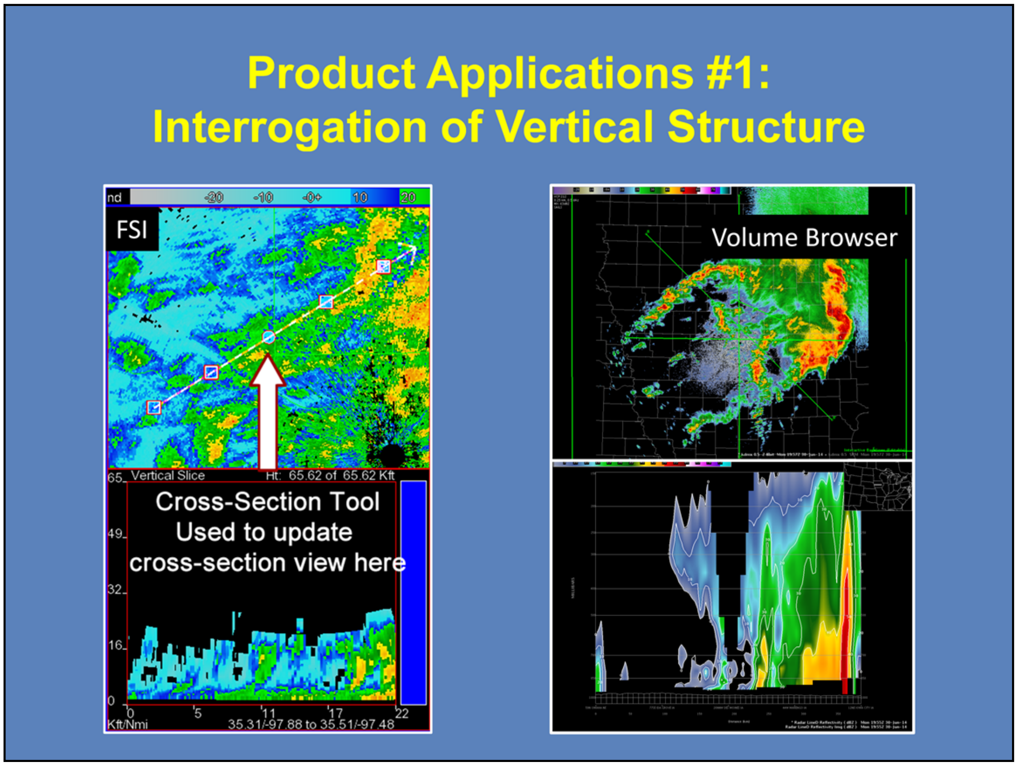
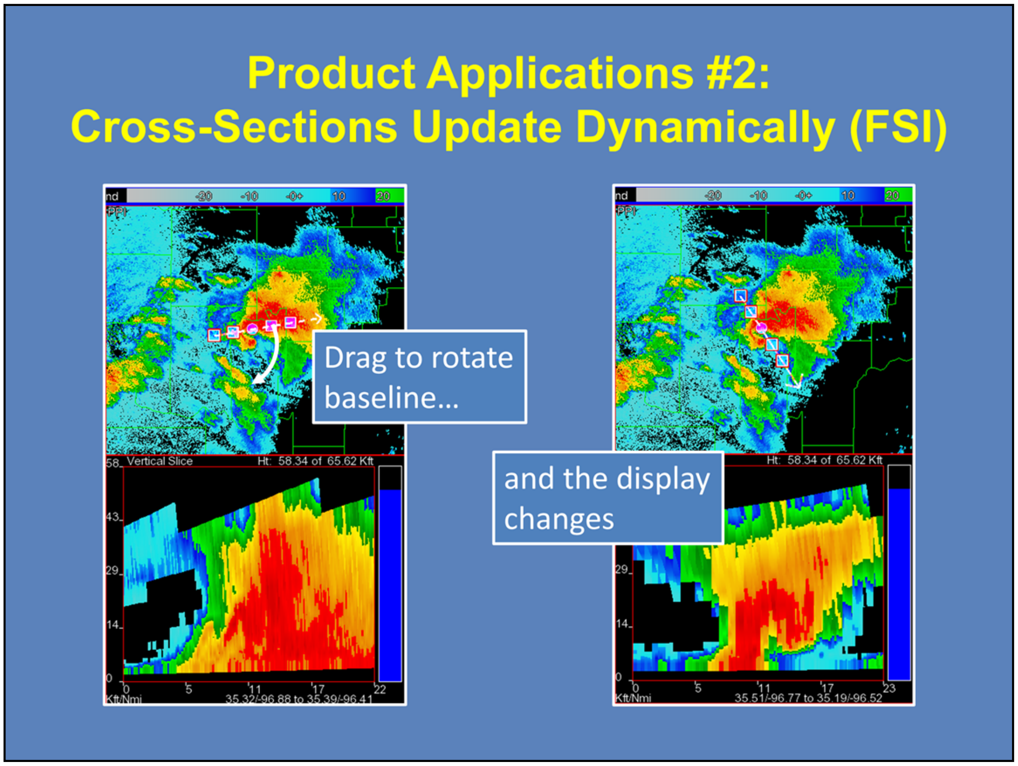


Now let’s look at some applications with these products. All three types of cross-sections are much easier to create than the old RPG-based cross-sections. These solutions make it simpler to analyze the vertical structure of storms in real-time, which aides in warning operations.



If you choose FSI or GR2Analyst to display cross-sections, the display will update dynamically as you edit your baseline. This feature allows you to quickly change from storm to storm or alter your view of a particular storm. This dynamic update feature can be highly beneficial during high end events where you need to interrogate multiple storms quickly.

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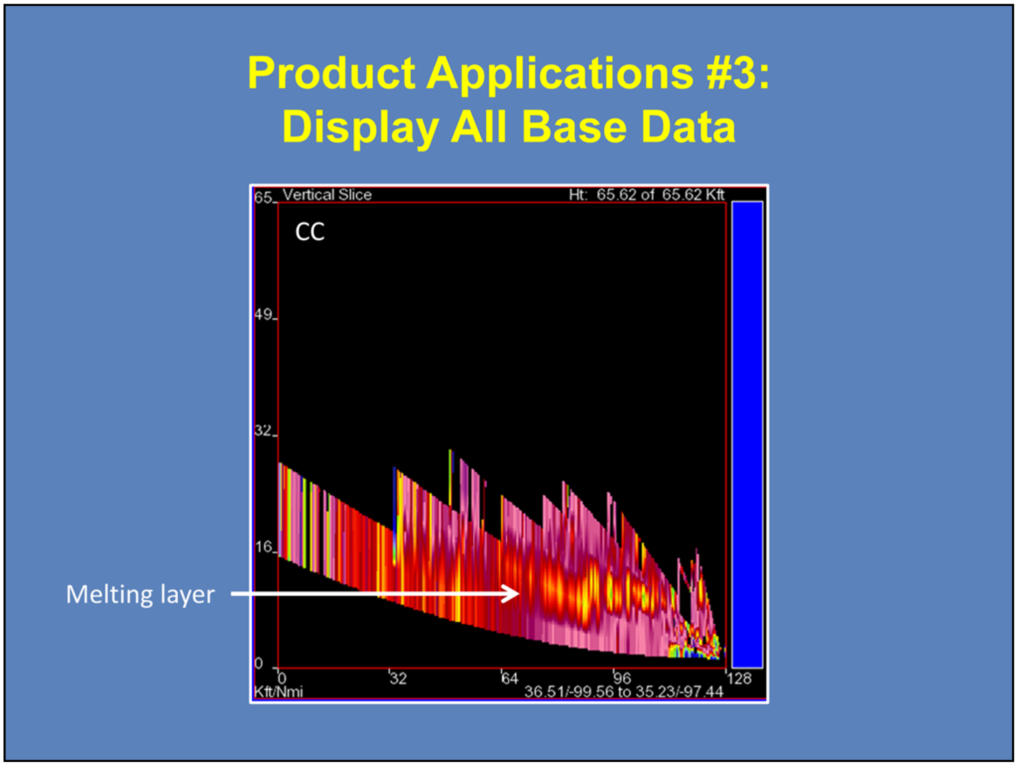
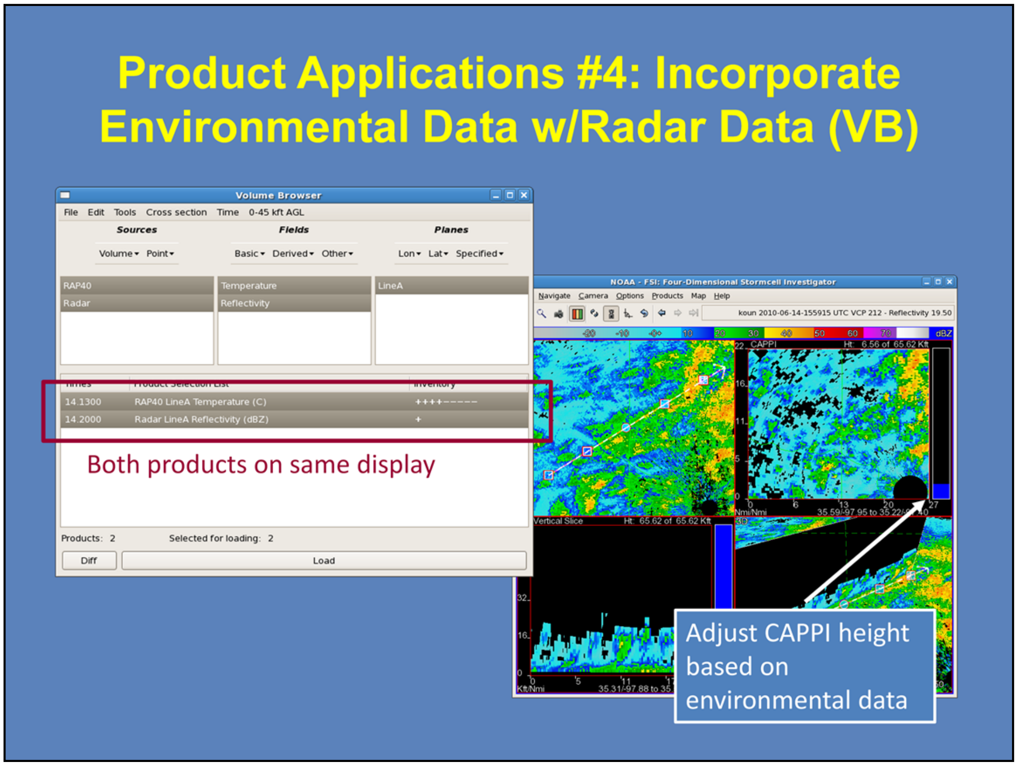


The RPG only generates cross-sections for Reflectivity and Velocity. FSI and GR2Analyst can display all base data in a cross-section, which can be very handy if you are trying to identify a feature, like the melting layer, as in the Correlation Coefficient image shown.



Lastly, the Volume Browser cross-sections allow you to overlay environmental data directly on the display. While FSI lacks this specific capability, you can adjust the CAPPI height to match heights of specific temperature levels and manipulate the display based on the environmental data at your disposal. GR2Analyst has the ability overlay surface data and other GIS shape files, too, but it doesn't provide the same capabilities as the volume browser cross-sections.

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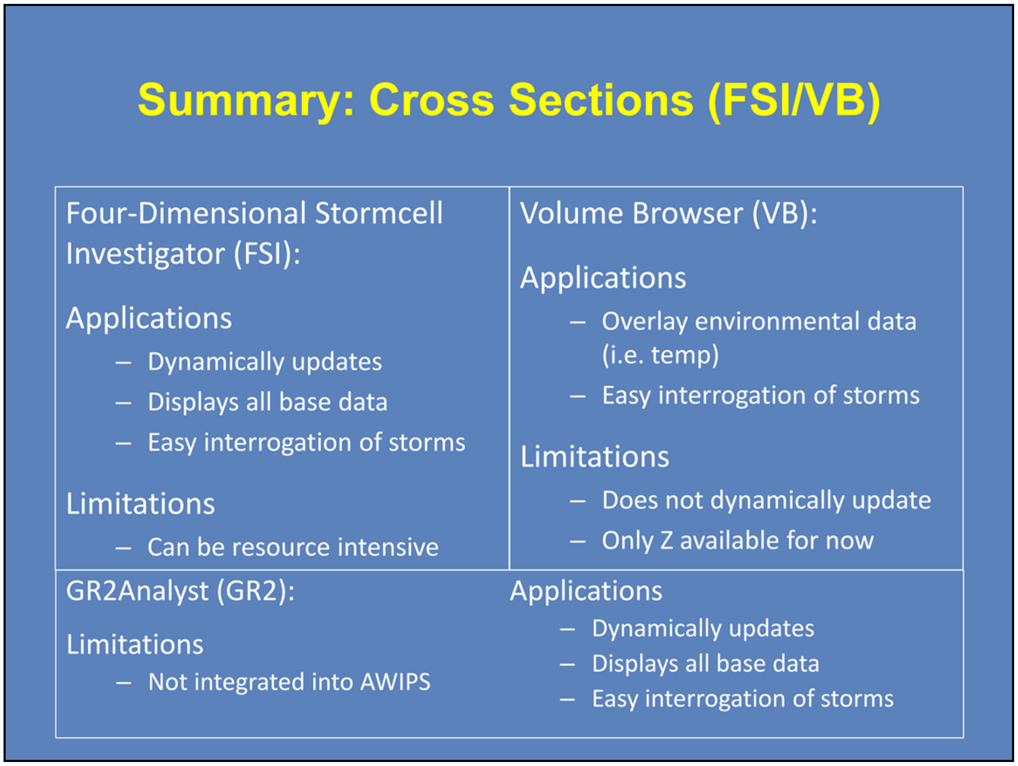

In summary, FSI, Volume Browser, and GR2Analyst are all useful tools for doing cross-sectional analysis. There are several advantages to these tools. First, all base data are available (at least with FSI and GR2 Analyst). It's easier to update the data when needed. You can also include environmental data into your analysis (at least with the AWIPS-2 tools). While there are limitations with these tools, most of the limitations exist with any cross-sectional tool you would use for radar analysis.

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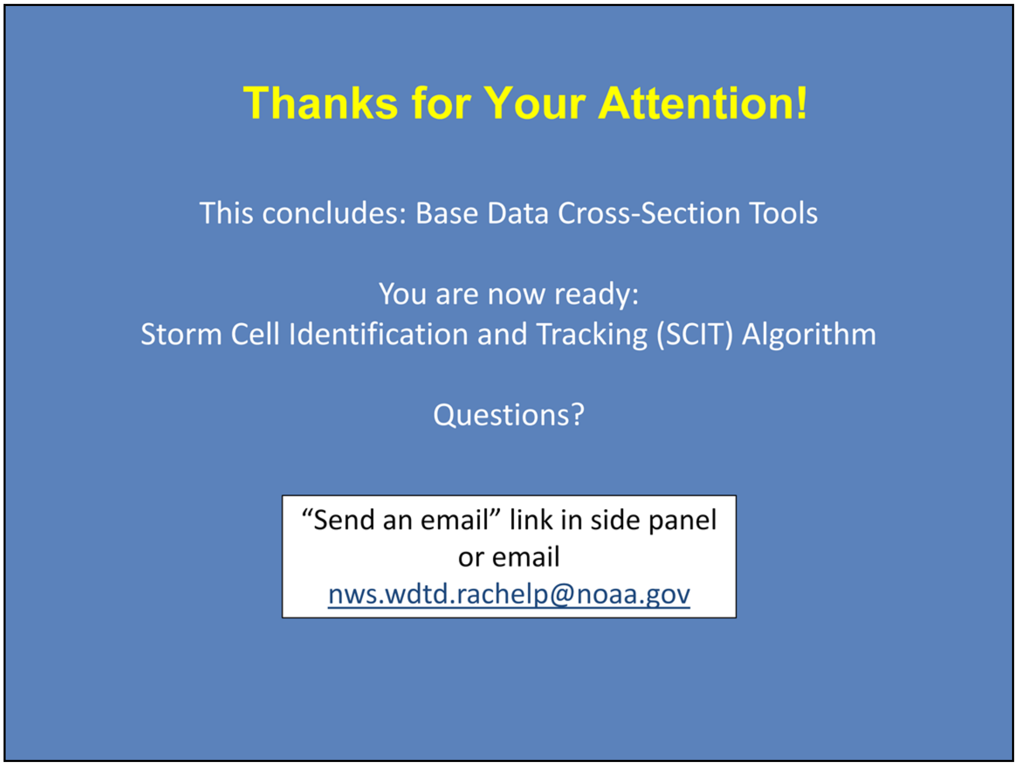

If you have passed the quiz, then you have successfully completed this lesson. You are now ready to move onto the next lesson (on the SCIT algorithm). If you have any questions, please contact us using any of the e-mail addresses listed below.

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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.

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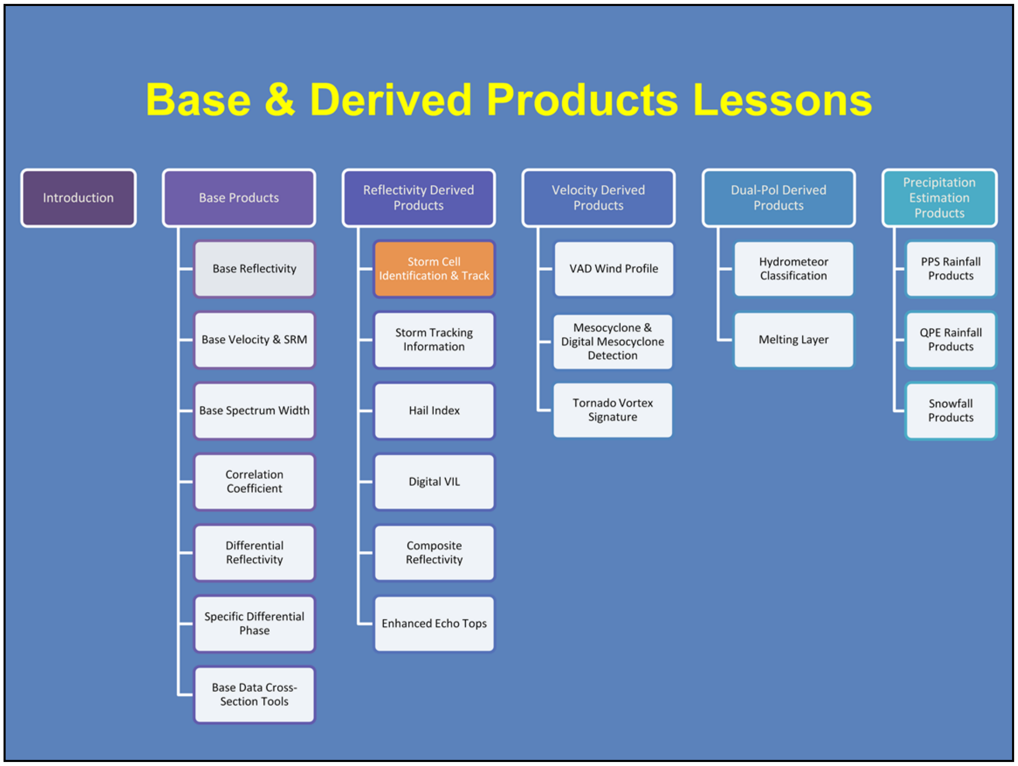

Here is a roadmap for the lessons in this topic. This lesson on the SCIT algorithm, shown shaded in orange, is the first in the Reflectivity Derived Products Section of this topic.

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

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.

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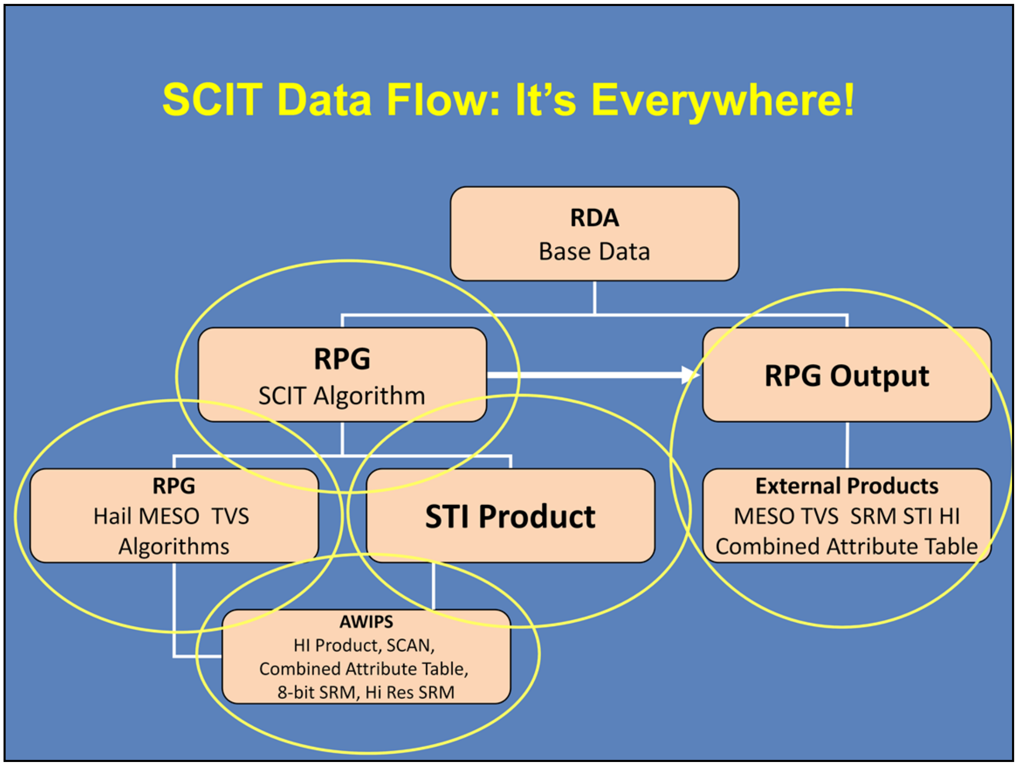
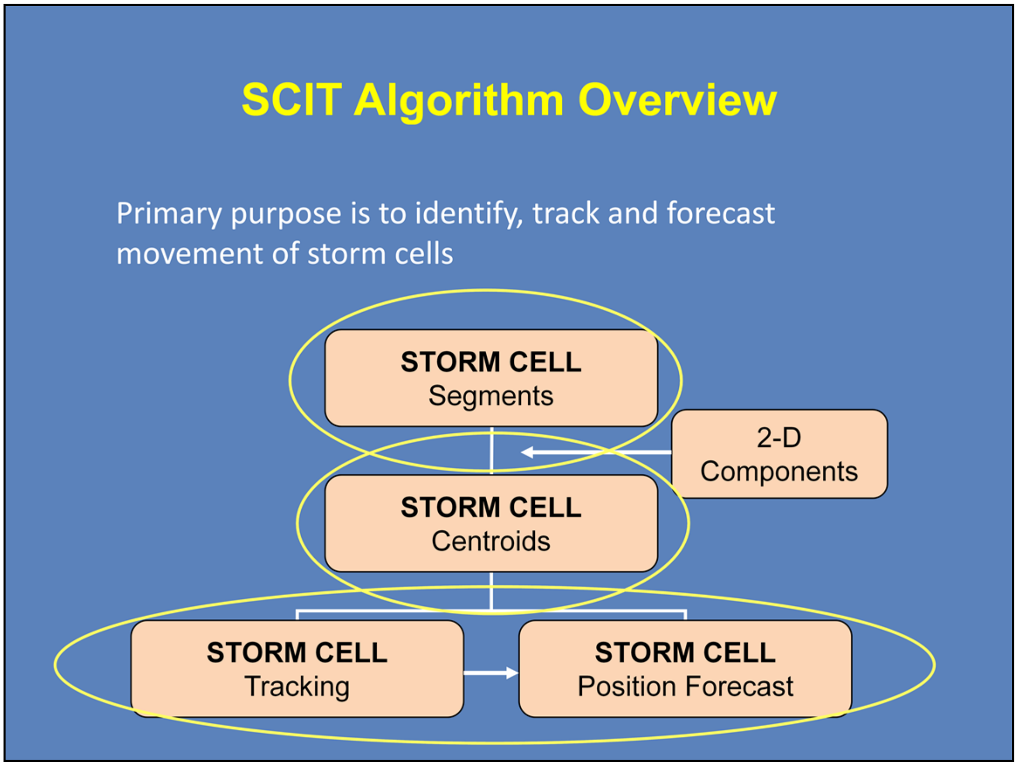


We start our discussion on algorithms with SCIT because it plays an important roll in so many other algorithms at the Radar Product Generator (RPG). As base data flows into the RPG, the SCIT algorithm (Johnson et al., 1998) processes the data and produces the Storm Track Information product (which will 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).



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.

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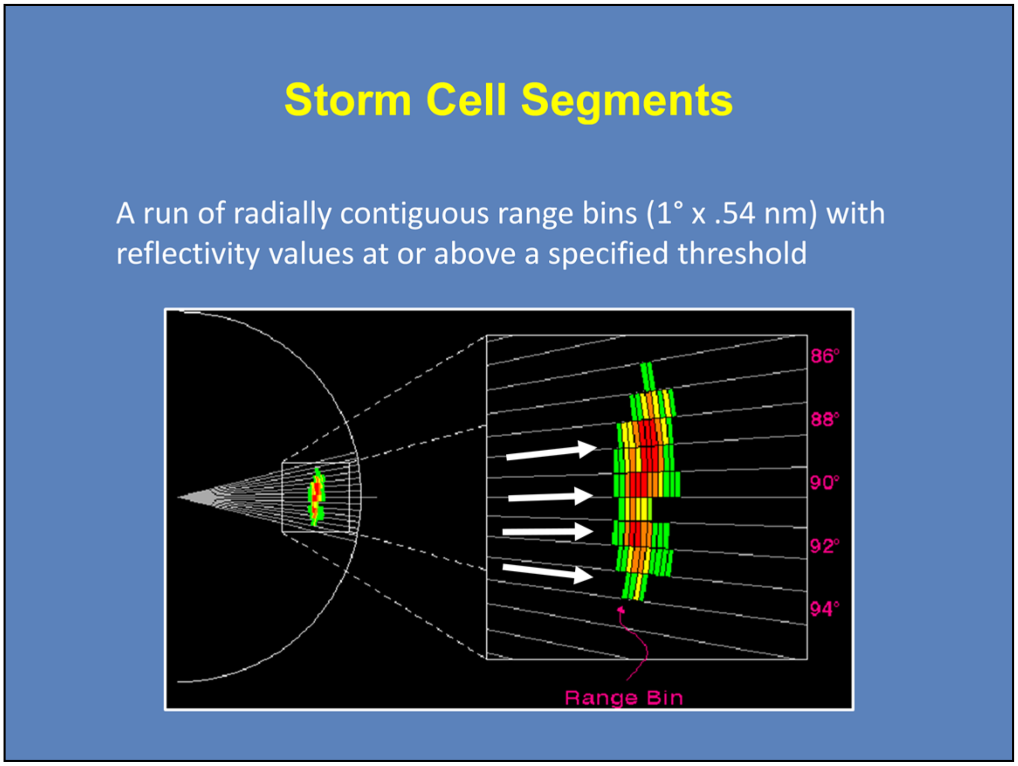

Storm cell segments are the fundamental traits that the algorithm identifies. A segment is defined as a run of contiguous range bins oriented down a specific radial. The SCIT algorithm uses legacy Reflectivity data resolutions of 1 deg by 0.5 nm for its range bins. As the algorithm processes the data 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.

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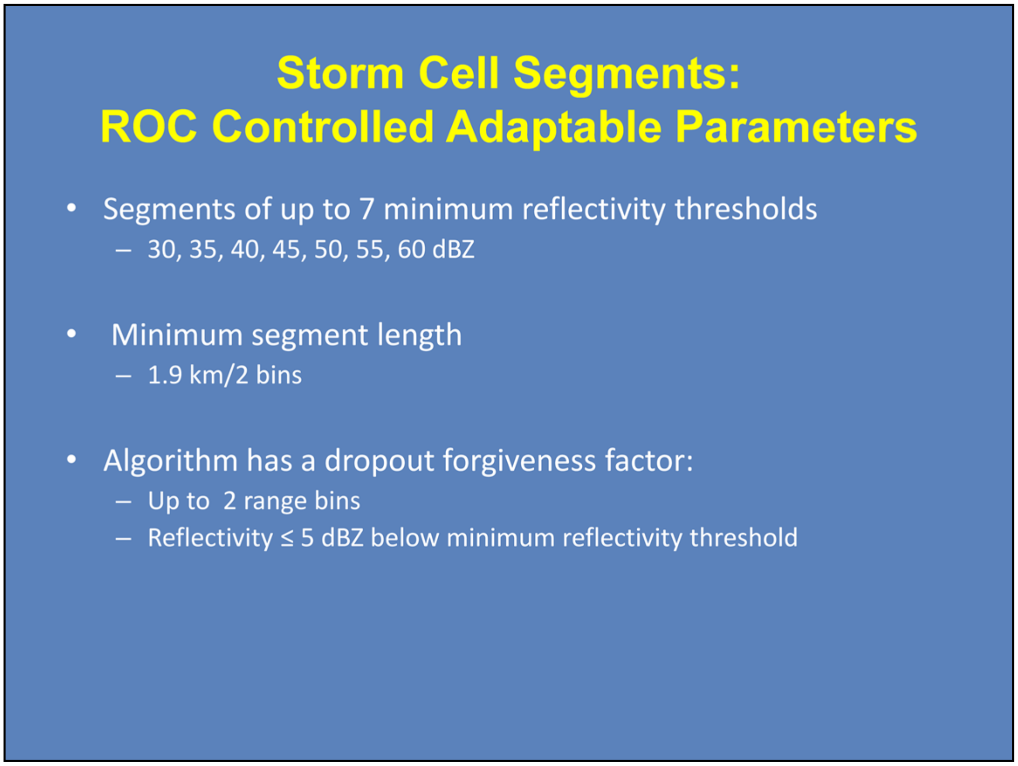

The SCIT algorithm relies on adaptable parameters that are controlled by the Radar Operations Center. These parameters are: minimum reflectivity thresholds and minimum segment length. The algorithm uses seven minimum reflectivity thresholds from 30 to 60 dBZ in 5 dBZ increments. This means the radar 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.

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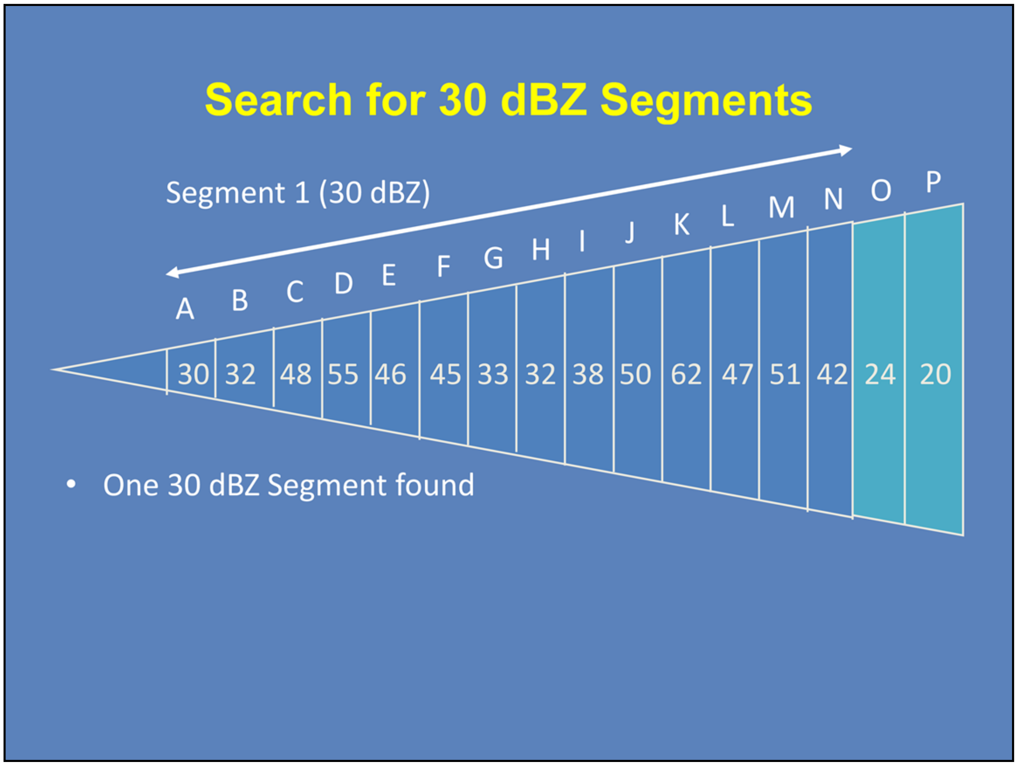
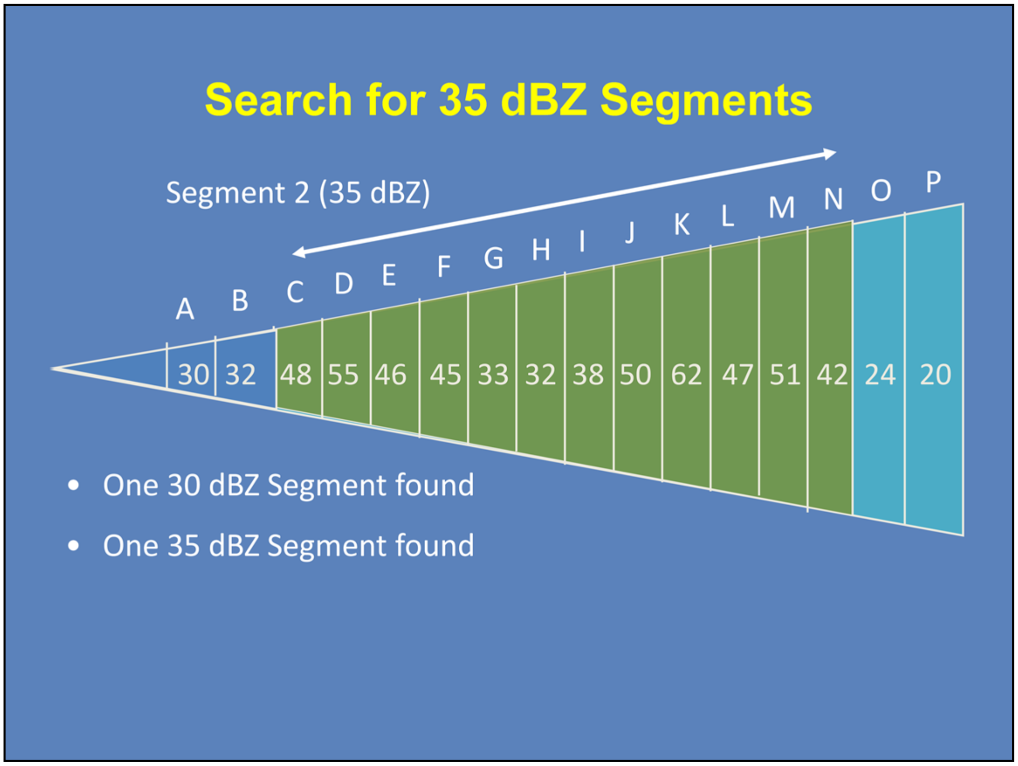


Let's walk through an example just to make sure I am making sense to you. The slide shows you a segment of a single radial of Reflectivity data. Once the algorithm finds a couple of bins at or over 30 dBZ, so it starts identifying a segment. The algorithm proceeds looking at each range bin down radial 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.



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 incremental 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.

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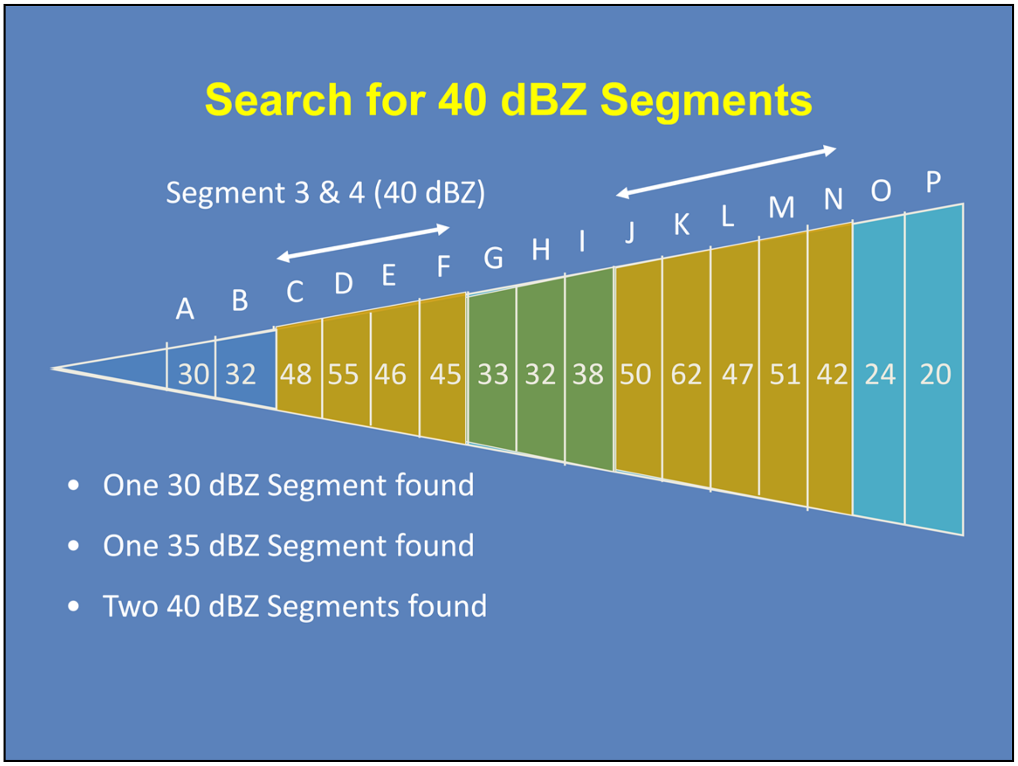
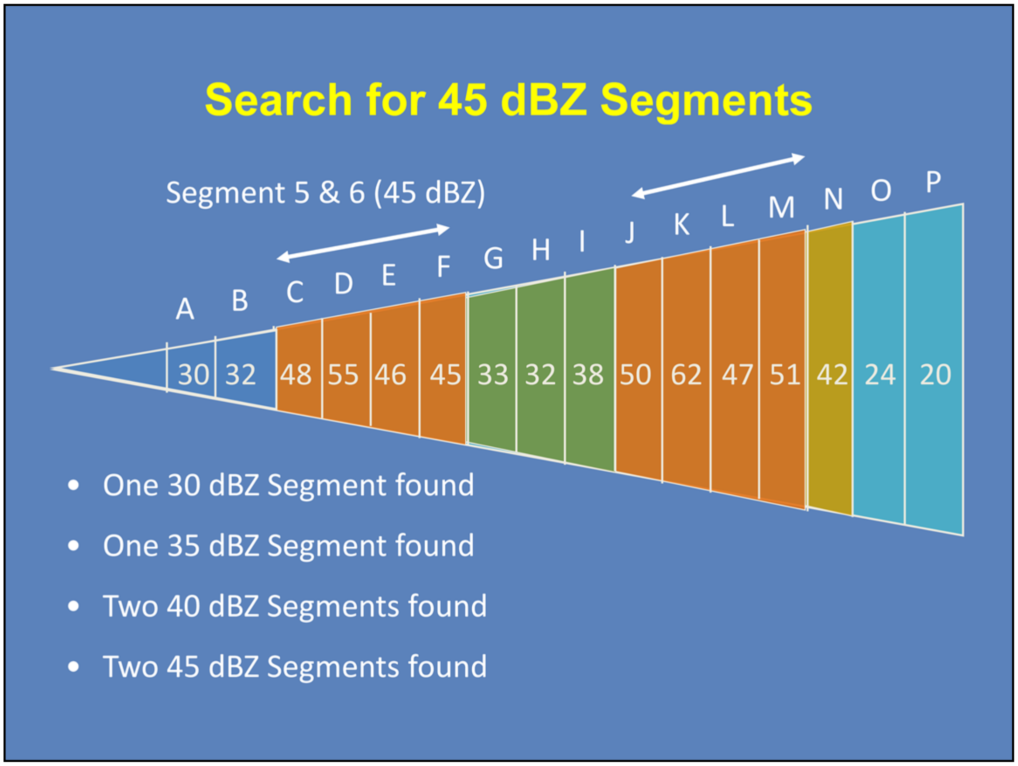
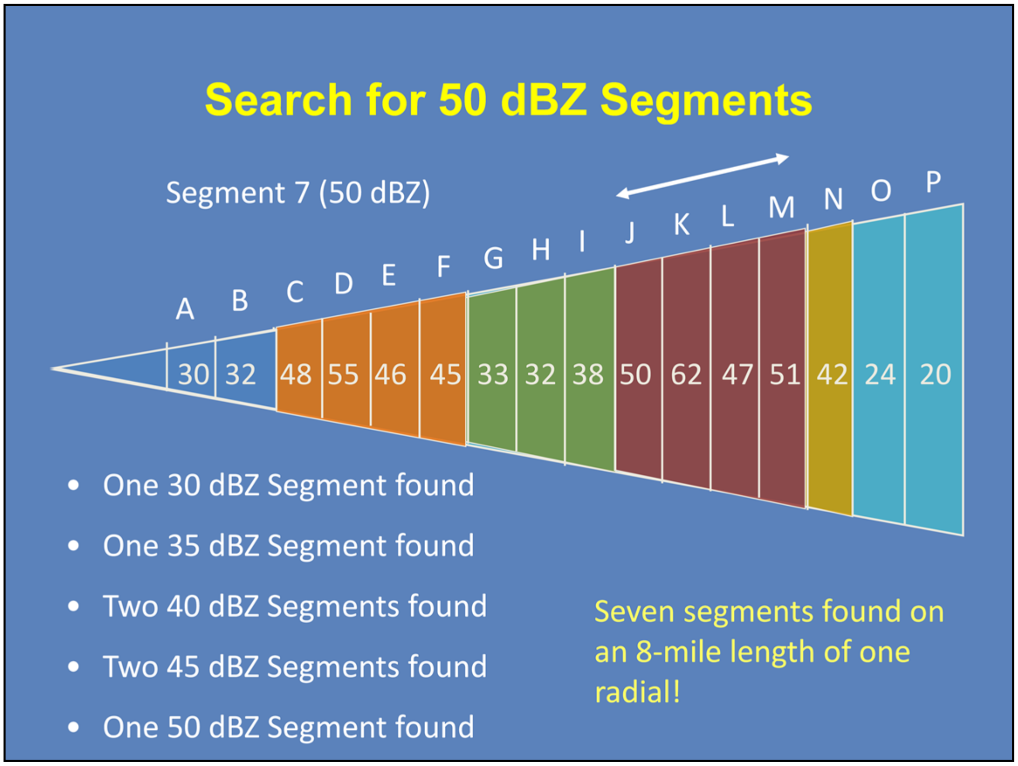


The process gets a little more interesting at the 40 dBZ threshold. A segment starts at bin C again, but now terminates at bin F because of the drop in values in the bin G. However, the algorithm continues down the radial and finds another segment starting in bin J and ending at bin N.

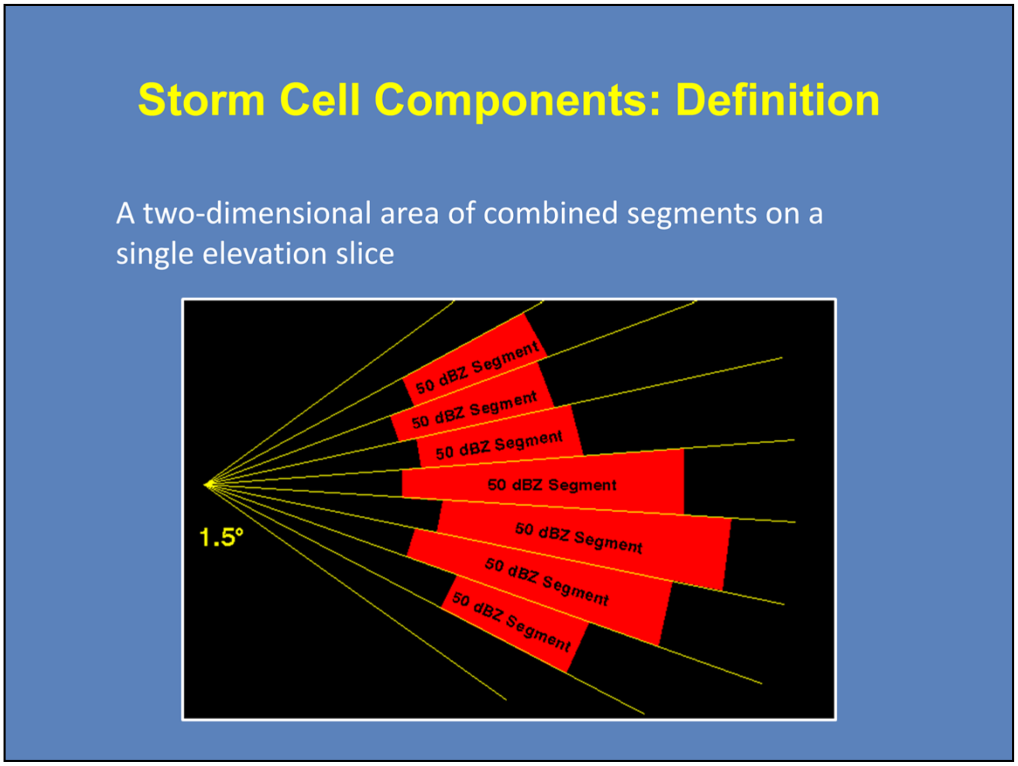


Continuing on at 45 dBZ, the algorithm furthers its attempt to isolate the higher reflectivity cores in these two segments. Note, the value in bin N is within the 5 dBZ dropoff range, but there are more than two range bins between locations of 45 dBZ values. Hence, this range bin is not included in the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



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!



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.

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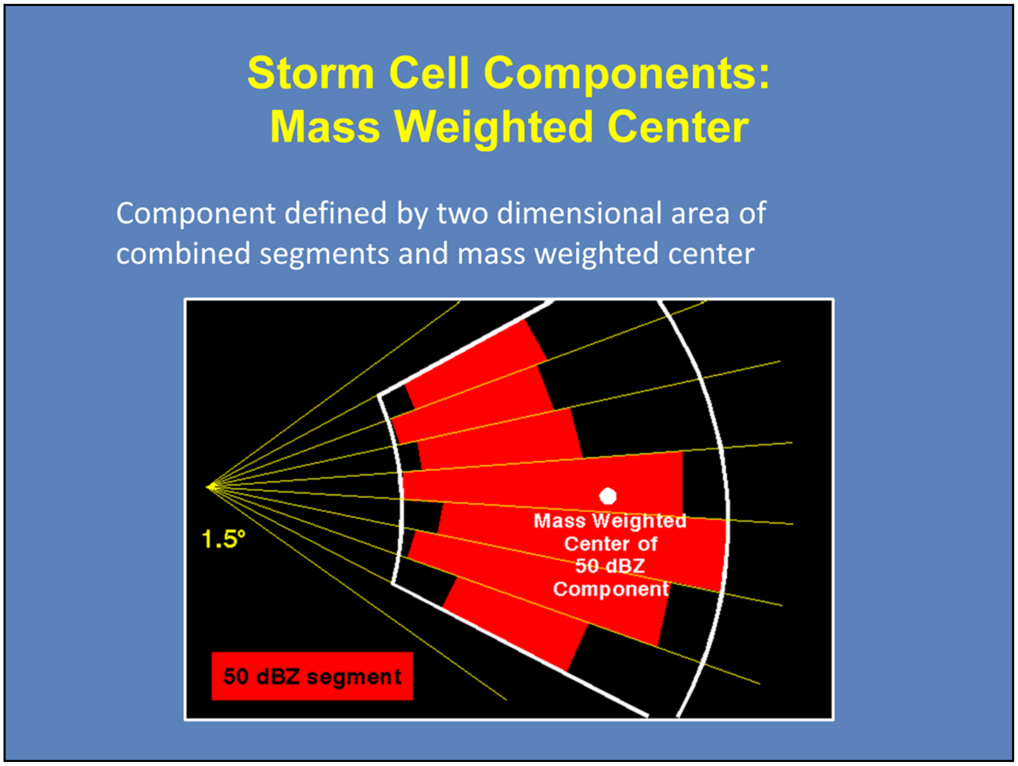
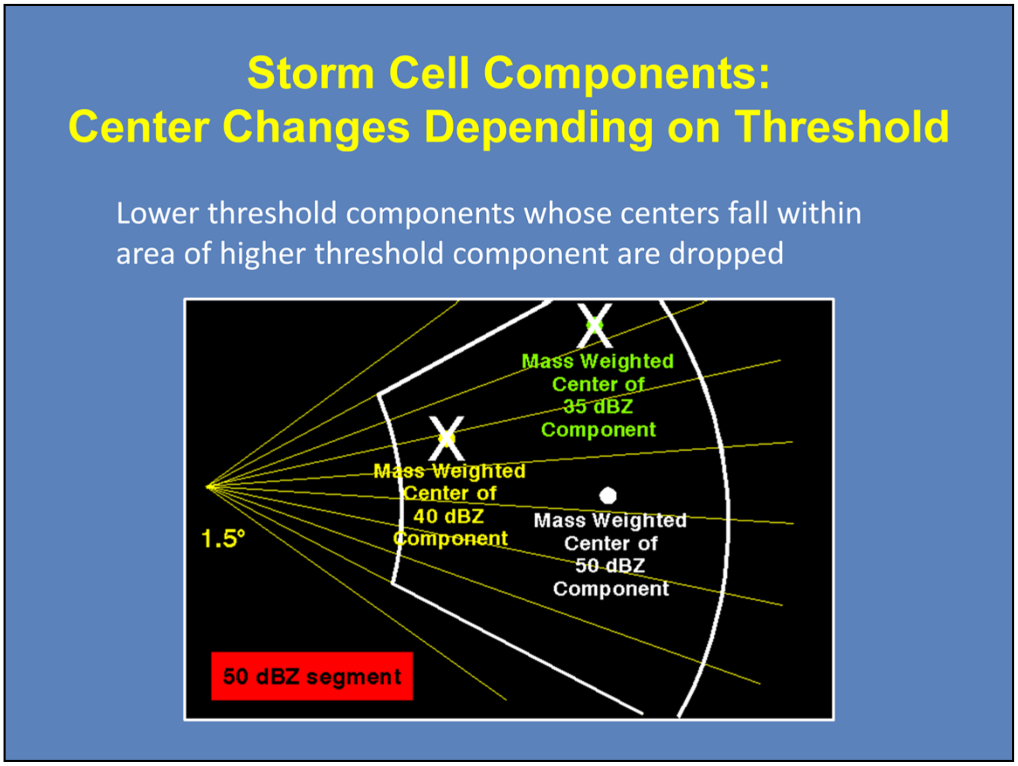


As components are assembled, the algorithm looks for the mass-weighted center of the component. This image shows the 50 dBZ component with its mass weighted center identified. The term “mass-weighted” comes from the reflectivity values “pulling” the storm centroid in that location. This process prevents 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.



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.

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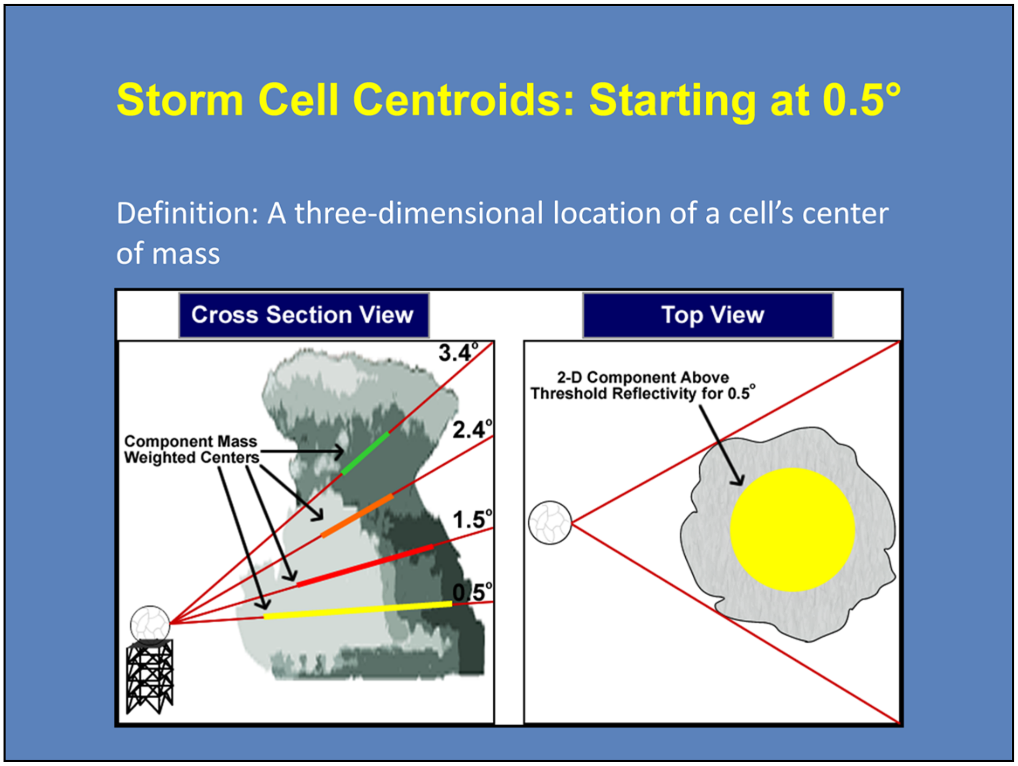

The last trait that the algorithm will identify are centroids. Centroids are identified by looking at the mass-weighted centers of components on each elevation slice and correlating them together vertically to create a three-dimensional object.

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.

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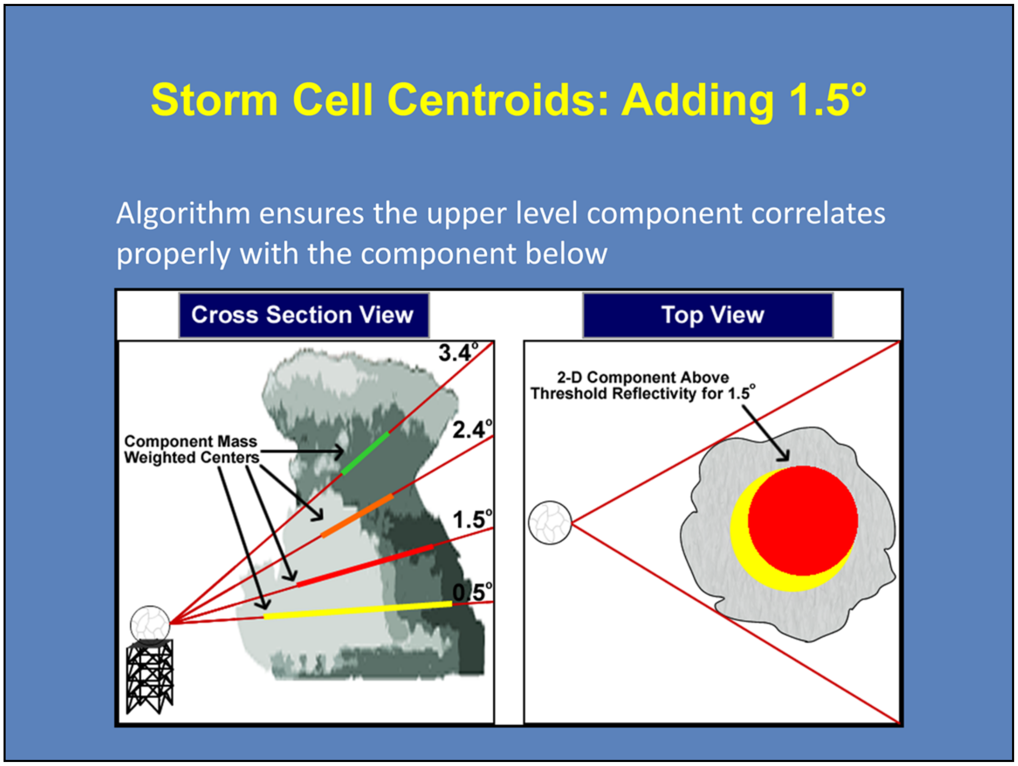

Adding the 1.5 degree component, there appears to be some agreement between the two. The algorithm will perform some checks to make sure that two components are found within a particular search radius of each other. Specifically, the algorithm ensures the upper level component correlates properly with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

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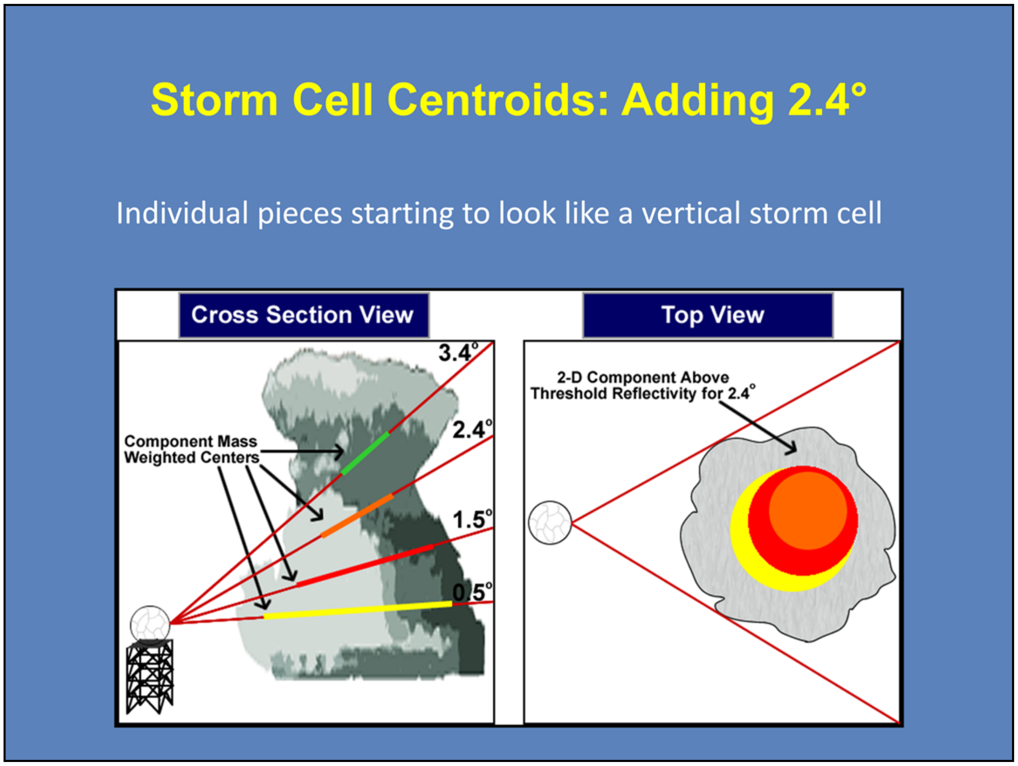
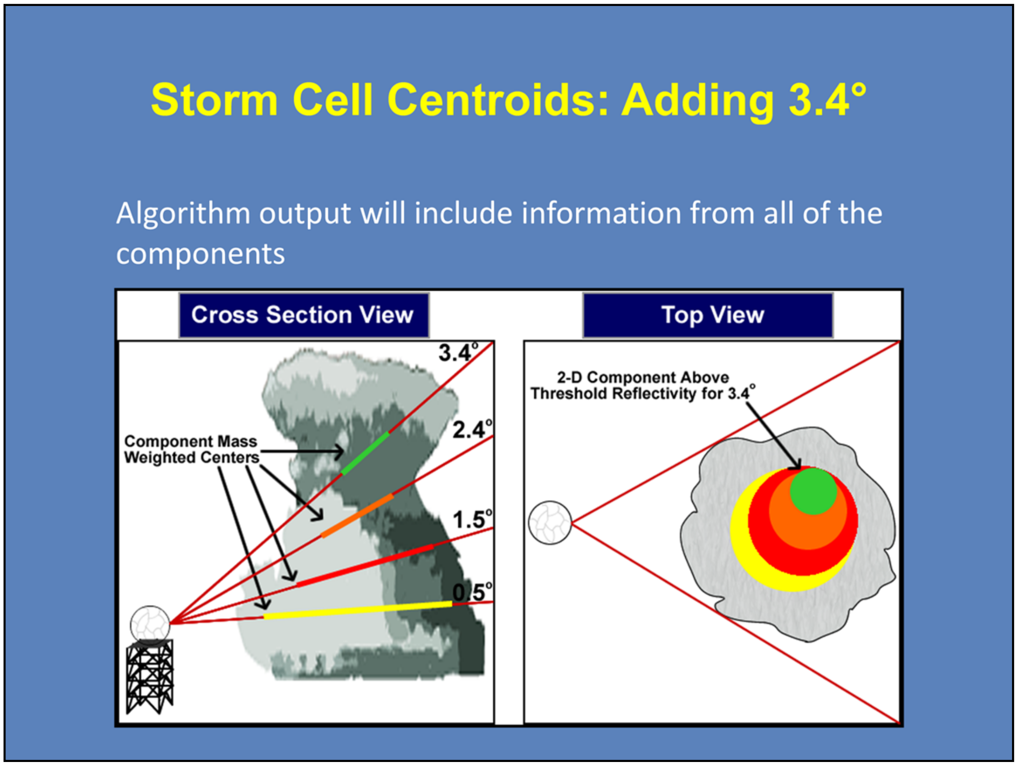
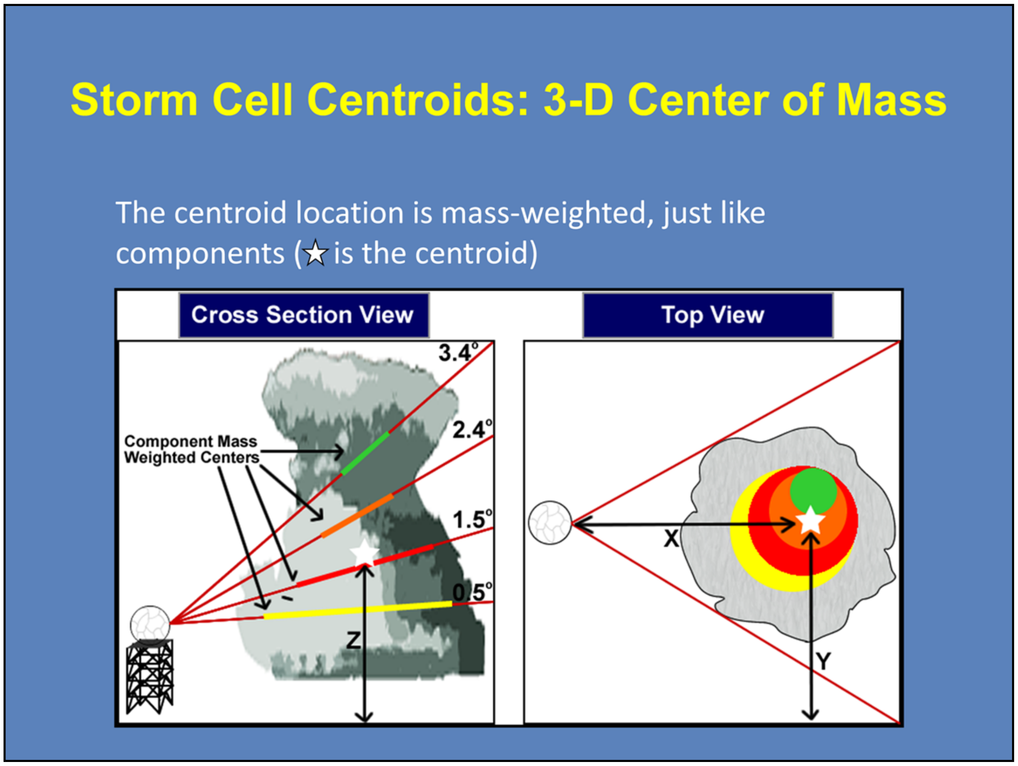


As we move up to 2.4 degrees, we add the next component. You can see how the individual pieces start looking more like a vertical storm cell, algorithmically speaking.



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.



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.

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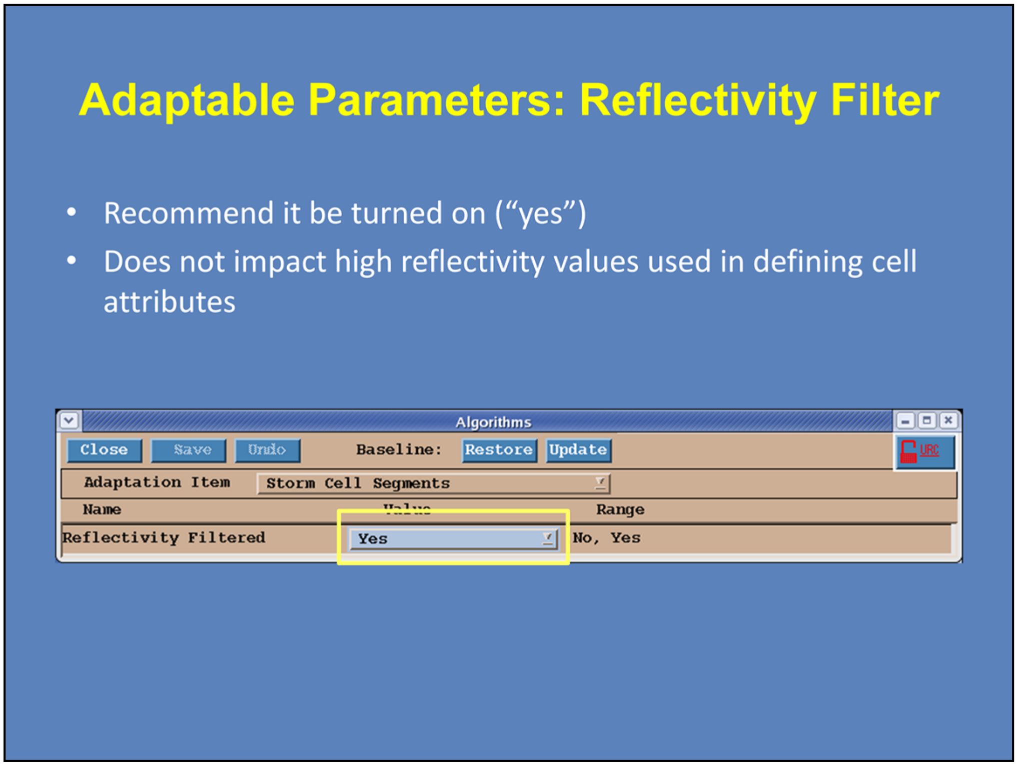

There's one adaptable parameter your office has control over under Storm Cell Segments called "Reflectivity Filtered" that we want to highlight. The purpose of this filter is to eliminate spurious noise in the Reflectivity that might mess up the SCIT algorithm. It only filters the values that go into 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.

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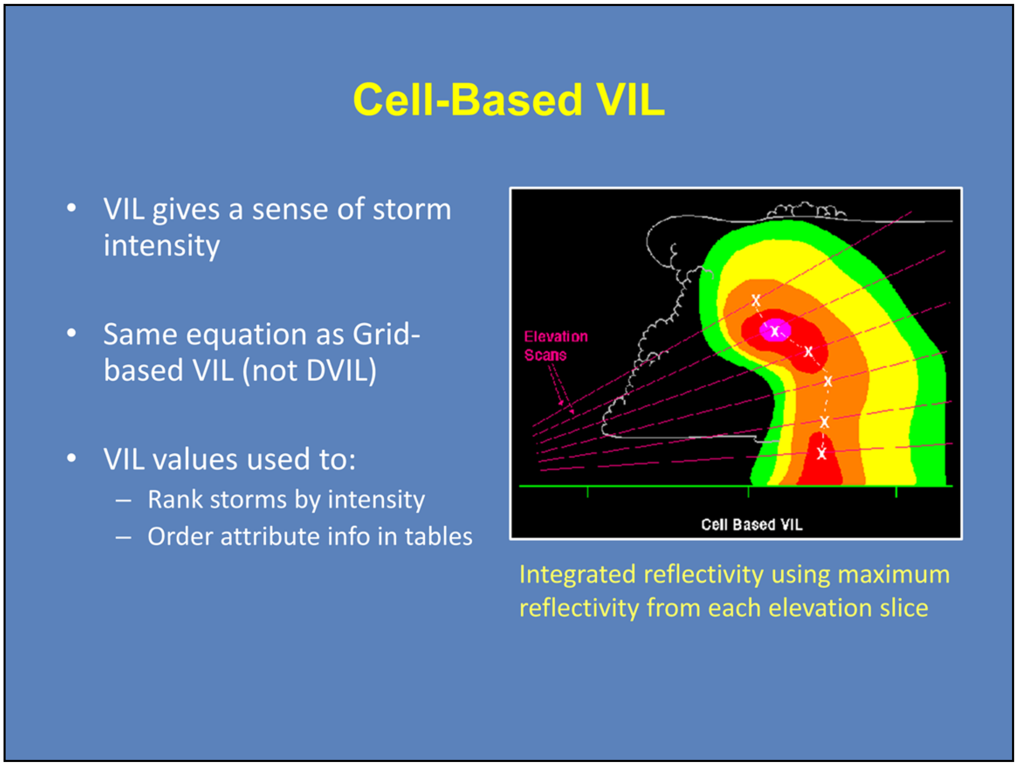
Storm Cell Centroids Output: Available on Up to 100 Cells

- 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)

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.



If you are taking the Base and Derived Products lessons in the order prescribed in the RAC curriculum, than 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.

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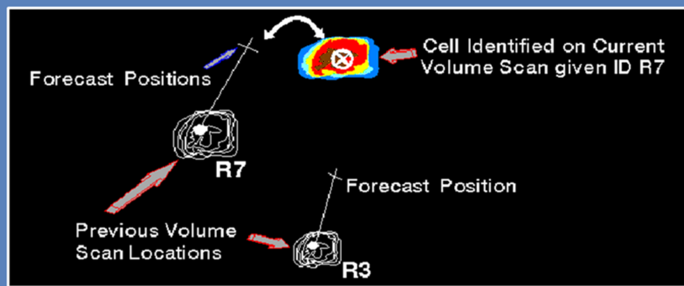
Storm Cell Tracking Process



- 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.

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.

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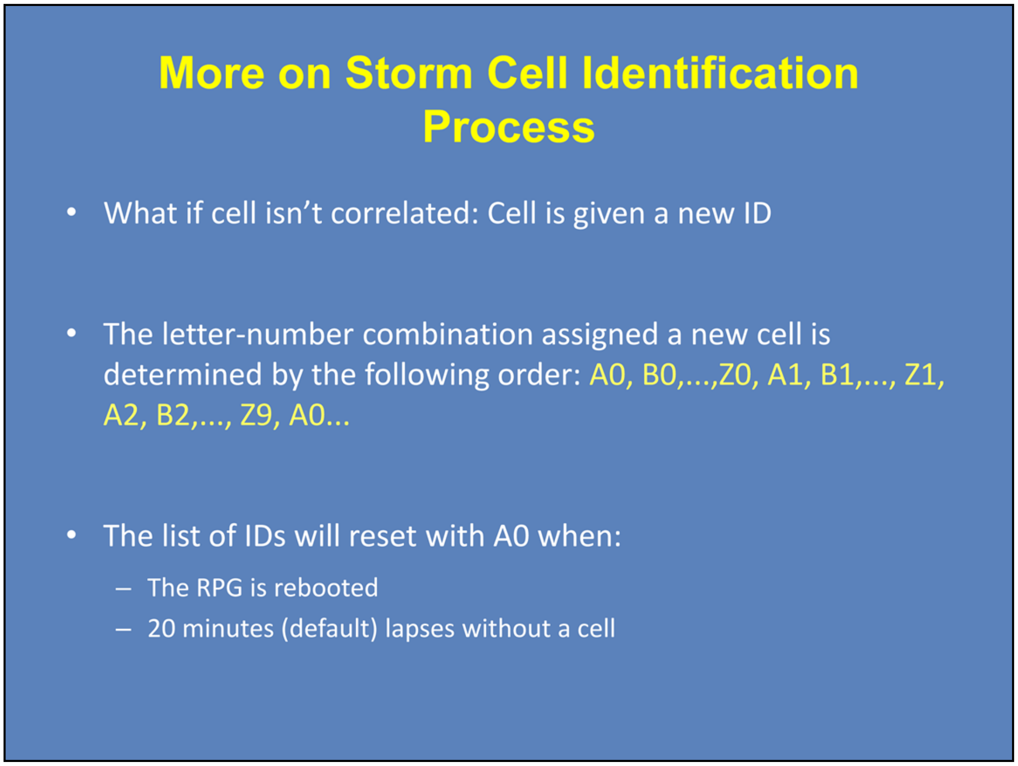

So, what happens if a storm doesn't correlate with any previously existing cells? Well, the cell will be considered a new storm and given a new ID based on a simple letter/number convention. The first identified storm is given the ID of A0. The next storm is given the ID B0, and so on, until the algorithm 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 storms 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.

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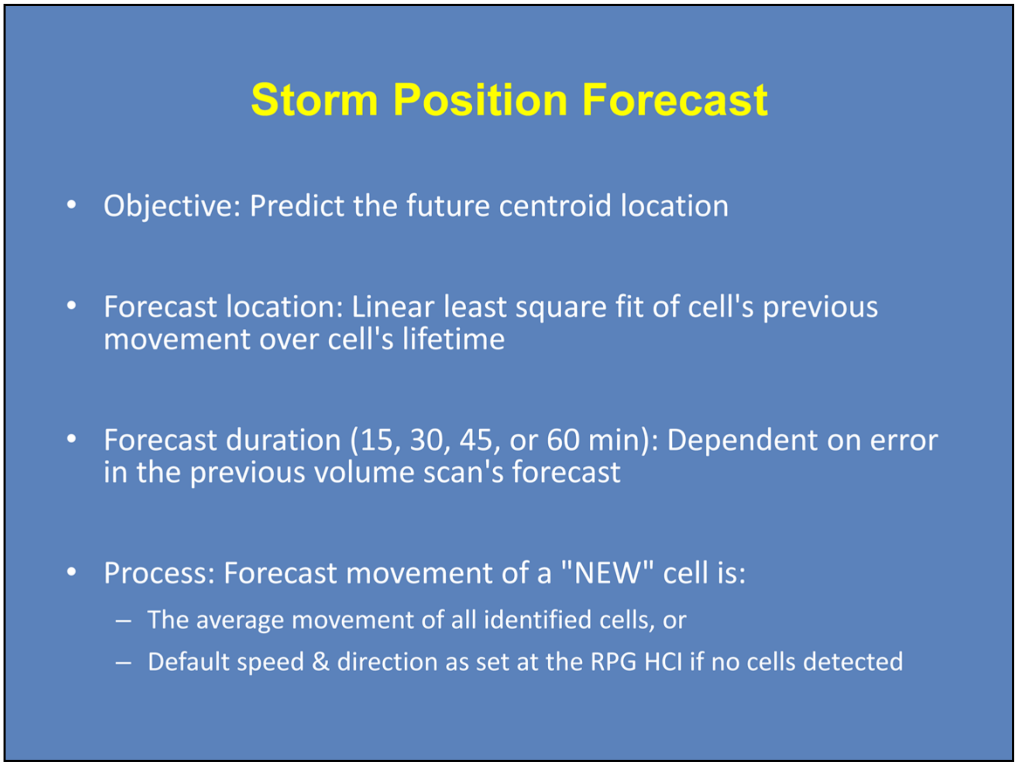
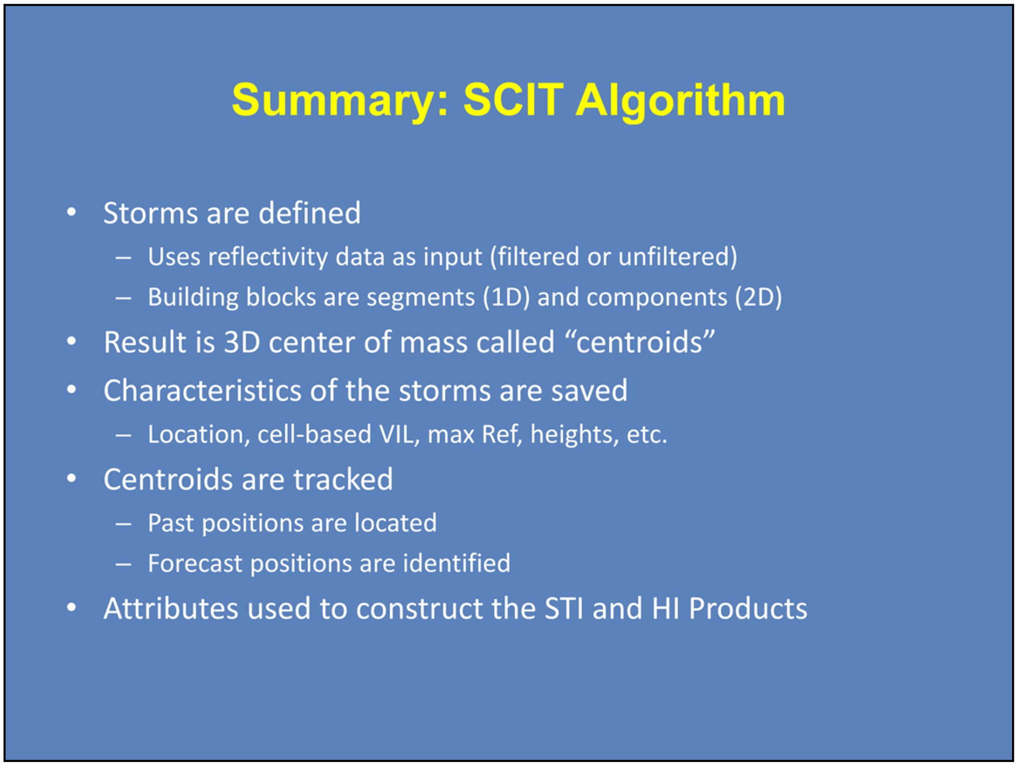


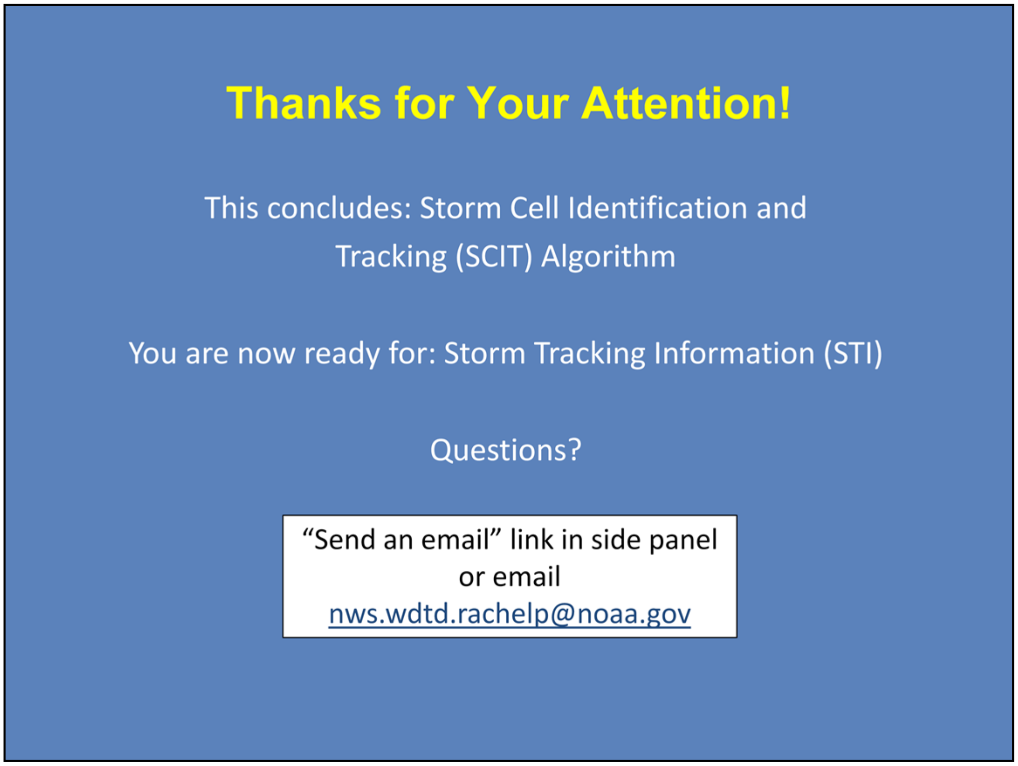
We talked previously about the storm position forecast. Let's look at this process in more detail. This part of the SCIT algorithm attempts to predict the future location of the storm centroid. This forecast is based on a linear least square fit of the storm's previous movement over its lifetime. If 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.



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.



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.

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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.

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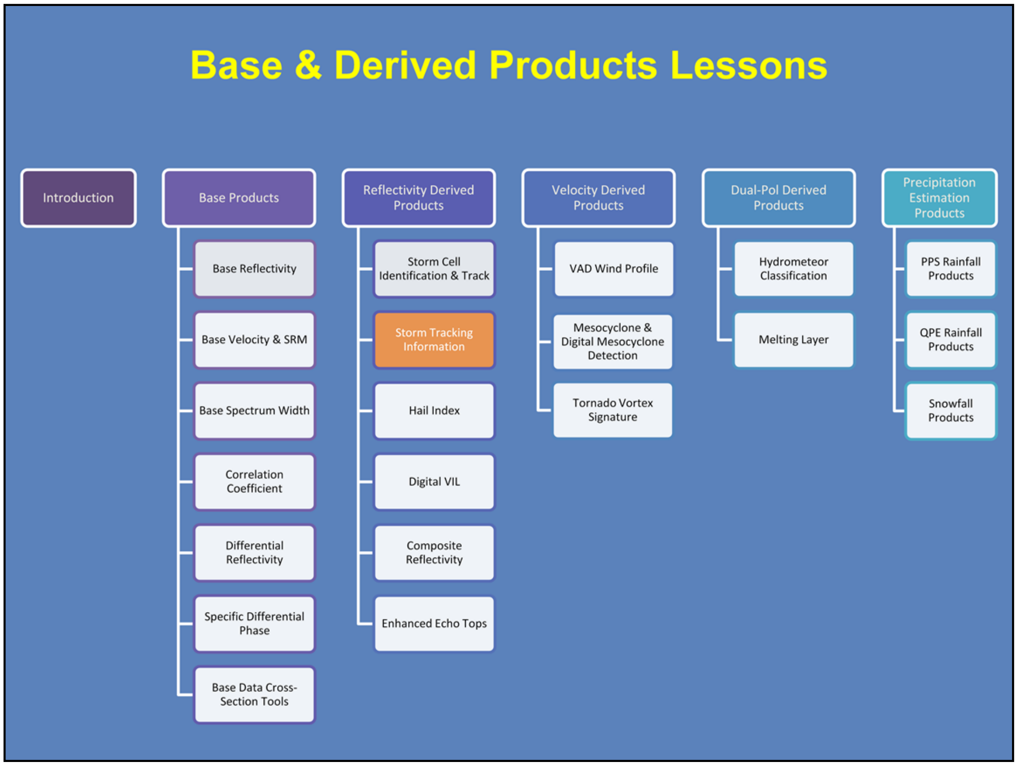


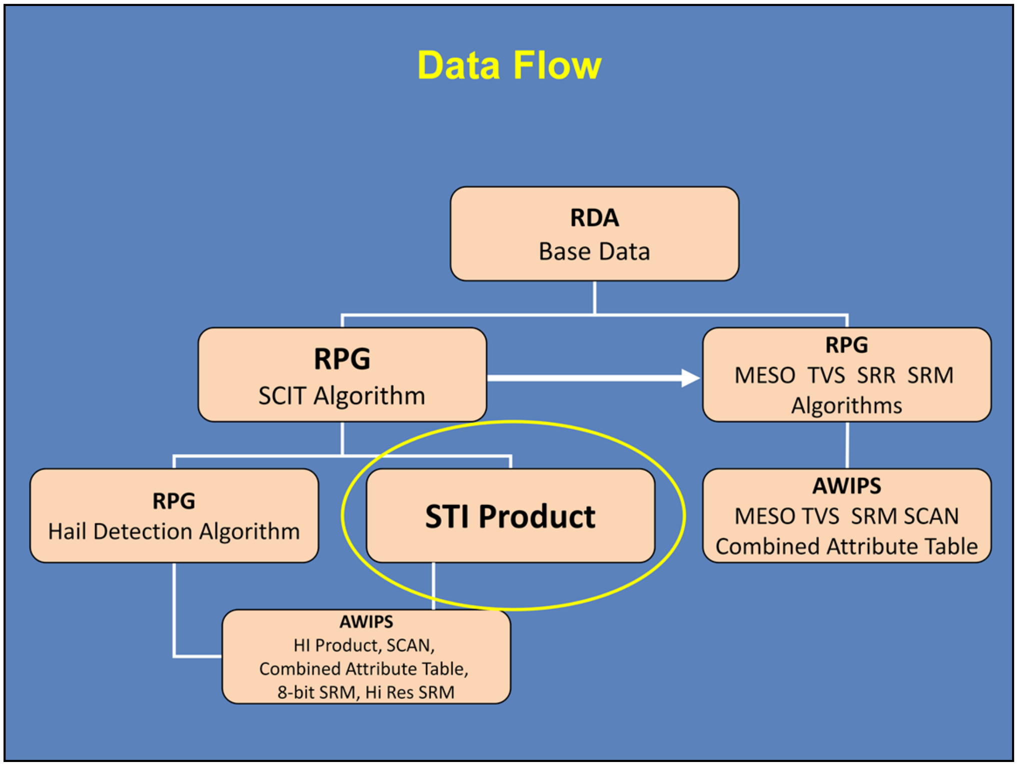
Here is a roadmap for the lessons in this topic. This lesson on the STI product, shaded in orange, is part of the Reflectivity Derived Products Section of this topic.

Learning Objectives

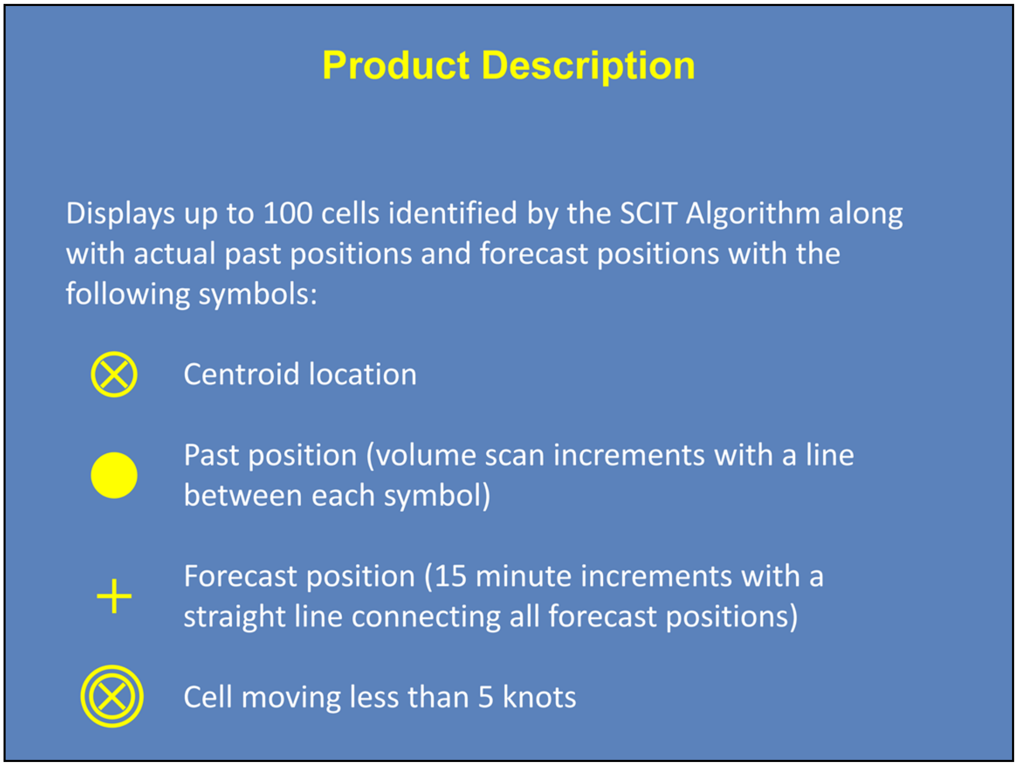
1. Identify the key attributes and display characteristics (including how the Radar Display Controls impacts them) of the Storm Tracking Information (STI) product in AWIPS

2. Identify the limitations & applications of the Storm Tracking Information product

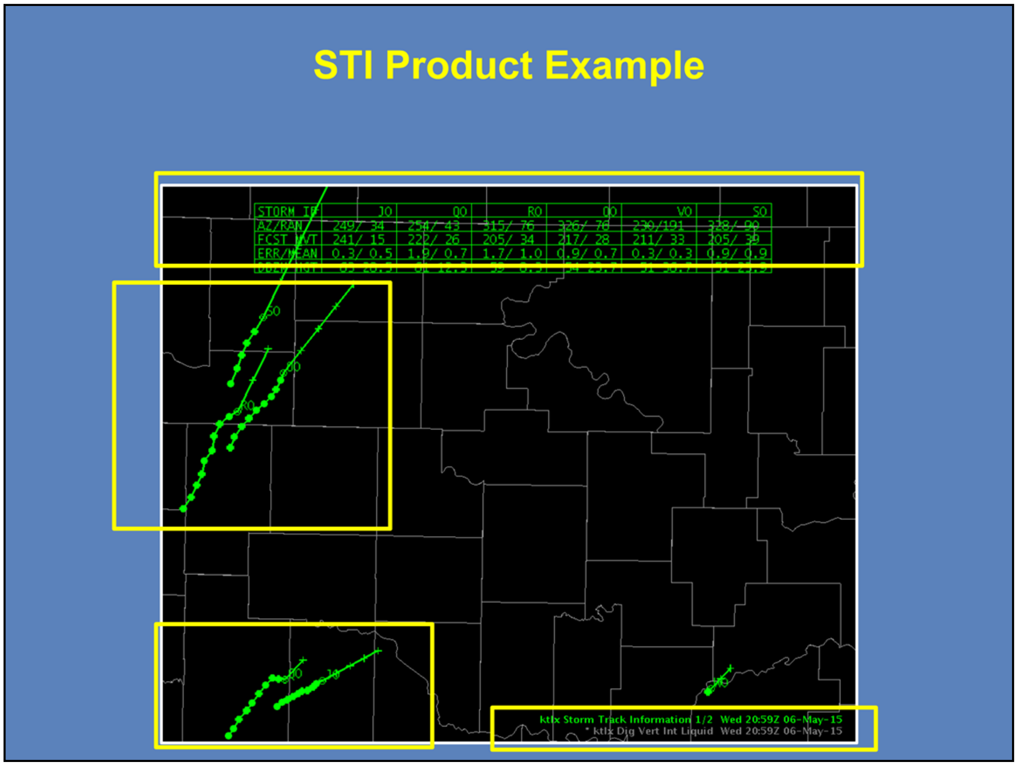
Here are the learning objectives. Take a moment read them and advance the slide when you are ready.



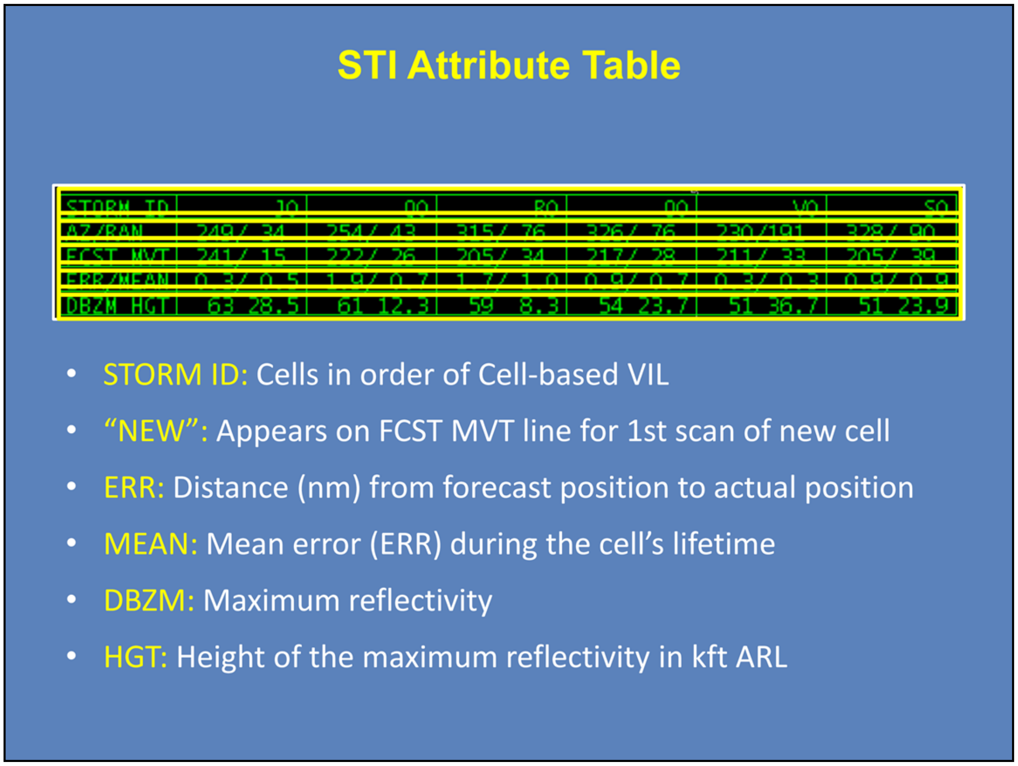
The Storm Cell Identification and Track algorithm (or SCIT) lesson discussed how the WSR-88D RPG identifies storms as a three-dimensional object. This lesson will talk about one product that is produced from that algorithm's output: the Storm Tracking Information, or STI, product.



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.



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.



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.

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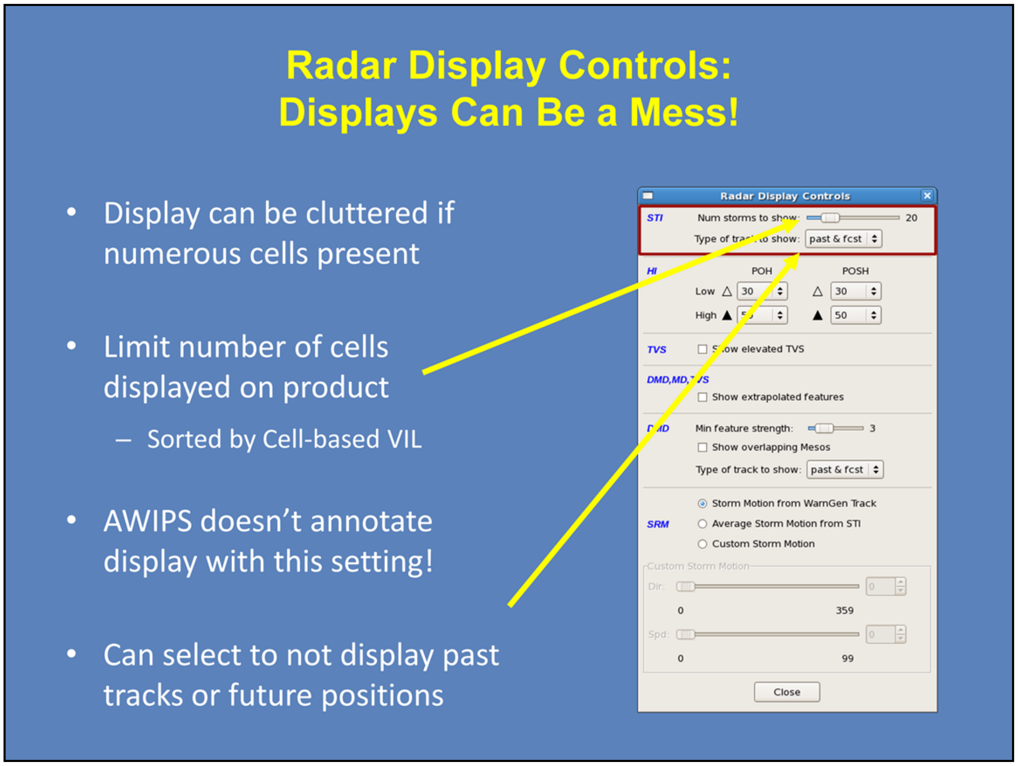
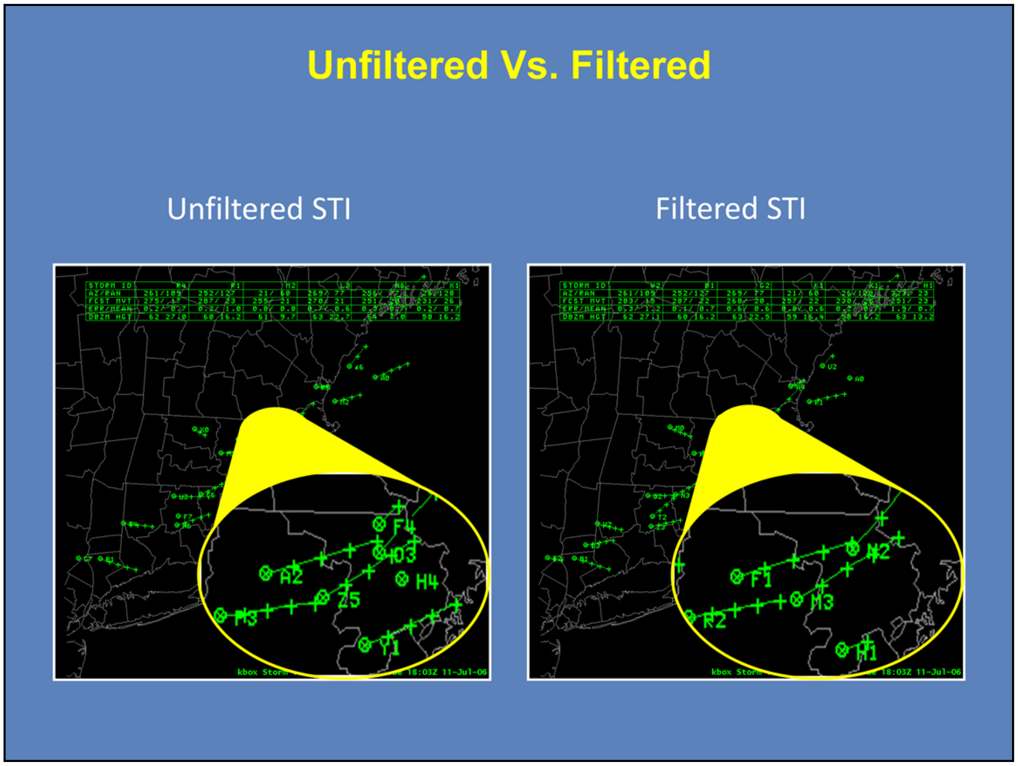


If the RPG identifies numerous, persistent storm centroids, the STI product can become very cluttered. Users have the ability to control the appearance of the STI product using the Radar Display Control GUI. At the top of the interface, a slider bar limits the number of storm centroids that are displayed. 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.



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.

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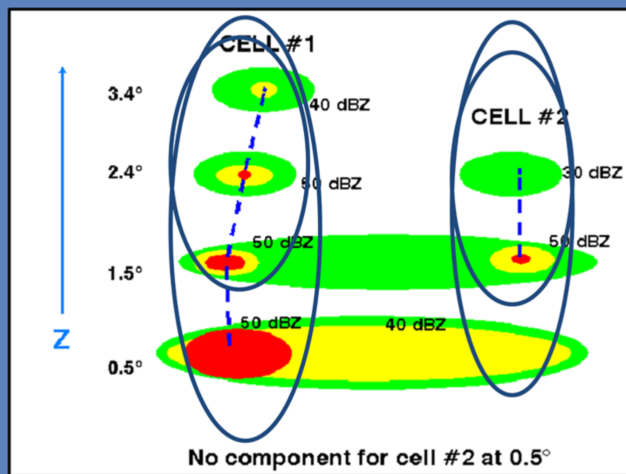
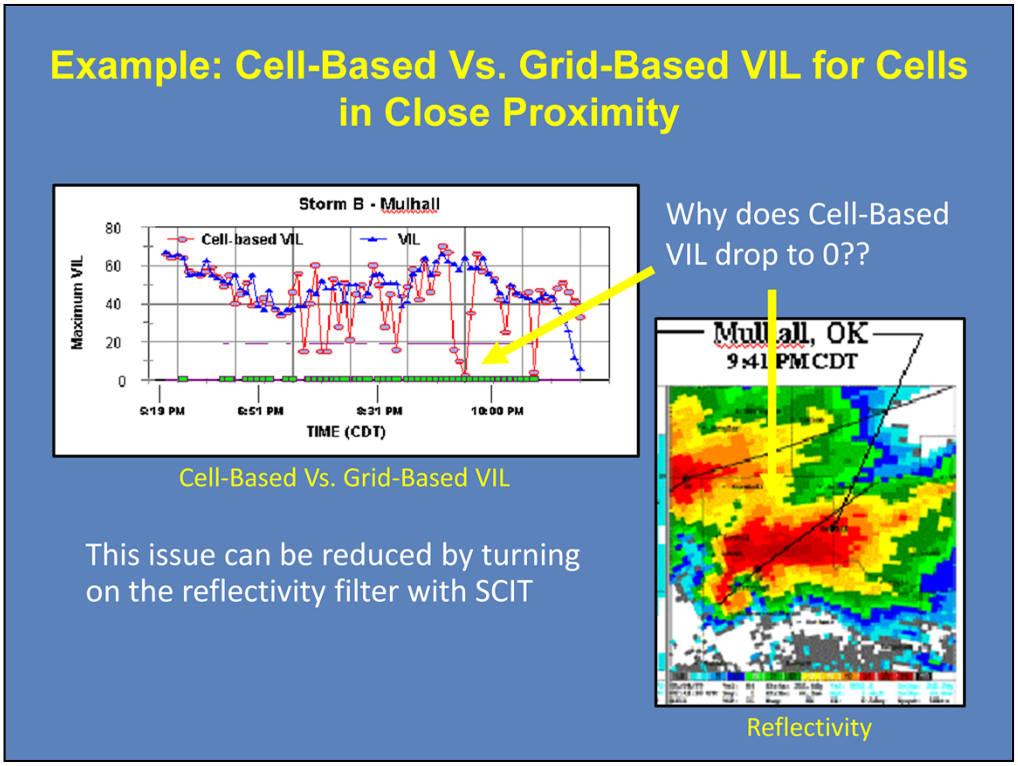
Product Limitations #1: Cells in Close Proximity



Cell attributes may fluctuate wildly when other cells nearby

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 1.5 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 were 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.



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 kg/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.

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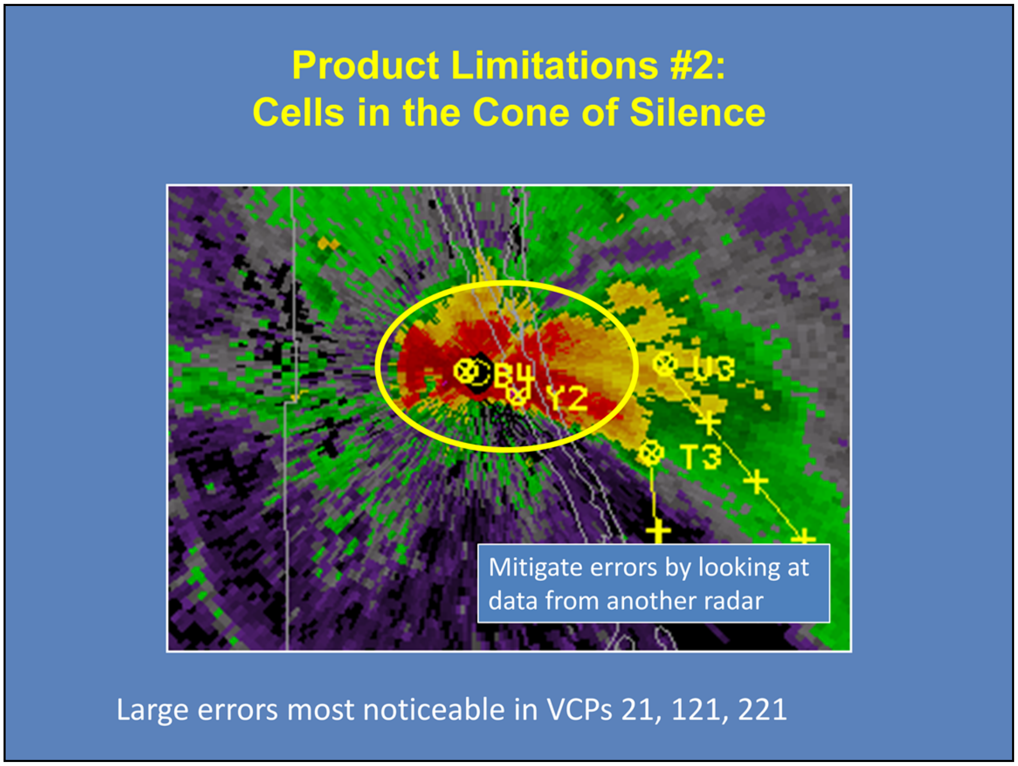

A second limitation is large errors in cell attributes can occur for cell located in the cone of silence near the RDA. This limitation is most noticeable when using VCP 21, 121, or 221 because they use fewer elevation cuts, with larger gaps, than other precipitation mode VCPs. You can mitigate this issue 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.

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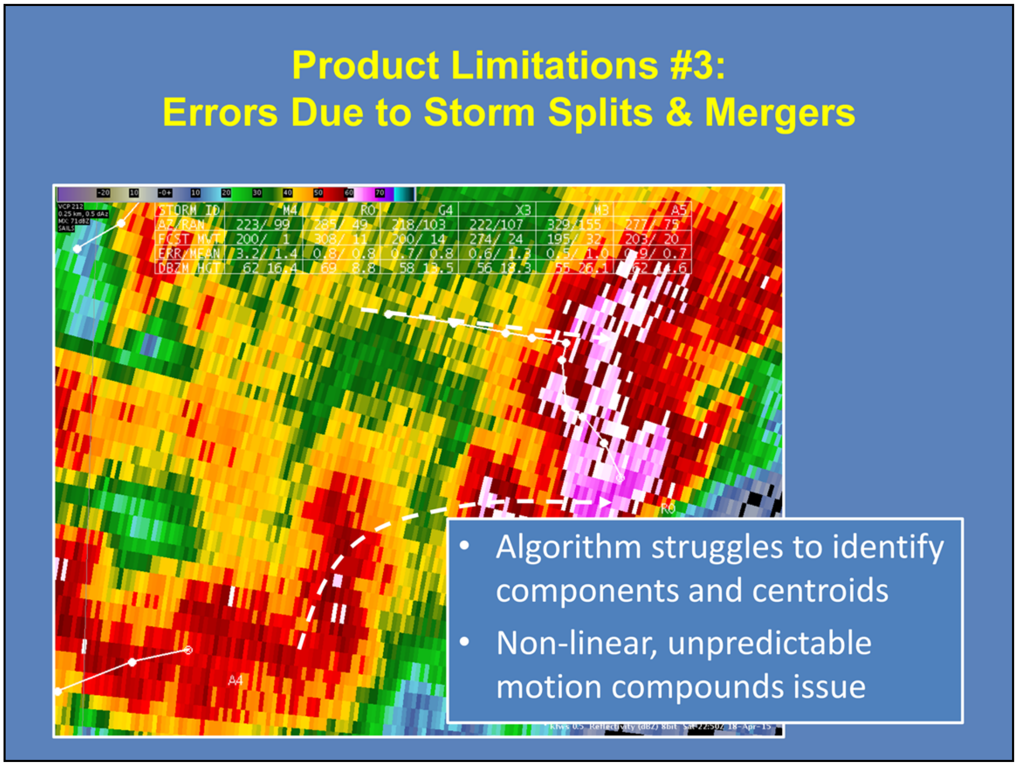

A third limitation occurs when you have a large storm that splits or smaller storms that merge. As these processes occur, the algorithm can struggle to identify the storm components and centroids in a manner that makes the most sense to a human forecaster. Combine this issue with the non-linear, and 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.

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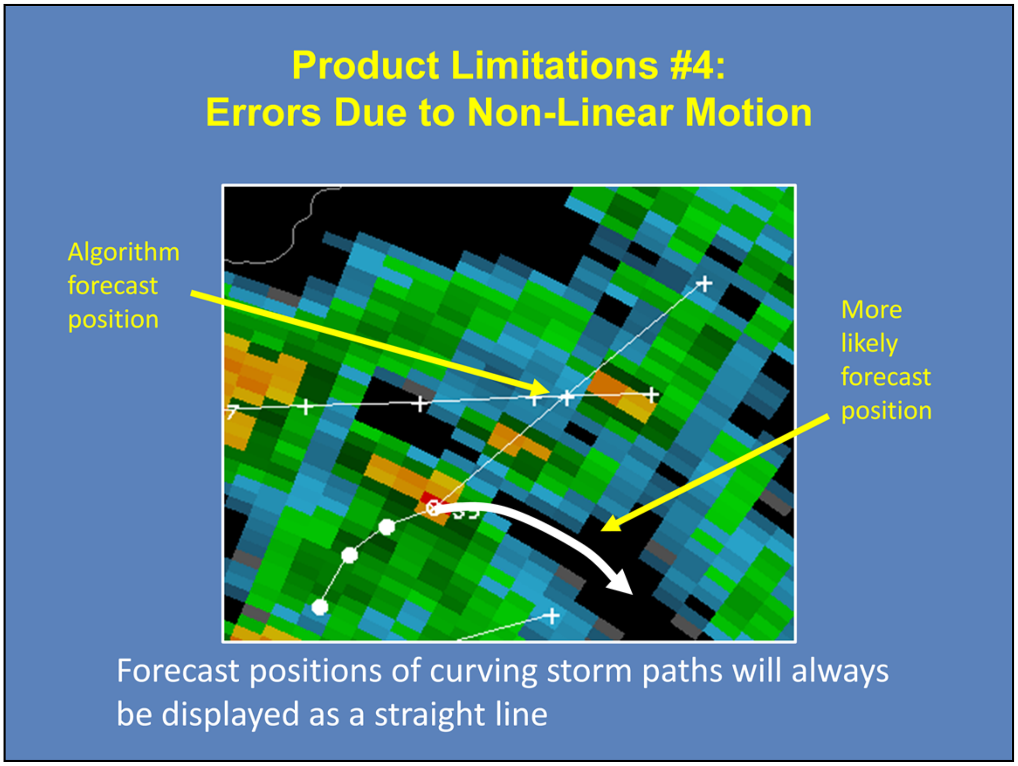
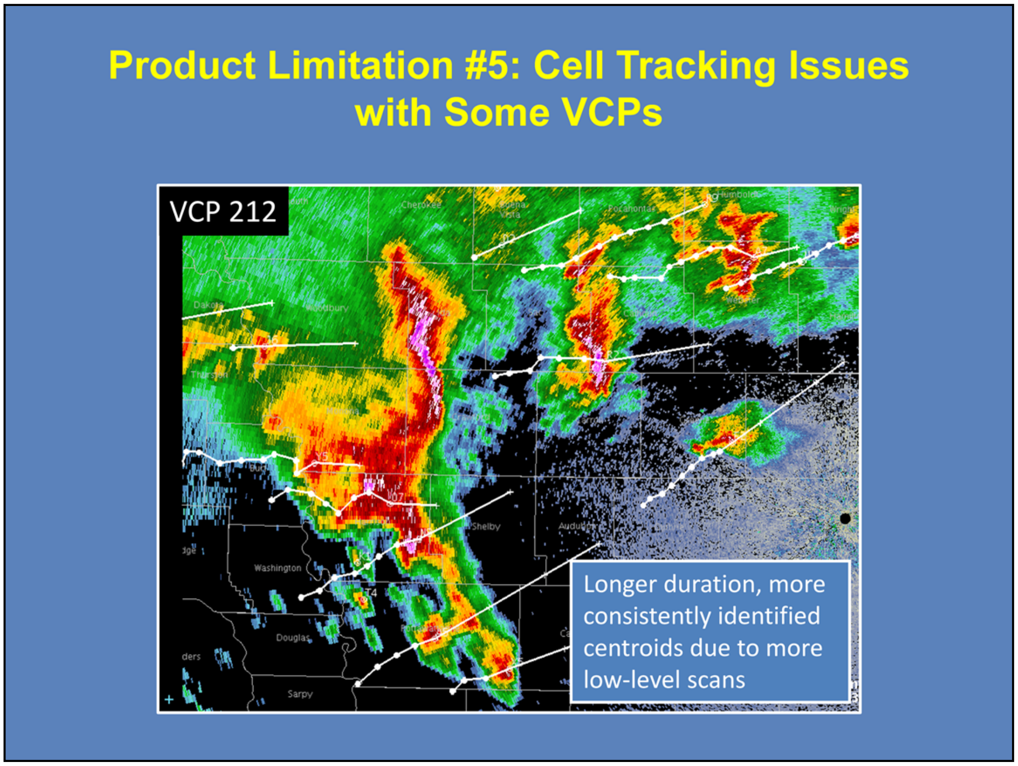


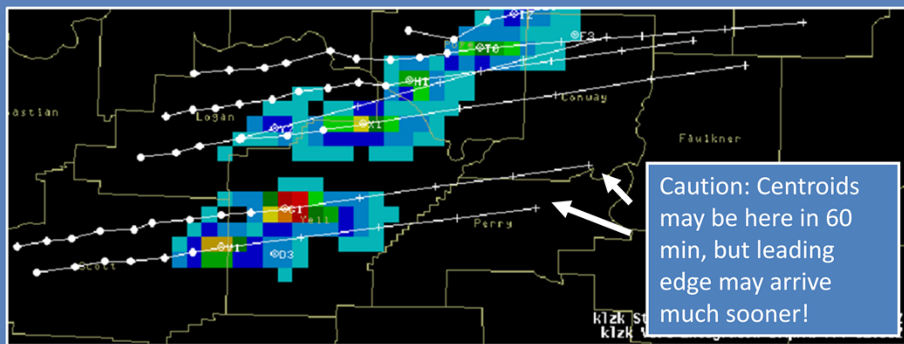
A fourth limitation occurs with cells experiencing non-linear motion. For each storm centroid, the SCIT algorithm generates a linear storm motion. So, the forecast positions shown in STI will always be a straight line. In the example on the slide, cell S9 clearly has been following a right-ward curving 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.



The last limitation presented here has to do with the consistency of cell tracks over time. Depending on which VCP you use, storm tracks can have more continuity or less continuity. In general, cells detected using VCPs 12 or 212 will be tracked with more consistency by the SCIT algorithm than cells detected using VCPs 11, 21, and other similar scanning strategies (Brown et al., 2005). The improved consistency results from VCPs 12/212 more thorough sampling at lower elevation angles.

In a nutshell, we have demonstrated why you can't blindly trust the STI displays. Now, let's talk about how this product can be usefully applied.

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



Algorithm should have small errors and give a good sense of storm track

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.

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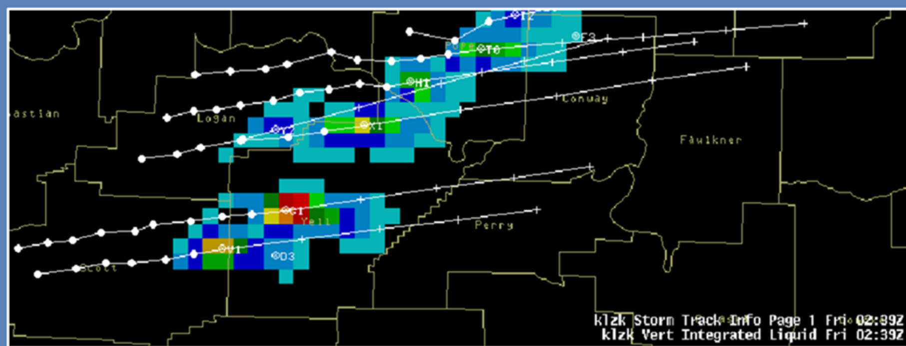
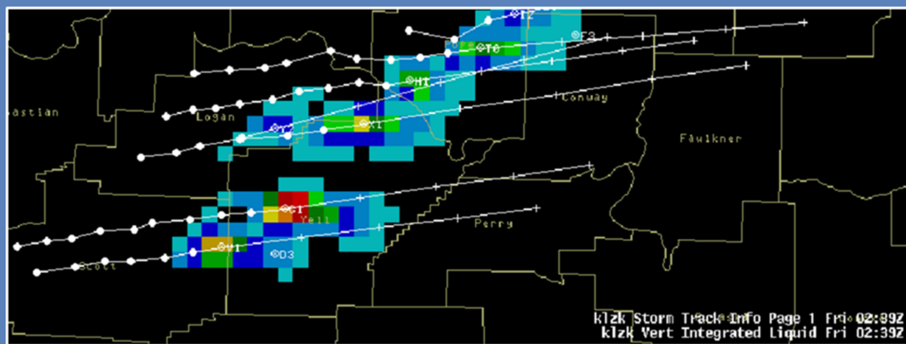
Product Applications #2: Past Location Markers Correlate to Reliable Cell Motion



Always eyeball past location tracks and ask, “Do they make sense?”

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



Pairing with volumetric radar products maximizes view time on the latest data available

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.

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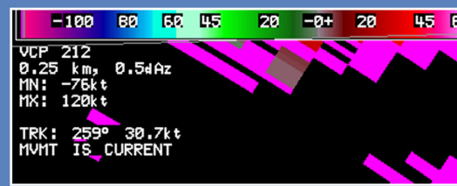
Other Product Applications

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



5. Attributes are input to the Hail Index product and SCAN display

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 those products.

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Summary

- Errors occur in cell identification and tracking when cells are in close proximity
- Cell attributes are less reliable in VCP 21 (121,221) close to the RDA
- 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

The Storm Tracking Information product provides a graphical display of the storm cell attributes generated by the SCIT algorithm. This products 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. In particular, cell attributes are unreliable close to the radar when using VCPs 21, 121, and 221. In fact, they can be impacted out to 60 nm of the RDA. 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 or more forecast positions, the algorithm thinks that the storm motion is quite reliable.

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.

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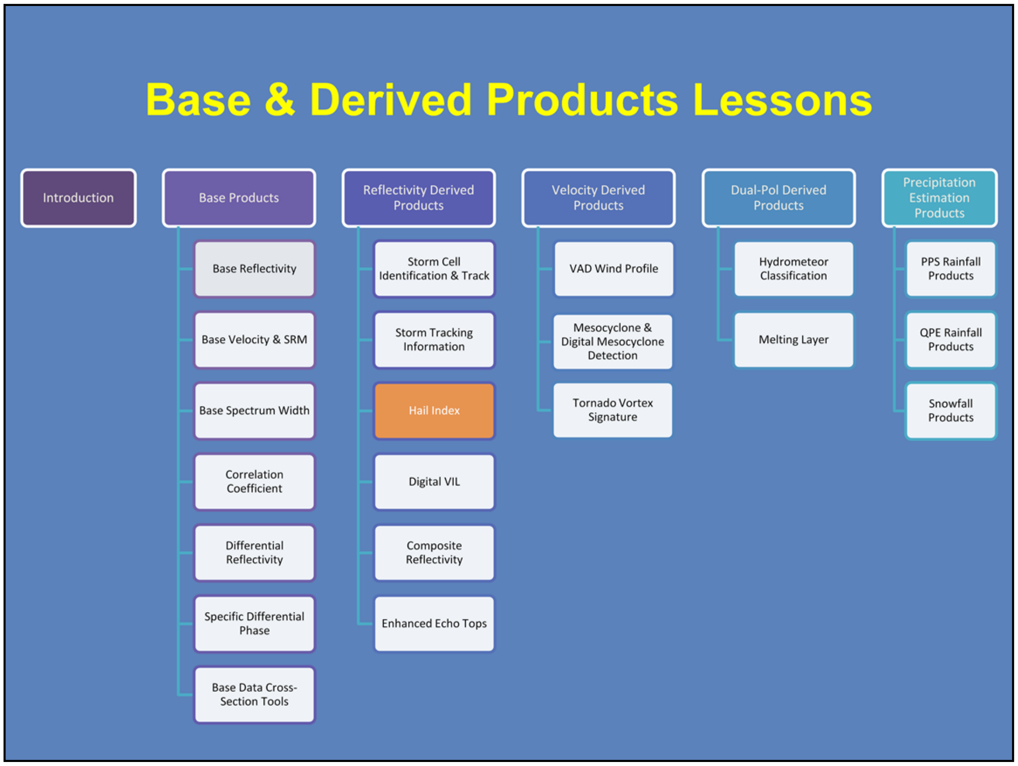

Here is a roadmap for the lessons in this topic. This lesson on the Hail Index algorithm, shaded in orange, is the third in the Reflectivity Derived Products Section of this topic.

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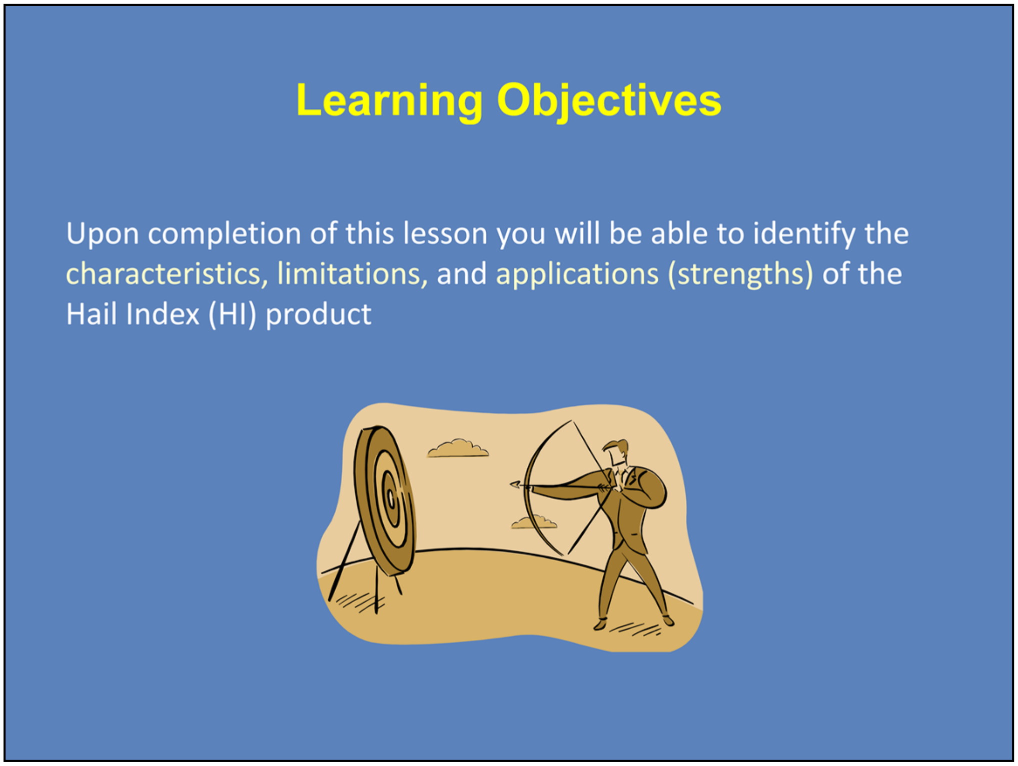

Here are the learning objectives for this lesson. When you are ready click advance to start this lesson.

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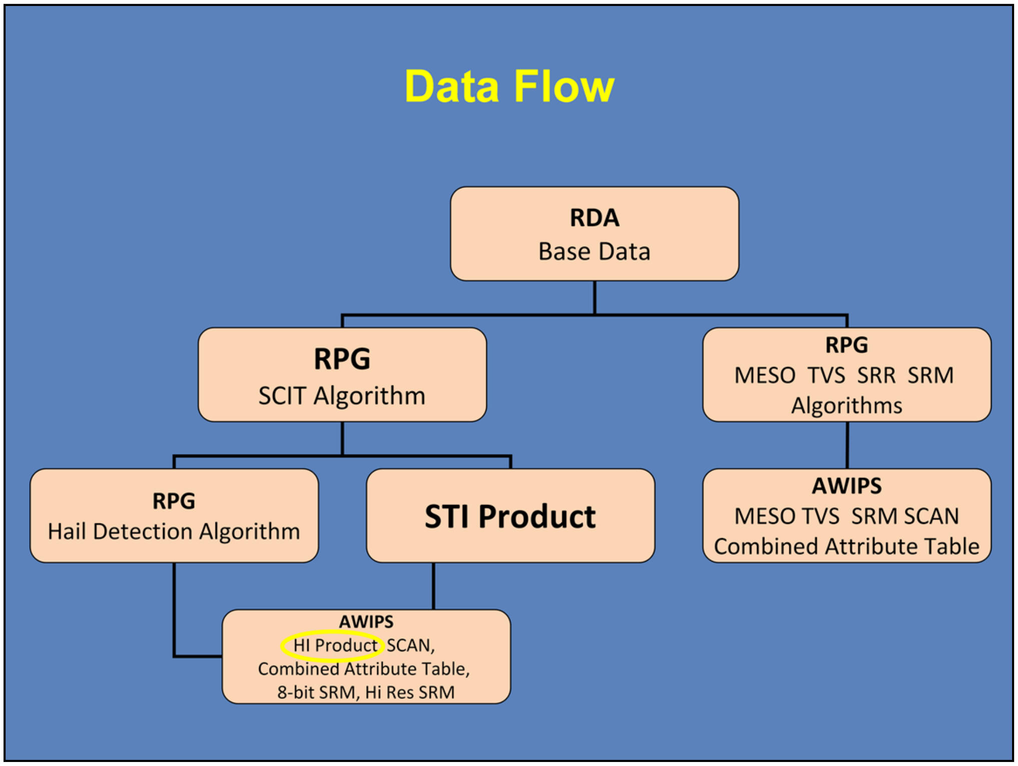

Here is the flow of data from the RDA to the RPG and ultimately to your AWIPS-2 workstation that you have seen before. On the right side is velocity derived products that we'll discuss soon, but for this lesson we can see that output from the SCIT algorithm is ingested by the Hail Detection Algorithm 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^{0}C and -20^{0}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 new requirement of 1" hail

Now 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 ¾" in 10% increments…and finally the maximum expected size of hail in ¼" increments which we call MESH. One note here…despite the new 1" criteria for severe hail, the POSH was never updated to reflect this.

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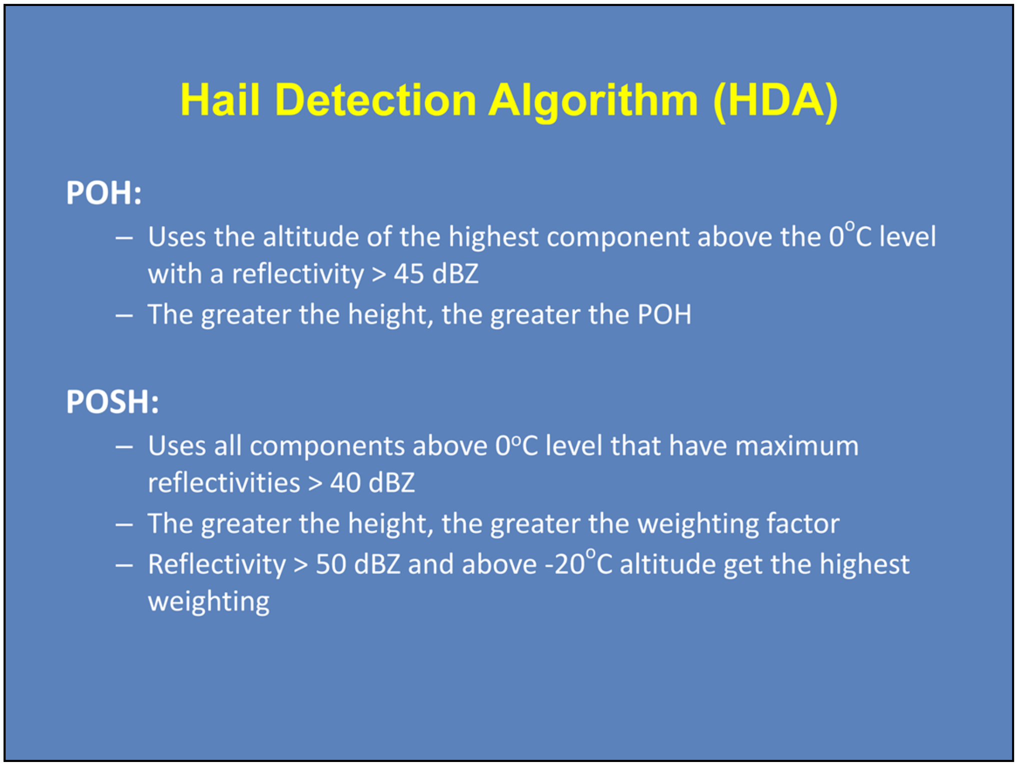

Let's examine the details of the HDA output, the probability of hail first. This uses the altitude of the highest component above the 0 degree Celsius level with a reflectivity greater than 45 dBZ. It is a linear relationship. The greater the height, the higher the probability of hail. POSH uses all 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.

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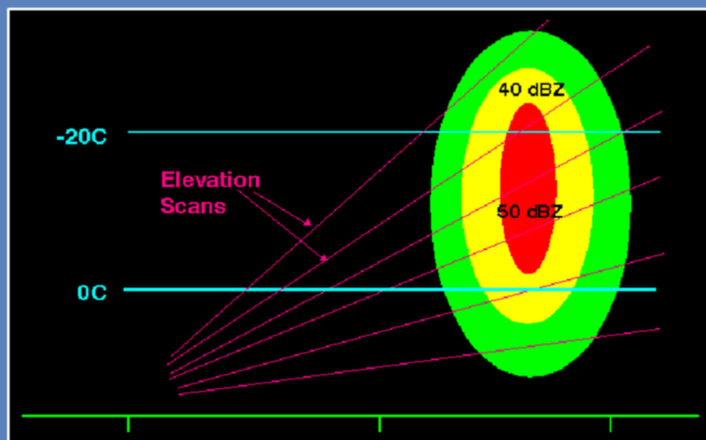
Hail Detection Algorithm

- > 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 is located between the 0 and -20 C heights.

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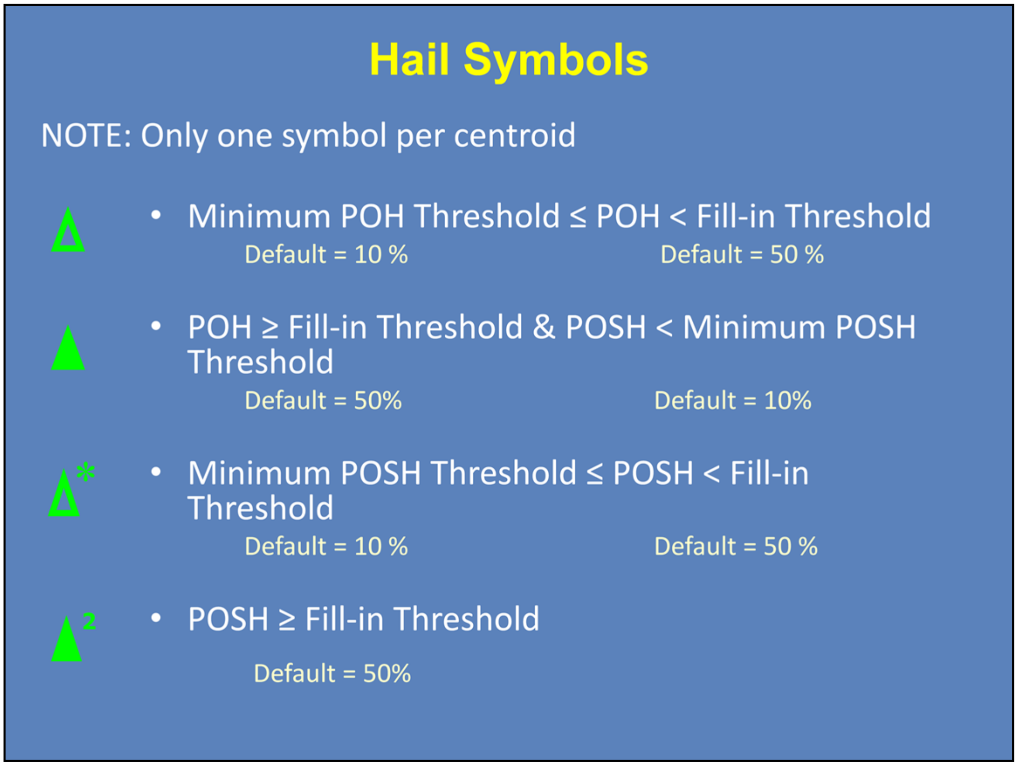
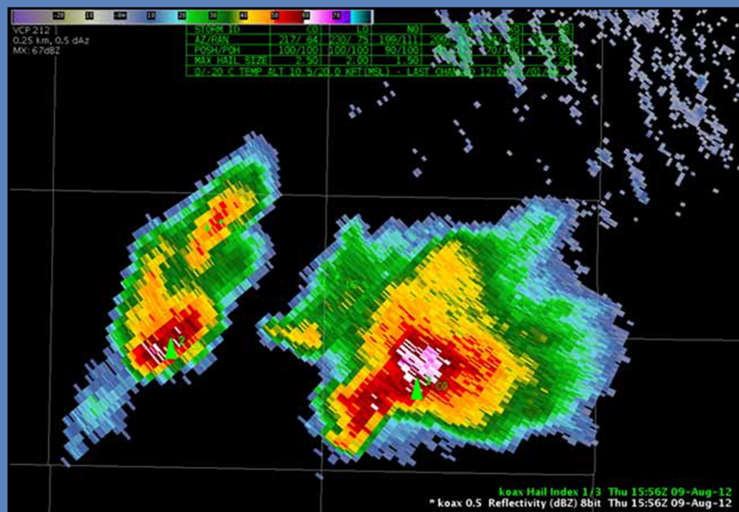


There are multiple symbols that can be assigned to a hail centroid, but only 1 is allowed. Let's look at these different symbols and see what they mean. The first is a small, open triangle shown at the top. This means that the POH value is between the minimum POH threshold (10% by default) and the minimum POH fill-in threshold (50% by default). The next symbol is a small, filled-in triangle which means that the minimum POH fill-in threshold (50% by default) has been met, but the minimum POSH threshold (10% by default) has not been met. A large, open triangle means that the minimum POSH threshold (10% by default) has been reached, but the minimum POSH fill-in threshold (50% by default) has not been met. Finally, a large, filled-in triangle means the minimum POSH fill-in threshold (50% by default) has been met. It is worth noting here that these thresholds are defined at your workstation through the Radar Display Controls GUI which we'll discuss in a few slides. And, the last thing here is the numbers listed in the upper right of some of the symbols. These represent the maximum expected hail sizes in inches. An asterisk just means that the maximum expected hail size is less than ¾ inch. In a warning environment, a forecaster pretty much will only concern themselves with the large, filled-in triangles.

Hail Index Product (HI)



Here is an example of the HI product overlaid on top of reflectivity as you will see it in AWIPS-2. We will take a closer look at the various characteristics of this product over the next few slides.

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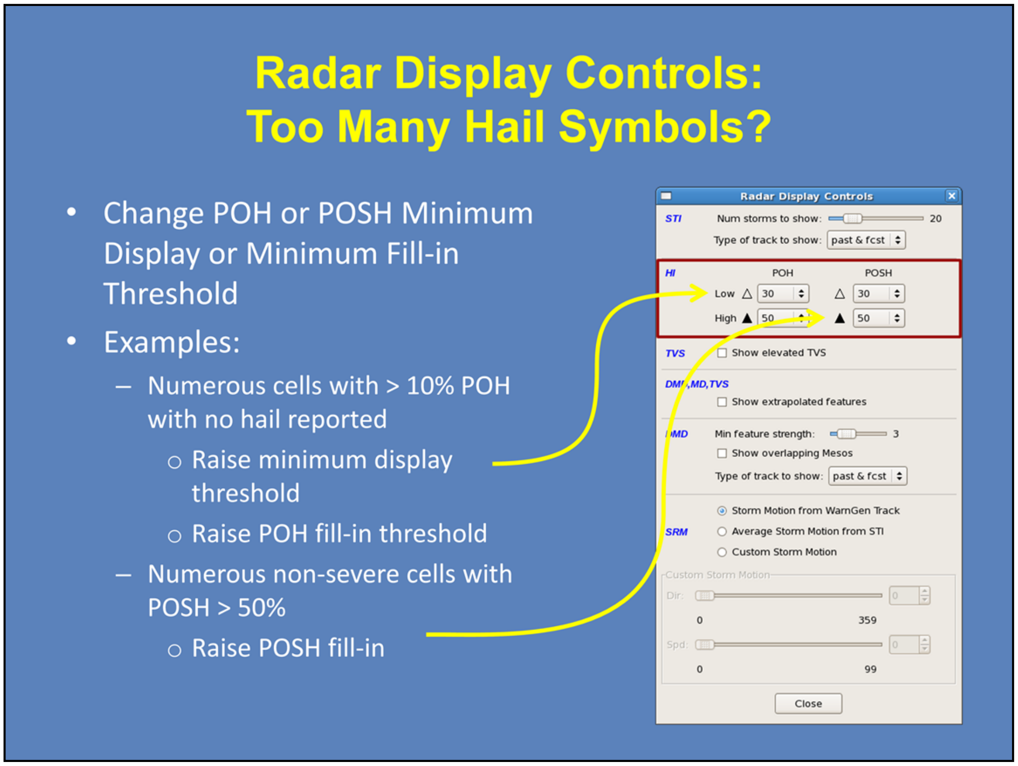
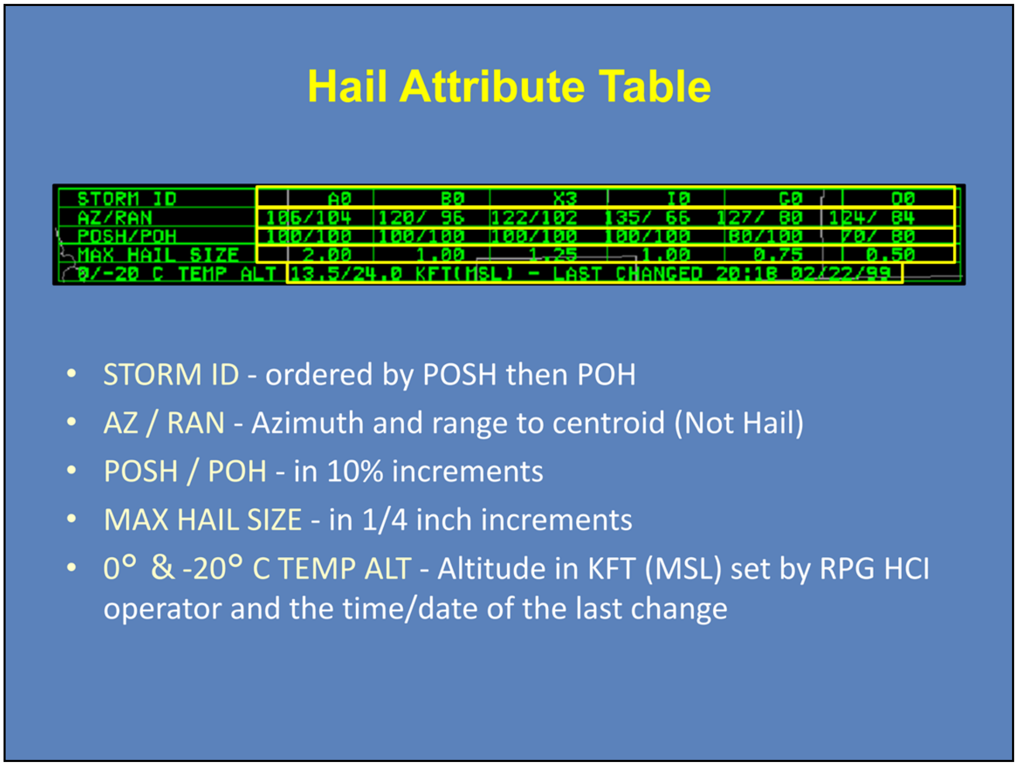


First, the thresholds for the triangles in the HI product are adjustable at your AWIPS-2 workstation. You most likely will never have to adjust these thresholds, but they are adjustable from the Radar Display Controls window found in your Tools menu. A couple of examples where you might want to change the thresholds are…If there are too many symbols and no hail is reported, you may want to raise the thresholds for POH. Another scenario would be if numerous non-severe cells are displaying POSH > 50%, or lots of filled-in, large triangles. In this instance you would want to raise the POSH fill-in threshold.



Here is the Hail Attribute Table that can be found toward the top of the HI product. Let's examine the various information available in this table. 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. Remember the centroid is the 3D center of mass from the SCIT identified storm. The next row is the POSH and POH values for the identified storm in 10% increments. The fourth row is the Maximum Expected Hail Size (MESH) and is listed in ¼" 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 last updated.

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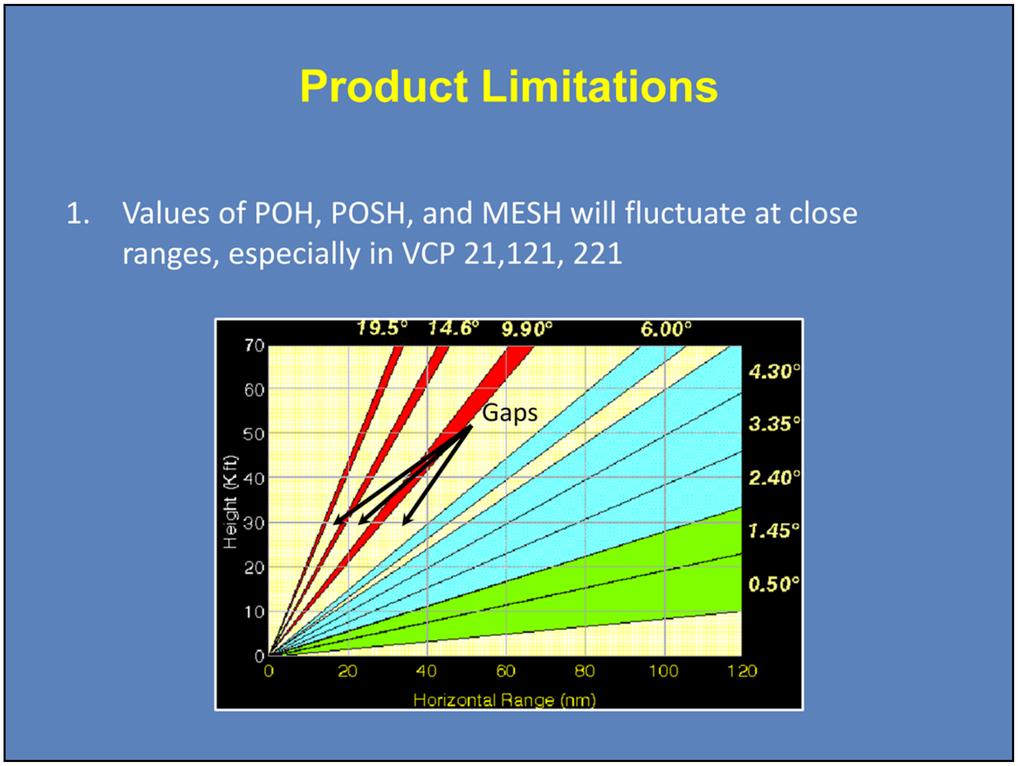
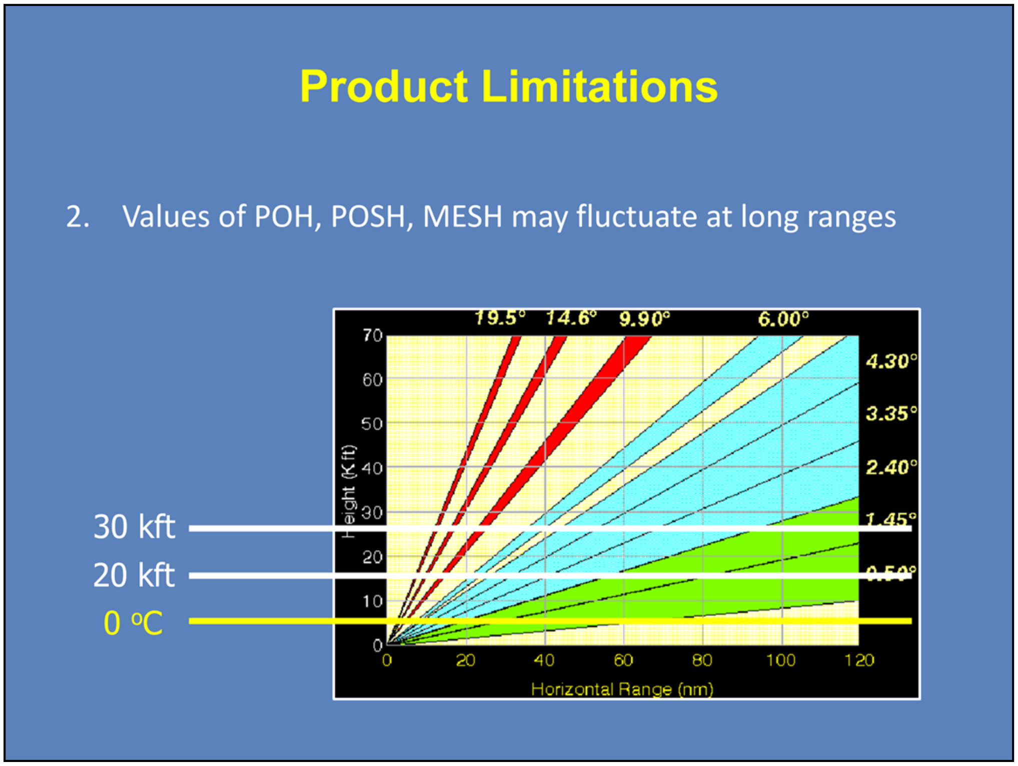


Now for the limitations. The first one is values of POSH/POH and MESH will fluctuate at close ranges to the radar, especially in VCPs 21, 121, and 221. The primary reason is the gaps in elevation which are more prominent when storms are close to the radar.

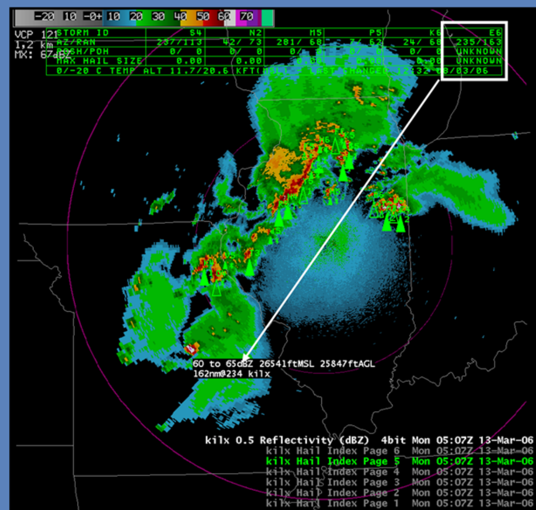


The opposite is also true. At further ranges the values of POSH, POH and MESH may fluctuate. Now, this is not so much tied to VCP choice as it is the earth curvature issue. Recall that at long ranges, the beam is sampling higher and higher into the atmosphere. So at long ranges, only a couple elevations 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.

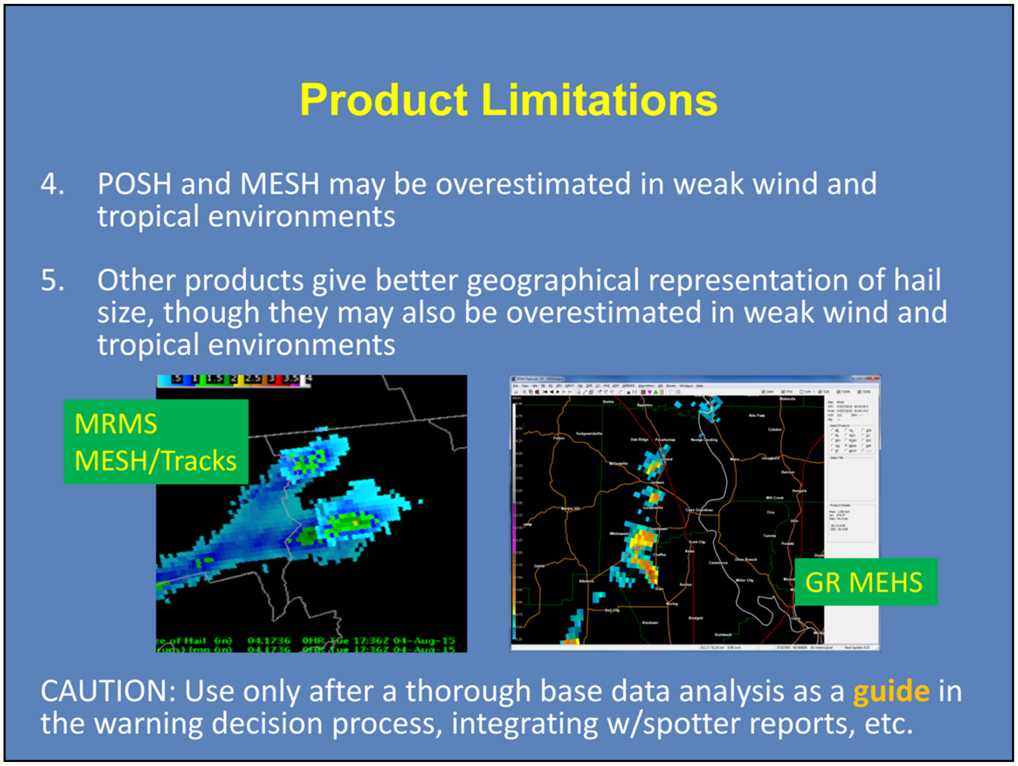
Product Limitations

3. Cells beyond 124 nm will be identified as UNKNOWN

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



Storms can be identified out to ranges beyond 124 nm, but the HI product only goes out to a range of 124 nm. 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 here which was at a range greater than 124 nm so its HI characteristics were listed as “Unknown”. But, you can clearly see it is severe in nature so you would want to pay attention to it.



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.

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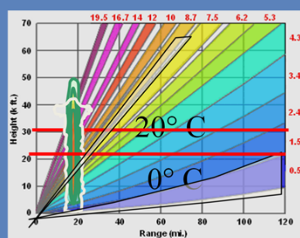
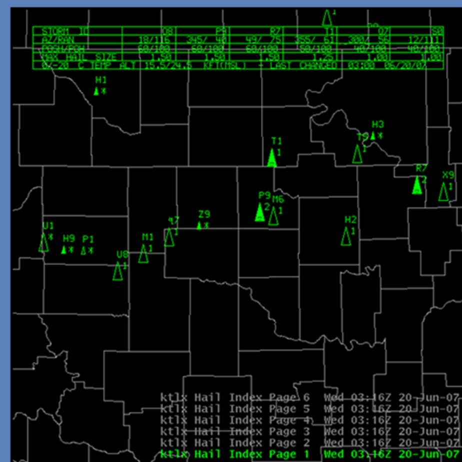
Product Strengths

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, which is 1 inch in diameter or larger. 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.

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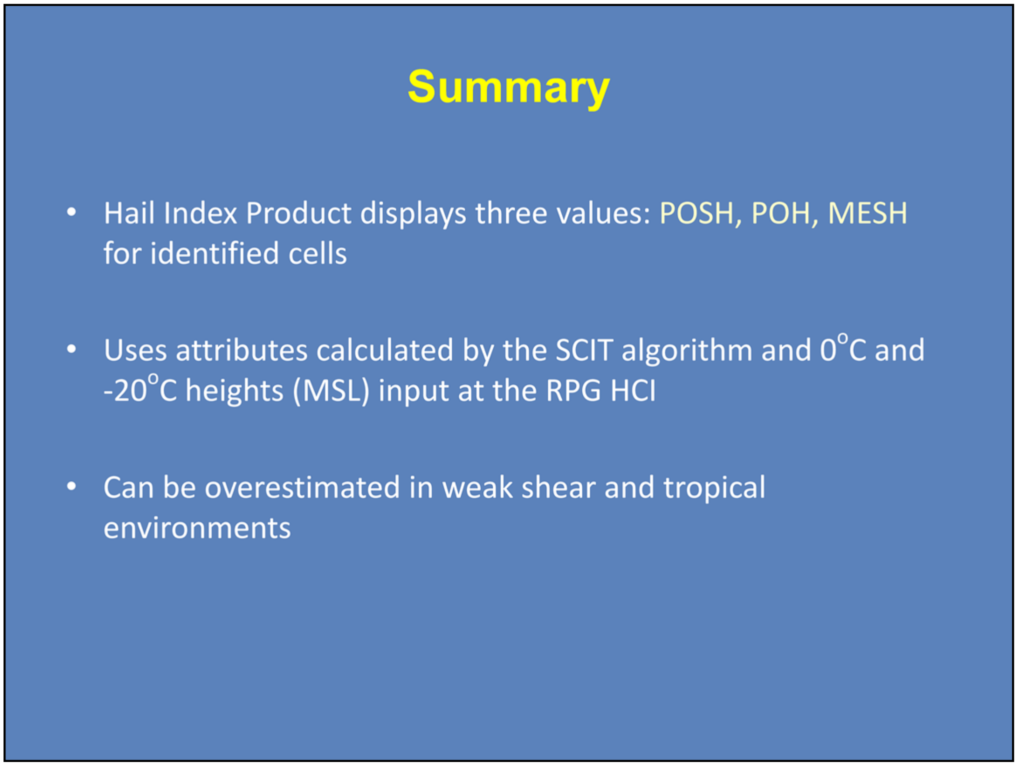

Summarizing this lesson, HI displays three different values; POH, POSH and MESH for all identified cells. It uses attributes calculated by the SCIT algorithm and the 0 and -20 C heights MSL input at the RPG HCI. Keep in mind it can be overestimated in weak wind and tropical environments. The next slide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

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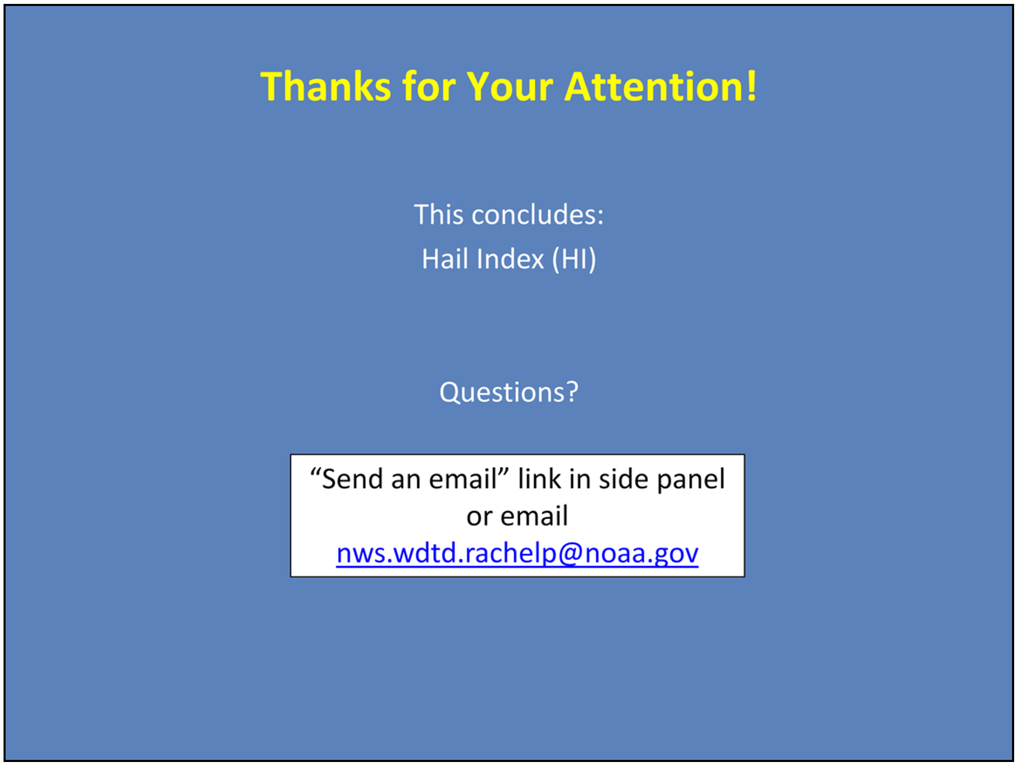

This concludes the lesson on the HI product. You can now move onto the next lesson. If you have any questions, feel free to email the contacts listed.

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

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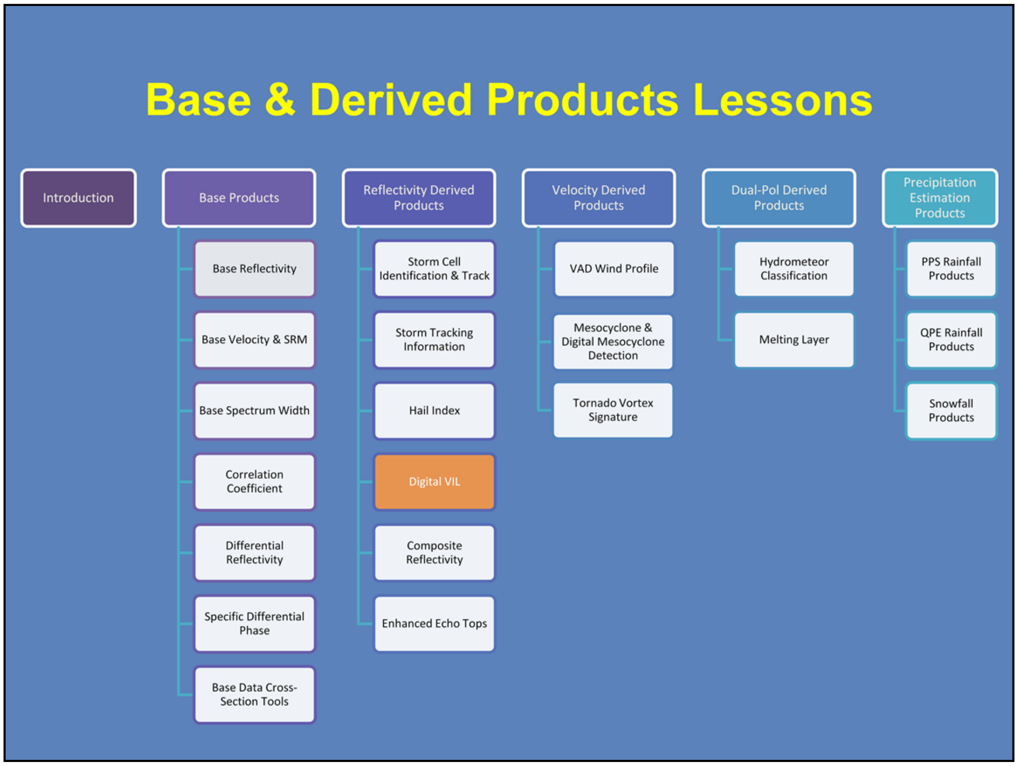

Here is a roadmap for the lessons in this topic. This lesson on the Digital Vertically Integrated Liquid (DVIL), shaded in orange, is the fourth in the Reflectivity Derived Products Section of this topic.

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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

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

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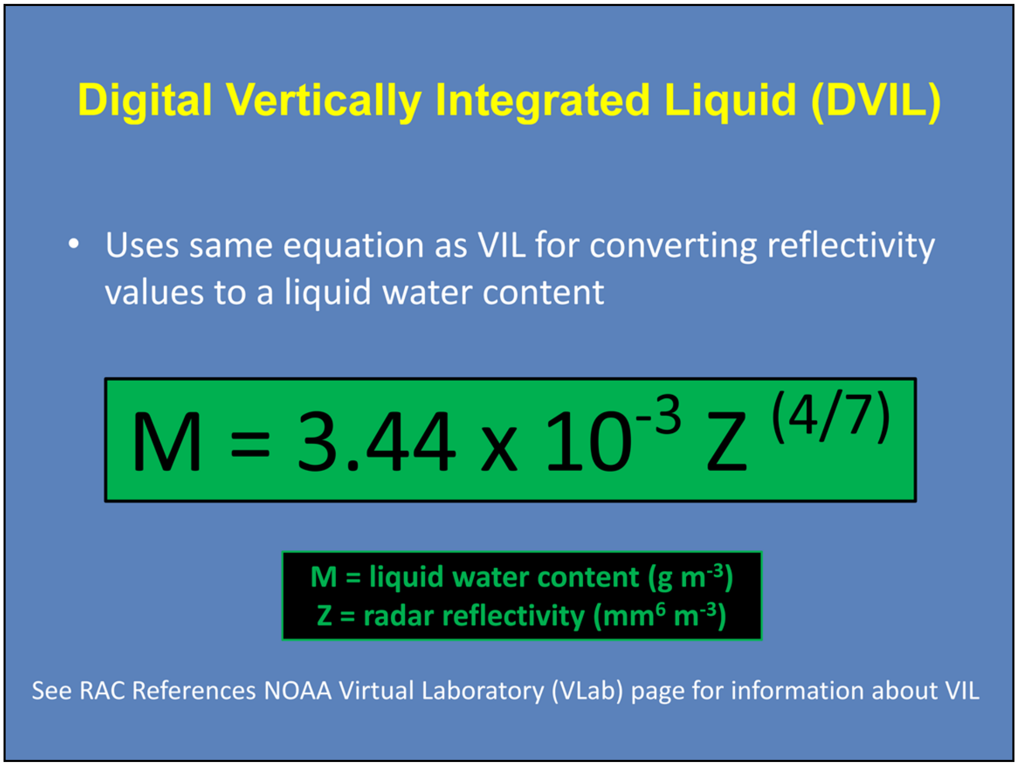

First, let’s note that this lesson only covers the Digital VIL product. If you’d like to learn more about the VIL product, you can refer to the RAC References NOAA Virtual Laboratory (VLab) page for this lesson. What’s important here is to note that DVIL uses the same equation as VIL which is shown here, where M = liquid water content (g m-3) 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/m2, and displayed in 256 data levels from 0 to 80 kg/m2 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.

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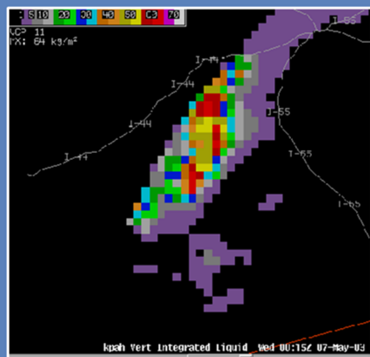
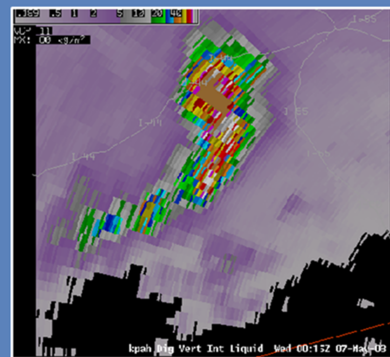
VIL ≠ DVIL





VIL
- 2.2 x 2.2nm grid
- Reflectivity > 18dBZ as input
- Truncates reflectivity > 56dBZ

DVIL
- 0.54nm x 1 deg
- Uses <u>All</u> reflectivity
- No truncation

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.

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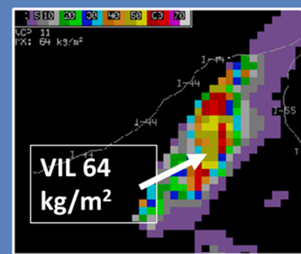
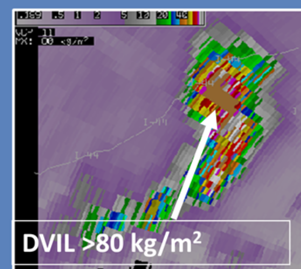
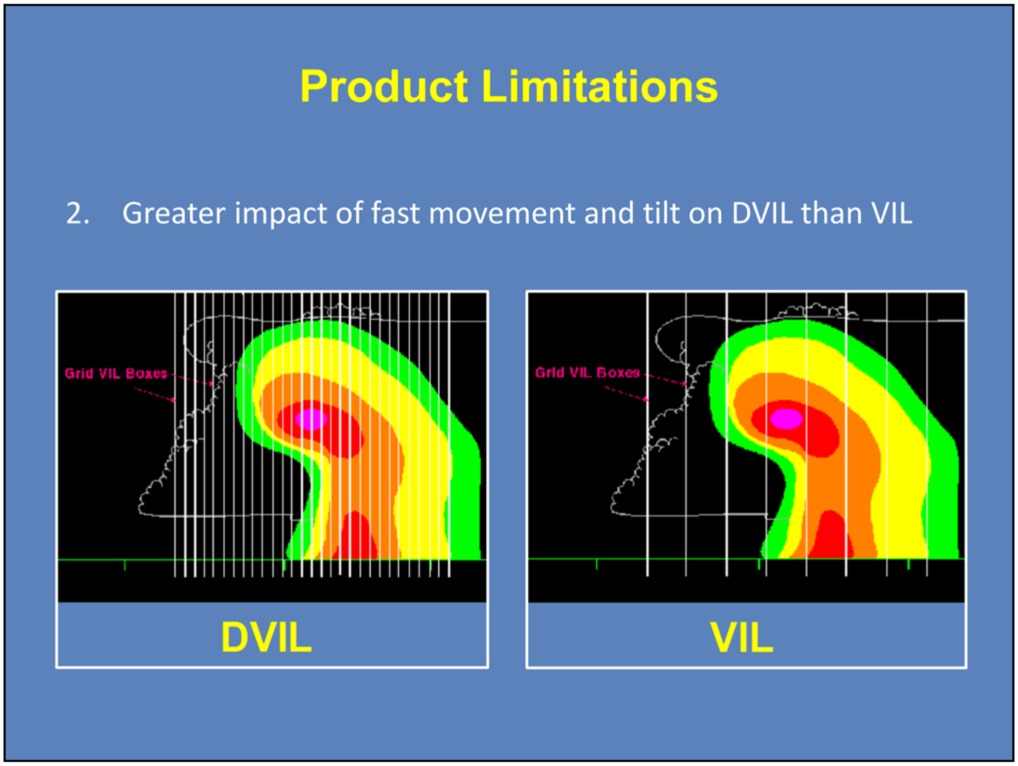
Product Limitations

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





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.



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.

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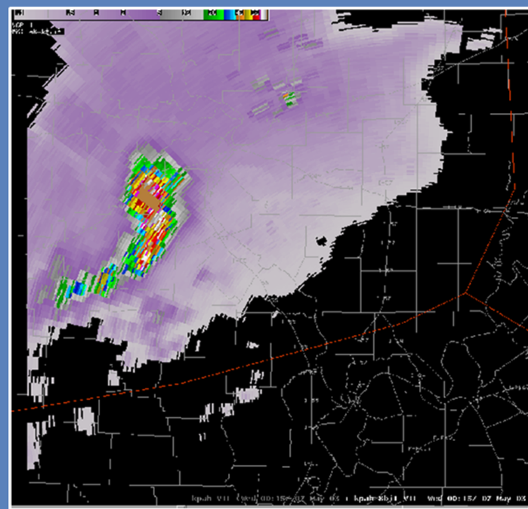
Product Limitations

3. 80 kg/m^2 max value is commonly reached due to lack of truncation



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^2, 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.

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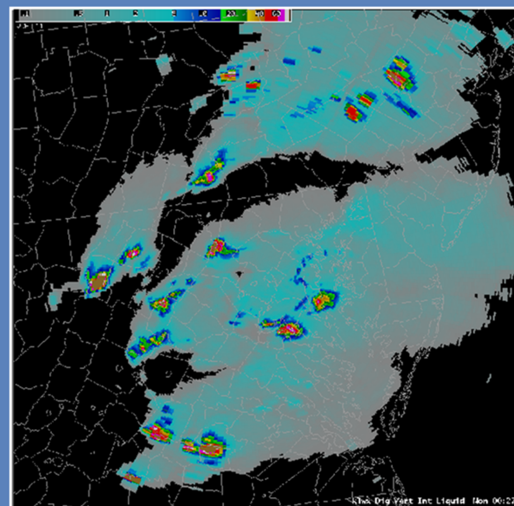
Product Applications

1. Helps locate areas of more significant Z cores



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.

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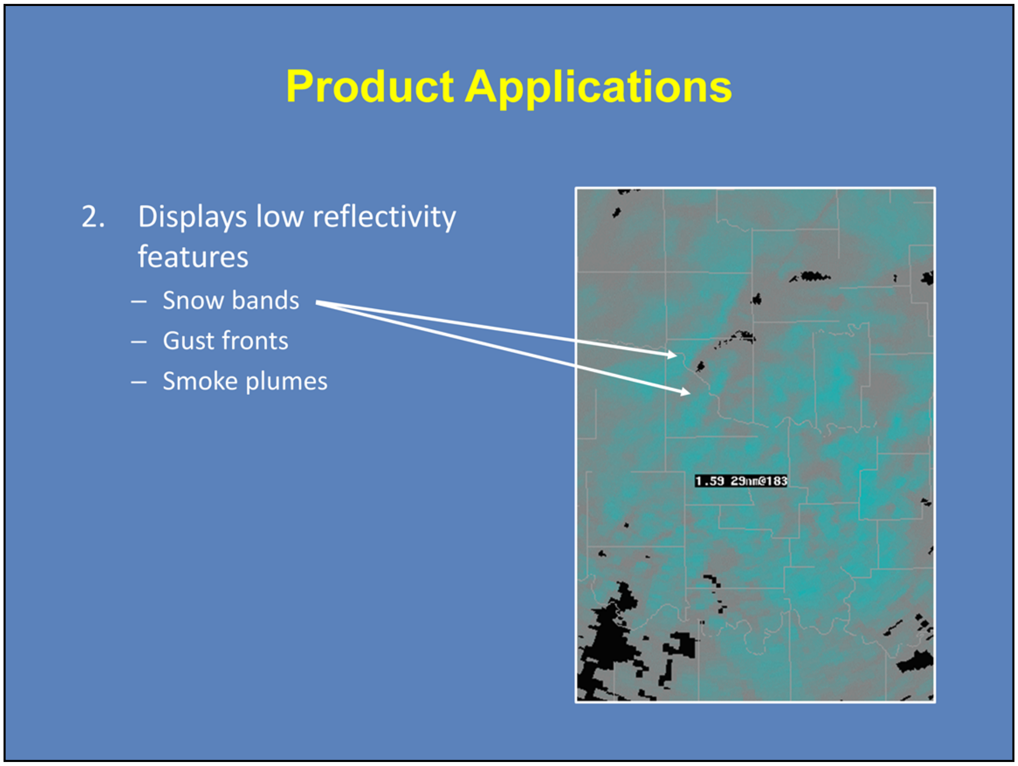

As is often the case with most of these products, sometimes its limitations in one area becomes a strength elsewhere. This is an example we have with DVIL. Because we are including all reflectivities, especially the lower reflectivities, we can see weak features such as snow bands, gust fronts or smoke 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.

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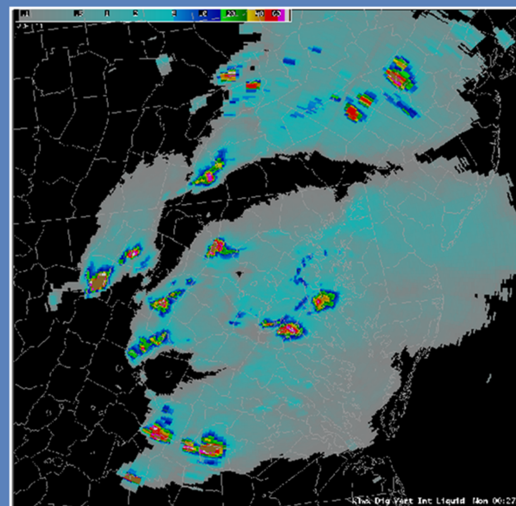
Product Applications

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



You might be able to better able to 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.

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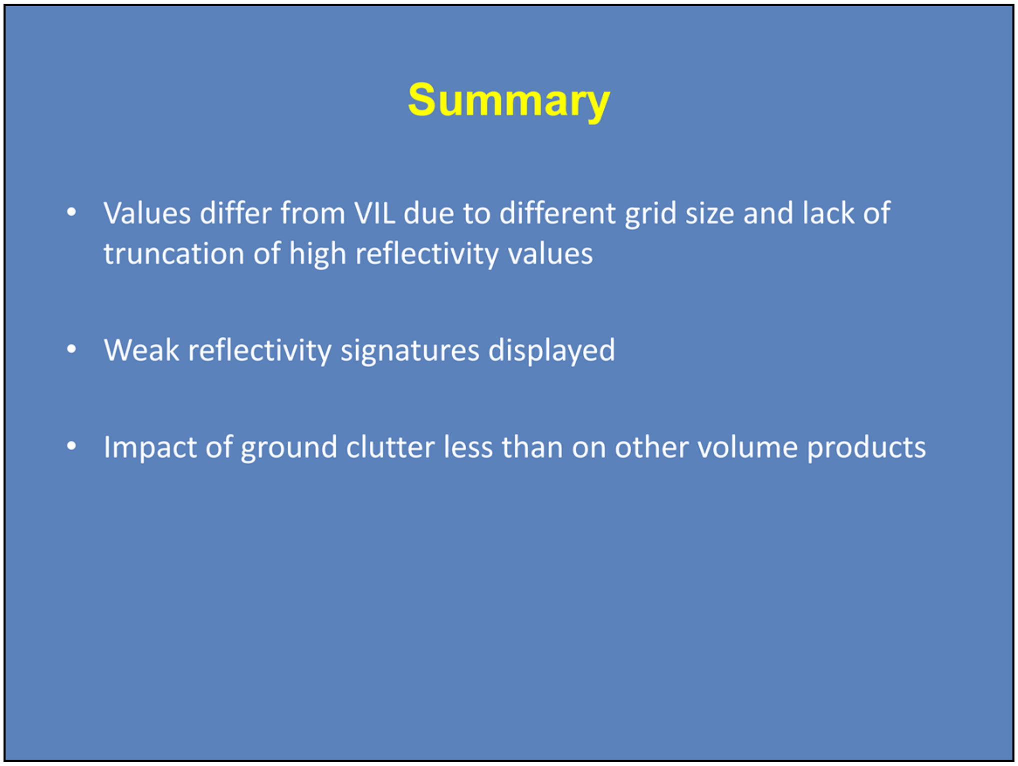

In summary of the digital VIL or DVIL product…the values differ from VIL due to different grid size and the lack of truncation of high reflectivities. You can see very weak reflectivity features displayed, and the impact of ground clutter is less than that of other volume products such as CZ. The next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

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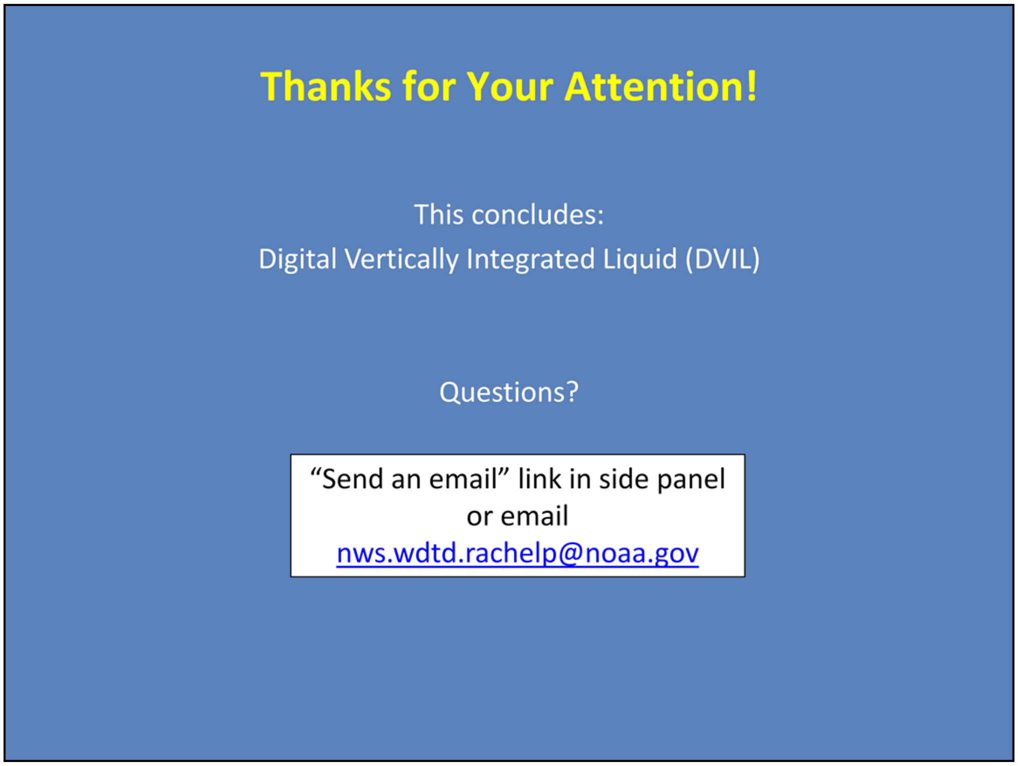
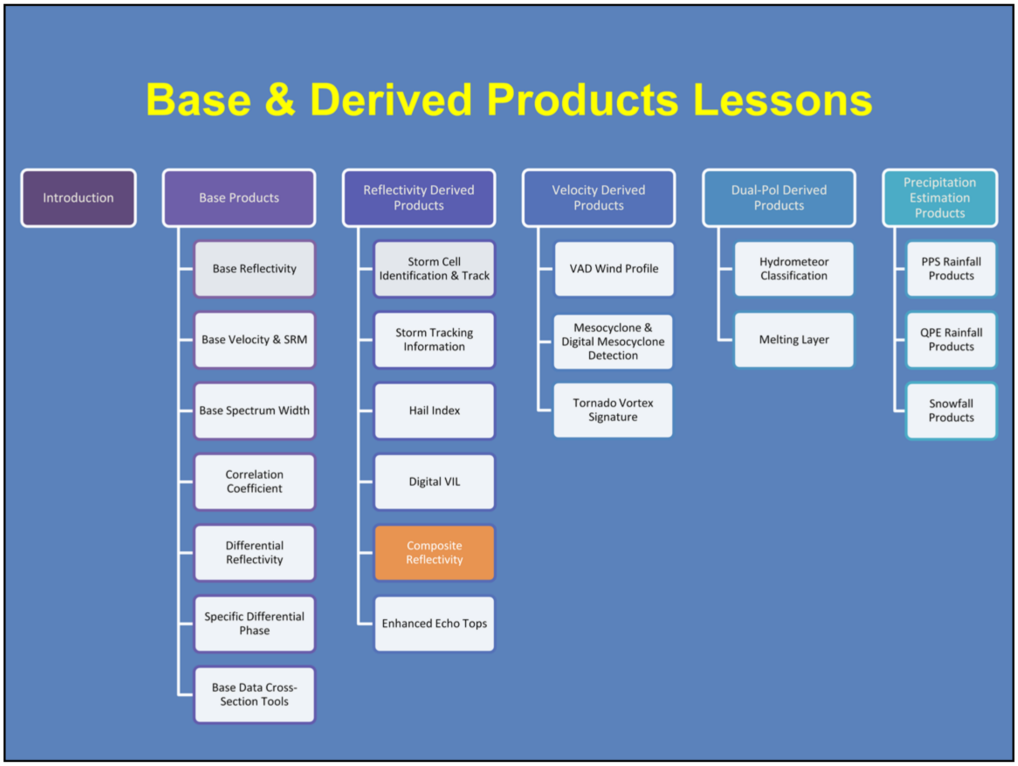
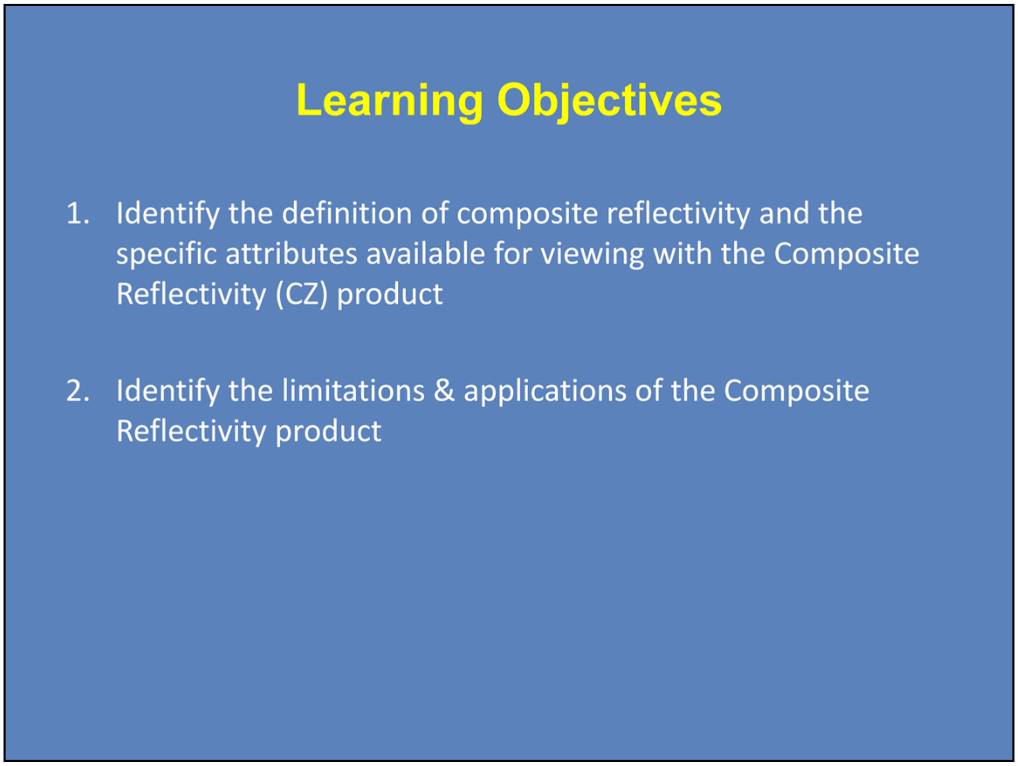


This concludes the lesson on the DVIL product. You can now move onto the next lesson. If you have any questions, feel free to email the contacts listed.

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.



Here is a roadmap for the lessons in this topic. This lesson on the Composite Reflectivity product, shaded in orange, is part of the Reflectivity Derived Products Section of this topic.



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

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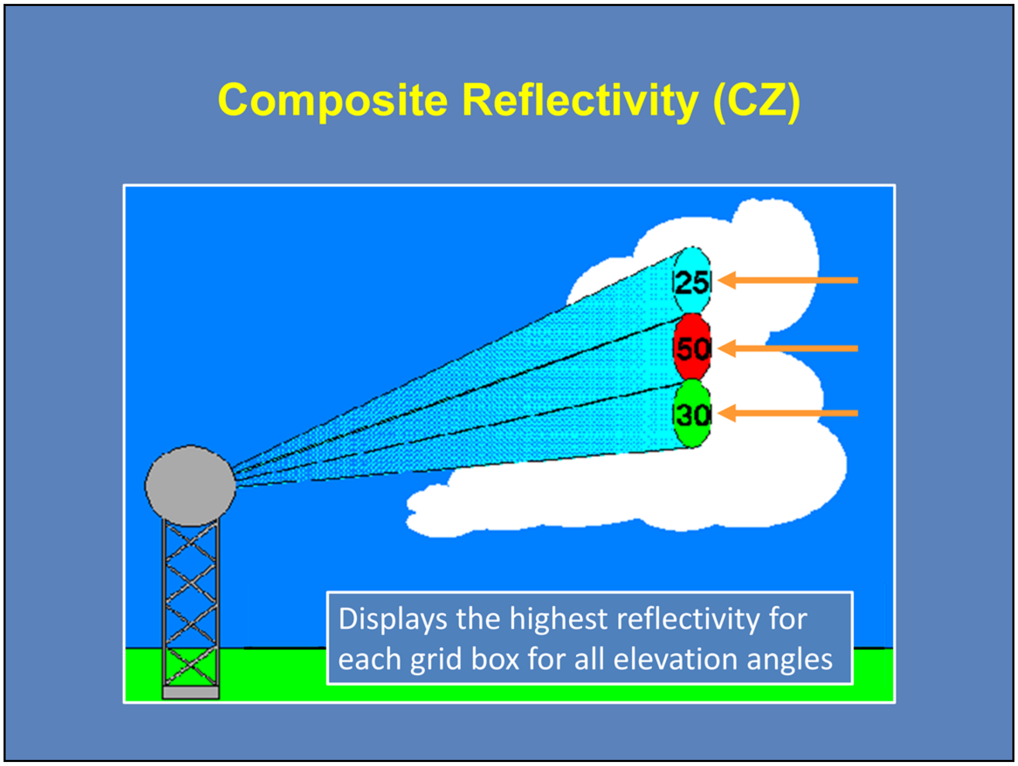
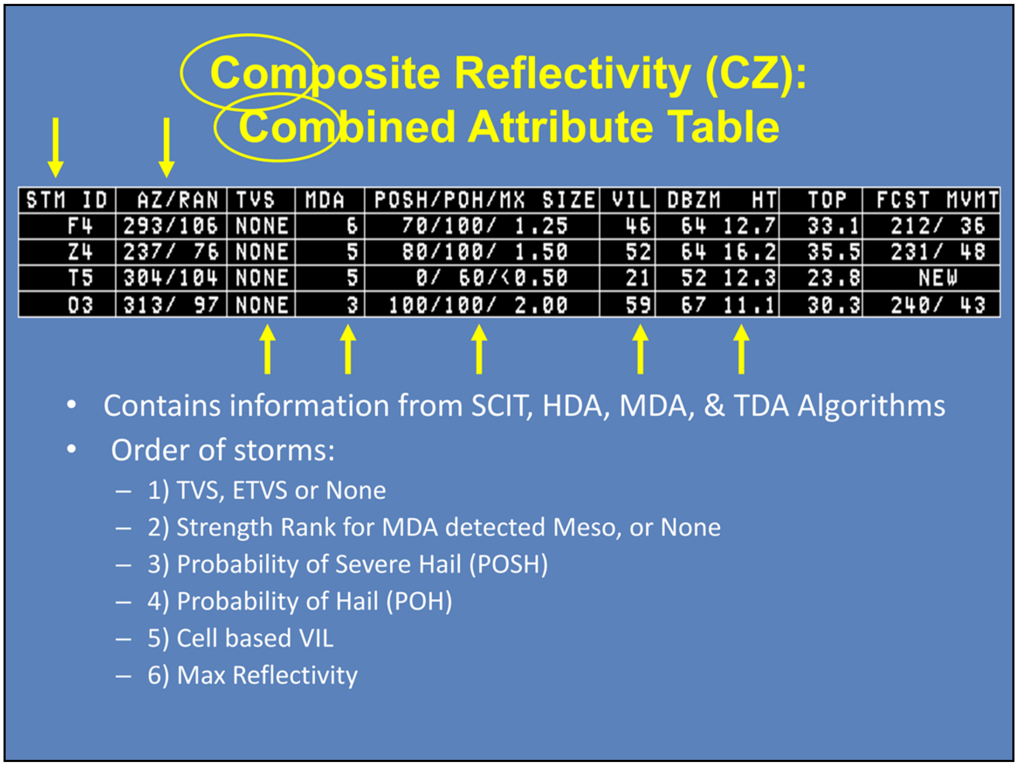


The composite reflectivity product is based on a straight-forward concept. The purpose of CZ is to indicate the maximum reflectivity at a point for the entire volume scan. The RPG accomplishes this task by picking the highest reflectivity value for that point from each elevation angle scan from that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

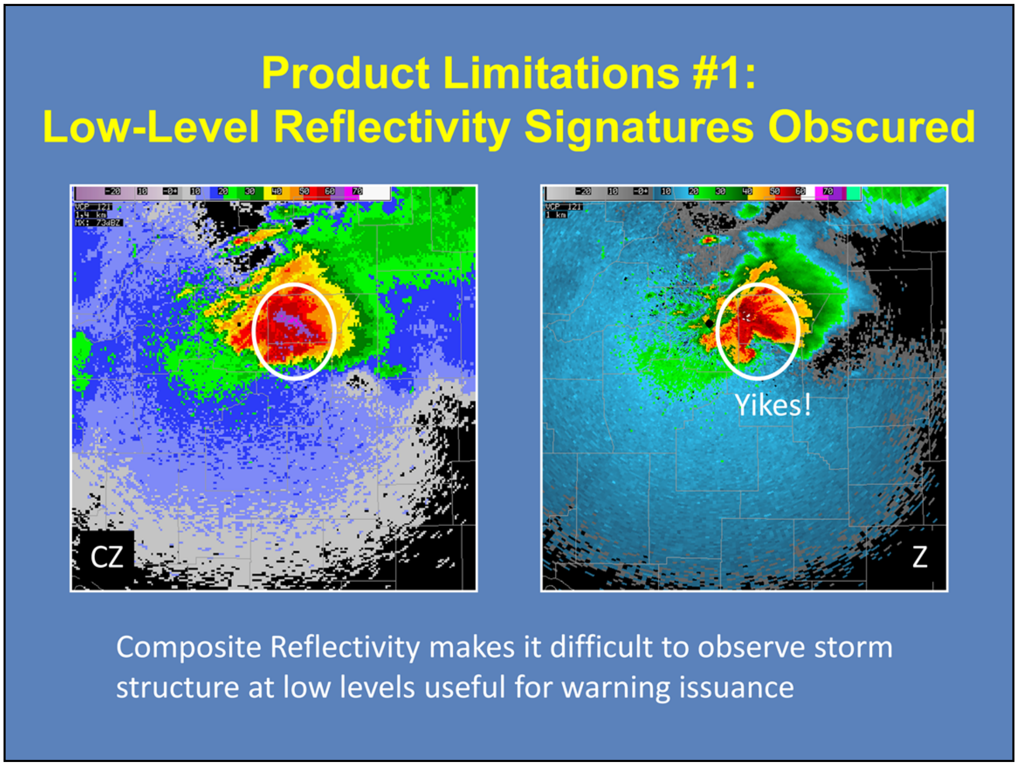
The key point is this: when we look at the CZ product, we don't know from which elevation angle the displayed value was observed. We just know that was the highest value in the volume above that grid box.



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.

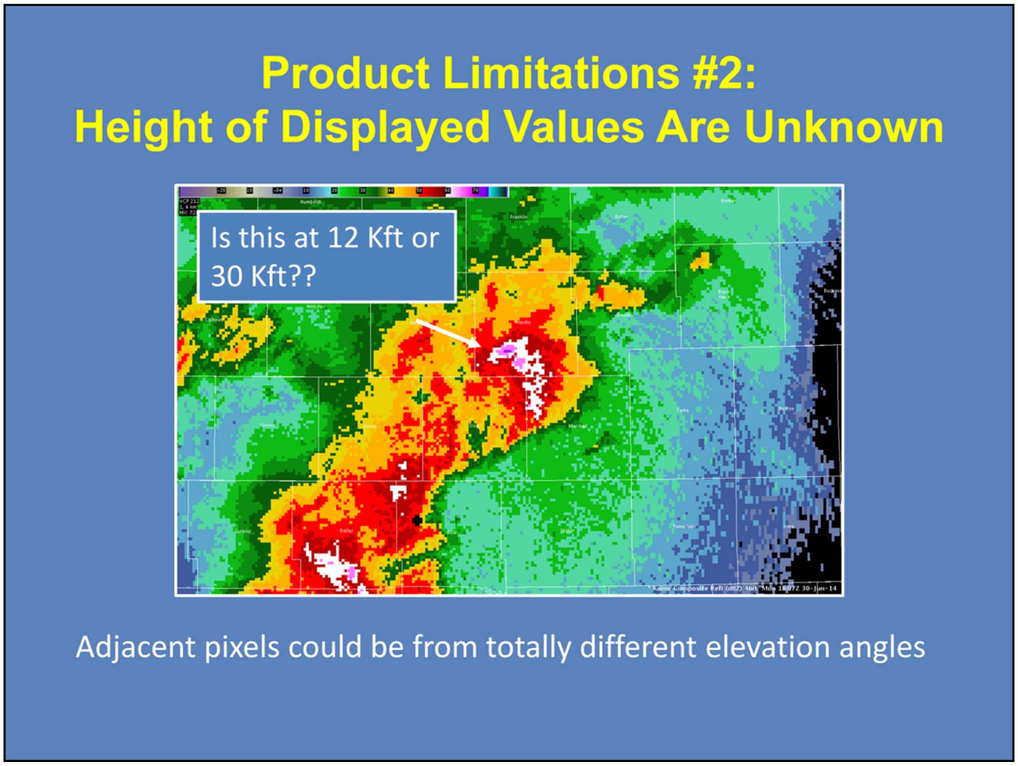
Notice that the table is organized with the Storm ID from SCIT on the left. The next column contains the azimuth and range where the SCIT defined storm centroid is the located (not necessarily the most significant portion of the storm weatherwise).

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.



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.



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.

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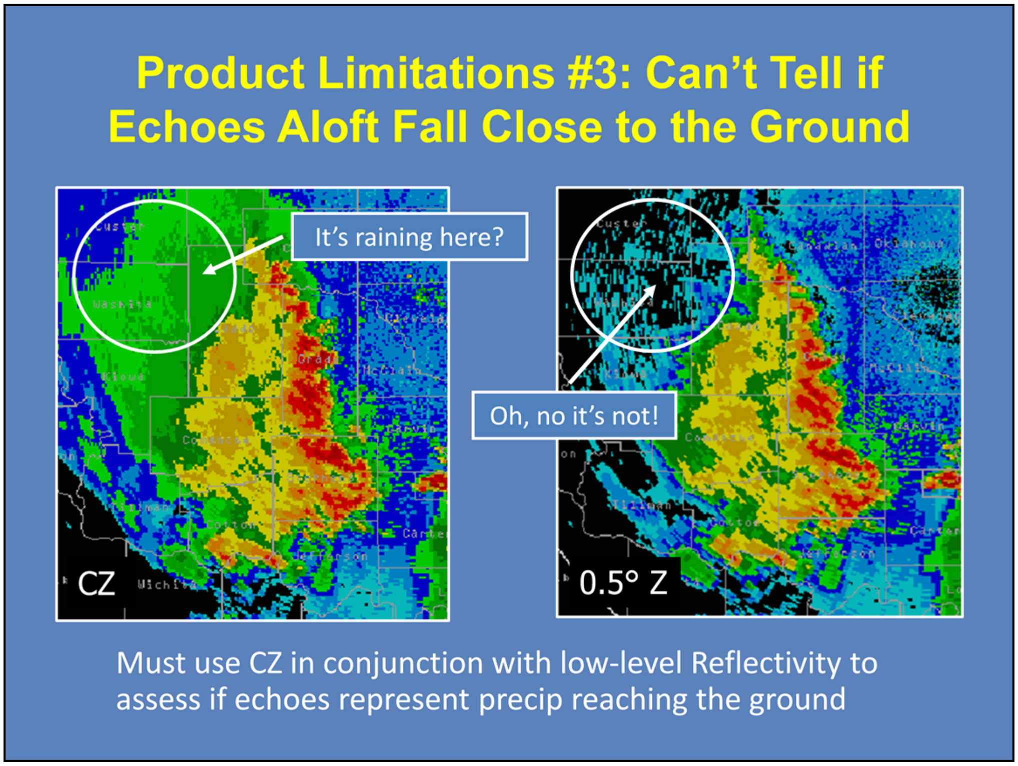

This next limitation is similar to the one we just talked about. Composite Reflectivity doesn't allow you to discriminate whether the reflectivity displayed is precip that actually reaches the ground (i.e., virga).

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.

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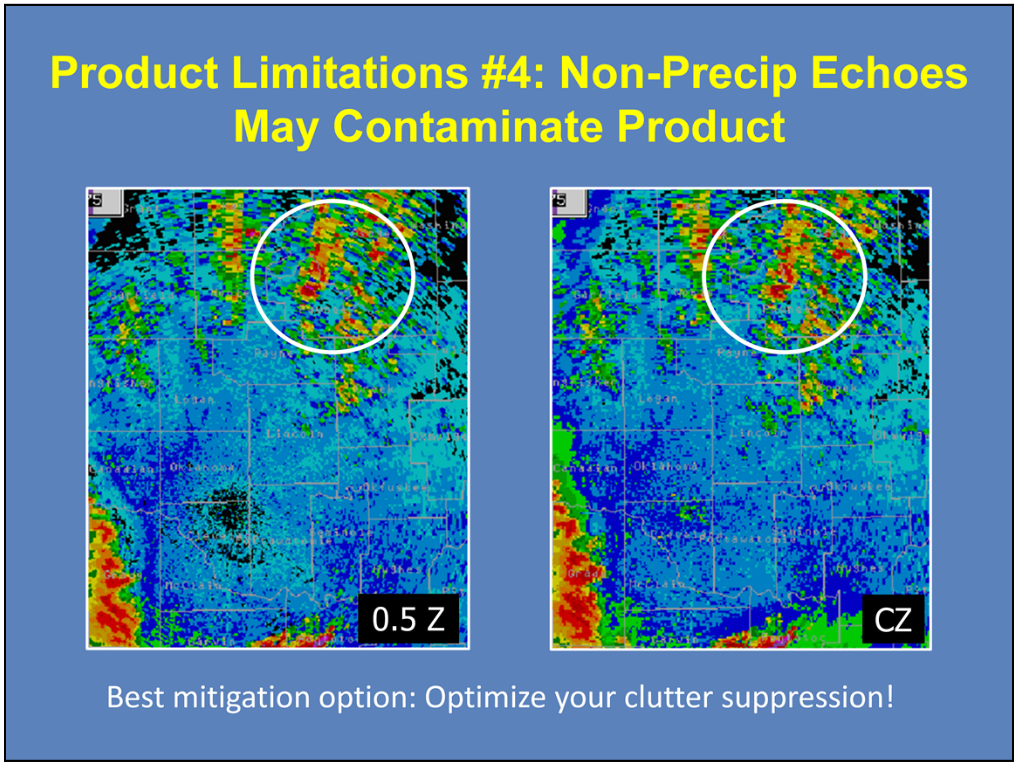

The next limitation involves anomalous propagation and ground clutter. The images on this slide are an example of how these returns on low elevation angle scans can contaminate the CZ product. Remember, the values displayed in CZ are not required to have vertical extent to be included in the product.

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.

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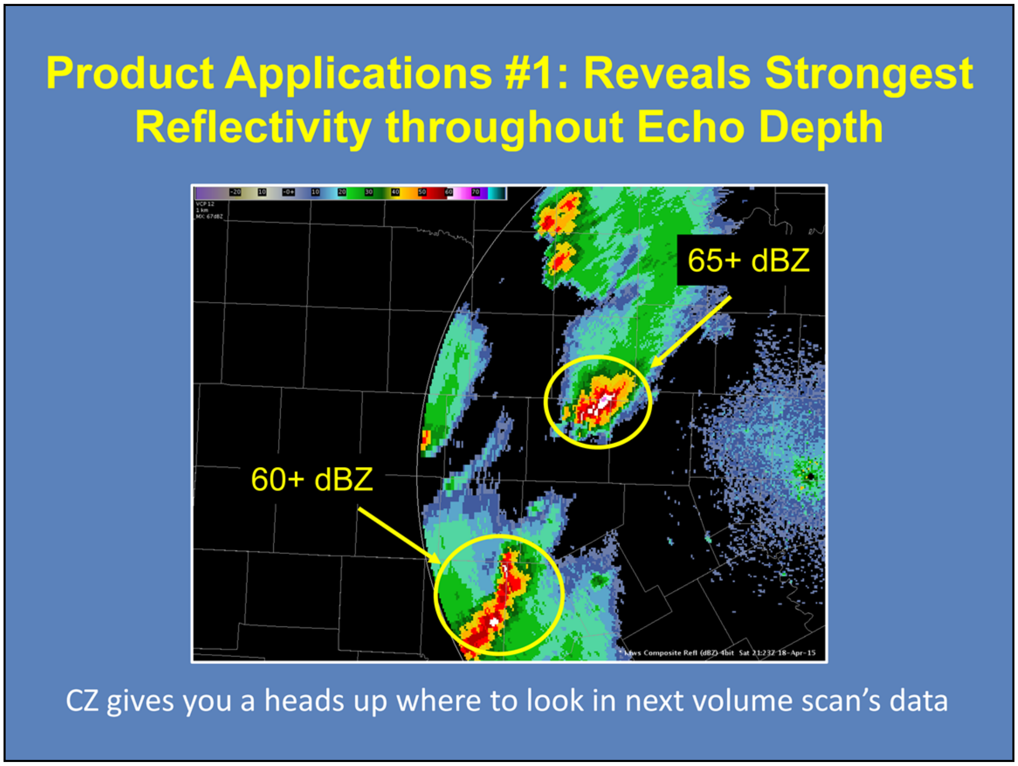

Enough with the limitations, let's look at how CZ can be useful to you.

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 that 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.

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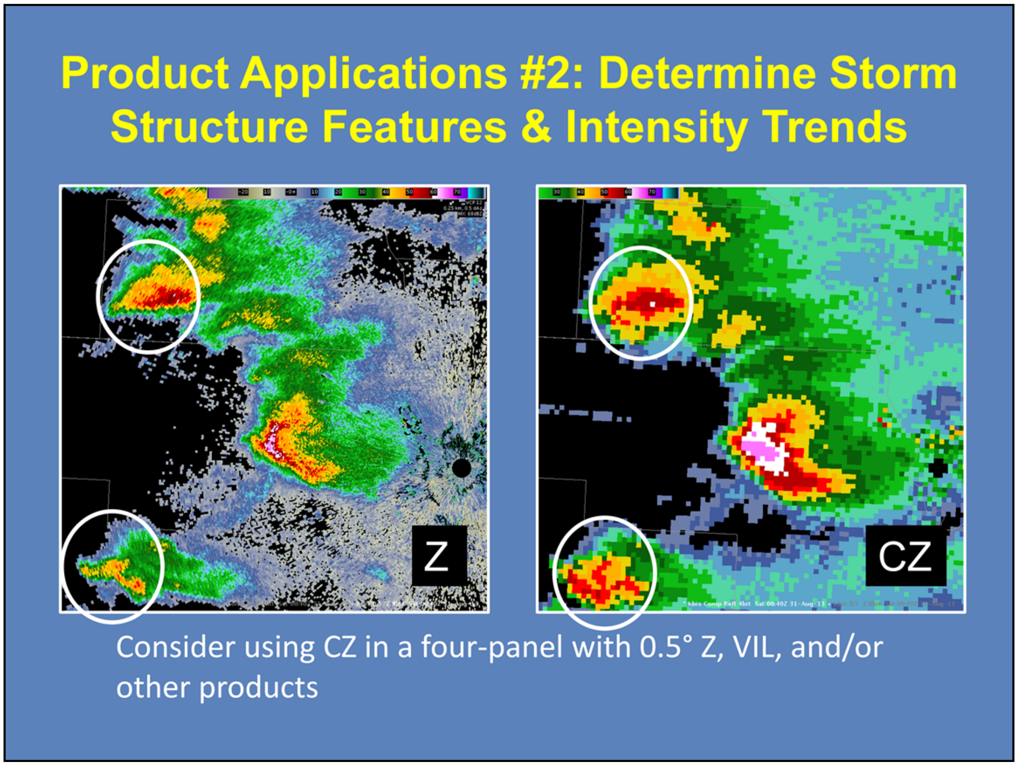

You can get around the limitations we mentioned by using other products with CZ. Often, you will want to use CZ in conjunction with Z. In the example, some of the storms have noticeably strong low-level reflectivity values. However, the storm to the southwest is noticeably stronger aloft than it is at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

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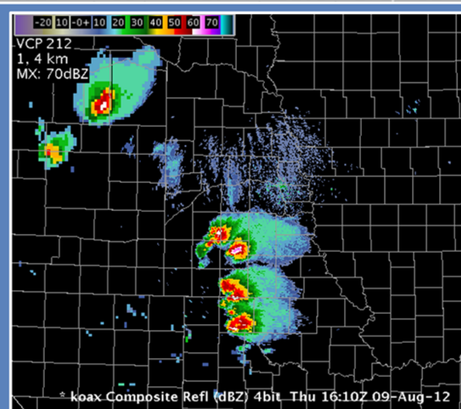
Product Applications #3: Combined Attribute Table

STM ID	AZ/RAN	TVS	MDA	POSH/POH/MX SIZE	VIL	DBZM HT	TOP	FCST MVMT
P4	146/ 31	TVS	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



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 and will be discussed at the RAC workshop.

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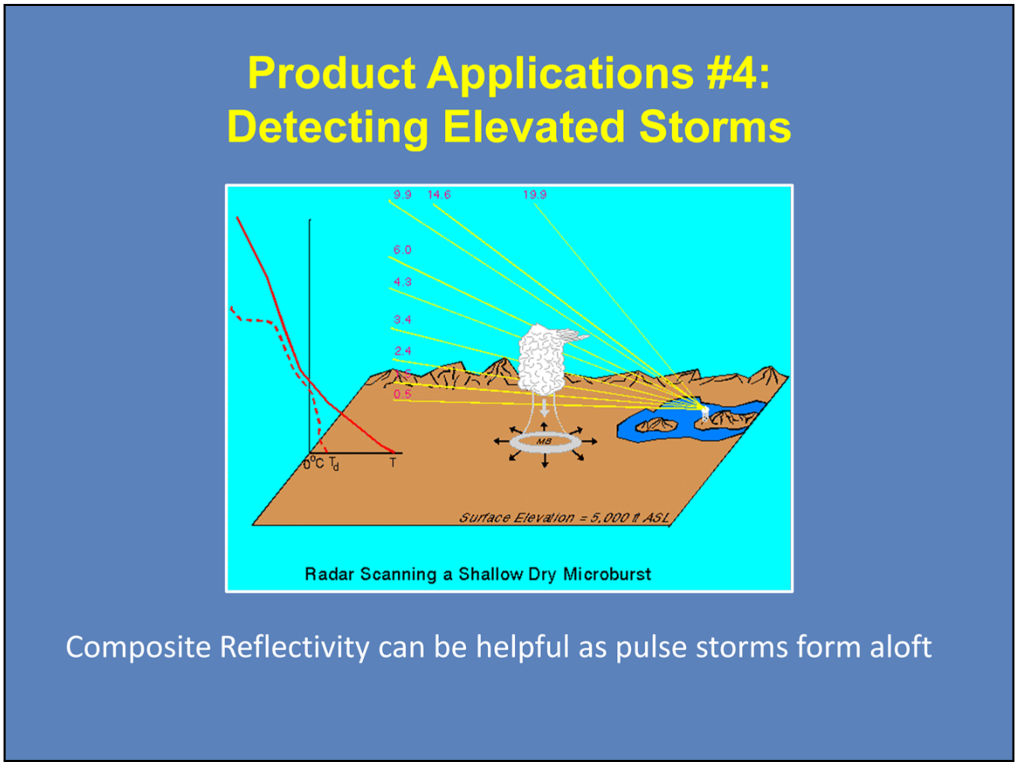

In some regions, like the western U.S., elevated pulse storms may lead to significant downbursts (Wakimoto, 1985). Radar echoes at the lowest elevation tilt may not appear until the downburst is occurring. Composite Reflectivity can be helpful for spotting these storms as they form aloft.

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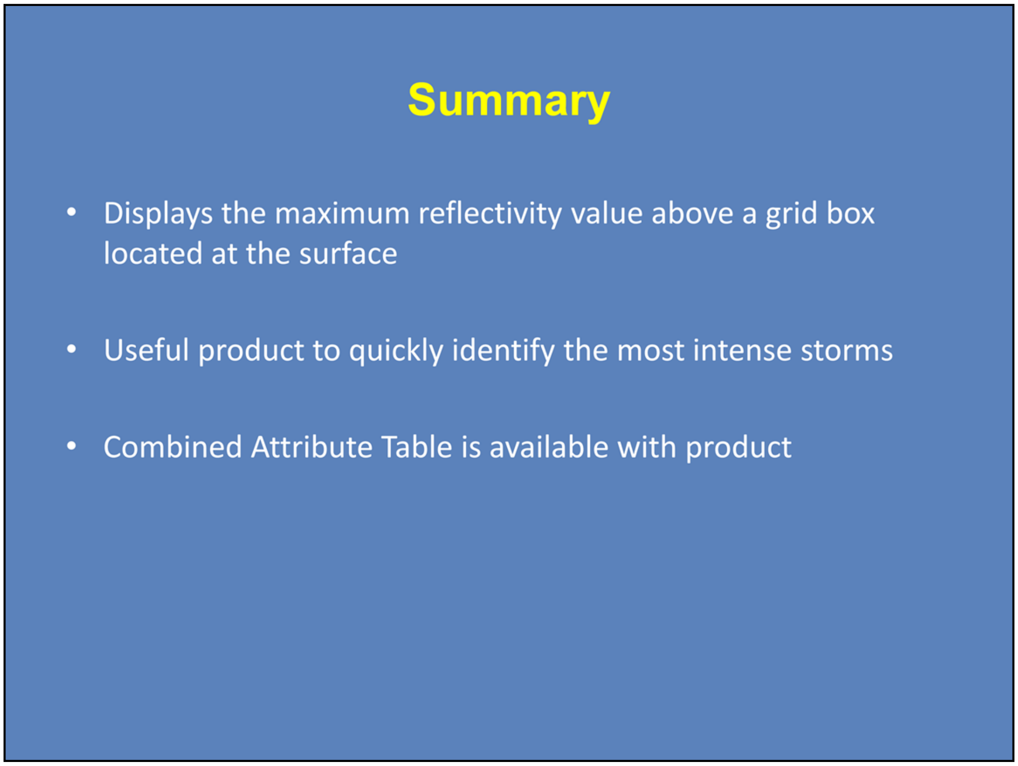
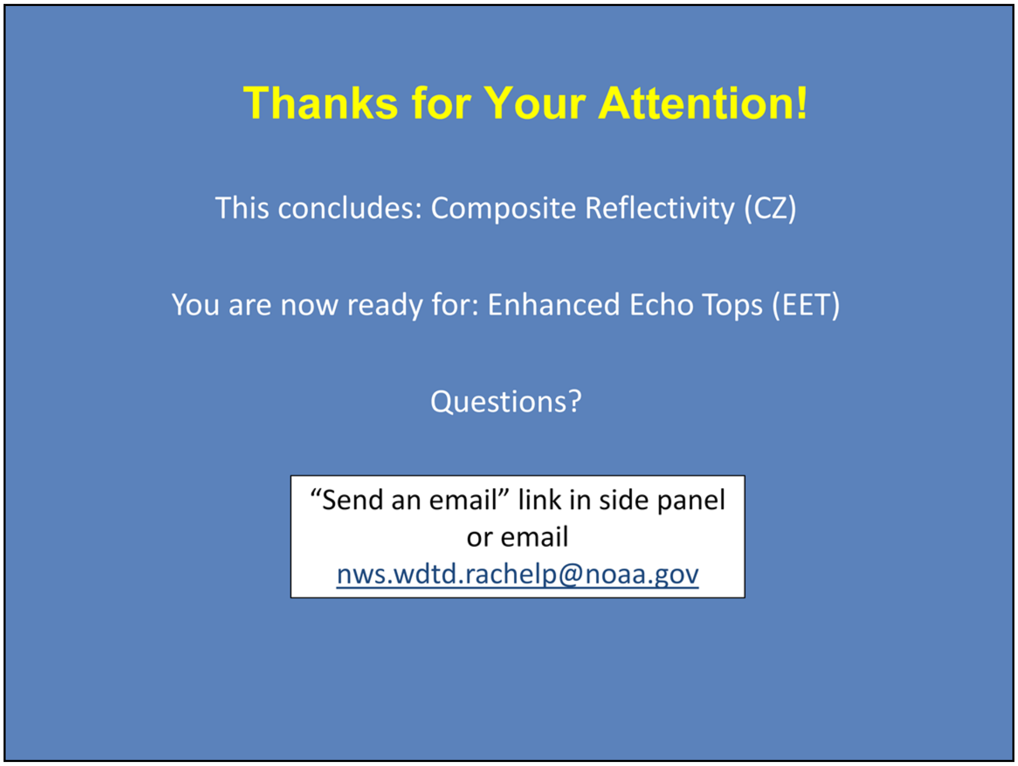
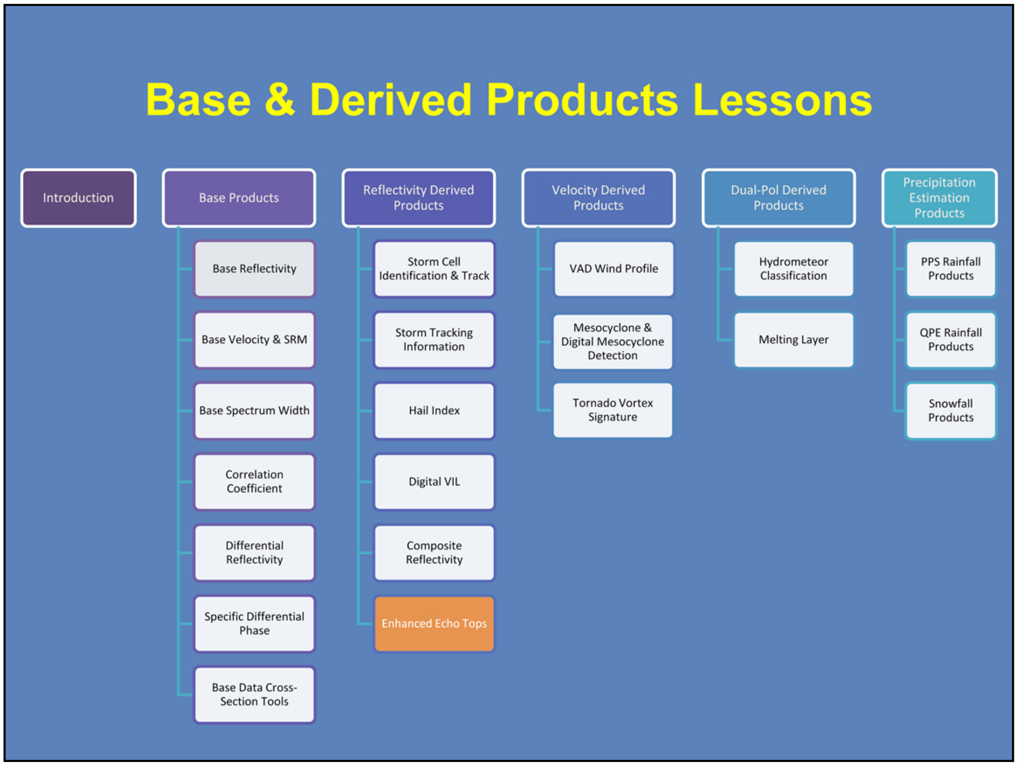


To summarize, the CZ product determines the highest reflectivity value above a grid box at the surface for you radar coverage area using all the elevation scan reflectivity data in the current volume coverage pattern. It is most useful to quickly identify the most intense storms in your local area. CZ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



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 on the bottom of the slide.

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.

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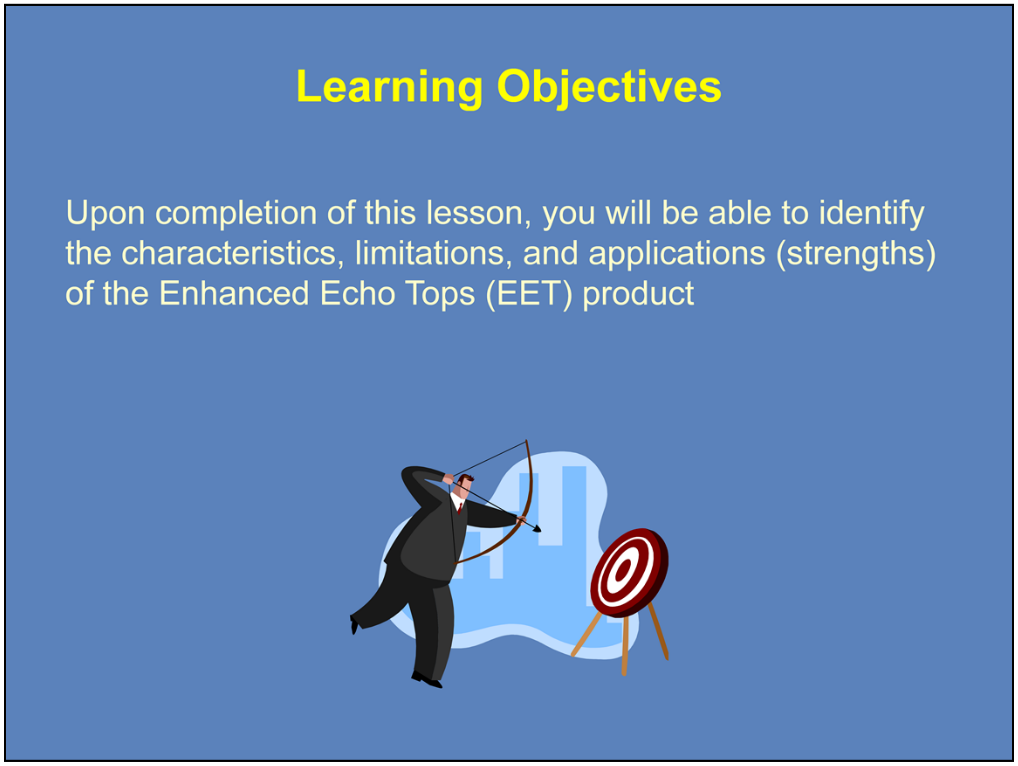

Here are the learning objectives for this lesson. Please advance the slide when you are ready to begin.

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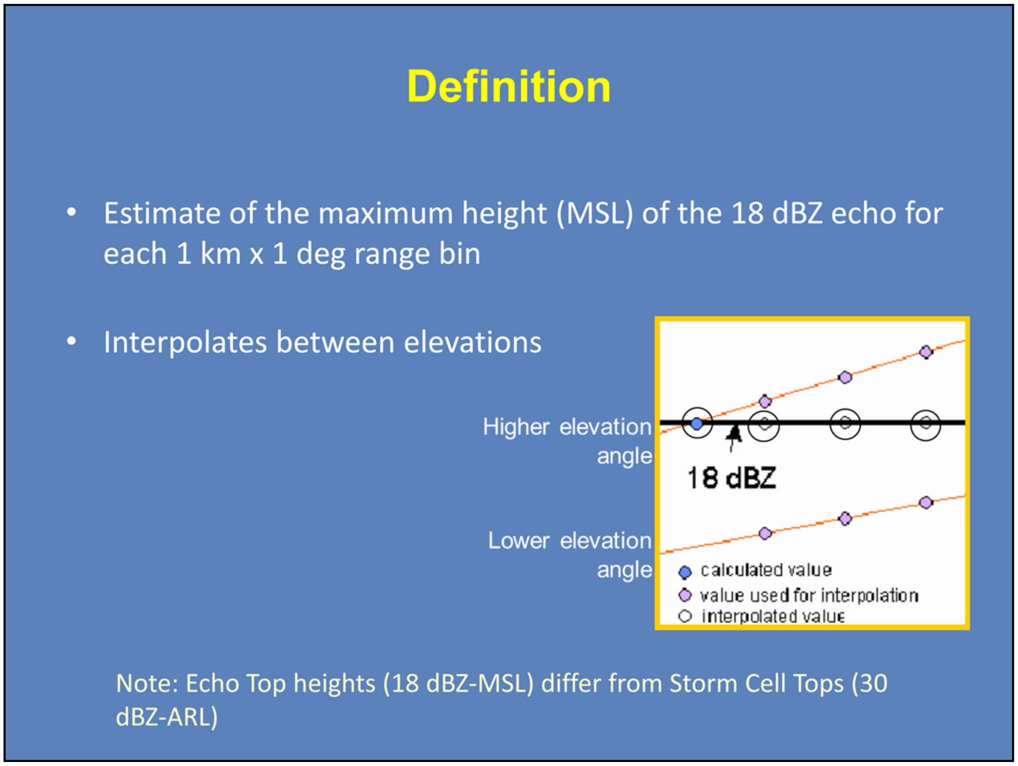
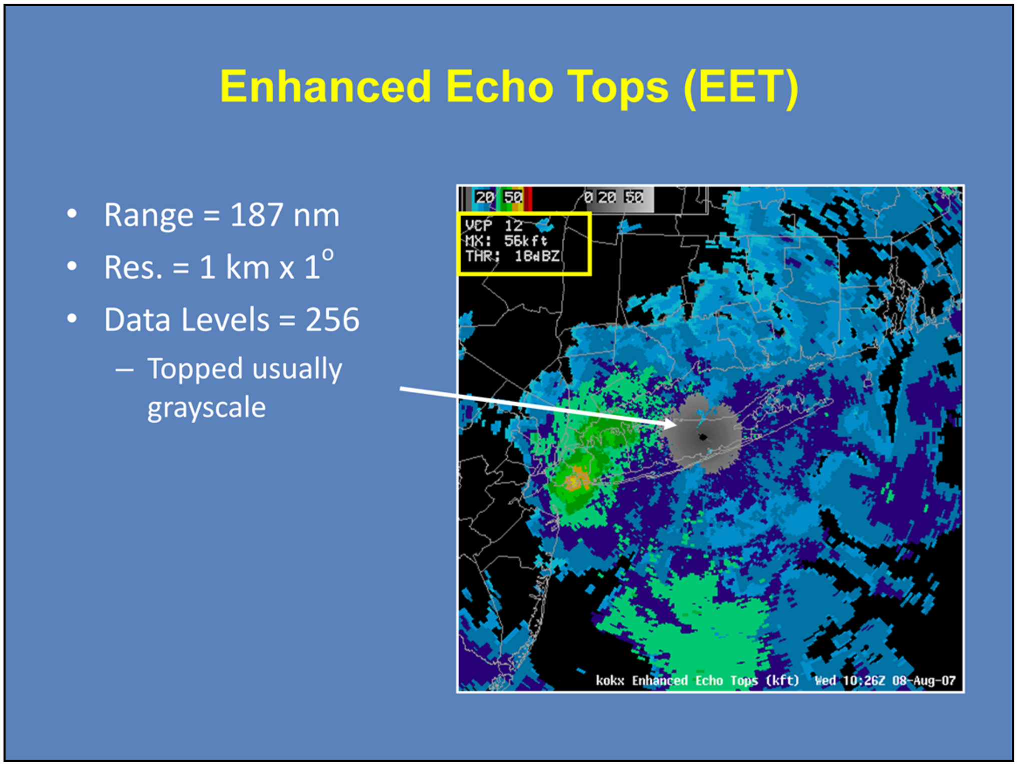


Let's start by defining enhanced echo tops. The echo top is defined as the estimate of the highest height of the 18 dBZ echo for each range bin. Heights are given in MSL and interpolation is used to determine the height of the 18 dBZ echo in between elevation angles. Look at the graphic on the right 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.



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.

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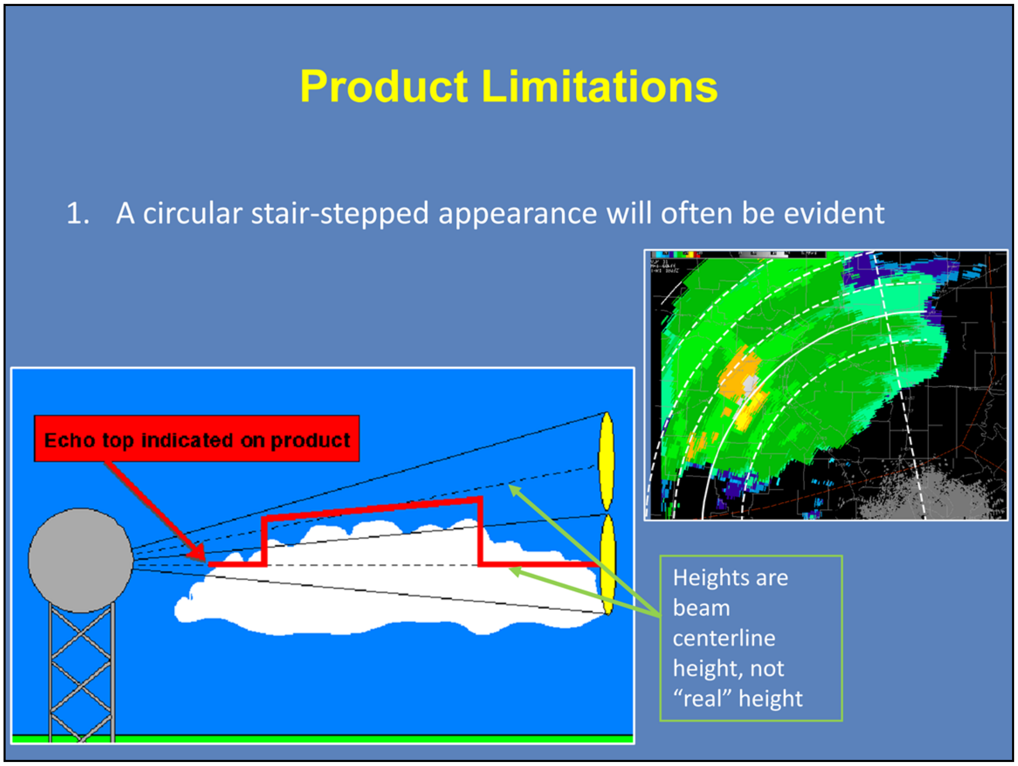

So, for limitations, a circular stair-stepped appearance will often be evident with widespread precipitation. Recall from other reflectivity derived products with stair-stepped appearances, this is due to the gaps in elevations and the fact that beam center point is being used in the calculation of the 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 could top, the echo height goes back down to the height of the lower beam.

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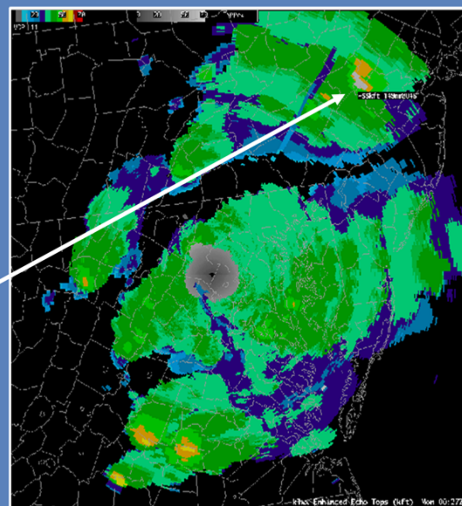
Product Limitations

2. Tops will be underestimated close to the radar (coded as “topped”)

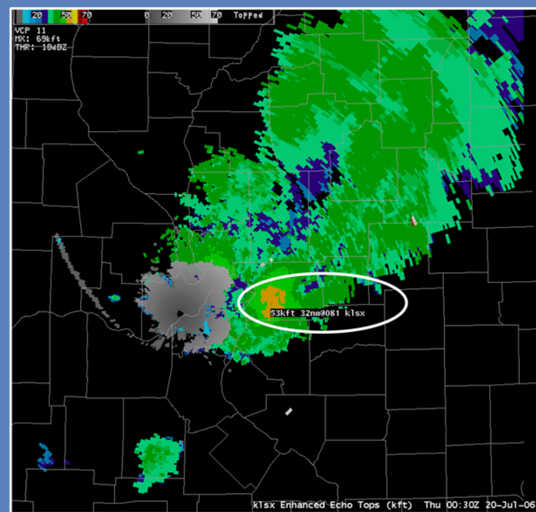
Far range too!



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.

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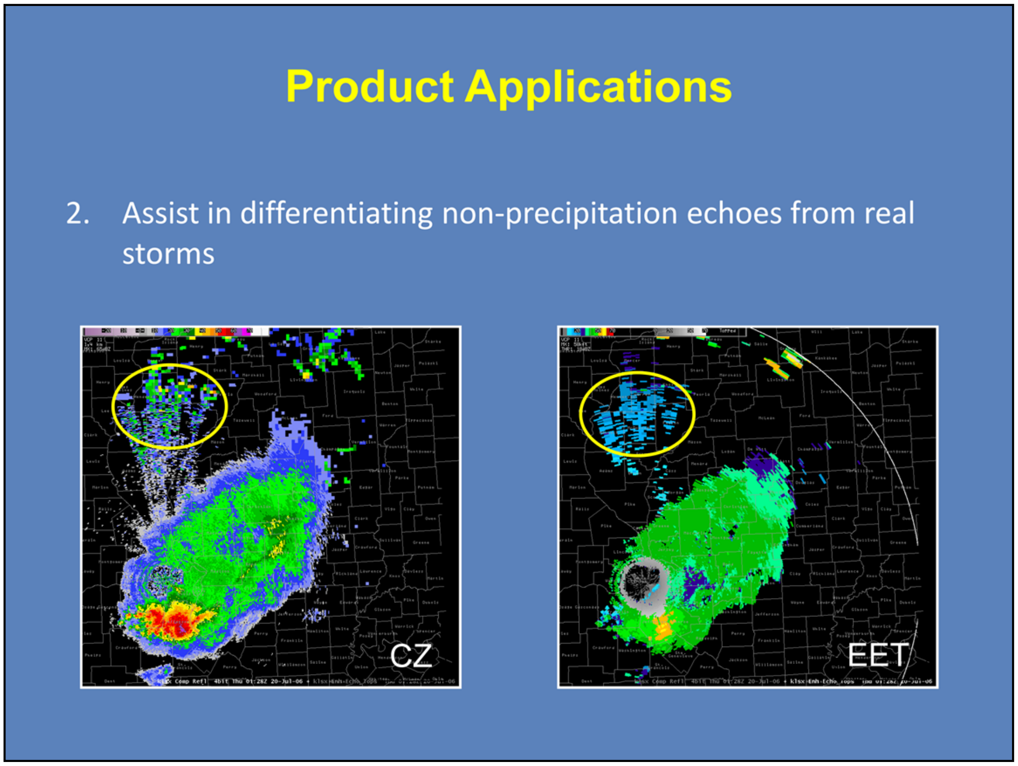

A second application is to assist in differentiating non-precipitation echoes from real storms. Recall that this application applies to many of the reflectivity derived products. In the example below, we have a lot of AP in the CZ product in the area to the north of the radar. Notice in the EET product 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.

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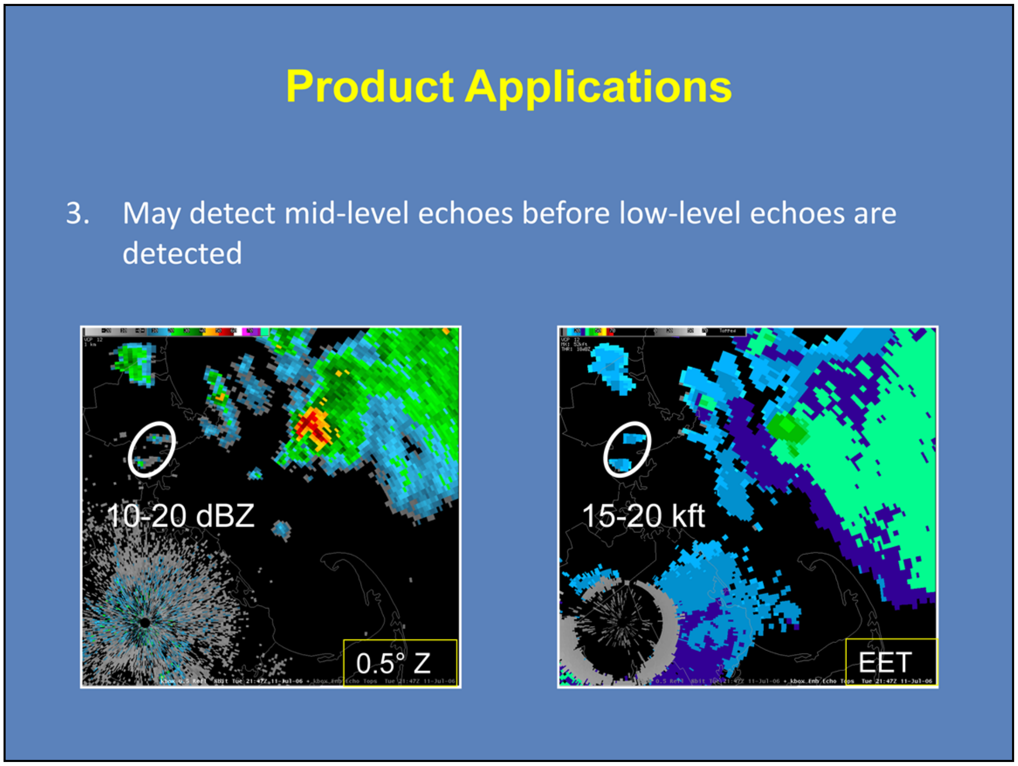
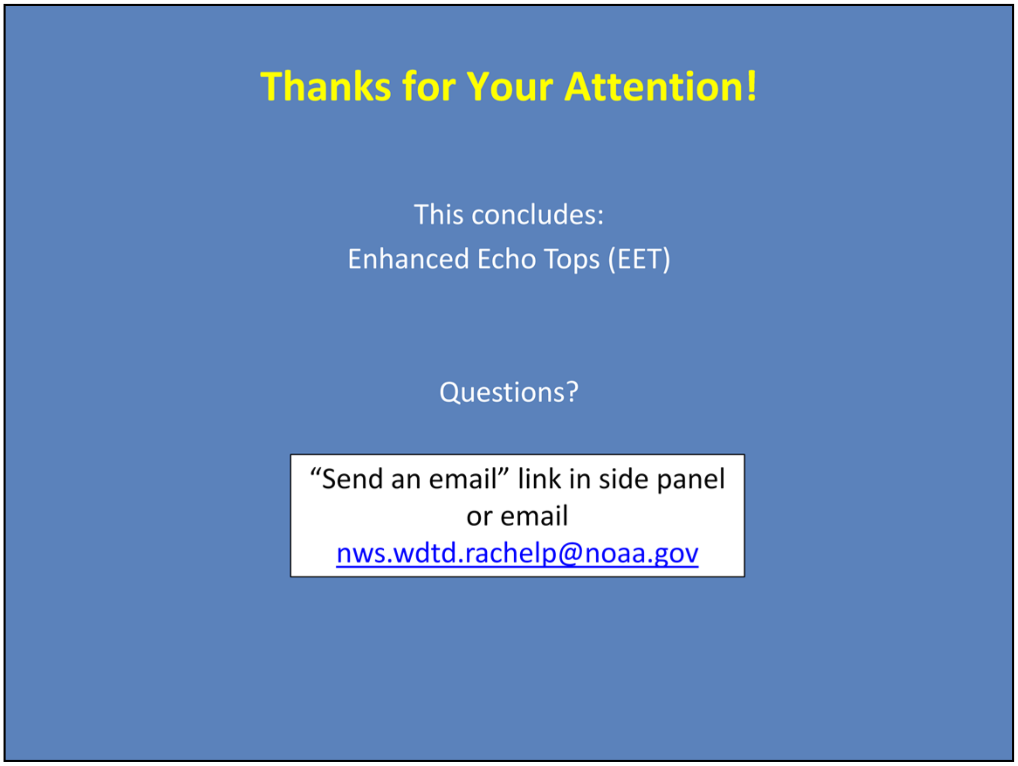


Finally, EET can be very useful in detecting mid-level echoes before low-level echoes are detected. In the example below, the 0.5 deg Z is shown on the left and the EET product is shown on the right. The two little blobs of reflectivity in the white circle eventually went on to be mini supercells. Notice 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.



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. See you in the next lesson!

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Welcome to the first lesson on velocity-derived products. This lesson will cover the Velocity Azimuth Display Wind Profile, or VWP.

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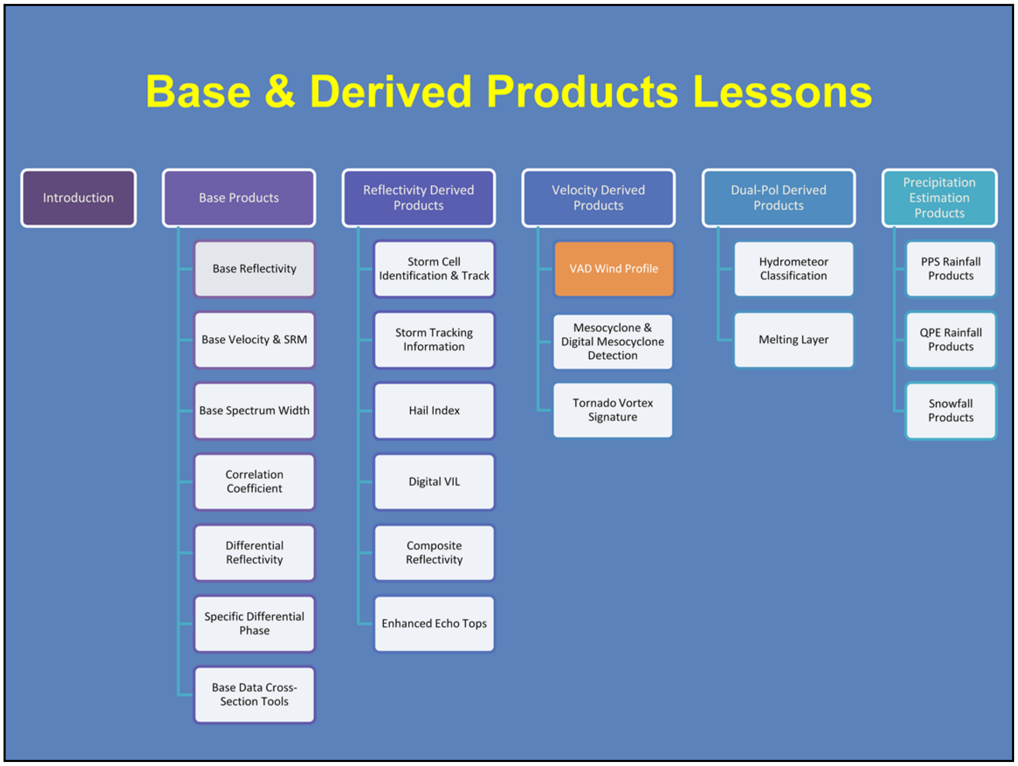
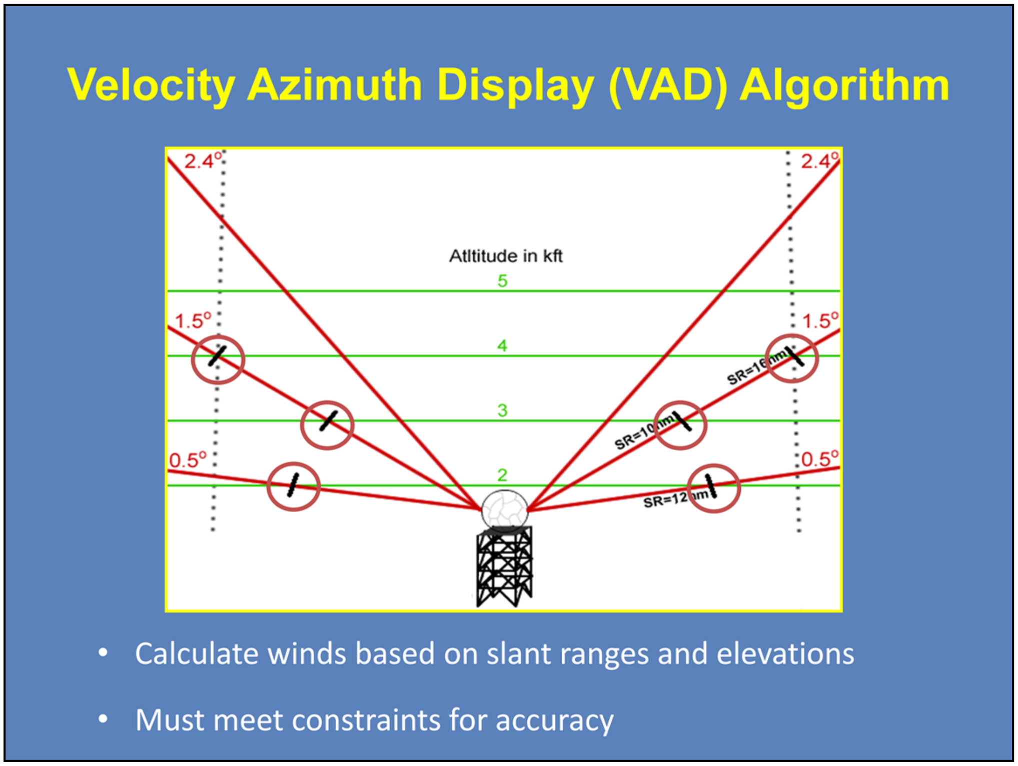


Here is a roadmap for the lessons in this topic. This lesson on the VWP profile, shaded in orange, is the first in the Velocity Derived Products Section of this topic.

Here are the learning objectives for this lesson. When you have read them, click next to start.



The VWP product is an output of the Velocity Azimuth Display (VAD) algorithm. So 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..

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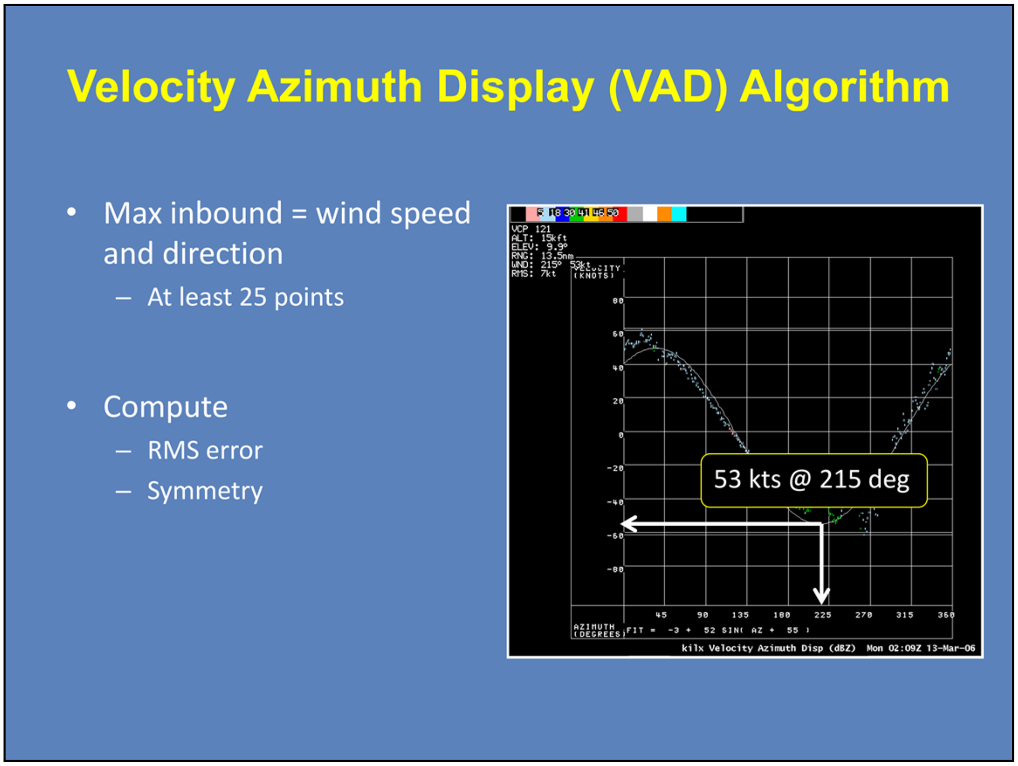

When all the points are plotted, it looks like this graph here. Notice that it looks like a sine wave, so the algorithm fits a sine wave to the plotted data. From the fitted sine wave, the maximum inbound velocity, or maximum negative velocity value, is recorded as the wind speed at that height. The 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, we 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 telling us the reliability of that estimated wind speed and direction.

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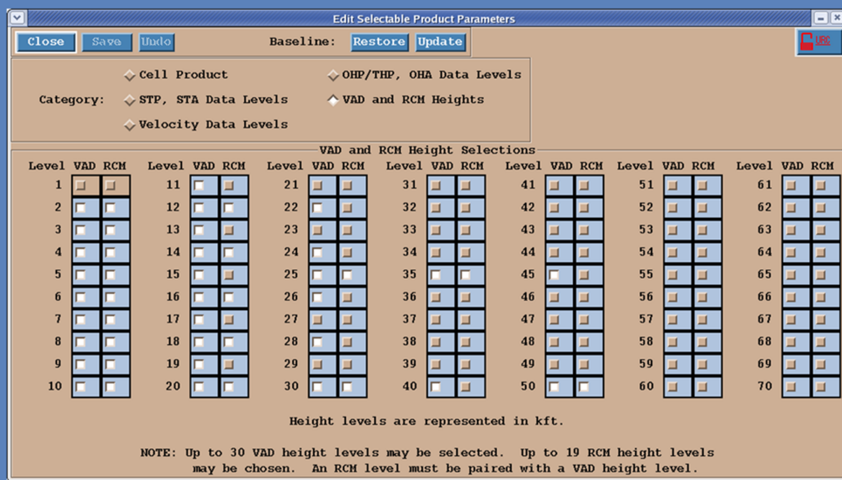
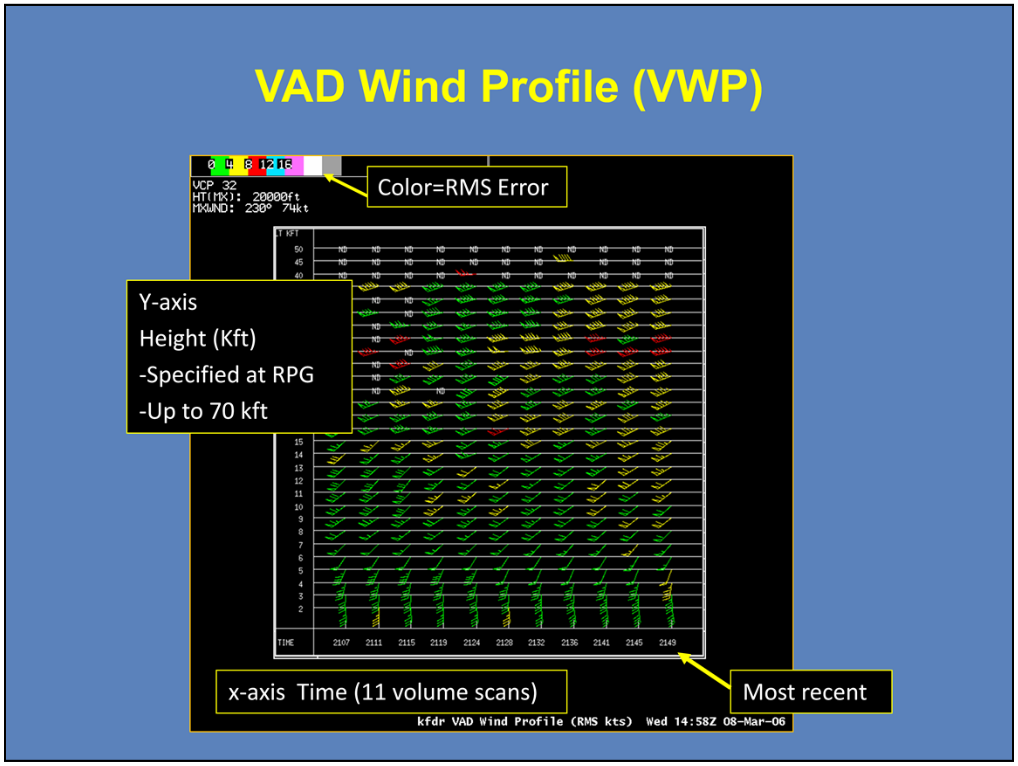
VAD Heights



See RAC Reference VLab page for more adaptable parameters

I'll let you explore the RPG at your leisure, but here is the RPG window where you can specify the heights that will be used to compute the VAD winds. You can select winds in 1,000 ft increments from 1 kft to 70 kft.



So, for each volume scan you can plot the wind at each height and construct a wind profile, which is the VAD Wind Profile product, or VWP. It's found in your local radar-derived products menu. The most recent profile is on the right and previous profiles are to the left. Time is on the x-axis and the heights requested are plotted on the y-axis in thousands of feet up to 70 kft. As shown in the previous slide, these heights are specified at the RPG. The color bar in the upper left corresponds to the color of the plotted winds and represents the RMS error. So, looking at this example, winds plotted in green have low RMS error, and winds plotted in red have high RMS error. Basically, this tells us the reliability of those plotted winds. You can trust the green plots, but you should be suspicious of the red winds, or at least check and make sure they can be verified.

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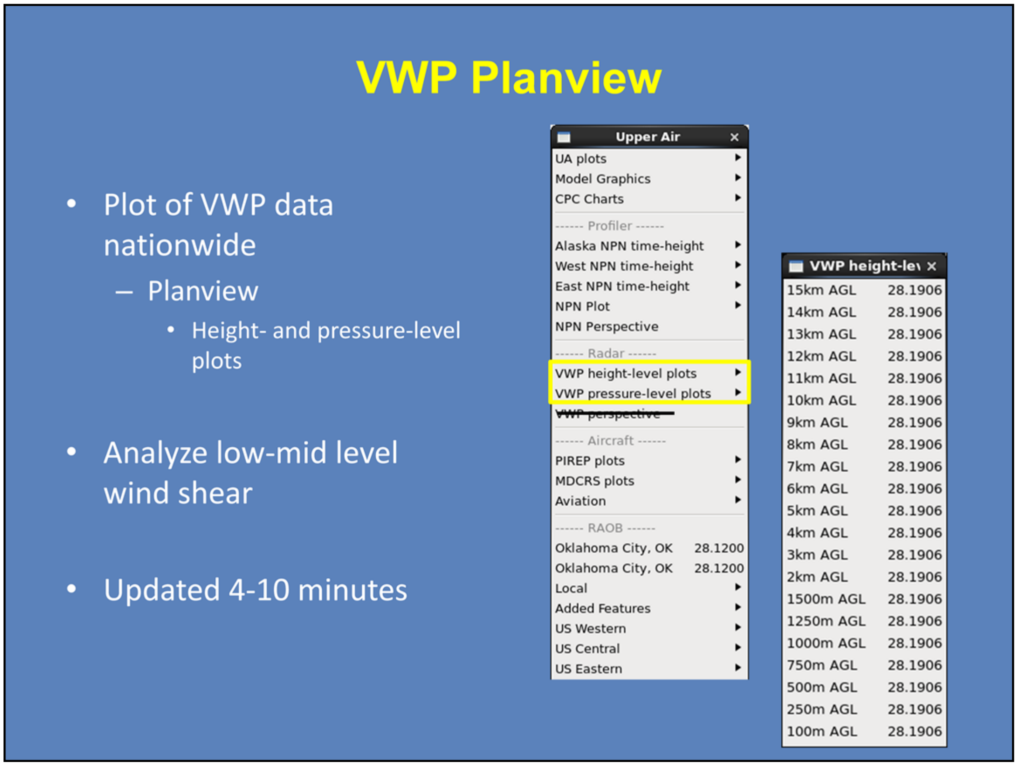

You can also plot the VWP winds on Plan views to get a spatial feel for the wind patterns when upper air plots from RAOBs are not available. You can find these plots in the Upper Air menu in CAVE as seen in the image. These winds are updated every 4-10 minutes, or whenever new volume scans are available.

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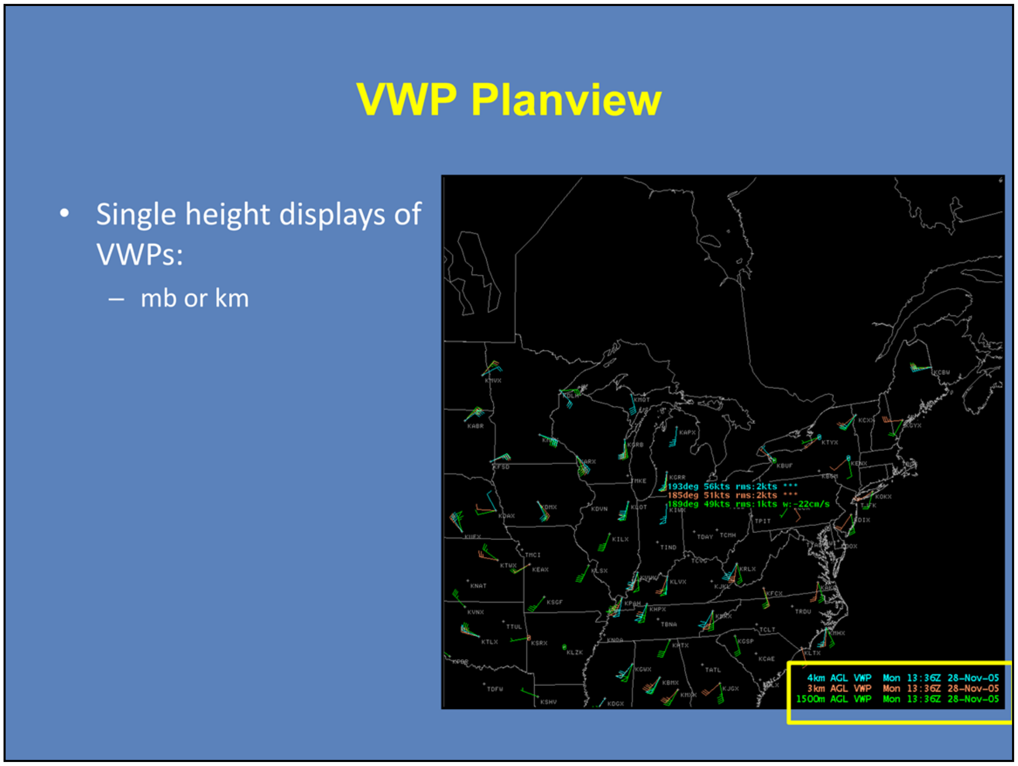

Here is an example of the Planview VWP product. Notice that you can plot not only one height, but multiple heights. This is great for getting a feel for the magnitude and direction of horizontal shear evolving throughout the day if you are anticipating severe weather. Obviously, the plots are dependent upon the availability of data to plot these wind speeds.

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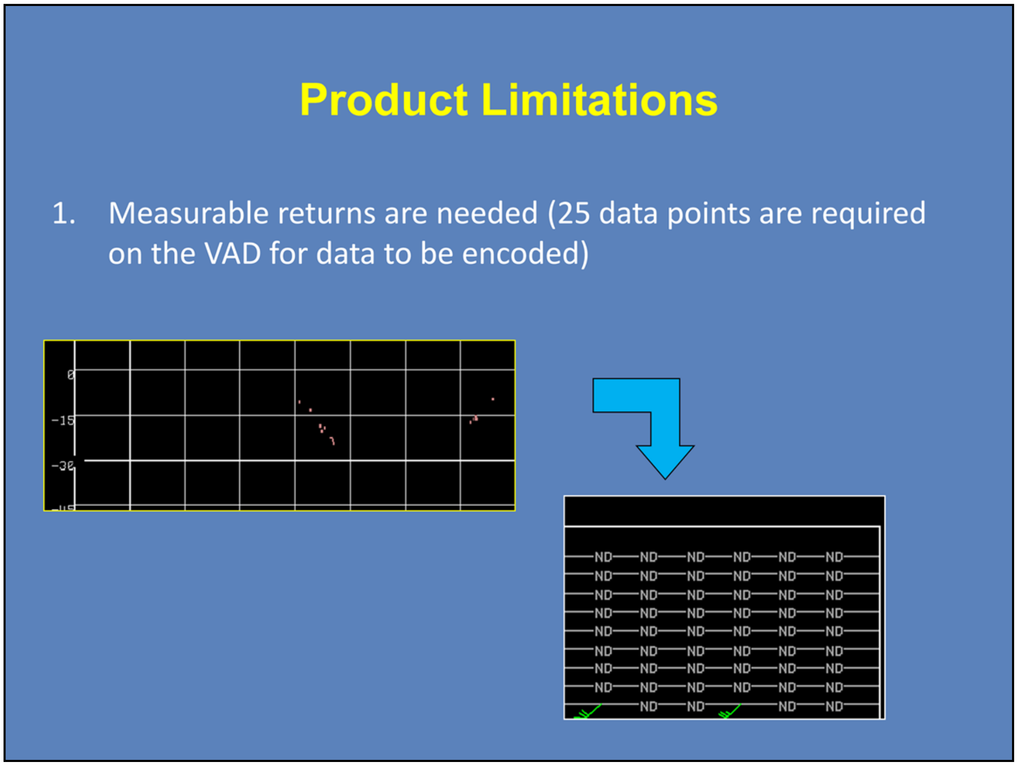

Now let’s discuss the limitations of the VAD wind profile, we have to keep in mind the limitations of the VAD algorithm because that is what the product is based on. The first limitation is we need at least 25 points to produce a wind from the VAD algorithm to be plotted in the VWP. Here is an example of what happens when there are not enough data points. Since there are not enough points, it doesn’t try to fit a sine curve and therefore it sends nothing to the VWP, and you’ll see “ND” plotted where this occurs.

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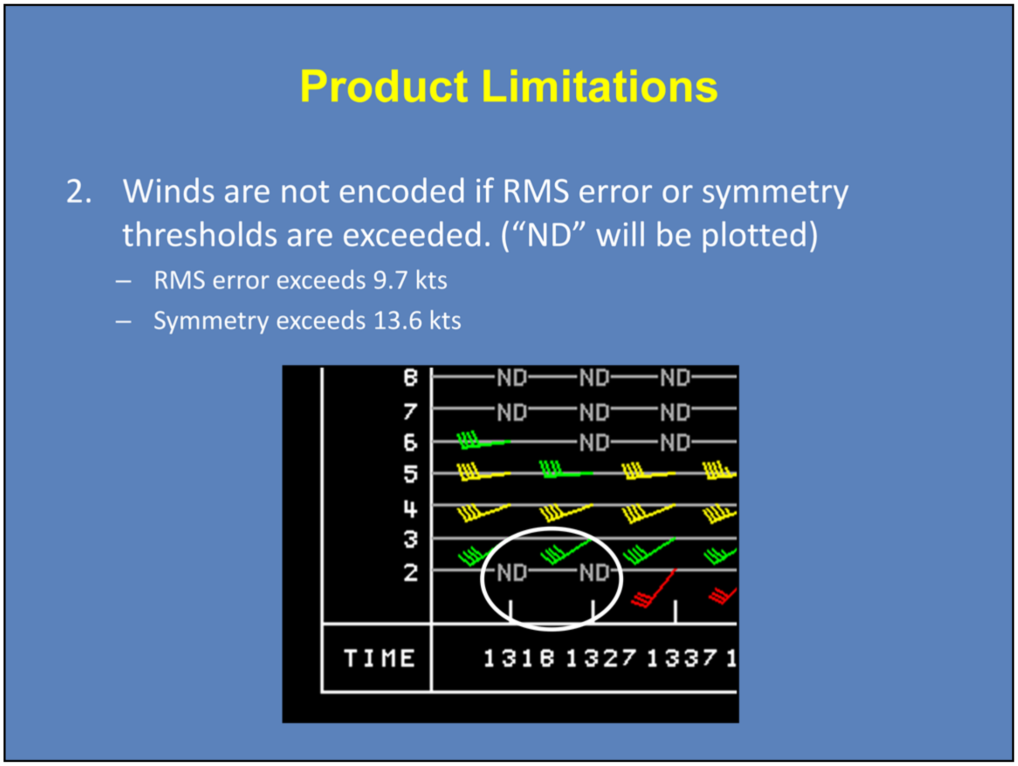
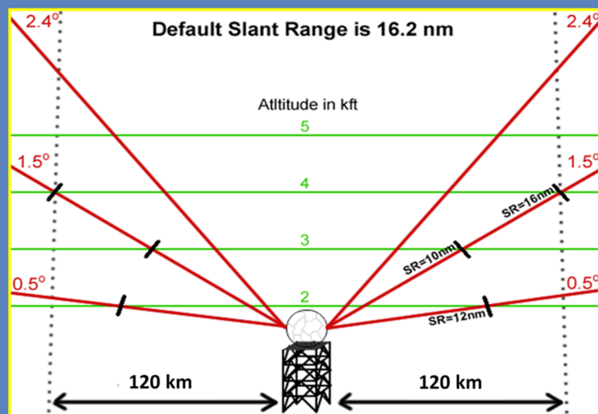


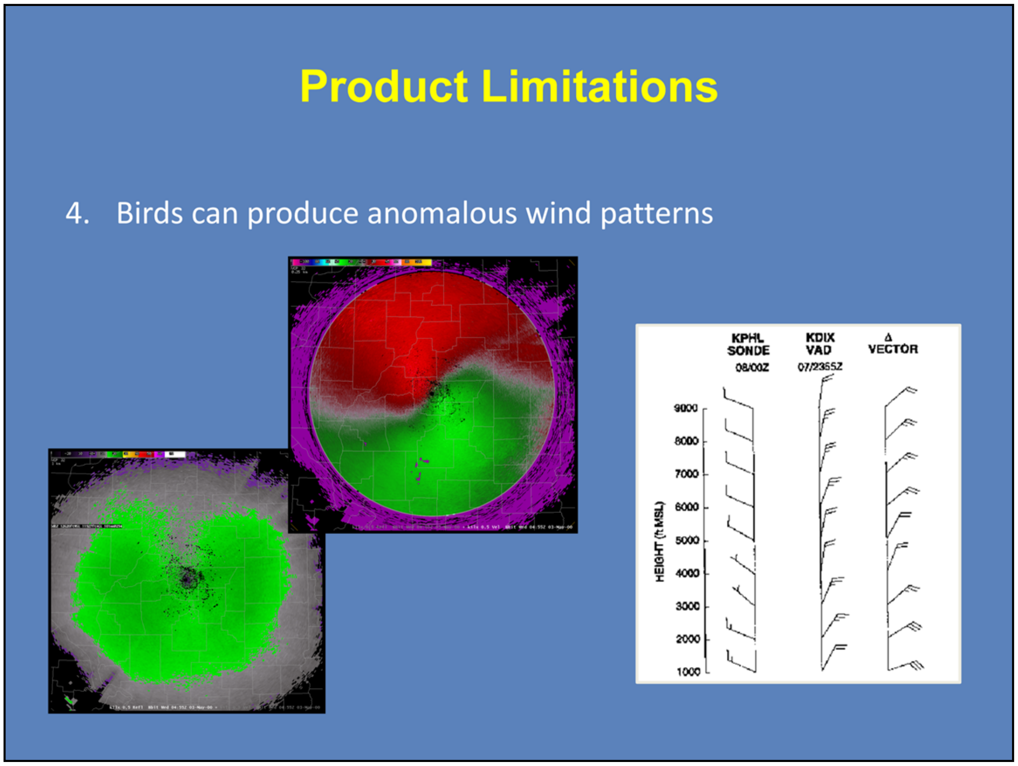
There is also another way ND is plotted, and that has to do with our second limitation. Winds will not be plotted if the RMS error or symmetry thresholds are exceeded. And, those values are 9.7 knots for RMS error, which is a measure of how well the plots fit the sine curve and 13.6 knots for symmetry, which is the measure of how homogeneous the wind flow is around the radar. So, if either of these thresholds are exceeded, then ND will be plotted as well.

Product Limitations

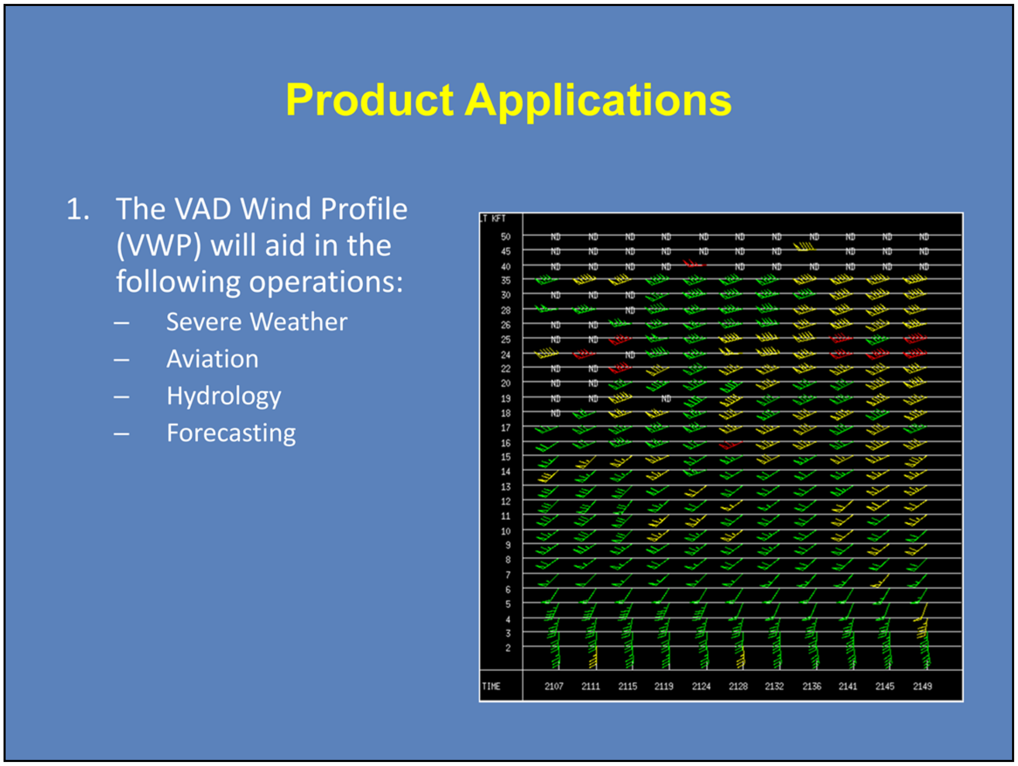
3. Generally representative of winds within 120 km of the RDA



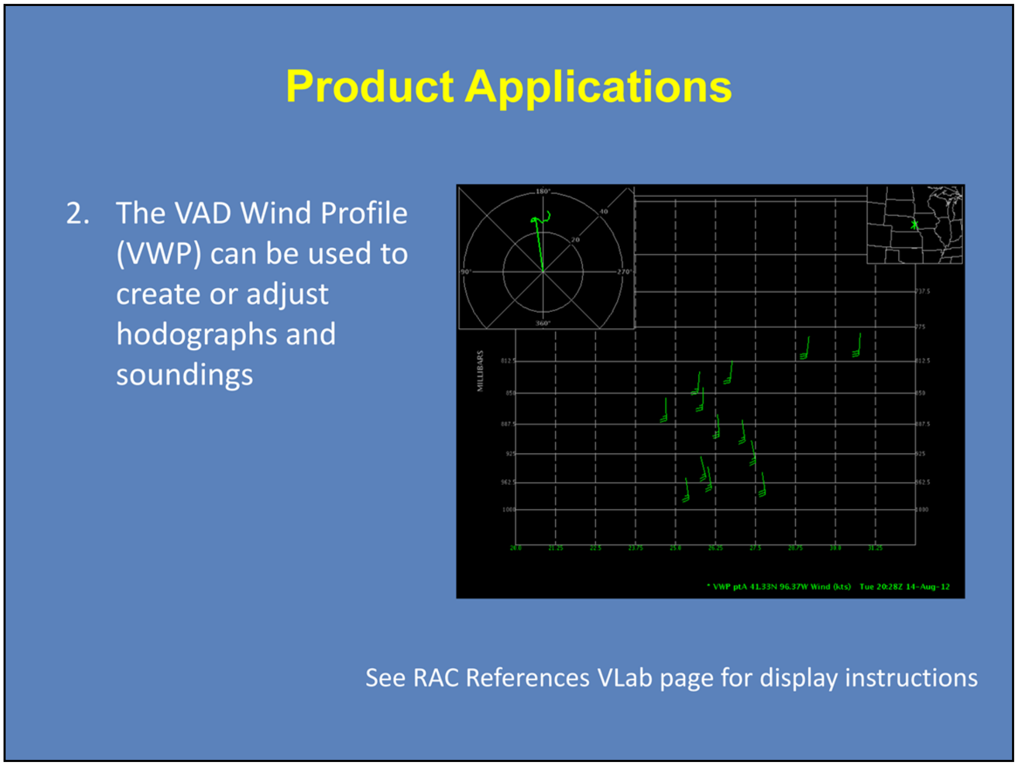
Our third limitation we have to keep in mind that the VAD winds plotted on the VWP are only generally representative of the winds within 120 km of the radar, because that's the limit of the slant range calculations. If you've got storms developing 150 km from the radar, you will want to use other sources of data to assess the wind profile in that area.



This is another limitation that ties back to the VAD algorithm. 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. So, be mindful of this if you are in the path of migrating birds.



The VWP product is useful in the severe weather, aviation, and hydrology sectors and forecasting in general. Obviously 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 animate and see that. That can help you decide what type of precip you are going to anticipate, either freezing rain, rain or snow.



The VWP can also be used to update hodographs for times in between upper air soundings.

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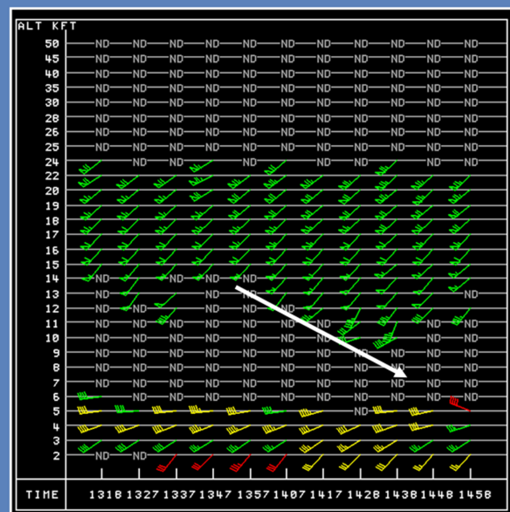
Applications (Strengths)

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. You can see that noted by the white arrow in the graphic. This is what virga descending will look like. 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 if you are trying to get a good track on a balloon as it's released.

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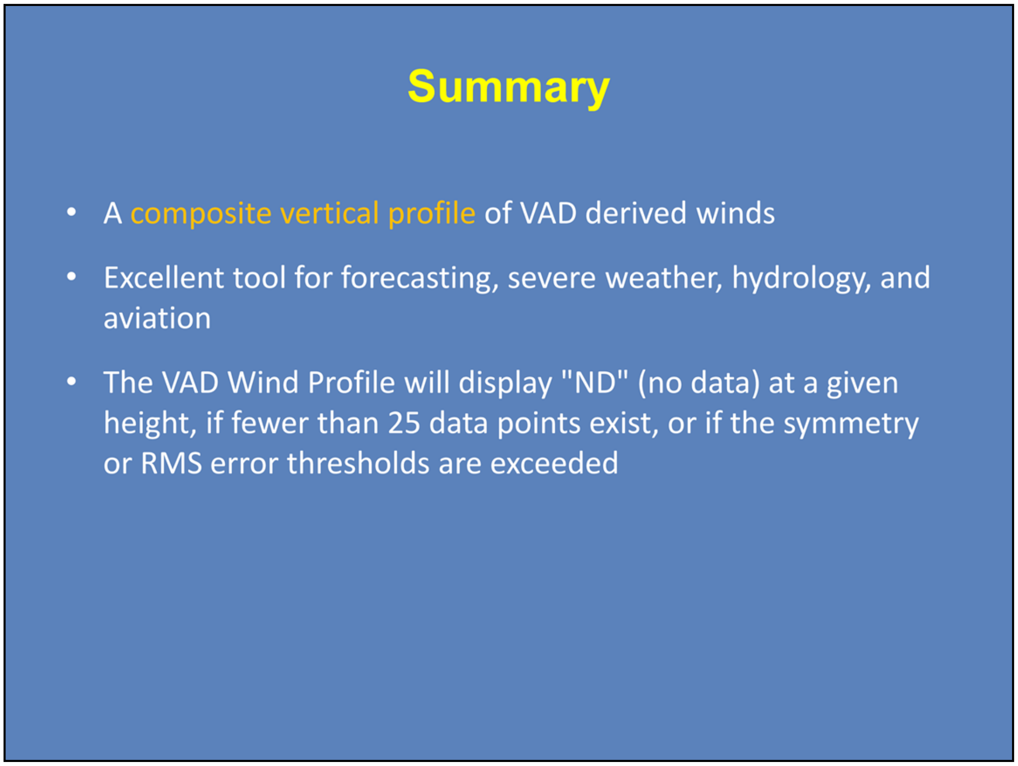
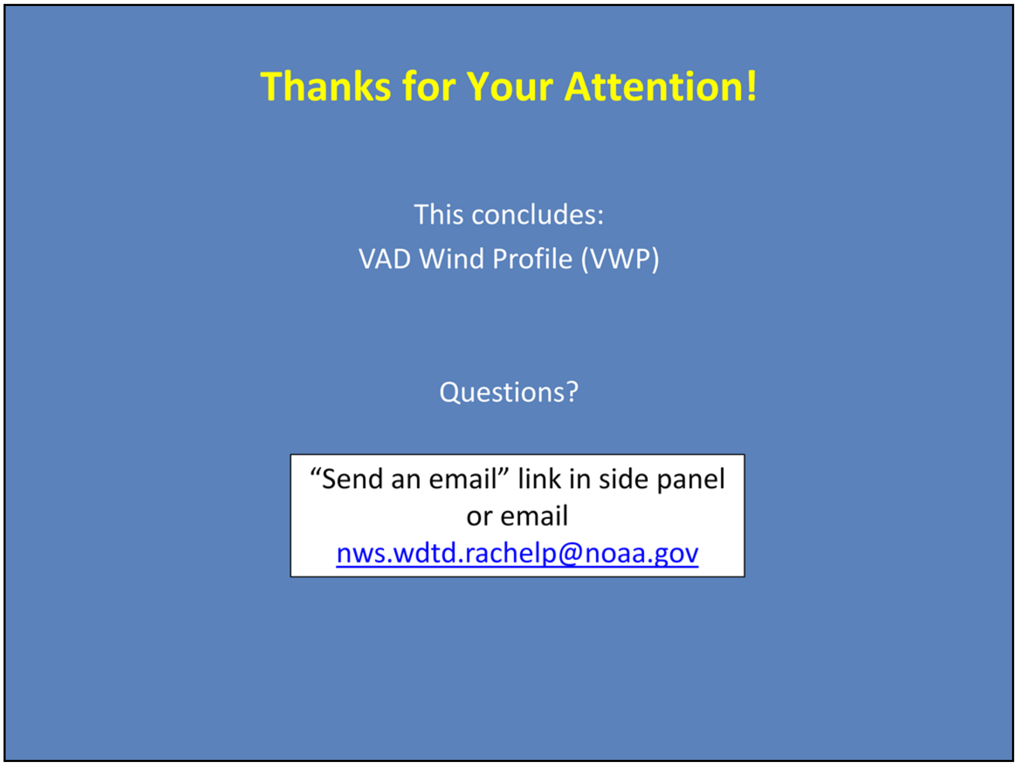


In summary, the VWP is a composite vertical profile of the VAD derived winds. It's a great tool for forecasting, severe weather, hydrology and aviation. The VWP will display ND at heights where there are fewer than 25 data points for the VAD algorithm or if symmetry or RMS error thresholds are exceeded. The next slide will be a short quiz on this lesson.



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.

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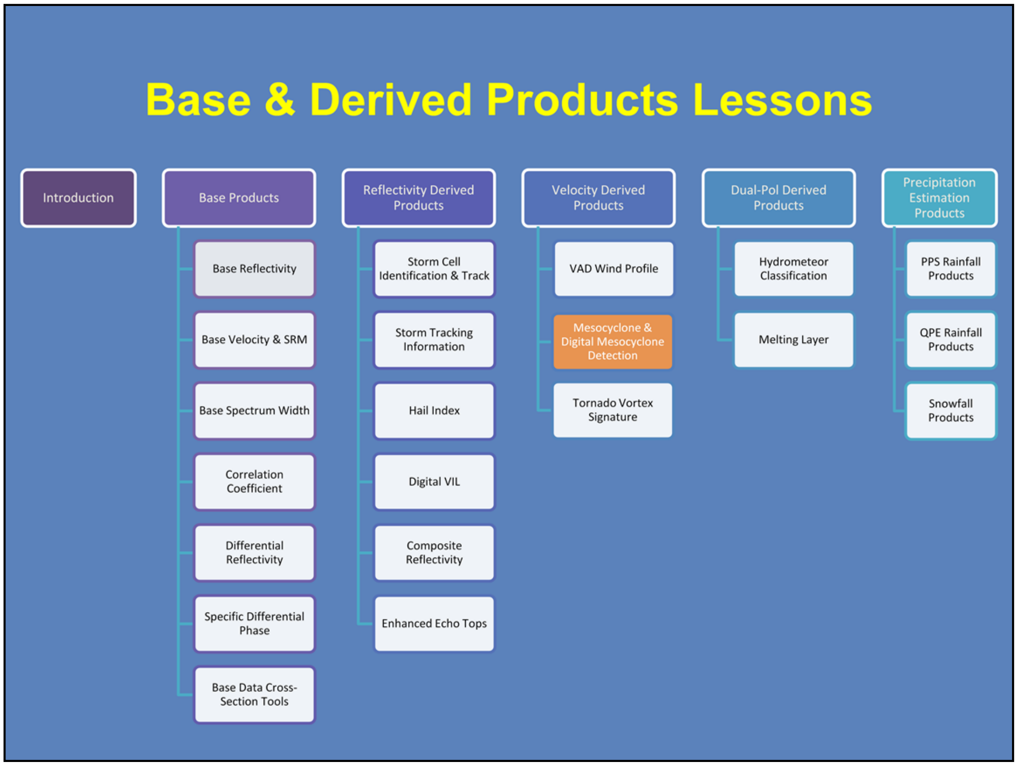

Here is a roadmap for the lessons in this topic. This lesson on the Mesocyclone (MD) & Digital Mesocyclone (DMD) products, shaded in orange, is the second in the Velocity Derived Products Section of this topic.

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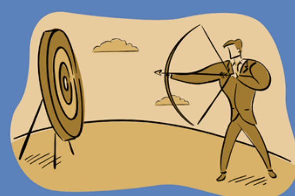
Learning Objectives

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.

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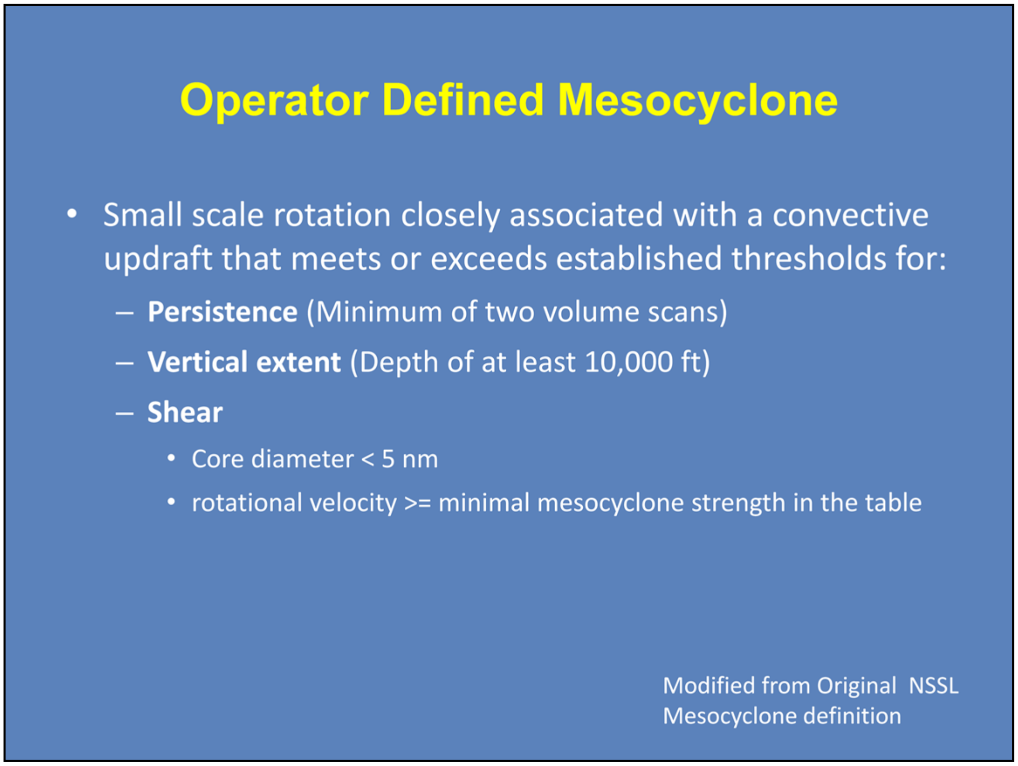

Let's make a distinction real quick between what you as an operator would define as a mesocyclone versus what the algorithm will define as a mesocyclone. This definition comes from the original work done by NSSL done back in the 70s and 80s. An operator defined mesocyclone is defined as a small-scale 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.

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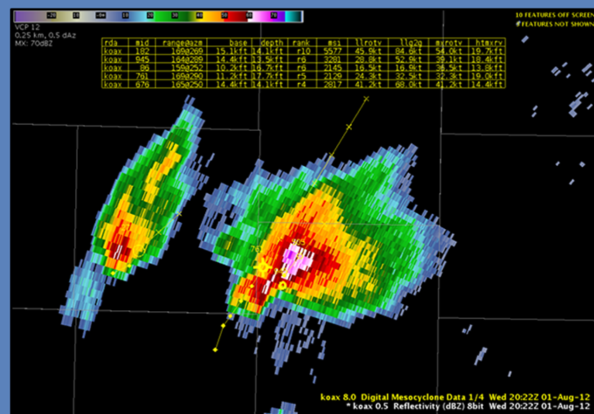
Mesocyclone Detection Algorithm (MDA)

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 mesocylone. 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.

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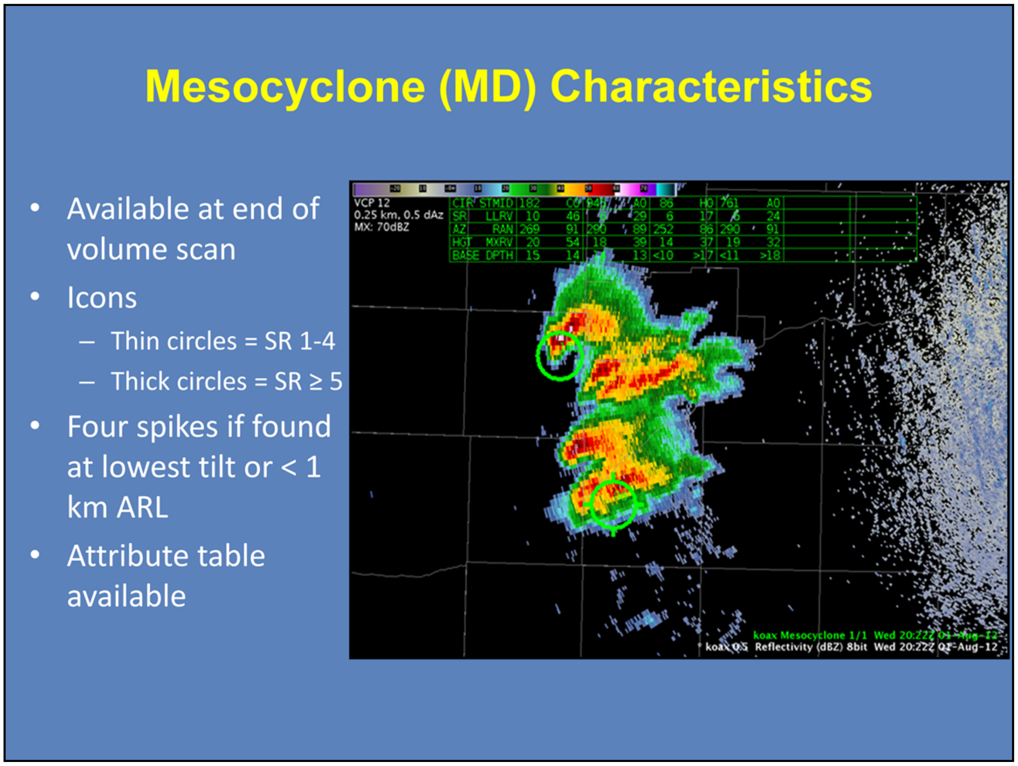

Enough about the algorithm. Now, let’s get to the products. First, we’ll talk about some of the characteristics of the mesocylone detection product. It is available at the end of a volume scan and you’ll see a few different icons with it. You’ll see thin circles if the strength rank is 1 to 4, and thick 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.

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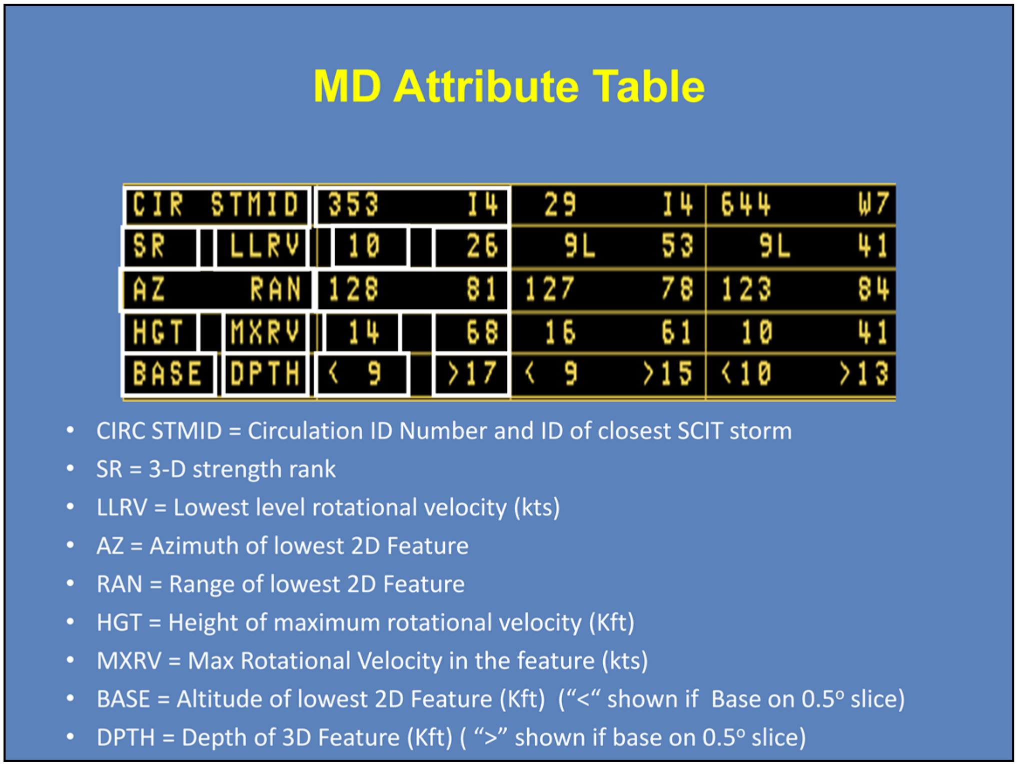
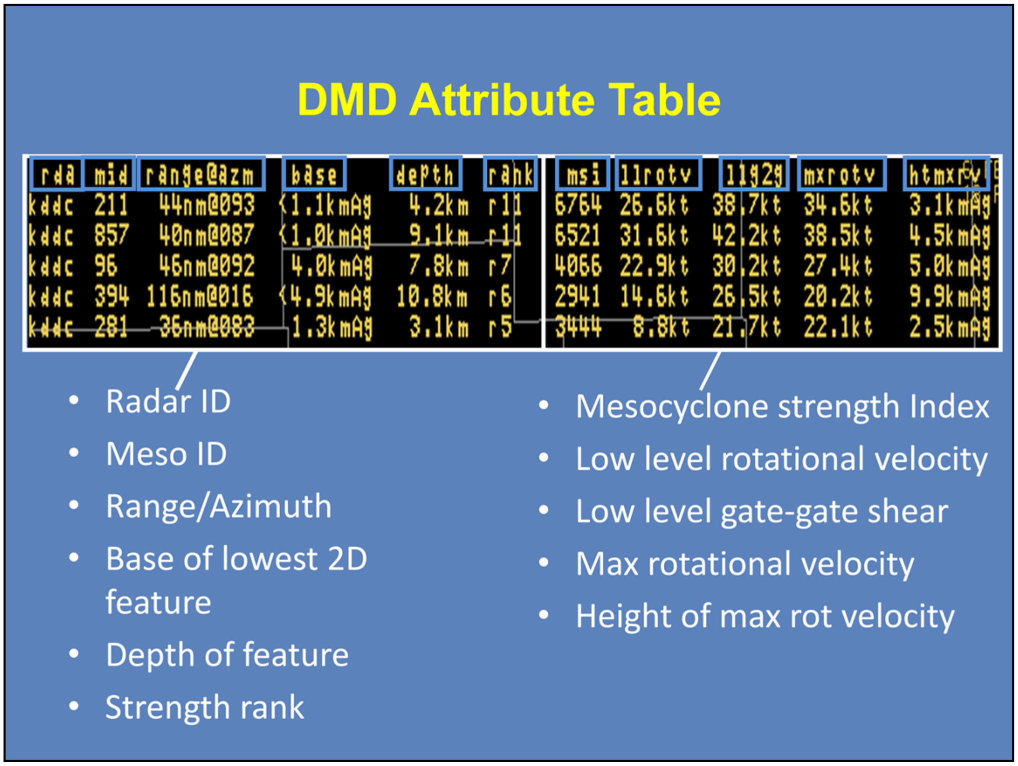


Let’s take a moment to go through the MD attribute table. First you’ll have a circulation identification number and this is an individual mesocyclone identification number, in this case 353. Next to that is the ID of the closest identified storm output by SCIT. Next, you have a strength rank, and it’s 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 depicited.

Digital MD (DMD) Characteristics

- Updated every elevation slice
  - Includes extrapolated features
- 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 is going to give you a little more information and done a little bit differently. First, it is updated every elevation slice. They wanted to give you some intermediate output instead of always having to wait until the end of the volume scan. Therefore, this product will have extrapolated features which appear as broken circles on the display. And 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. And, cursor readout has a lot of the attributes available. For more details on these characteristics, see the RAC References VLab page for this lesson.



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.

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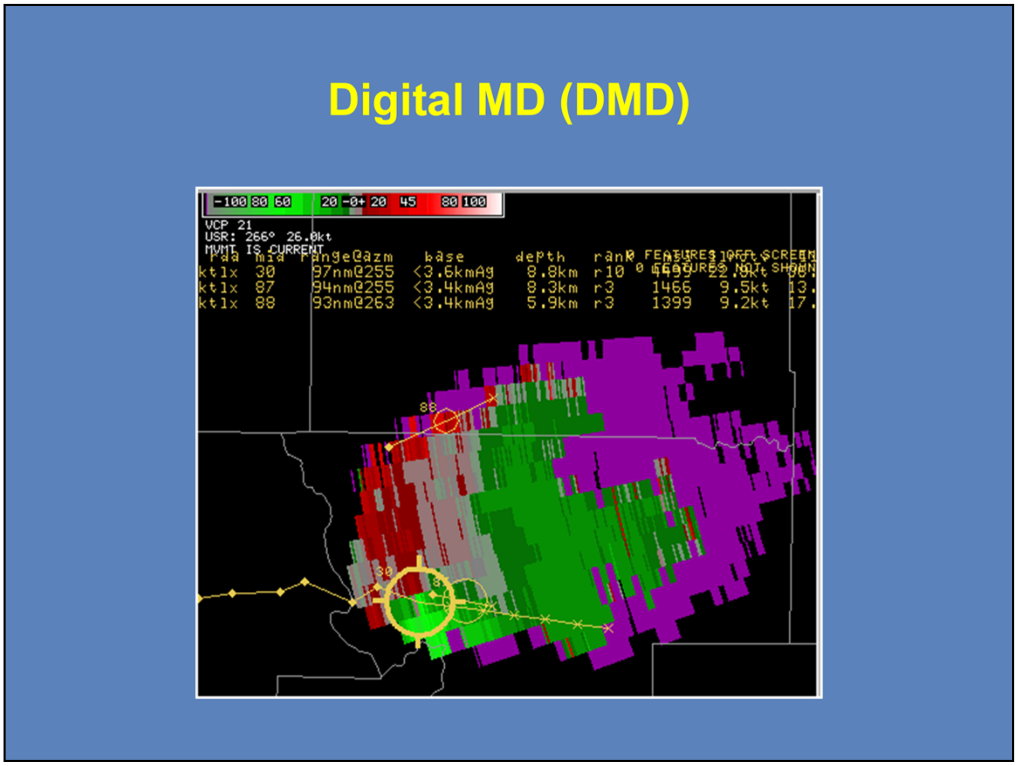
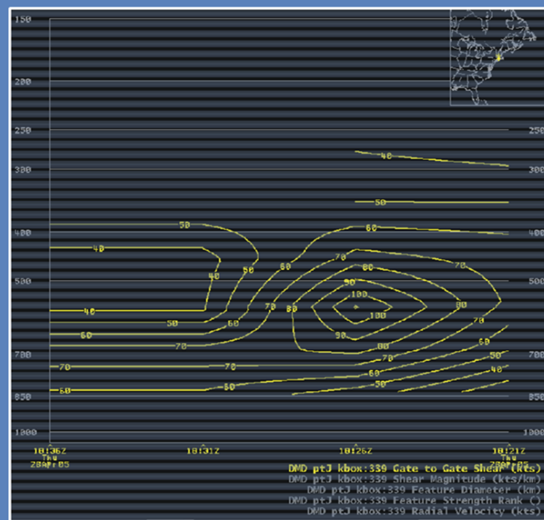


This is what the DMD product looks like and we have overlaid on top of a base velocity image.

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.

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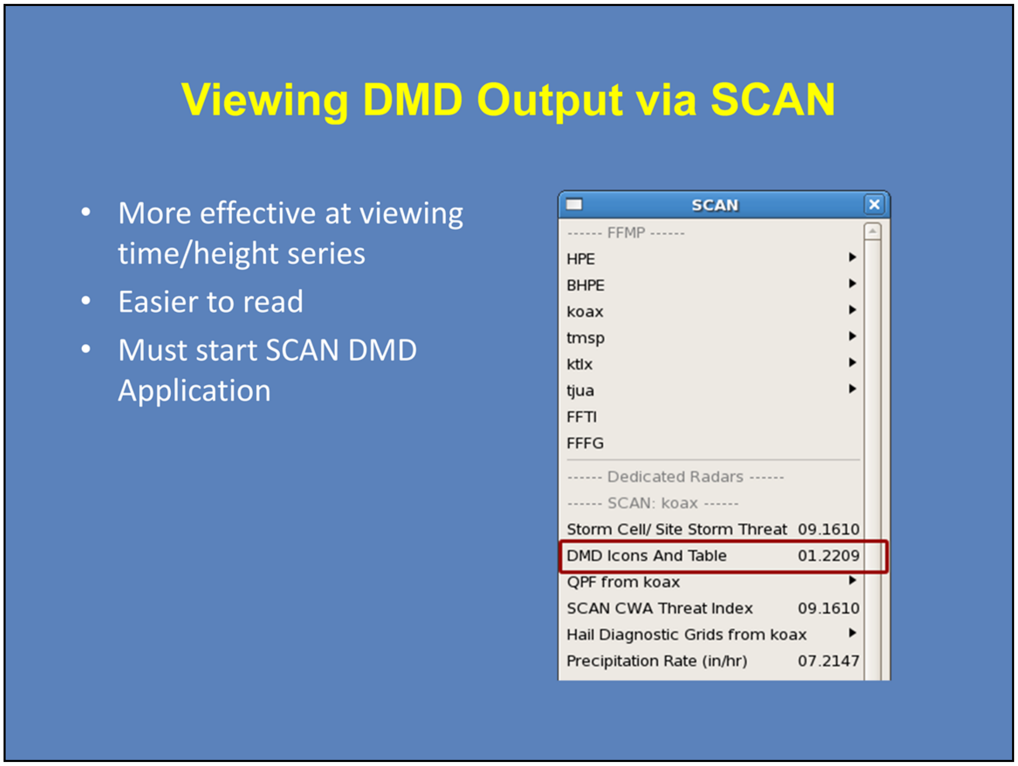

Using the volume browser time-height option can be cumbersome. Another option you have is the DMD Icons and Table via the SCAN menu. This is a more effective way of viewing the time-height series and is easier to read. It does require you to start the SCAN application at your workstation.

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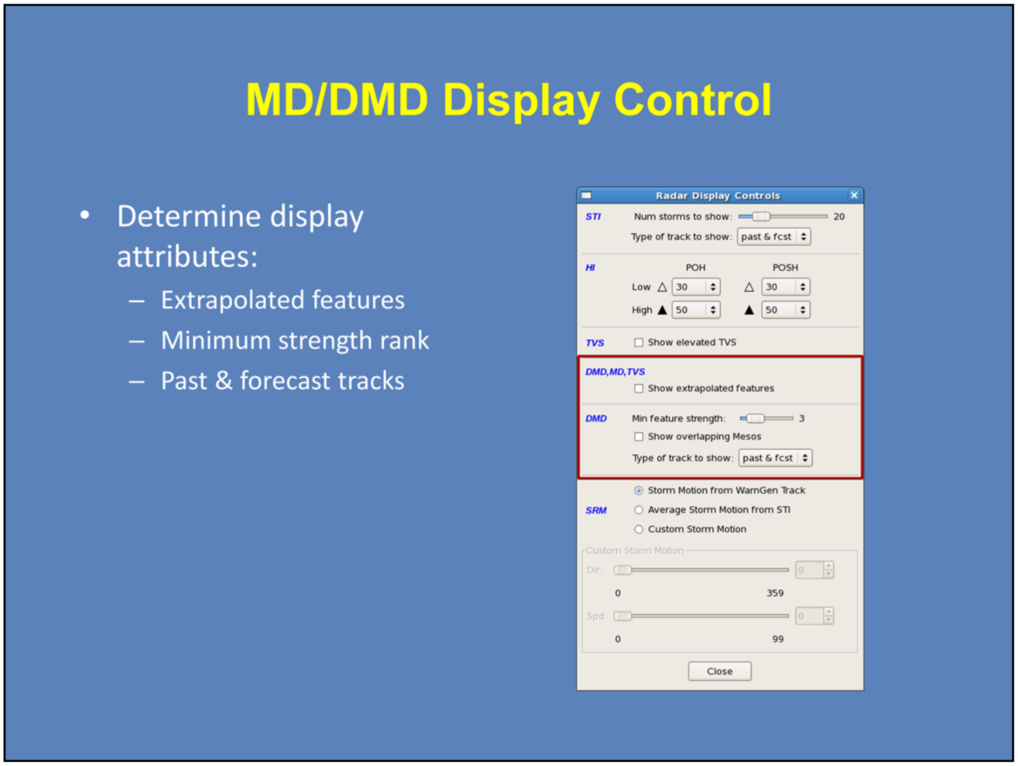
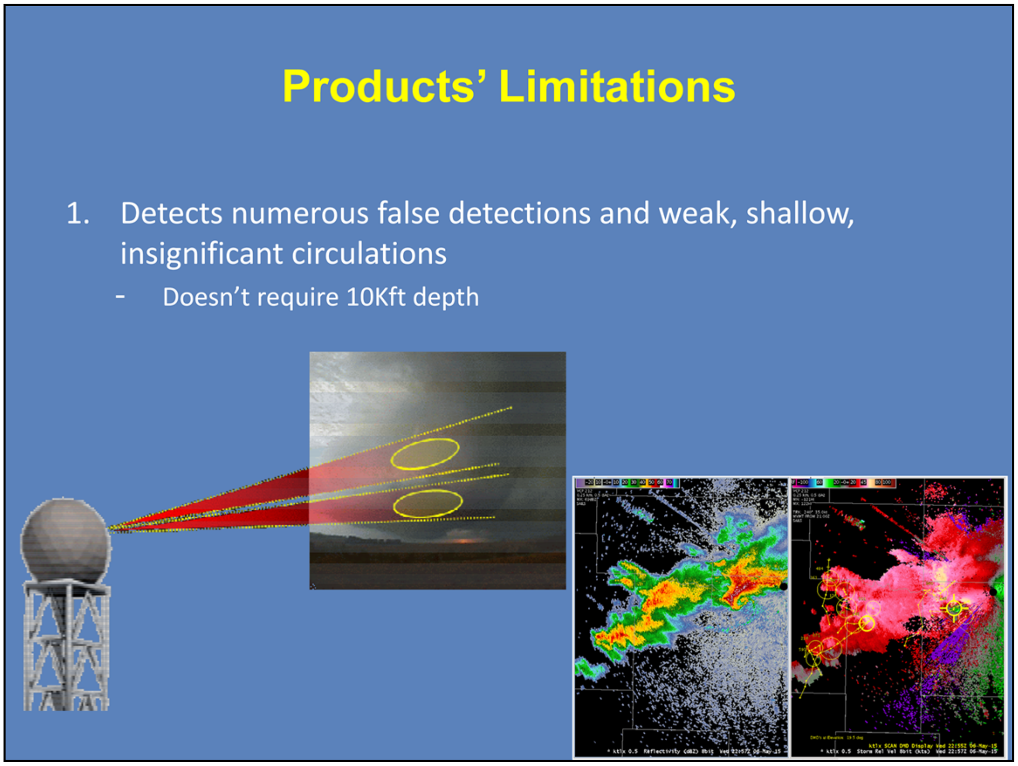


As with many other algorithms, you can affect how the DMD data are displayed at your workstation by using the radar display controls sub menu that you are familiar with already. Here you can decide if you want to see extrapolated features. You can also decide what DMD features to see, what strength rank to filter, and whether to see past or forecast positions.



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.

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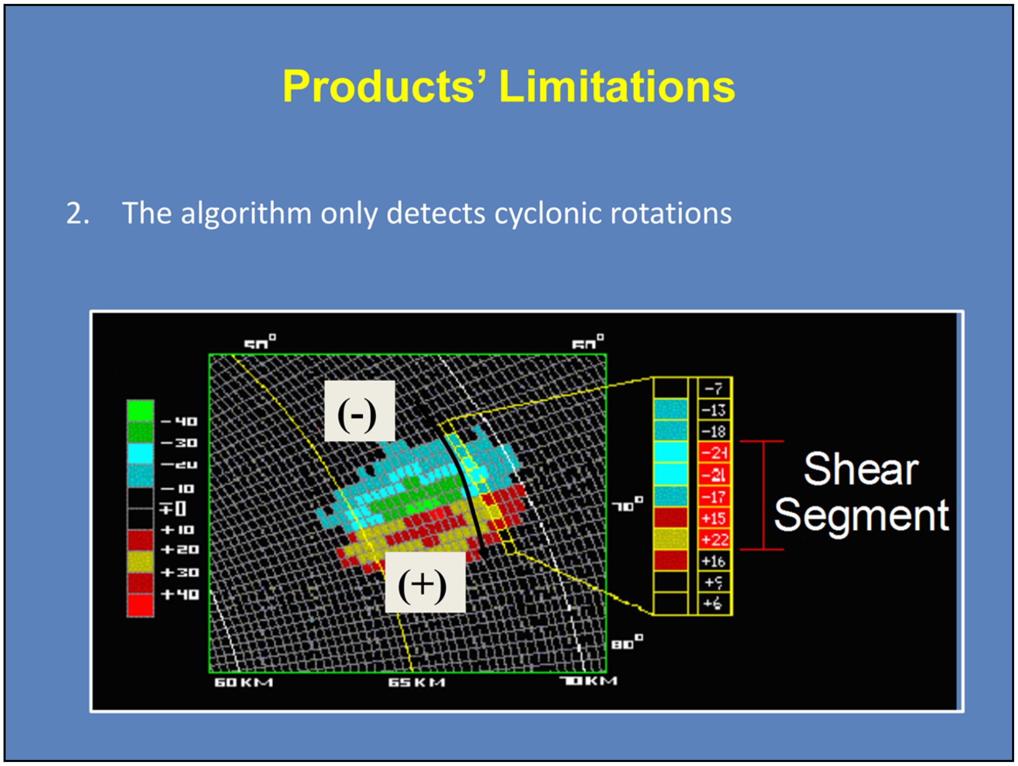
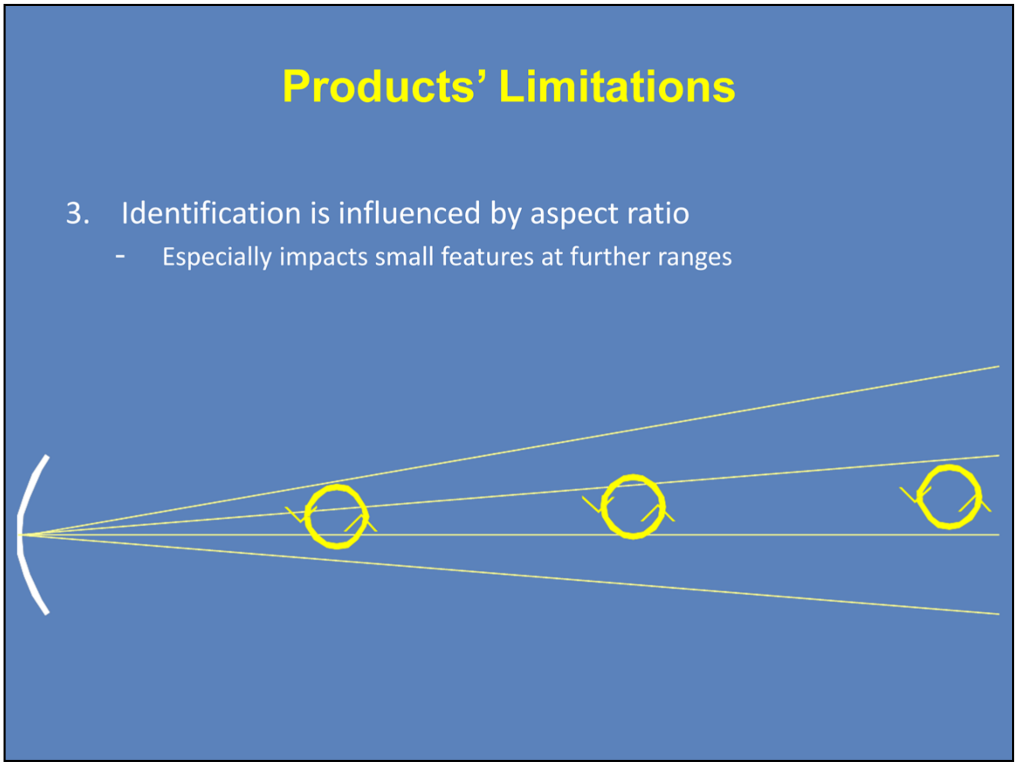


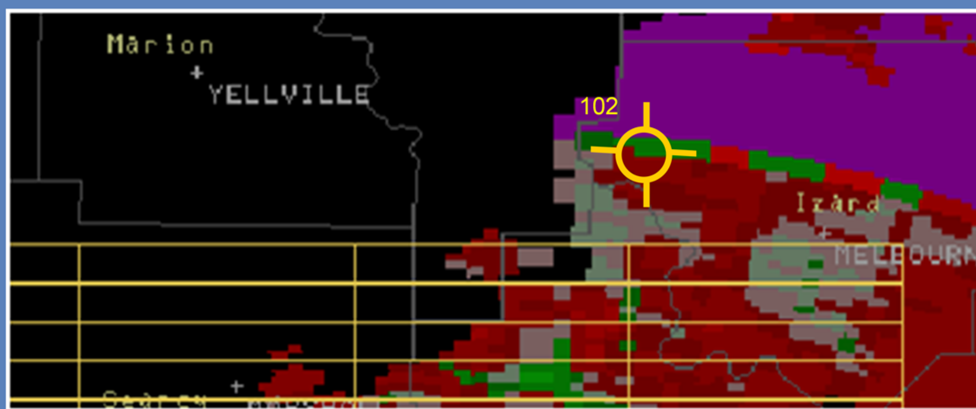
Because we are searching for increasing velocities as the radar rotates clockwise, we are only searching for cyclonic rotations. We are not able to detect anticyclonic rotations.



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.

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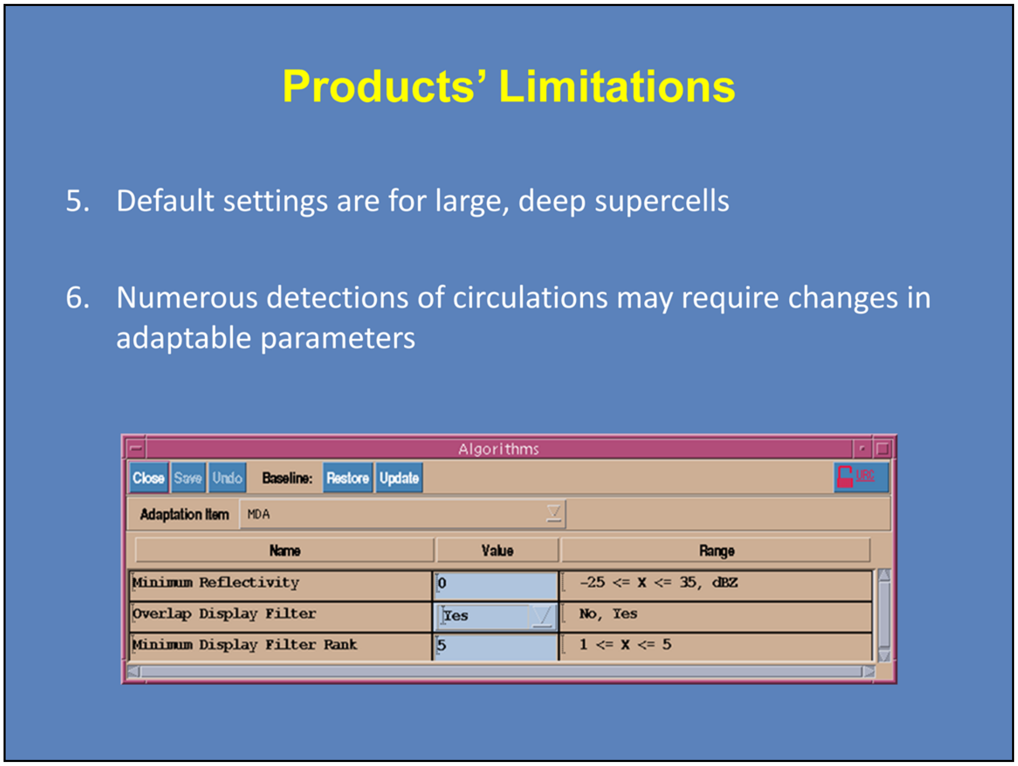

Limitations 5 and 6 have something to do with the adaptable parameters for the algorithm. First, the default setting is for large, deep supercells and this is fine if that's what you have, but it may not be fine on other occasions. If you get a lot of detections, you may need to tweak these parameters 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.

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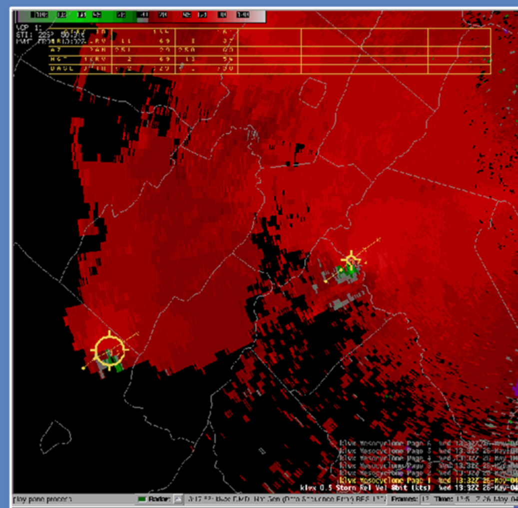
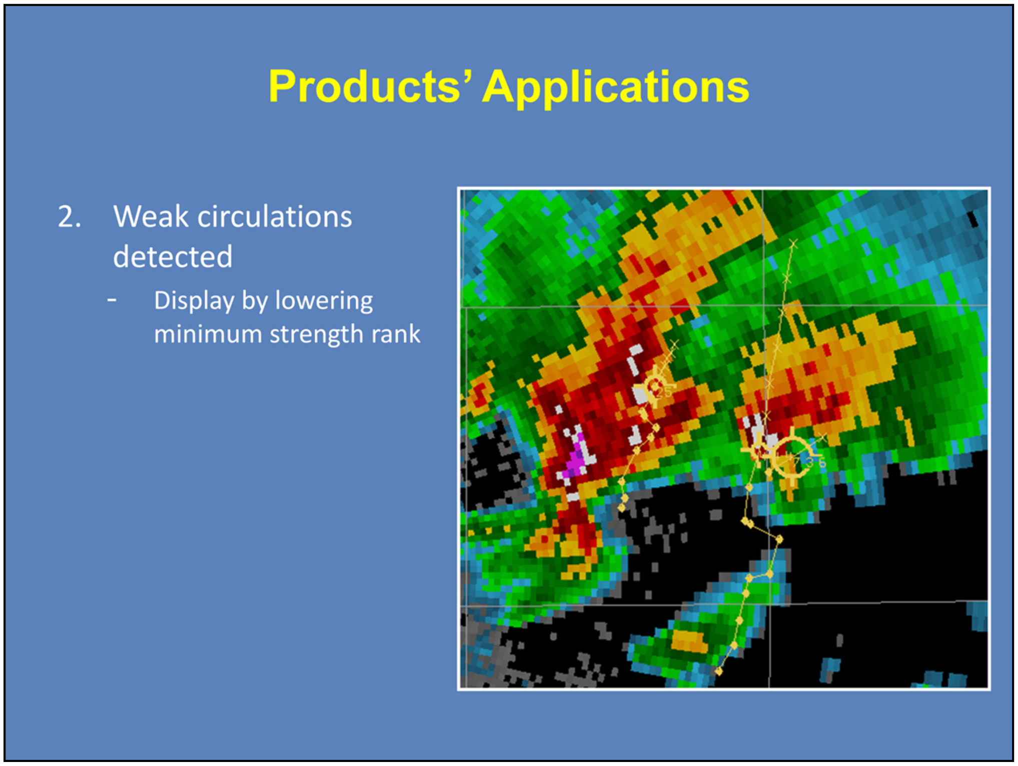
Products' Applications

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.



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.

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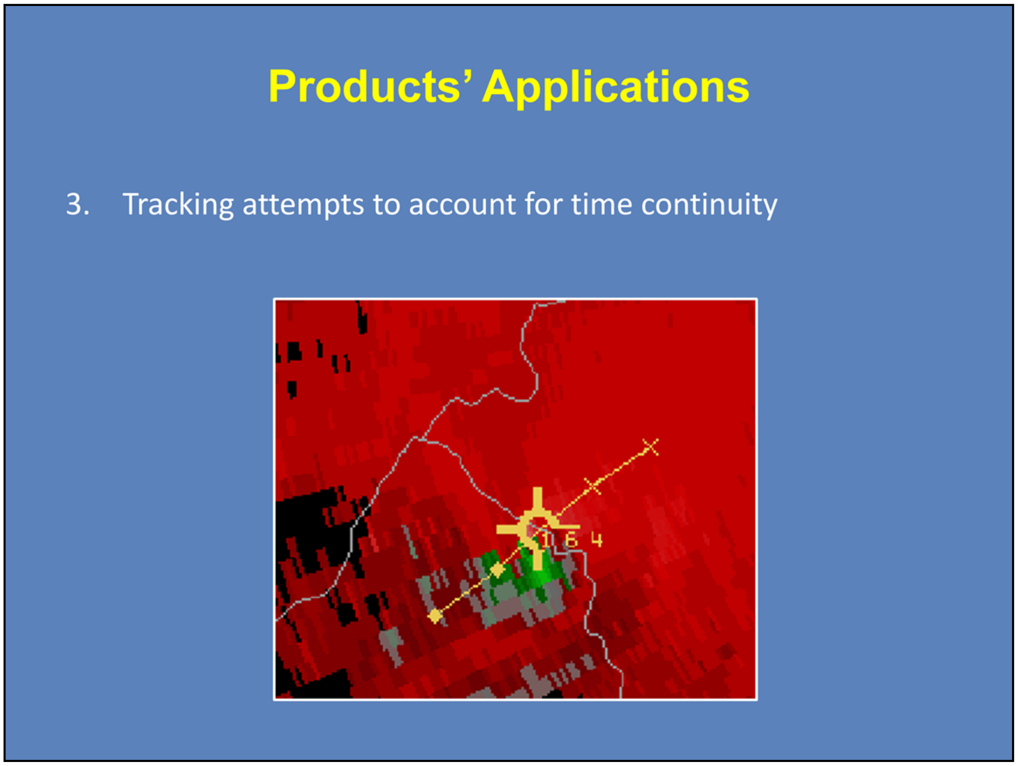
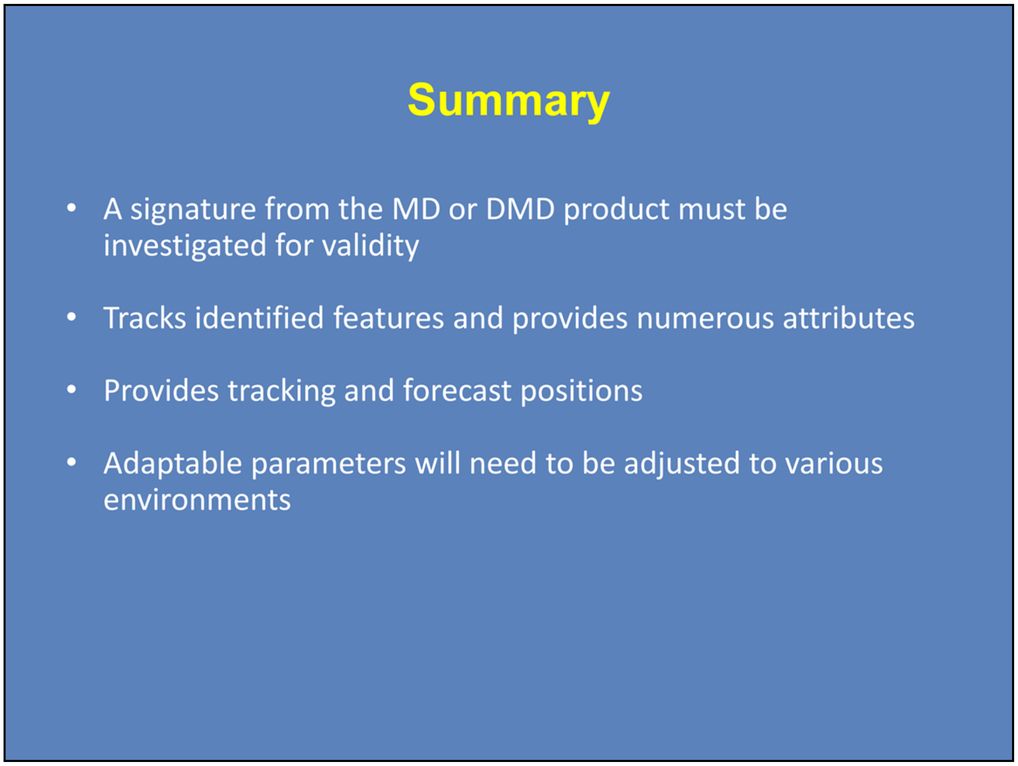


This product does attempt to give you time continuity by showing you the past and forecast positions.



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.

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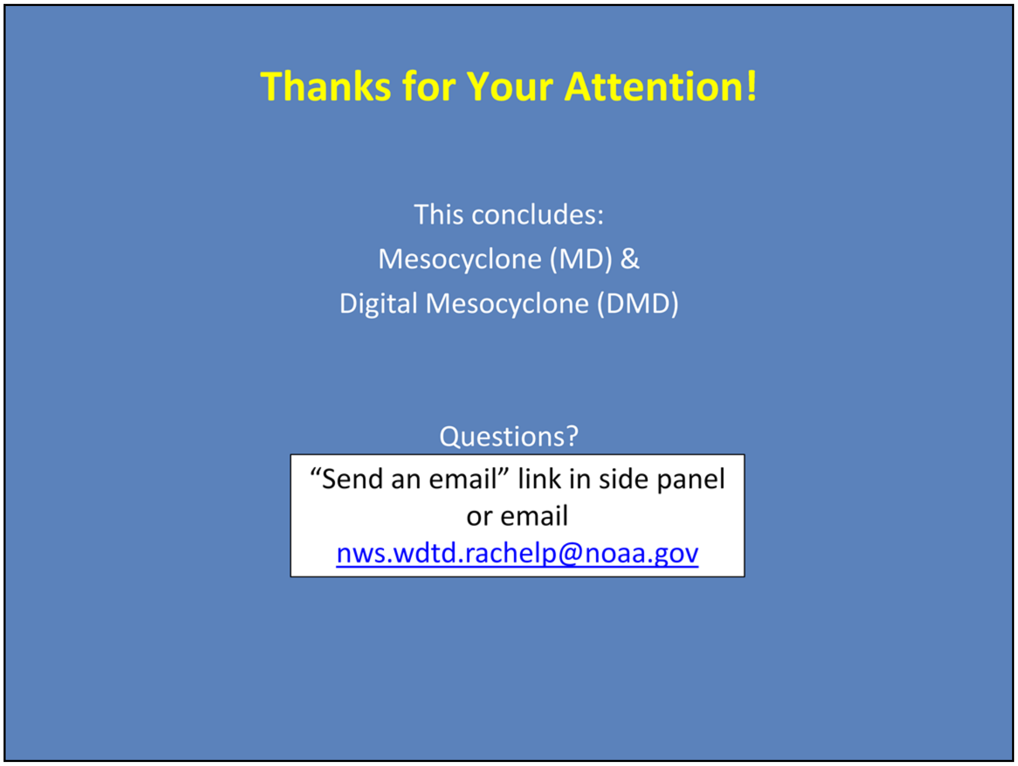

This concludes the lesson on the MD/DMD products. You can now move onto the next lesson on the Tornado Vortex Signature. If you have any questions, feel free to email the contacts listed below.

Welcome to the next lesson on Velocity-Derived Products. This lesson will cover the Tornado Vortex Signature.

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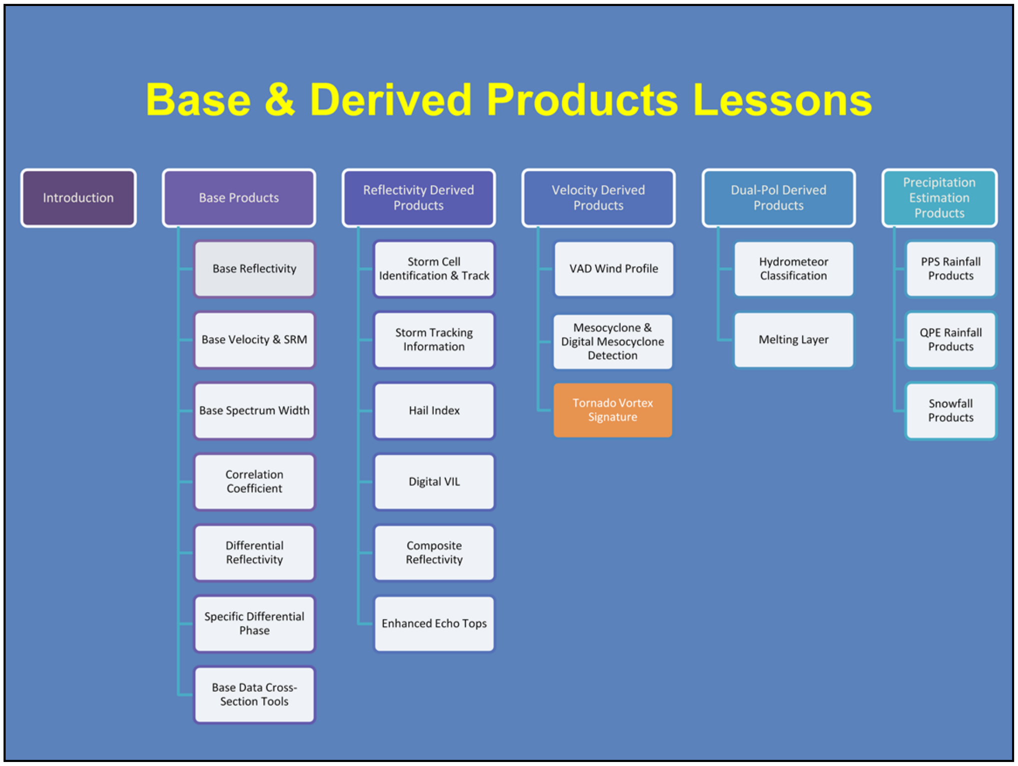
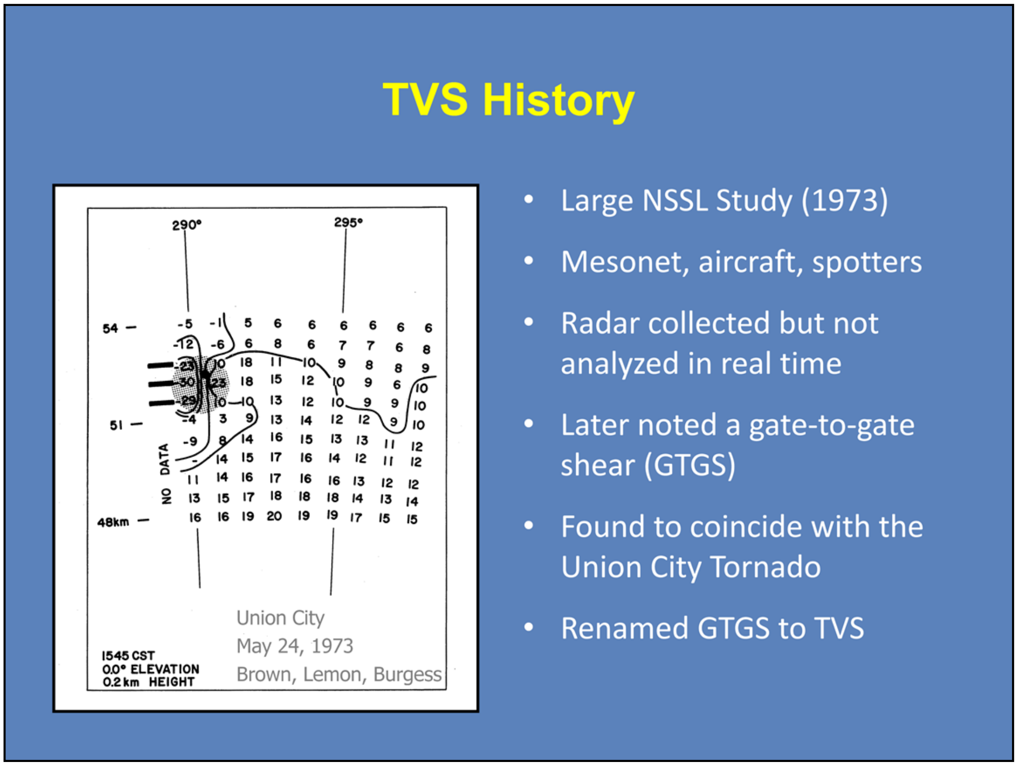


Here is a roadmap for the lessons in this topic. This lesson on the Tornado Vortex Signature, shaded in orange, is the third and last in the Velocity Derived Products Section of this topic.

Learning Objectives

Upon completion of this lesson you will be able to identify specific characteristics, limitations, and applications (strengths) of the Tornadic Vortex Signature (TVS) product

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.



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.

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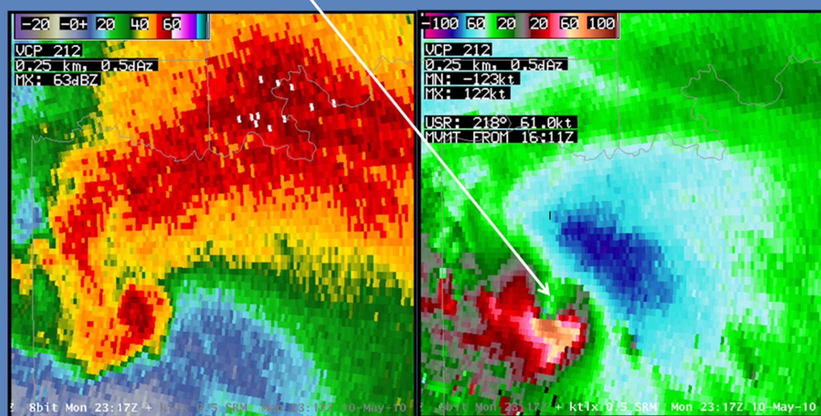
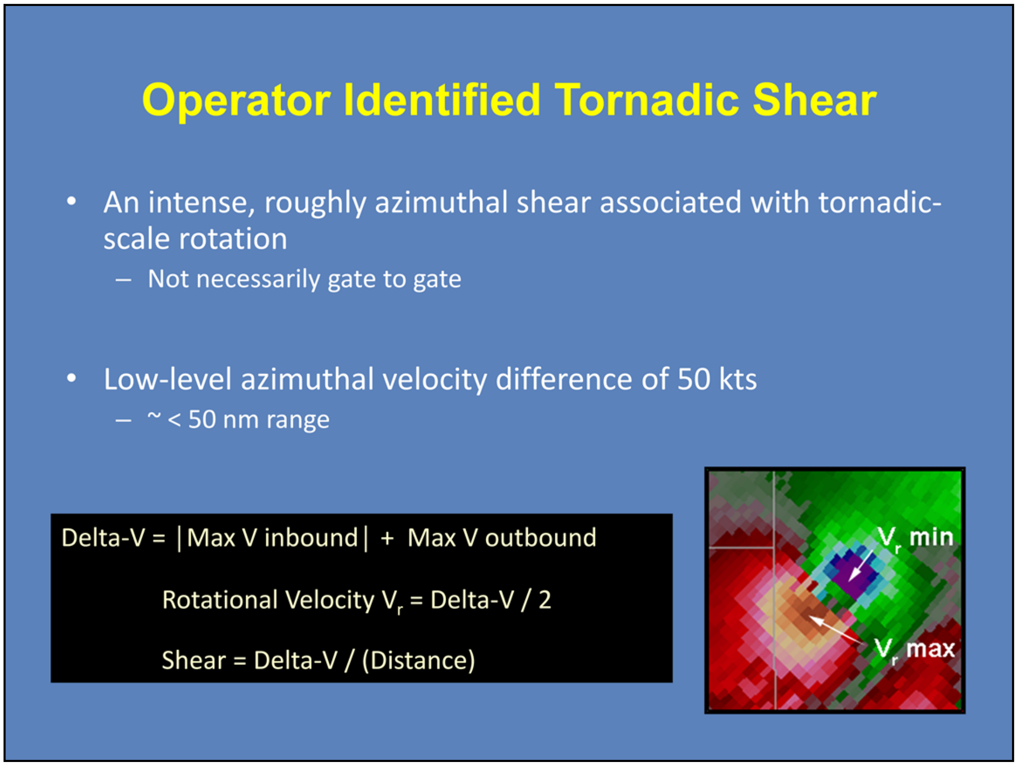
TVS and Tornadic Signatures (TS)

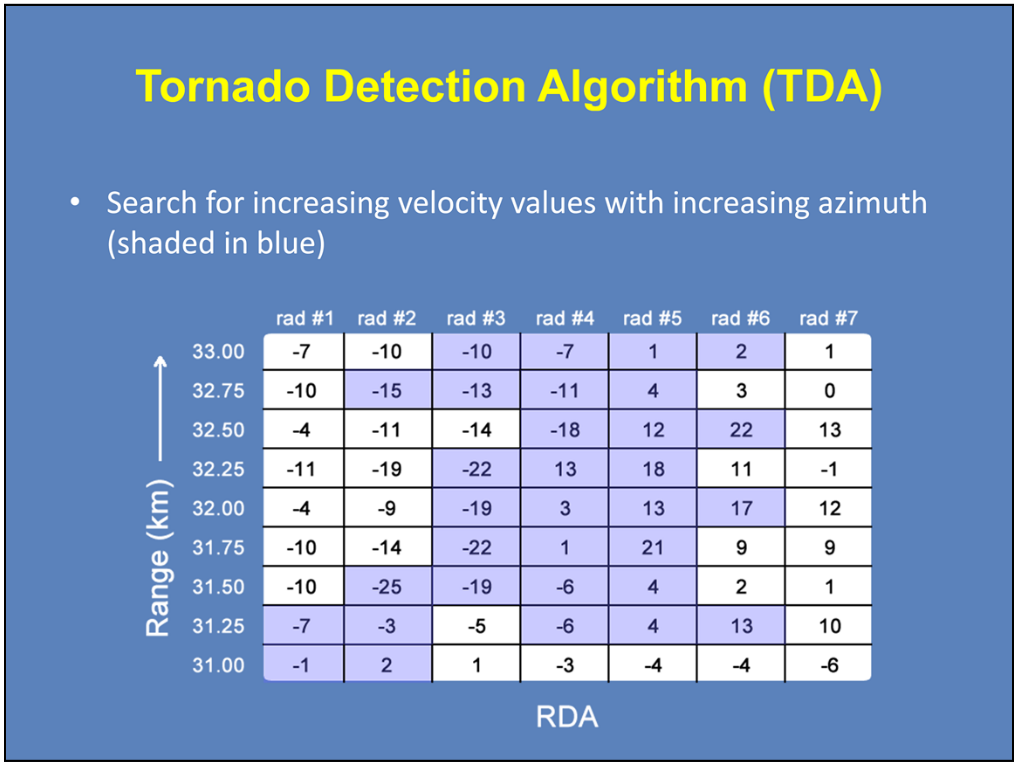
- Radar may see tornadoes with a shear signature that is not gate to gate
  - Tornadic Signature (TS)



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 Topic 7. 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.



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, Vr, 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.



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.

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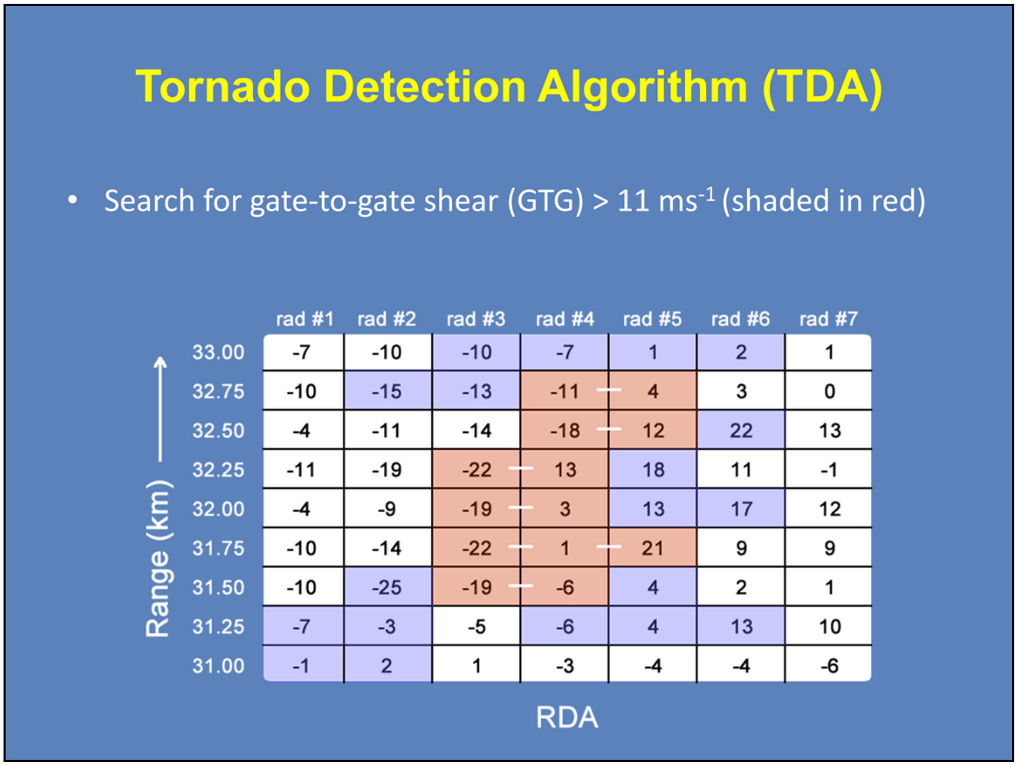
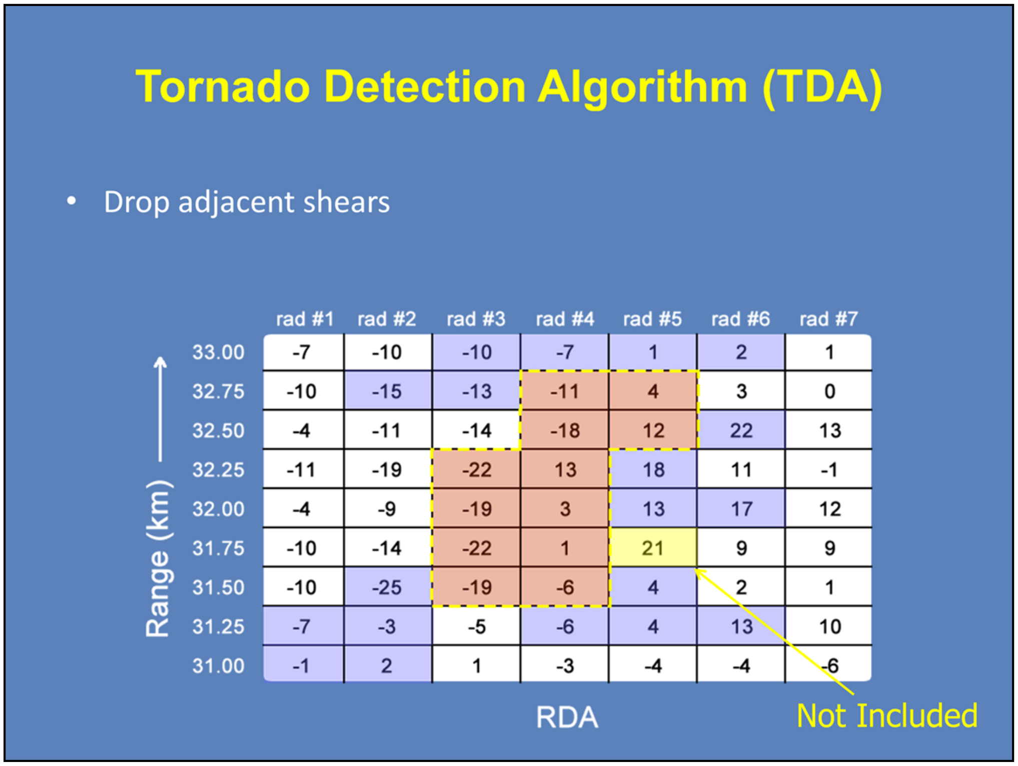
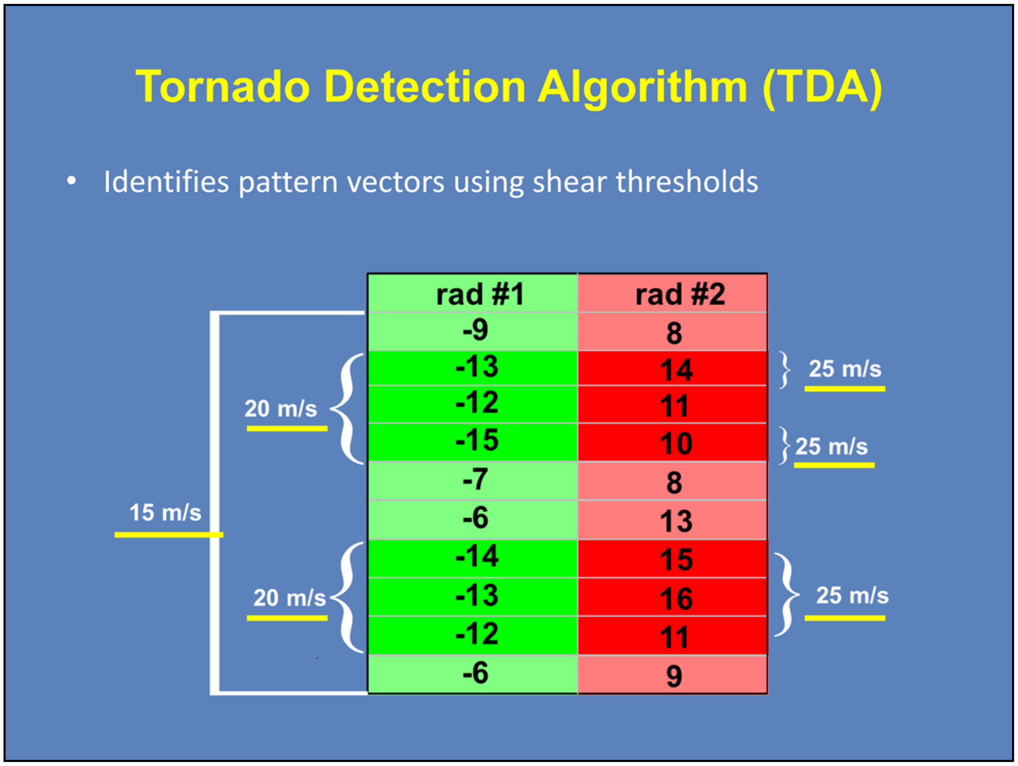


Range (km)	rad #1	rad #2	rad #3	rad #4	rad #5	rad #6	rad #7
33.00	-7	-10	-10	-7	1	2	1
32.75	-10	-15	-13	-11	4	3	0
32.50	-4	-11	-14	-18	12	22	13
32.25	-11	-19	-22	13	18	11	-1
32.00	-4	-9	-19	3	13	17	12
31.75	-10	-14	-22	1	21	9	9
31.50	-10	-25	-19	-6	4	2	1
31.25	-7	-3	-5	-6	4	13	10
31.00	-1	2	1	-3	-4	-4	-6

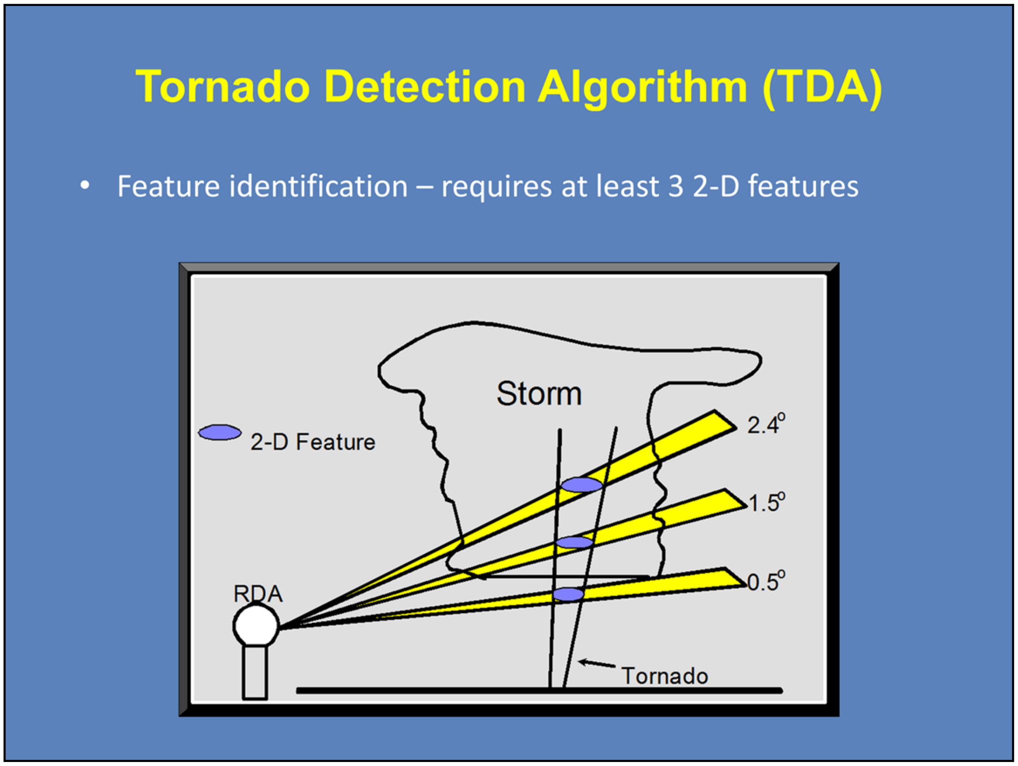
It then calculates the actual values of shear greater than 11 m/s, or 22 knots. The values of shear greater than 11 m/s, or 22 knots, are shaded in a reddish color.



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.



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.



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.

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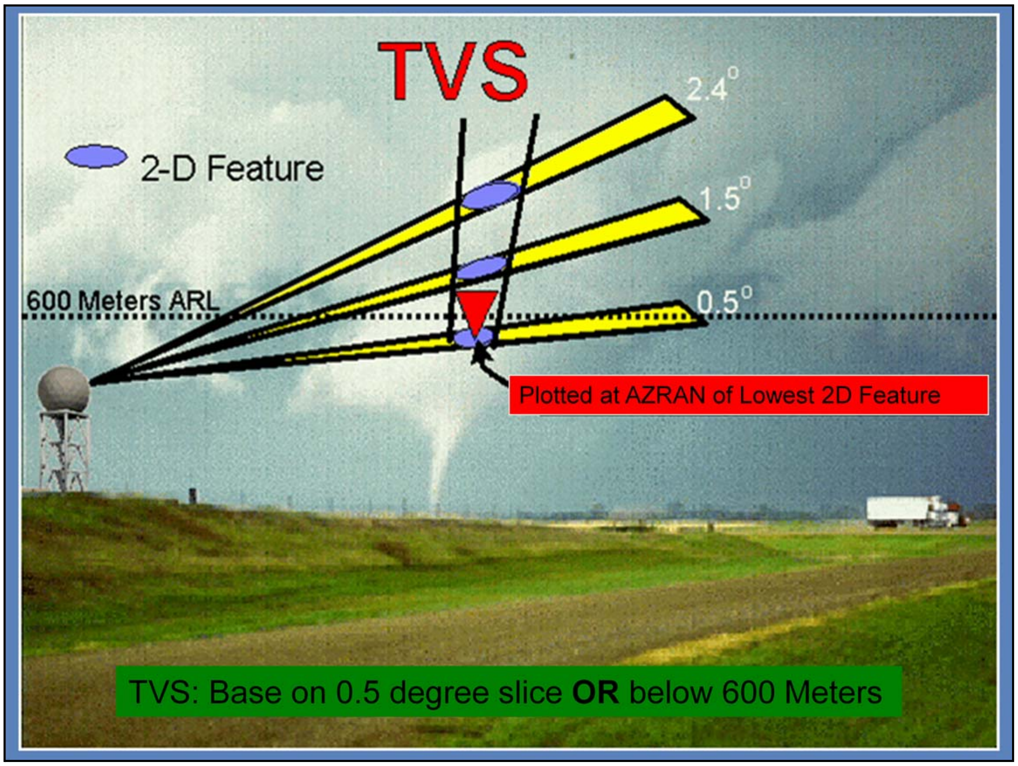
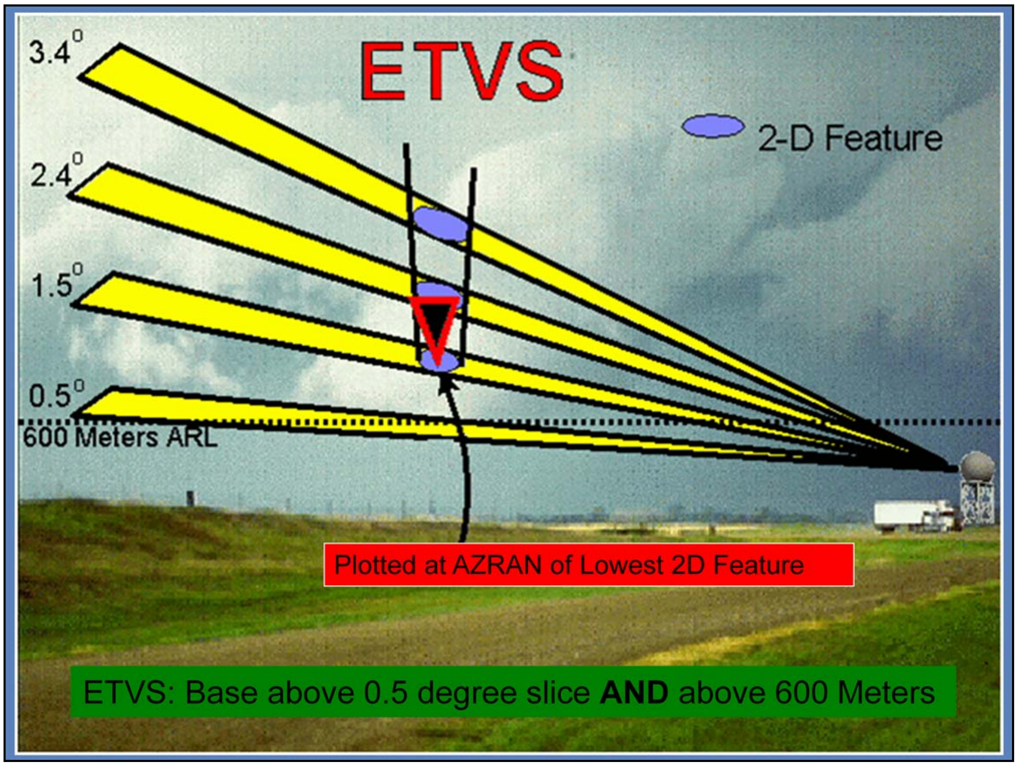


We saw just a few slides ago that for a TVS to be identified, there needs to be at least 3 vertically correlated 2D circulations identified and ideally these vertical correlations will have no gaps, but a one elevation gap is permitted for unforeseen data quality issues like range folding. Anyhow, one 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, isocoleses triangle will be plotted at the azimuth and range of the lowest 2D feature.



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.

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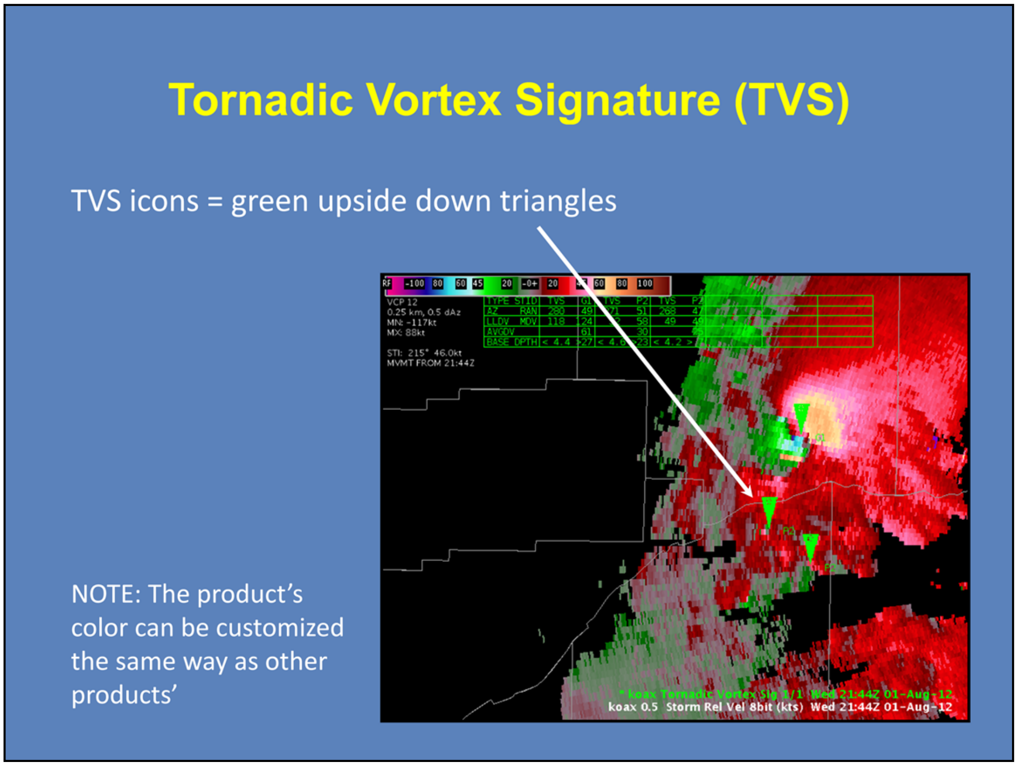

Here is what the TVS product looks like in AWIPS-2 CAVE. In this graphic I have the TVS overlaid on top the base SRM product. The closest storm ID from SCIT is plotted next to each TVS icon symbol.

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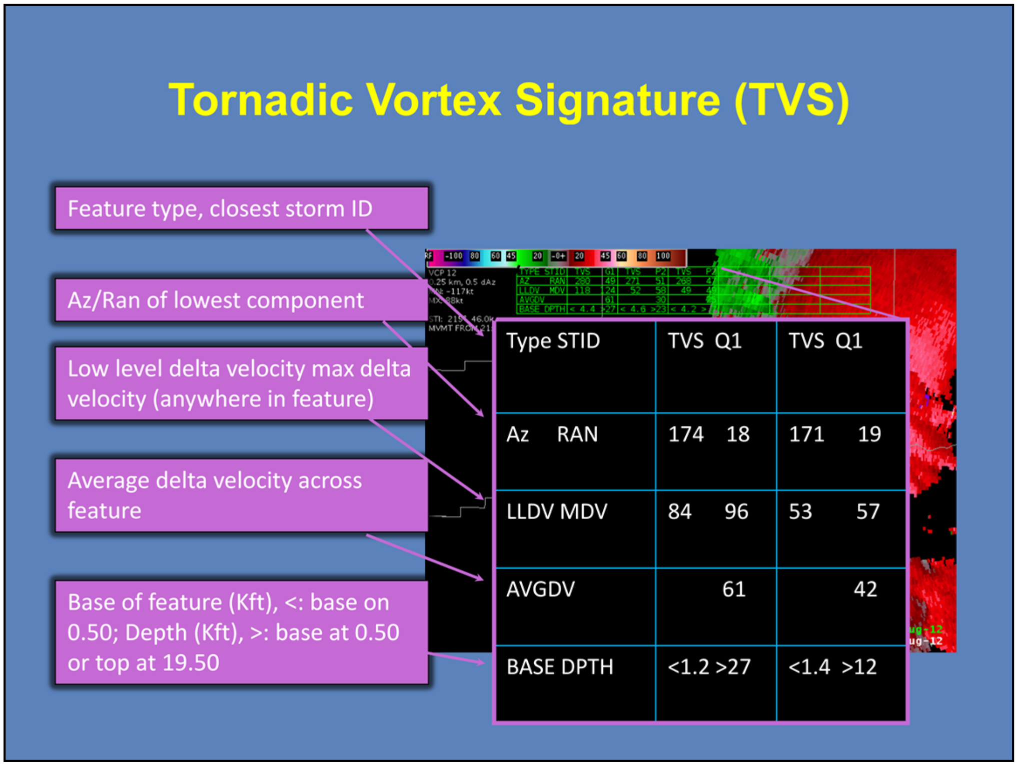
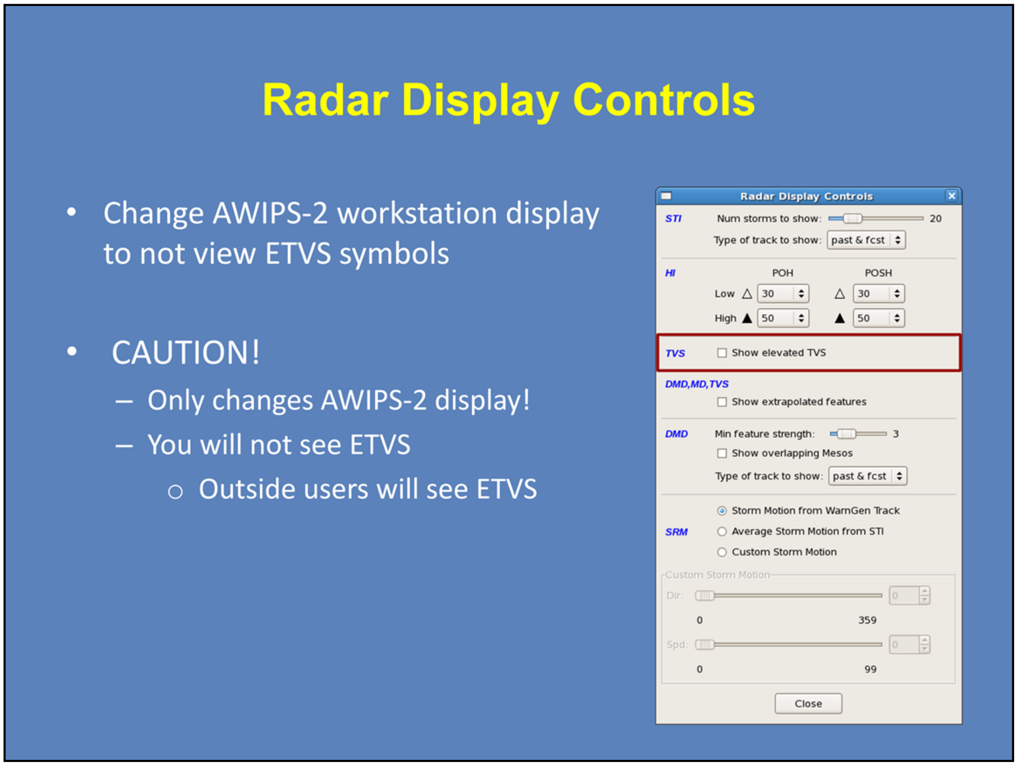


Notice there is also an attributes table. The first row gives you the circulation type and the closest storm ID to that circulation feature. The second row is the azimuth and range of the lowest 2D feature. The third row gives you the low-level delta velocity in knots, and the max delta velocity in knots, 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.



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. Partway down there is a little box you can check that will turn off ETVS icons when checked and turn them on when not checked in your CAVE 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 uses from having there display cluttered with ETVSs is to have them turned off at the RPG.

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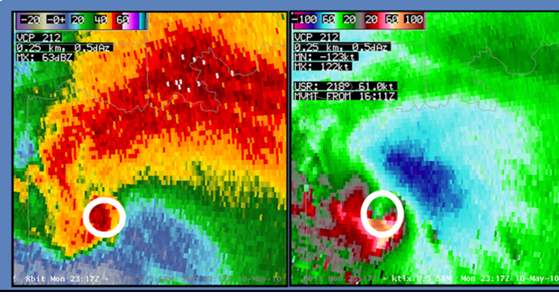
TVS Operational Considerations

- 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



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.

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

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.

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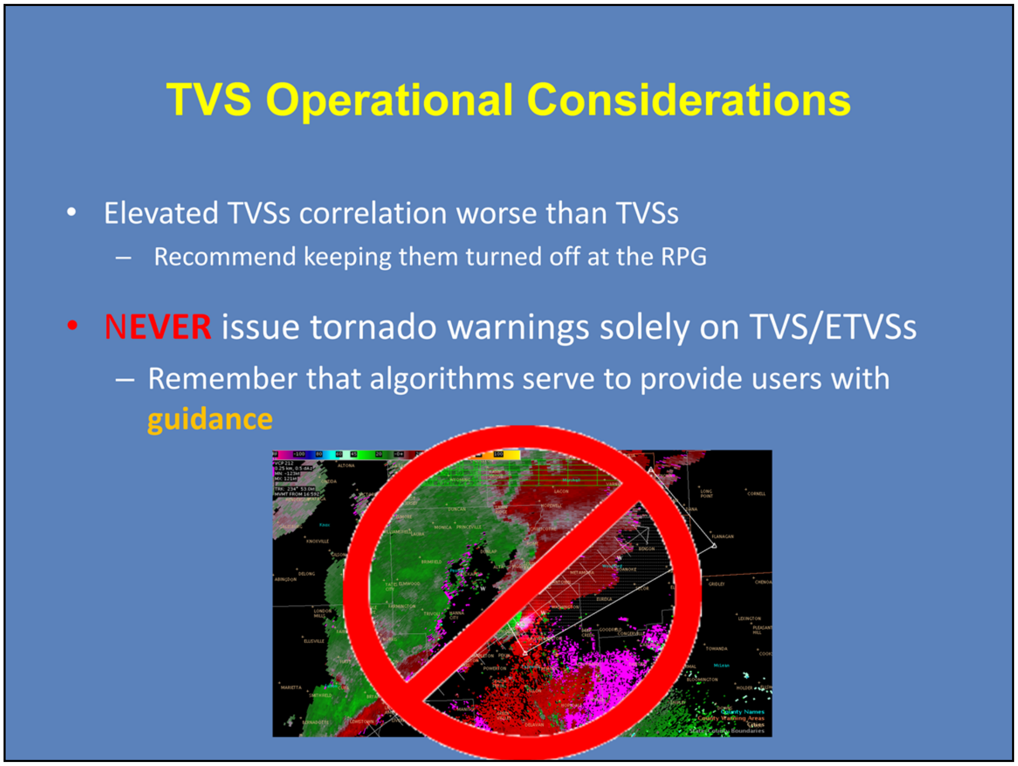

Some final operational considerations. The elevated TVS has worse correlations than TVSs relative to tornado occurrence. So, it is recommended that you keep the ETVS turned off at the RPG until evidence says otherwise. We would be doing our customers a great dis-service if we issued tornado warnings based solely on the TVS 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.

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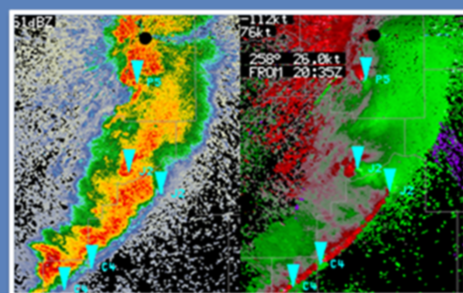
Product Limitations

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



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.

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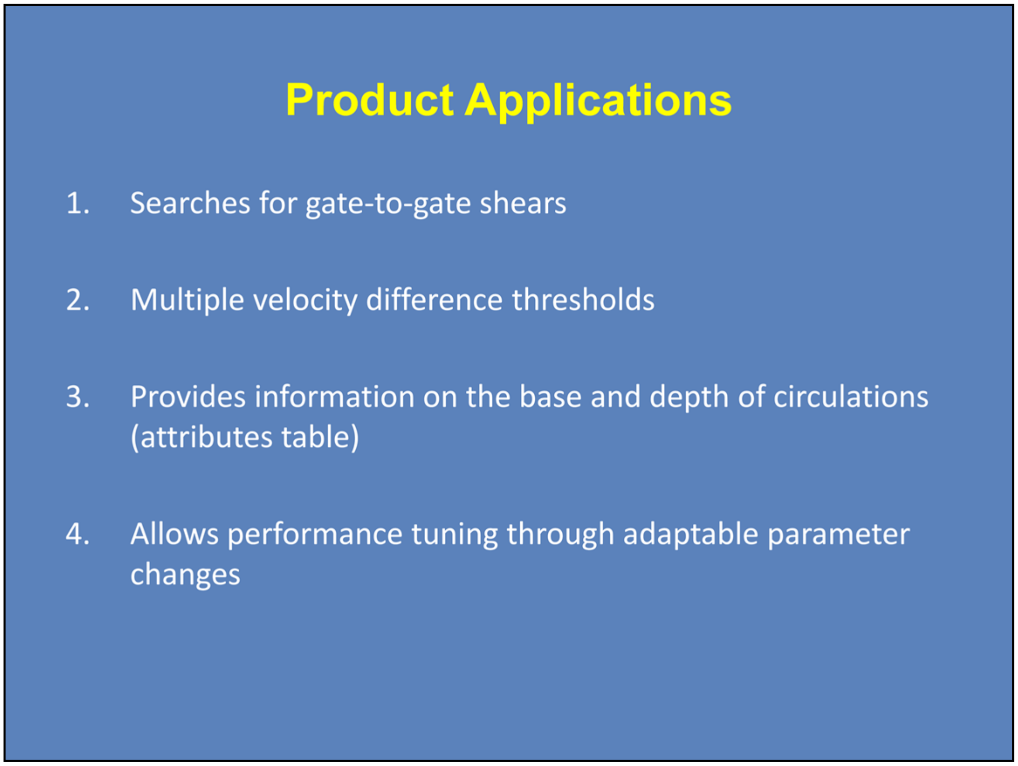
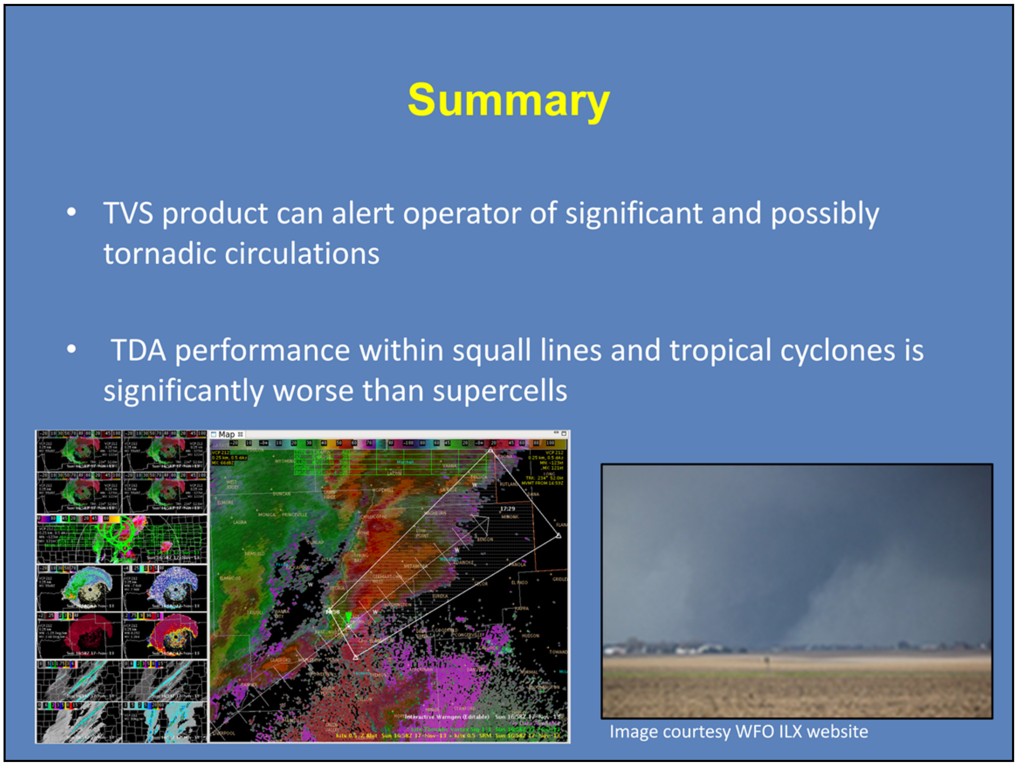


Here are the applications of the TVS. First, it searches for all gate-to-gate shears. So, after doing a thorough base data analysis, you can use the TVS product to see if you missed anything. Second, it does use multiple velocity difference thresholds. The product is displayed with an attributes table 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.



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.

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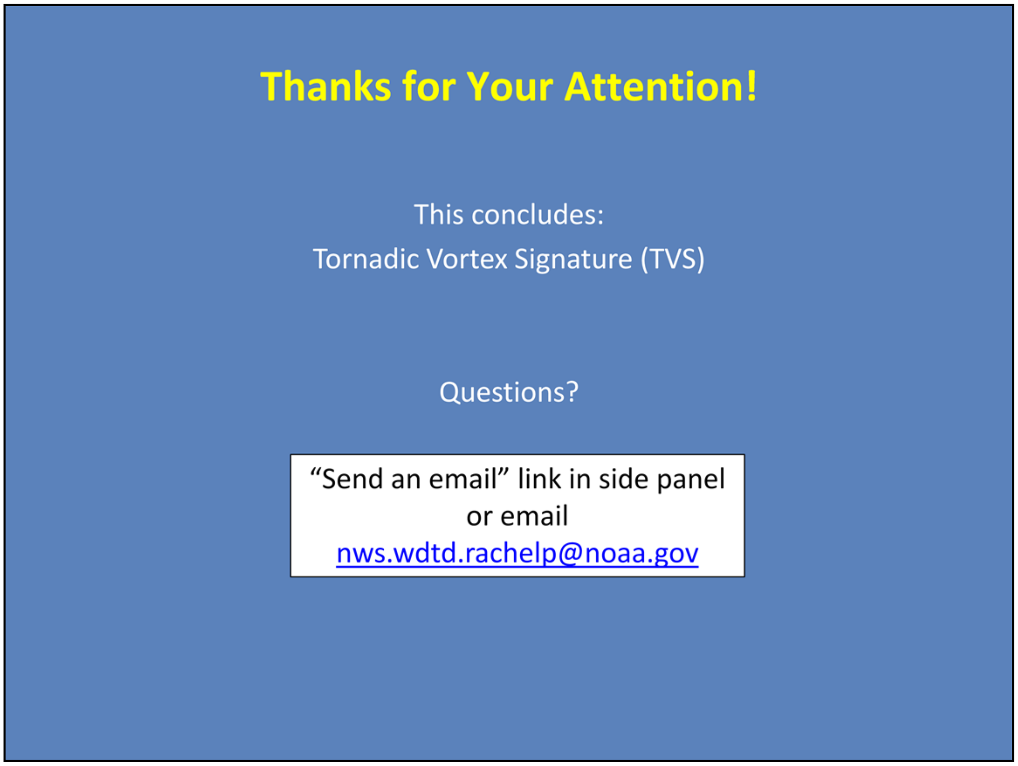
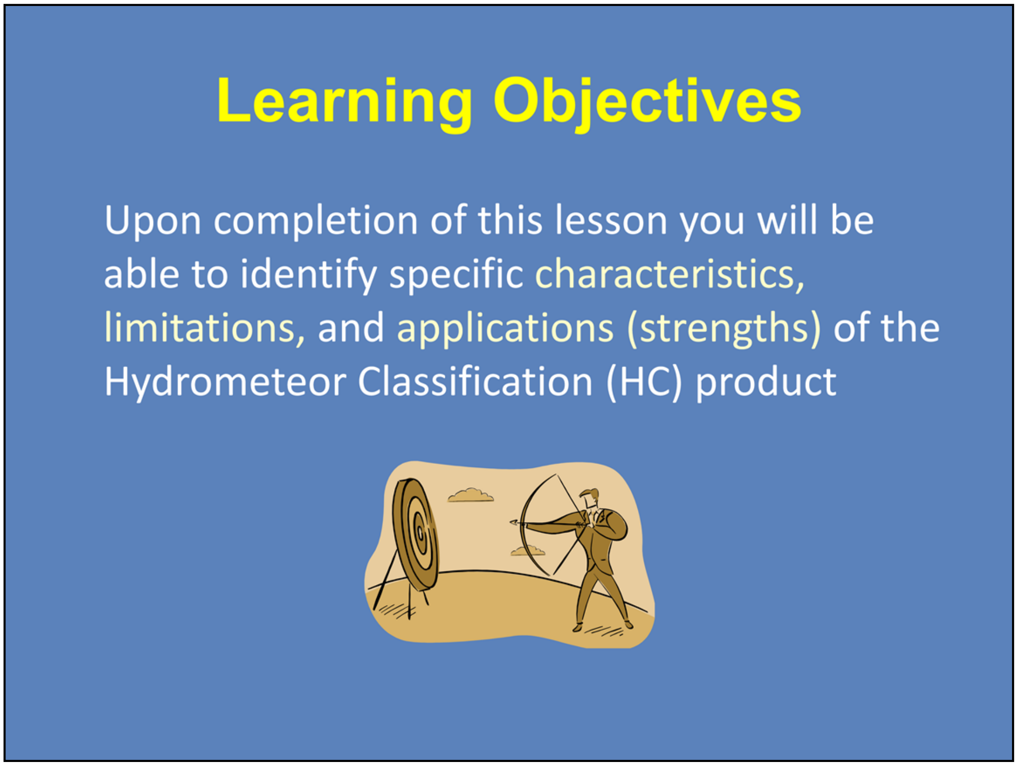


This concludes the lesson on the TVS/TS products. You can now move onto the next lesson. If you have any questions, feel free to email the contacts listed.

This Topic 4 lesson will be on Hydrometeor Classification. I'm Justin Gibbs of the Warning Decision Training Division.



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

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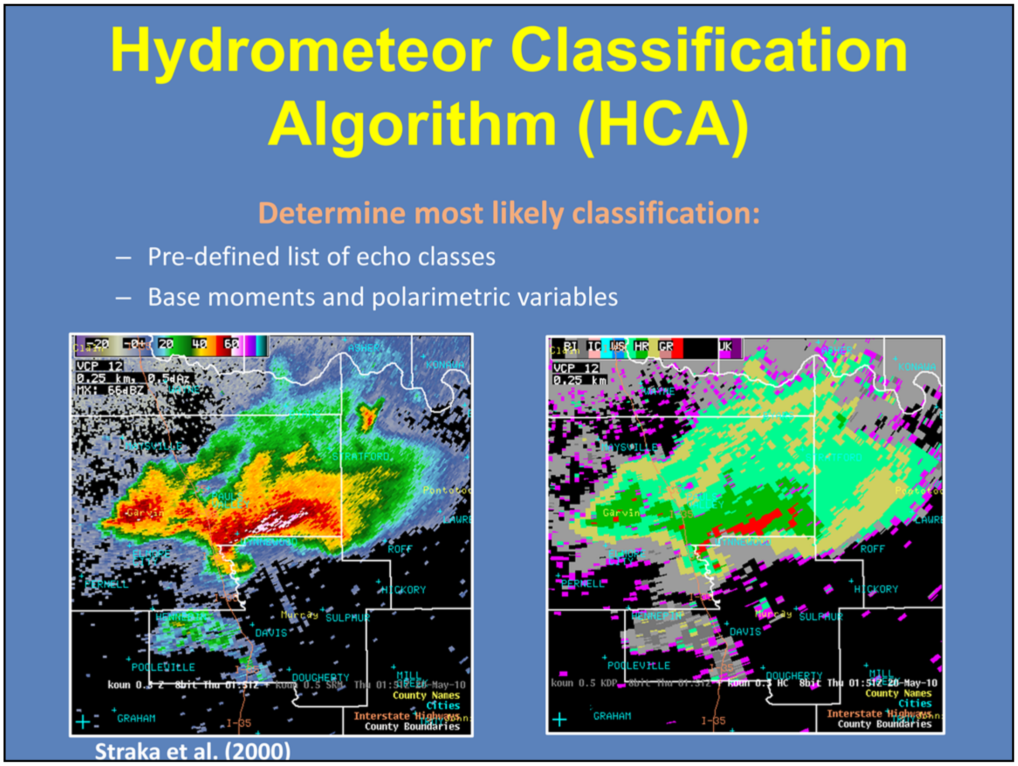

The purpose of the hydrometeor classification algorithm, or HCA, is to determine the most likely classification of all the range bins that the radar detects at all elevation angles. What most likely is what the radar is sensing in each bin. It attempts to put all the echoes into a predefined list of echo classes, and uses base data and polarimetric variables to reach its estimate.

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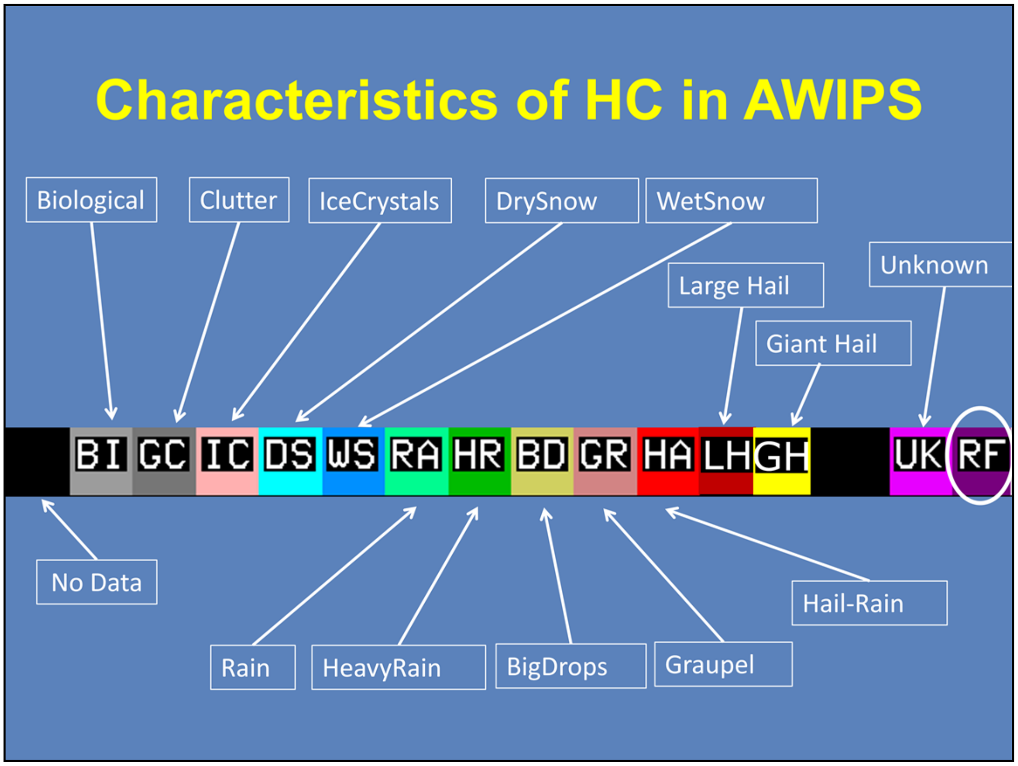

The bins that the HCA attempts to place echoes into are , No Data (ND), biological scatterers (BI), ground clutter / anomalous propagation (GC), ice crystals (IC), dry snow (DS), wet snow (WS), light/moderate rain (RA), heavy rain (HR), big drops (BD), graupel (GR) hail possibly mixed with rain (HA), Large Hail (LH), Giant Hail (GH) , and Unknown (UK).

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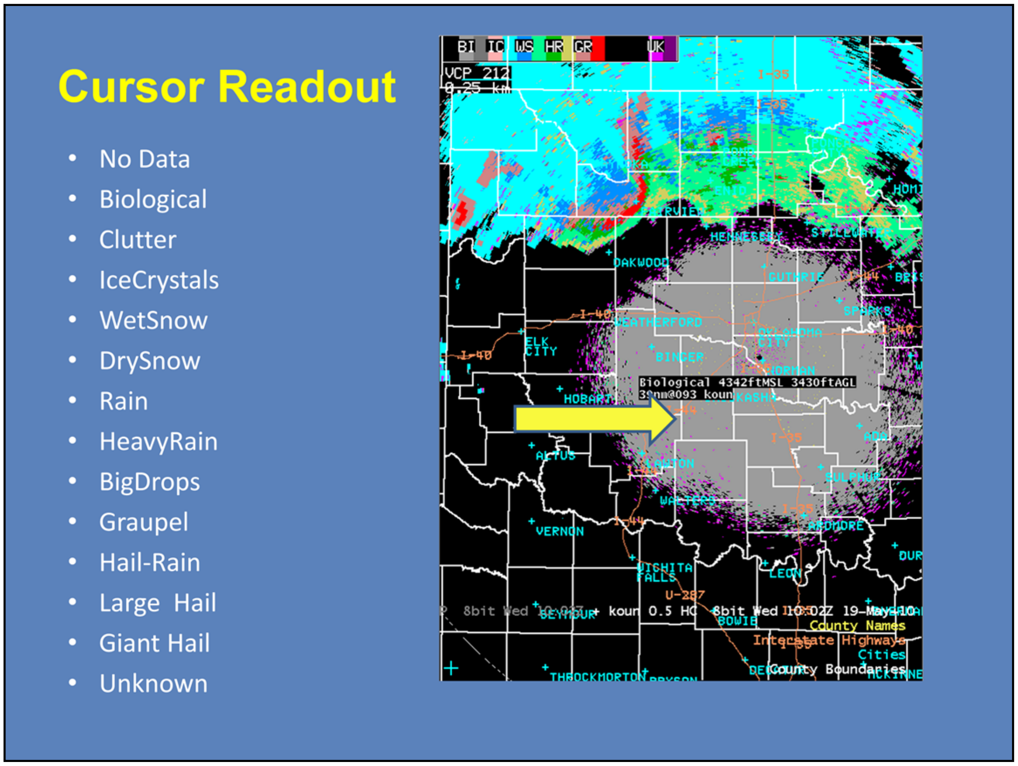
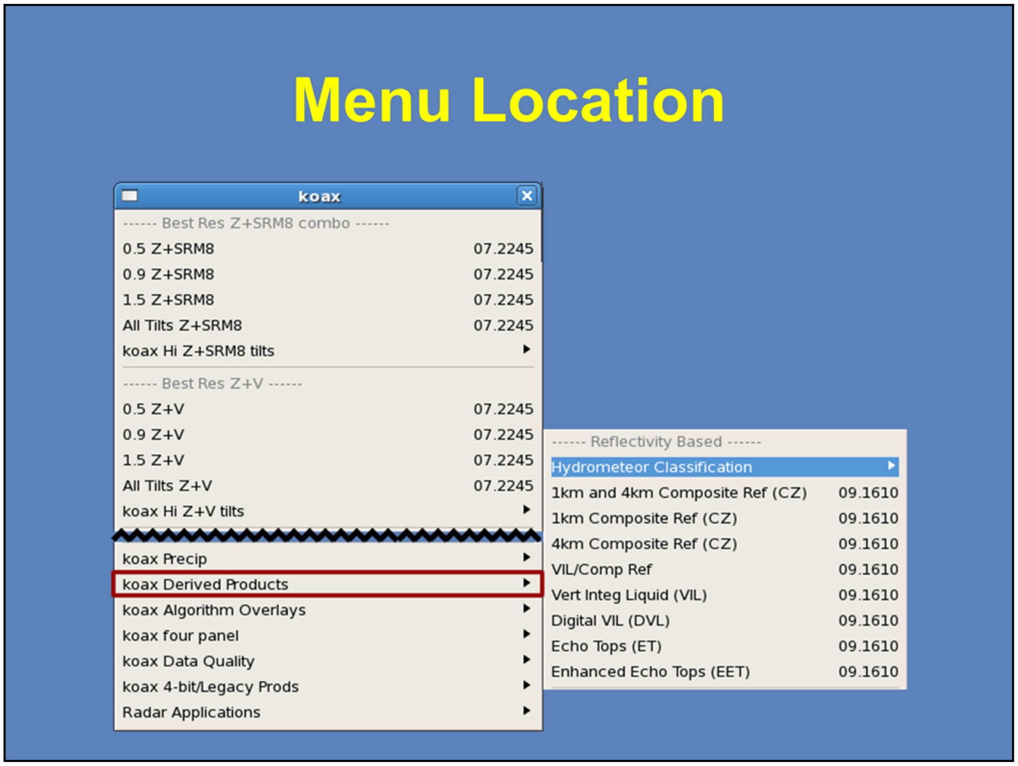
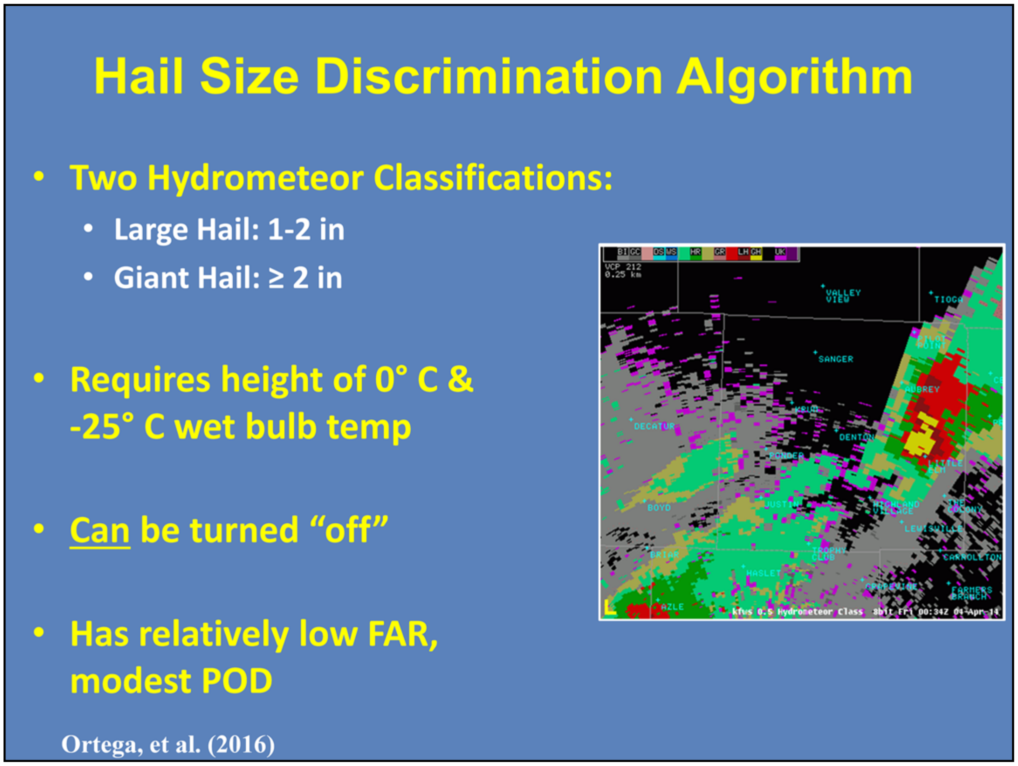


You can enable sampling and do a mouse over of each target in plan view. In this case the target was biological scatterers at 4,342 MSL, and it will give you any of the returns we mentioned before.



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.



A relatively new addition to the HCAis 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.

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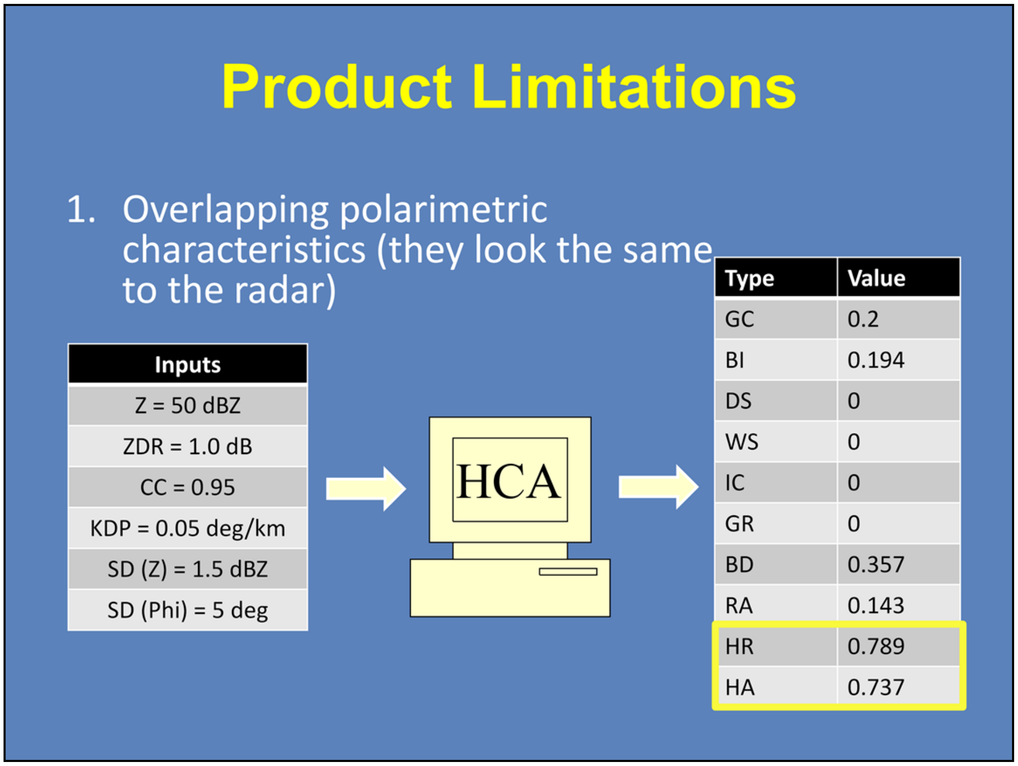

One of the key limitations of the hydrometeor classification algorithm are overlapping polarimeteric characteristics. Basically two different bins of possible answers that look the same to the radar. In this example the input has 50dbz a zdr of 1db, CC of 0.95 an SD Z of 1.5 dBZ and an SD Phi of 5 degrees. 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.

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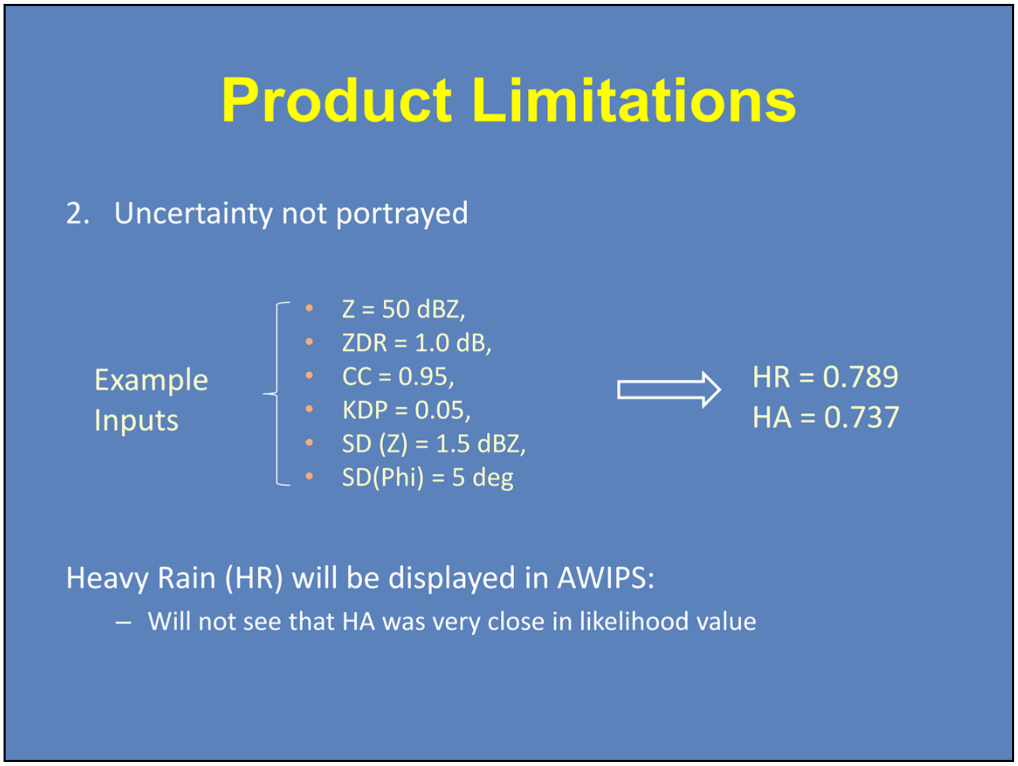

And its important to understand that uncertainty is not portrayed in the HCA output. It just takes the most likely answer and spits that out to you. So in our situation we had in the previous slide where its about 79% chance its heavy rain and 74% chance its hail, AWIPS is only going to display heavy 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.

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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.

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Product Limitations

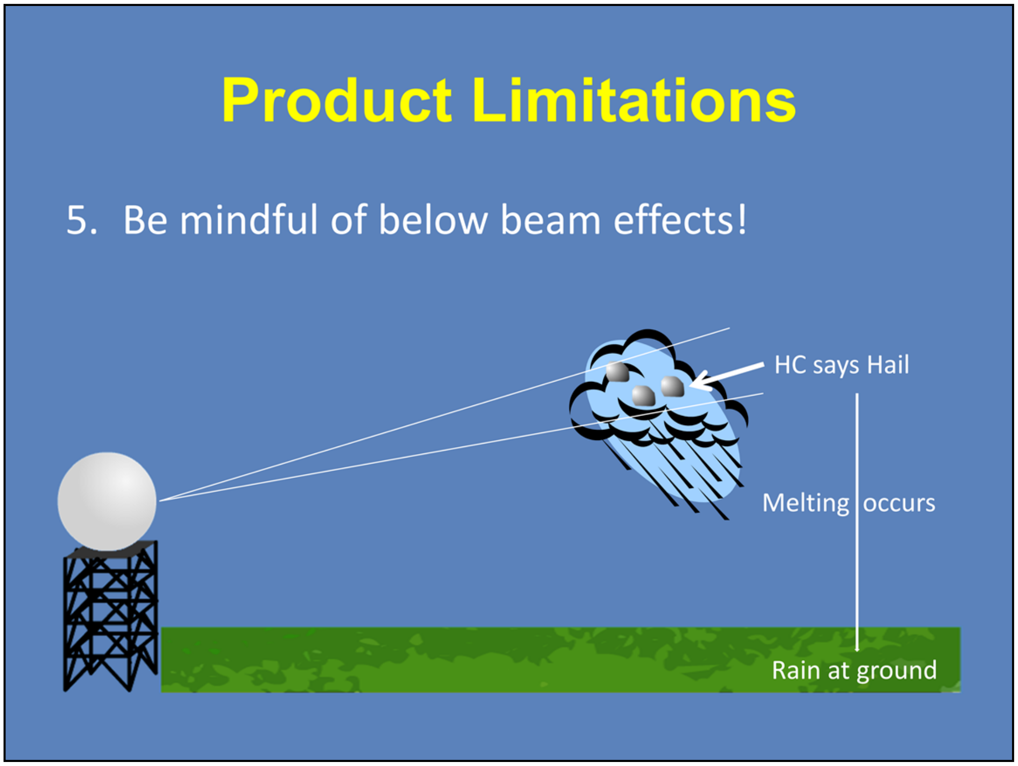
4. Thresholds are empirical and/or subjective

Fuzzy-Logic Membership Function (Dry Snow) | Weighting (Dry Snow)

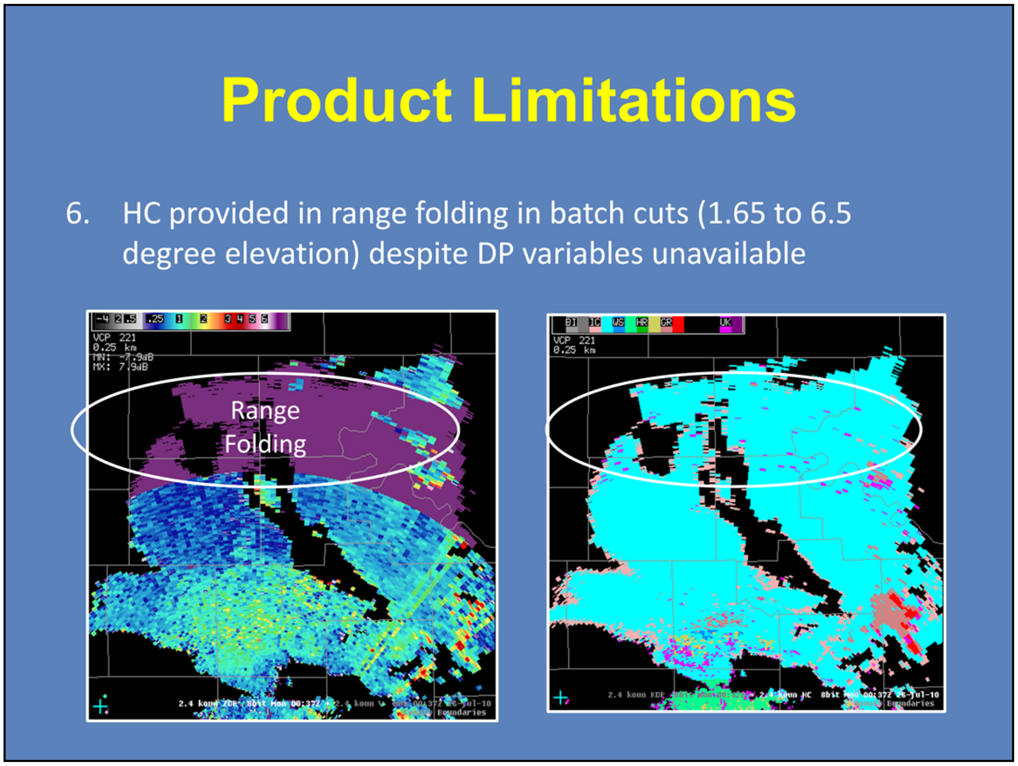
	X1	X2	X3	X4		Weight
Z	5	10	35	40		1.0
ZDR	-0.3	0.0	1.3	1.6		0.8
CC	0.95	0.98	1.0	1.01		0.6
KDP	0.001	0.003	10	100		1.0
SD(Z)	0	0.5	3.0	6.0		0.2
SD(Phi)	0	1	15	30		0.2

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. Theres 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.



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.



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.

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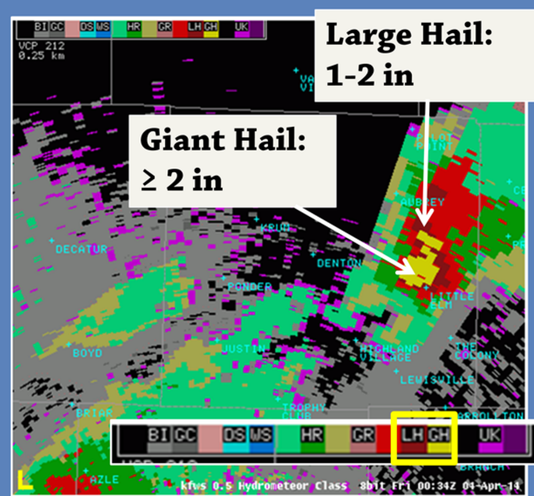
Product Limitations

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.

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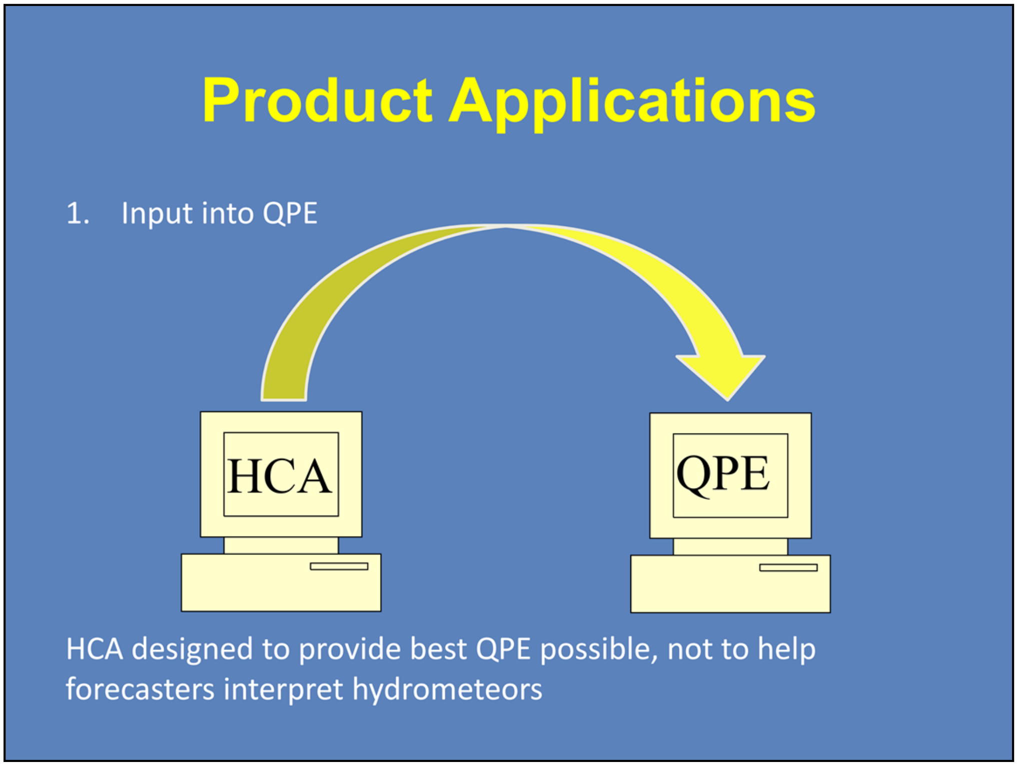
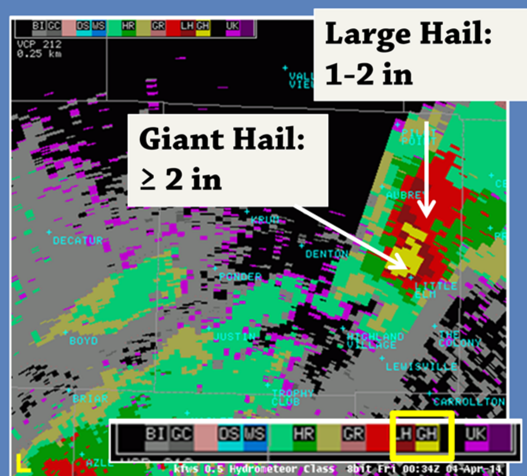


One of the main applications of the HCA is that it is used to improve the QPE output. The HCA is really designed to provide the best QPE possible, and its not really there to help forecasters interpret hydrometeors. Its just a nice by product that is available, so might as well have it. So its going 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 too, and particularly as an alerting tool given its apparently low false alarm rate, 10-12% in validation tests

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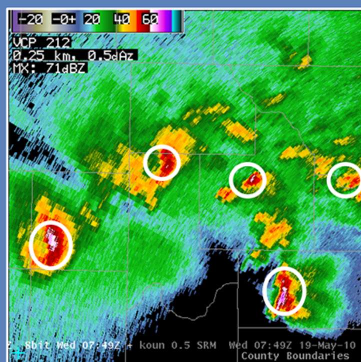
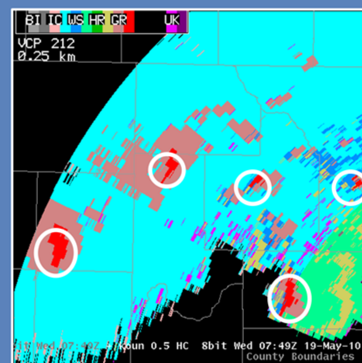
Product Applications

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 whats 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.

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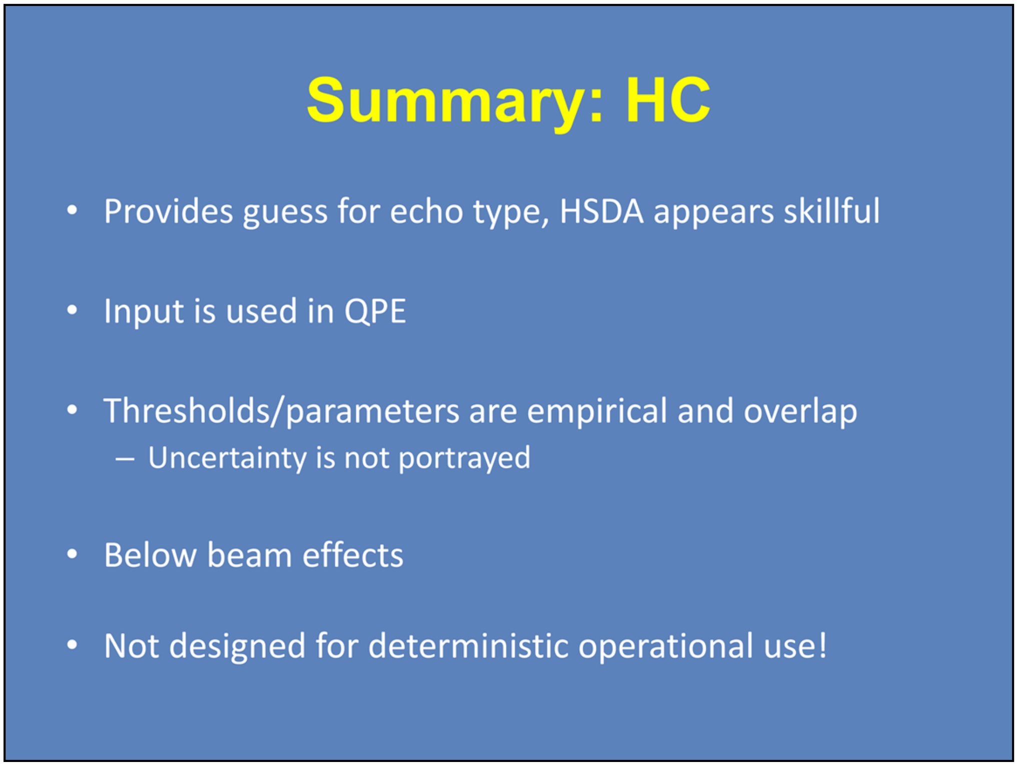


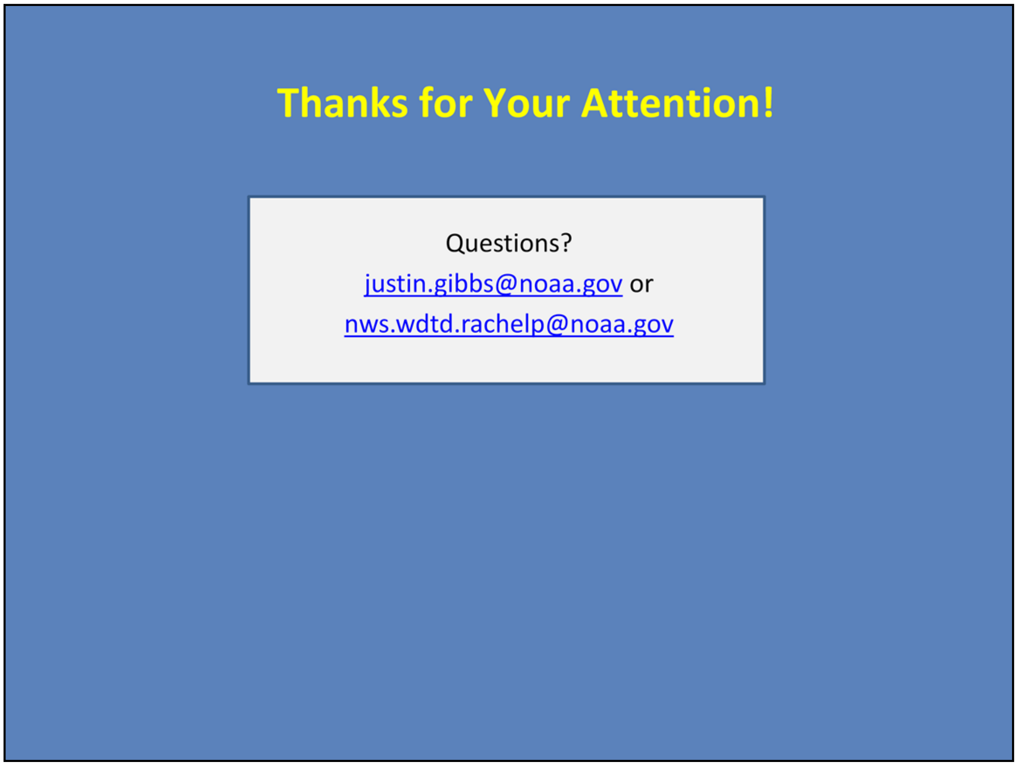
So in summary the HCA provides a guess for echo type, the new HSDA appears skillful but the algorithms

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.



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!

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Welcome to this Topic 4 lesson on the Melting Layer.

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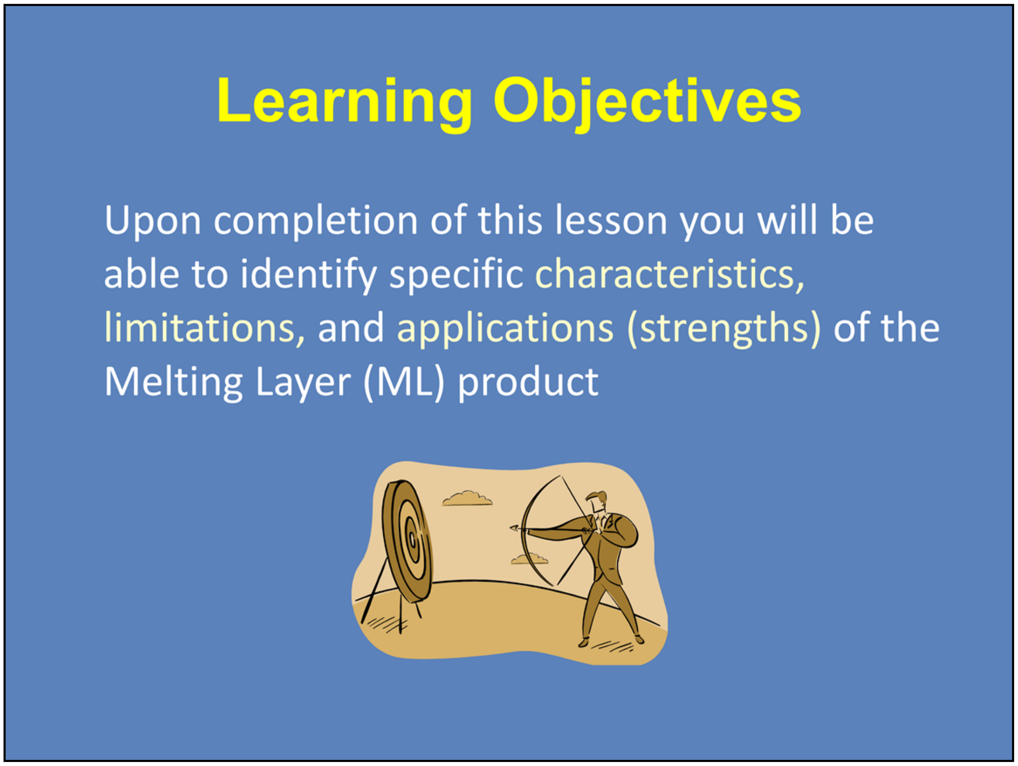

Here are the learning objectives for this lesson. Advance to the next slide when you are ready to begin.

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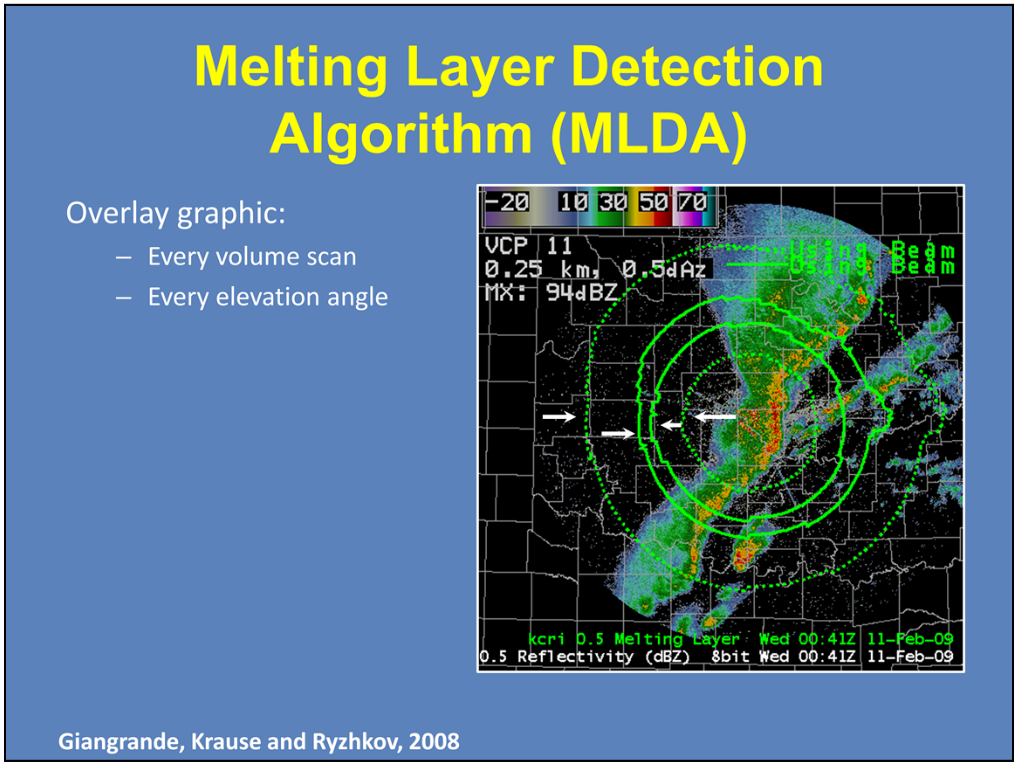
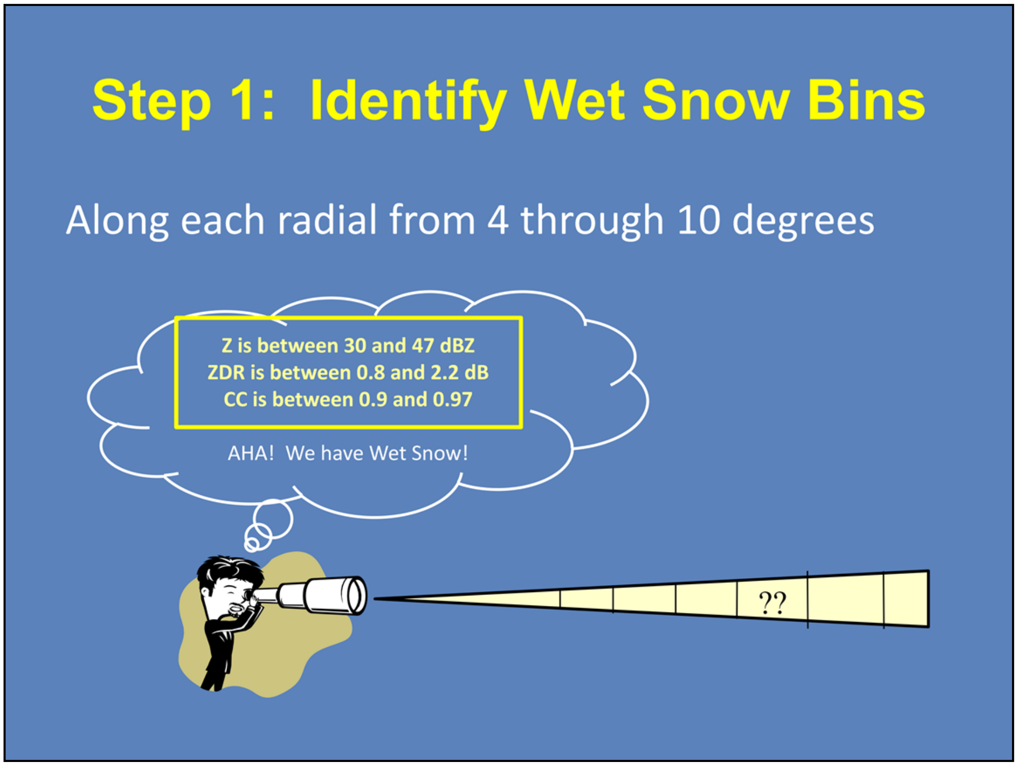
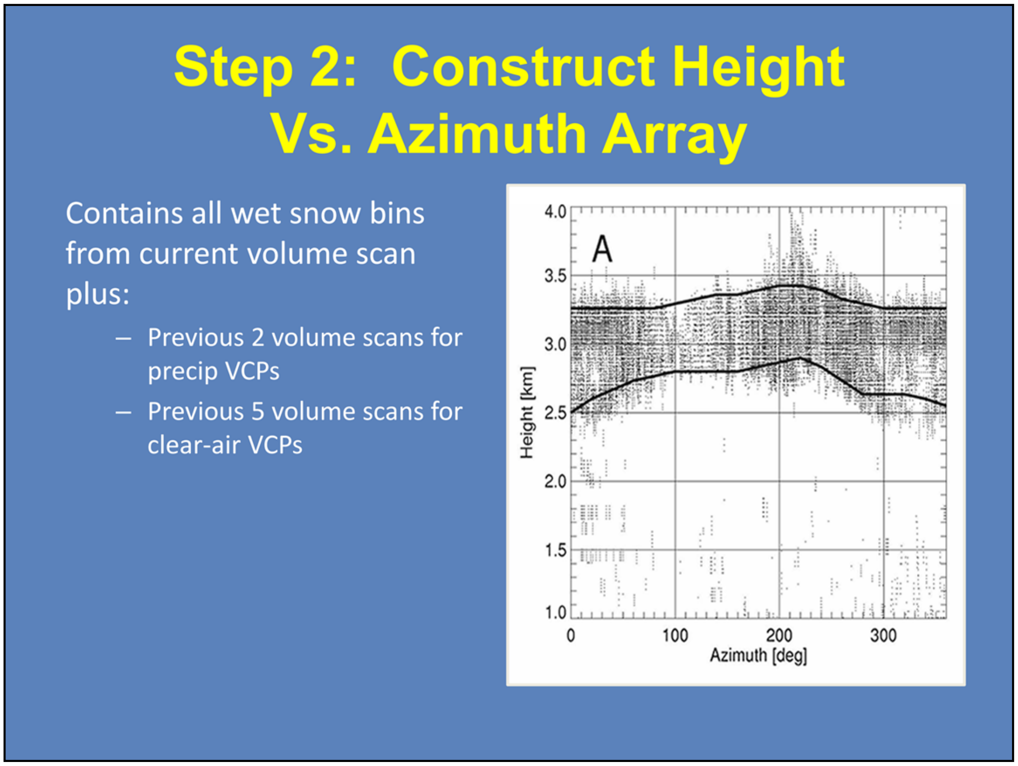


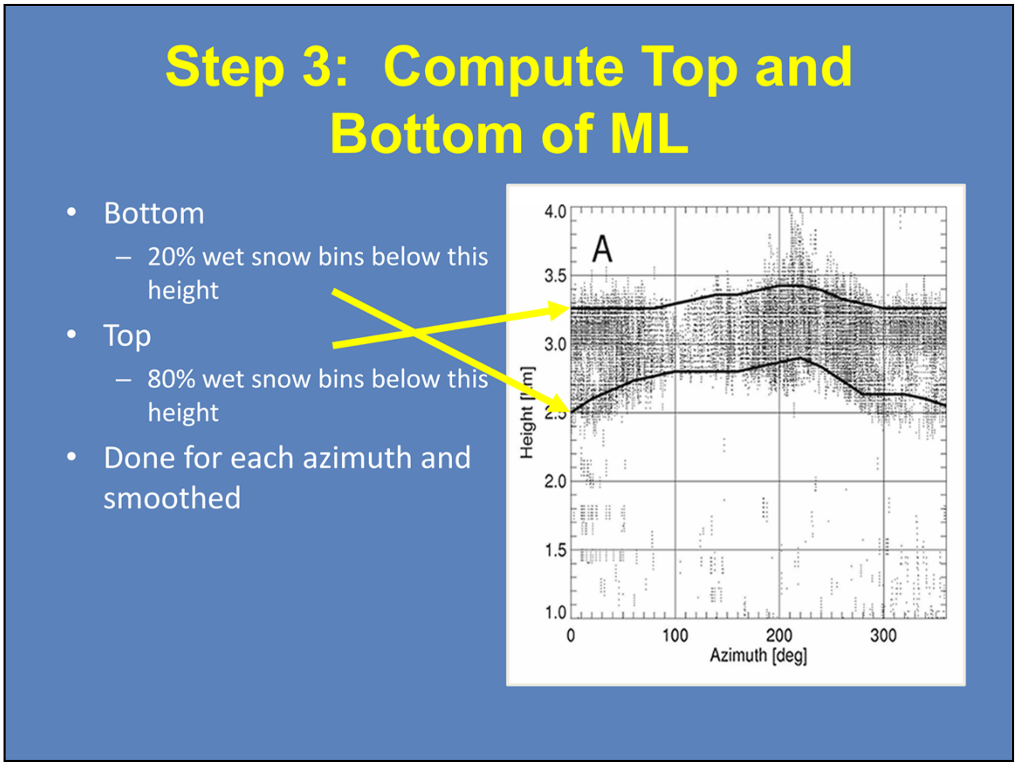
As we mentioned earlier, the melting layer has a distinct signature in both ZDR and CC. This fact is by the Melting Layer Detection Algorithm (MLDA) to automatically detect a melting layer from the radar data and then display it as an overlay on other radar products. The green solid and dotted lines 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.



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.



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.



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 20th percentile location (bottom black line) while the top of the melting layer is identified at the 80th 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.

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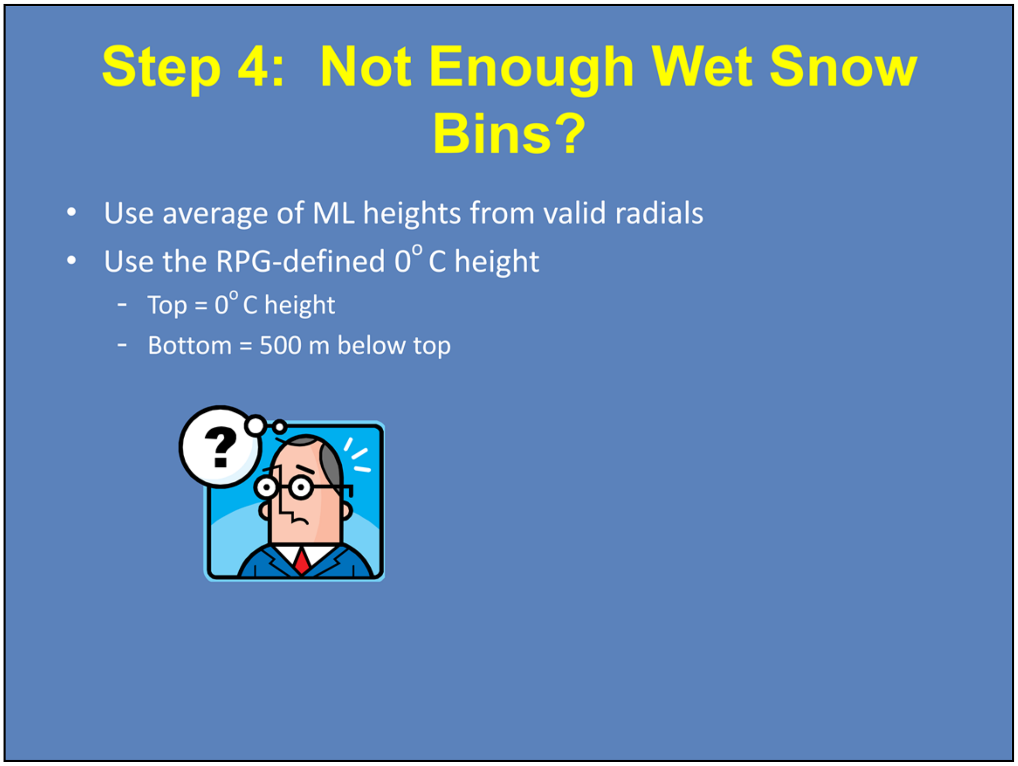

So what happens if the MLDA doesn't identify enough wet snow bins to locate the melting layer? Well, the algorithm still identifies a melting layer height using one of two methods.

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.

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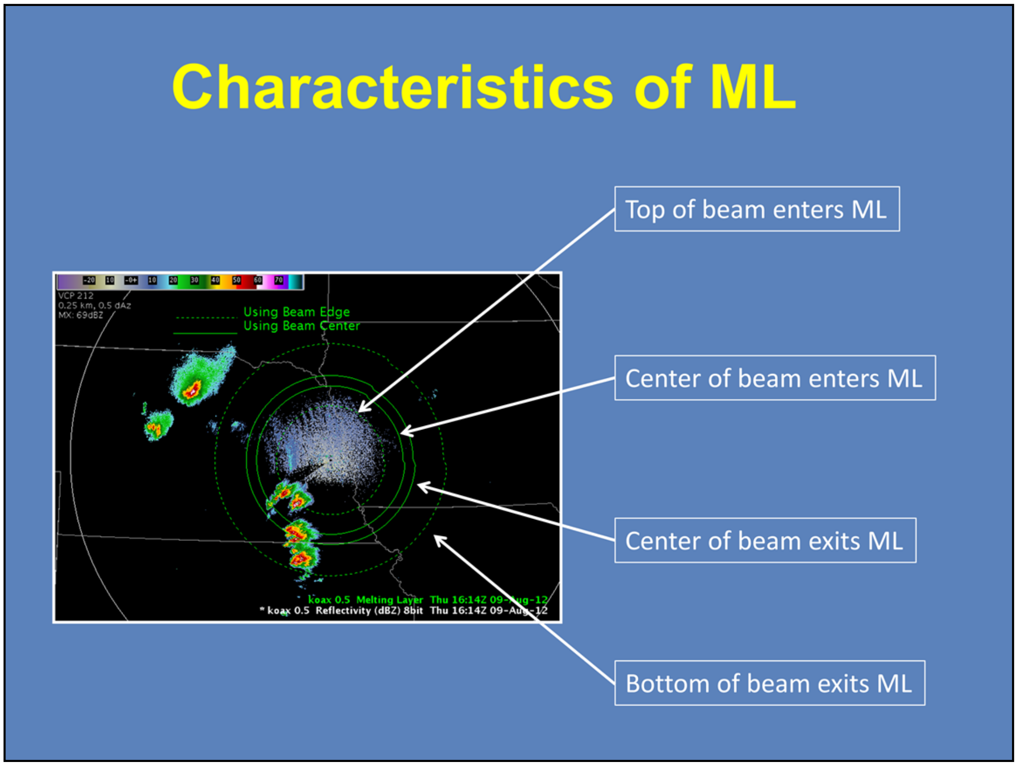

The heights determined by the MLDA are then used to construct the Melting Layer (ML) product. This example shows the 0.5 deg ML overlaid on top of the 0.5 deg Reflectivity. I should note that, although the algorithm only uses tilts between 4 and 10 degrees to identify the melting layer, the ML product 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.

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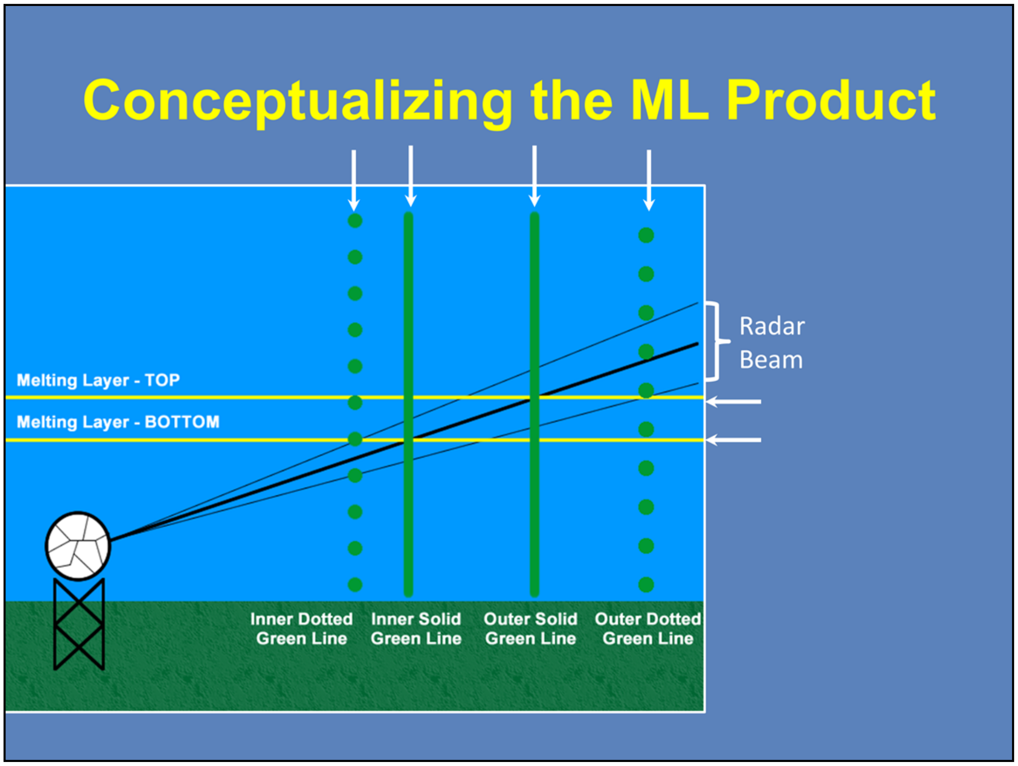

We provide this graphic to conceptualize the ML display further and aid your understanding further. In this graphic, the radar beam is illustrated with a thick black line for the center of the beam and two thin black lines for the radar beam edges. The two yellow lines represent the identified melting 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.

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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.

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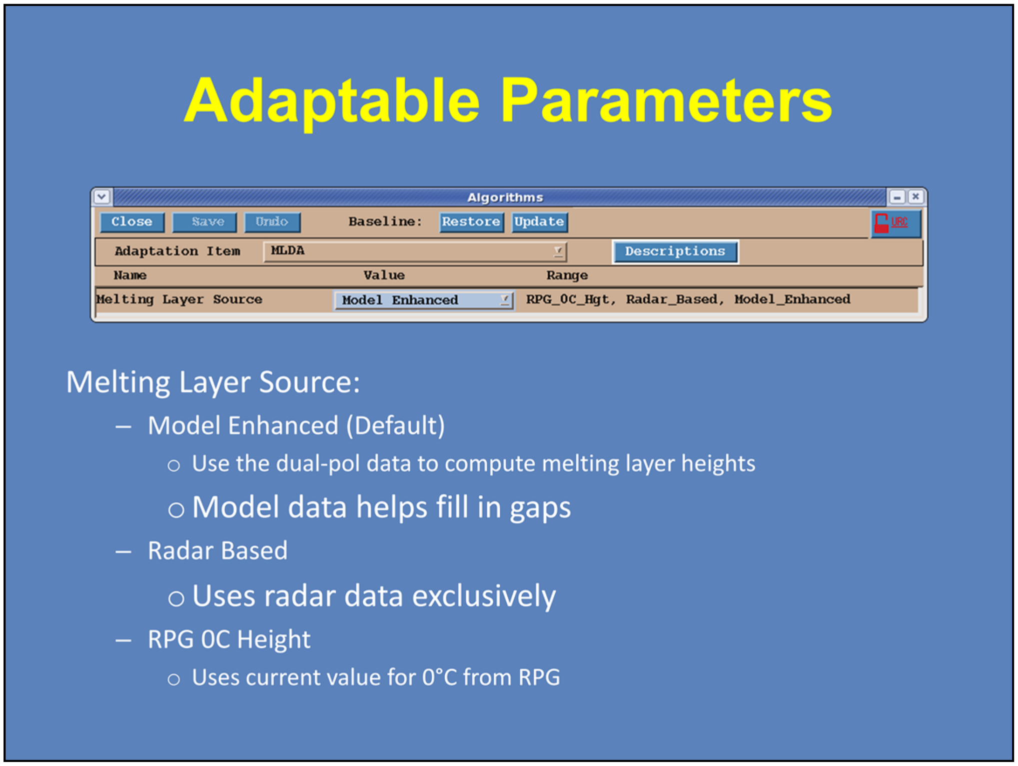

In the RPG window, you will see one adaptable parameter, entitled Melting Layer Source, with three possible options. “Model Enhanced” is the default option shown on the slide. When “Model Enhanced” is selected, the MLDA will look at the data available radial by radial. When sufficient data exists, the 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.

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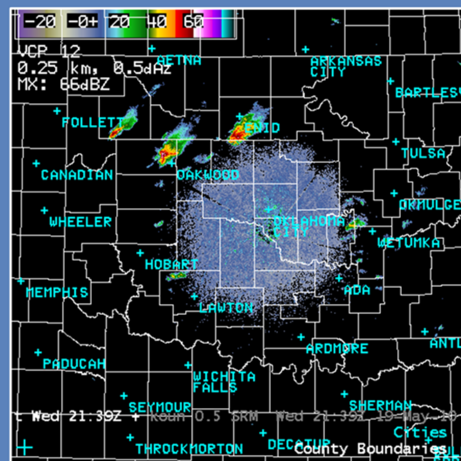
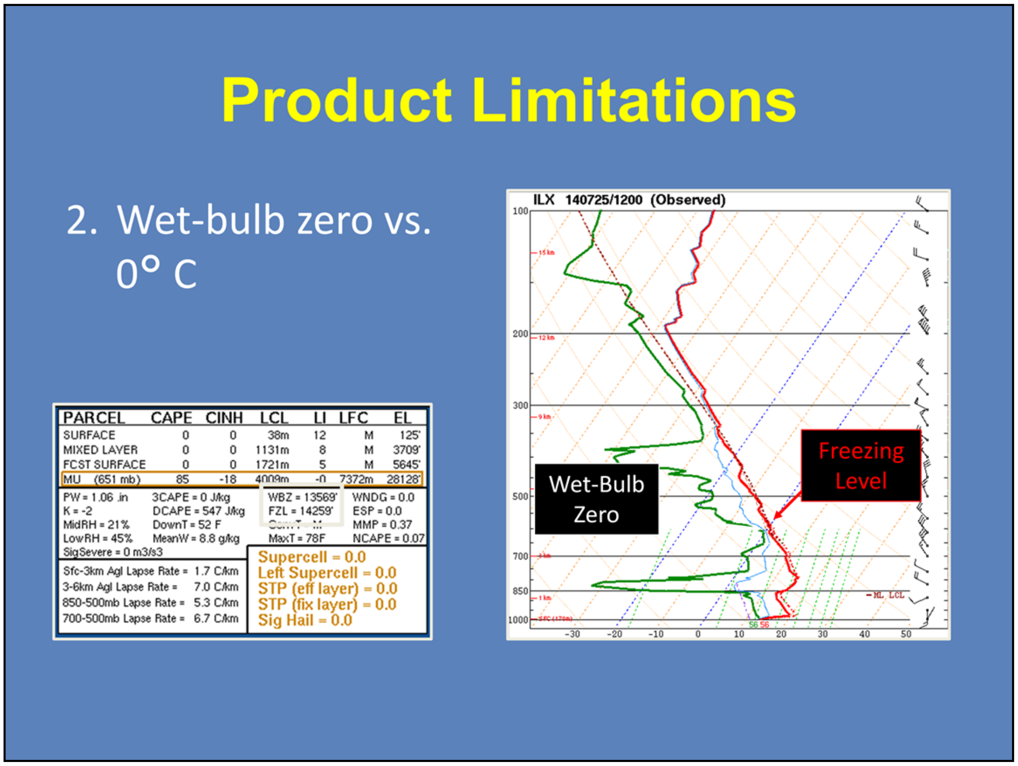
Product Limitations

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?

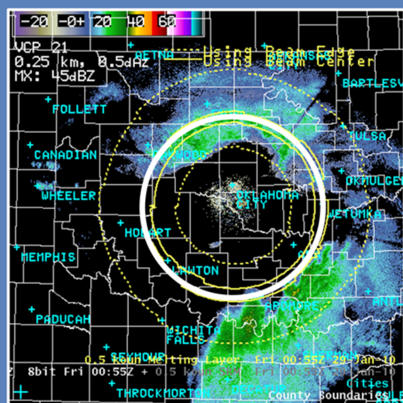
The first situation is when there are fast moving cold fronts. During quick frontal passages, the algorithm can have difficulty maintaining temporal continuity unless there is a lot of precipitation present. A second difficult situation occurs during small-scale stratiform rain events where there is 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.



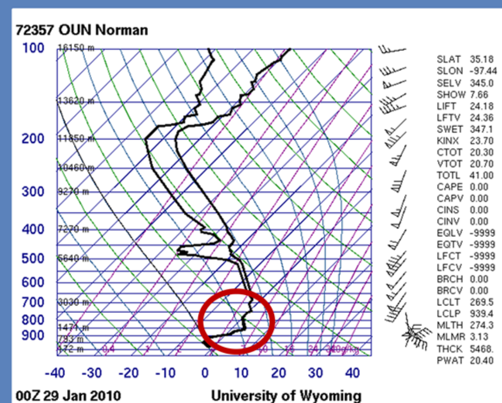
The top of the melting layer is considered synonymous to the 0º C height. While this is true in some cases, the top of the melting layer is actually the wet-bulb zero height. In some environments, there may be a significant difference (~1000 ft or more) between the two heights. If the algorithm has to 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

3. Situations with two melting levels



HC: Liquid precip



Obs: Frozen precip

In the event there are multiple 0 degree Celsius levels, the algorithm will only detect one of them. An example of such a situation includes sleet events. You may see both melting layers in the base data itself under the right circumstances. On the left is the Reflectivity with ML overlaid. On the right is a sounding from the event. Note that the sounding shows two melting layers present, but the ML product only indicates one.

One implication of this limitation is the HC product will indicate liquid precipitation in areas where frozen precip is observed at the ground. Therefore, you should rely on any surface-based spotter reports and sounding data that are available during these types of events.

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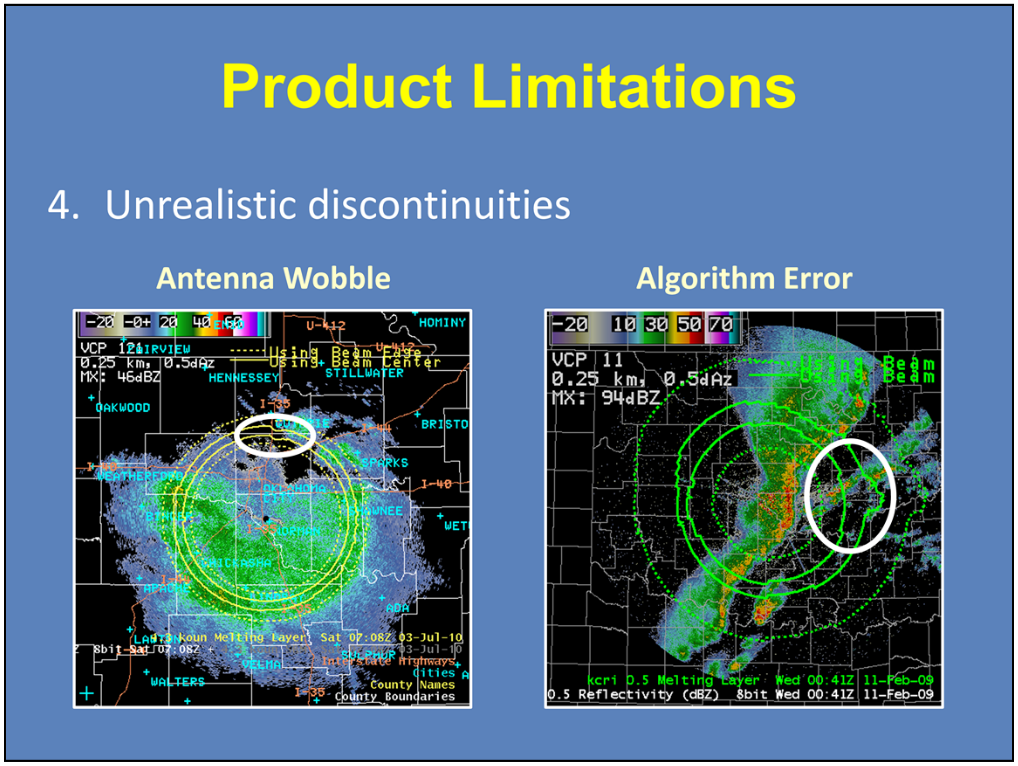

Another limitation to be aware of occurs when there are unrealistic discontinuities in the melting layer display. When this situation occurs, there are two likely causes: antenna wobble and algorithm error.

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.

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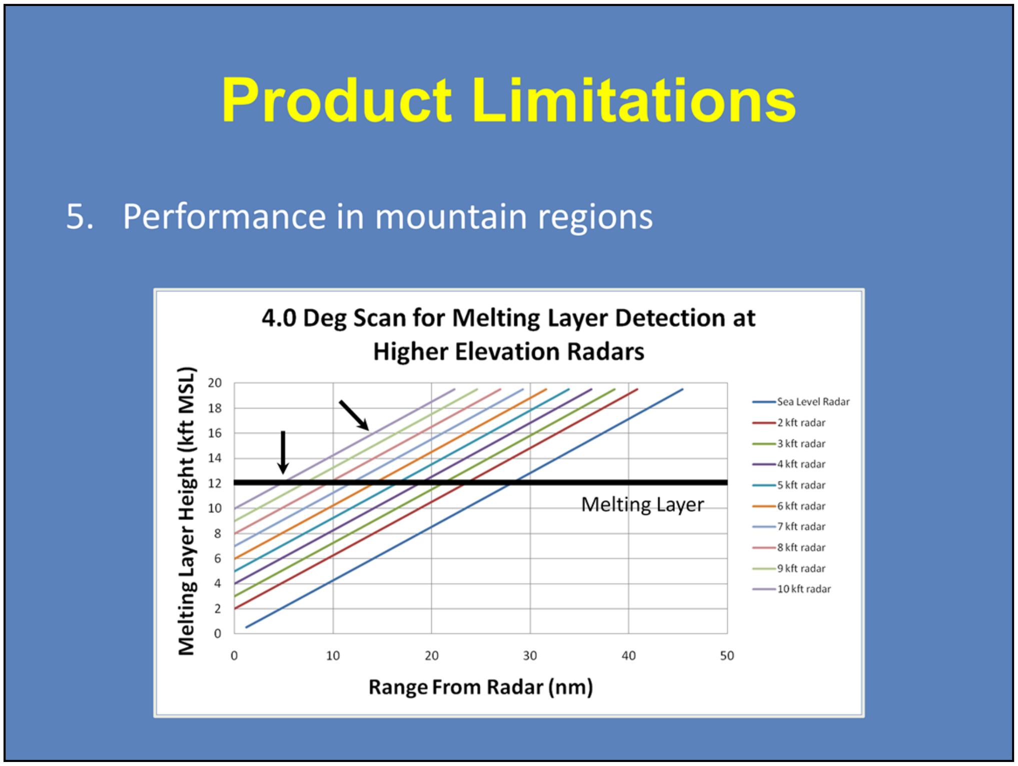
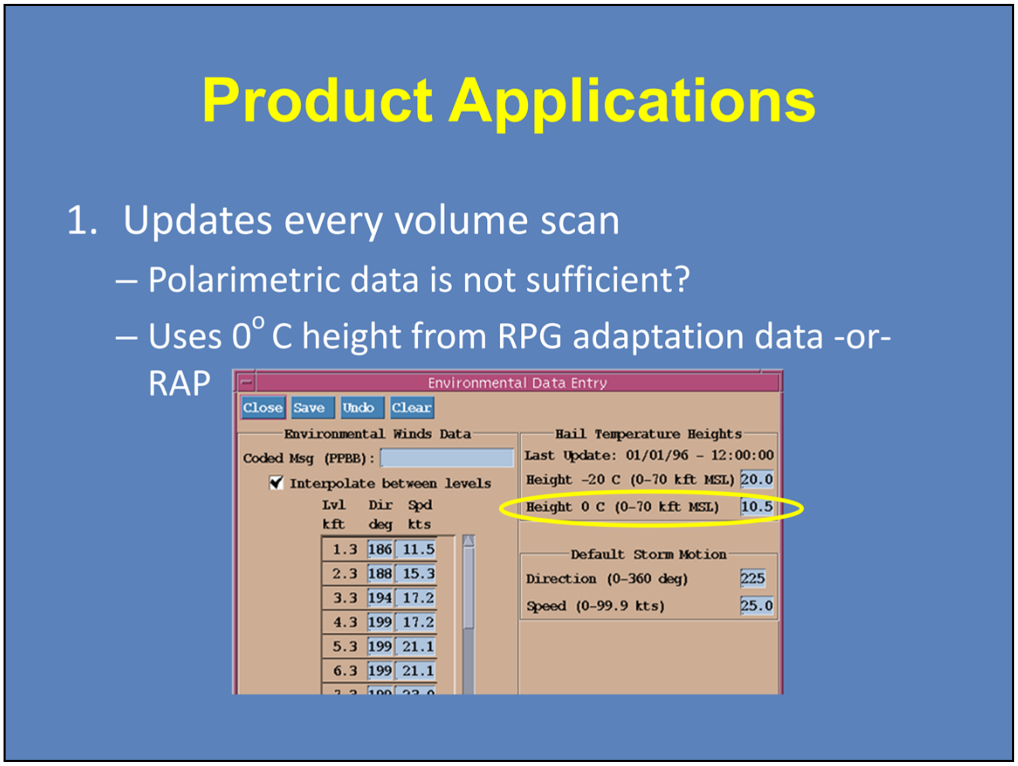


The higher the surface elevation of the radar, the greater the likelihood the radar beam will start in the melting layer or completely overshoot it.. Recall that the MLDA computes the ML product using data between 4 and 10 degrees. At lower elevation regions, using these scans will rarely be a problem. 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.



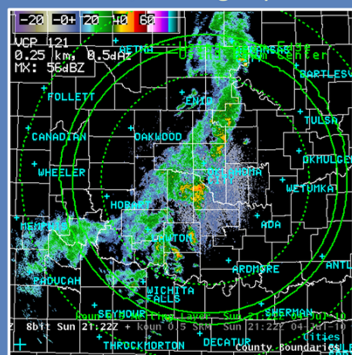
Enough with the limitations…let's move on to the ML applications.

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.

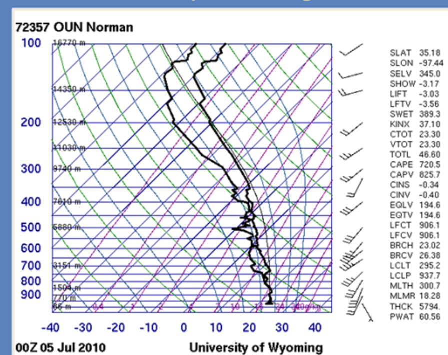
Product Applications

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.

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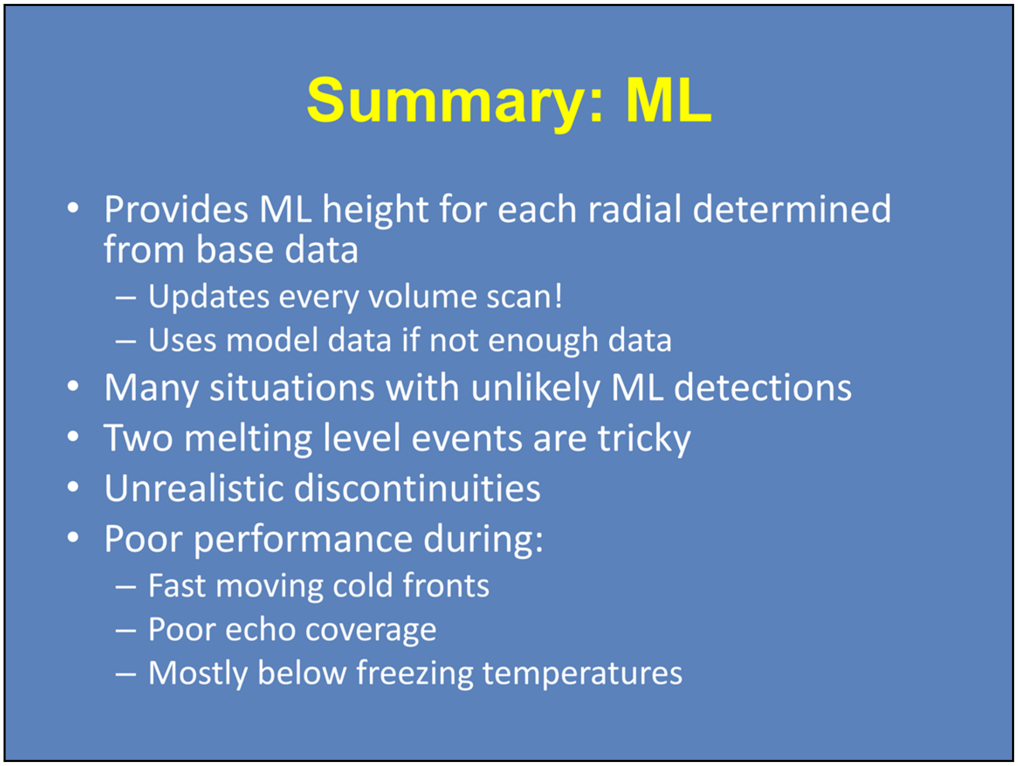

In summary, the ML product provides an updated melting layer height for every elevation, each volume scan based on the base data and/or environmental input at the RPG! There will be many situations where the algorithm cannot identify the melting layer based on radar data alone. The algorithm can only 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.

If you have any questions, feel free to contact us using any of the e-mails listed below.

Welcome to this Topic 4 lesson on PPS rainfall products.

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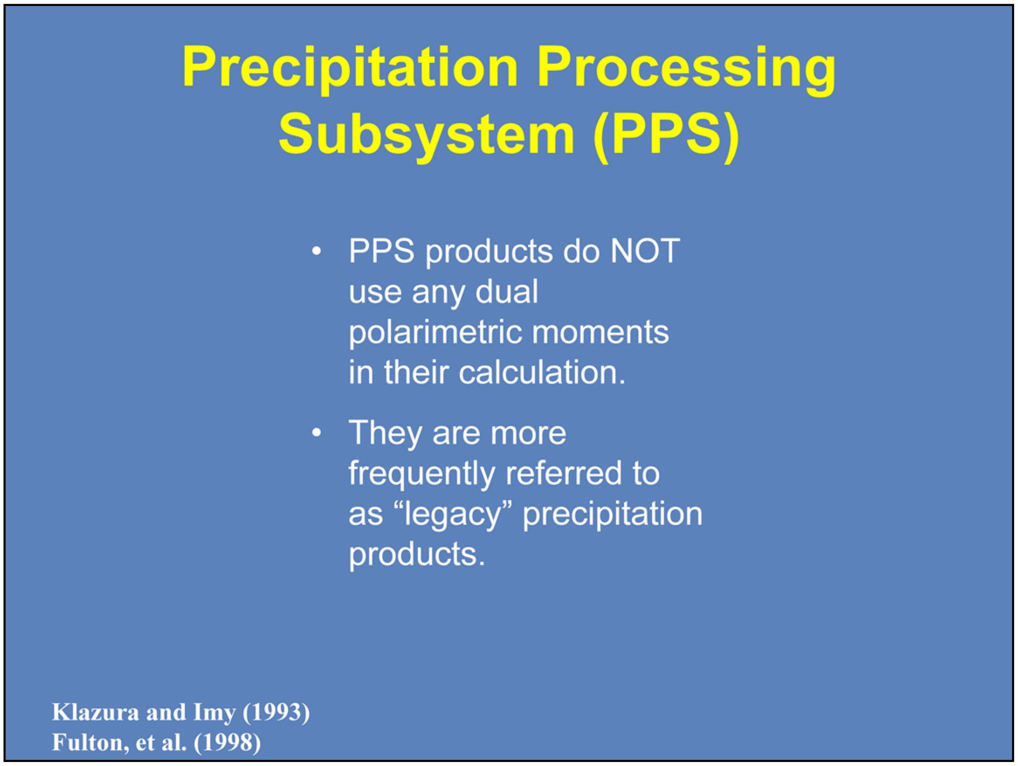

PPS stands for the precipitation processing subsystem. PPS products are the original estimation of precipitation algorithms that came with the WSR-88Dand we're last updated in 2004 . These predate dual pol and as a result do not have any dual polarimetric moments included in the calculations. Operationally, 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.

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.

Products are all located under your precipitation menu on your radar under the legacy precip accumulation products

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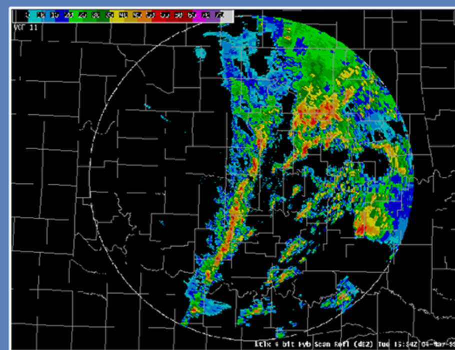
Hybrid Scan Reflectivity (HSR)

- 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.

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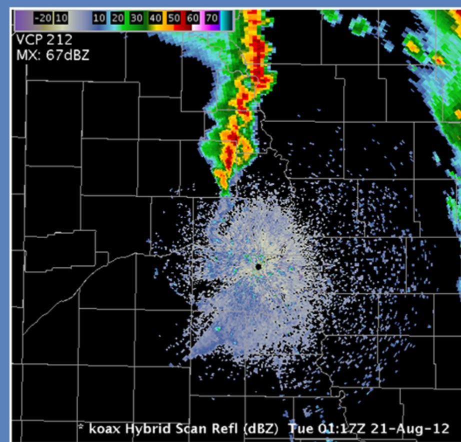
Digital Hybrid Scan Reflectivity (DHR)

- 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.

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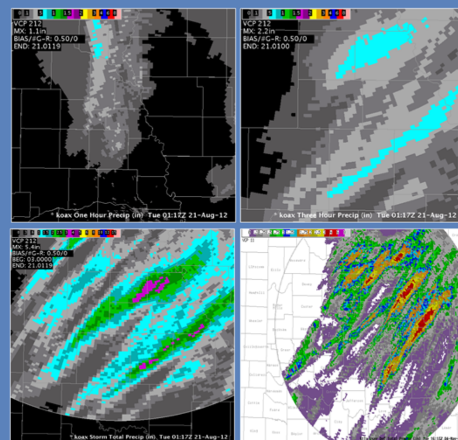
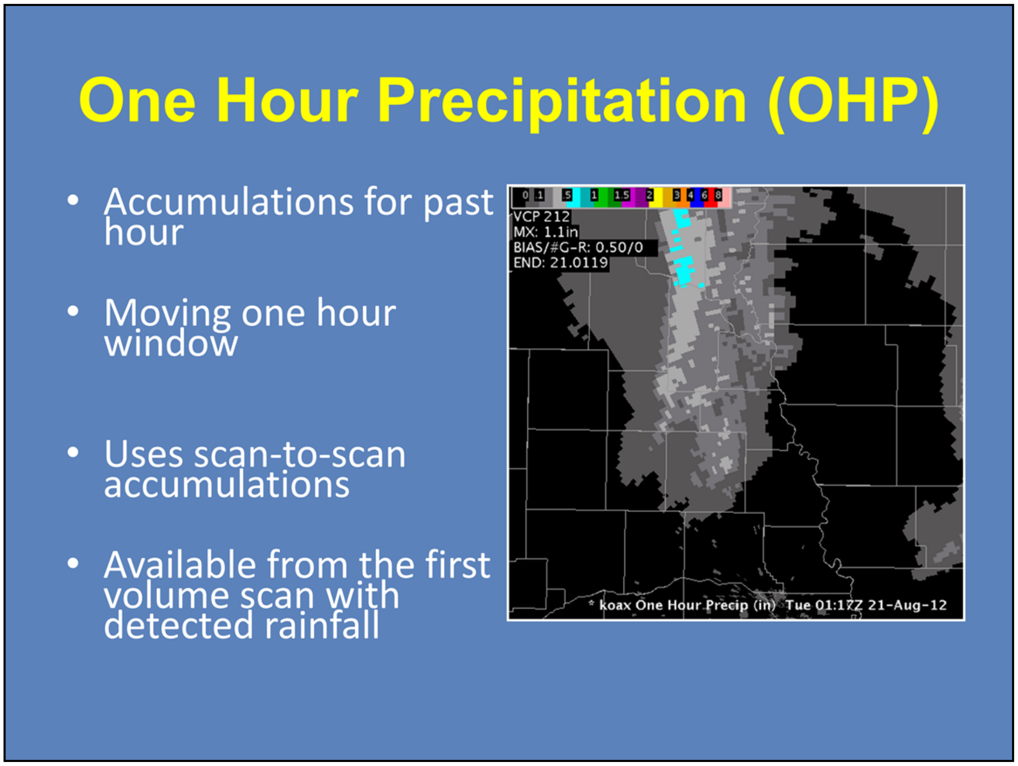
Common Characteristics of All PPS Rainfall Accumulation Products

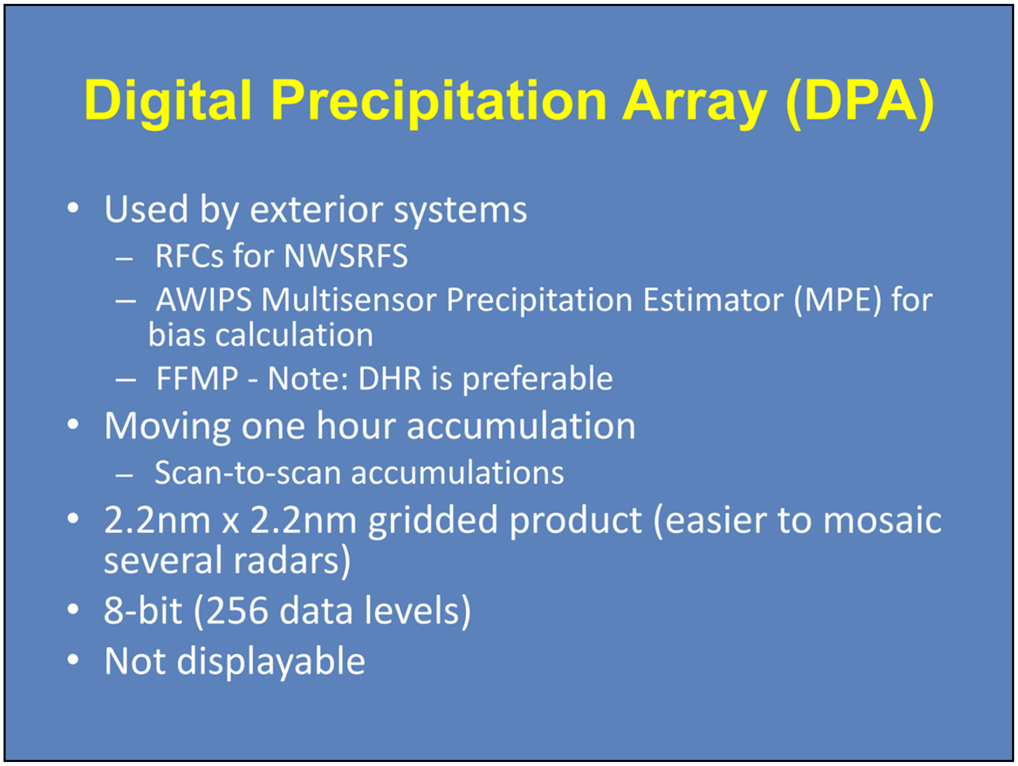
- Built from HSR
- 2 km (1.1 nm) x 1 deg
- 4-bit (one exception)
- 124 nm range



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



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 be one hour. It uses scan to scan accumulations and is available from the first volume scan precip is detected.



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.

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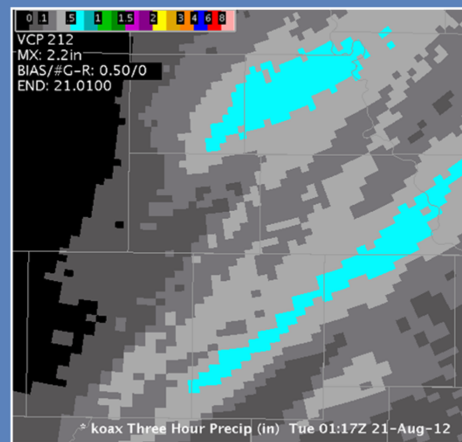
Three Hour Precipitation (THP)

- 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.

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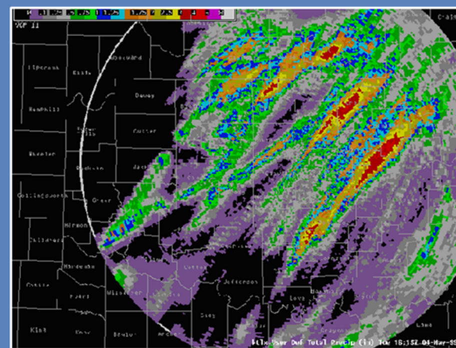
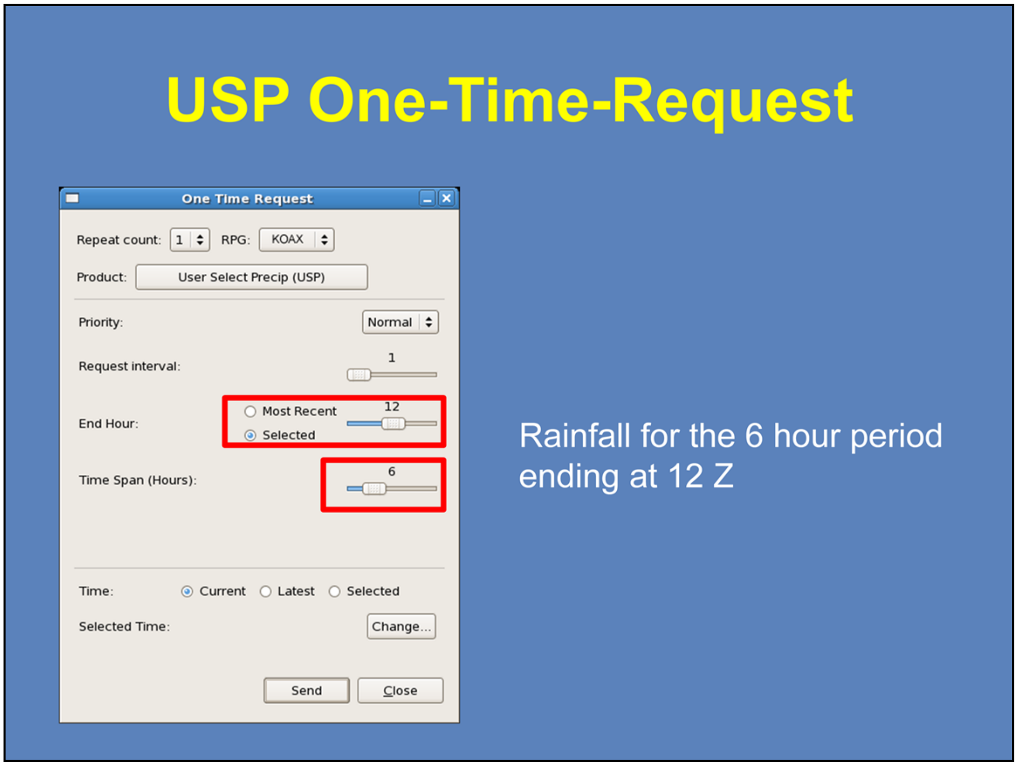
User Selectable Precipitation (USP)

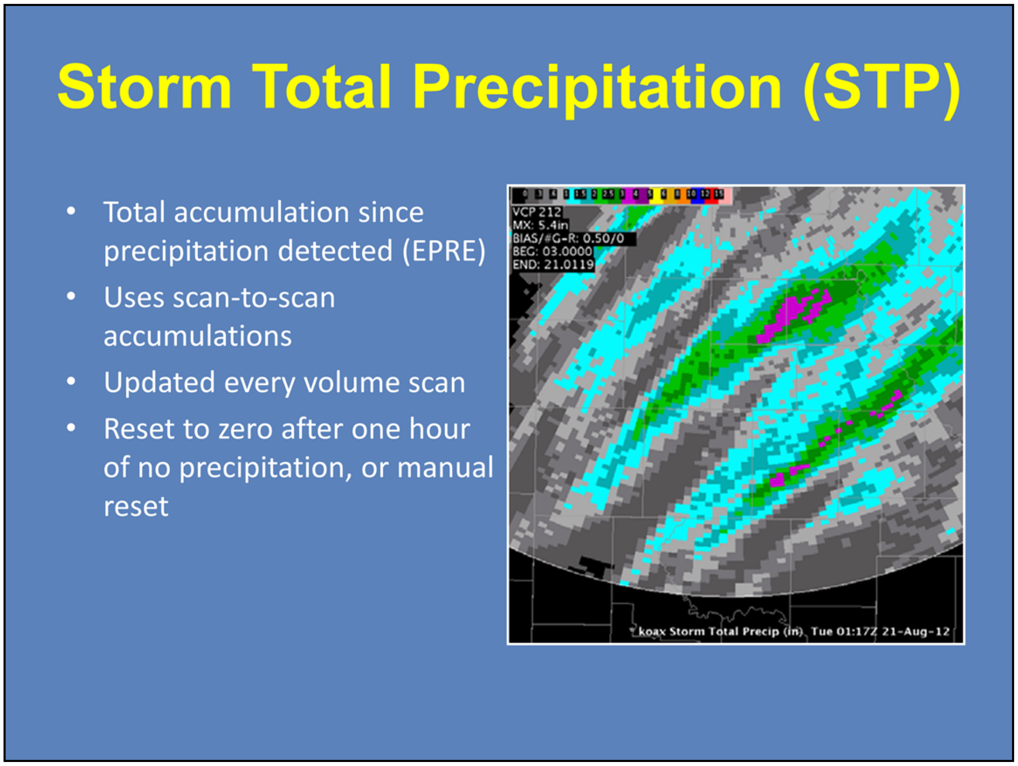
- Accumulations for user specified time
- Top-of-the-hour accumulations
- Past 30 hours are available
- User selects duration (up to 24 hours) & end time
- Default USP:
  - 24 hours ending 12Z



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.



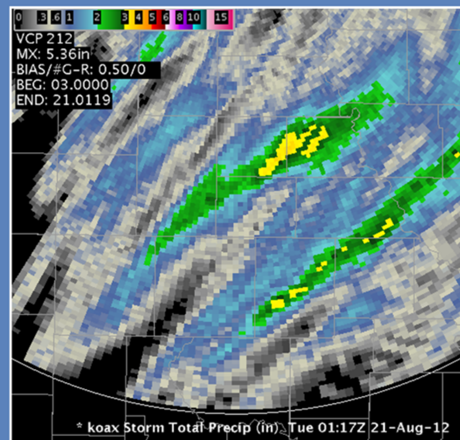
If you're interested in doing a USP one time request you can go to the one time request option on your radars menu, then select the end hour, you can choose the most recent or whichever hour that you would like. You can select a time span going back up to 24 hours. In this case you would get an accumulated rainfall for six hour period ending at 12Z.



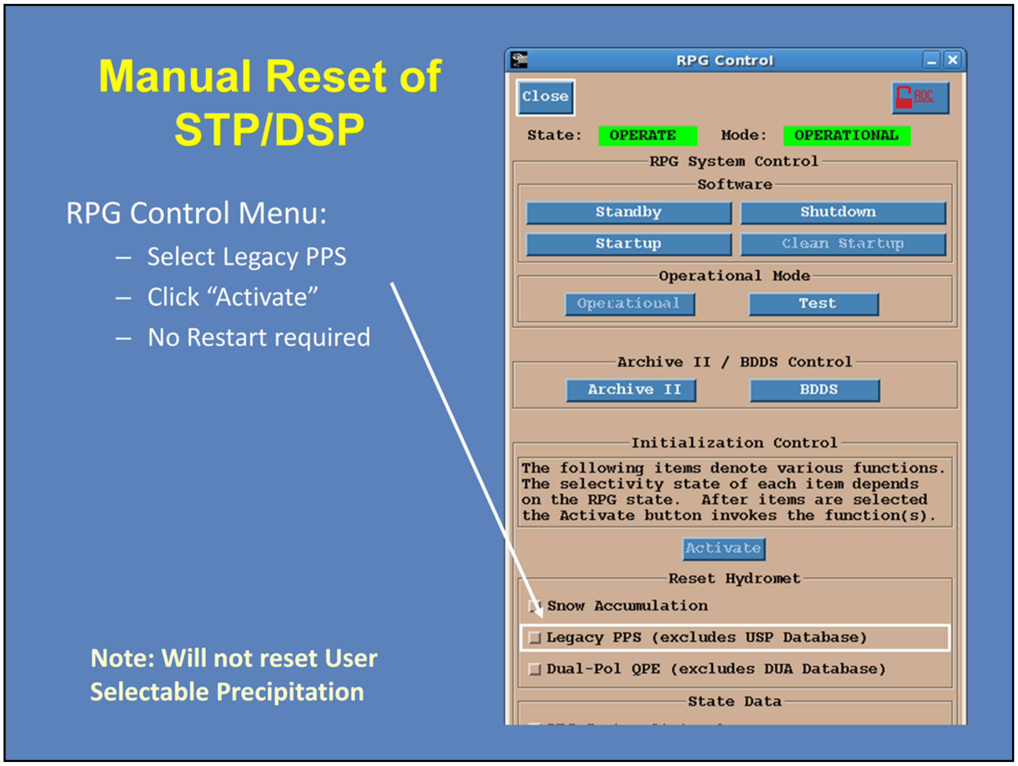
Next product is the storm total precipitation product or STP. This is the total accumulation since precipitation was detected using the enhanced preprocessing algorithm which was last updated in 2004. It uses scan to scan accumulations and it's updated every volume scan. it's reset to 0 after 1 hour of no precipitation or can be manually reset which some offices do as part of their daily checklist.

Digital Storm Total Precip (DSP)

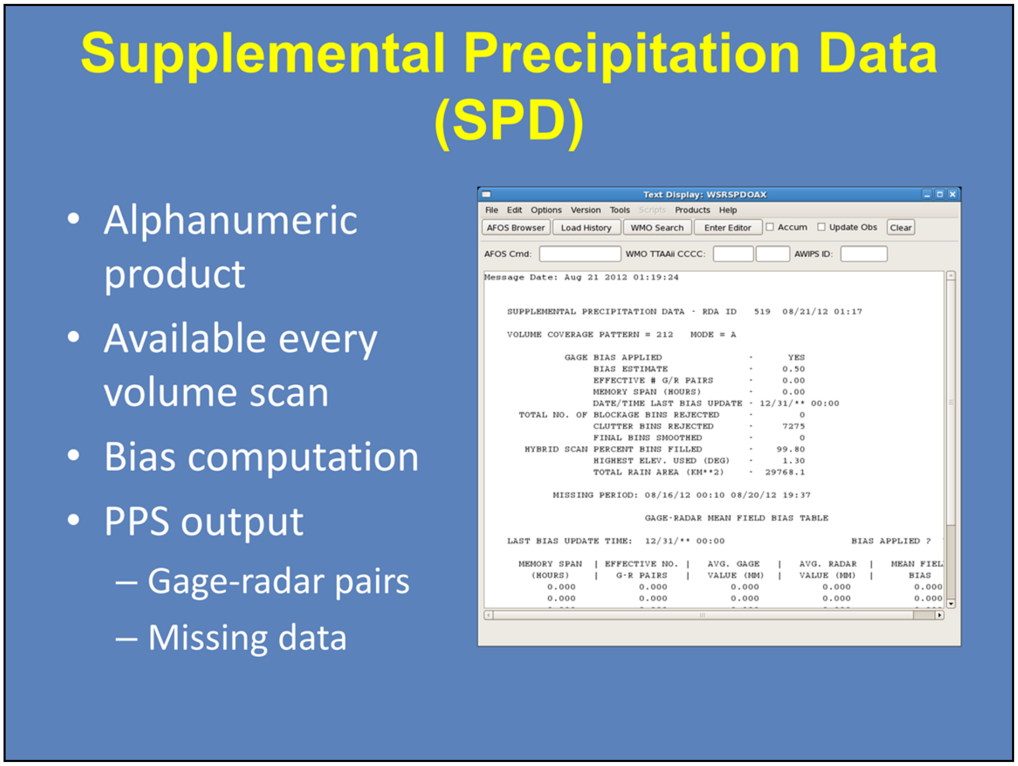
- 8-bit (256 data levels) allows for higher precision in estimates
- Produced same way as 4-bit STP product
- Preferred storm total product, except if you have bandwidth issues



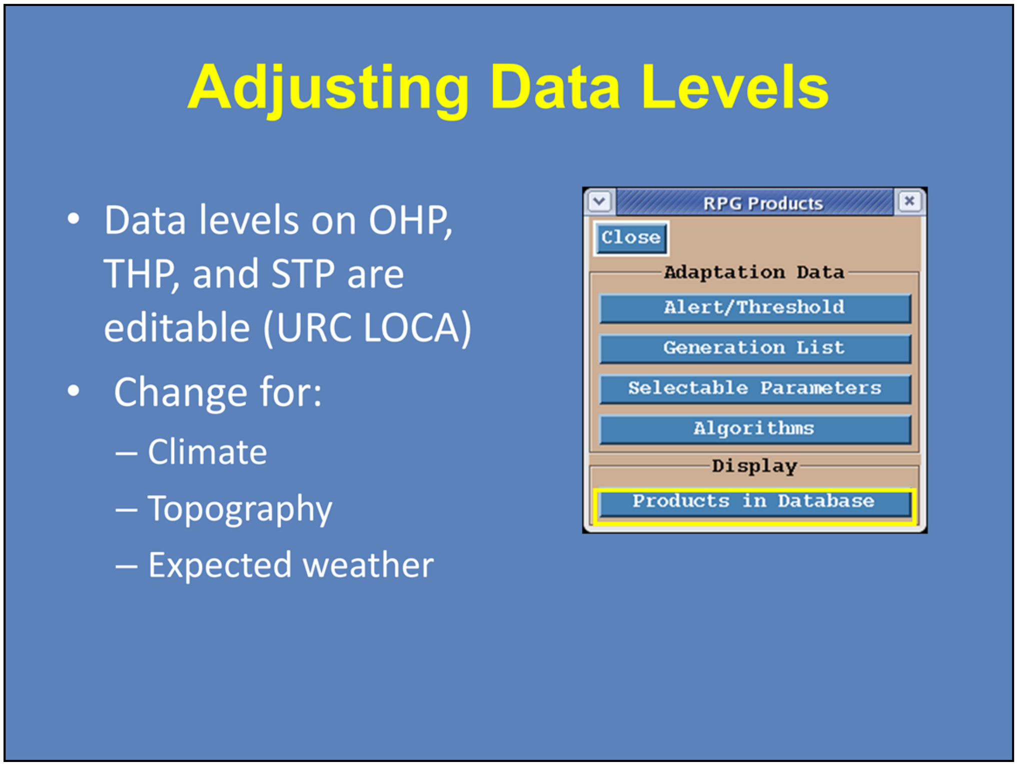
This is the one exception that I mentioned earlier with respect to 4-bit being the standard resolution. I know there was DPA, but it was not a displayable product. Anyhow, this product here is the high resolution storm total precipitation product, or DSP. It is 8-bit allowing for higher precision in 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, provided you do not have bandwidth issues.



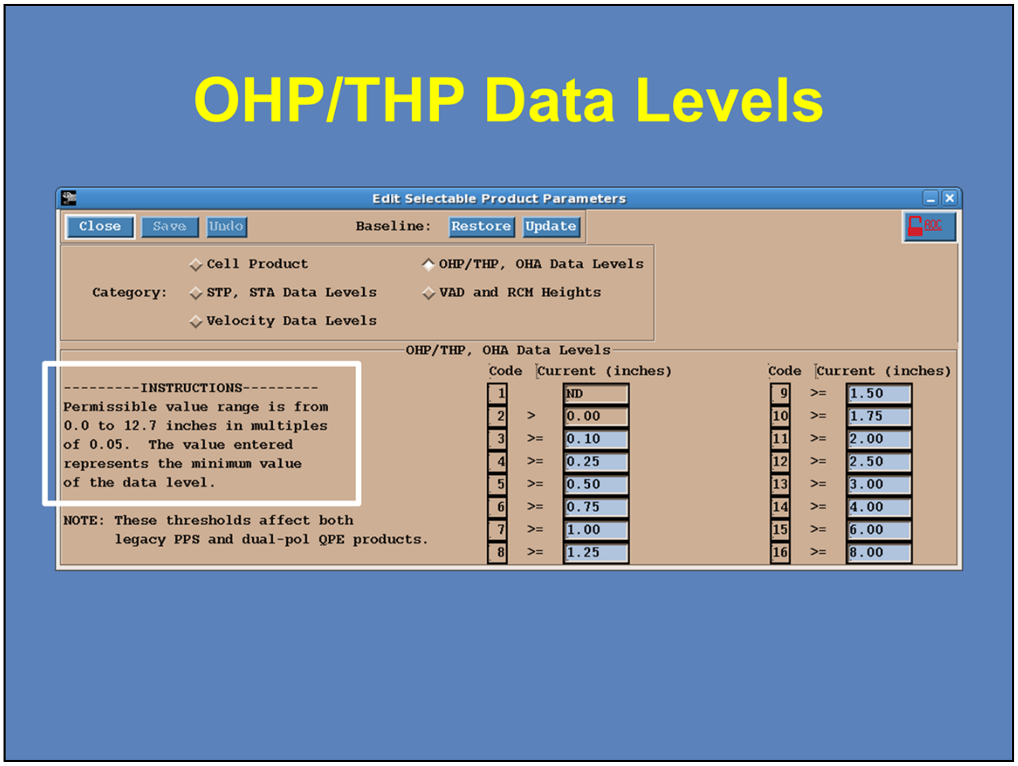
Manual reset of your STP and DSP can be conducted through your RPG control window on your HCI. It will not reset user selectable precipitations if you have a one-time request there that will continue to keep going. Just go to your RPG control, enter your URC password and then select legacy PPS and click 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.



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.



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 but in the open rolling hills of Nebraska maybe a different level of rainfall and that way you can make calls on if you want to see a different level to account for those higher or lower values.



Here’s what the edit window looks like in the RPG. Notice that you can go from 0 to 12.7 inches in multiples of 0.05 inches in the OHP in and THP products.

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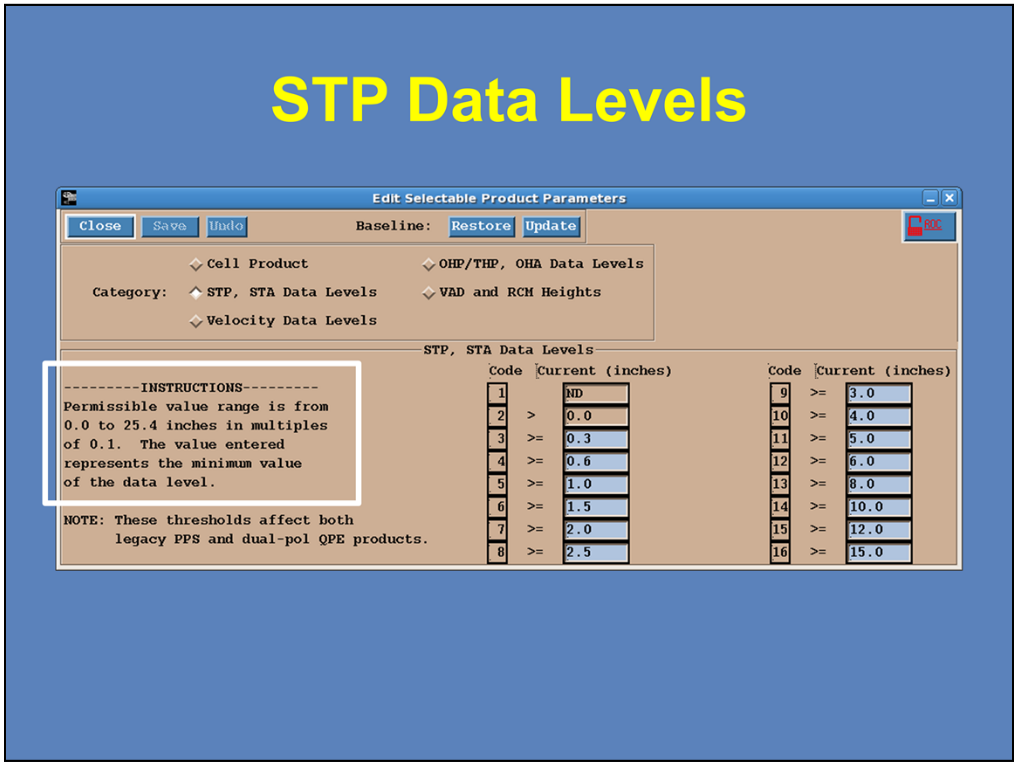

The storm total precipitation products are editable up to 25 point 4 inches in multiples of 0.1 But you notice in this case if you happen to have a 15 or 16 or 17 inch rainfall there wouldn't be any way to discriminate that so if you're expecting a tropical cyclone maybe you give up the first couple degrees of levels in order to discriminate a higher level rainfall.

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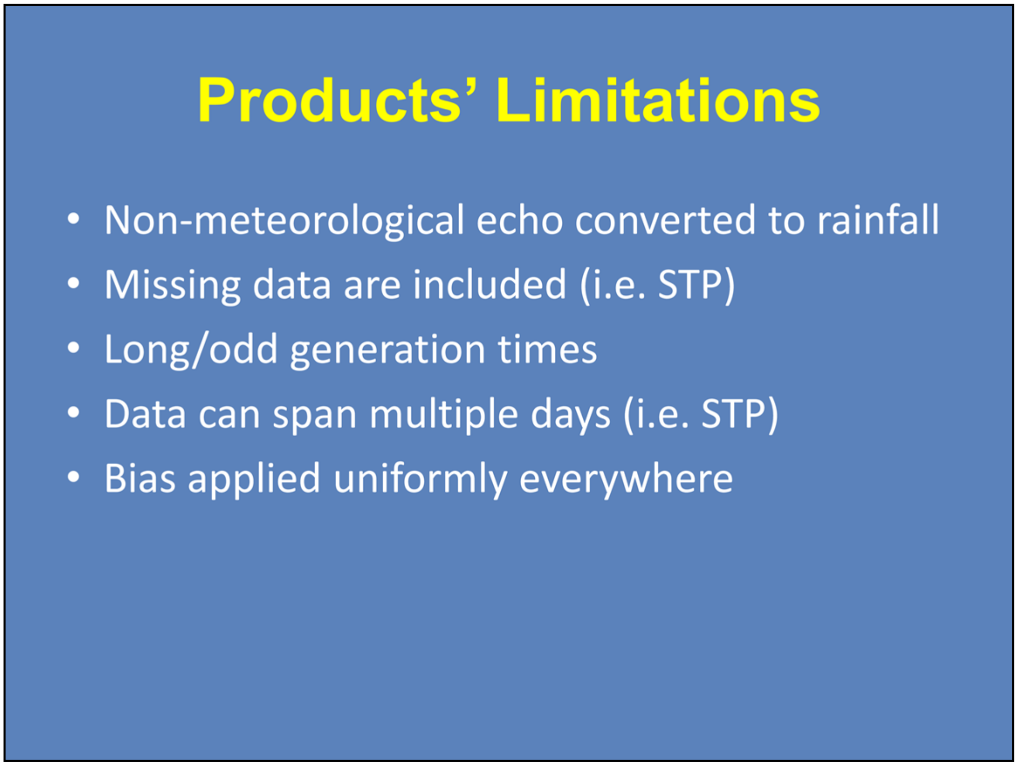
Missing Data / Outages

Missing Data > 6 min (outages > 30 min)	
OHP	Not generated until 1 complete hour of data
THP	Not generated until 2 top of the hour accumulations are available
USP	Not generated until 2/3 of the requested hourly accumulations are available
STP	Generated regardless of missing data / outages

So with the terminology “missing data” versus “outage”, what do the two mean? Missing data implies greater than 6 minutes where an outage implies greater than 30 minutes of missing data. The 1 hour precip product is not generated until 1 complete hour is available. THP is not available until two top of the hour accumulations are available. The User-selectable precipitation product is not generated until at least two-thirds of the requested hourly accumulations are available. And storm total precip is generated regardless of missing data or outages, it just keeps trucking along.



Limitations of all of the precipitation products include non-meteorological echoes in the legacy products can be converted to rainfall. If you have a lot of biological scatterers, or wind farms or bird migrations or ground clutter that can be converted to rainfall.

Missing data are included in the storm total accumulation product. It can have long or odd generation times if you're having trouble with your radar getting information. If everything is running smoothly though it shouldn't be a major problem.

The data can span multiple days especially if its not reset. You see this frequently, lets say you have flash flooding on a Tuesday and you come in on a Wednesday and you pull shift in your STP product is going to have that previous days rainfall rainfall is in there. Now that's useful because maybe you're looking at sore spots for additional flash flooding but if you want to see what's currently falling it could be contaminated by the previous days rainfall.

And the bias is applied uniformly everywhere where in reality it is a little higher or lower depending on how the climate changes from one end of your CWA to the other.

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Products' Applications

- Assessing flash flood potential (most commonly OHP and STP)
- Radar-gauge pair bias applied
- DHR used as input into FFMP/HPE
- Flexible time intervals (i.e. USP)
- Tracking rainfall paths
- Post storm analysis

Applications of the PPS or legacy products are primarily assessing flash flood potential. That is the primary emergency reason you're going to be using these products like OHP and STP you could also use it for any other meteorological operational application like how much rain is fallen in the last hour, is it light rain or heavy rain. Like in a NOWcast you might say rainfall rate so "generally be less than a tenth of an inch." A radar gauge pair bias is applied so its including ground-truth gauge data in the calculation. Digital Hybrid Reflectivity is also an input into FFMP. Flexible time intervals are available using the user selectable Precip product. You can also track rainfall paths and conduct post storm analysis.

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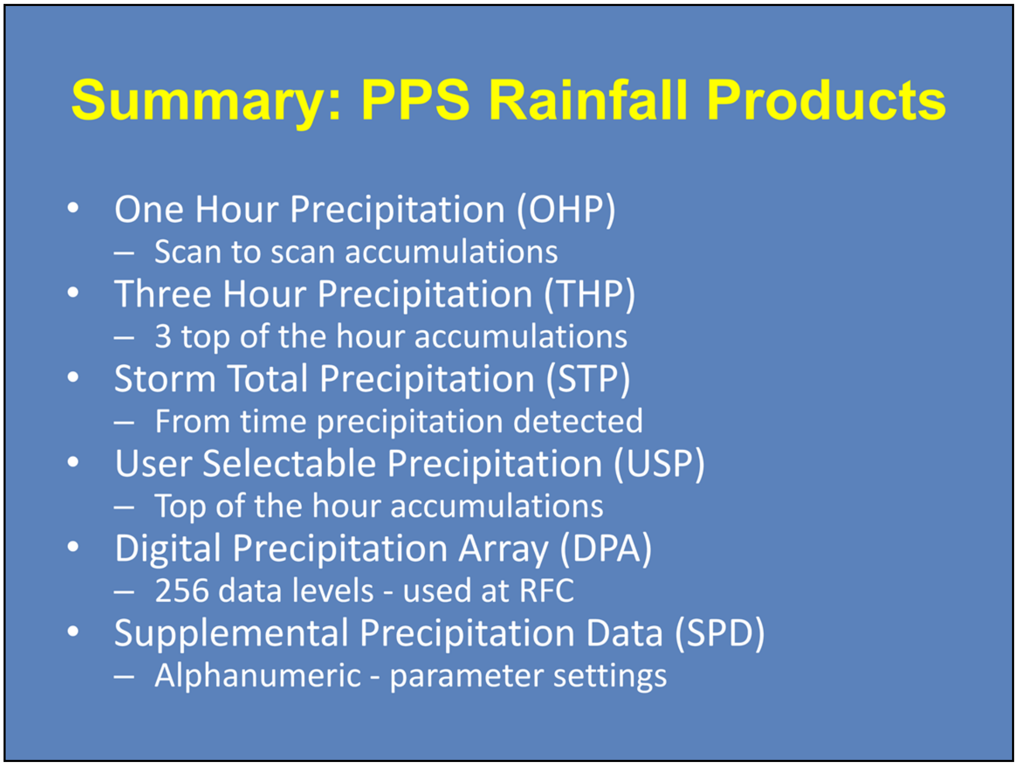

In summary, here are the products we just learned about and their primary uses. OHP tells you the past hour of precipitation that has fallen, and it is updated every volume scan. The THP tells you the past 3 hours of precip and it is generated using the past 3 top of the hour accumulations. STP tells you the amount of precip that has fallen since the first precip was detected. USP allows you to determine accumulations that are off the 1 and 3 hour time frames, using top of the hour accumulations. The DPA product is a 1-hour accumulation product that is 8-bit, but it is only used at the RFCs and is not displayable in AWIPS-2. Finally, the SPD is an alphanumeric product that gives you parameters setting used in EPRE.

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That’s it for lesson, Any questions email myself or anyone on this team responsible for putting everything together, and thank you for listening.

Welcome to the Topic 4 lesson on Dual-Pol QPE rainfall products.

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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.

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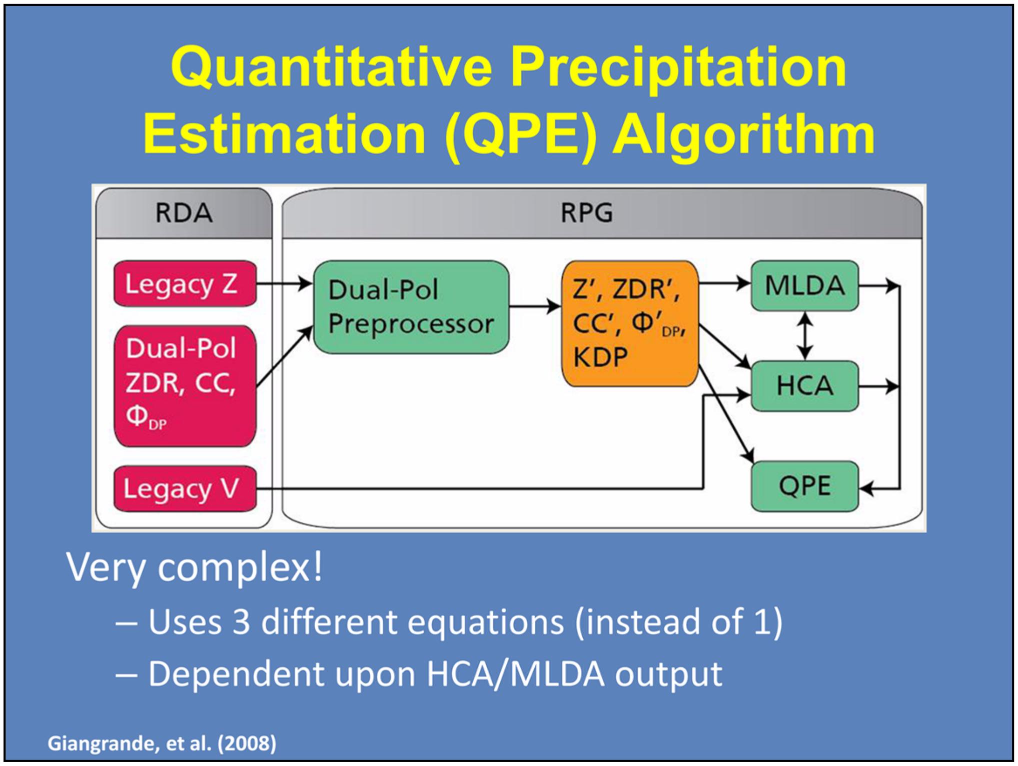

Like the PPS lesson, we'll quickly go over the algorithm that outputs the QPE rainfall products. As the name implies, the algorithm is the Quantitative Precipitation Estimation algorithm, or QPE. This graphic should look familiar from Topic 3. The QPE is much more complex than the PPS. It uses 3 different 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 ☺

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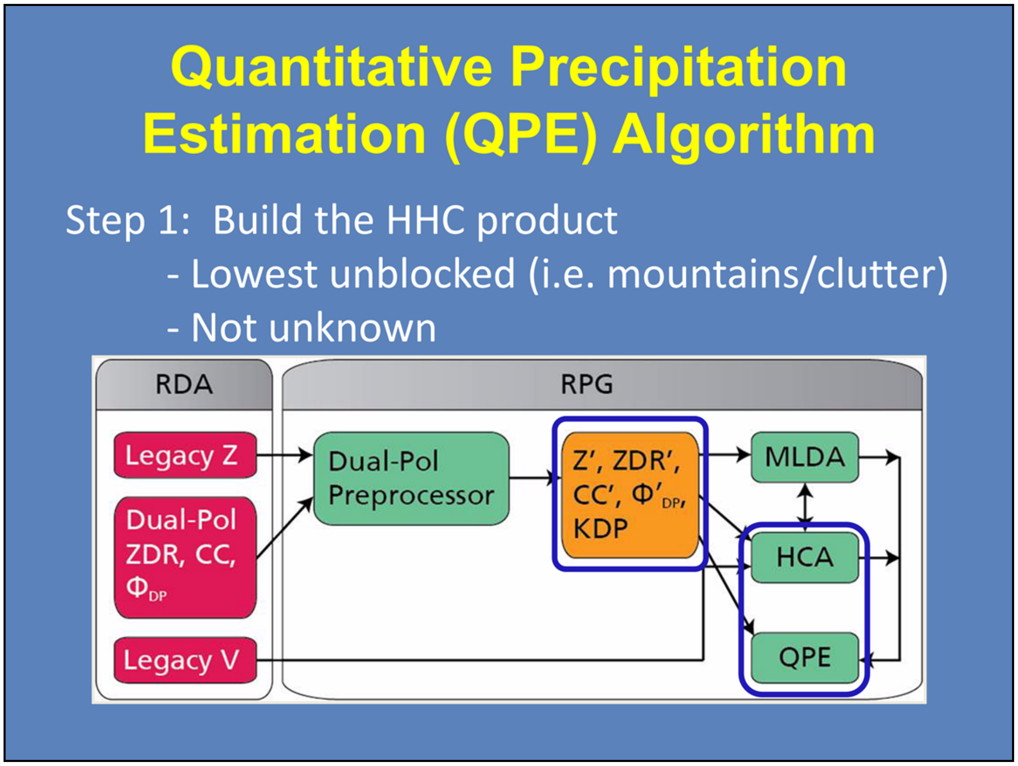

Step 1 in QPE is to build the hybrid hydroclass product, or HHC. It is the basis for what precipitation equation is used for each bin. This product is built by the base data first going into the HCA. From there, the HCA outputs the hydrometeor classification product, as we learned a few lessons ago. 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.

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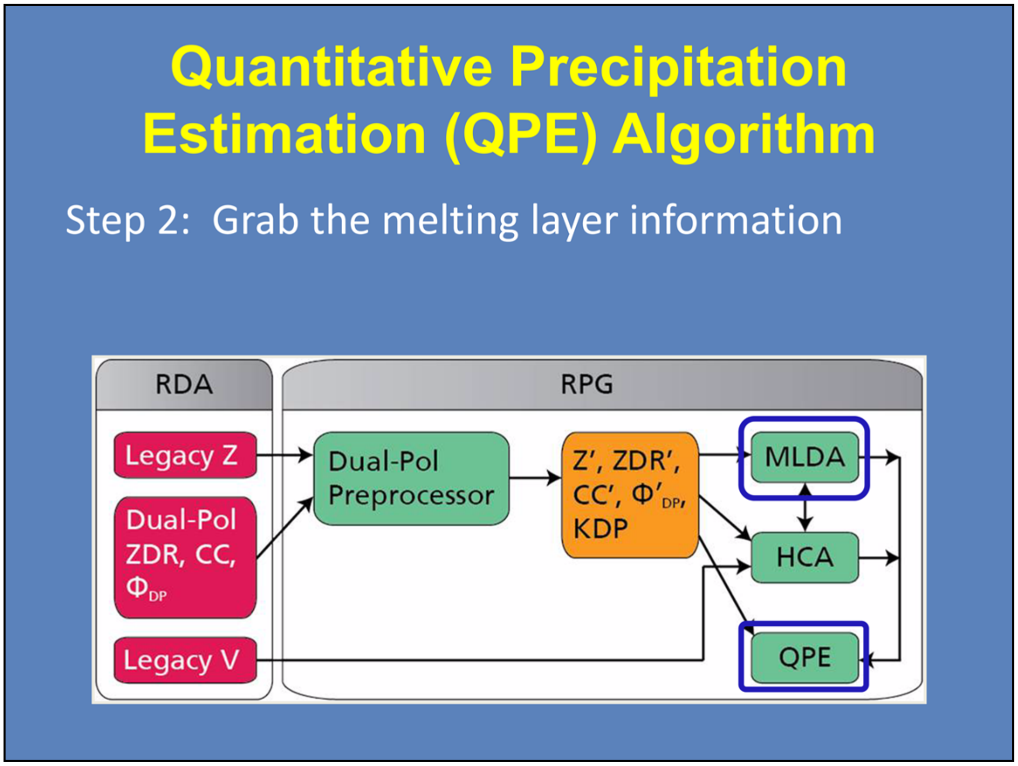
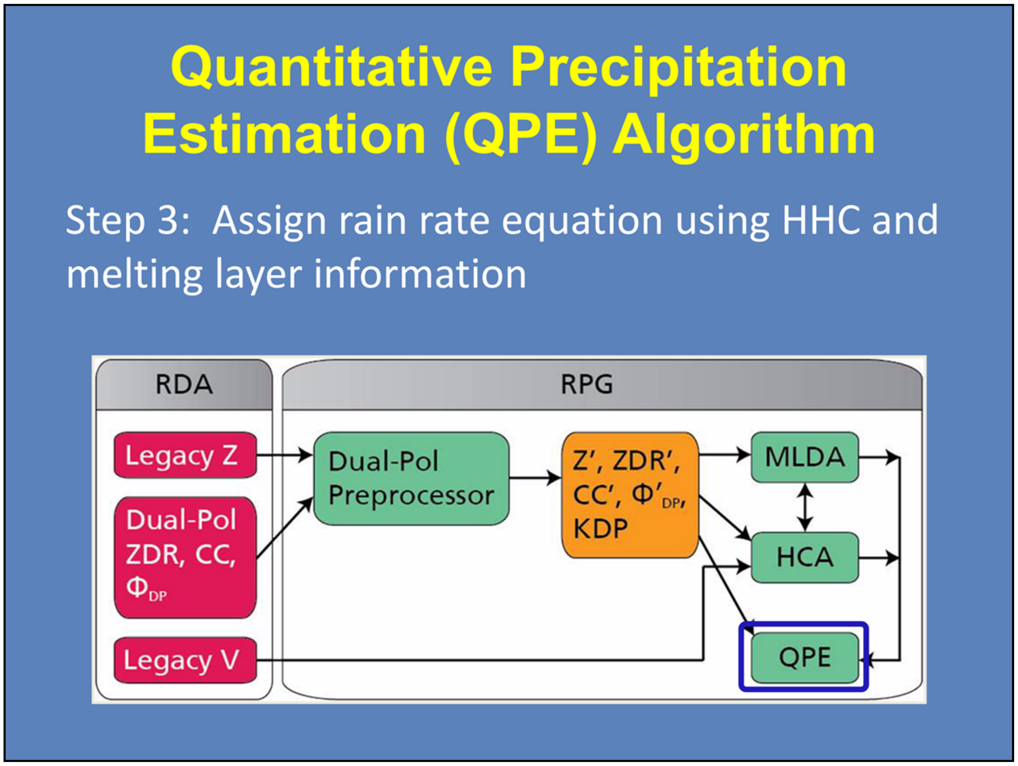


Next, the QPE inputs the melting layer height information. This basically is used as a quality control check for what precipitation types are allowed in the HHC. For instance, rain above the melting layer does not make sense. Secondly, different rain rates are applied depending on the height of the bin relative to the melting layer.



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.

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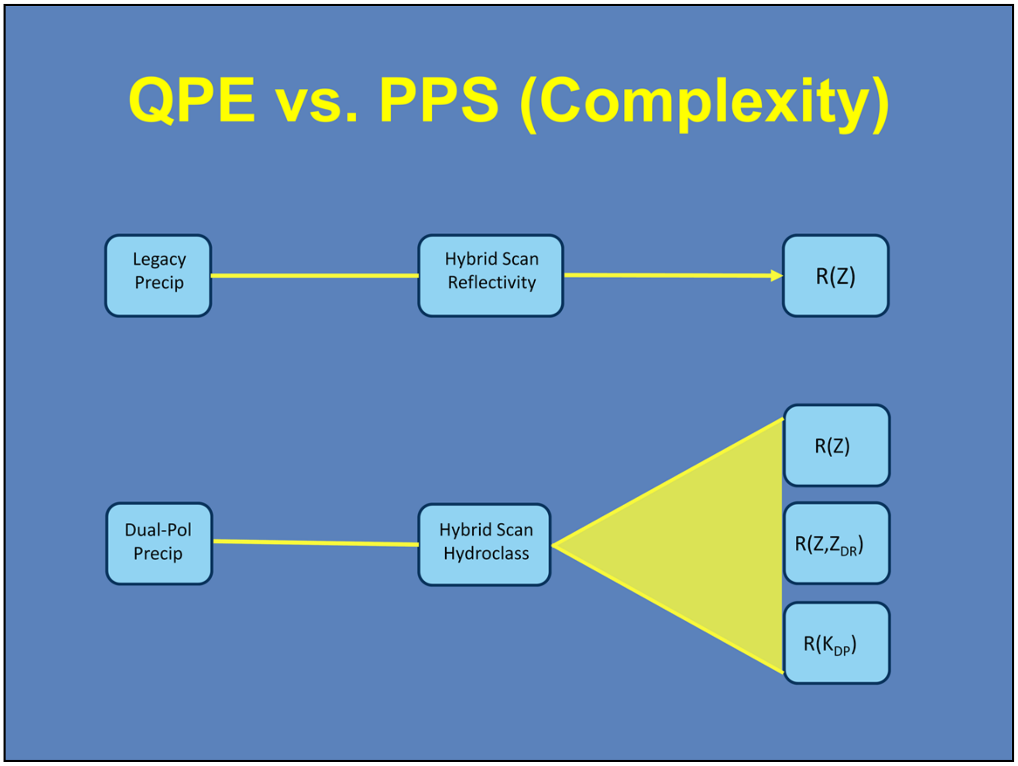

Here is just a graphic to show you the complexity of the QPE compared to the PPS. See how the PPS has only one rainfall accumulation equation, whereas the QPE has 3.

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* ≤ 45 dBZ	R(Z, Zdr)
Heavy Rain (HR) *and* blockage ≥ 20% *or* Z > 45 dBZ	R(Kdp)
Rain/Hail (HA) *and* blockage ≥ 5%	R(Kdp)
Rain/Hail (HA) *and* echo is *at or below* the top of the melting layer (ML) *and* blockage < 5%	R(Kdp)
Rain/Hail (HA) *and* echo is *above* 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 *at or below* the top of the ML	R(Z)
Dry Snow (DS) *and* echo is *above* the top of the ML	2.8*R(Z)
Ice Crystals (IC)	2.8*R(Z)

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 its raining based on what the radar is returning. Some of the key differences, especially with regard to legacy PPS, and also some changes that have been made, keep in mind this is the latest technology. So 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 thats customizable and the ROC suggests that you attempt to do that, to try to add some skill.

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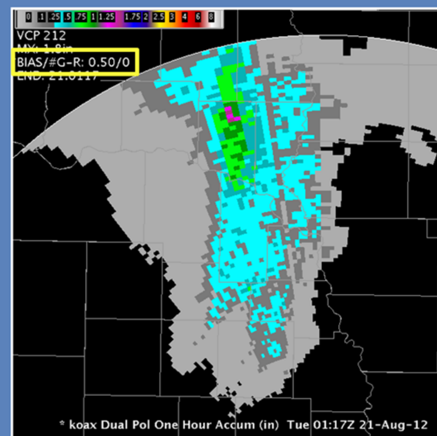
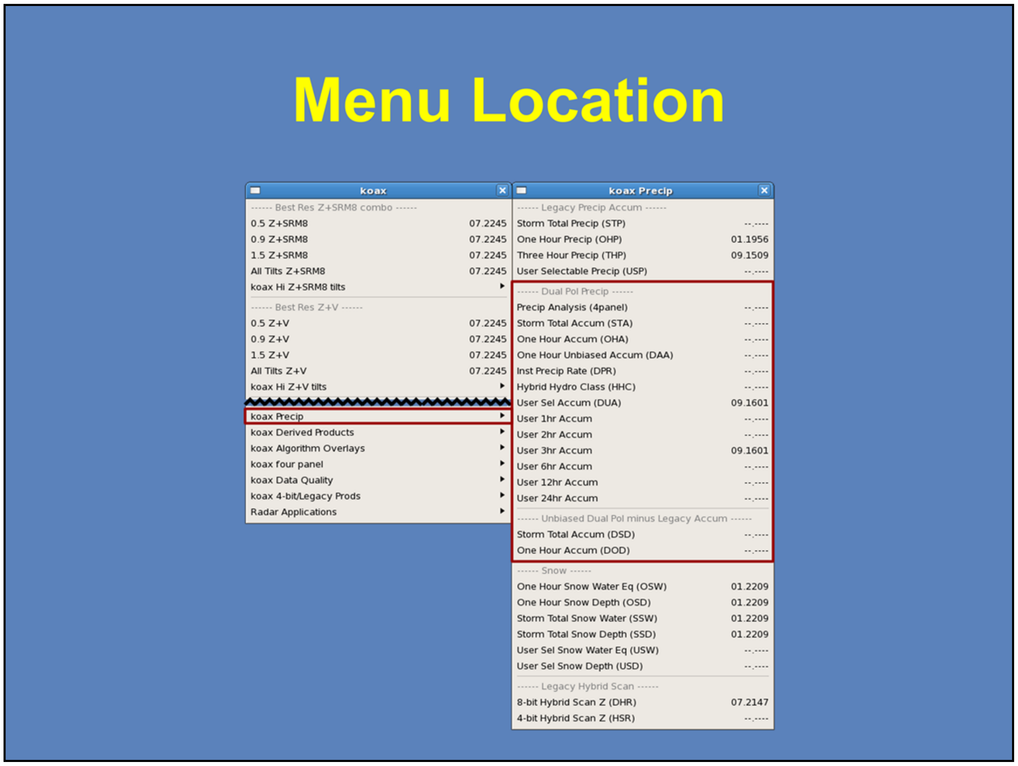
First!

- 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.



The QPE products can be found in the dedicated radar drop down menu inside the Precip submenu shown here.

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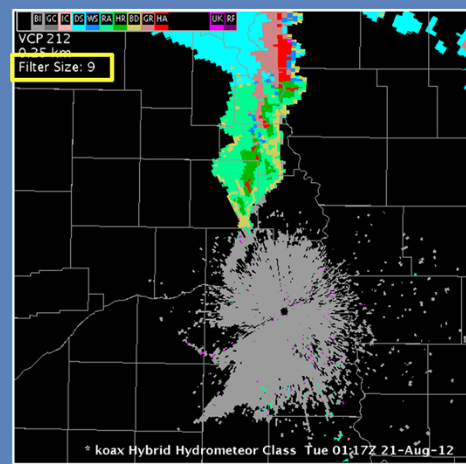
Hybrid Hydroclass (HHC)

- 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.

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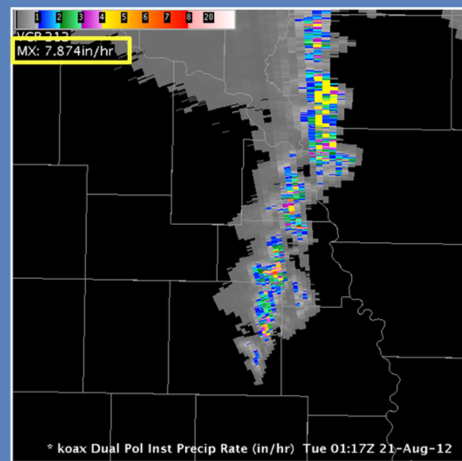
Digital Precipitation Rate (DPR)

- Displays instantaneous precipitation rate!
- 250-m resolution
- 16-bit product (65536 data levels)

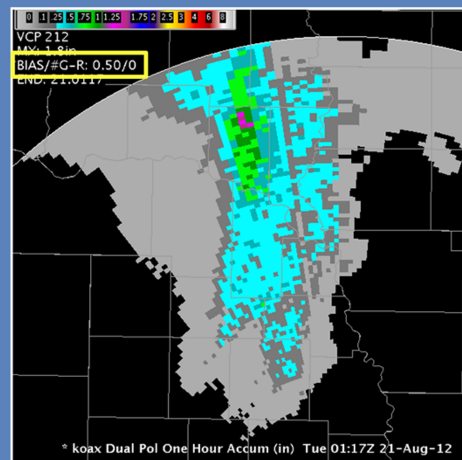
Caution: Large product size



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 caution about DPR: because of file size, low bandwidth connections to some radars may not be able handle it.

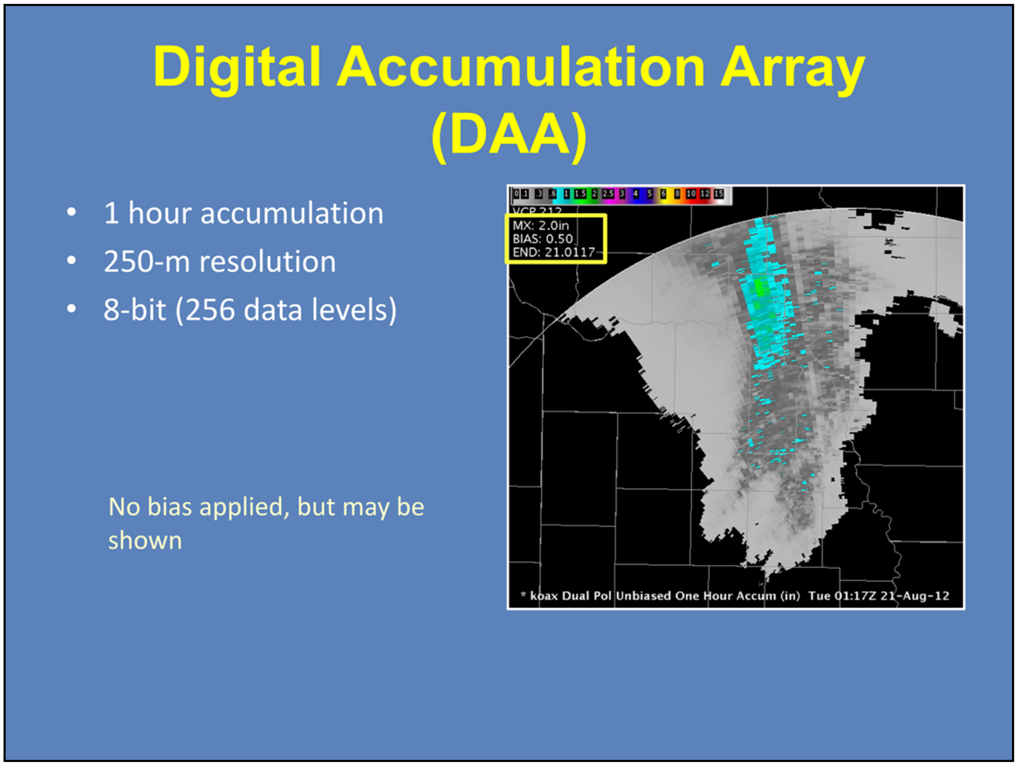
One Hour Accumulation (OHA)

- 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 even though you see an entry in the product annotation. Also, if you do see a value other than 1 listed here, as is the case in this example, this means that the PPS is applying that bias to its products, and the QPE products will display that bias, but it is not applying it.



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.

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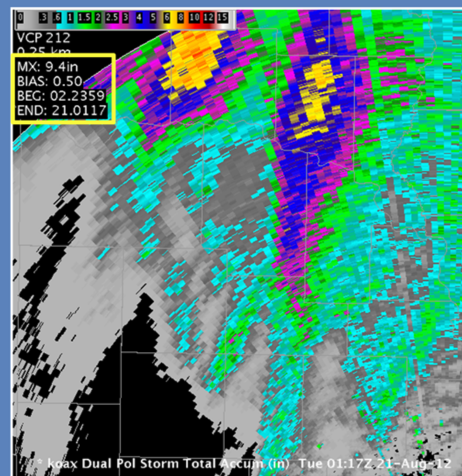
Storm Total Accumulation Products (STA / DSA)

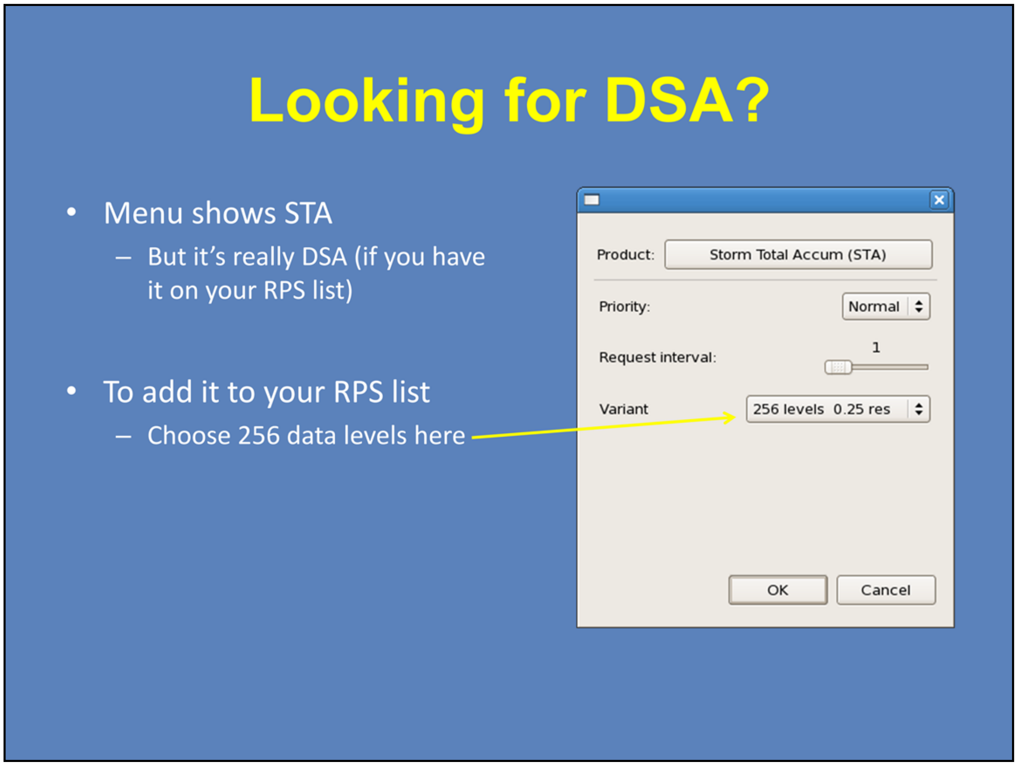
Digital Storm-total Accumulation (DSA):

- 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.



If you look in the menu for DSA, you'll never find it! Only STA is listed. So, where can you load it? If you have DSA in your RPS list and you choose STA from the menu, it will load the DSA product. Very confusing, I know! And, if you don't have DSA on your RPS list, when adding it, choose STA as the product, but then choose "256 levels, 0.25 res" to make it DSA. If you really want STA, choose "16 levels, 2 res".

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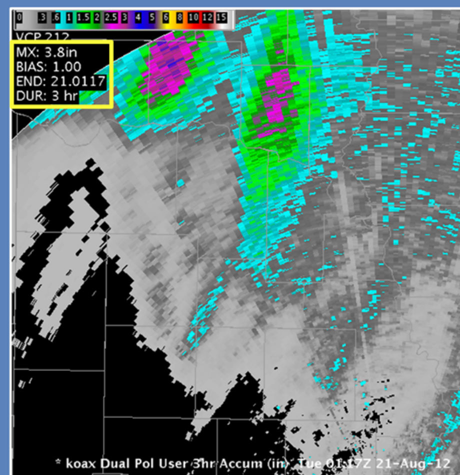
Digital User-Selectable Accumulation (DUA)

- 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.

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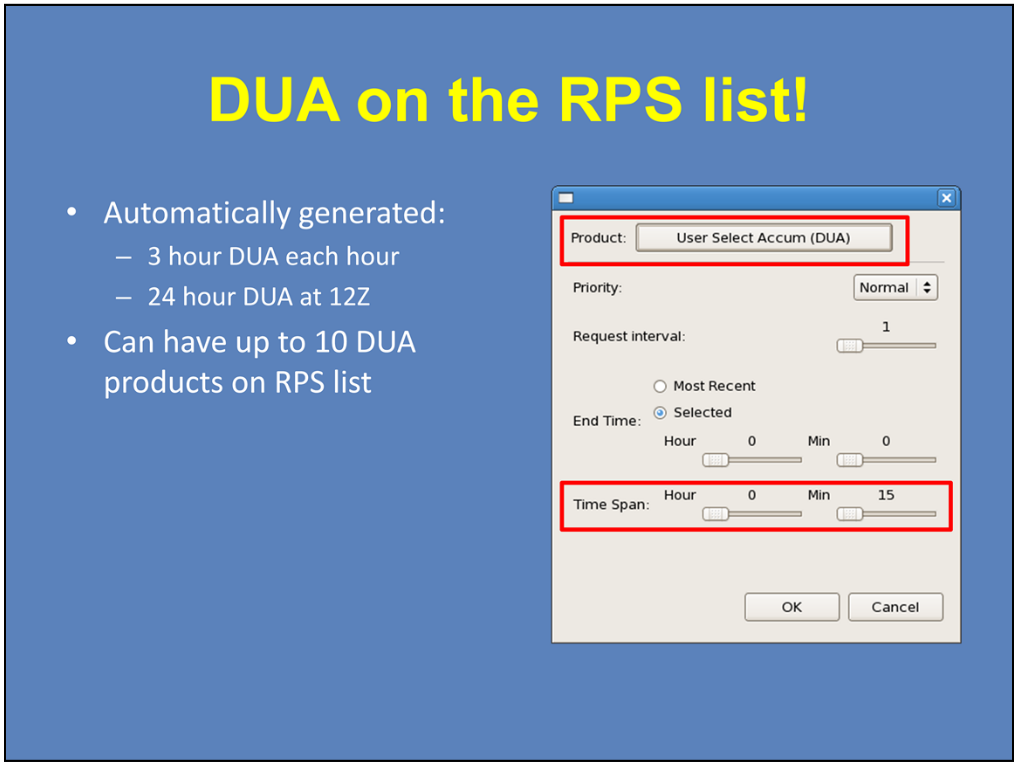

You can request DUA for other durations by adding them to the RPS list. Open the RPS list editor and choose "User Select Accum (DUA)" from the product dropdown menu. Use the two slider bars to choose the desired duration of the product in hours and minutes. Remember, the lowest duration you can choose is 15 minutes and the highest is 24 hours. Up to 10 additional DUA products can be on the RPS list at once.

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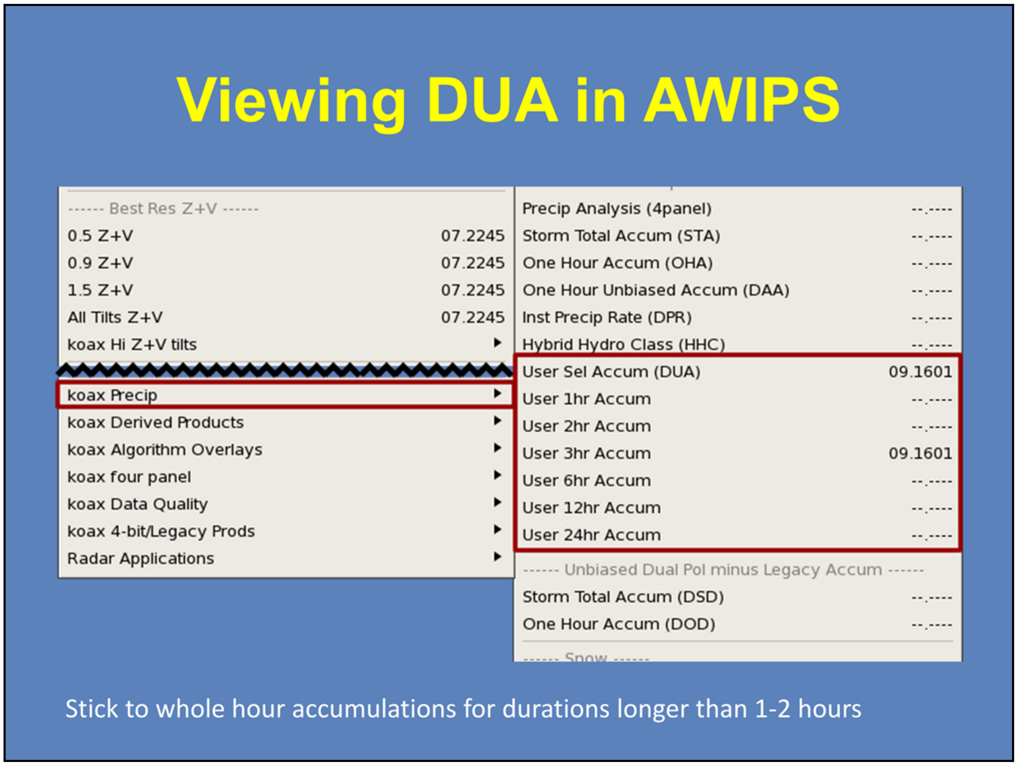

You will notice on the precip submenu that there are a number of entries for DUA. These 6 entries, seen inside the red box, will load any DUA product exactly matching the duration given in the menu, if that product is on the RPS list. Any off-hour products will be under the “User Sel Accum (DUA)” menu 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 AWIPS-2 straightforward.

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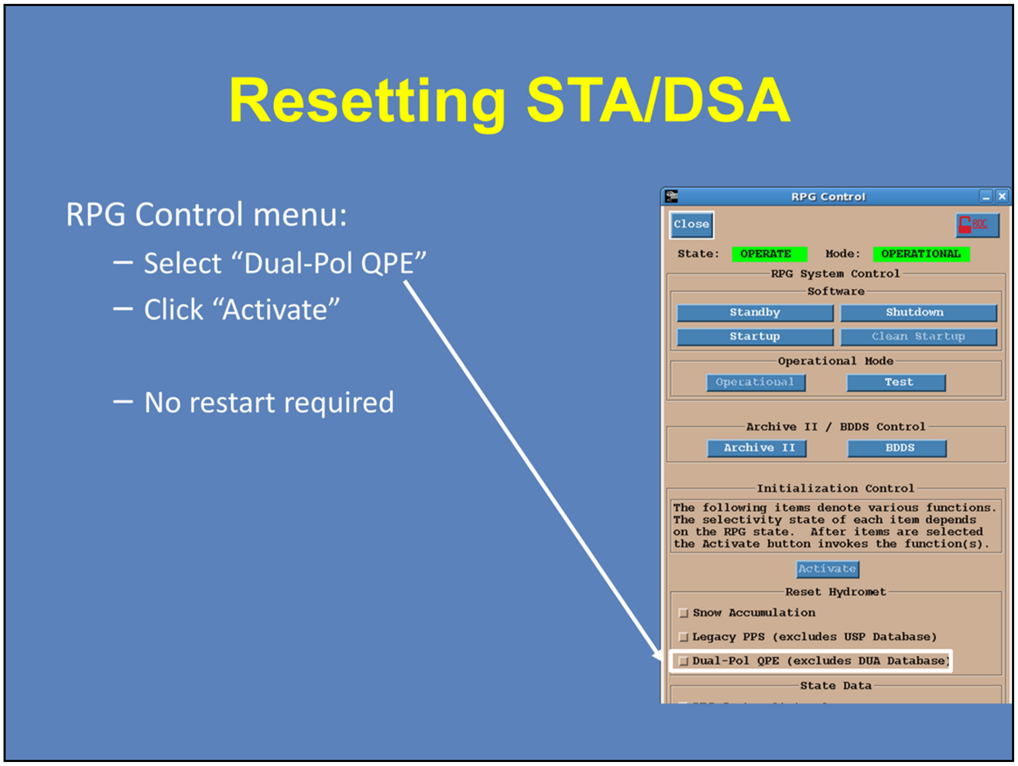

As mentioned, there may be times when the RPG does not automatically reset accumulations and you think it is warranted. Thus you are allowed to manually reset the storm total accumulation products at the RPG. Note that this will not reset the DUA products. From the main RPG HCI window, go to the "Control" 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.

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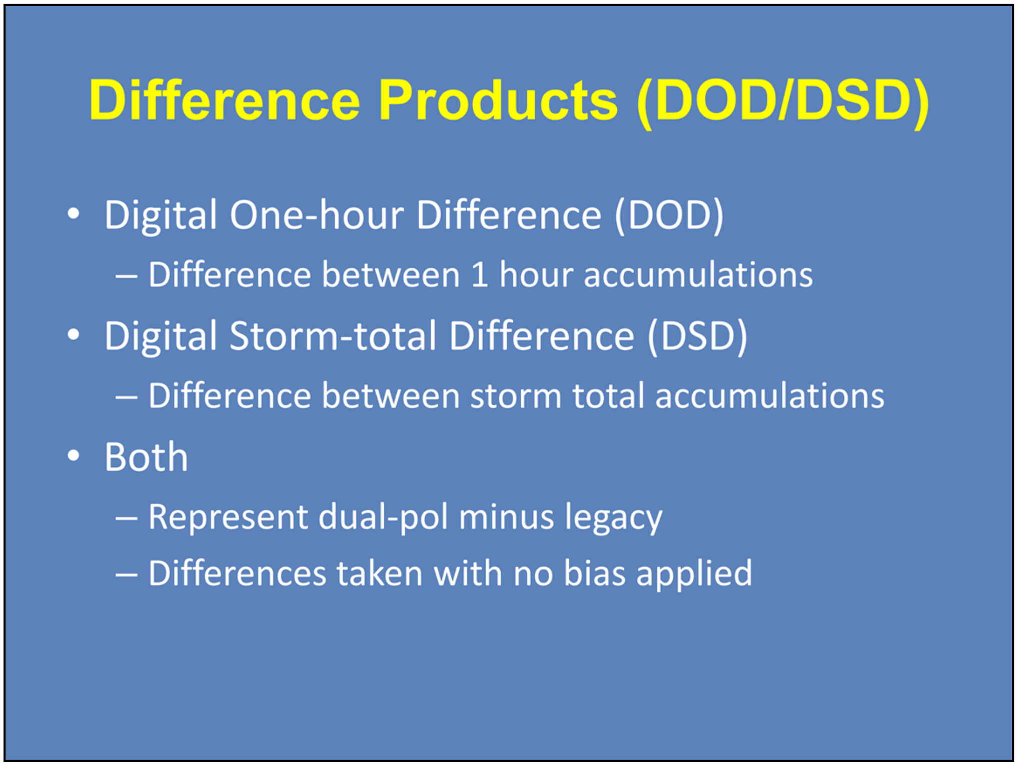
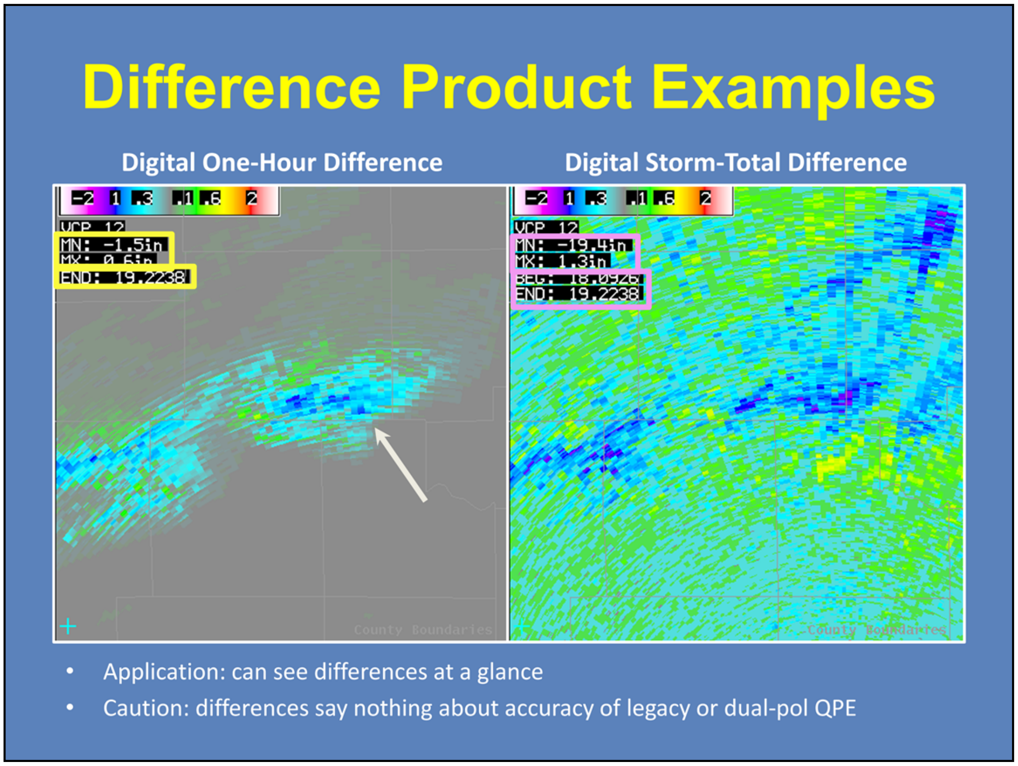


Since PPS products are not going away with the arrival of QPE products, there are two difference products to help compare legacy precip products to dual-pol precip products. They are: Digital One-hour Difference (DOD) and Digital Storm-total Difference (DSD). DOD is the difference between dual-pol and 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. Also, note that this is not a straight subtraction because the resolutions between the analogous one hour and storm-total products used to compute these differences are not the same. The main point here is it 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.



Here is how the difference products look when displayed in AWIPS-2. 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.

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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. And, in general, remember that QPE is new to the WSR-88D and is still under development. As we begin to understand more, 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.

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Products' Limitations

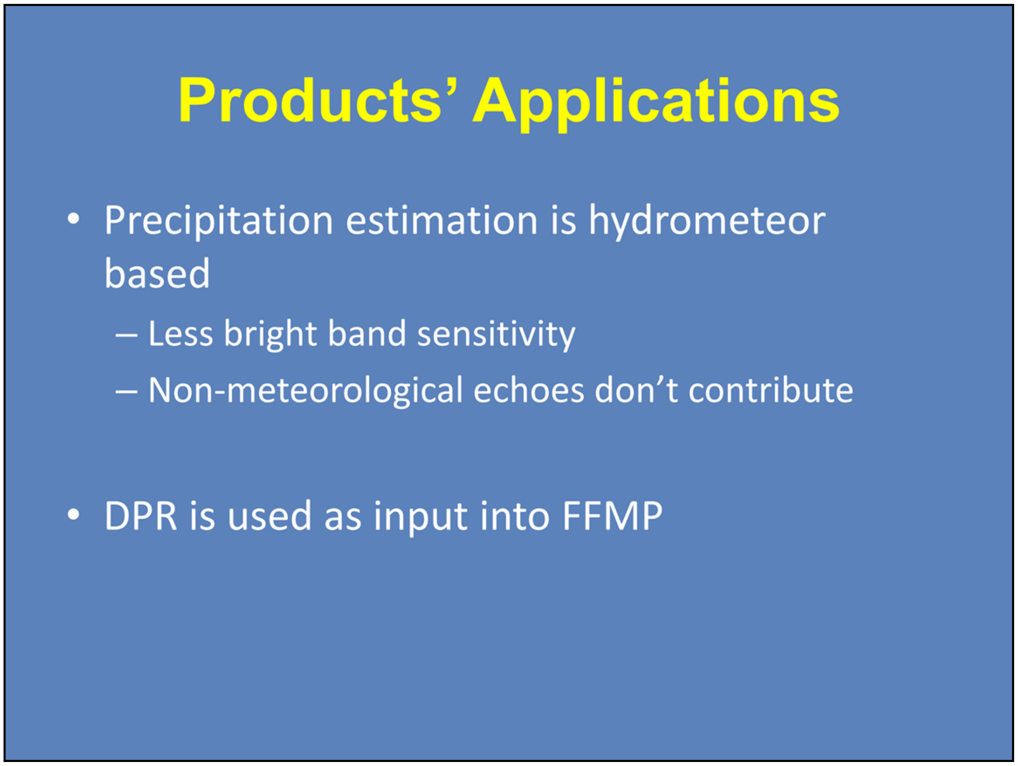
- Standard radar limitations apply
- Missing data aren't highlighted (STA/DSA, and DUA)
- Data can span multiple days (STA/DSA)

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.



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.

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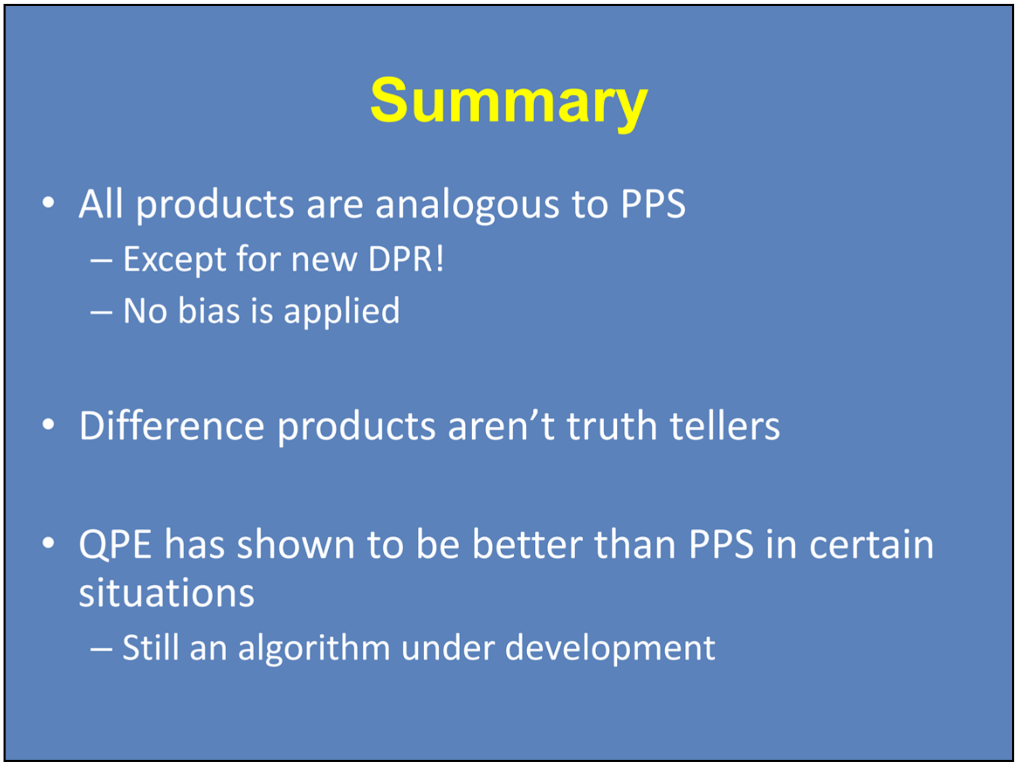

In summary, we saw that many of the new QPE products have an analagous PPS product except for the new DPR product. Also, no bias is applied to any of the QPE products despite it being shown in the product annotations. The difference products are not truth tellers. They only give you a sense of the relative 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. So, growing pains are inevitable.

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!

Welcome to this topic 4 lesson on PPS snowfall accumulation.

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Learning Objectives

Upon completion of this lesson, you will be able to identify specific characteristics, limitations, and applications (strengths) of the following products:

Product	ID
One-Hour Snow Water Equivalent	OSW
One-Hour Snow Depth	OSD
Storm-Total Snow Water Equivalent	SSW
Storm-Total Snow Depth	SSD
User-Selectable Snow Water Equiv	USW
User-Selectable Snow Depth	USD

Here are the snowfall products we'll discuss. For each product you should be able to identify the characteristics, limitations and applications of each when you are finished with this lesson. Advance this slide when you are ready.

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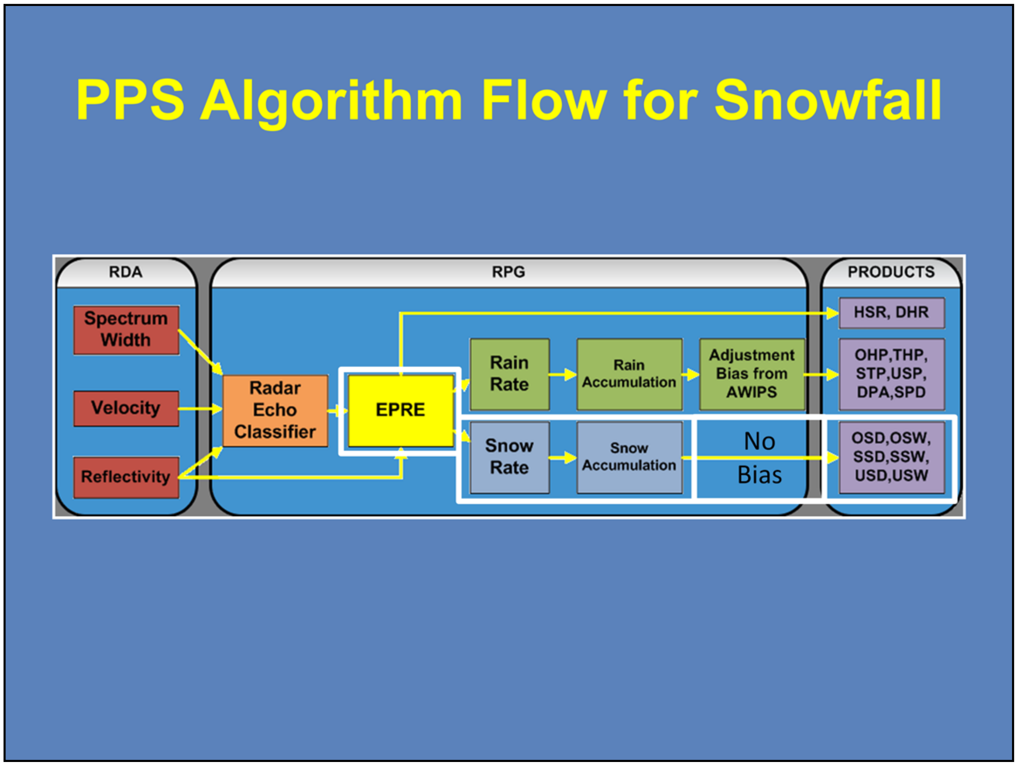

Recall this graphic from Topic 3 and the lesson on the PPS rainfall products. Starting with the EPRE function in the RPG, that computes a snow rate, which then is used to compute the 6 snowfall accumulation products we'll discuss in this lesson. Unlike the rainfall accumulation products, there are no bias adjustments with the snowfall products.

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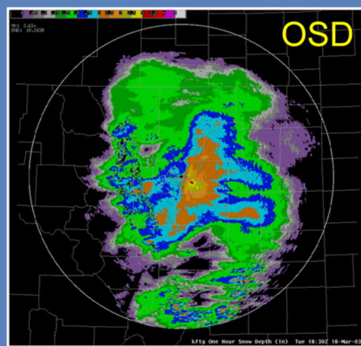
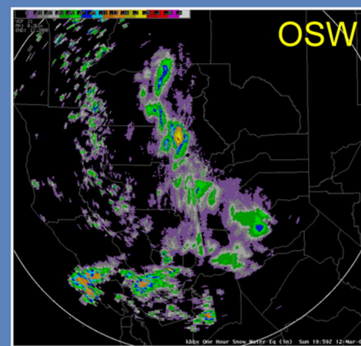
One-Hour Accumulation & Water Equivalents (OSD & OSW)





- 1 km x 1 degree
- 124 nm range
- 4-bit (16 data levels)
- 1-hr moving window

The first two products are the one hour snowfall accumulation with the product code OSD and the one hour snow water equivalent accumulation with the product code OSW. They are both 1 km by 1 degree range and azimuthal resolution out to a maximum range of 124 nm. Recall that ALL the rainfall accumulation products were 2 km by 1 deg. These have 16 data level and are accumulated over a one hour moving window.

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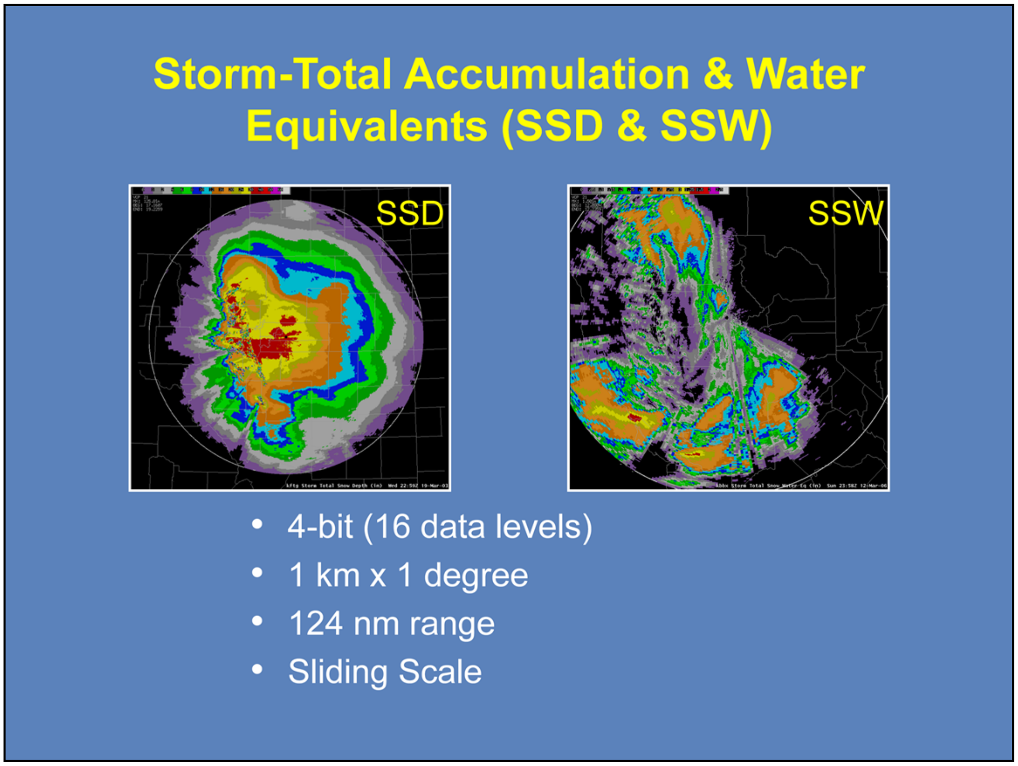

The next two products are storm total products: The storm total snowfall accumulation or SSD and the storm total snow water equivalent or SSW products. These are analogous to the 4-bit rainfall storm total accumulation or STP product. The one difference is that SSD and SSW are 1 km by 1 degree range and azimuthal resolution out to a maximum range of 124 nm. They have 16 data level product that use a “sliding scale” for assigning snowfall accumulations to each data level. For example, the storm total snowfall accumulation product begins with a range of data levels from 0 to 30 inches. If a sizable region of storm total snowfall accumulation exceeds 30 inches, all the data levels are doubled, increasing the max data level value to 60 inches. Both the SSD and SSW update every volume scan.

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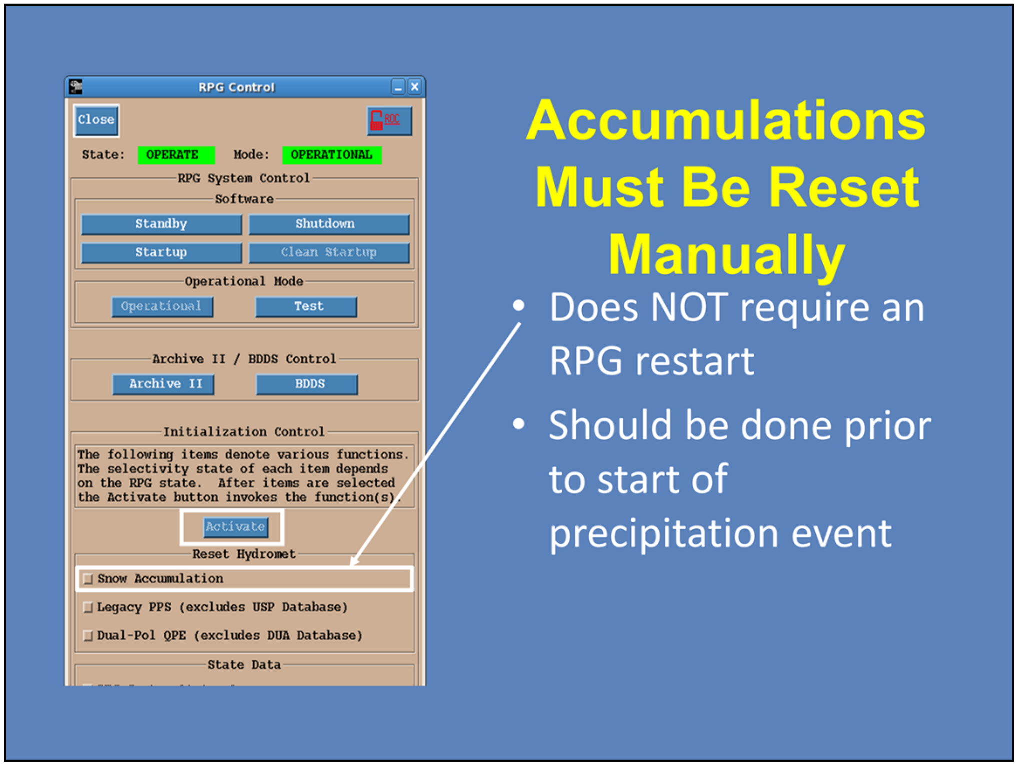
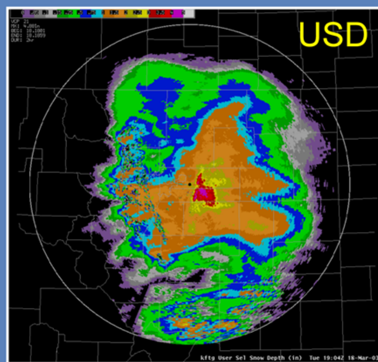
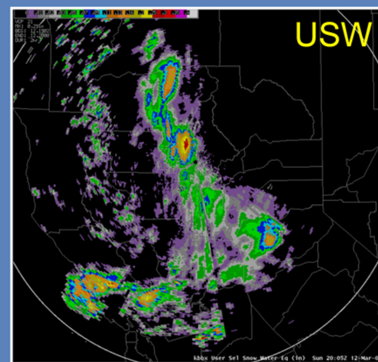


As opposed the rainfall accumulations, snowfall accumulations must be reset manually. In other words, there is no automatic reset like there is with the rainfall products. As a best practice, this should be done prior to the start of a precipitation event. To do that, go to the RPG control window…check the box for reset “Snow Accumulation” and click “Activate”.

User Selectable Accumulation & Water Equivalents (USD & USW)





- 4-bit (16 data levels)
  - Sliding scale
- 1 km x 1 degree
- 124 nm range

- OTR
- Can tailor time period of accumulation to compare to snow spotter reports

The final snowfall accumulation products are the user-selectable snowfall accumulation and snow water equivalent, product codes USD and USW respectively. The USD and USW have similar product characteristics as the storm total snowfall accumulation and snow water equivalent products. They are available as a one time request, and can be done for any duration up to 24 hrs for the previous 30 hours. They are produced as a top of the hour accumulation. Thus, you can tailor the time period of accumulation to compare to snow spotter reports.

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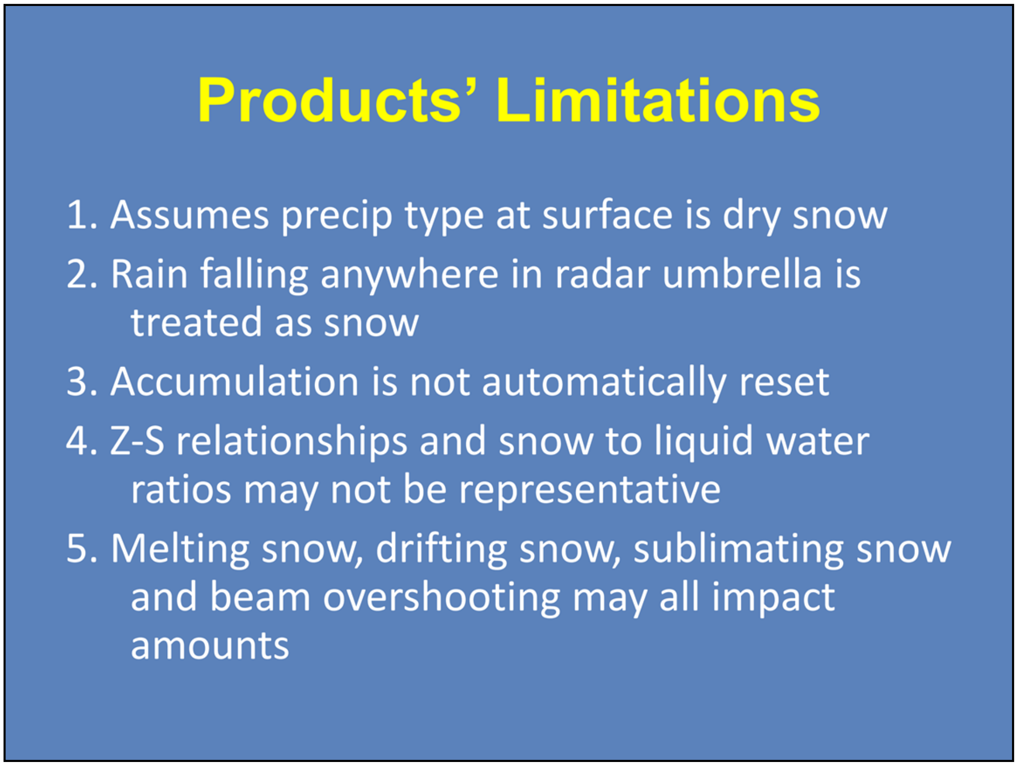

Here are the limitations that can be applied to all the snowfall products. Many of these limitations are due to the fact that the radar cannot distinguish frozen precipitation types. Now, with dual-pol there is promise that this might be possible, but more research is needed to confirm this notion. Right now, snowfall products will only be available with the legacy algorithm, so the radar assume the precip type is dry snow.

Another limitations…rain falling anywhere in the radar umbrella is treated as snow. And, where this is the case, vast overestimation will result.

Third, accumulations are never automatically reset. You must manually reset it before any event. Fourth, the Z-S relationships used and the snow-to-liquid ratios may not be representative of the event and wet snow versus dry snow or sleet will have vastly different accumulations. Z to S relationships will also be very be different across events, but also across your CWA especially if you have a lot of terrain. Finally, melting snow, drifting snow, sublimating snow and beam overshooting may impact amounts. The radar just can't handle these types of things and it has nothing to do with the algorithm.

Given the inherent difficulties the radar has in estimating snowfall amounts, applications for these products are certainly lacking. Advancements with dual pol snow estimation are possible in the future. In the meantime, here are a few general applications. First, you can modify the Z-S coefficients and the snow-to-liquid ratio used in the algorithm at your RPG to tailor it to your local research or spotter reports. Another application is that these snowfall products are updated every volume scan.

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Summary

- Product does not work especially well
- With some effort and the right conditions it can be made to be useful, potentially

In summary this product just does not work especially well, due to physical limitations and the application of the product. It was part of the legacy pps so its not being developed and updated, its just still in there. With some effort and the right conditions it can be made useful potentially. There are some customizations you can do.

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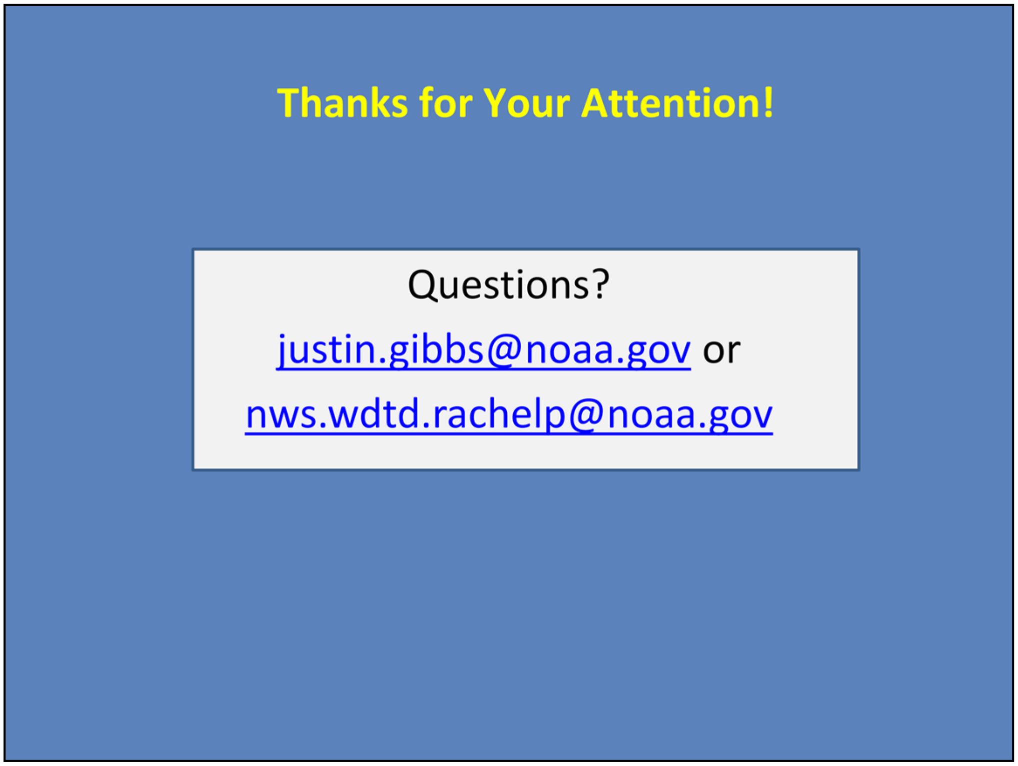

That’s it for lesson, Any questions email myself or anyone on this team responsible for putting everything together, and thank you for listening.