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MRMS Pre-requisites

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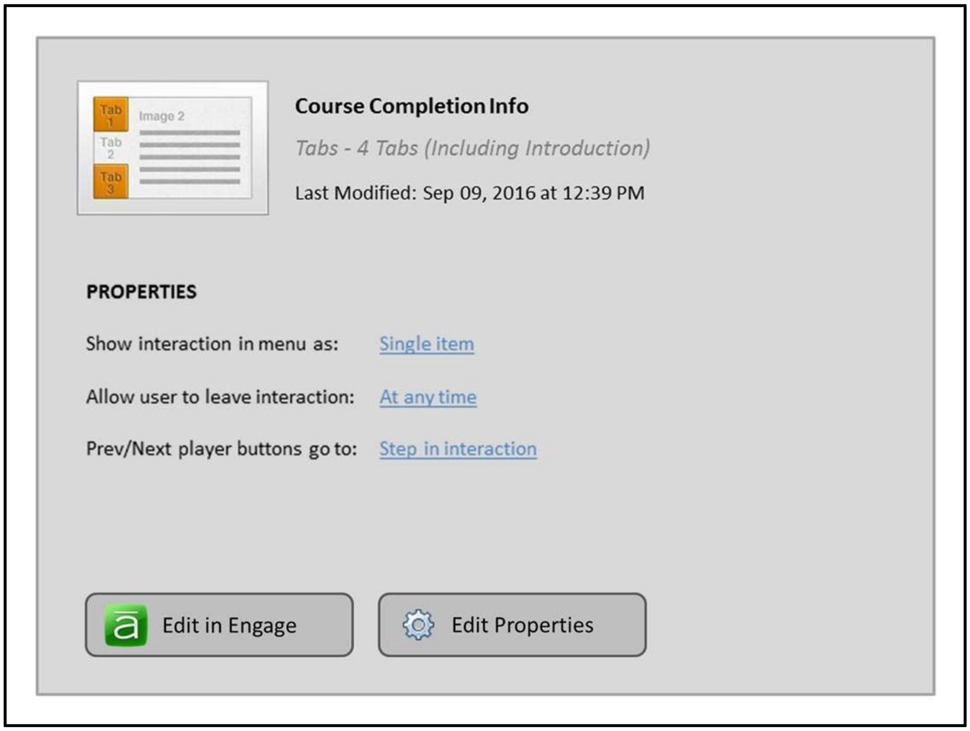
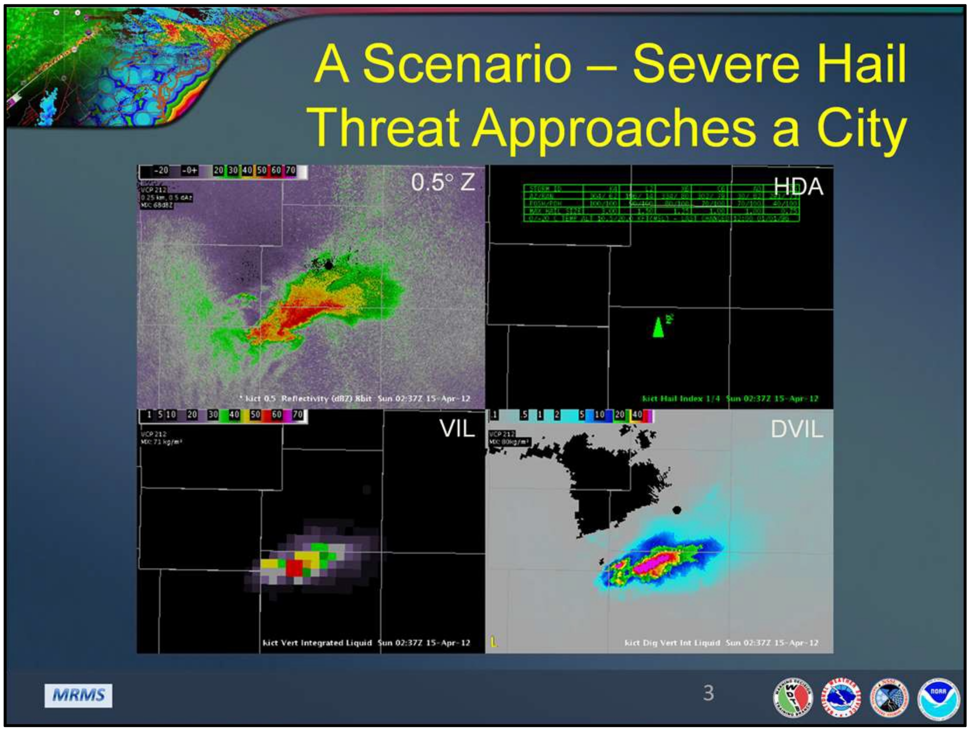
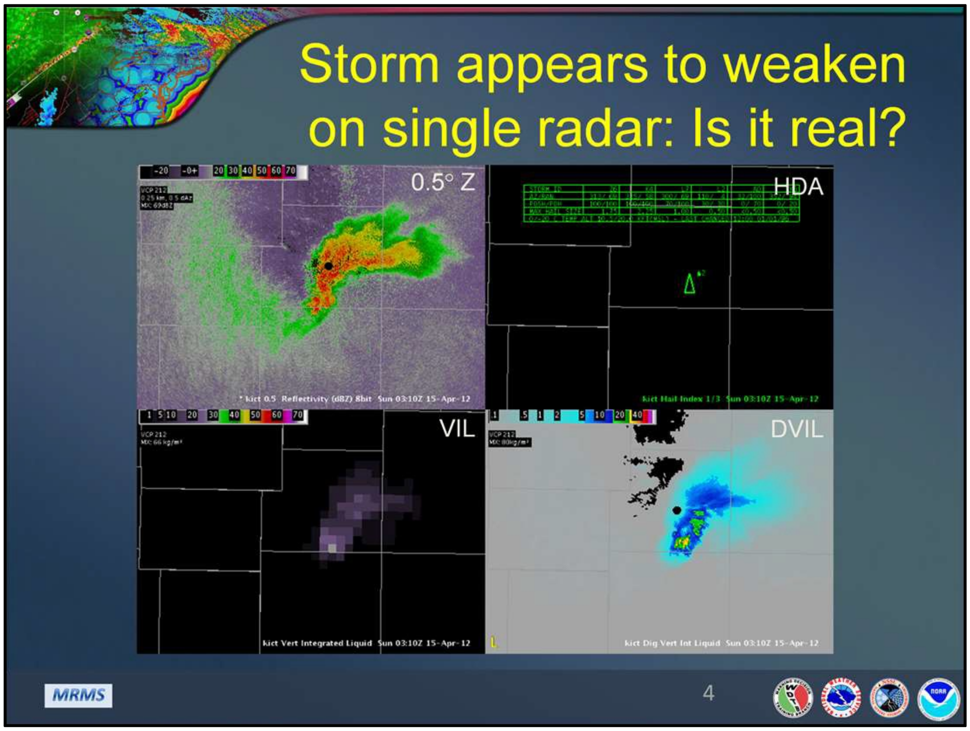
Welcome to the Multi-Radar / Multi-Sensor products course. Called MRMS, this represents a whole new way to use key inputs into warning and forecast decision-making for public, hydrological and aviation service sectors. MRMS has become operational in October of 2014 and is now undergoing its latest evolution as of November 2016. This course is designed as a step to familiarize you with MRMS, how it's created, and initial steps of applying these new data sets in operations. This course overview lesson should last about 30 minutes followed by a quiz to check your understanding should you be taking this lesson in the LMS.



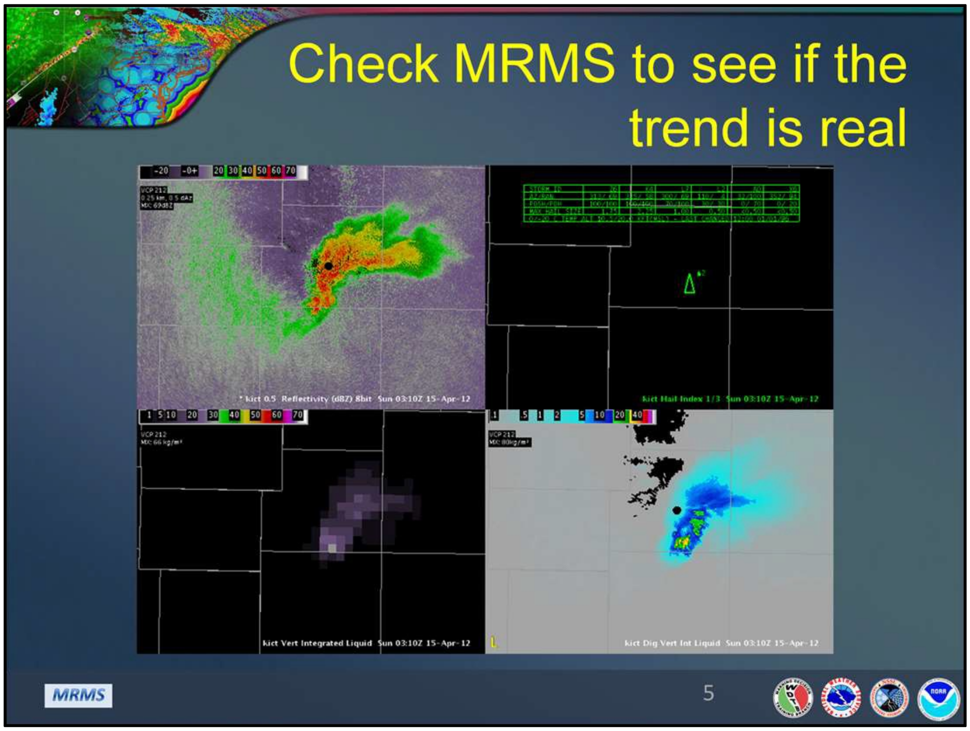
Please go through the steps in this page to get credit for this course in the LMS.



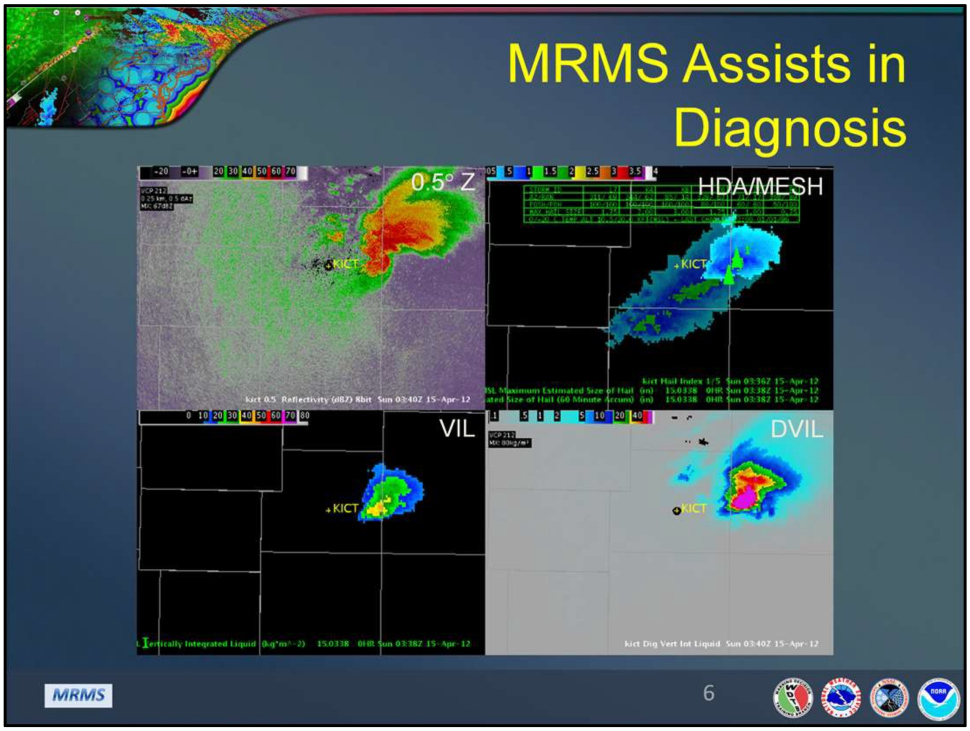
I present to you a scenario where a storm is approaching your radar, which happens to also be in a major city. The storm approaches with obvious supercellular characteristics and the local WSR-88D is depicting 2-3” diameter hail. You assume the steady state nature of the storm means a warning is warranted that mentions damaging hail.



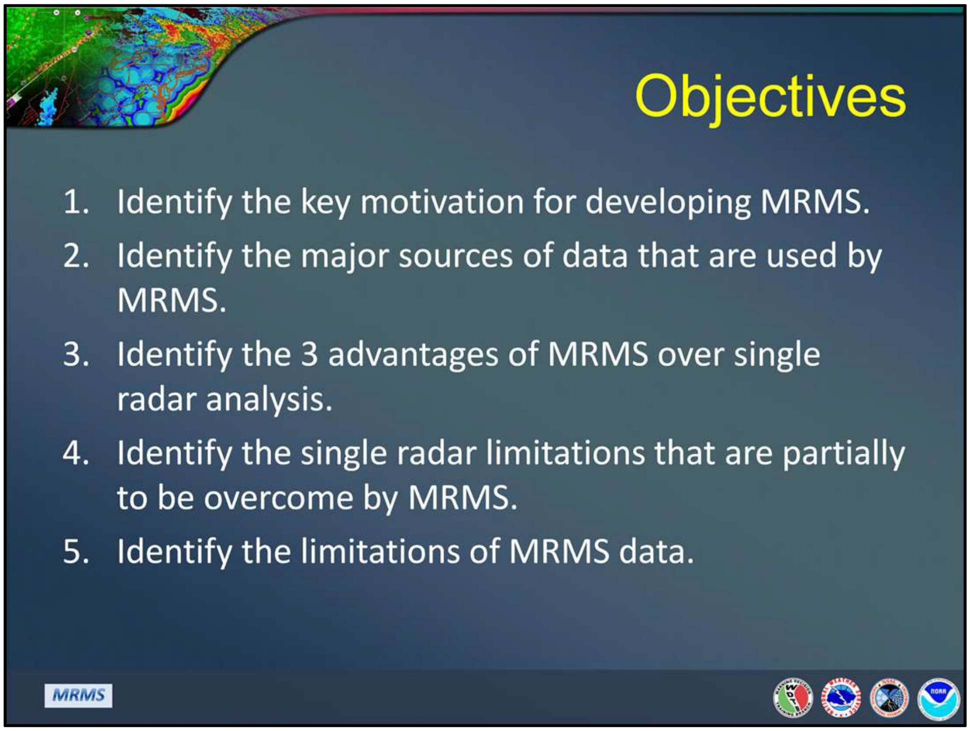
As you track the storm near the radar, the hail size estimate drops suddenly. You check the VIL and it also drops. The trend of the storm seems to be quickly downward. Thus you immediately suspect the output from all algorithms that vertically integrate reflectivity have been truncated due to the cone of silence. Since this event represents extremely favorable supercell parameters, you may be inclined to keep the hail size estimates constant in your warning updates assuming that the storm is actually maintaining a steady state intensity.



But is that always that case? Well, one could always check the same products from a nearby radar by bringing up a new display. Or you could simply bring up two quick Multi-Radar/Multi-Sensor (MRMS) products, the MESH and VIL to directly compare the trends to the KICT radar on one display. Now you can step back in time and verify that indeed, the MRMS Maximum Expected Size of Hail (MESH) and VIL did drop as the storm approached the radar. The trend that the WSR-88D observed may have been an artifact due to sampling but the MRMS showed that the storm reflectivity core aloft actually did weaken as the storm approached the radar. This may influence how you word the next severe weather statement or warning with respect to hail size.



Now you step forward and see a reintensification of the storm's upper-level reflectivity core both in the local radar data and the MRMS as you see the VIL and MESH increase. The one added advantage of the MRMS is that you get to see MESH not as a triangle but as an area and as a track. Now you can see how the storm behaved with respect to estimated hail size over the past hour or more. And yes indeed, there is the short-term drop off right next to the radar.



The scenario I played out is one of many potential applications to MRMS, you may be interested to know more about MRMS. Let me introduce you to the objectives which define the topics of this lesson:

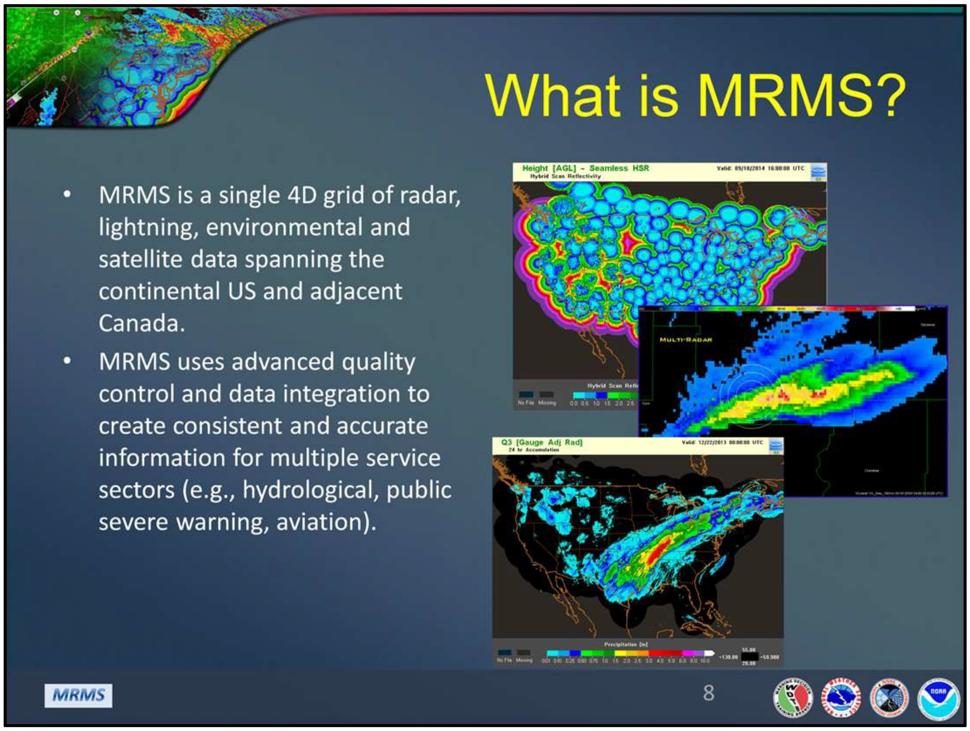
1. Identify the key motivation for developing MRMS.

2. Identify the major sources of data that are used by MRMS.

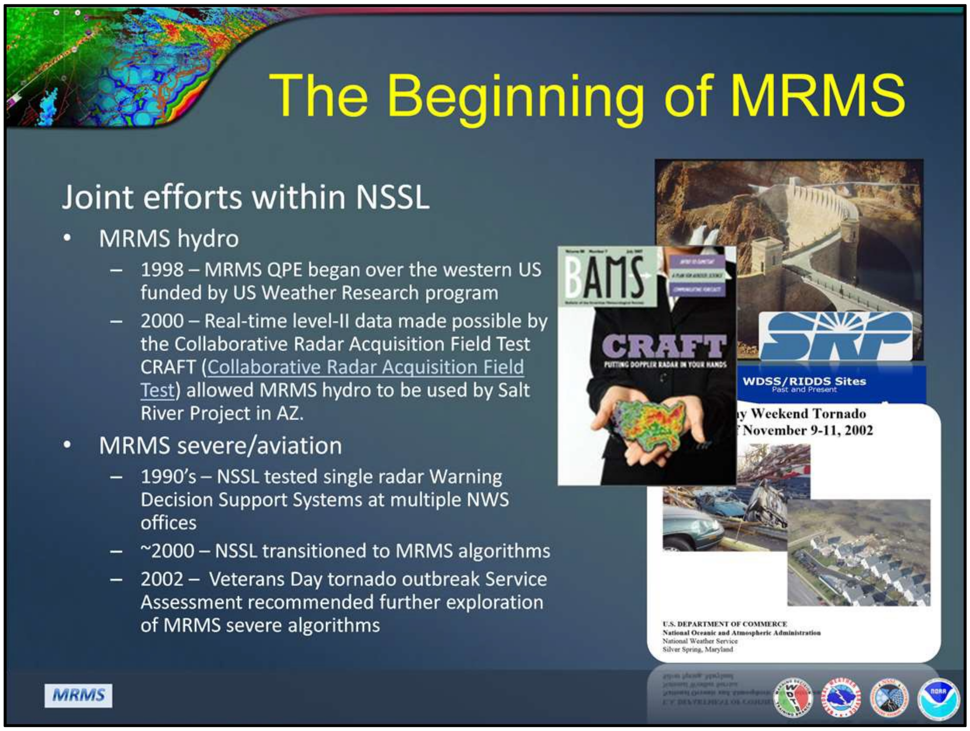
3. Identify the 3 advantages of MRMS over single radar analysis.

4. Identify the single radar limitations that are partially to be overcome by MRMS.

5. Identify the limitations of MRMS data.



MRMS is a single 4D grid of radar, lightning, environmental and satellite data spanning the continental US and adjacent Canada. MRMS uses advanced quality control and data integration to create consistent and accurate information for multiple service sectors (e.g., hydrological, public severe warning, aviation).

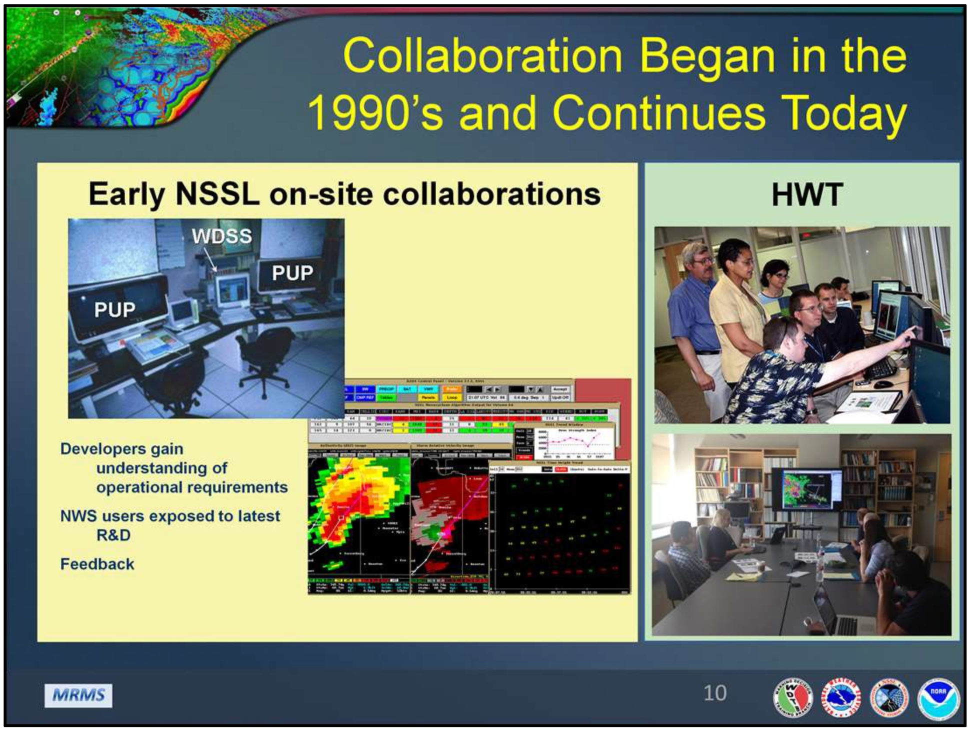


How did MRMS come into its current form? The National Severe Storms Lab (NSSL) began to produce MRMS through the efforts of the hydrological and severe weather research teams.

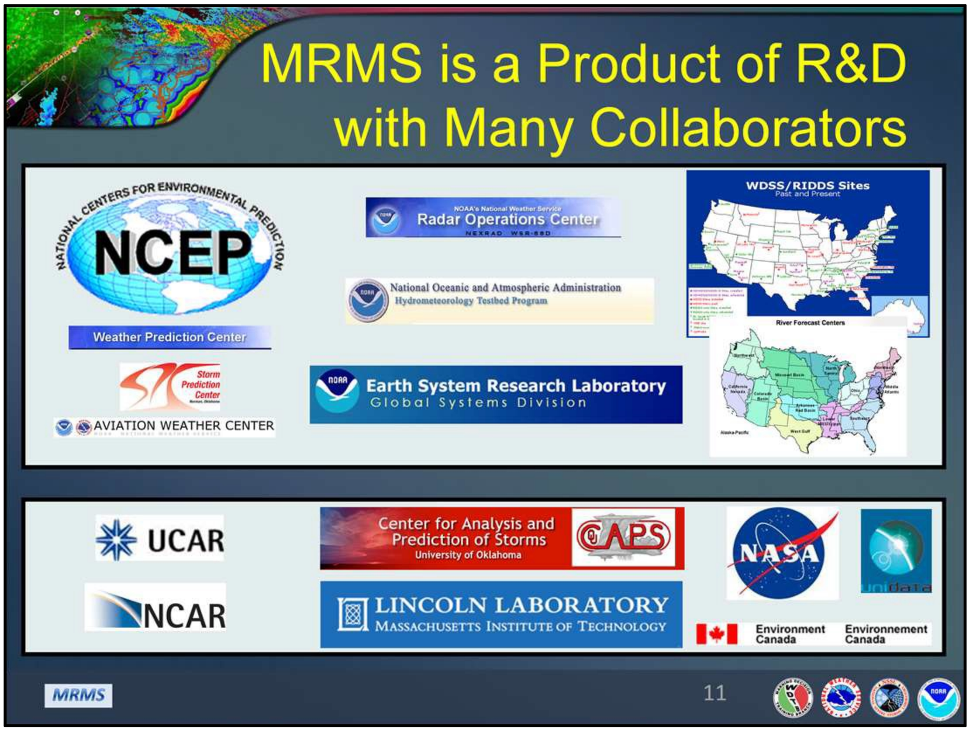
In 1998 the hydrological research team began to develop Quantitative Precipitation Estimation (QPE) using a regional network of WSR-88Ds in the southwest US as part of a US Weather Research Program. With the advent of real-time level-II data made possible by the the Collaborative Radar Acquisition Field Test CRAFT (Collaborative Radar Acquisition Field Test), real-time MRMS QPE was made available to the Salt River Project in AZ. The success of that project promoted the expansion of MRMS to the CONUS.

Meanwhile in the 1990's NSSL began testing single radar severe weather warning decision support systems at multiple NWS offices. When the limitations of single radar applications to severe became clear, NSSL transitioned to an MRMS approach.

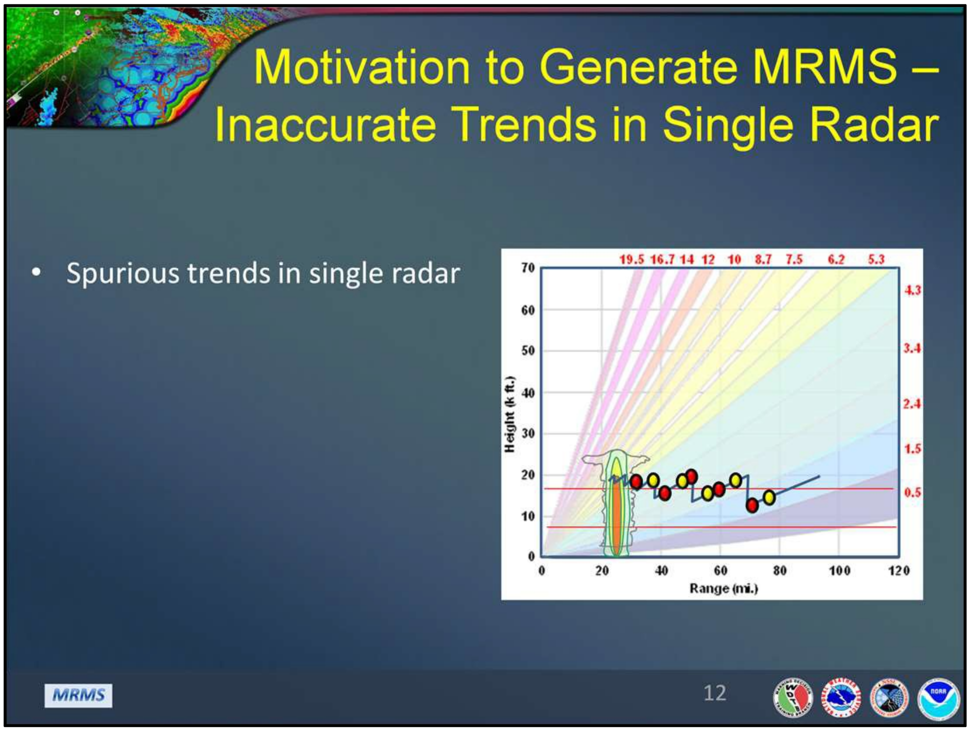
In 2002 the incentive to make MRMS data operational came to light after a NWS service assessment team visited the Jackson, MS NWS forecast office after the Veteran's day tornado outbreak. They were impressed by the experimental MRMS products made available to NWS forecasters there such as seamless composite reflectivity, rotation tracks and hail tracks. A recommendation came out that the office of science and technology should meet with developers of Warning Decision Support System version II (WDSS-II) to itemize the capabilities of the system and identify those beneficial to NWS operations. The products of that day were nowhere near as mature as they are today but yet still provided value, especially with a NSSL scientist on the scene to help interpret their meaning to the forecasters.



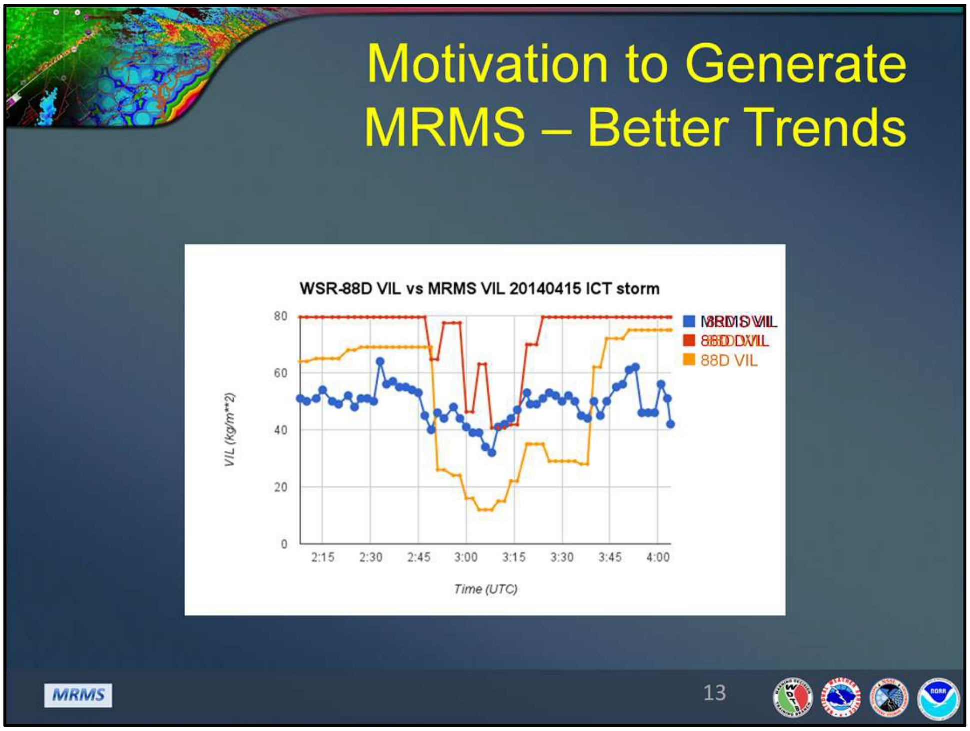
The history of NSSL collaborations began well before the 2002 tornado outbreak. National Weather Service (NWS) forecast offices have been providing feedback to NSSL since the mid 1990's as the WDSS-II's predecessor was installed in multiple offices as part of a long collaborative experiment to improve radar product services. These collaborations continue, more in the form of visiting forecasters to the Hazardous Weather Testbed (HWT) as new product experimentation continues to this day.



Over the past two decades many collaborators have become involved in the refinement of MRMS data and quality. On the US federal side, these include the NWS National Centers for Environmental Prediction (NCEP), the Radar Operations Center (ROC), testbeds, the Earth System Research Laboratory, NWS Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs). Other organizations span UCAR, NCAR, CAPS, Lincoln Labs, NASA, UNIDATA and Environment Canada.

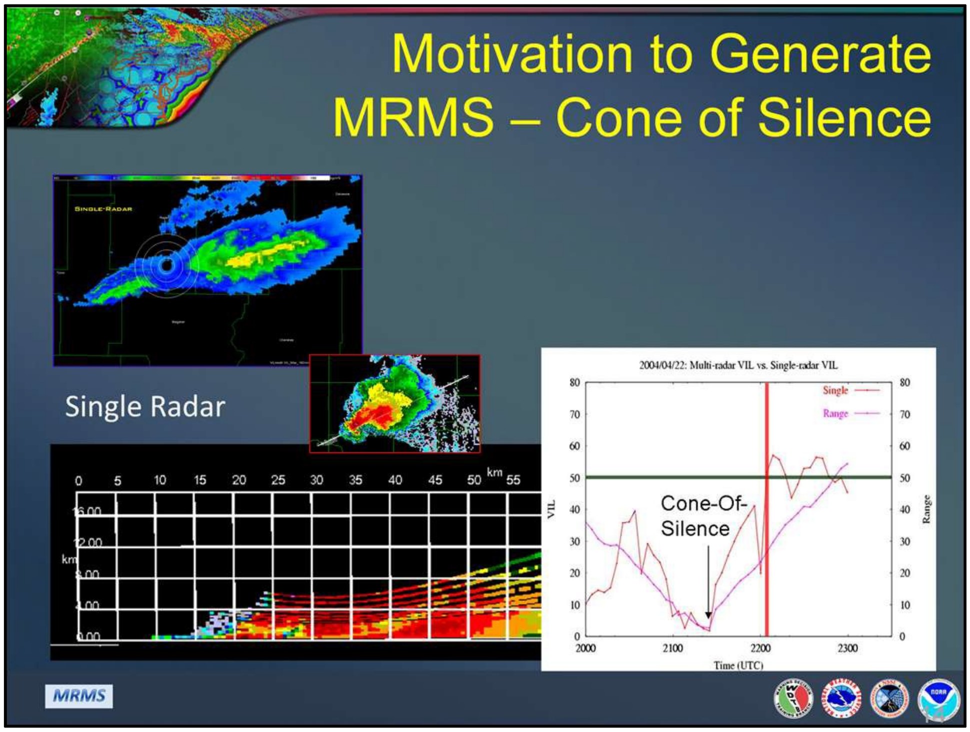


What motivated the development of MRMS? Perhaps the most prominent single radar limitation has been the numerous artifacts in severe storm trends caused by discrete vertical sampling. Picture a storm moving away from a WSR-88D sampled by Volume Coverage Pattern (VCP) 11 and you're measuring the 50 dBZ echo top (red) to get an idea if the storm is weakening, staying the same or strengthening. In reality, storm intensity remains unchanged. But as you see it on radar, the height of the 50 dBZ echo top zigs up and down, small zigs at first, getting worse with increasing distance. Maybe overall you could just mentally average the trend and see that radar sampling artifacts for what they are. However, your radar is only sampling the 50 dBZ echo top every 4-6 minutes (red dots), even with SAILS. Because of these sampling limitations, the storm may appear to be weakening even when it's not. Another radar scanning the same storm may depict an entirely different height (yellow dots) with a slight temporal phase shift in sampling. This kind of thing happens all the time.

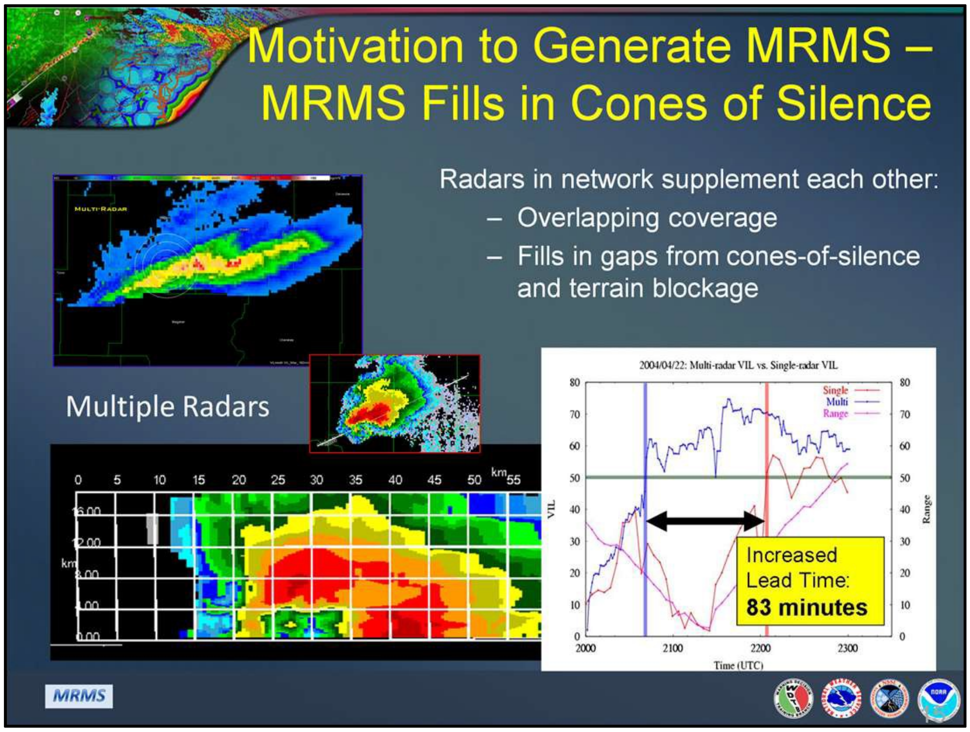


Going back to our scenario and looking at VIL, you can see the impact of trends with time with the single radar. I plotted both the legacy VIL (orange) and the newer digital VIL (red) of the storm from 0208 – 0410Z. Both of the trends show a big dip and numerous up and down spikes, especially with the digital VIL. Note on either side of the big dip, the digital VIL was maxed out on the AWIPS2 display.

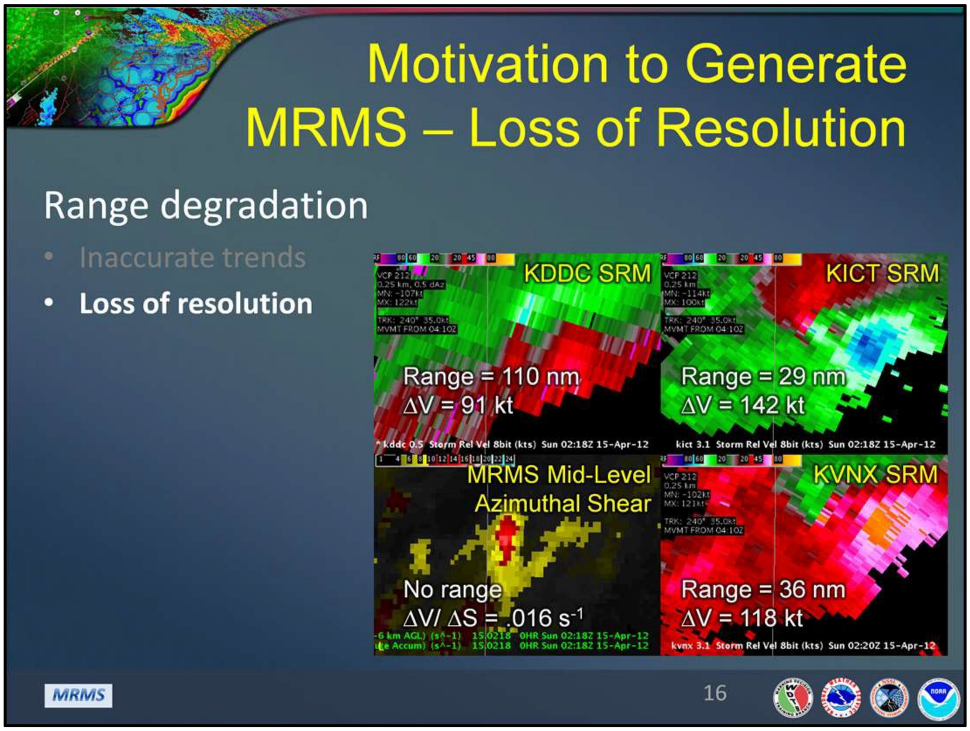
Enter in MRMS VIL (blue) and we see a trend that doesn't exhibit the sharp rises and drops but instead shows more samples and a smoother trend. It still shows that dip in values from 0235 – 0308Z followed by a rise in values afterwards consistent with a storm weakening and strengthening. But the smaller dips and peaks add confidence that the trends are real.



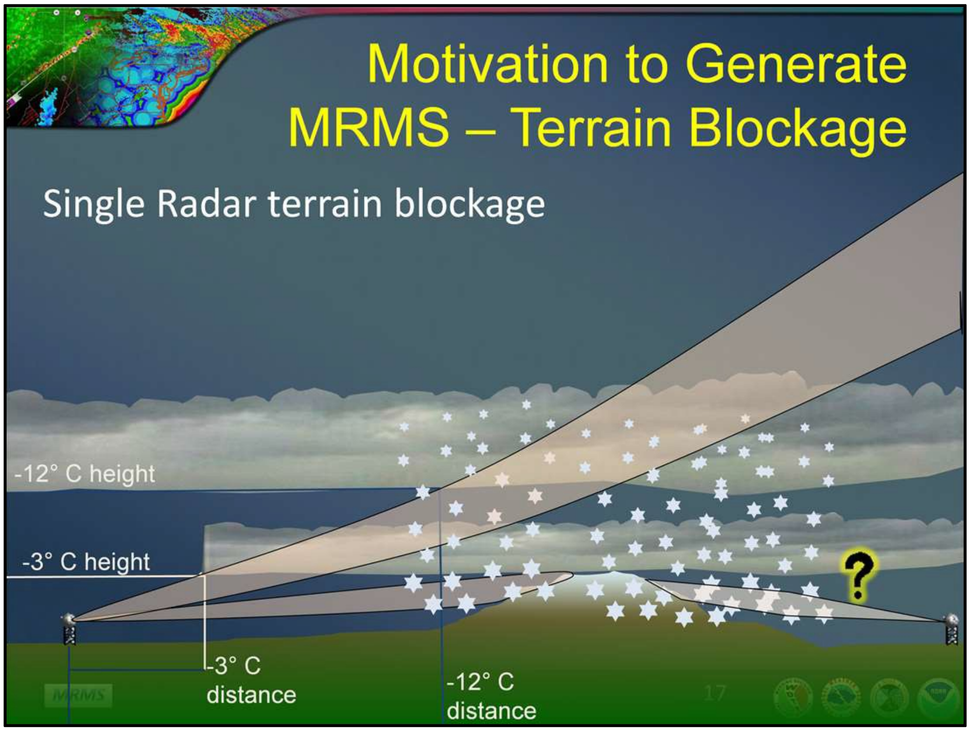
The sharp drop seen in the single radar in our scenario was partially real, but also partially a consequence of the cone-of-silence, a handicap that has beset many a warning forecaster through the years. Here are several illustrations of another storm that passed through a radar cone-of-silence. On the lower left is a vertical cross section through a storm using only single radar data (the inset shows the location of the cross-section). Note that a significant portion of the upper part of the storm is missing. On the upper left, a 2D accumulated "track" of maximum VIL is plotted. Note the minimum in VIL history as the storm passed over the radar. The graph on the lower right shows what a forecaster would see on their display -- as a storm moves closer to the radar (range from radar is the purple line), the VIL, in red, decreases and then increases again as the storm moves away and more of its depth can be sampled. However, experienced forecasters realize that this measurement of VIL is probably an underestimate, and they may scramble to look at a 2nd radar to get another view.



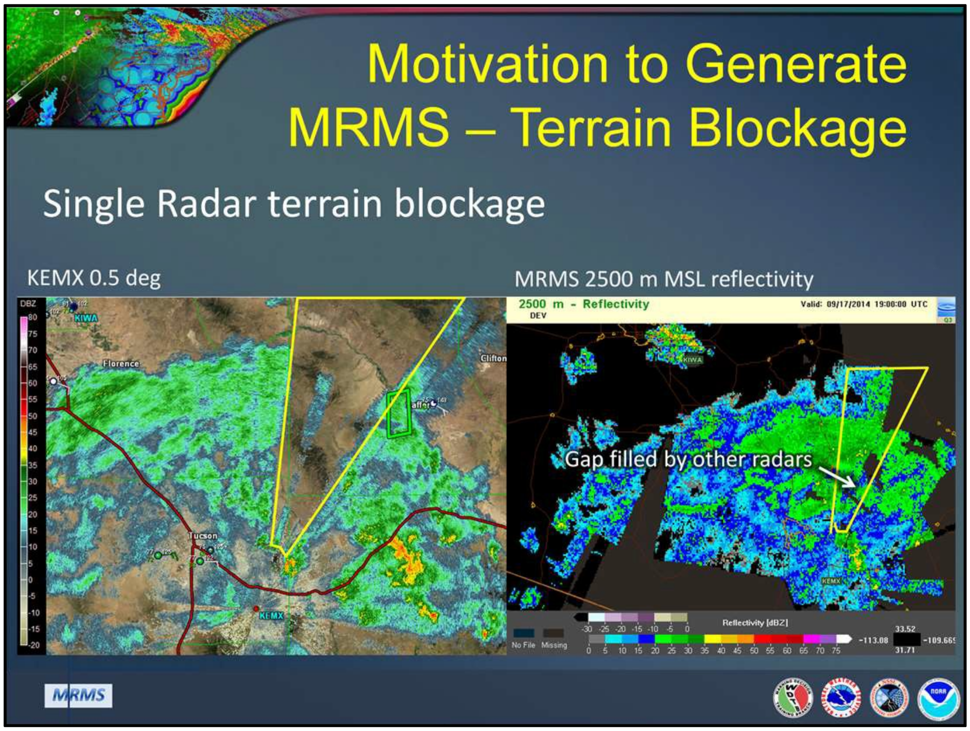
We can blend in a 2nd or 3rd radar into a 3D cube of radar data to fill in the missing details, and the true vertical depth of the storm becomes clearer in both the vertical cross-section and the VIL track. On the graph, the multiple-radar VIL is shown in blue. Note that if a forecast was using a VIL threshold of 50, the multiple-radar VIL value would reach that value 83 minutes earlier than the single-radar VIL value. Note that WDTB does not condone using a single threshold for issuing a warning, but I believe the point has been made.



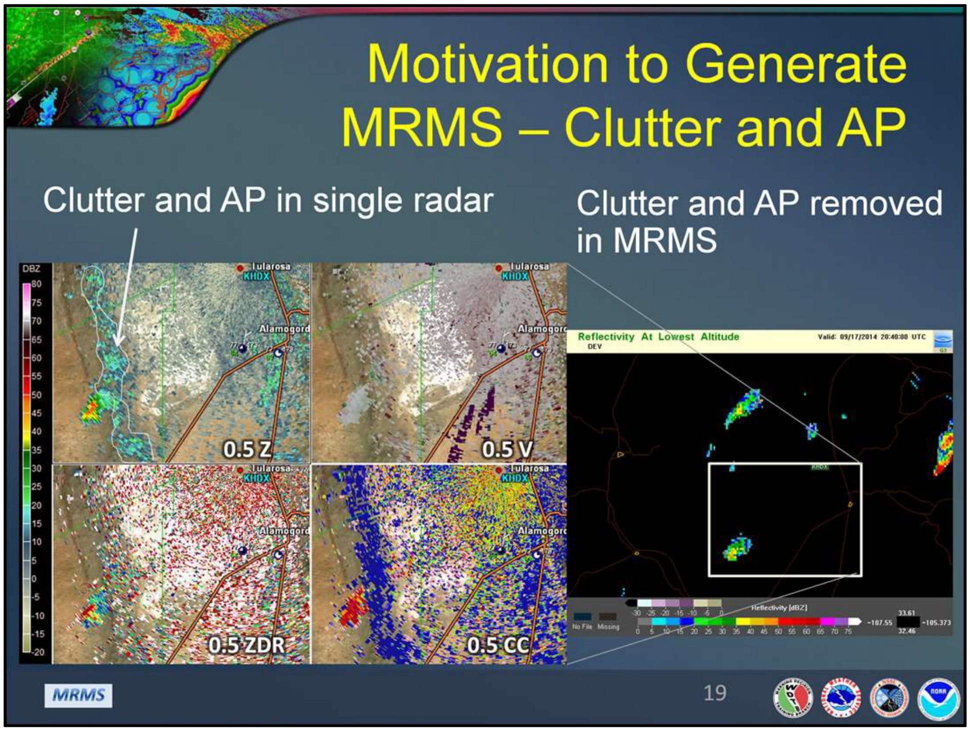
Another motivation to generate MRMS data is the impact of beam broadening upon resolving important features. This example highlights the impacts on mesocyclone or TVS strength represented by delta-V. Consider a mesocyclone sampled by KDDC 110 nm away. We calculate a Delta-V of 91 kts. At the same time and altitude, the KICT measures a whopping 142 kts from 29 nm away. KVNX measures 118 kts at 36 nm range. Three radars, three answers with increasing range largely determining the decreasing value of Delta-V. MRMS mitigates this problem by assimilating three different values of shear from three radars into one answer of .016 s^{-1}.



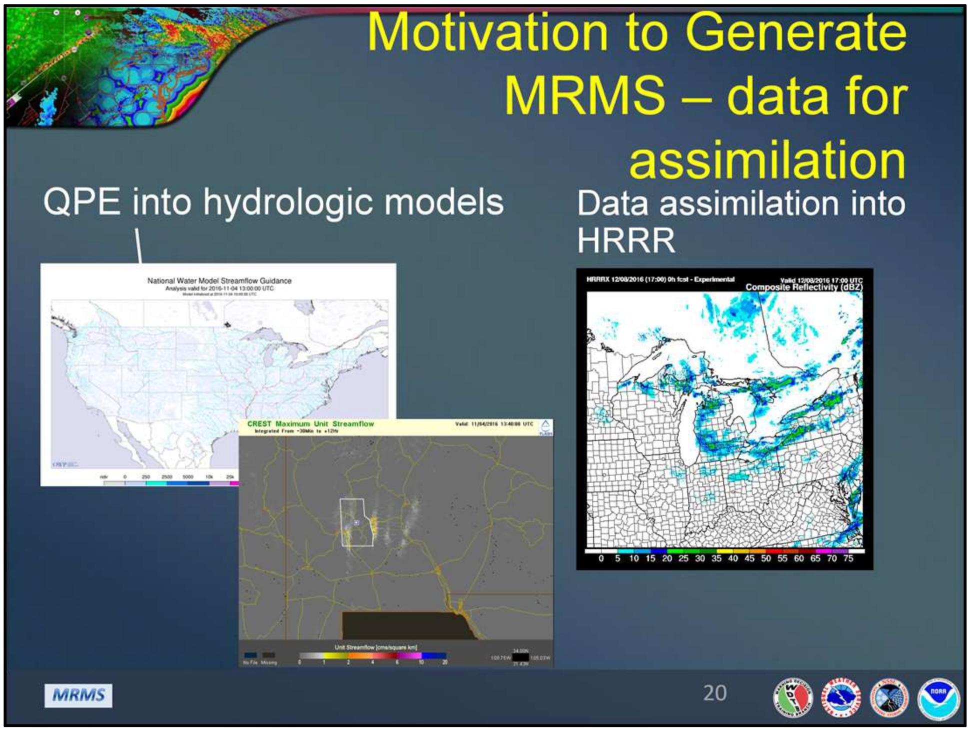
Terrain blockage is a common single radar nemesis, not just applicable to the mountains but even in the Plains! Just ask anyone who uses KVNX in northern OK. Some trees prevent an adequate low-level view to the southwest. A single radar simply cannot collect information beyond the point of blockage. But what if we combine information with a second radar, say on the other side of a mountain?



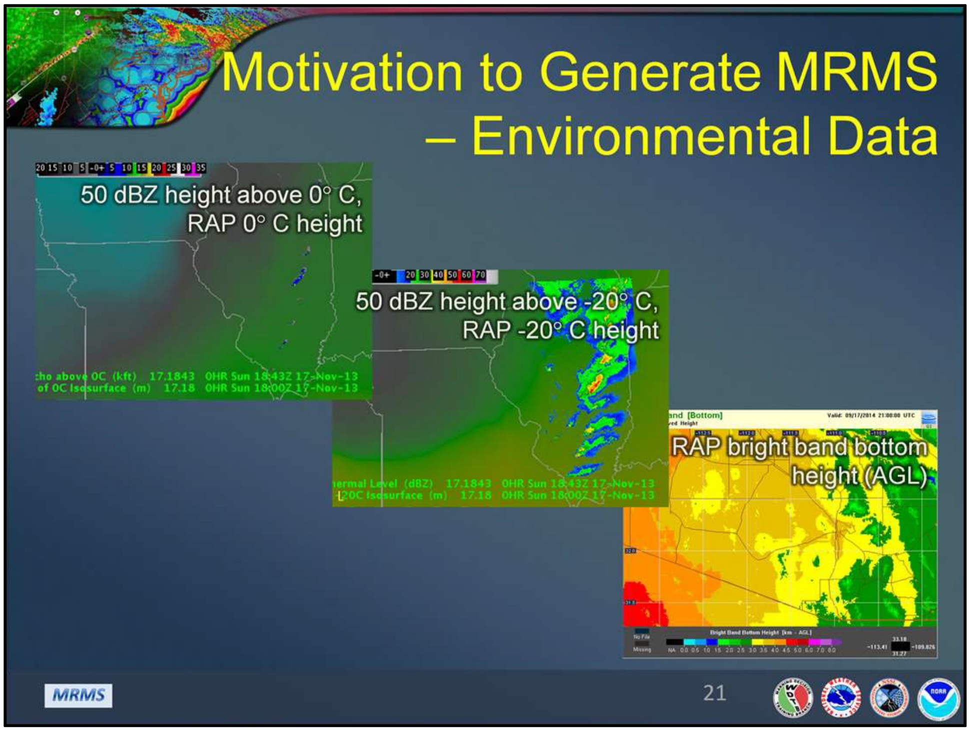
This question can be answered using a rainfall event in the Tucson area. Reflectivity estimates are impossible northeast of the radar. But on the right, the MRMS reflectivity fills in the gap with information provided from other radars.



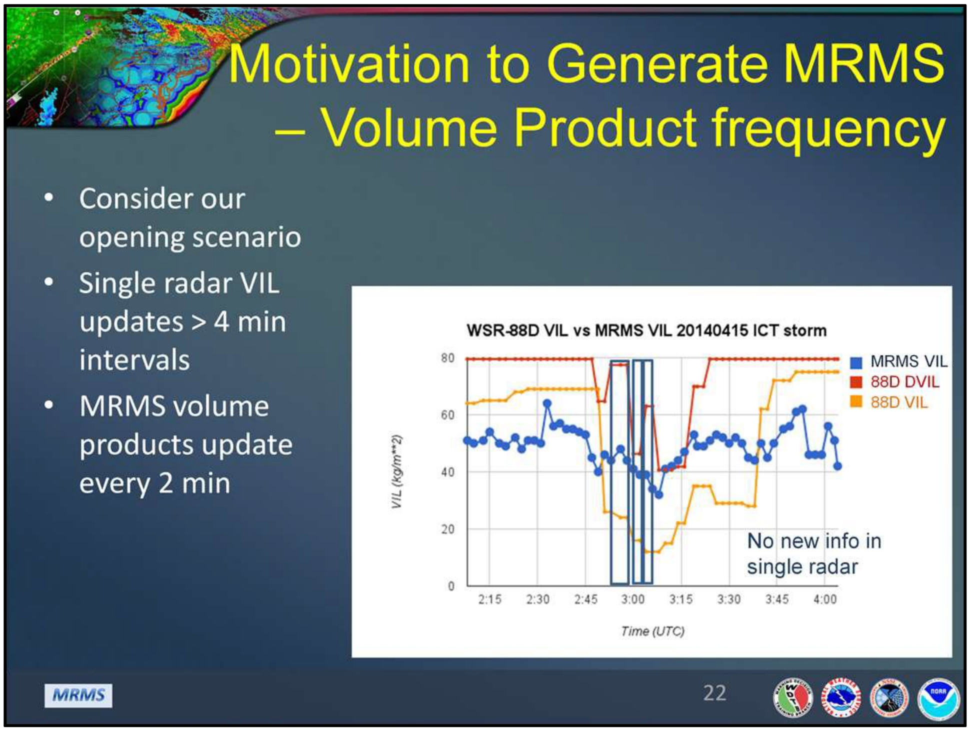
A close relative to beam blockage is clutter and Anomalous Propagation (AP). MRMS employs significant quality control to remove clutter as highlighted in this example where the White Sands, New Mexico (KHDX) WSR-88D observes both the San Andrews mountains (in white perimeter) and a new storm. The MRMS reflectivity at the lowest altitude shows that the QC removed the clutter from the mountains and left the storm intact.



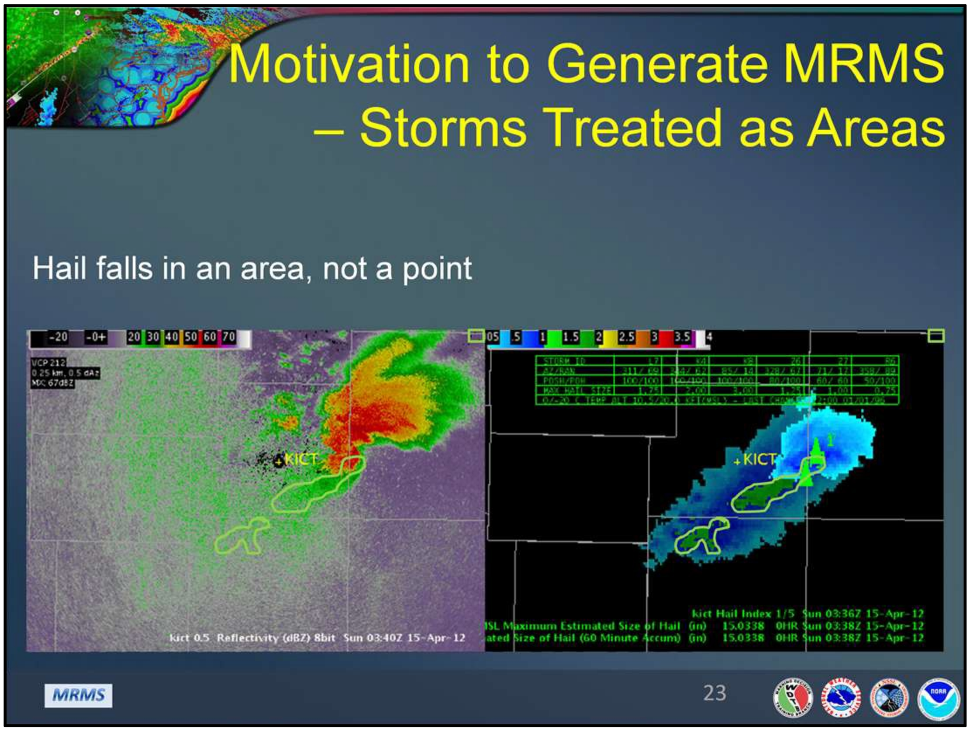
MRMS is now routinely ingested into high resolution models. The National Water Model ingests the radar-gauge adjusted and radar observed QPE on an hourly basis. The Flooded Locations and Simulated Hydrographs (FLASH) ingests the radar-only MRMS QPE as it's run every 15 minutes. On the meteorological side, high resolution models, such as the HRRR, benefit from direct assimilation of MRMS 3-D reflectivity.



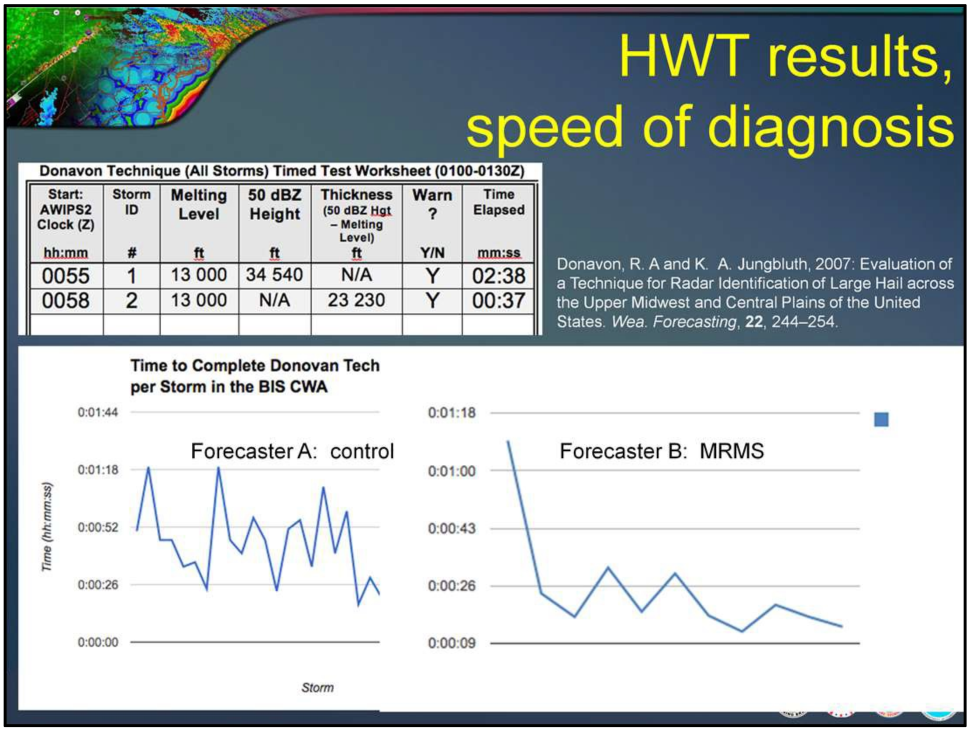
MRMS integrates environmental data into all its service sector products. Forecasters have quick access to reflectivity products in temperature coordinates that will allow them to quickly determine severe weather potential. The QPE algorithms heavily use temperature data from the highest CONUS model available, now it's the HRRR, to determine how to adjust reflectivities such as those associated with the bright band. These are just a few of many examples of the infusion of environmental data into the MRMS.



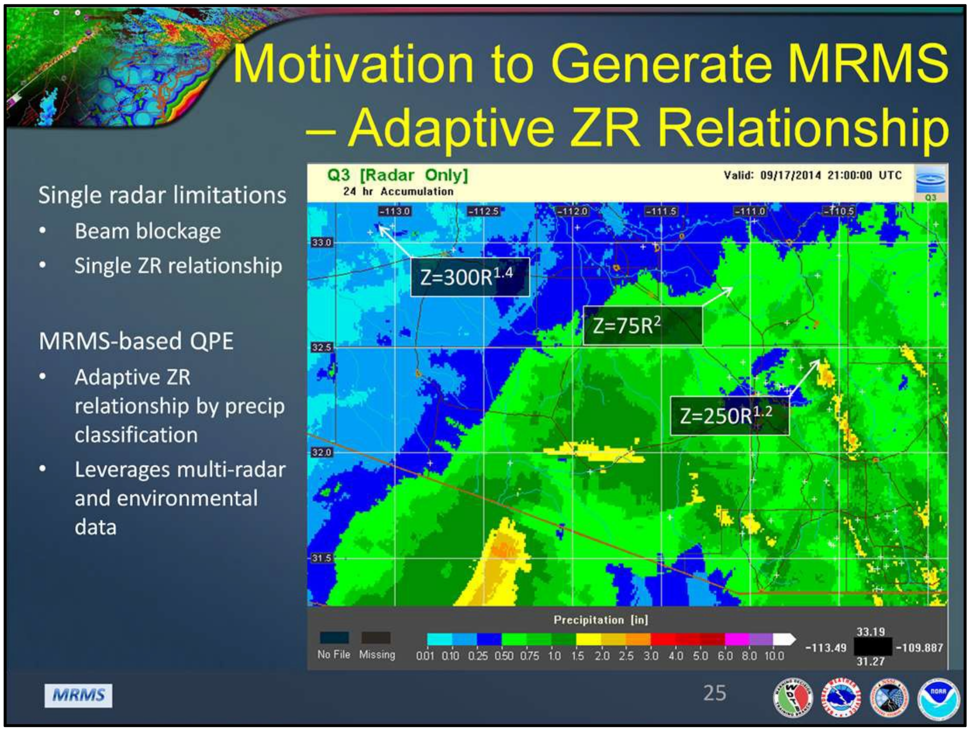
Volume product frequency is another issue with single radars. Going back to the time tendencies we've seen before note that an update time of 4-6 minutes results in relatively long periods of time with flat trends. MRMS grid points in the 3-D volume are updated anytime a beam from any nearby radar sweeps by, allowing new information to be updated more frequently, say 2 min. The result is more accurate and timely updating process.



MRMS treats storms as areas and swaths, more reflective of nature. This is true for QPE, hail size swaths, and mesocyclones. This example highlights the differences between the single radar Hail Detection Algorithm (HDA)-based Maximum Estimated Size of Hail (MESH) and the MRMS-based MESH. Forecasters now can view the areal extent of the MESH to compare with their warnings.

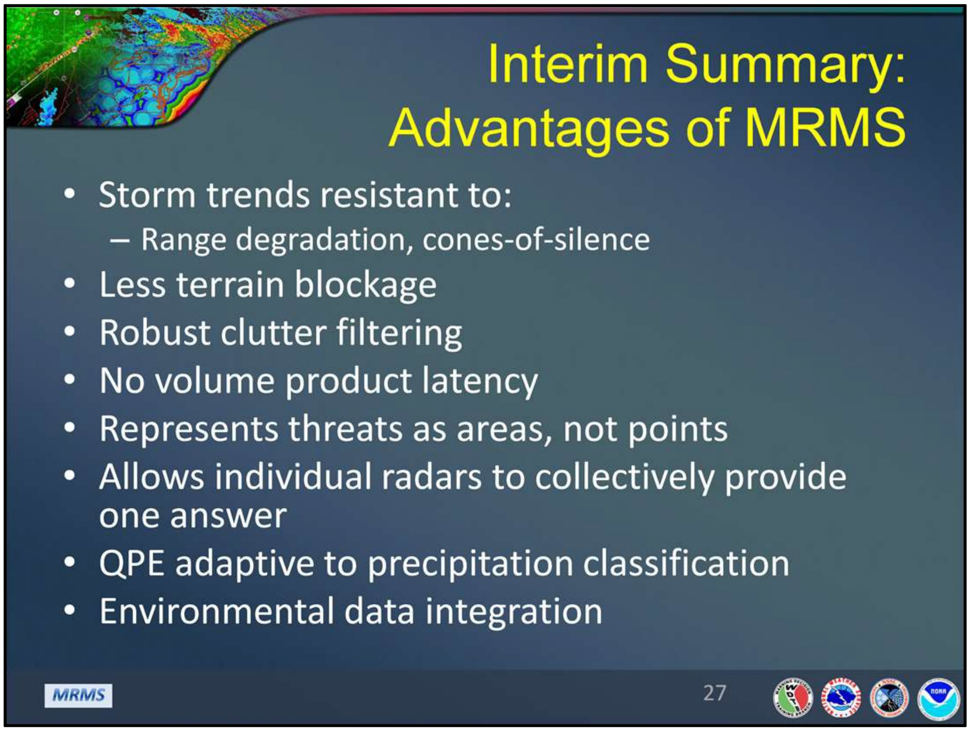


Closely related to getting one quick answer, we found that forecasters in the HWT experiments could quickly diagnose storm attributes such as hail severity potential using the Donavon technique. On the left display, an example forecaster would take anywhere from 26 sec to a minute to evaluate each storm's severe hail potential using one or more individual radars, while another example forecaster would quickly learn how to use MRMS data to reduce the time of diagnosis down to 30 sec or less.

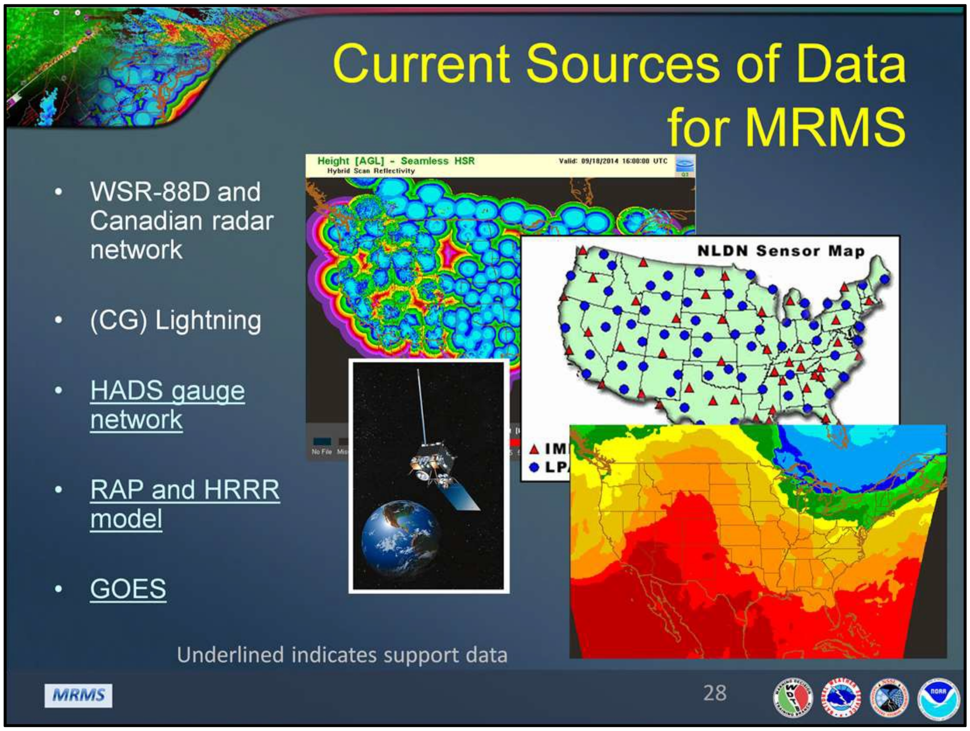


Another motivation to generate MRMS is an improved QPE process where precipitation systems are classified into categories with a following adaptation of the reflectivity-rainfall rate (ZR) relationship. This approach allows for better accuracy based on our knowledge of precipitation particle size distributions as a function of the nature of falling precipitation. The MRMS QPE mitigates errors induced by monolithically applying a single ZR relationship as this example shows when the remains of tropical cyclone Odile visited southeast AZ. Much of the precipitation was classified tropical but a few storms northwest of the remnants were appropriately classified as convective. Single radar cannot do that.

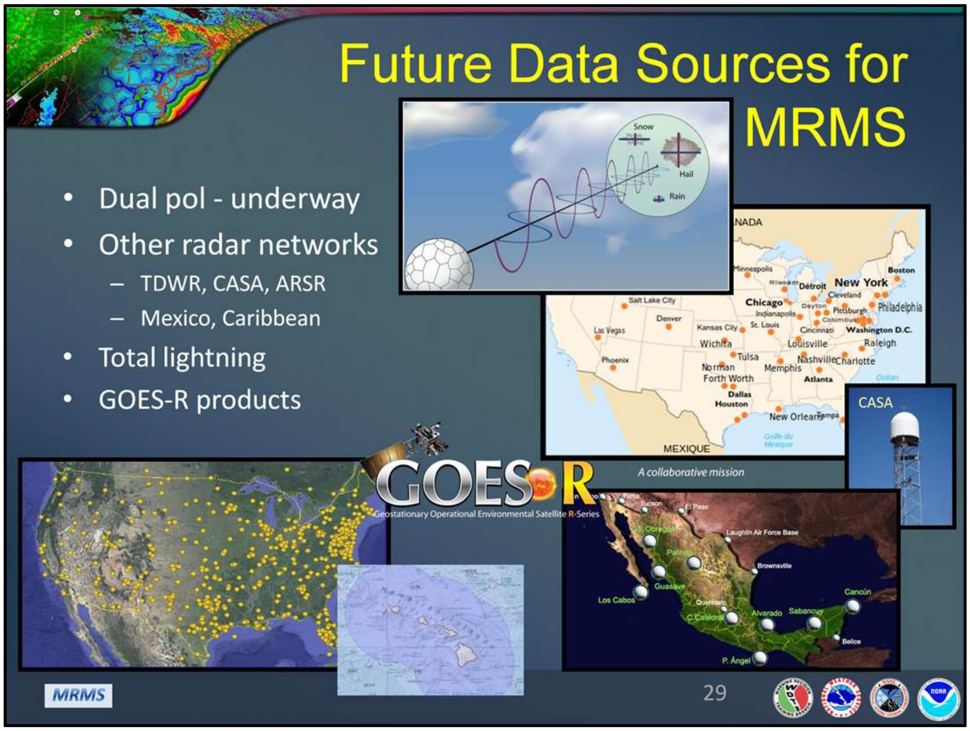
And so pulling all the motivations for MRMS together, we reveal what lies underneath. The motivation for MRMS is to provide a suite of products which incorporate data from multiple radars and multiple sensors to help forecasters manage the "fire hose" of data during warning operations



And the advantages of MRMS are many. We reviewed each one of these by going through the individual motivations.
Storm trends resistant to:
Range degradation, cones-of-silence
Less terrain blockage
Robust clutter filtering
No volume product latency
Represents threats as areas, not points
Allows individual radars to collectively provide one answer
QPE adaptive to precipitation classification
Environmental data integration

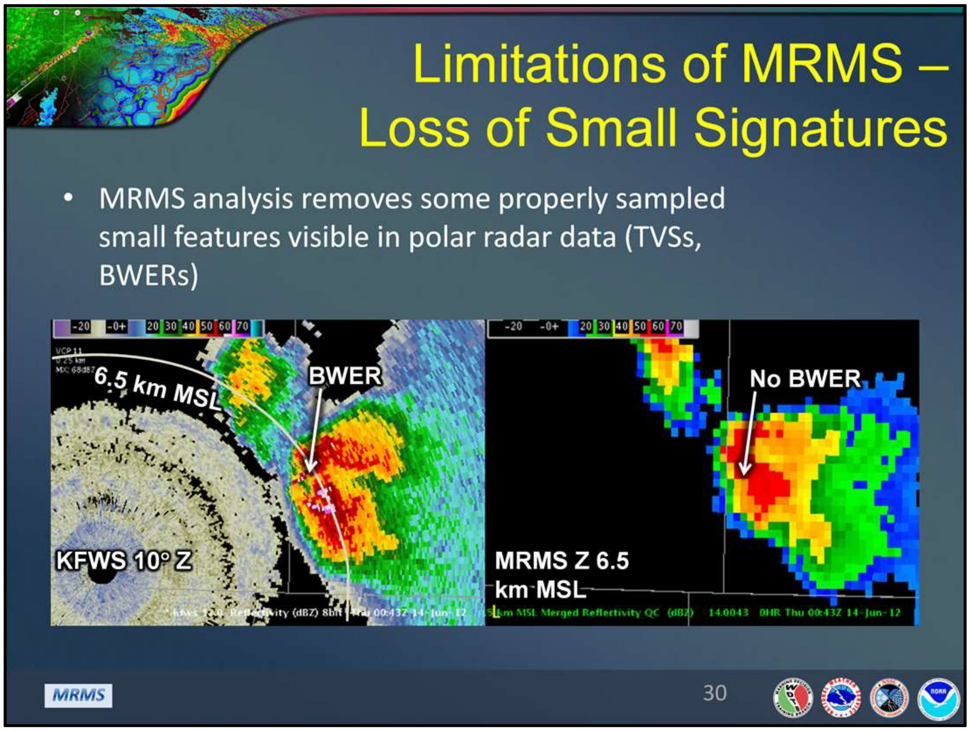


So what goes into MRMS at this time, all WSR-88Ds and radars from Environment Canada, the Earth Networks lightning data, the HADS gauge network, the RAP model for environmental analysis, and GOES provides some support data though its inclusion is somewhat limited.

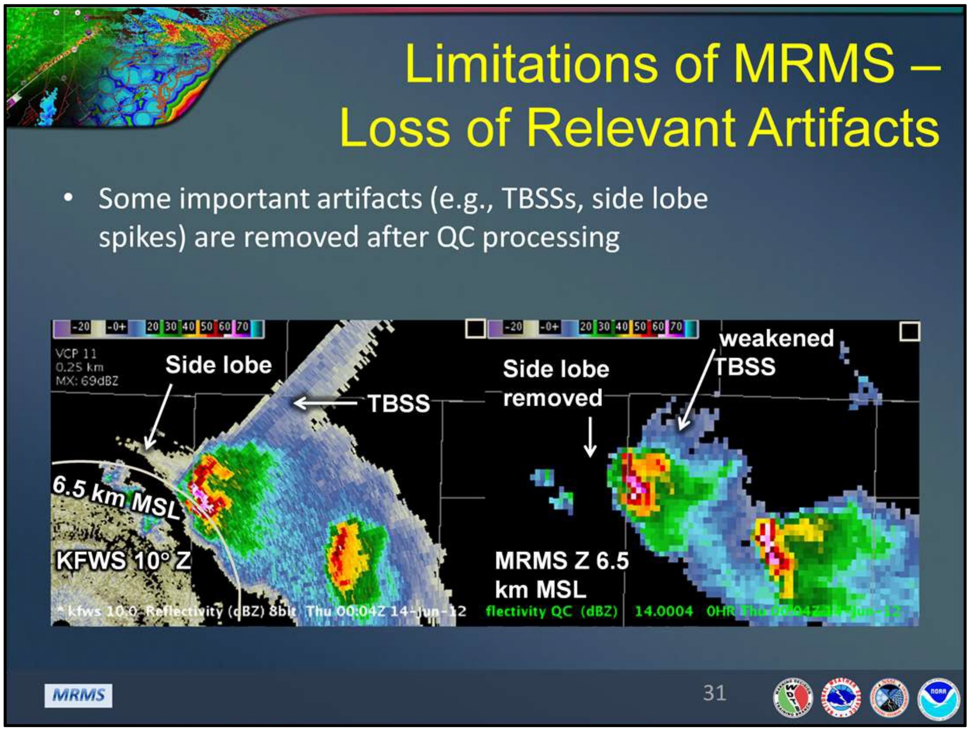


What will go into MRMS? Probably first up will be Dual pol components of the WSR-88D network due by spring of 2017. But almost as quickly will be Terminal Doppler Weather Radar (TDWR) and Air Route Surveillance Radar (ARSR) data. Caribbean and Mexican radar data will be as early as 2018. However any radar data can be added, perhaps including the Collaborative Adaptive Sensing of the Atmosphere (CASA) network or other networks. Total lightning will be available for inclusion at some point as well as GOES-R products when they become available.

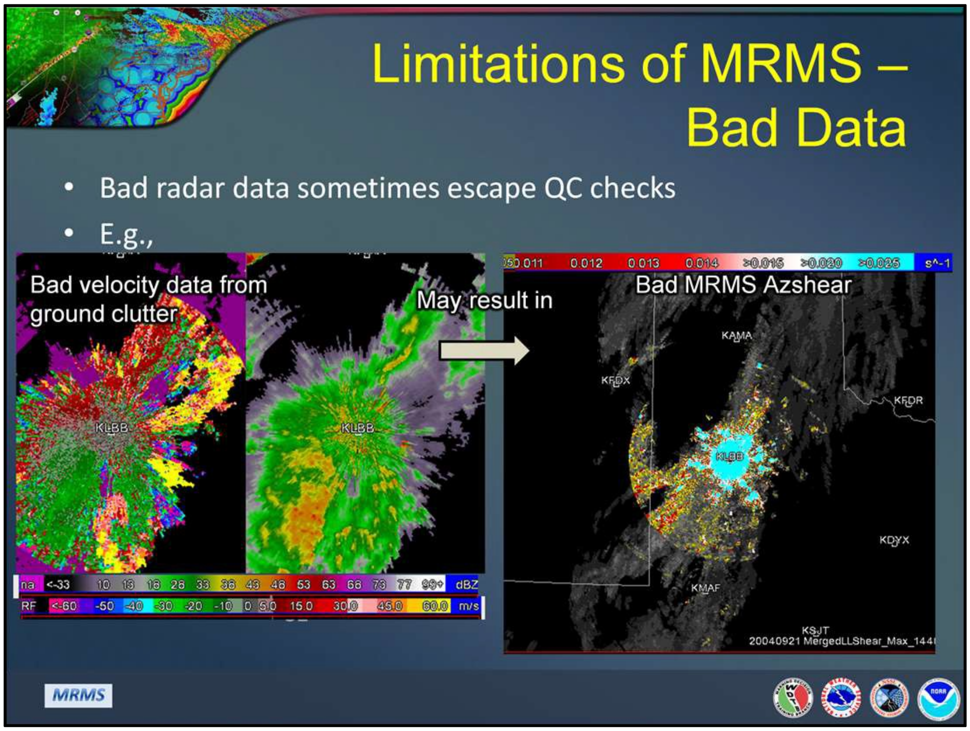
MRMS sectors for OCONUS areas will be made available soon incorporating WSR-88Ds and other data, starting with Hawaii and Guam in 2017 and continuing with Alaska and then the Caribbean.



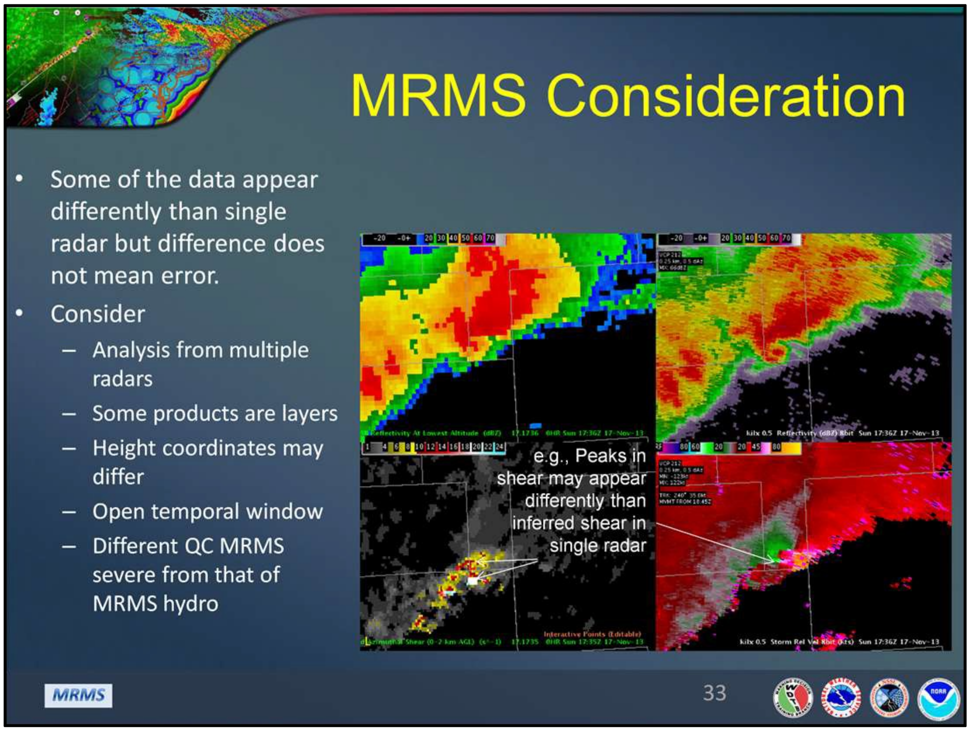
As with all technologies, there are limitations to consider. I will discuss broad limitations that can apply across many products while the follow up lessons will discuss product-specific limitations. One of the first is resolution. While MRMS can add detail at long range to one radar, the same process can smooth valid small scale signatures. In this case, a Bounded Weak Echo Region (BWER) sampled by the KFWS radar at 6.5 km MSL failed to appear in the MRMS 6.5 km MSL reflectivity.



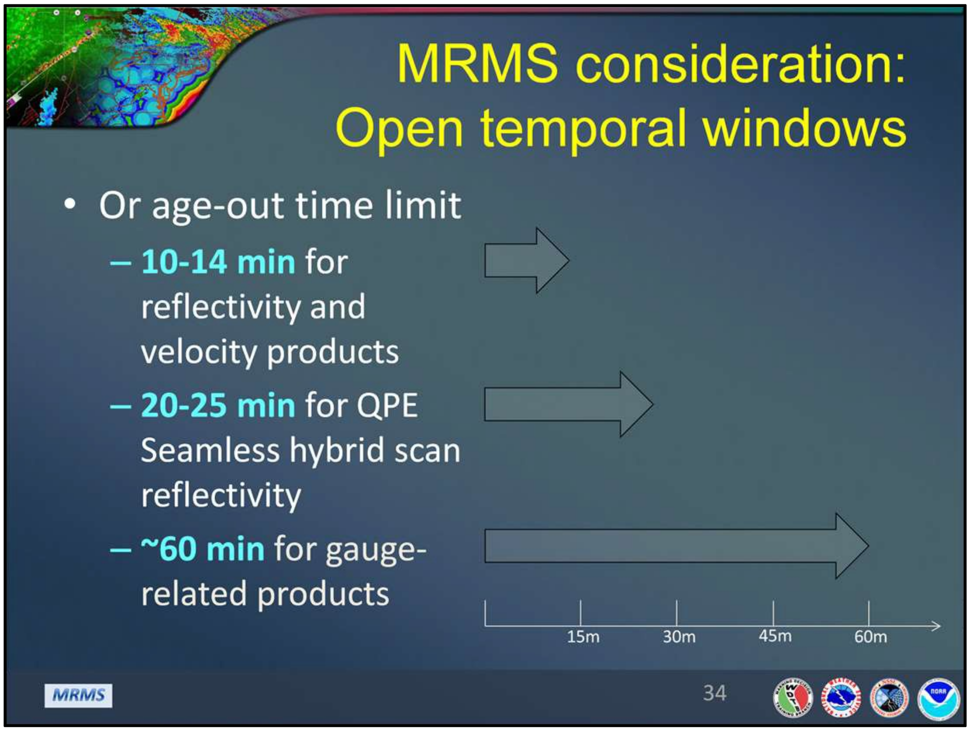
Likewise, the process that MRMS uses to eliminate non-precipitation echoes also removes useful echo artifacts forecasters use to evaluate a storm's severity. Any storm that exhibits a side lobe and Three-Body Scatter Spike (TBSS) like the one in the upper left, should support a very significant large hail and downburst threat. Like with the BWER, MRMS also eliminated the side lobe and weakened the TBSS. The lat-lon grid nature of the MRMS also softened the prominent radial appearance of the remains of the TBSS that often helps in its identification.



Despite the improving QC algorithms in MRMS, bad data sometimes gets through to negatively impact its products. In the case above, spurious velocity data inadvertently caused the MRMS AzShear product to produce extreme shear. Luckily such an extreme example appears quite obviously bad. But there may be more subtle errors.



Some aspects of MRMS are neither limitations or advantages. They are simply called considerations. The biggest consideration is that MRMS may look different from that of single radar. However that difference doesn't mean error. Consider that MRMS is analyzing multiple radars, each with their respective viewing angle. MRMS also produces some products that are layers (e.g., Azimuthal shear) that means a direct comparison to single radar data is not easy. Height coordinates may differ. MRMS often does MSL, but some products are in an AGL coordinate. But none of the coordinates are above radar level. The MRMS grid points collect data for a period of time. In combination with multiple contributing radar viewpoints, the data may appear different, such as the multiple peaks in azimuthal shear compared to what could be inferred from a single radar. Finally, the quality control for MRMS hydro products differs somewhat from the severe/aviation products. These differences are by necessity to do what's needed to ensure the highest quality of the respective products.



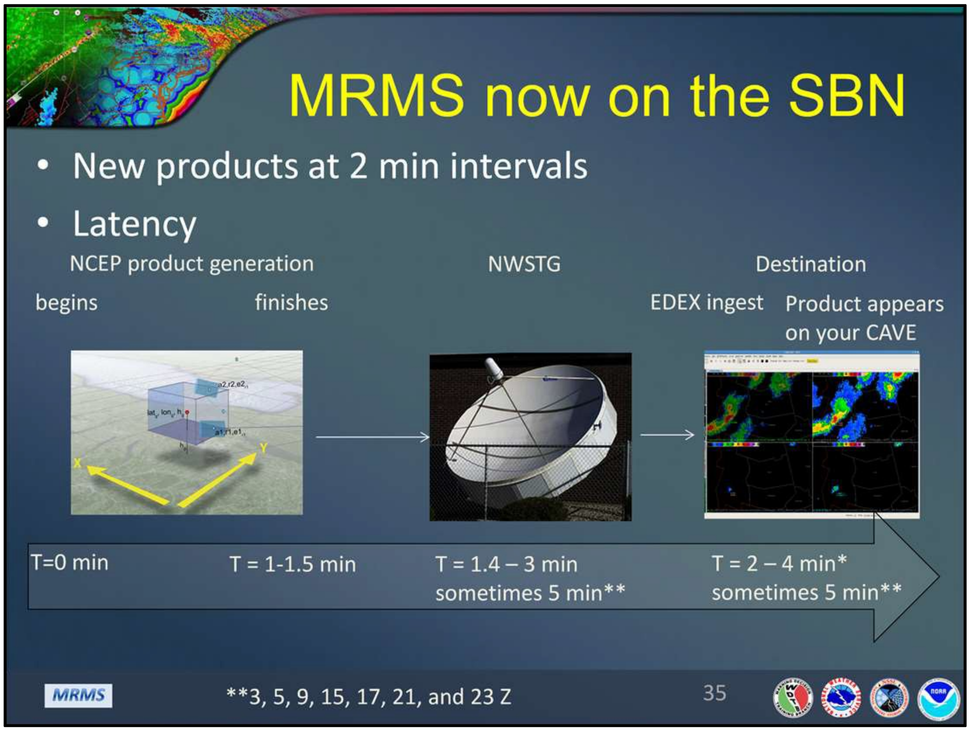
The MRMS system employs an open temporal window in which it accepts all new data. Another name could be an age-out limit. It's basically a limit in which old data gets purged. This is helpful because on occasion a radar will go out and/or old data tries to get in.

For the merged 3-D reflectivity grid and the two azimuthal velocity layers, the age-out is up to 10-14 minutes.

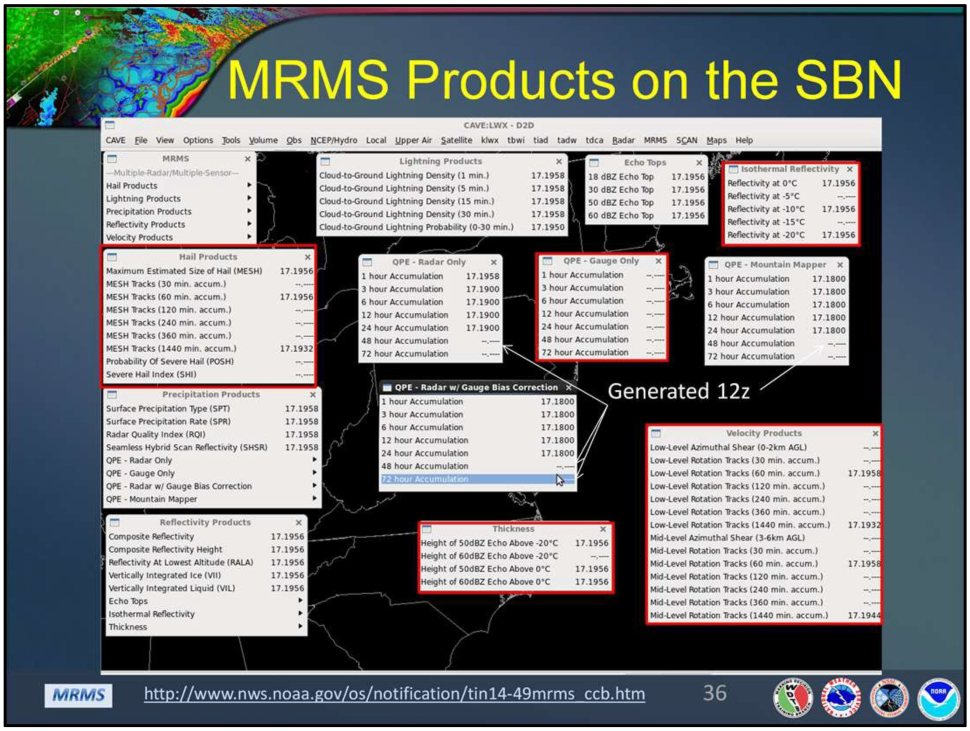
The age-out increases to 20-25 minutes for the QPE Seamless hybrid scan reflectivity.

Gauge data gets to stay in the system up to 60 minutes after the report time.

Consider these age-out times and their impacts on the products. If a radar goes out, the algorithm searches for active data to update grid cells from other radars. If no other radars are available then an echo may persist for some time before being purged. Gauges report less frequently and so the age-out is understandably longer.



MRMS is now available on the SBN where the data updates in 2 minute intervals. However how much later you get the product compared to the product legend time is the latency. Let's start with the beginning and show how the time latency builds. Products get generated at the NCEP National Computing Office (NCO), then get sent to the NWS Telecom Gateway (NWSTG), transfers to the SBN where then your local (EDEX) ingests the product for display on your machine (CAVE). At the beginning, MRMS generation software begins to process the raw data accumulated over a temporal window for each product. At the moment, a time stamp is created that eventually winds up in the product legend in CAVE, that's T=0 min. The time it takes to generate each product varies depending on the complexity of the algorithm, mostly 1 to 1.5 minutes (note that some QPE products take a long time). Then the product goes in a queue to be sent to the NWSTG for upload through the SBN. The queue can build the latency up to 1.4 to 3 minutes, but every 3 hours the queue raise the latency up to 5 minutes as MRMS data competes with model data. Once on the SBN, the product quickly goes to your ingester where a fraction of a minute is needed to make it visible on your CAVE. In summary, MRMS latency is 2 – 4 minutes with occasional spikes to 5 minutes or even more.



This is the list of MRMS products available on the SBN. Look to the MRMS menu along the top row of CAVE. Once in the menu, the MRMS products are broken down by general classifications, eg., reflectivity, hail, lightning, velocity, precipitation.

The majority of the products arrive at two minute intervals while a subset of the QPE products arrive at longer intervals. These products are covered in more detail in the following lessons of this products course.

You will notice that not all the menu items are currently being filled with products because of bandwidth limitations.

Some of the green times may be missing for the 48 and 72 hour precip products because they're generated daily at 12 Z. Check your purge if you have problems viewing these products.

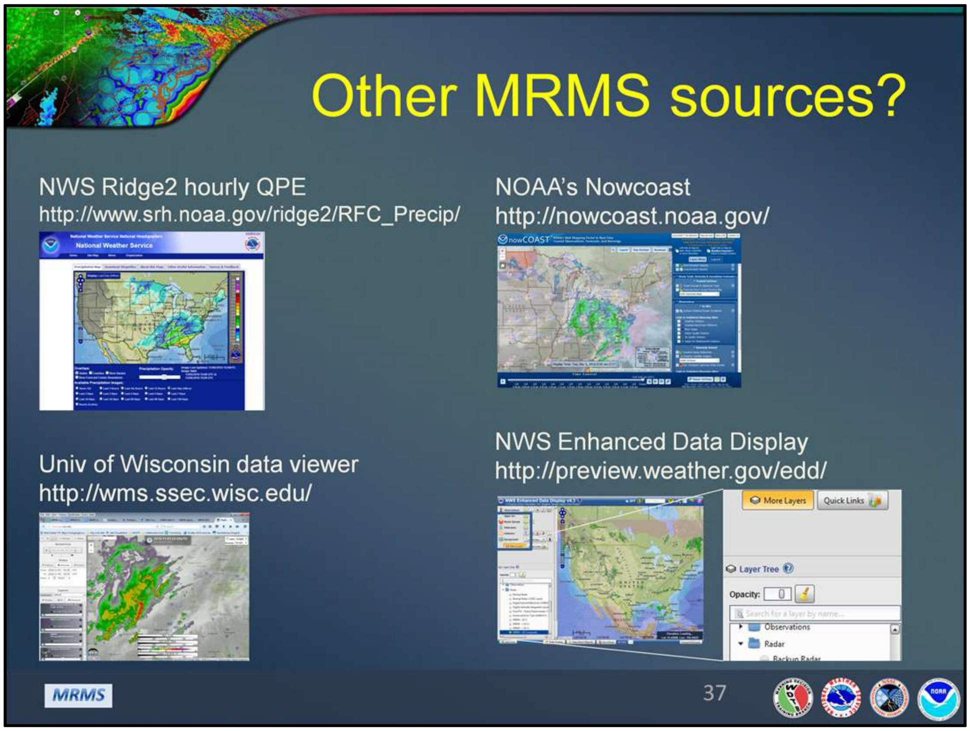
Only the 60 min and 1440 minute rotation tracks, and the 0C, -10C and -20 C isothermal reflectivity products are being transmitted on the SBN.

The instantaneous MESH, 60 minute and 1440 minute MESH tracks are being transmitted but not the others.

Currently there are no gauge-only MRMS products being transmitted via SBN.

Finally the 60 dBZ ET above -20 C is not being transmitted.

The link at the bottom refers to the announcement of MRMS products on the SBN.

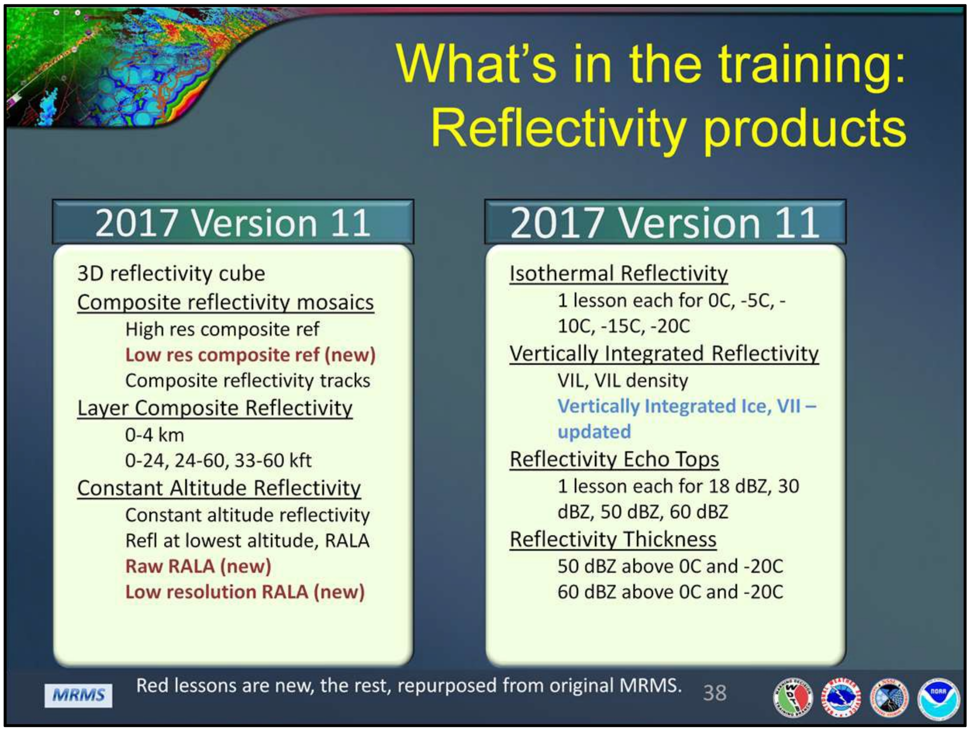


MRMS data can be accessed on a variety of public websites.

Starting with the most operationally reliable sites we start with the NWS Ridge2 site. It uses MRMS data for its reflectivity and hourly QPE displays. NOAA's Nowcoast site supplies low-level reflectivity data for people interested in marine and inland weather.

A very comprehensive weather data viewer at the University of Wisconsin offers you a variety of MRMS products and an experimental data viewer, called the Enhanced Data Display, is aimed at decision-makers in need of multiple overlays.

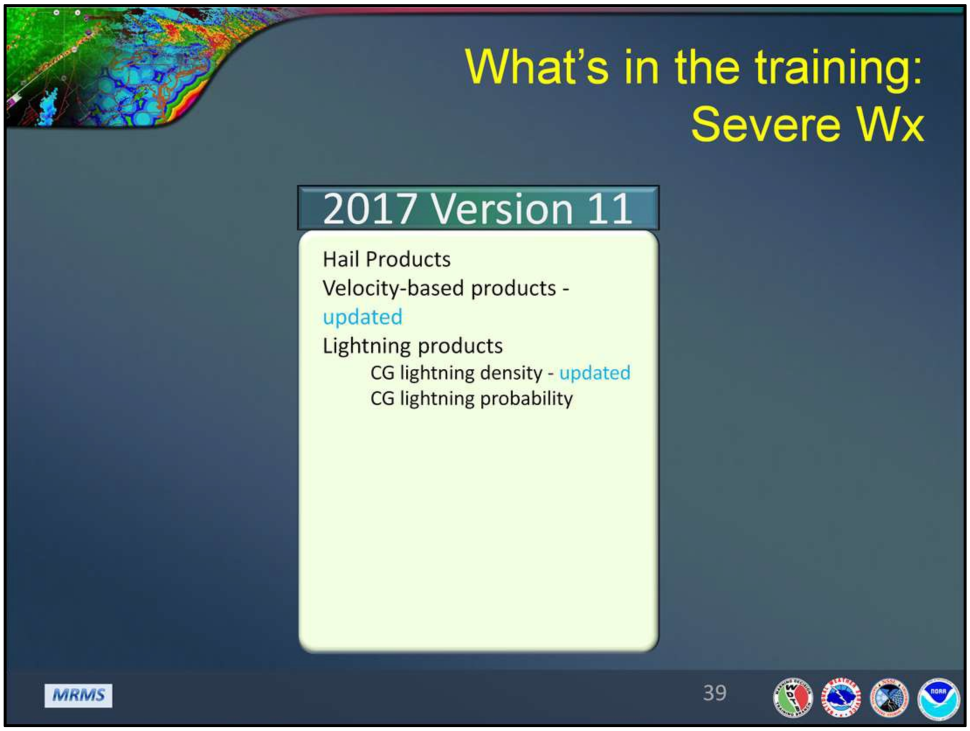
A word of caution about nonoperational sites is that the data may not always be available.



With respect to the MRMS training, you are almost done with the overview of the MRMS products course. The version 11 of the products course has been reorganized a bit so that each lesson covers fewer products. This strategy makes our job simpler when there are changes to products and offers you flexibility to access information on specifics more quickly.

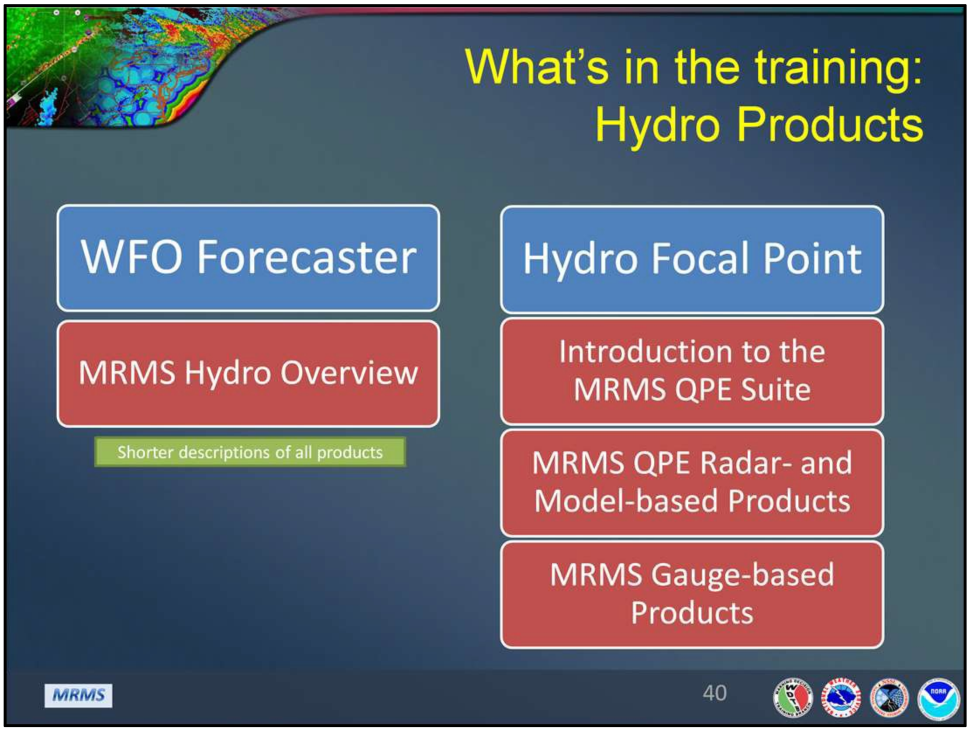
Each row of the tables under the headers above represents a lesson. The lessons in black have had no changes from the first version of the course and no retake is needed if you've completed the first MRMS products course. Lessons labeled 'blue' have minor changes where credit's applied if you've taken their previous version, however you may want to quickly review these lessons. New products lessons are labeled in red and should be taken.

These lessons are predominantly a description of the products, how they are made, quality control processes and a little bit about common applications and limitations. Three of the lessons reflect new products for version 11 of MRMS, low resolution composite reflectivity, raw reflectivity at lowest altitude (RALA), and low resolution RALA.



Products lessons for other MRMS severe products include one for hail, velocity – namely azimuthal shear and rotation tracks, and lightning products.

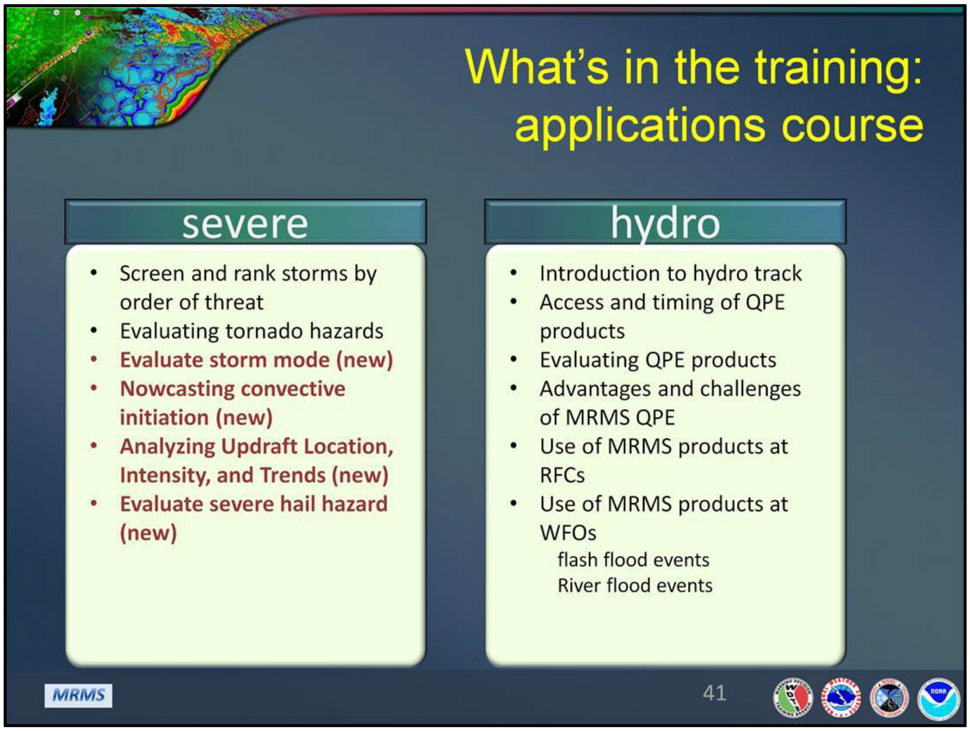
Two of the products listed here have changed since MRMS first became operational. There is an updated algorithm to calculate azimuthal shear that feeds all velocity products and the lightning density product has also changed.



For the MRMS hydro-related products, there are two tracks to choose from depending on your job responsibilities.

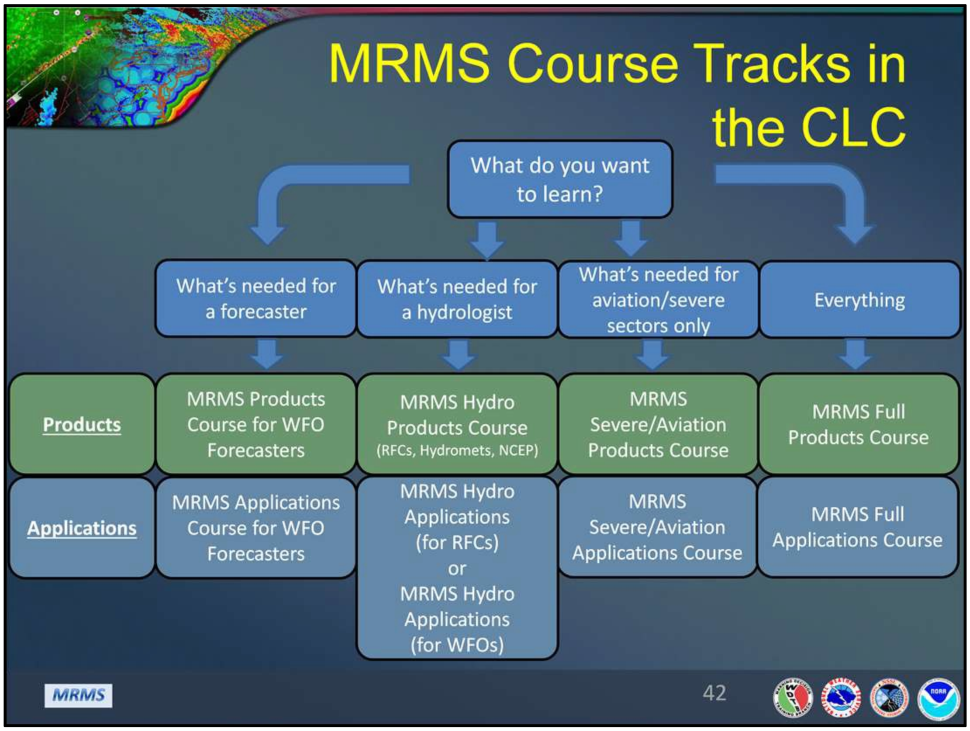
For the WFO forecaster who just wants to know what products are out there, take only the Hydro Overview lesson. This lesson is simply a more condensed version of the full hydro course, and best meets the needs of most forecasters.

For hydro focal points who want to know the nitty-gritty behind the quality control processes and product creations, take all three lessons of the Hydro Products Course. These lessons cover everything in the Overview lesson, just in greater detail. Therefore, this is no need for a Focal Point to take the Overview before taking these three lessons.



The MRMS applications course helps you to use MRMS to identify specific phenomena, as well as applying MRMS to more common problems you may experience. This version 11 now contains multiple new lessons including Evaluating Storm mode, Nowcasting convective initiation, Analyzing Updraft Location, Intensity, and Trends, and evaluating severe hail hazards.

The QPE applications include how to evaluate their accuracy and how to use them in RFCs and WFOs, the latter for flash flood and river flood events.



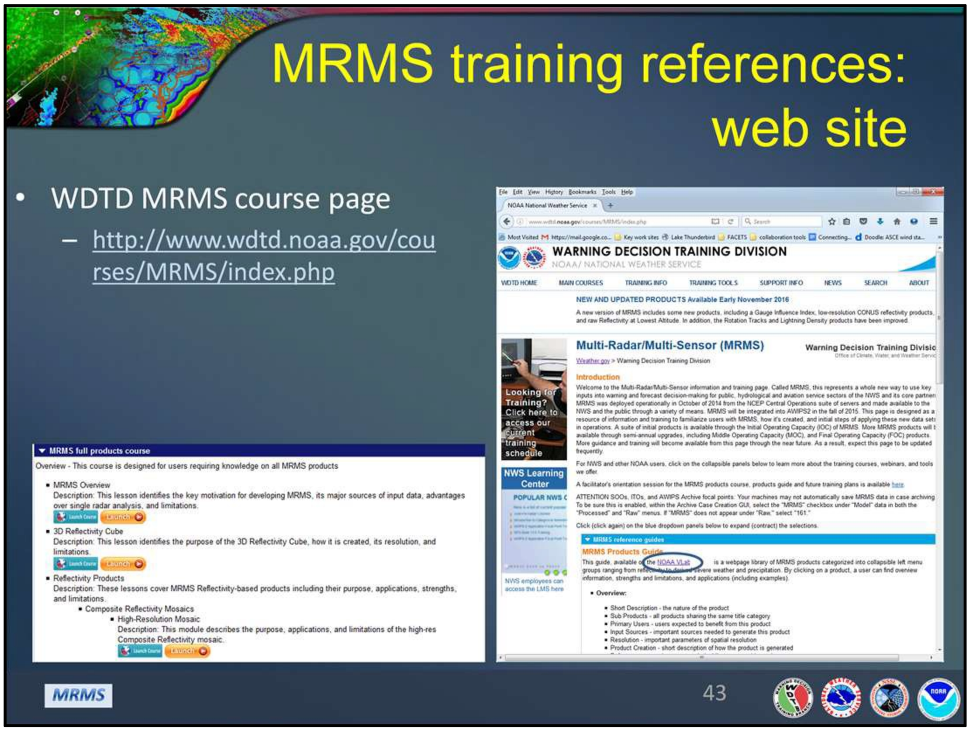
There are four MRMS training tracks divided up by what you need out of this training.

If you're a forecaster then you may be most interested in taking the MRMS Products Course for WFO forecasters followed by the MRMS Applications Course for WFO Forecasters.

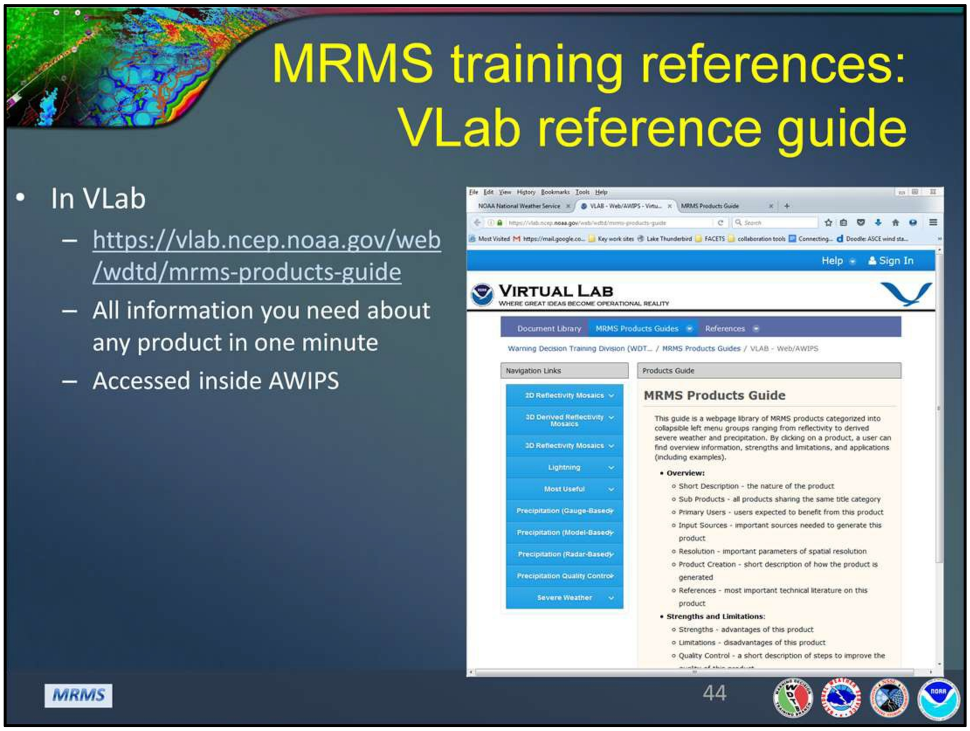
If you're a hydrologist, you may want to take the MRMS hydro products course then either the MRMS Hydro Applications course for RFCs or the one for WFOs, depending for whom you work.

If you're interested in severe and aviation applications of MRMS only then you would take the MRMS Severe/Aviation Products Course followed by the MRMS Severe/Aviation Applications Course.

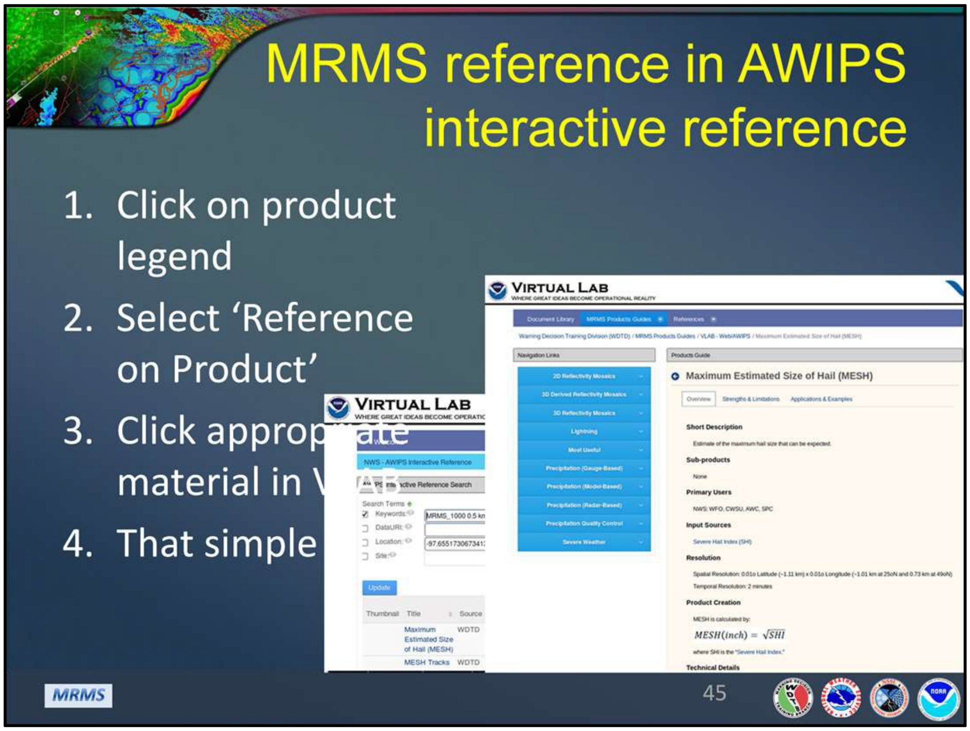
And finally, if you want to know everything, then take the MRMS Full Products course followed by the MRMS Full Applications course.



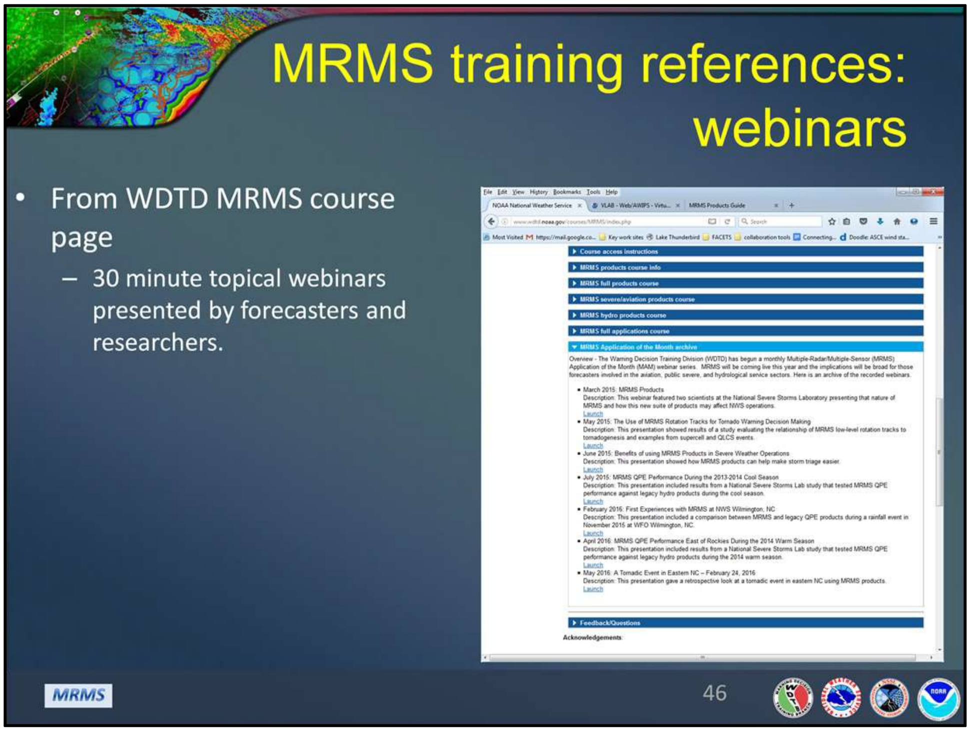
There are numerous references available concerning MRMS. The path to these starts at the MRMS web page in WDTD. In here you have access to our online courses, links to the lessons in the Commerce Learning Center and references. Note the link to the NOAA vlab MRMS reference guide.



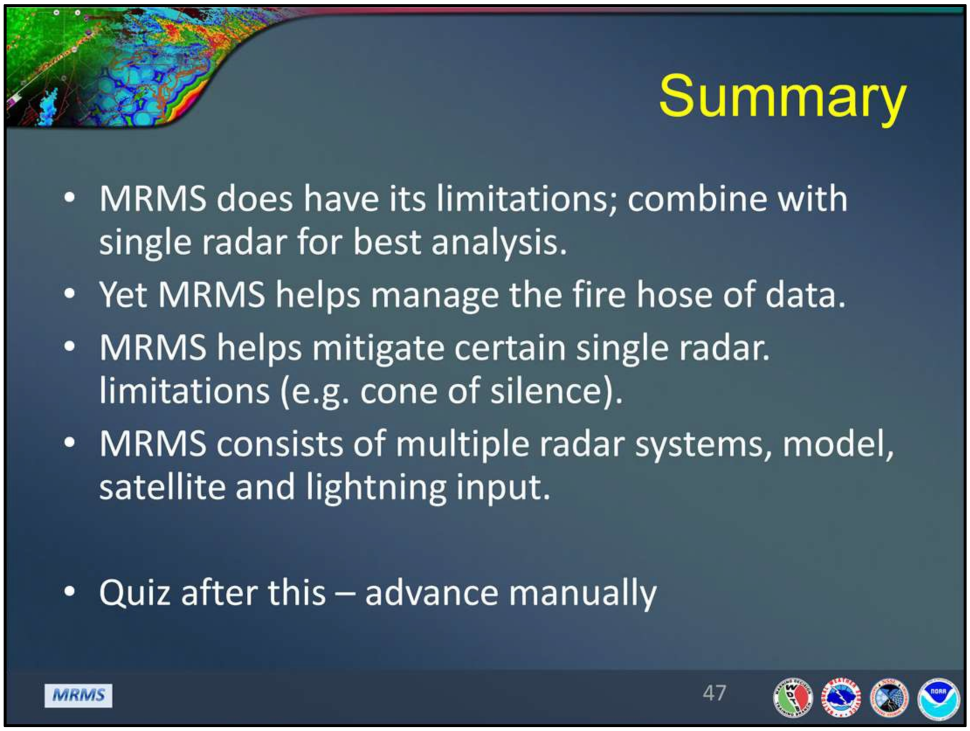
The reference guide is available in VLAB, which means also inside of AWIPS. From there, it has content about every product that you can easily access, including a description, strengths and limitations, and primary applications.



AWIPs now has a product reference guide, a feature that makes looking up information on MRMS products very easy. Right mouse button clicking on the product legend, in this case, MESH, brings up the familiar menu with an added option, product reference guide. Selecting it brings you into the VLAB MRMS product reference guide upon which you can select one of two MESH-based products. Up comes the VLAB reference guide for MESH and now you can quickly remind yourself of the salient features of the product.



Also in the main course page, you may access a series of MRMS webinars, presented by forecasters and researchers alike. They typically last 30 minutes with a similar format to the ‘Storm of the Month’ webinars.



In summary,

MRMS does have its limitations, especially in smoothing away important small scale signatures, so combine with single radar data for best analysis.
Yet MRMS helps manage the fire hose of data by providing a single answer on one display that should help facilitate situational awareness.
MRMS helps mitigate certain single radar limitations (e.g. cone of silence, better trends, more accurate QPE).
MRMS consists of multiple radar systems, model, satellite and lightning input.


MRMS Overview Quiz
Quiz - 5 questions
Last Modified: Sep 17, 2015 at 08:20 AM
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On failing, 'Finish' button:
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After user has completed quiz
User may view slides after quiz:
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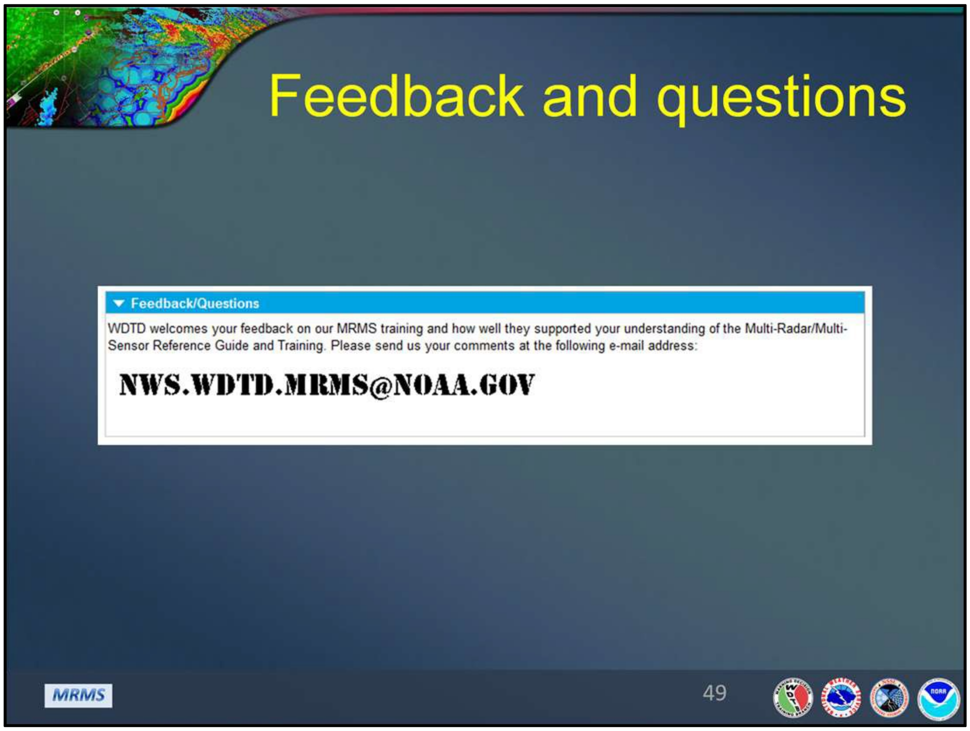
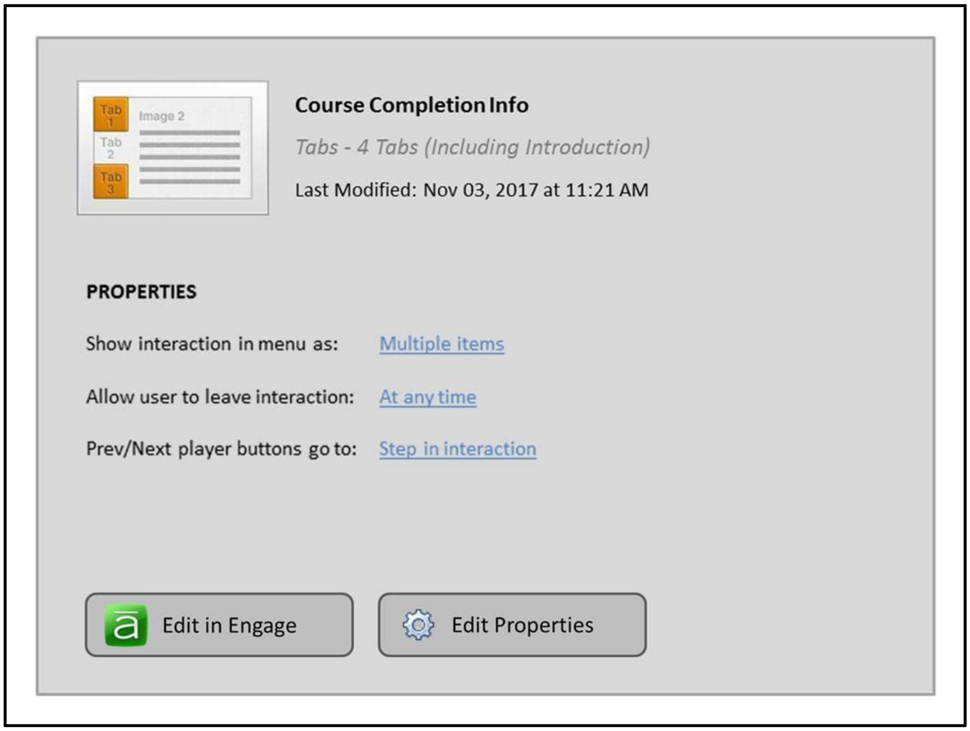


If you have any questions about MRMS, please contact the email address displayed here.

MRMS training team

- WDTD
  - Jim LaDue
  - Alyssa Bates
  - Jill Hardy
  - Clark Payne
  - Andrew Wood
- From NSSL
  - Steve Martinaitis
- educators in the NOAA VLAB
  - https://vlab.ncep.noaa.gov
  - MRMS community forum

Welcome to the Multi-Radar / Multi-Sensor Initial Operating Capacity Product Training Course Lesson on the 3D Reflectivity Cube!


Tab 1
Image 2
Tab 2
Tab 3
Course Completion Info
Tabs - 4 Tabs (Including Introduction)
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Prev/Next player buttons go to: Step in interaction
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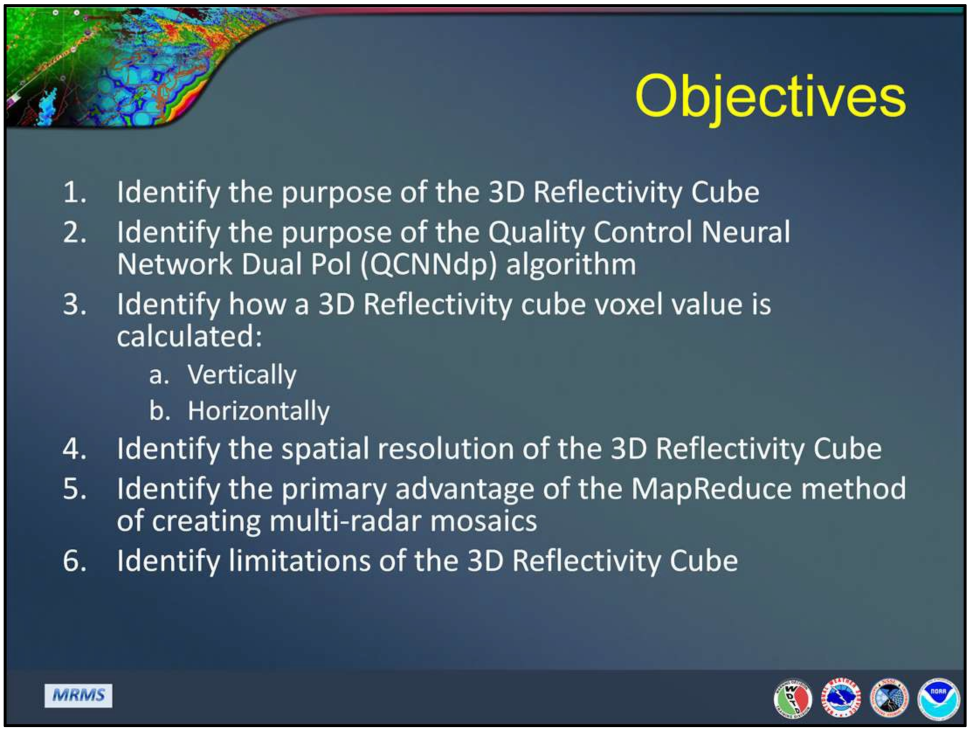
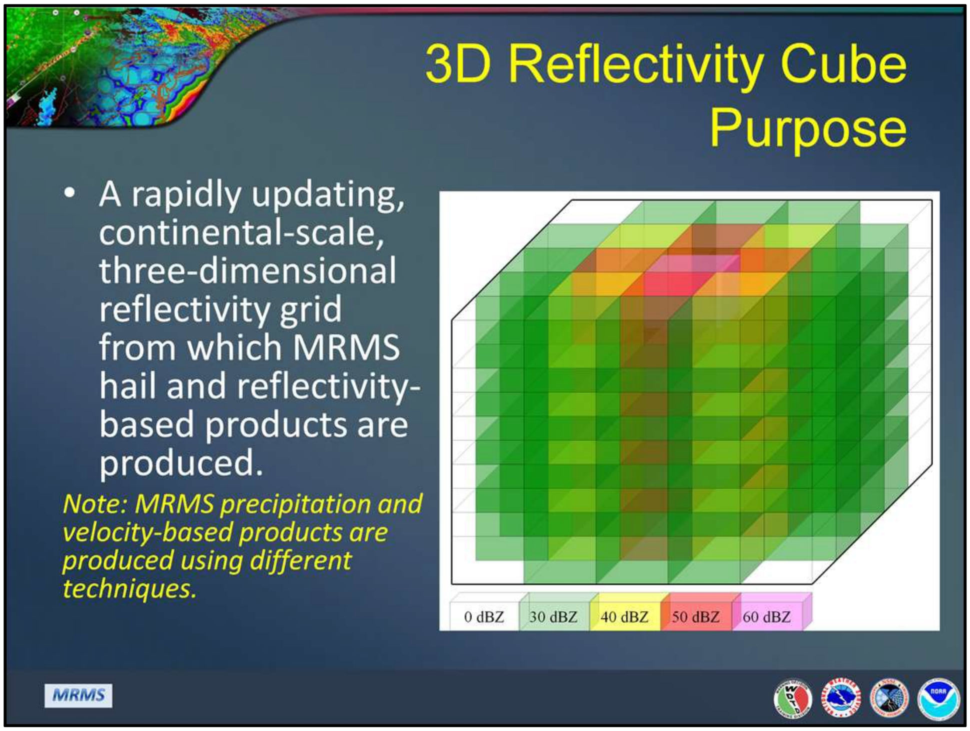
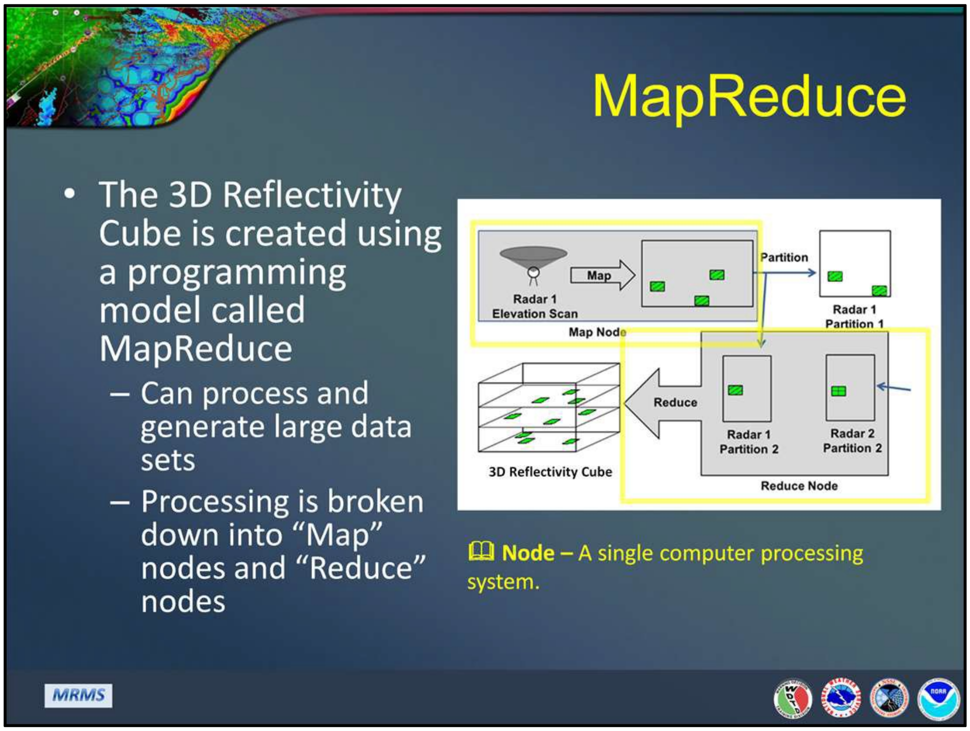


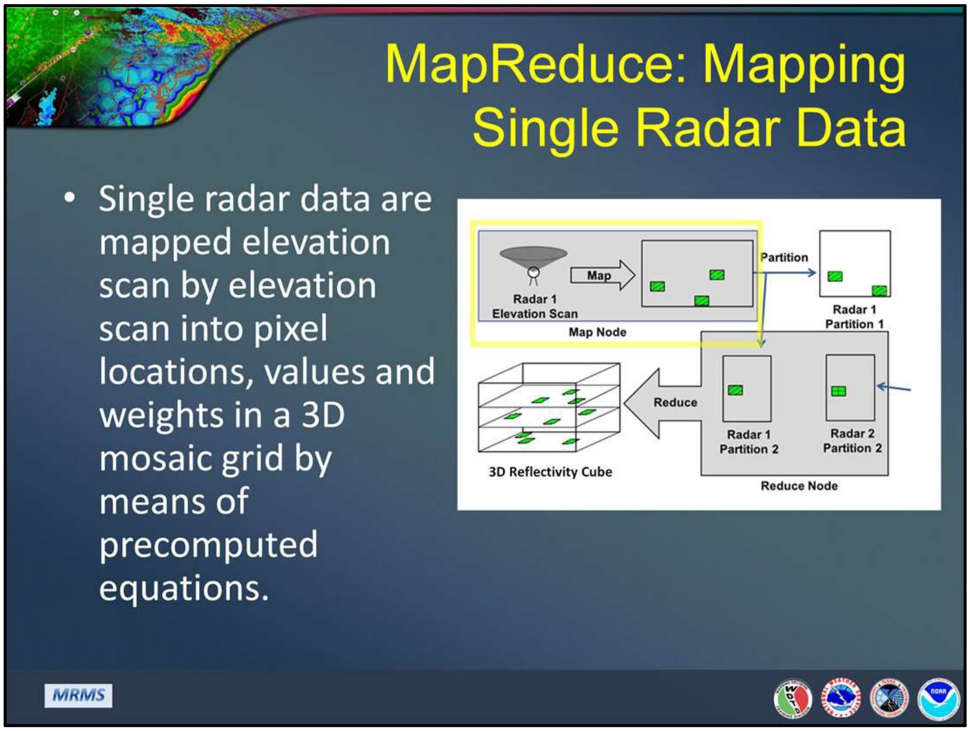
Here are the objectives for this lesson. Take a minute to review them before moving on to the next slide.



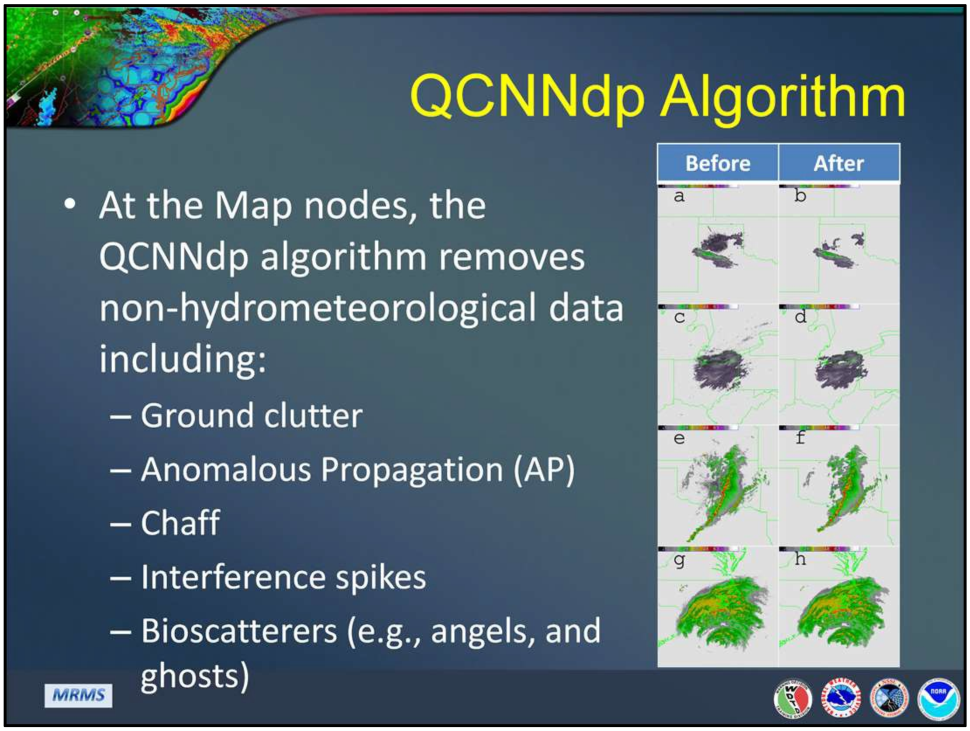
The 3D Reflectivity Cube is a rapidly updating, continental-scale, three-dimensional reflectivity grid from which Multi-Radar / Multi-Sensor (MRMS) hail and reflectivity-based products are produced. Note that MRMS precipitation and velocity-based products are produced using different techniques.



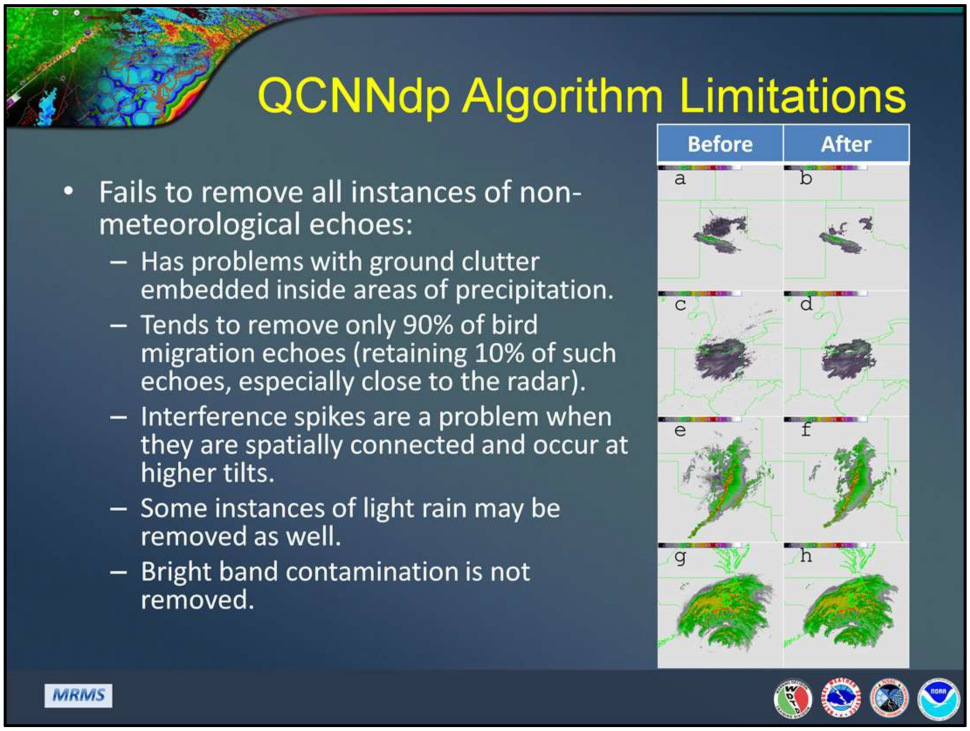
Because of the high temporal and spatial resolution of data available from the United States' (and surrounding countries') network of weather radars, creating radar mosaics in real-time has been possible only through compromises on the quality, timeliness or resolution of the mosaics. To address these issues, the 3D Reflectivity Cube is created using a programming model called MapReduce which can process and generate large data sets. MapReduce processing is broken down into "Map" nodes and "Reduce" nodes. The term "node" in this context refers to a single computer processing system.



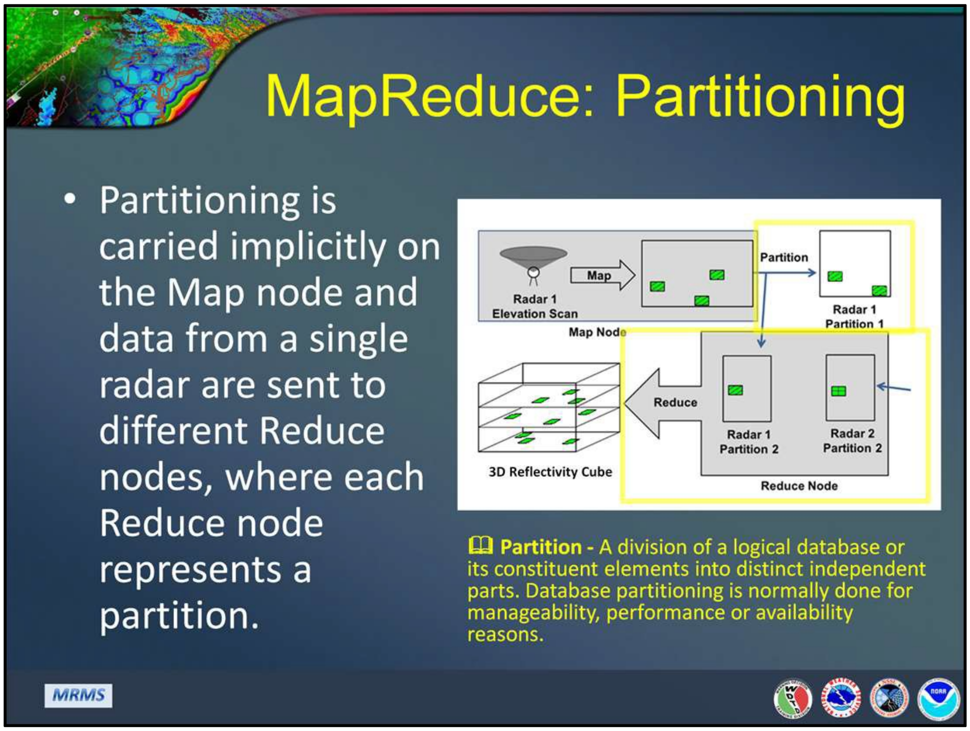
Single radar data are mapped elevation scan by elevation scan into pixel locations, values and weights in a 3D mosaic grid by means of precomputed equations. We'll discuss this process in more detail shortly.



At the Map nodes, the Quality Control Neural Network Dualpol (QCNNdp) algorithm removes non-hydrometeorological data including: Ground clutter, anomalous propagation (AP), chaff, interference spikes, and bioscatterers (e.g., angels, and ghosts).

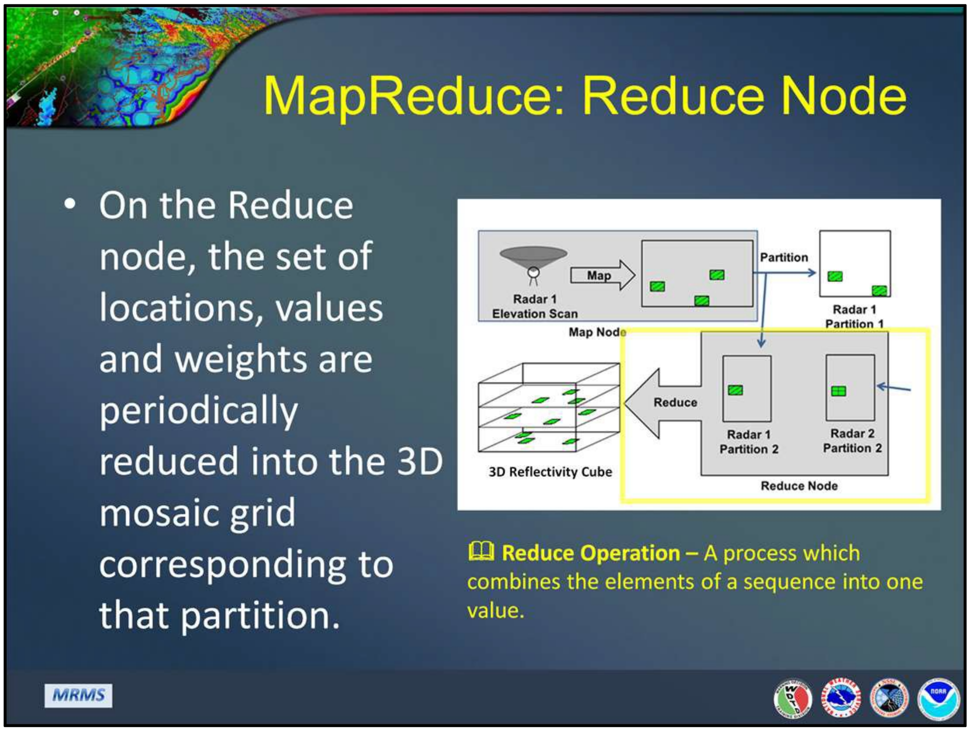


The Quality Control Neural Network Dualpol (QCNNdp) algorithm has a high degree of skill, but it fails to remove all instances of non-meteorological echoes. In particular, it has problems with ground clutter embedded inside areas of precipitation and tends to remove only 90% of bird migration echoes (retaining 10% of such echoes, especially close to the radar). In addition, interference spikes are a problem when they are spatially connected and occur at higher tilts. Some instances of light rain may be removed as well. Bright band contamination is not removed.



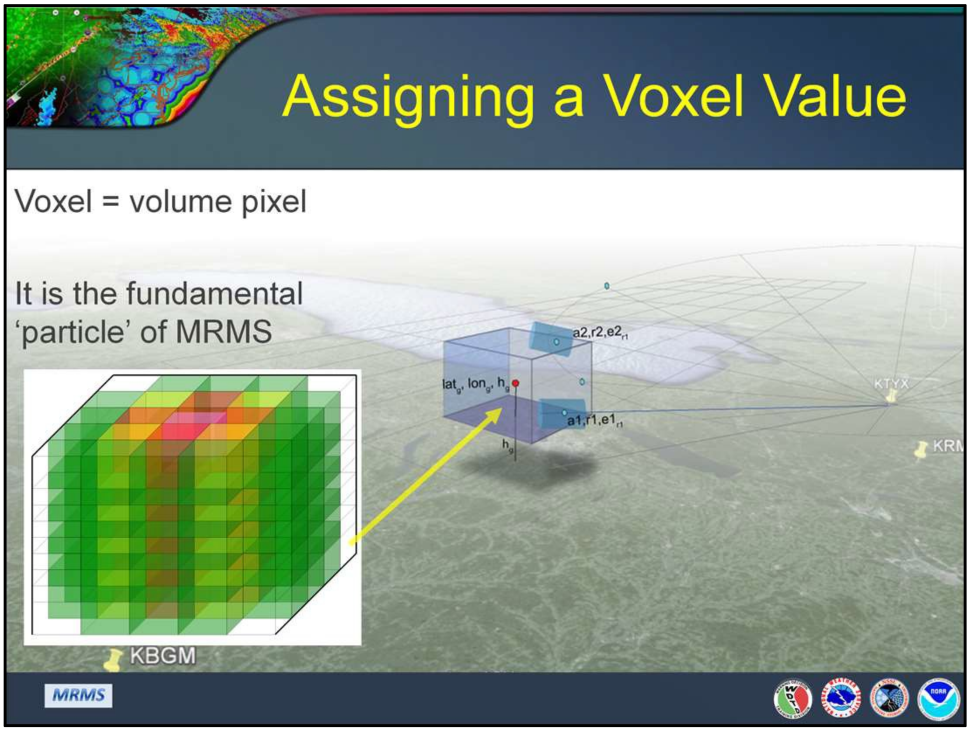
In computer processing, partition means a division of a logical database or its constituent elements into distinct independent parts. Database partitioning is normally done for manageability, performance or availability reasons.

In MapReduce, partitioning is carried implicitly on the Map node and data from a single radar are sent to different Reduce nodes, where each Reduce node represents a partition.

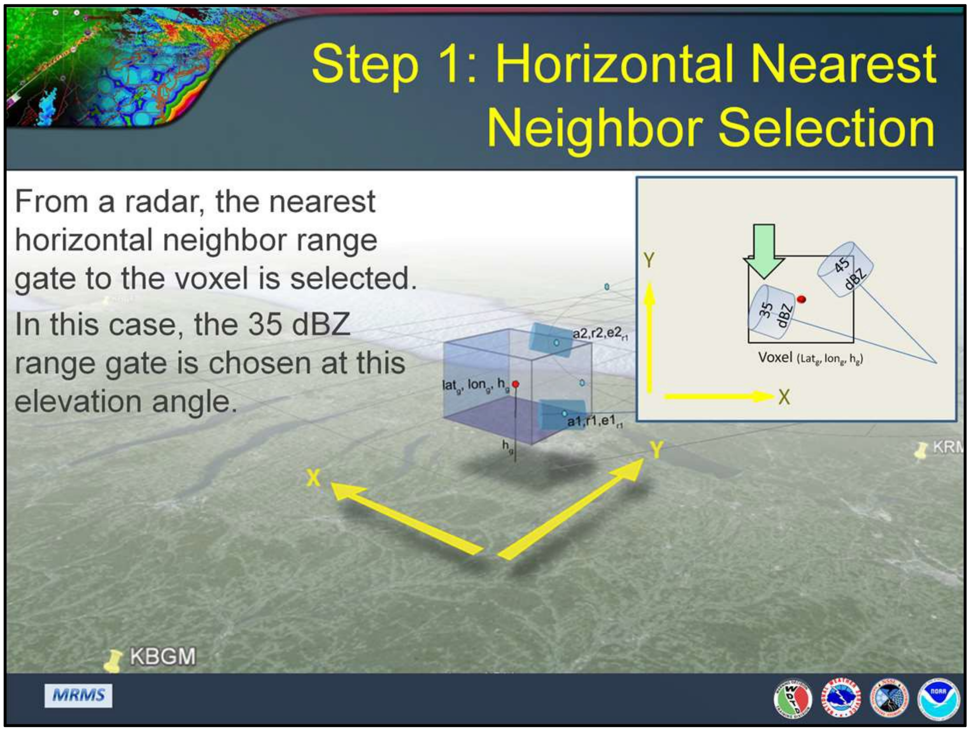


In computer processing, a reduce operation is a process which combines the elements of a sequence into one value.

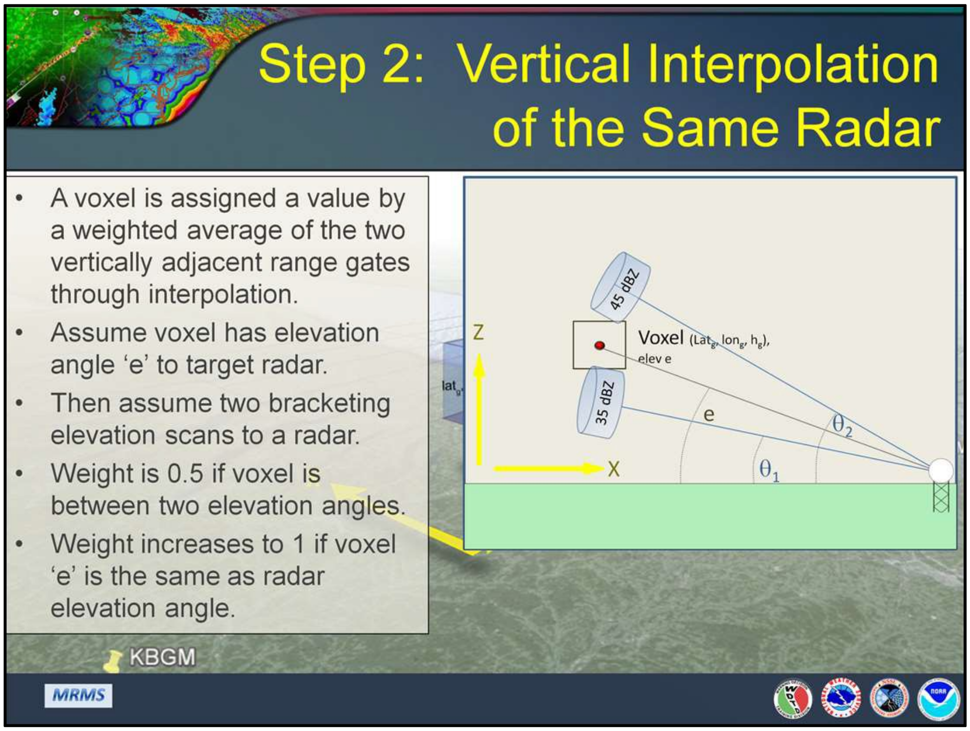
On the MapReduce's Reduce node, the set of locations, values and weights are periodically reduced into the 3D mosaic grid corresponding to that partition.



A voxel is a volume pixel and represents the most fundamental 'particle' of the MRMS system. A 3D Reflectivity Cube voxel must get its value from the contributing radars. Let's now discuss how this is done.

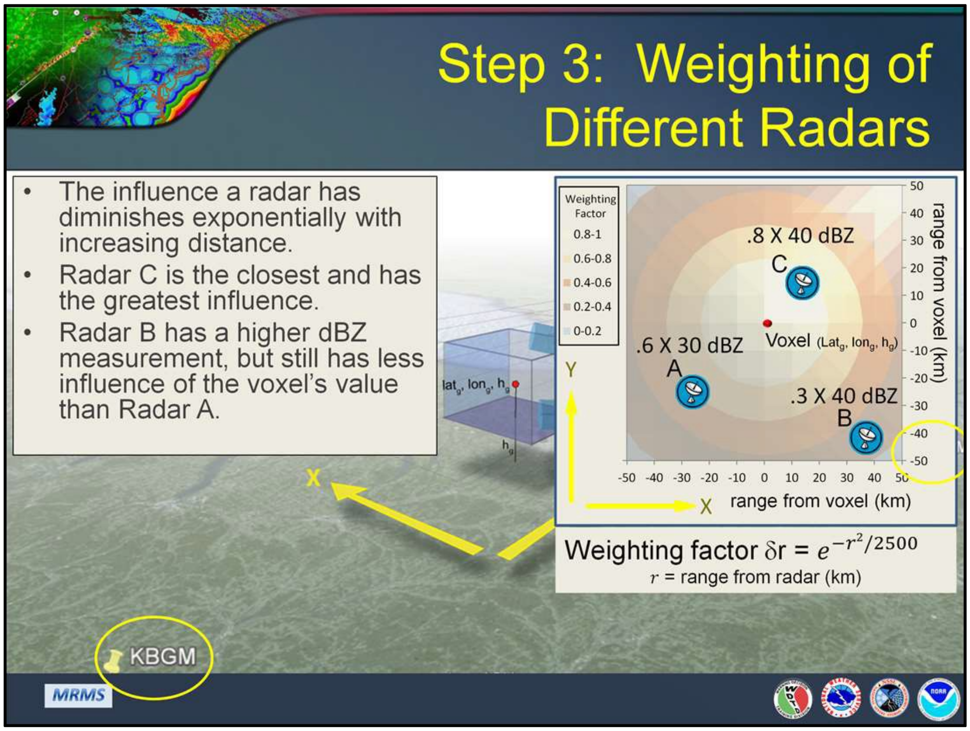


First, at the Map node, from a radar, the nearest horizontal neighbor range gate to the voxel is selected. In this case, the 35 dBZ range gate is chosen at this elevation angle.



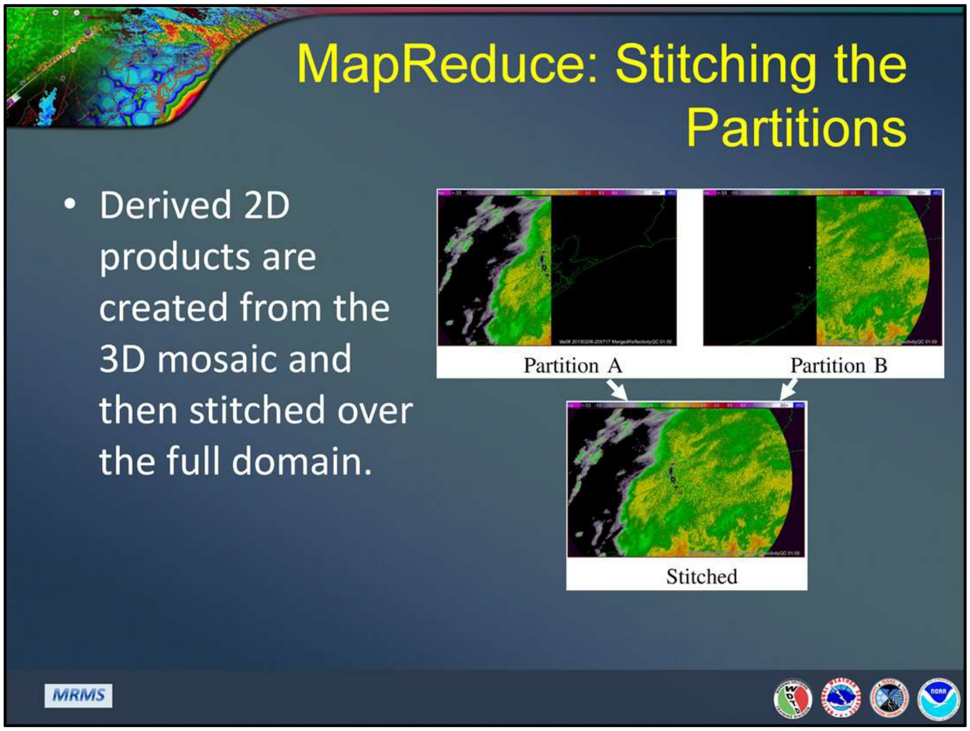
Once a horizontally nearest neighbor range gate has been chosen for a Voxel, the next step, at the Reduce node, is to assign a value to the voxel by vertical interpolation. A voxel is assigned a value by a weighted average of the two vertically adjacent range gates through interpolation.

Let's illustrate the concept. Assume a voxel has a elevation angle 'e' to a source radar to the range gates. Assuming two elevation angles (1 and 2) bracket the voxel, then a weight of 0.5 is applied if the voxel elevation angle is halfway between the two range gates. The weight increases towards 1 as the difference in elevation angles between the voxel and the closest range gate becomes the same.

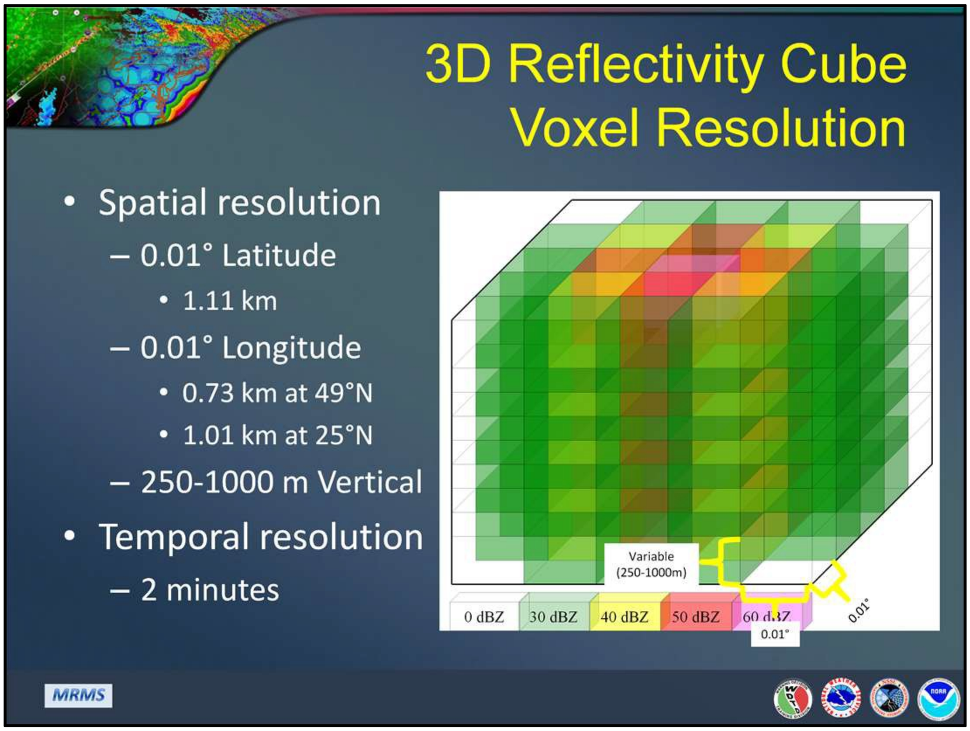


Recall, the first two letters of MRMS stand for "Multi-Radar." Voxels which comprise the 3D Reflectivity Cube typically receive input from more than one radar. In these cases, how is a voxel's value influenced by each radar? Well, it's calculated as a weighted average in which the influence a radar has diminishes exponentially with increasing distance.

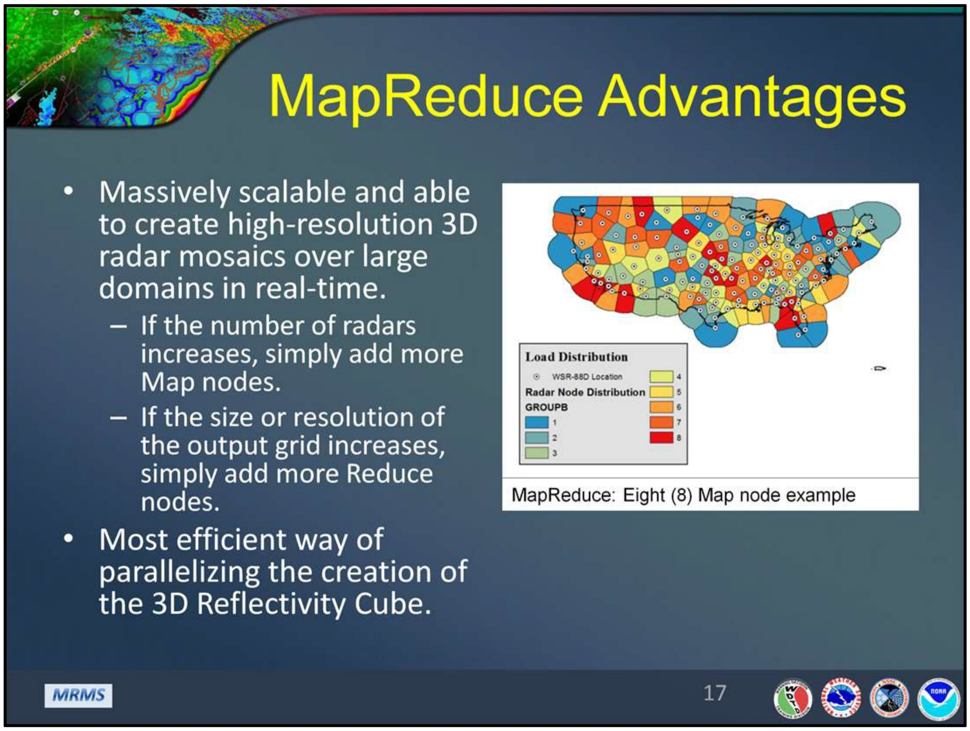
In the display on the right looking down, three radars along with their weighting factor and dBZ measurement are plotted relative to the voxel in the center. Radar C is the closest and has the greatest influence. Radar B's 40 dBZ measurement is larger than Radar A's 30 dBZ measurement. However, a weight of .3 applied to the 40 dBZ measurement from Radar B still results in less influence on the voxel's value than a weight of .6 applied to the 30 dBZ measurement from the closer Radar A.



Lastly, derived 2D products are created from the 3D mosaic and then stitched over the full domain.



The 3D Reflectivity Cube's voxel spatial resolution is 0.01° Latitude (or 1.11 km) x 0.01° Longitude (0.73 km at 49°N and 1.01 km at 25°N). It's vertical resolution varies between 250 meters to 1,000 meters. The 3D Reflectivity Cube's temporal resolution is 2 minutes. These resolution values could be increased at some time in the future.

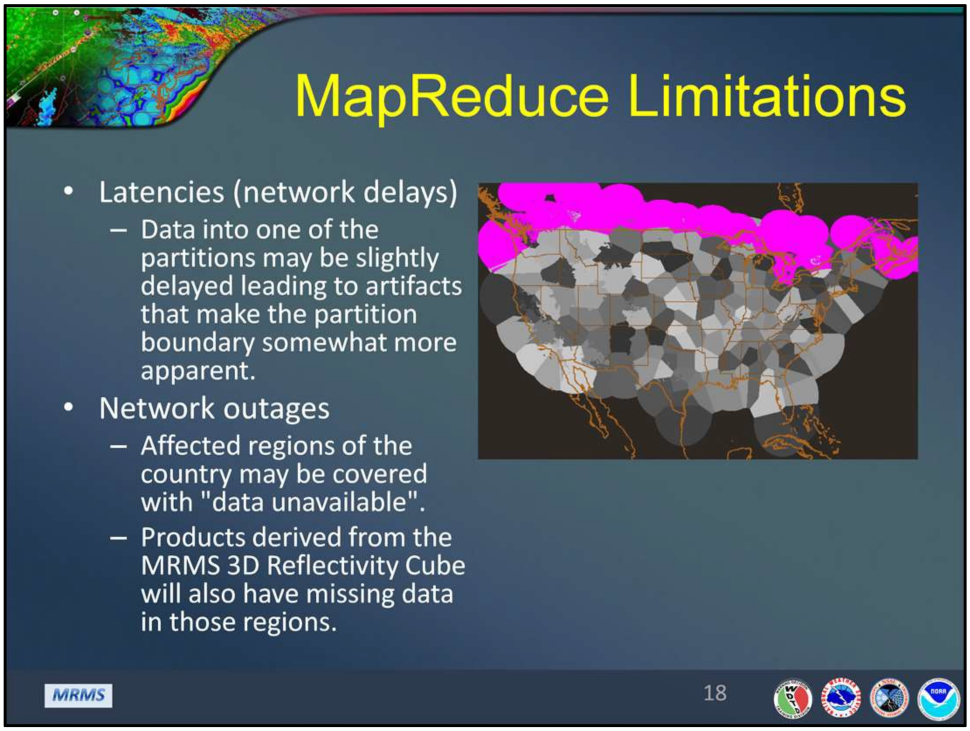


The MapReduce approach to creating the 3D Reflectivity Cube provides a few big advantages over other computer processing techniques.

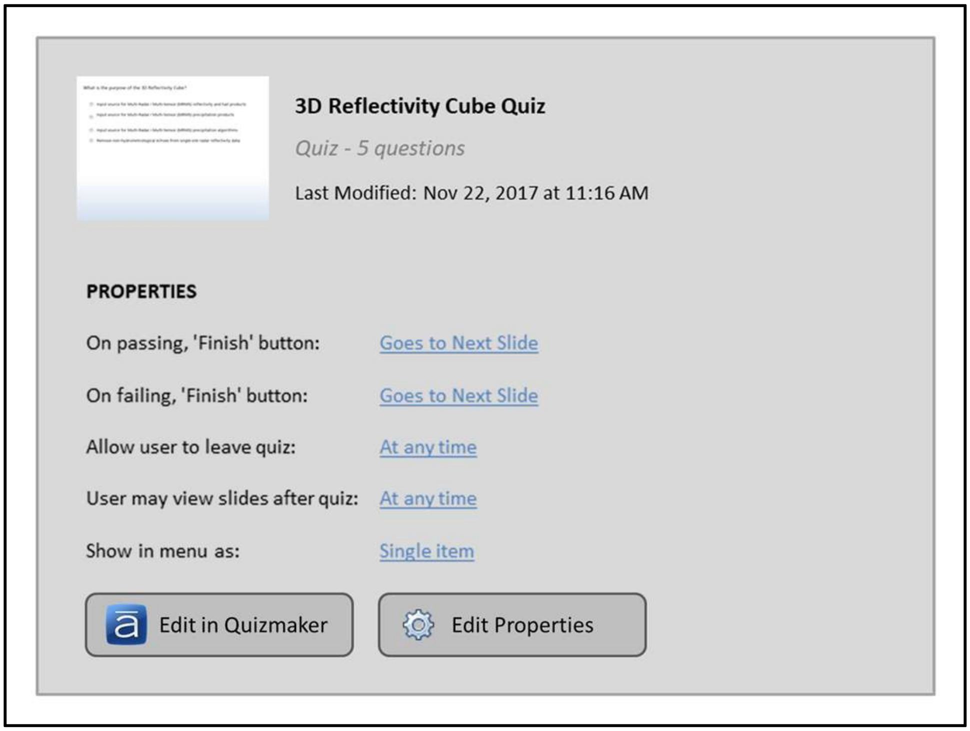
MapReduce is massively scalable and able to create high-resolution 3D radar mosaics over large domains in real-time. If the number of radars increases, one simply needs to add more Map nodes. The Map nodes are all independent of each other and can be scaled up without any penalties due to interprocess communication. Similarly, if the size or resolution of the output grid increases, one simply needs to add more Reduce nodes. It is also possible to time stagger the Reduce nodes so as to increase the temporal resolution and to increase the size of the partitions so as to be able to process the data within any desired latency tolerance.

There are advantages to the MapReduce approach beyond its massive scalability – it is also the most efficient way of parallelizing the creation of a 3D radar mosaic. In other words, if a domain is so large that the mosaic cannot be created on a single machine, the MapReduce approach requires less hardware than other approaches. Furthermore, the partitioning approach that MapReduce takes is the most effective way of splitting the output into geographical regions. The partitions are independent of each other and radar data processing is non-redundant. No interpolation needs to be carried out across partition boundaries and data from a radar are processed only once.

The MapReduce approach, therefore, permits for the creation of radar mosaics without compromises on the quality, timeliness or resolution of the mosaic.



The 3D Reflectivity Cube reflects all the radar data available at the MRMS server at the time that the 3D Reflectivity Cube was created. Issues, when they arise, are often related to latencies (network delays) and radar outages. With latencies, data into one of the partitions may be slightly delayed leading to artifacts that make the partition boundary somewhat more apparent. With network outages, you may see affected regions of the country covered with "data unavailable." Products derived from the MRMS 3D Reflectivity Cube will also have missing data in those regions.


3D Reflectivity Cube Quiz
Quiz - 5 questions
Last Modified: Nov 22, 2017 at 11:16 AM
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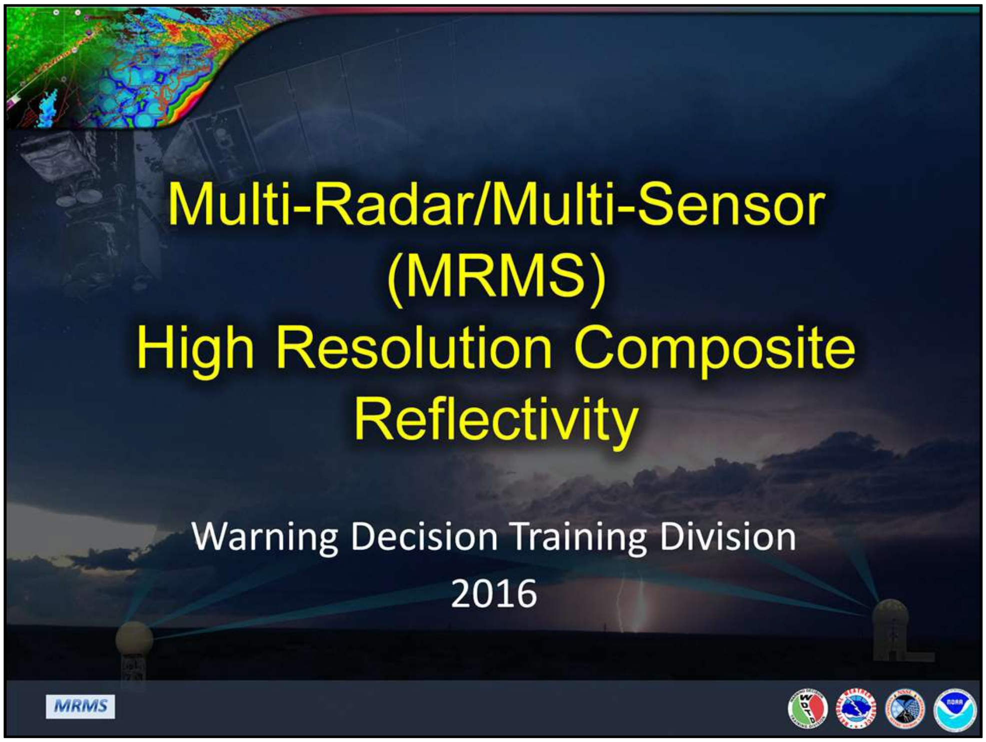
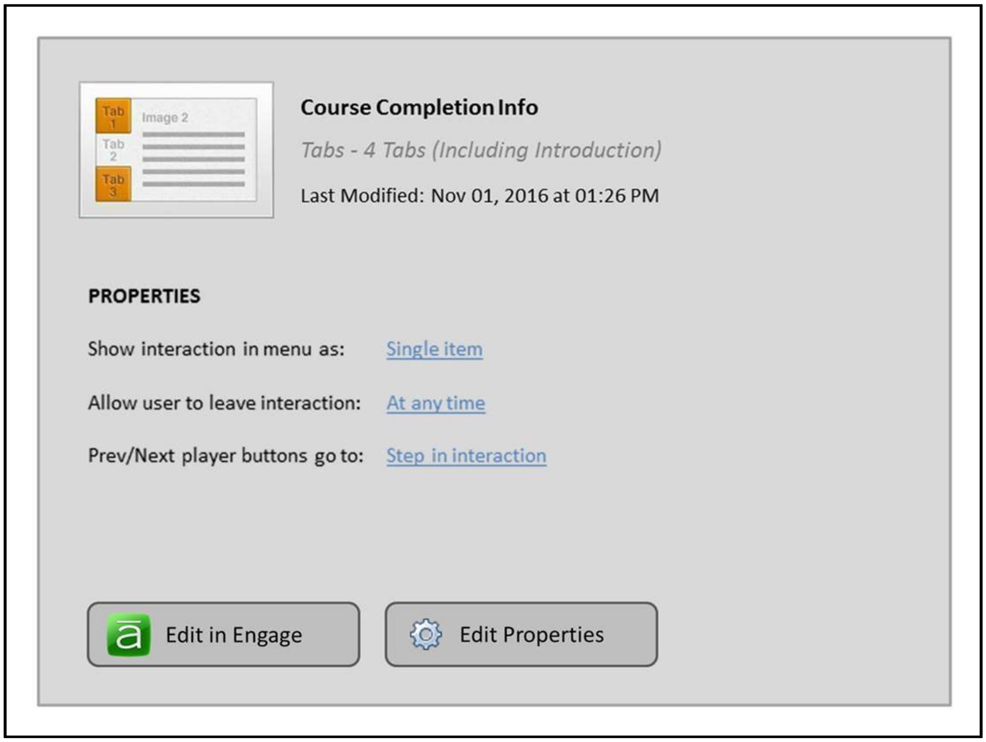


Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on High Resolution Composite Reflectivity developed here at the Warning Decision Training Division (WDTD).


Tab 1
Image 2
Tab 2
Tab 3
Course Completion Info
Tabs - 4 Tabs (Including Introduction)
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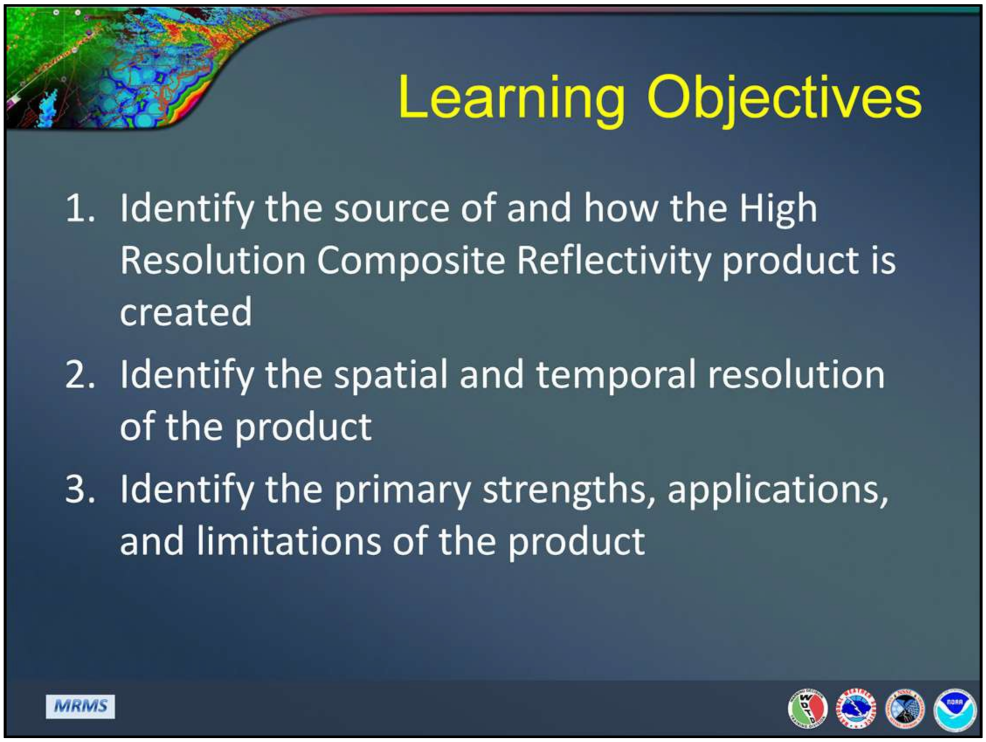
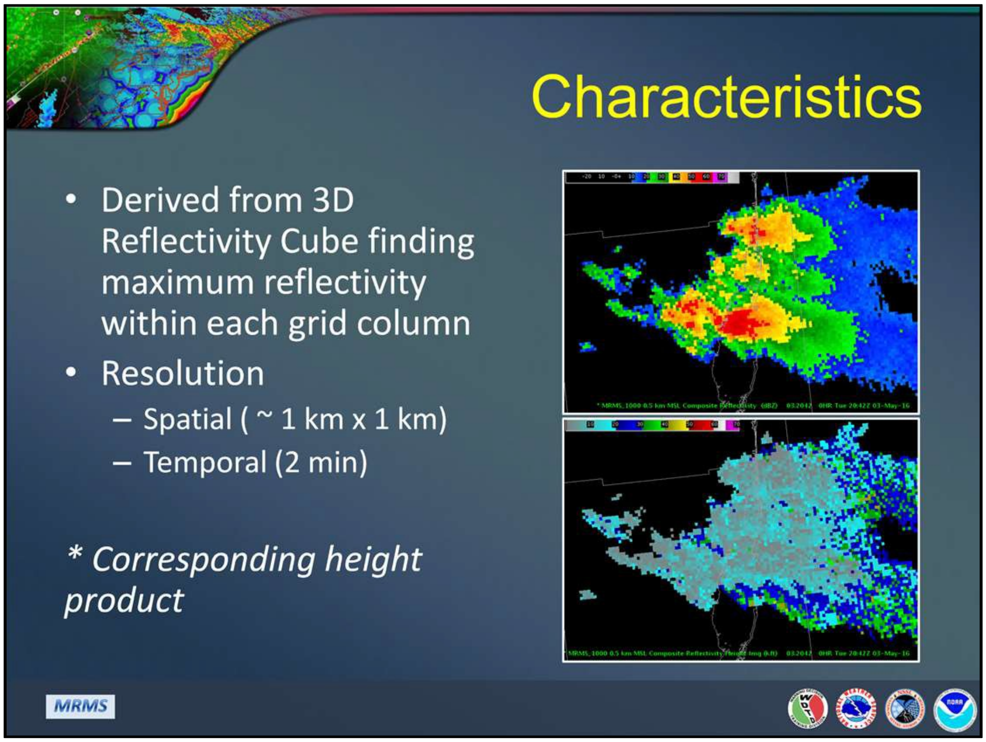
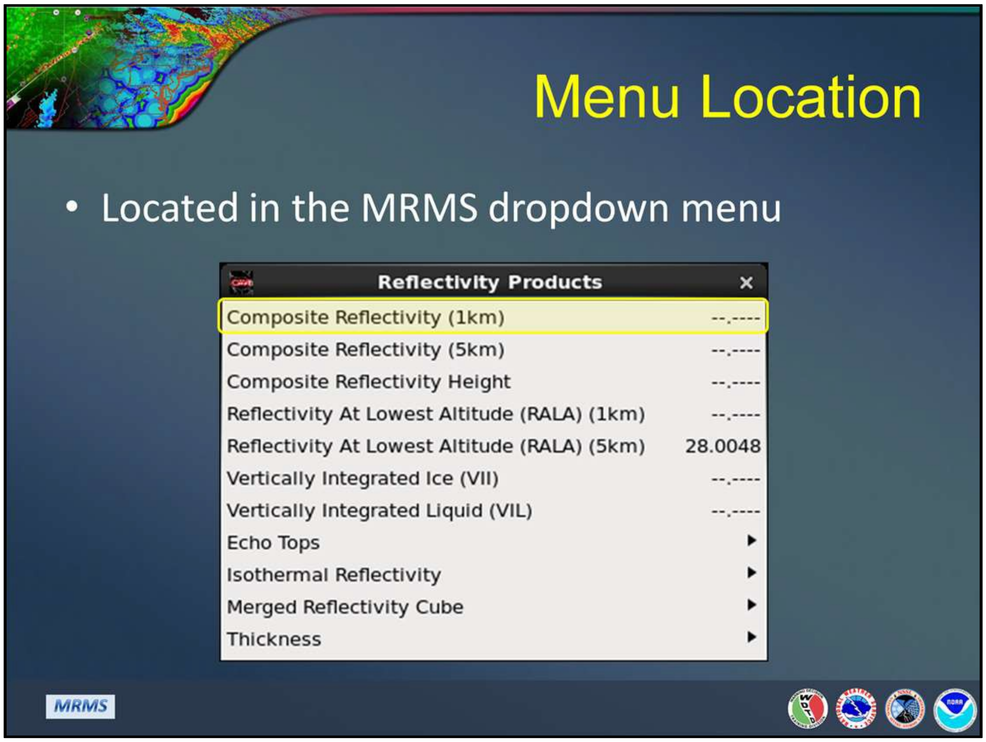


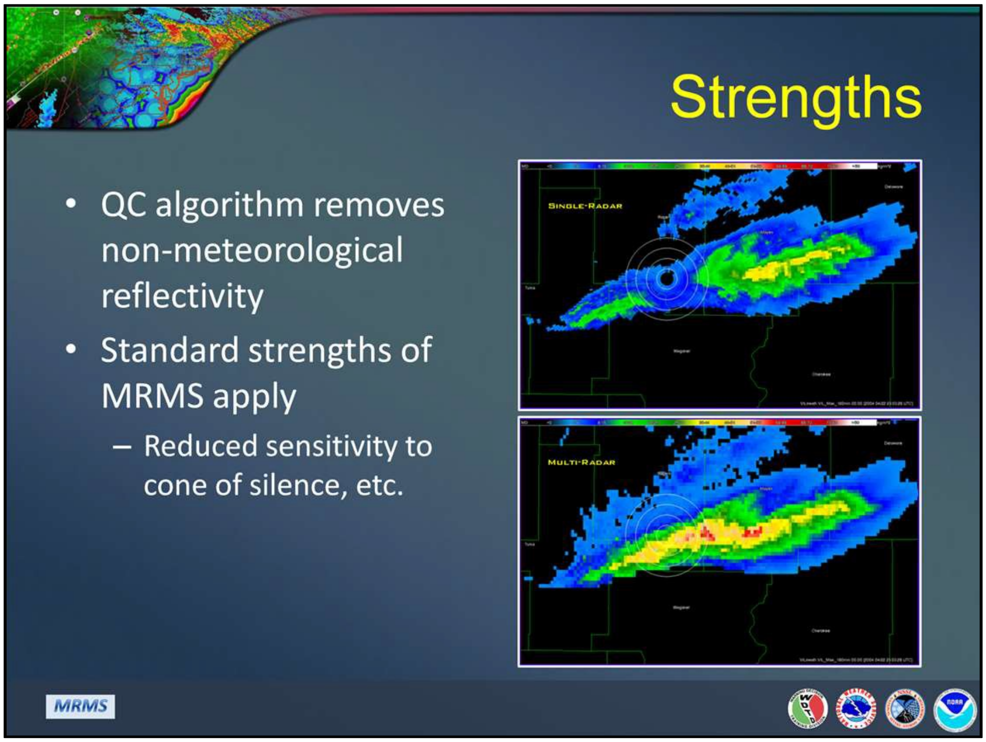
Here are the objectives for this lesson. Take a minute to review them before moving on to the next slide. You will be tested at the end of the lesson based on these objectives.



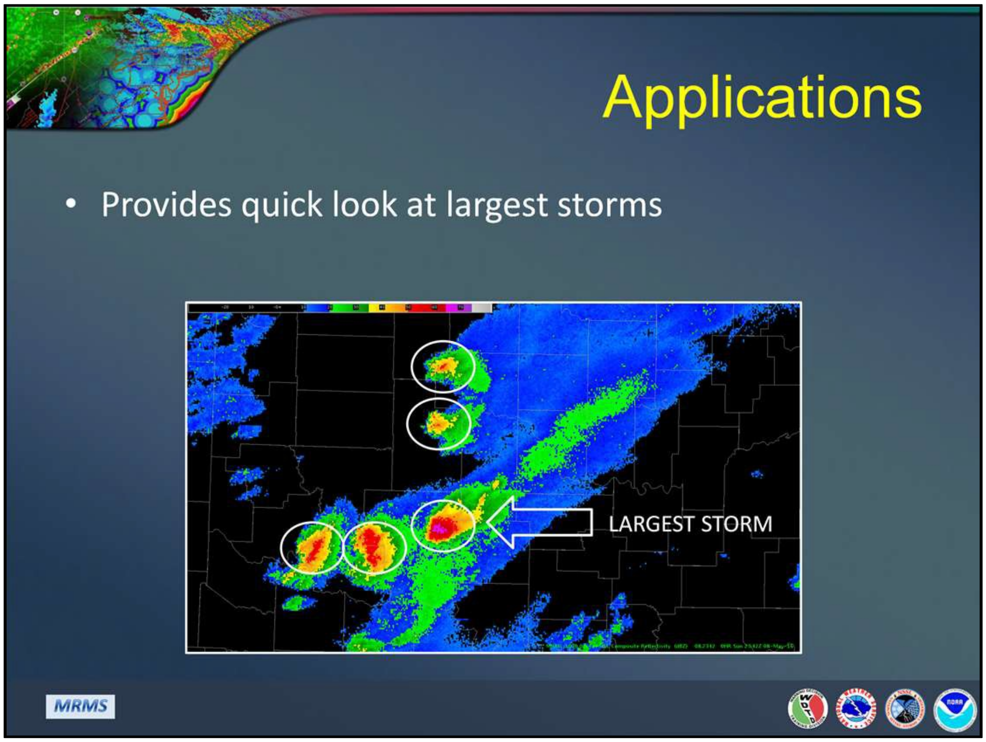
The composite reflectivity product is derived from the 3D reflectivity cube by finding the maximum reflectivity value within each grid column. The spatial resolution is approximately 1 km x 1 km with a temporal resolution of 2 minutes. Since the maximum reflectivity does not always occur at the same height within each grid column, a separate product is generated showing the height of each grid value from the composite reflectivity product.



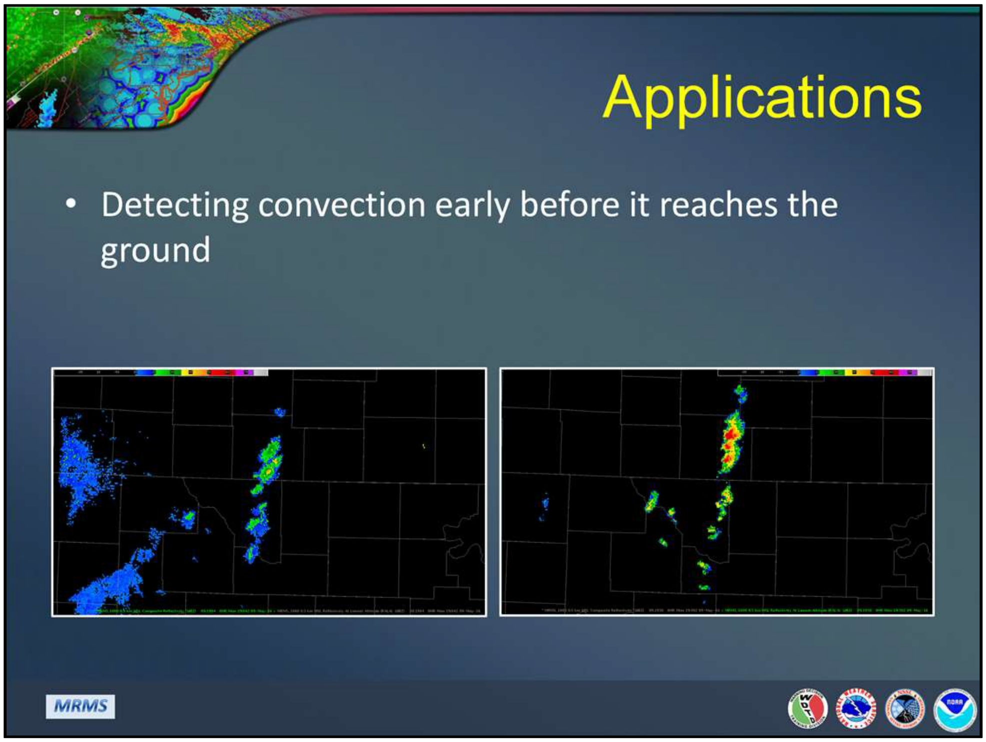
The composite reflectivity product can be found within the MRMS dropdown menu inside CAVE.



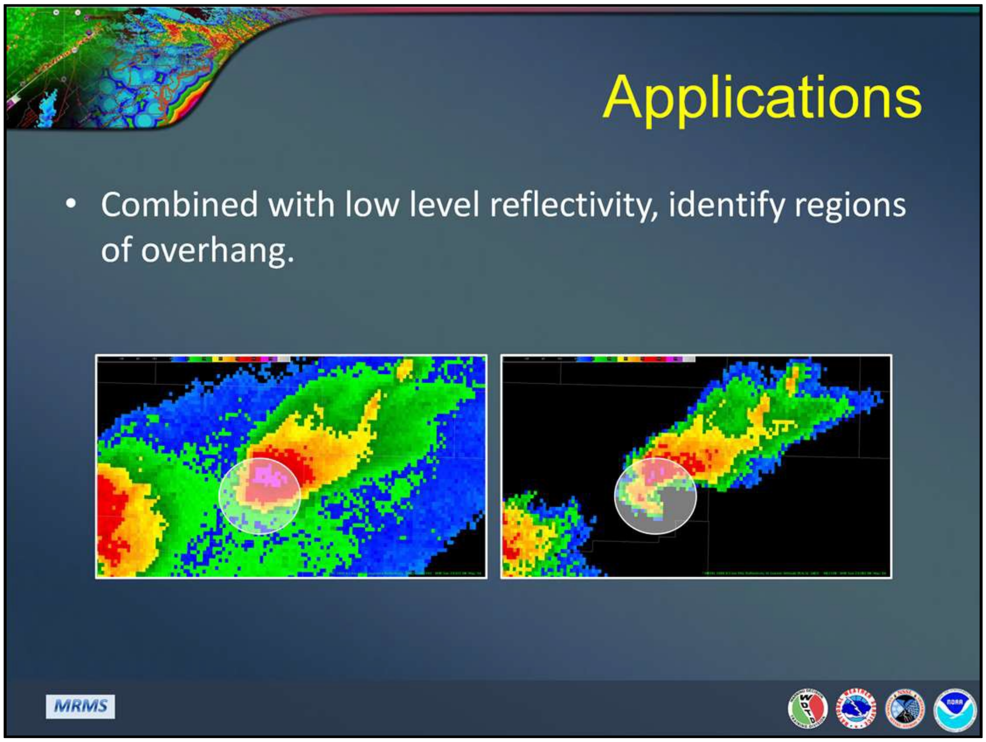
Due to the quality control algorithm removing the majority of non-meteorological echoes in the development of the 3D reflectivity cube, most non-meteorological echoes should not contaminate the composite reflectivity product, so high reflectivity from ground clutter should not be an issue. Other standard strengths of MRMS also apply such as reduced sensitivity to the cone of silence, as seen here in this example of the VIL product from a single radar vs. MRMS.



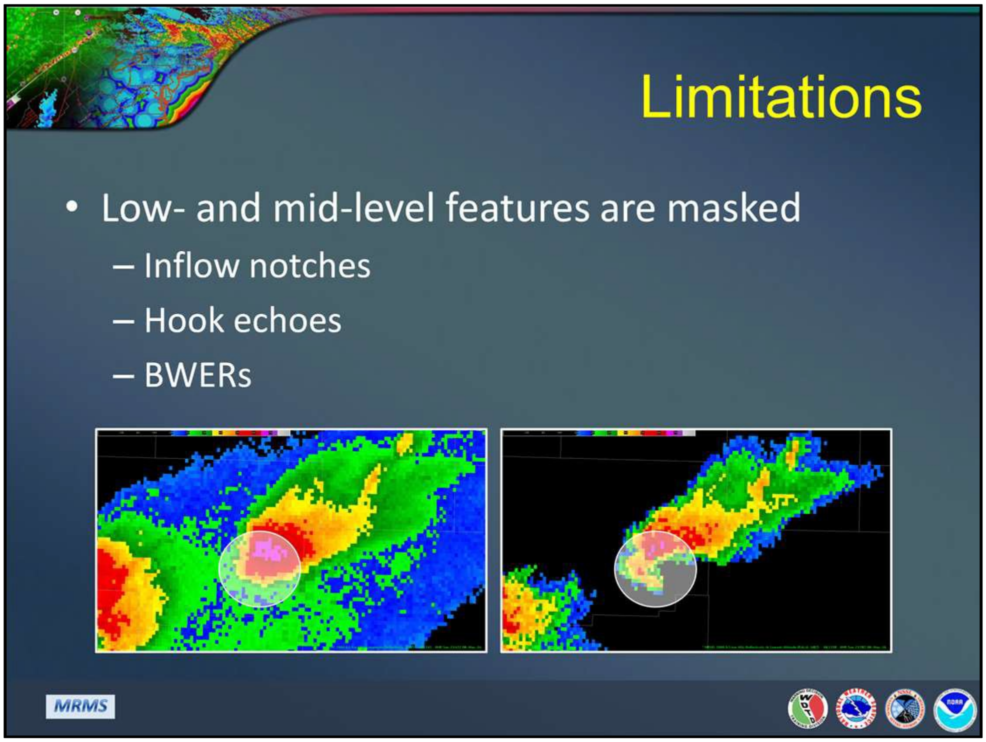
One of the applications of composite reflectivity will be to quickly identify the largest storms. In this example, notice there are 5 different potential storms of interest as noted by the white circles. The one furthest south and east appears to be the largest. Identifying the largest storms can be most helpful to tell pilots which storms to avoid.



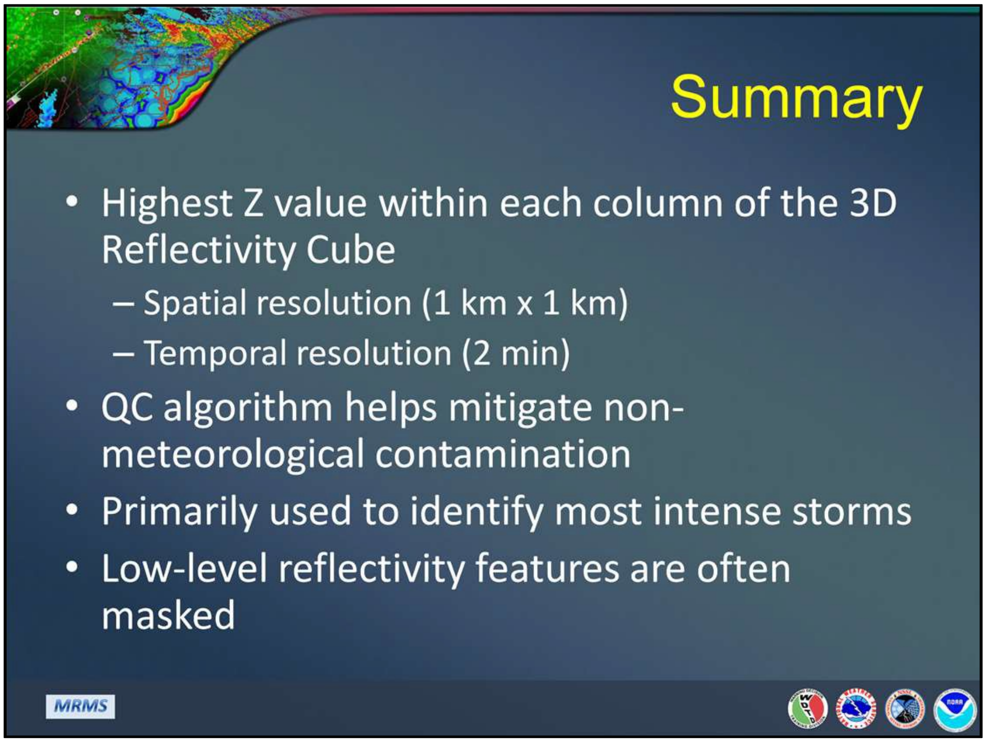
Another potential use of the composite reflectivity product is to identify regions of developing convection aloft before any low level features appear. In these first two images, the left image is the Composite Reflectivity and the right image is the low level reflectivity product (discussed in another lesson). Notice how upper level reflectivity can be noted and is very significant before any low level reflectivity appears. If we look at low level reflectivity just 30 minutes later, these storms went severe very quickly. One caveat, in already mature convective events, it will be more difficult to identify high reflectivity aloft while there is weak reflectivity in the low levels.



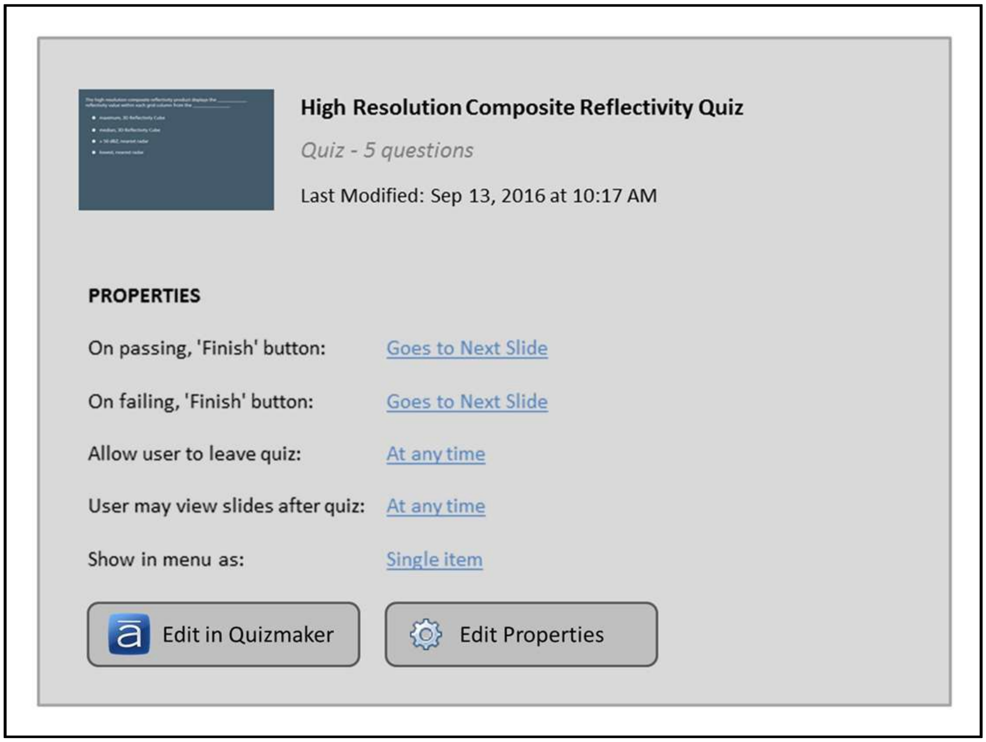
Finally, when combined with low level reflectivity, composite reflectivity can reveal regions of overhang indicative of intense storms. Here is an example of a supercell with a very well defined inflow notch and hook echo. Directly above the inflow notch is very high reflectivity indicative of a significant overhang.



The major drawback to composite reflectivity is low- and mid-level features are often masked. The associated height product could help alleviate this drawback by alerting you to the height of the composite Z, but more often than not, the highest Z values occur aloft. Using the example from before, if you just looked at the Composite Reflectivity without any low level context, you would miss the inflow notch and hook echo which would affect your interpretation of this storm.



This concludes our lesson on the High Resolution Composite Reflectivity product. It is a derived product from the 3D reflectivity cube showing the maximum Z value within each grid column. It has a spatial resolution of approximately 1 km x 1 km and temporal resolution of 2 min. Because the 3D reflectivity cube is QC'd to remove non-meteorological echoes, the composite reflectivity product should have very little contamination from things like ground clutter or anomalous propagation. It's primary use in operations is to quickly identify regions of the most intense storms, but do not use it for in-depth storm analysis as the low-level features are often masked. To help test your knowledge gained in this lesson, please complete the short quiz on the next slide.


High Resolution Composite Reflectivity Quiz
Quiz - 5 questions
Last Modified: Sep 13, 2016 at 10:17 AM
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User may view slides after quiz: At any time
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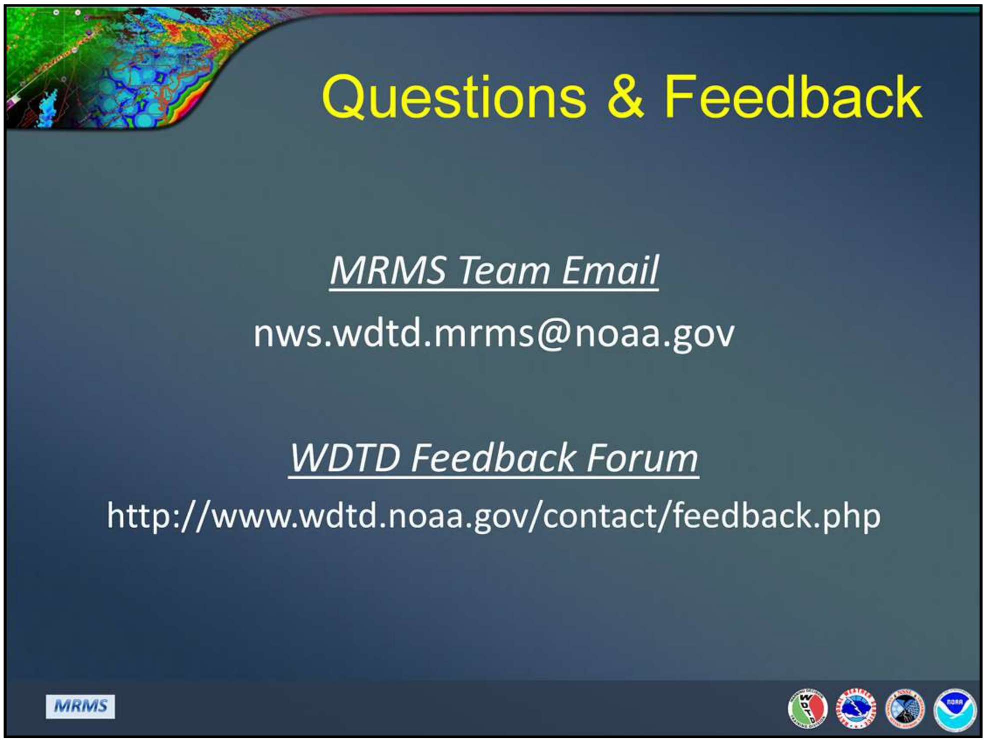
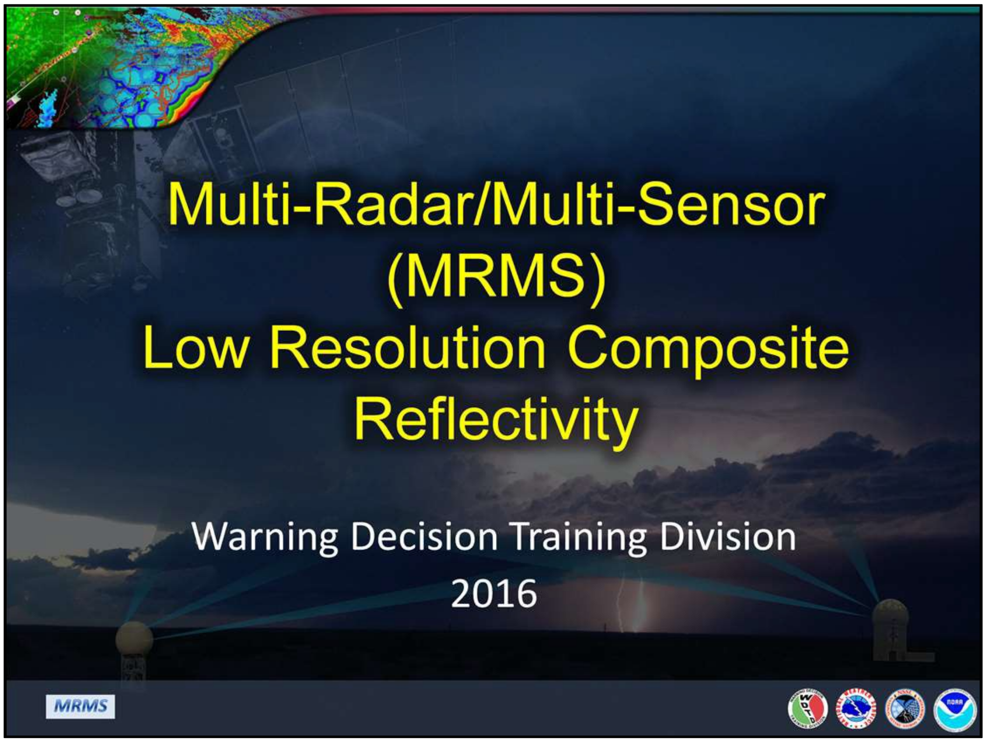
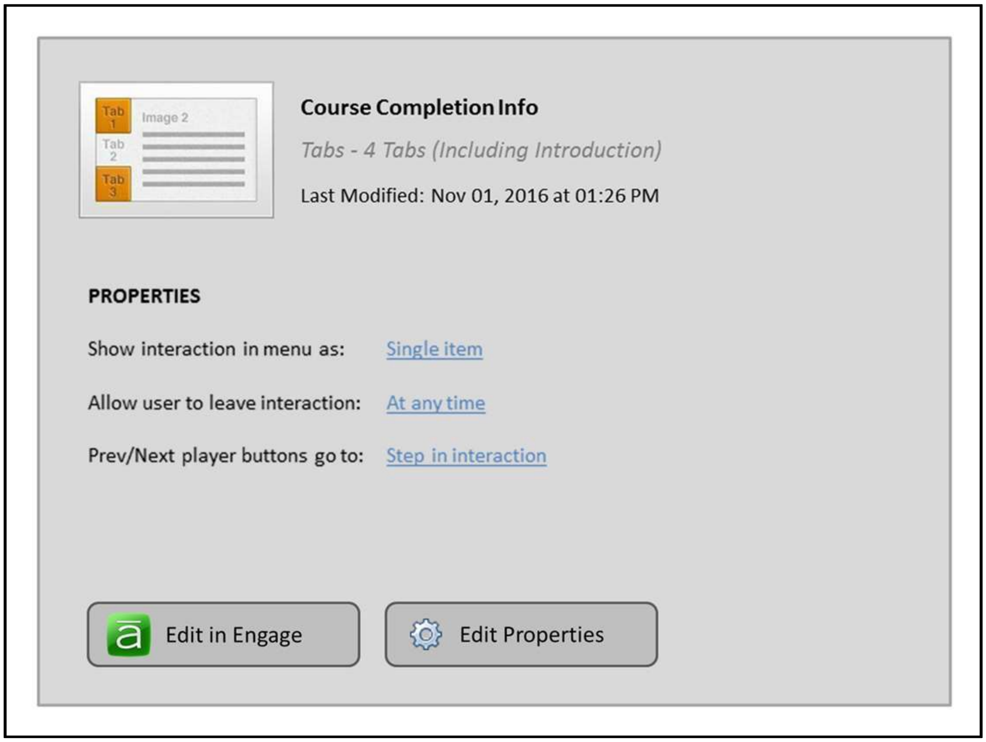


Thanks for completing this module on High Resolution Composite Reflectivity. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Low Resolution Composite Reflectivity developed at the Warning Decision Training Division (WDTD).


Tab 1
Image 2
Tab 2
Tab 3
Course Completion Info
Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 01, 2016 at 01:26 PM
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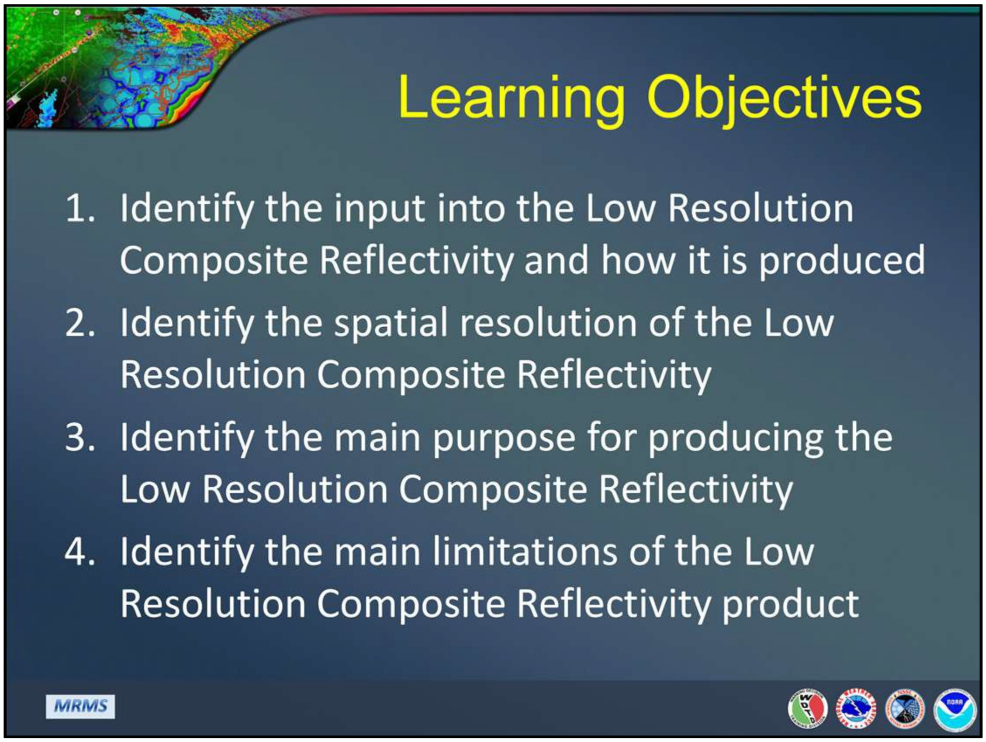
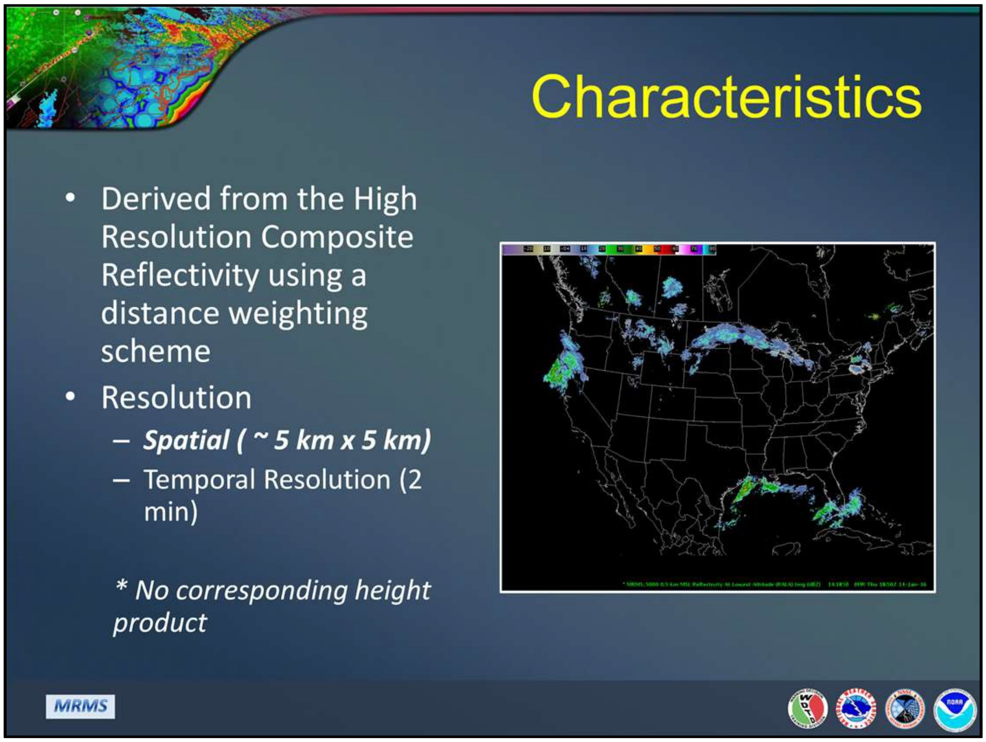
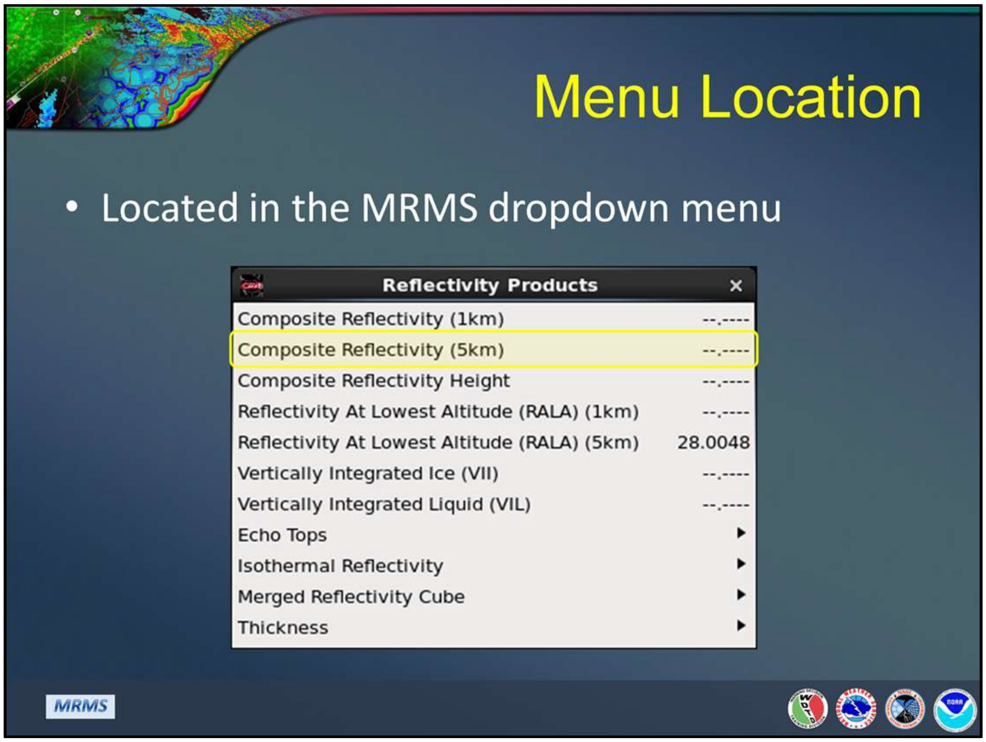
Edit Properties



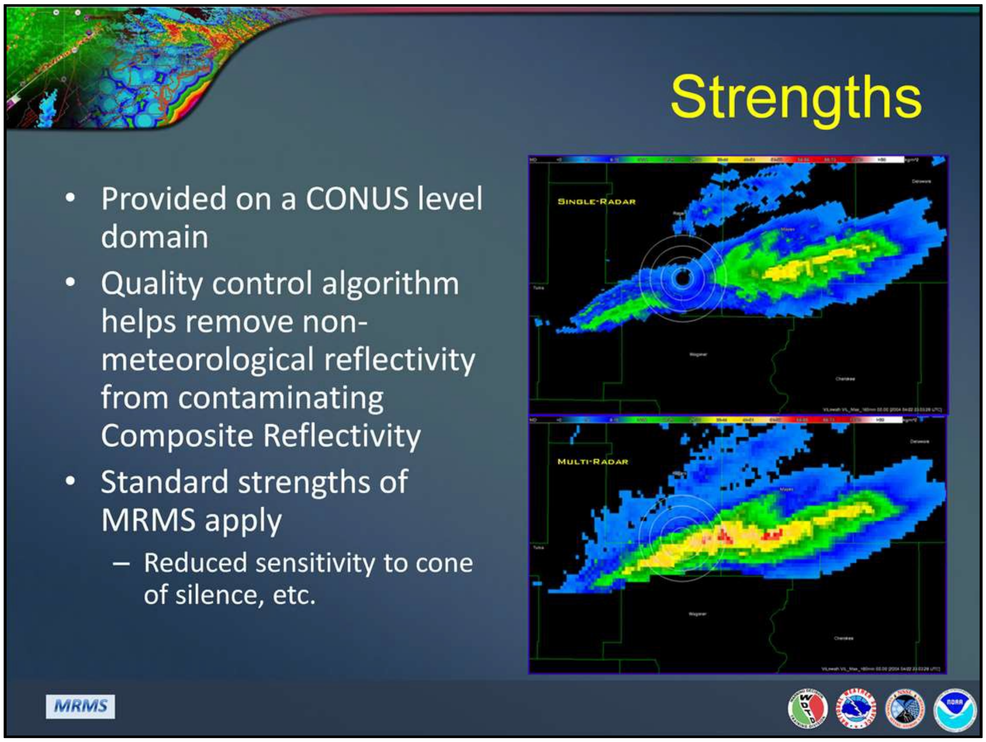
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. The quiz at the end of the lesson is based on these objectives.



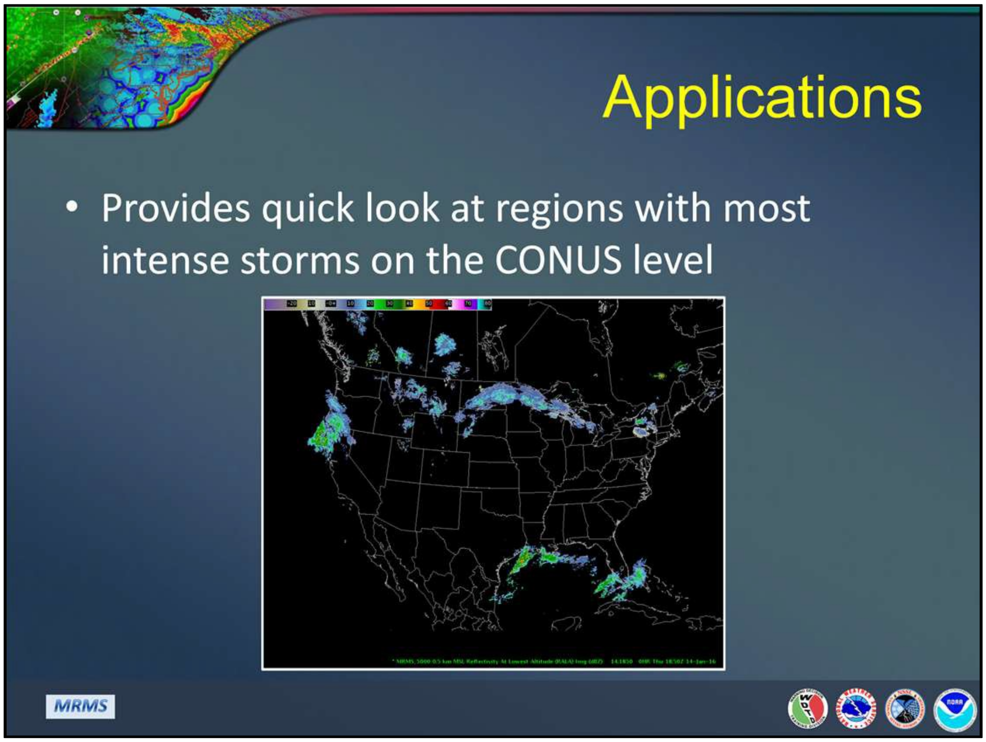
The low resolution composite reflectivity product is derived from the High Resolution Composite Reflectivity using a distance weighting scheme. This distance weighting scheme reduces the spatial resolution from 1 km x 1 km to 5 km x 5 km, and the temporal resolution remains at 2 minutes. There is no corresponding height product for this product, but the high resolution height product can be used as a good proxy. The example on the right is actually the 5 km RALA product, but in essence, this is what the 5 km Composite Reflectivity product will look like.



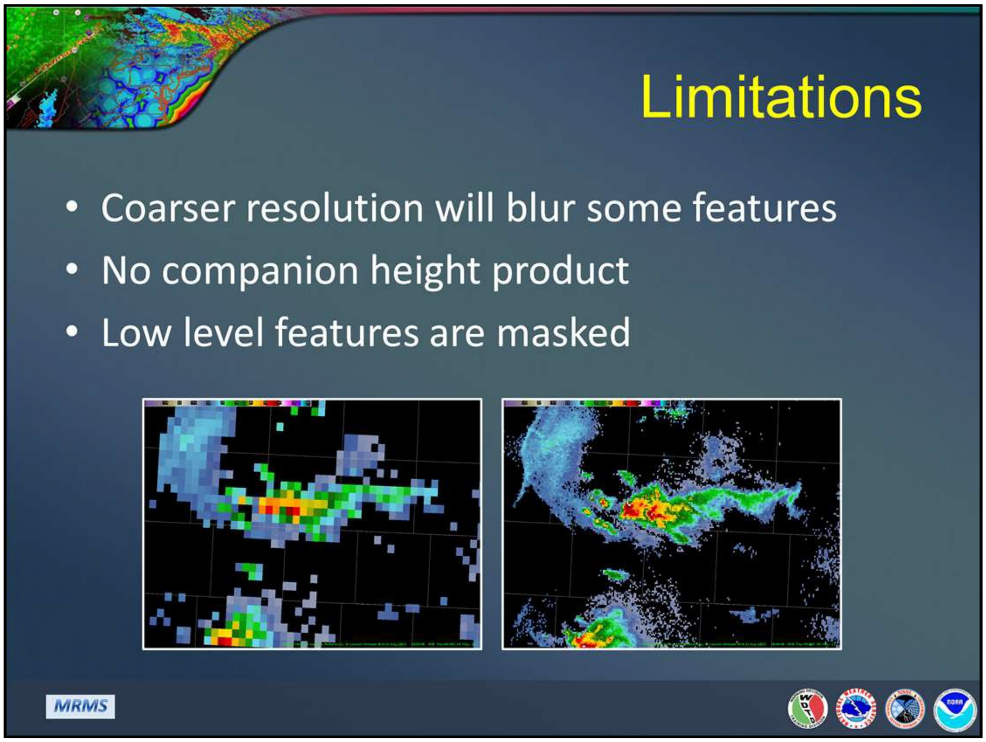
The low resolution composite reflectivity product can be found within the MRMS dropdown menu inside CAVE.



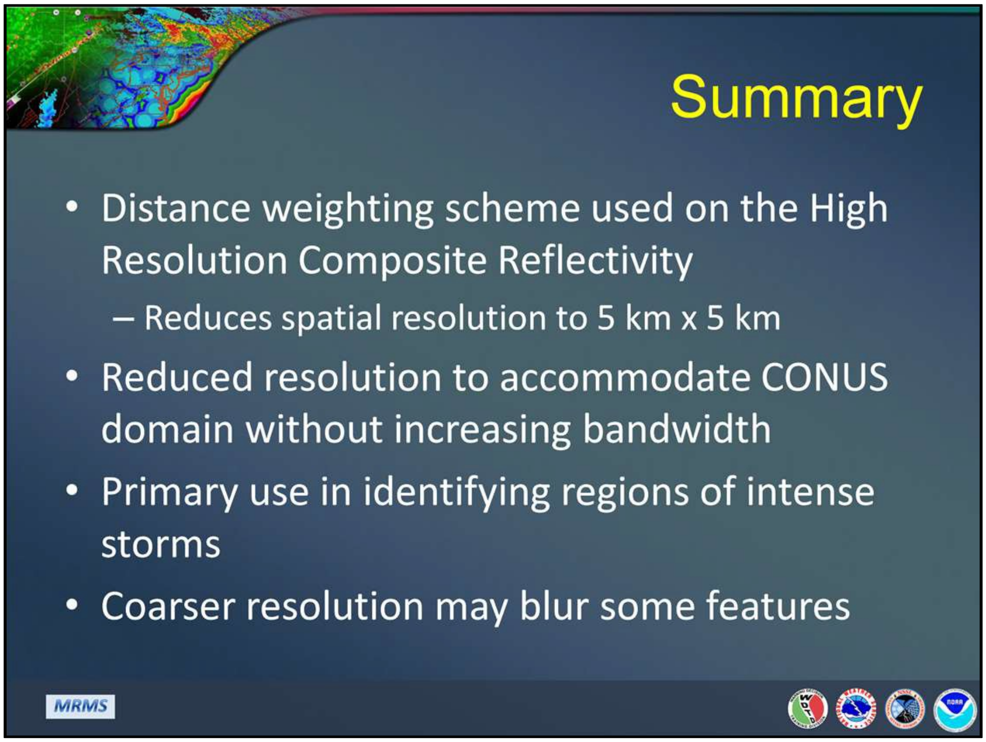
The lower resolution nature of this product allows for a CONUS domain without causing any bandwidth issues. The QC algorithm will help mitigate contamination from non-meteorological echoes like ground clutter, and standard MRMS strengths still apply (e.g. reduced sensitivity in the cone of silence).



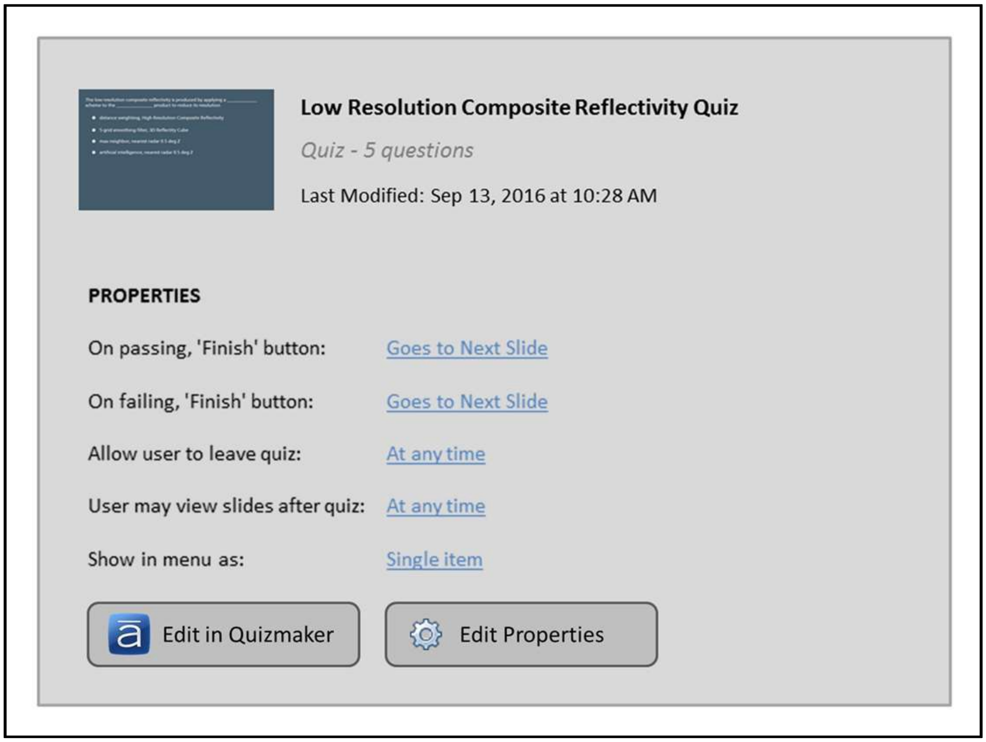
Very similar to the High Resolution Composite Reflectivity, the main application for the low resolution composite reflectivity would be to provide a quick look at the regions with the most intense storms on the CONUS level. And since the product is on a CONUS domain, this makes it easier to see the bigger picture overall.



Due to the reduced resolution, some of the maximum features noted in the high resolution product might not be as noticeable in the lower resolution product. Again, since there is no example of the 5 km product at the time this training was developed, I will show an example for RALA, which will be very similar in appearance. Notice how the 5 km product is much coarser in nature than the 1 km product. Since there is no companion height product, there is no way of knowing at what height the particular grid point lies. And finally, low level features will possibly bemasked.



This concludes our lesson on the Low Resolution Composite Reflectivity product. It is a derived product from the High Resolution Composite Reflectivity using a distance weighting scheme to reduce the resolution to 5 km x 5 km, but maintaining the temporal resolution of 2 min. The main benefit to reducing the resolution is for bandwidth issues when plotting on entire CONUS domain. It’s primary use in operations is to quickly identify regions of the most intense storms, but do not use it for in-depth storm analysis as the low-level features are often masked. Additionally, since the resolution is coarser, some of the distinct features in the High Resolution product may not show up in this product. To help test your knowledge gained in this lesson, please complete the short quiz on the next slide.


Low Resolution Composite Reflectivity Quiz
Quiz - 5 questions
Last Modified: Sep 13, 2016 at 10:28 AM
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User may view slides after quiz: At any time
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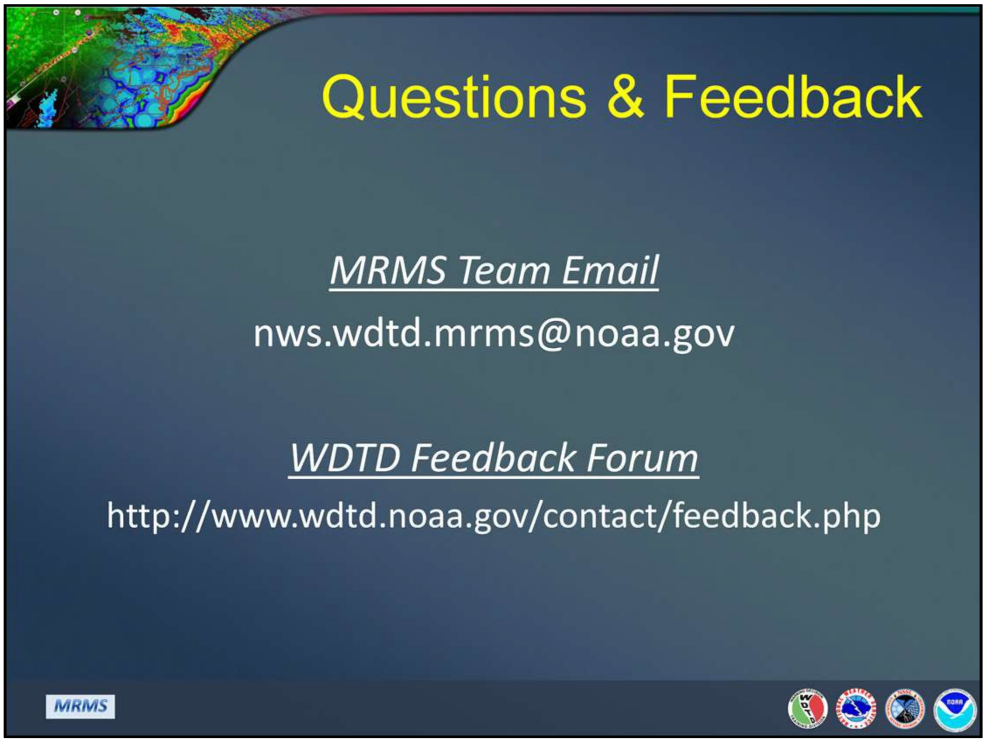
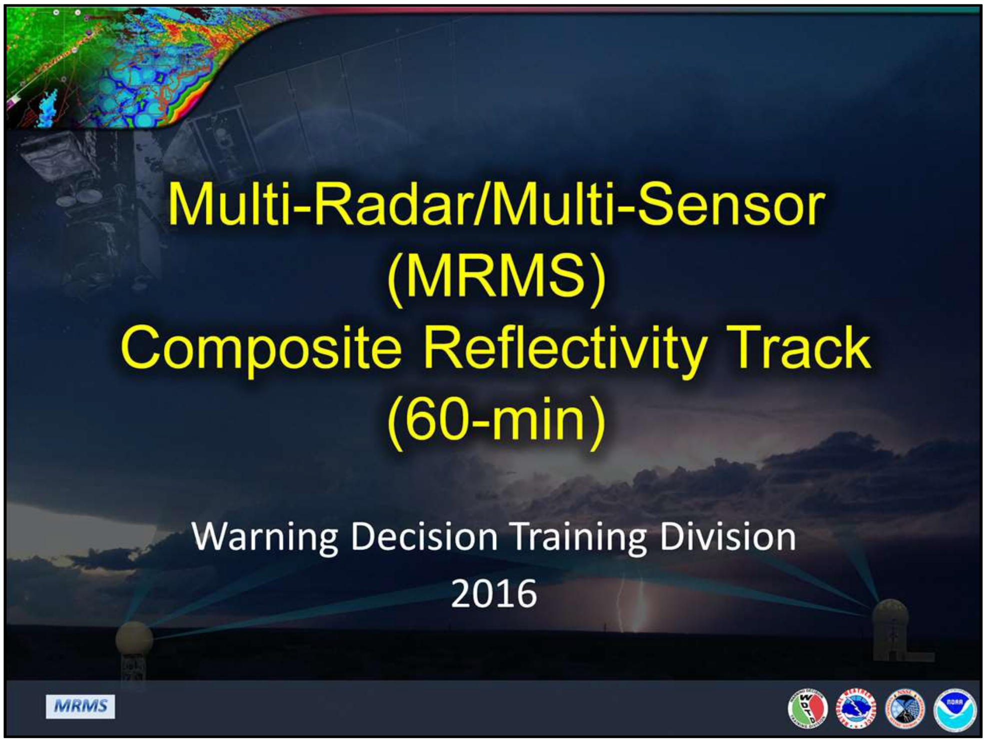
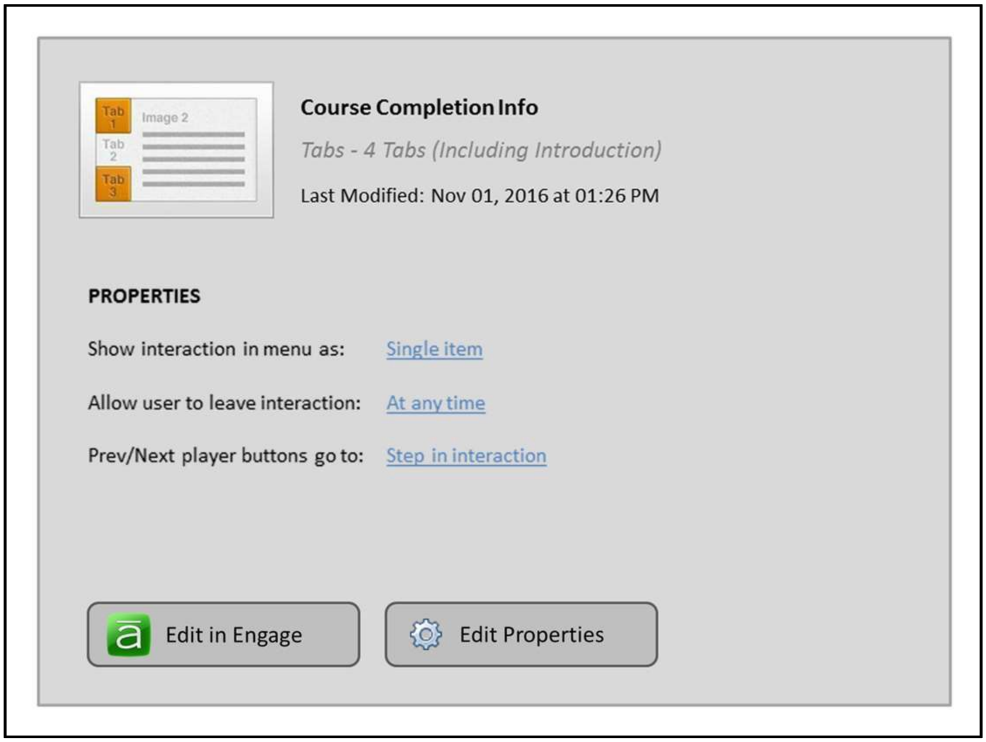


Thanks for completing this module on Low Resolution Composite Reflectivity. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on the 60-minute Composite Reflectivity Track product developed here at the Warning Decision Training Division (WDTD).


Course Completion Info
Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 01, 2016 at 01:26 PM
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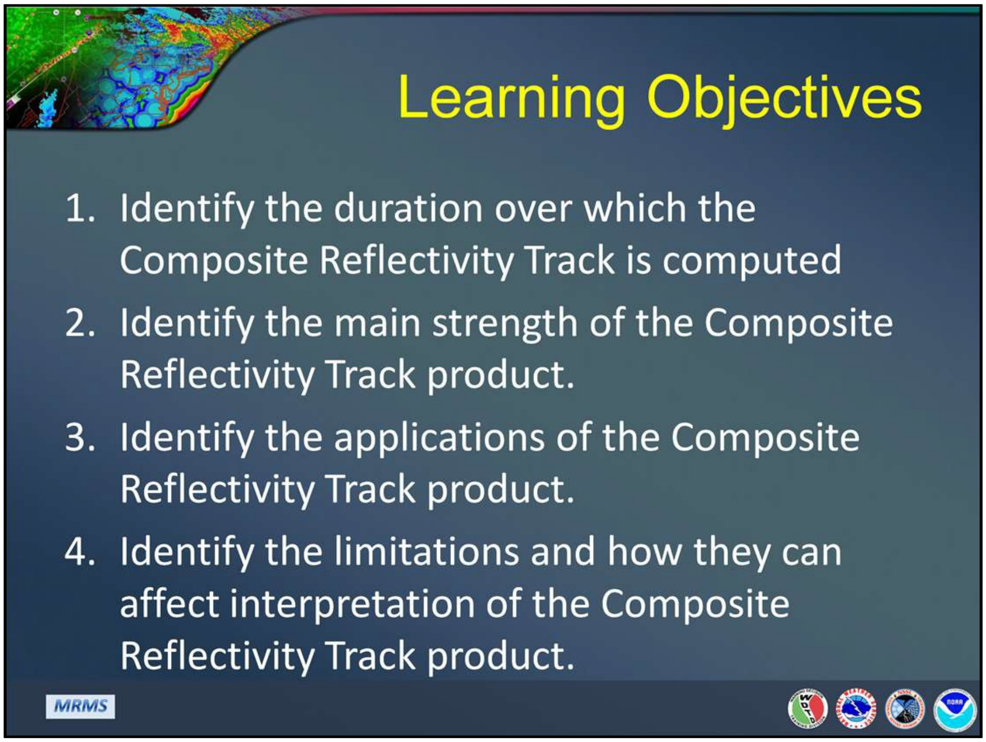
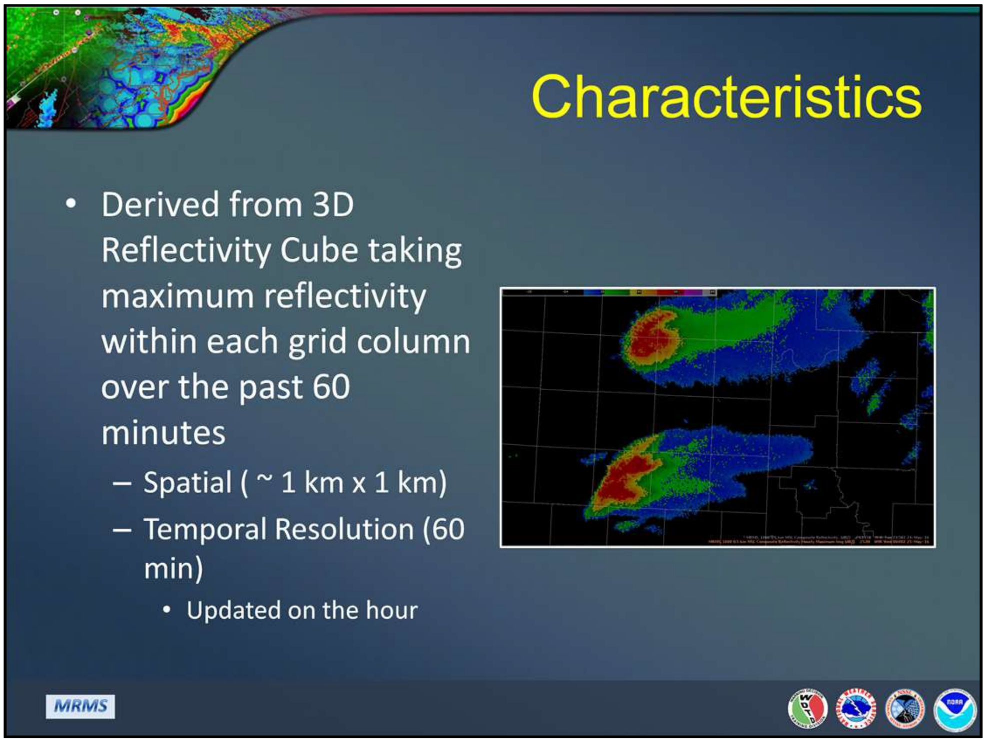
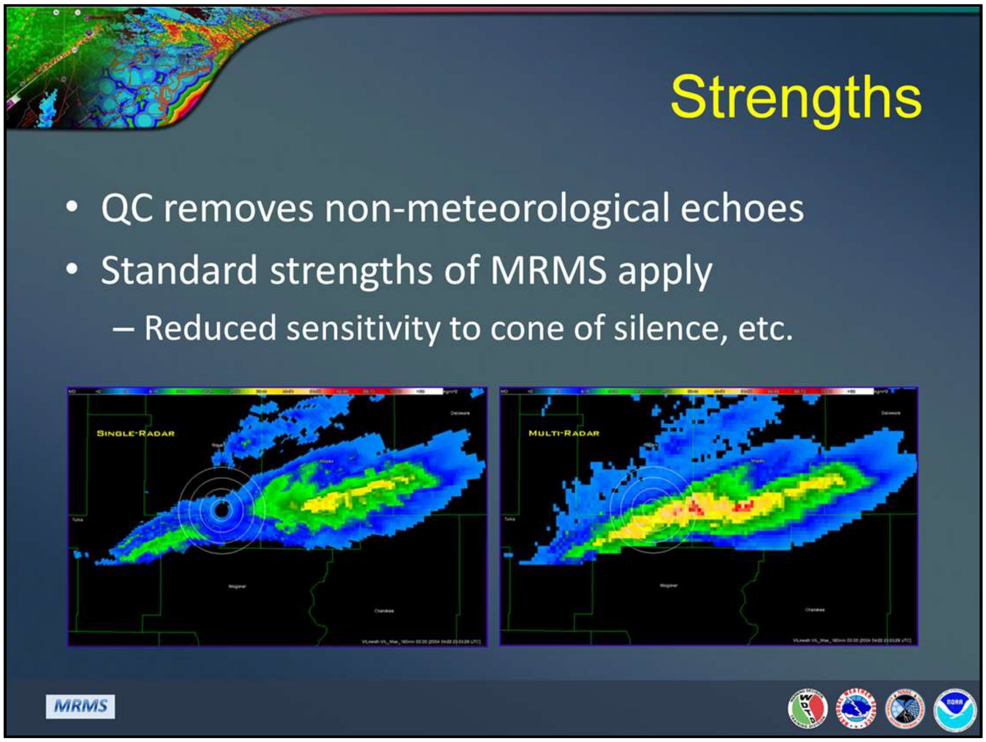
Edit Properties



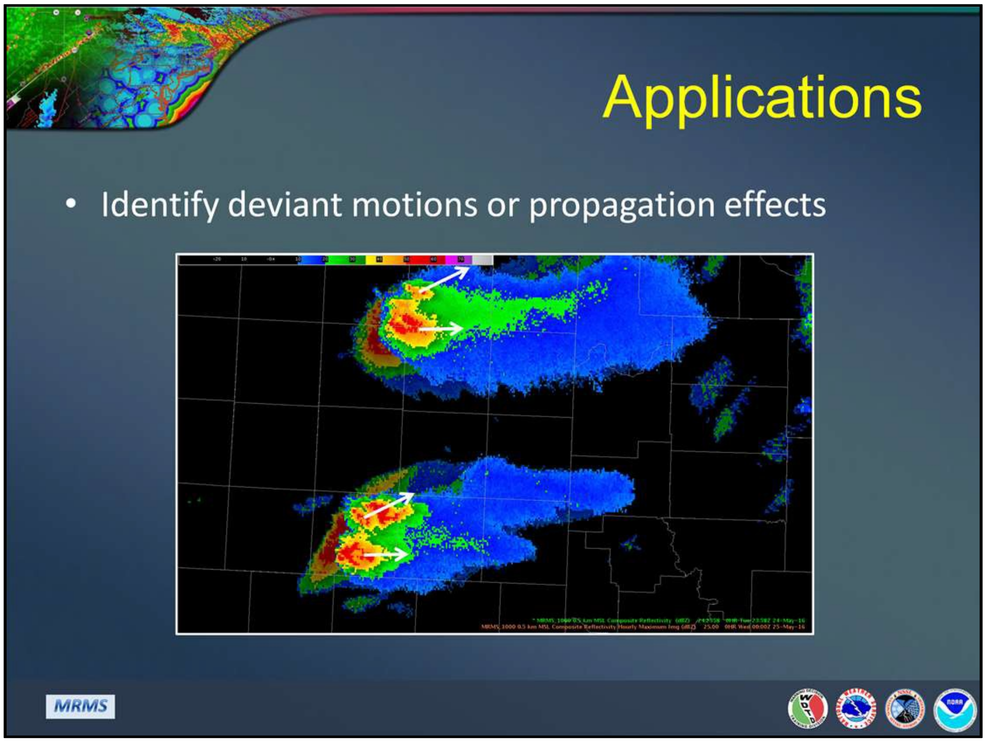
Here are the objectives for this lesson. Take a minute to review them before moving on to the next slide. You will be tested at the end of the lesson based on these objectives.



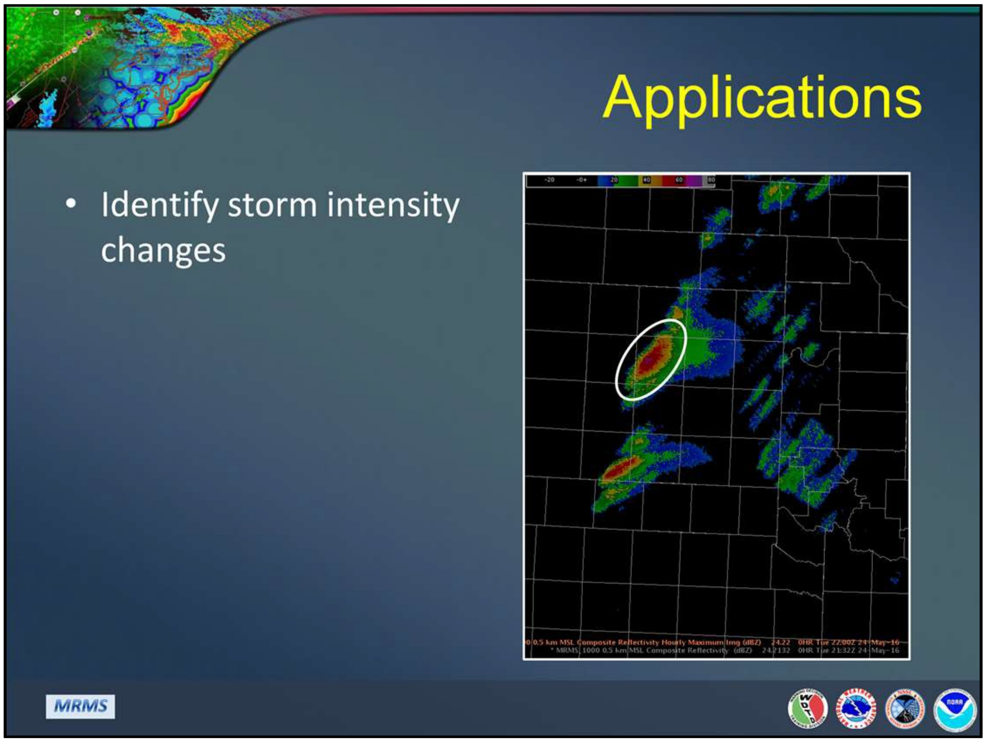
The composite reflectivity track product is derived from the 3D reflectivity cube by finding the maximum reflectivity value within each grid column over the past 60 minutes. The spatial resolution is approximately 1 km x 1 km with a temporal resolution of 60 minutes. The product is updated every hour on the hour.



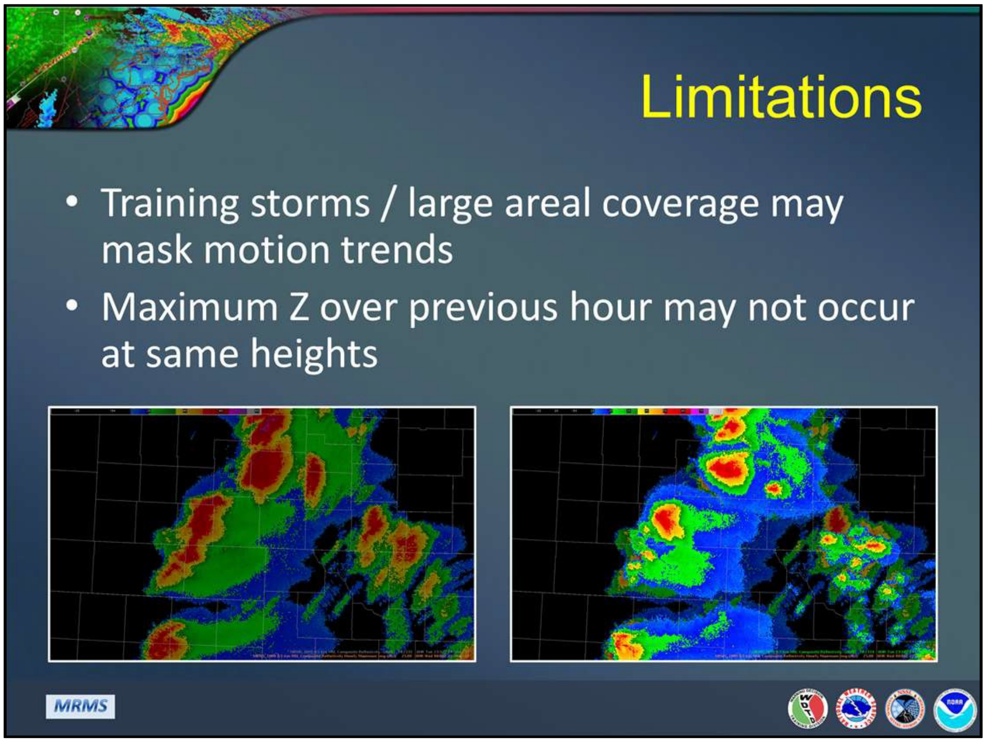
Due to the quality control algorithm removing the majority of non-meteorological echoes in the development of the 3D reflectivity cube, most non-meteorological echoes like ground clutter should not contaminate the composite reflectivity track product. Other standard strengths of MRMS also apply such as reduced sensitivity to cone of silence.



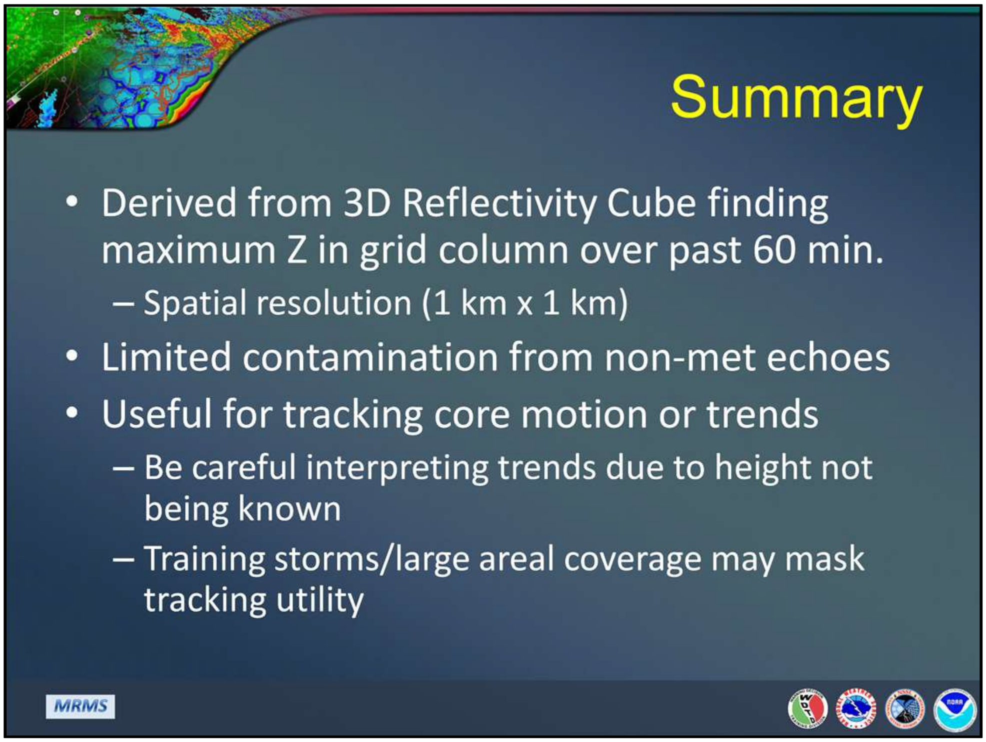
By displaying the maximum reflectivity within each grid box over the past 60 minutes, you can develop a feel for general storm motion (linear or deviant) or propagation effects. Here is an example from the Texas panhandle. To the south, it appears as though there has been a storm split and a deviation to the right. If we look at the current composite reflectivity plot, we definitely see this split and tendency for the southern storm to be heading more east. A similar pattern can be seen to the north as well.



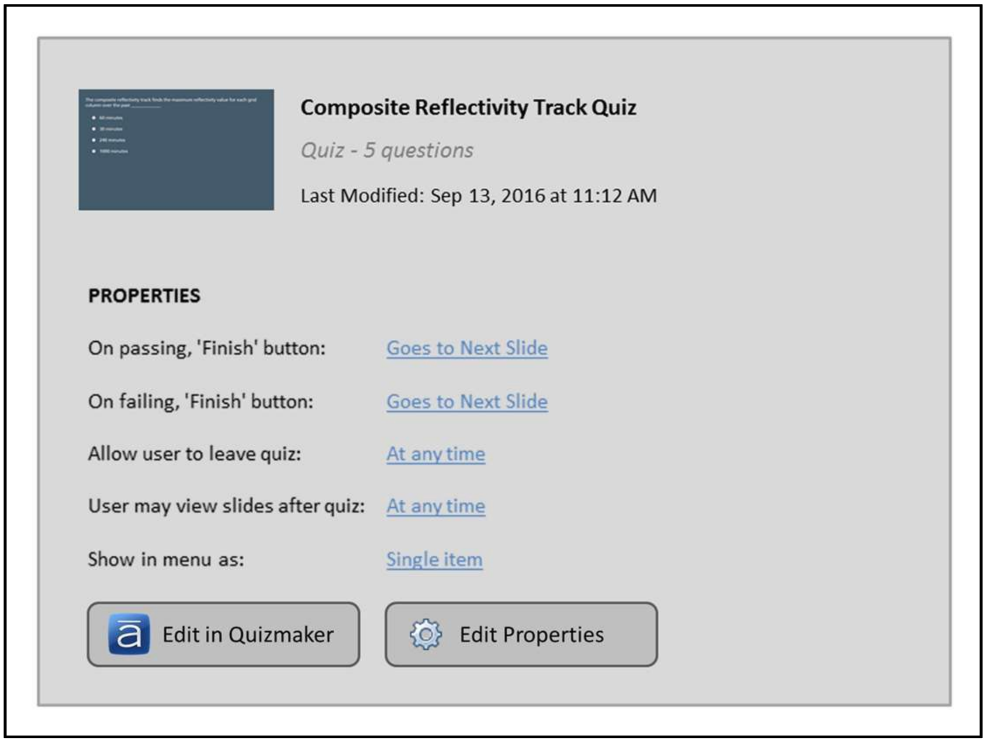
Additionally, if a storm intensifies this product may be useful in quickly identifying storm intensifications. Notice the storm over the past hour in the northern Texas Panhandle. The storm quickly intensifies and then diminishes in intensity over the past hour. If we toggle over to the composite Z track, we can see this increase and decrease in intensity in one product.



If multiple storms are training over the same area, be aware of this as the training effects may mask any motion determinations. Also, large areal coverage of storms will potentially do the same. Here is a training example from southwestern Kansas. Notice how the training storms on the right cause overlap in the composite reflectivity track. Additionally, remember that the maximum reflectivity within a grid column may not occur at the same height over the given 60 minute interval. Keep this in mind when trying to infer storm motion or trends.



This concludes our lesson on the High Resolution Composite Reflectivity Track product. It is a derived product from the 3D reflectivity cube finding the maximum Z value within each grid column over the past 60 minutes. It has a resolution of approximately 1 km x 1 km and is updated once an hour on the hour. Because the 3D reflectivity cube undergoes QC to remove non-meteorological echo, the composite reflectivity track product should have very little contamination from things like ground clutter or anomalous propagation. It's primary use in operations is to track core motions and thunderstorm intensity trends with one product, but beware there is no height product so intensity trends may be misinterpreted. Additionally, training storms or large areal coverage may mask any tracking information. To help test your knowledge gained in this lesson, please complete the short quiz on the next slide.


Composite Reflectivity Track Quiz
Quiz - 5 questions
Last Modified: Sep 13, 2016 at 11:12 AM
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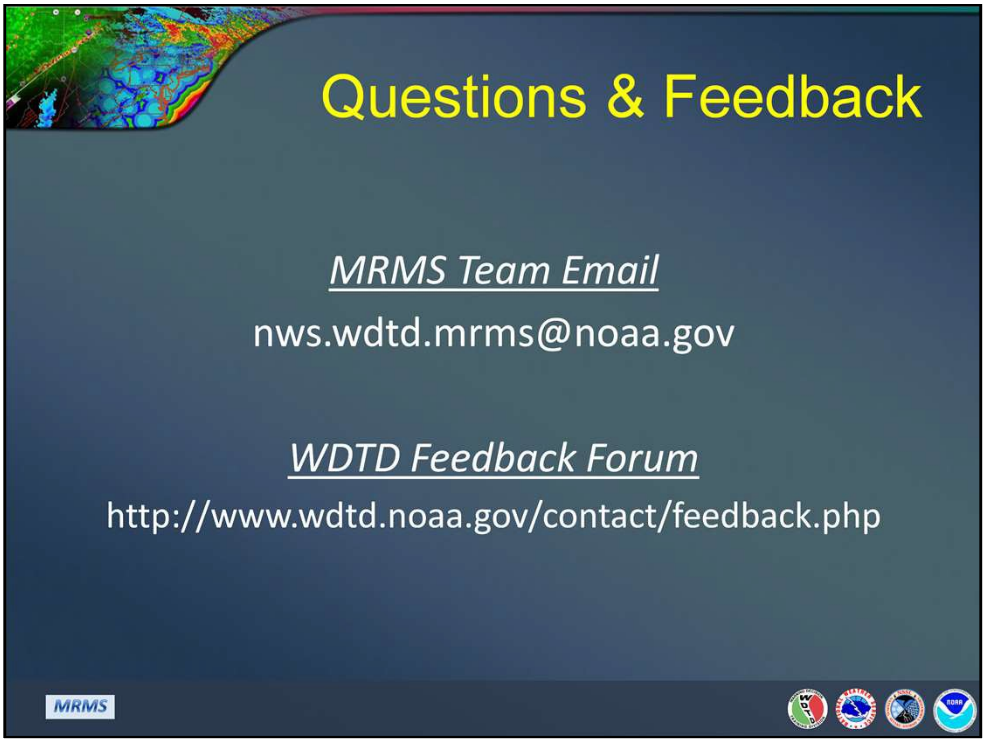
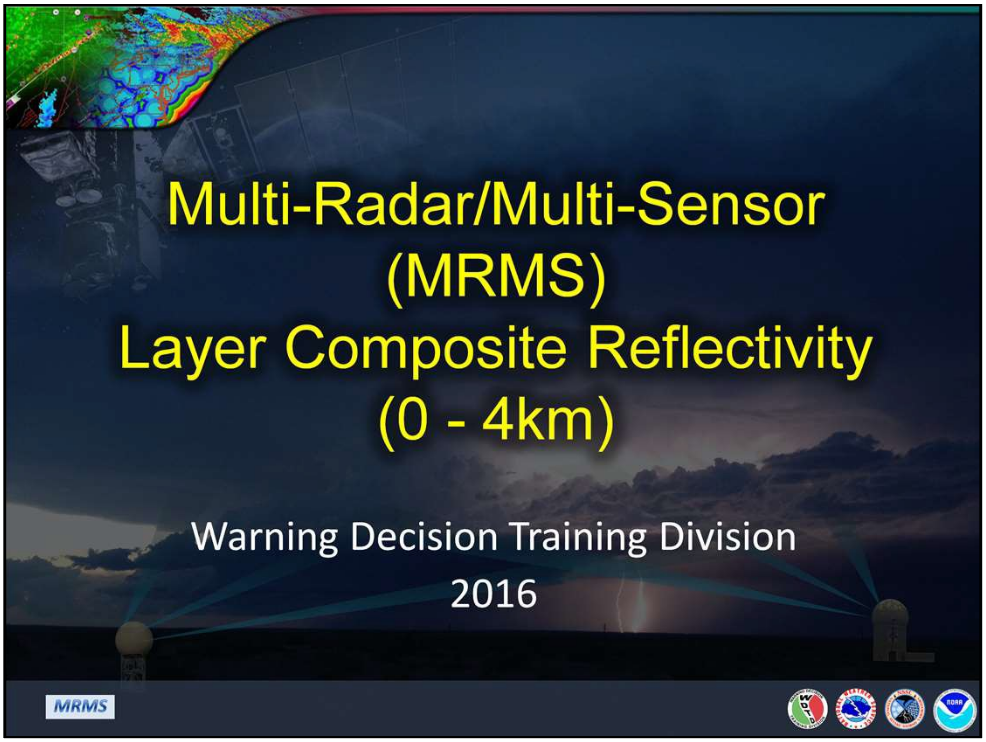
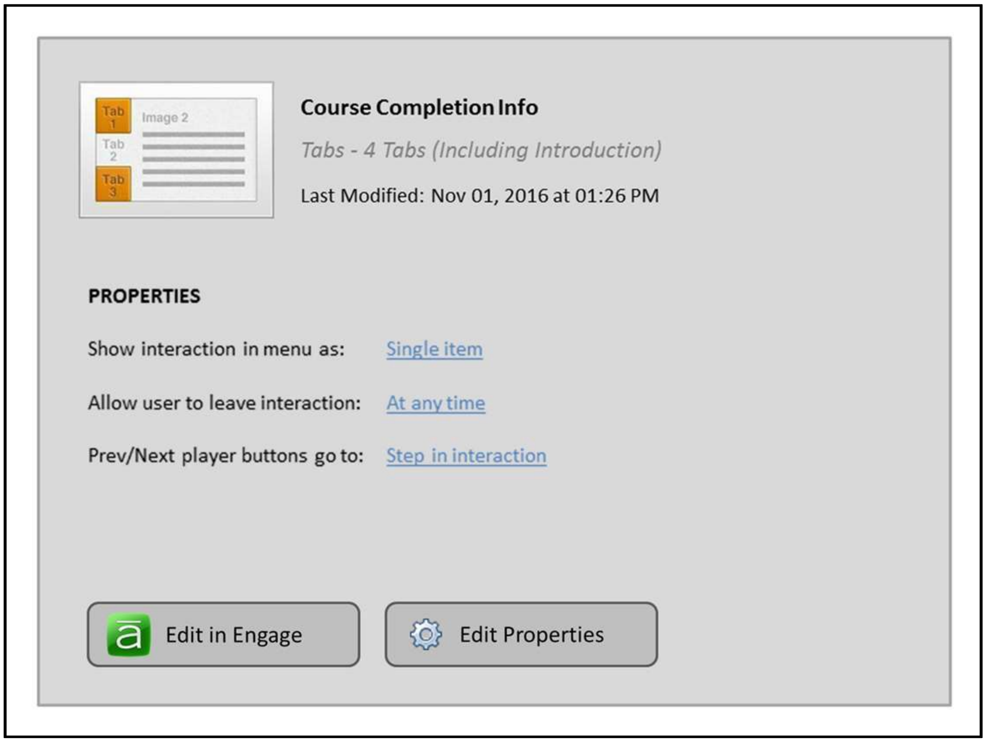


Thanks for completing this module on Composite Reflectivity Track. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Layer Composite Reflectivity (0 - 4km) developed here at the Warning Decision Training Division (WDTD).


Tab 1
Image 2
Tab 2
Tab 3
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Last Modified: Nov 01, 2016 at 01:26 PM
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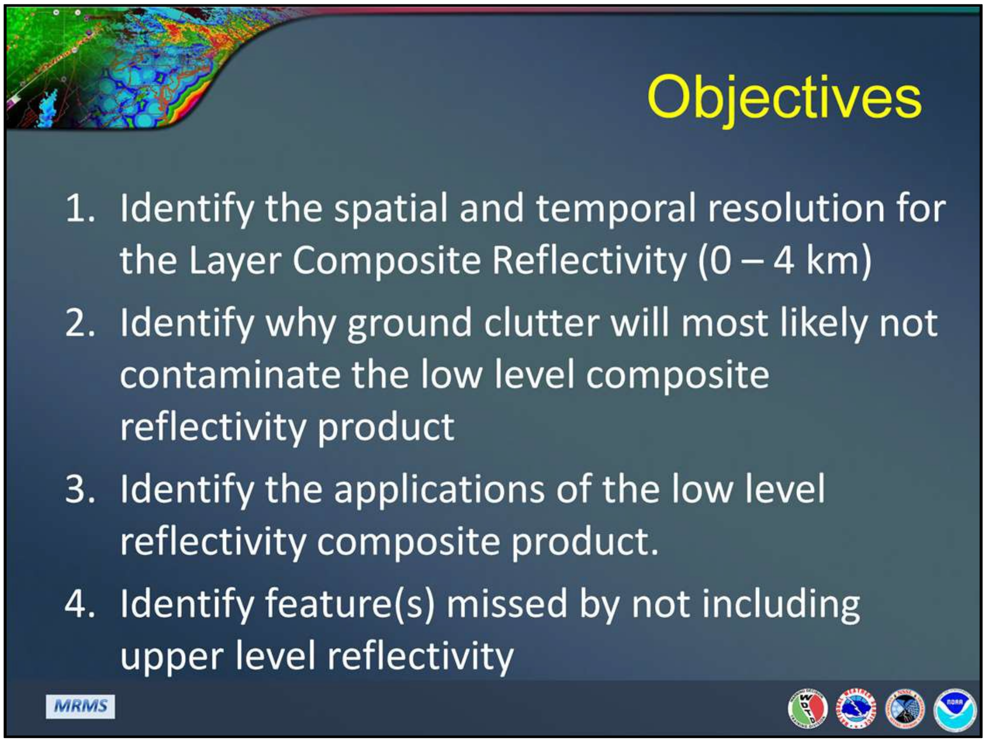
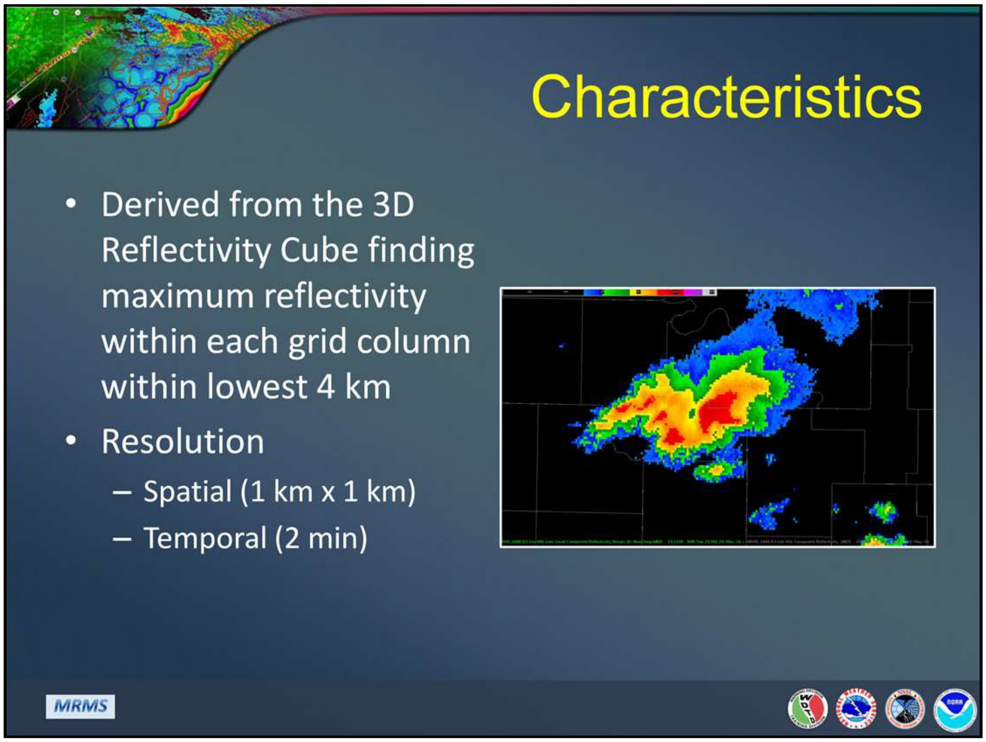
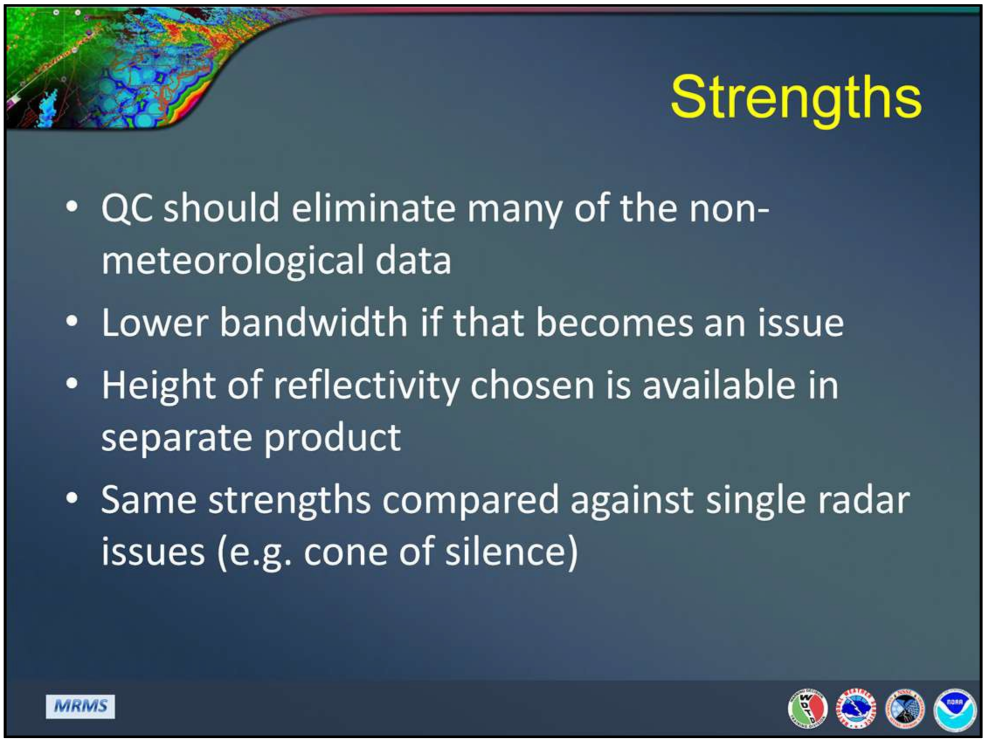


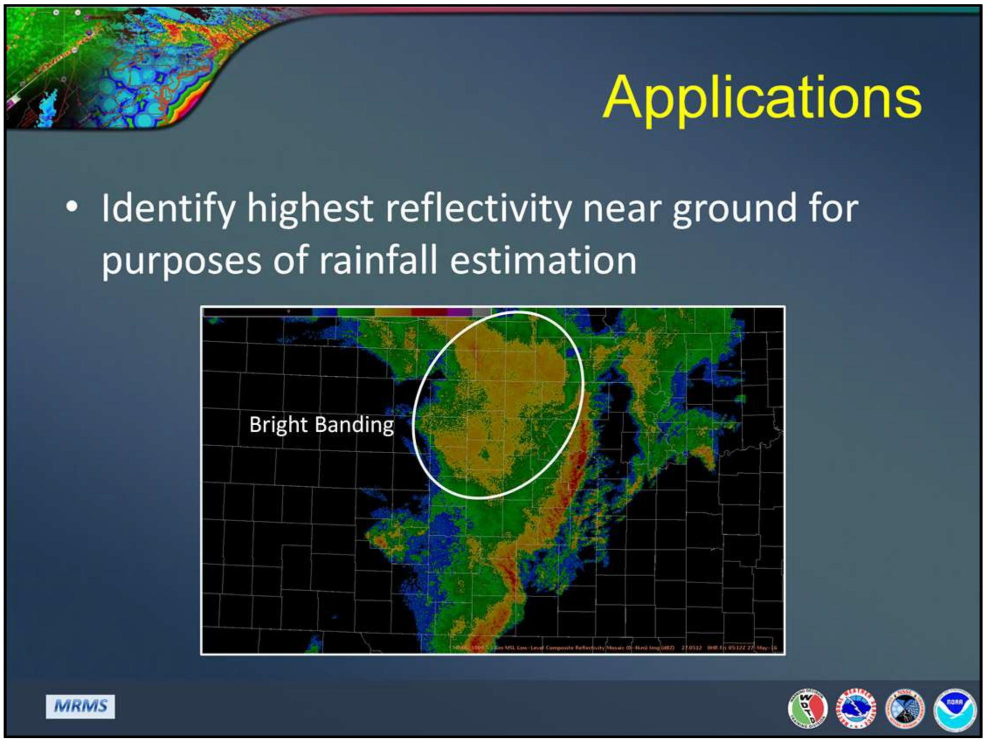
Here are the objectives for this lesson. Take a minute to review them before moving on to the next slide. You will be tested on these objectives at the end of this lesson.



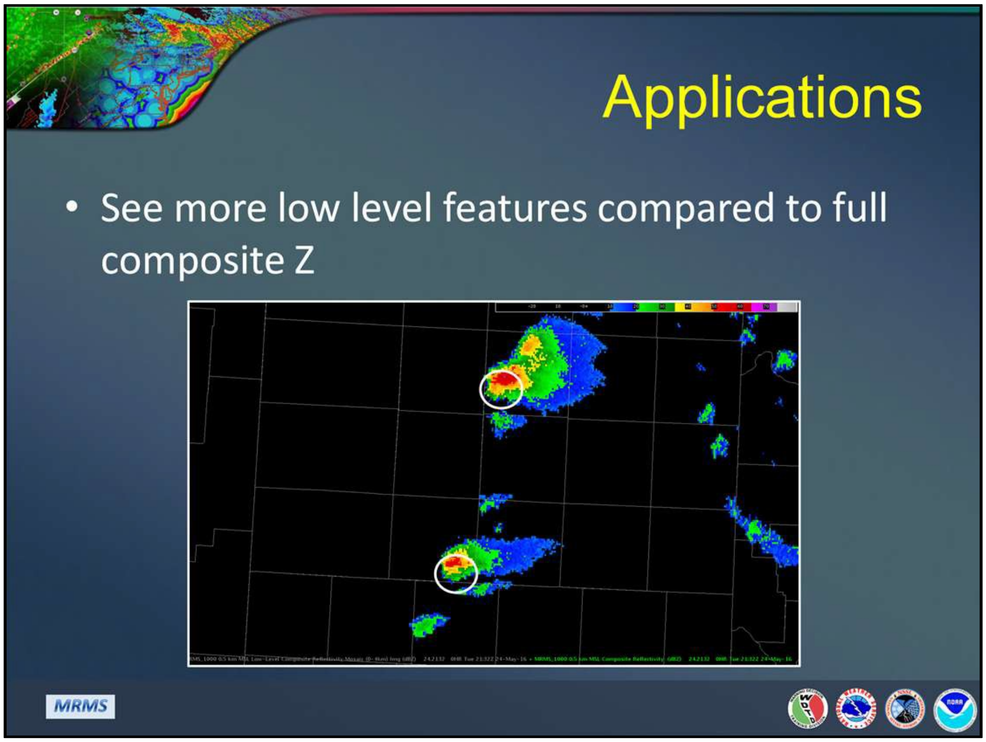
This product is derived from the 3D Reflectivity Cube by finding the maximum reflectivity within each grid column within the lowest 4 km. The spatial resolution is approximately 1 km x 1 km and is updated every 2 minutes.



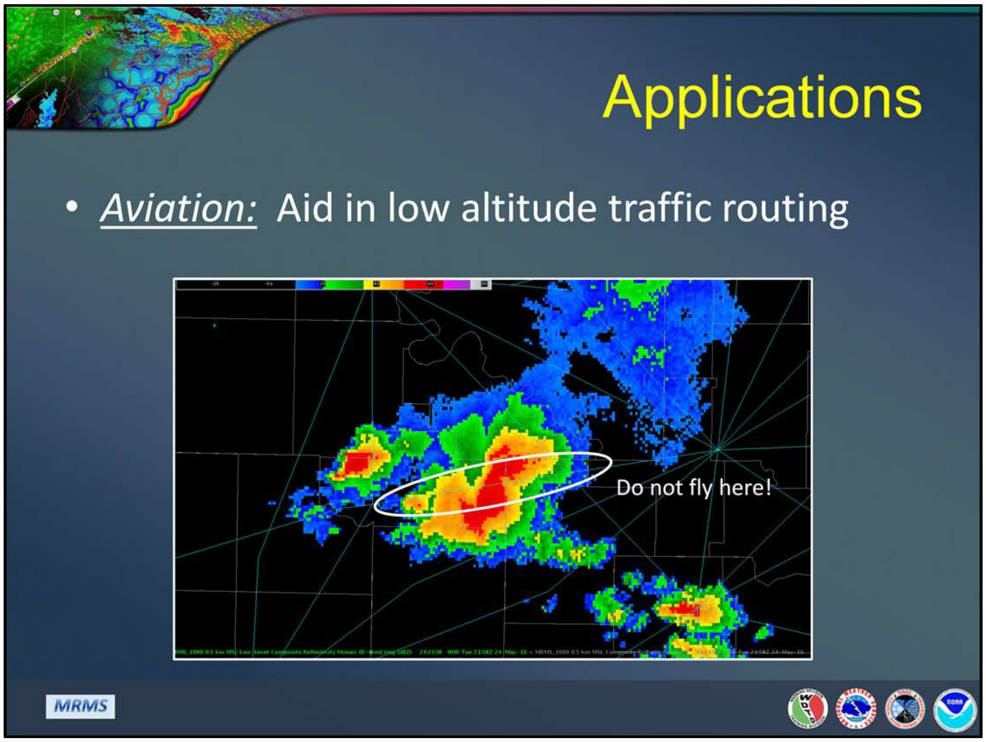
Because the 3D Reflectivity Cube undergoes quality control to remove non-meteorological echoes, this product should not have much contamination from non-meteorological sources like ground clutter. This product will also be smaller in size compared to the high resolution composite reflectivity, so if bandwidth issues are a problem, and you still want higher resolution composite reflectivity, this may be helpful. Additionally, the height of the reflectivity chosen is available in a separate product. The same strengths for MRMS compared to single radar still apply (e.g. cone of silence).



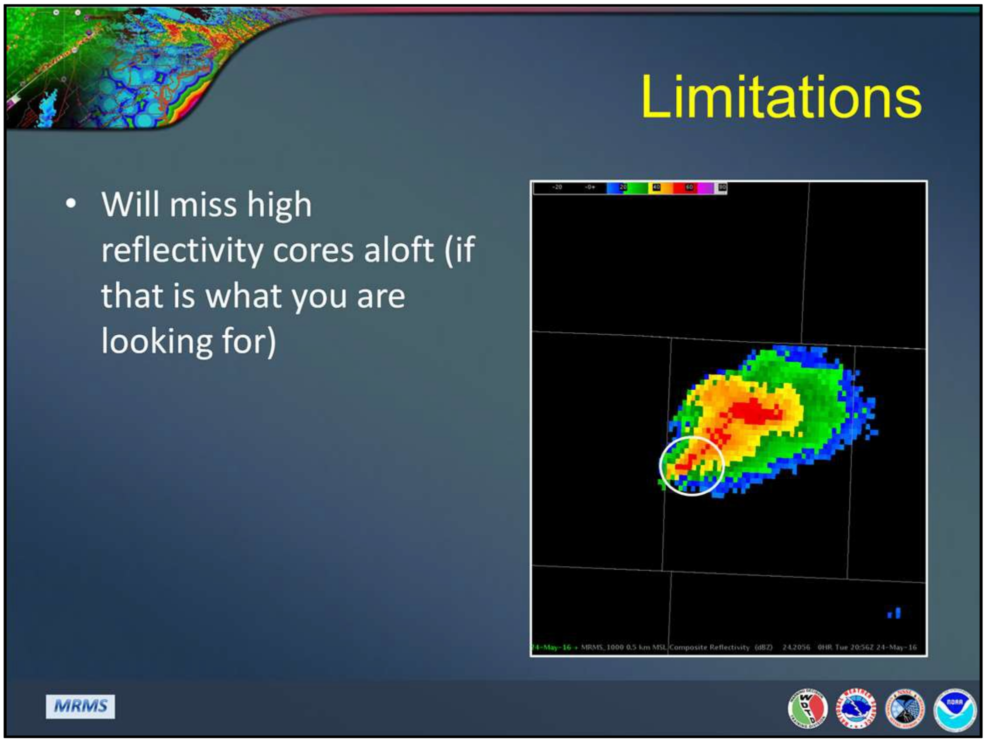
For purposes of rainfall estimation, this product may be helpful since it tells you the maximum reflectivity value in the lowest 4 km (i.e. near the ground). One caveat to be aware of though, is this product can be contaminated by bright banding. Here is an example from eastern Kansas where a strong line of storms is likely causing heavy rain. Behind the line is a large stratiform area of precipitation also contributing to heavy rainfall, but it is likely being contaminated by bright banding.



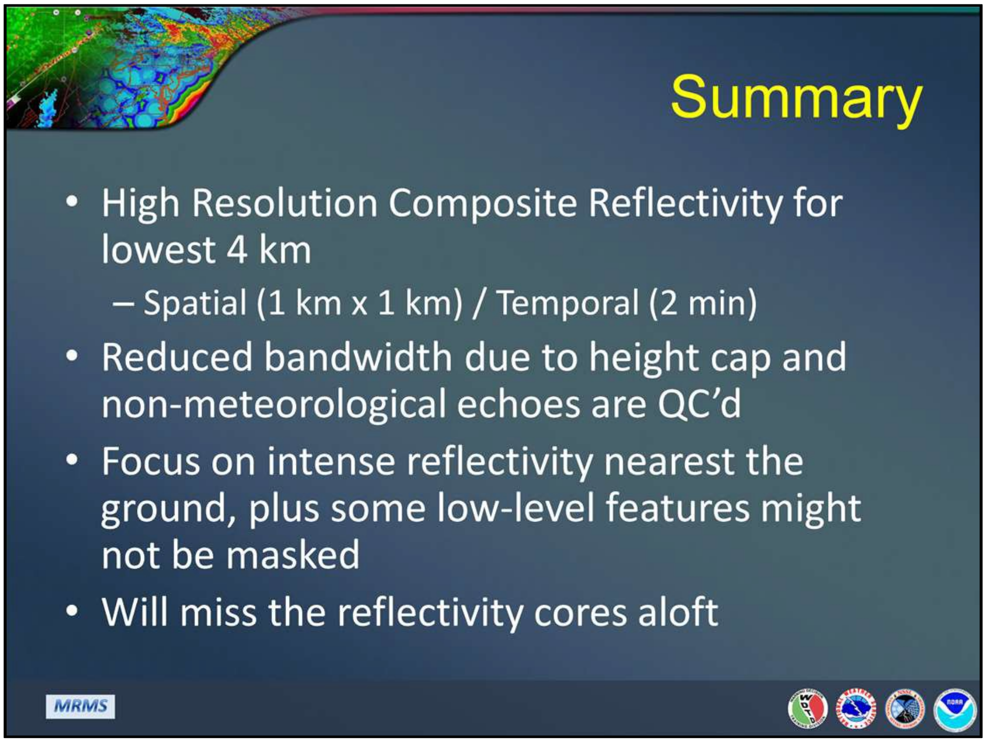
Since upper level features are not included, this product may reveal more low level features that might be of interest. Here is an example where you can see the inflow notch on the northern storm and the tight reflectivity gradient on the southern storm. However, toggle on the full Composite Z, and those features are masked by the echo overhangs.



For aviation purposes, this product may be helpful to identify the most intense areas of precipitation near the ground which can be helpful for traffic routing. In this example, the low level routes are overlaid on top of the 0-4km Composite Z. It would be advisable not to fly this route through the strongest core!



One major limitation of this product is you will miss the high reflectivity cores aloft which could potentially aid in warning decisions for hail, as an example. Also, you will not see echoes forming aloft before they extend down to the ground. These upper level echoes may not be what you are looking for, but just keep in mind you won't see them with this product. Here is an example from Kansas where a severe storm is showing high reflectivity aloft, but the echoes haven't quite reached the lower levels where it would show up on the 0-4km Composite Reflectivity.



In summary, this product is nothing more than the high resolution composite reflectivity but is just capped at a height of 4 km. Spatial resolution is approximately 1 km x 1 km, and temporal resolution is 2 min. Because of the height cap, the product will have less impact on bandwidth and the QC algorithm will mitigate non-meteorological contamination. The primary advantage of this product is to quickly identify the most intense storms nearest the ground. Additionally, the low level nature of this product makes it possible that some low-level features might not be masked by higher reflectivity aloft. However, this is the drawback to this product. The high reflectivity aloft will not be displayed. So, for certain threats, like hail, this product will not be useful. The next slide will be a short quiz on this material to test your understanding.

Low Level Composite Reflectivity Quiz

Quiz - 5 questions

Last Modified: Sep 13, 2016 at 11:46 AM

PROPERTIES

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On failing, 'Finish' button:	Goes to Next Slide
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User may view slides after quiz:	At any time
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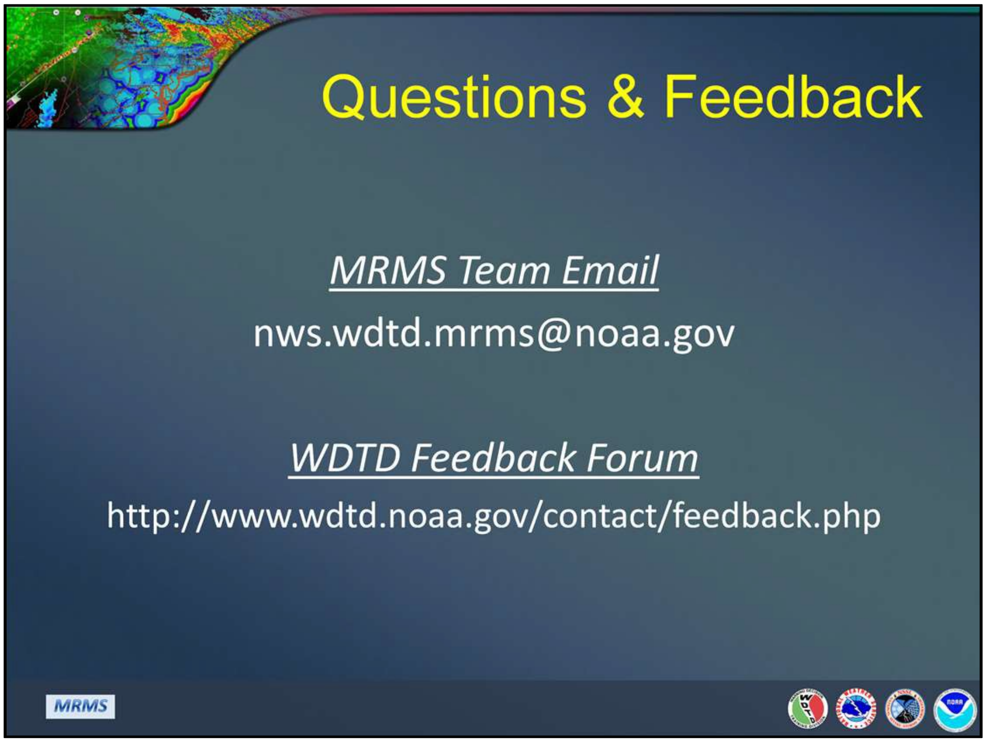
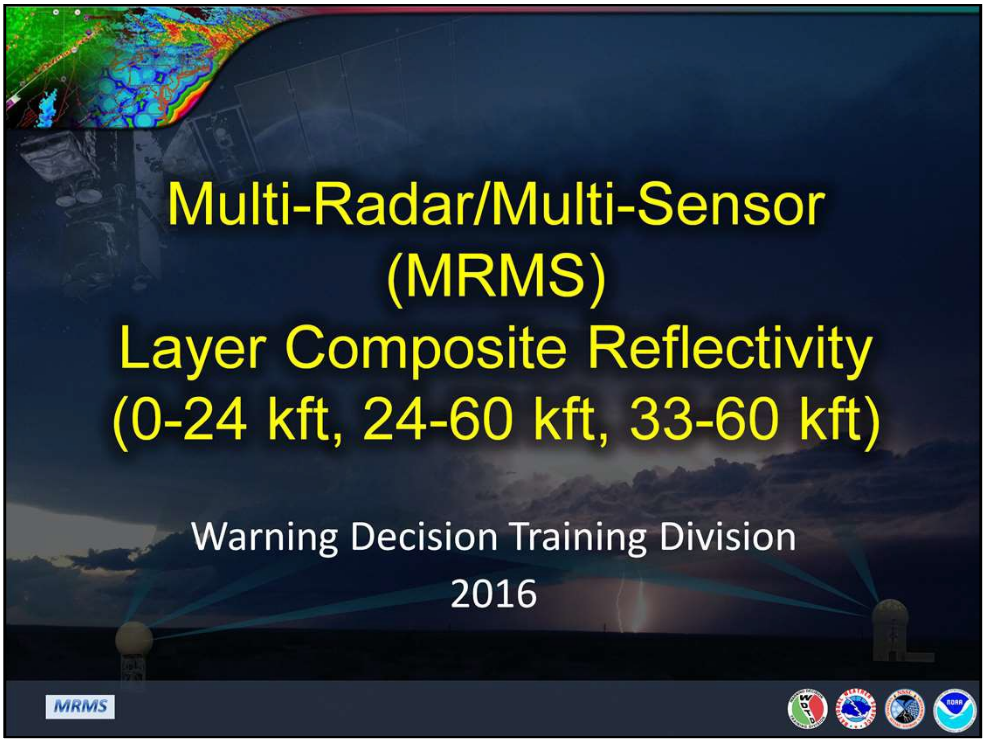
Edit in Quizmaker

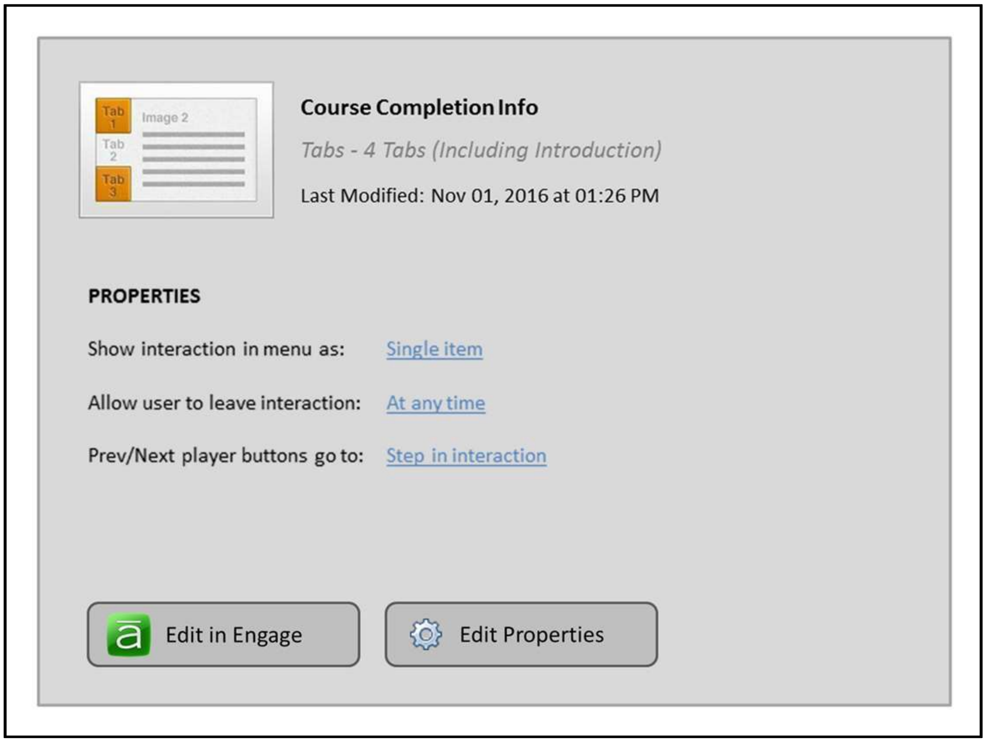
Edit Properties



Thanks for completing this module on Layer Composite Reflectivity (0 – 4 km). If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Layer Composite Reflectivity (0-24 kft, 24-60 kft, 33-60 kft) developed here at the Warning Decision Training Division (WDTD). This lesson will cover the three main aviation layer products.


Course Completion Info
Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 01, 2016 at 01:26 PM
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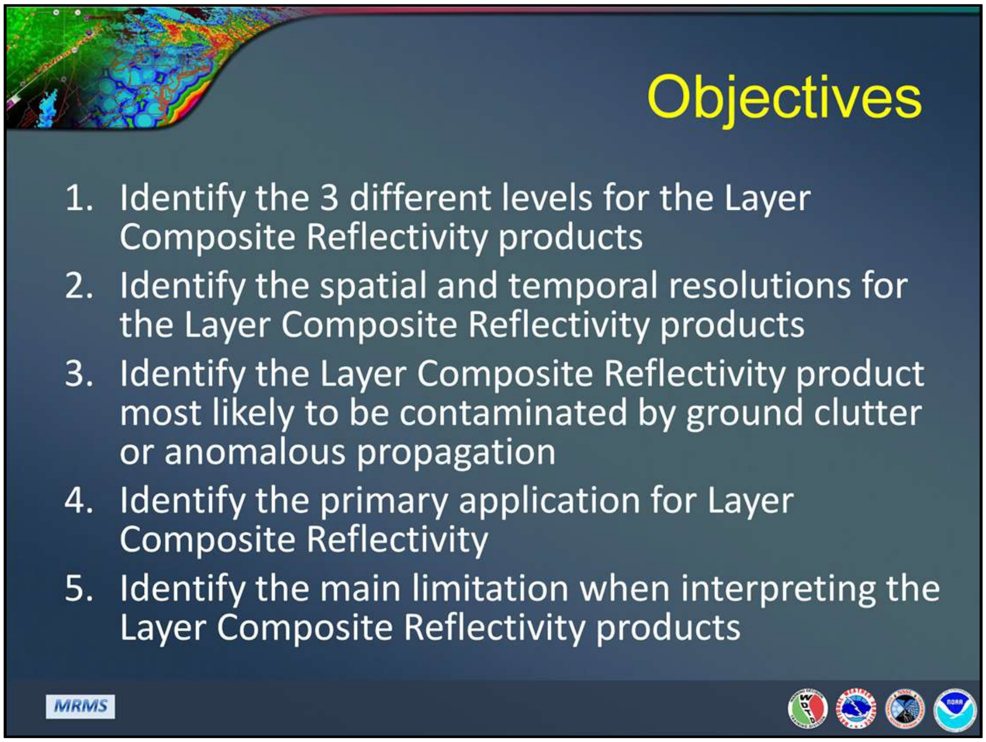
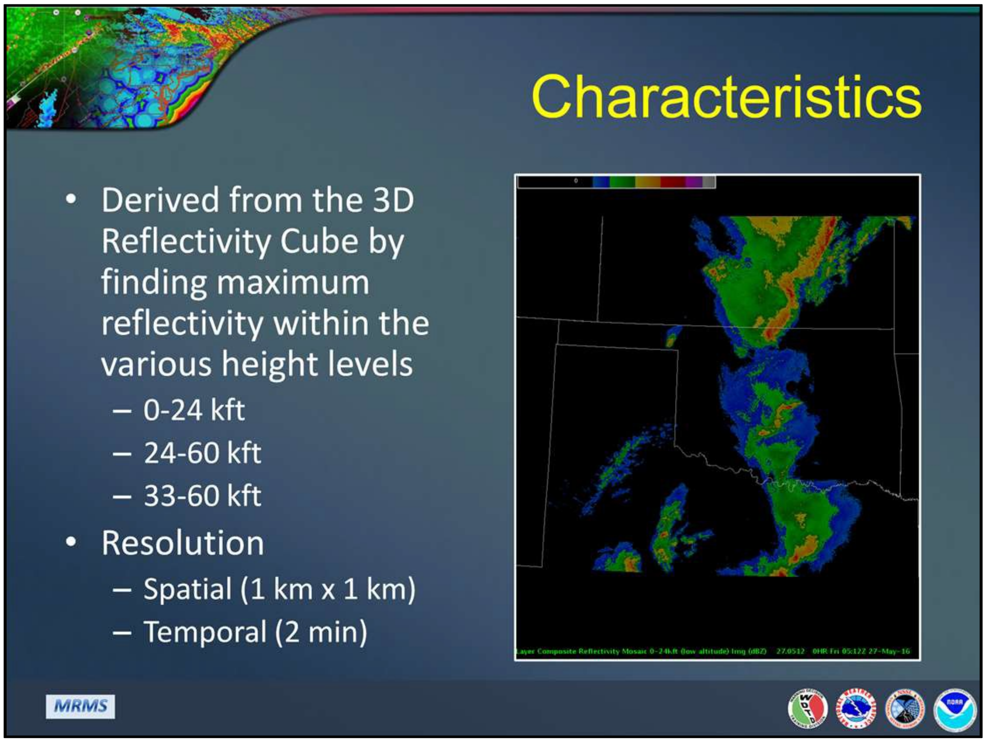
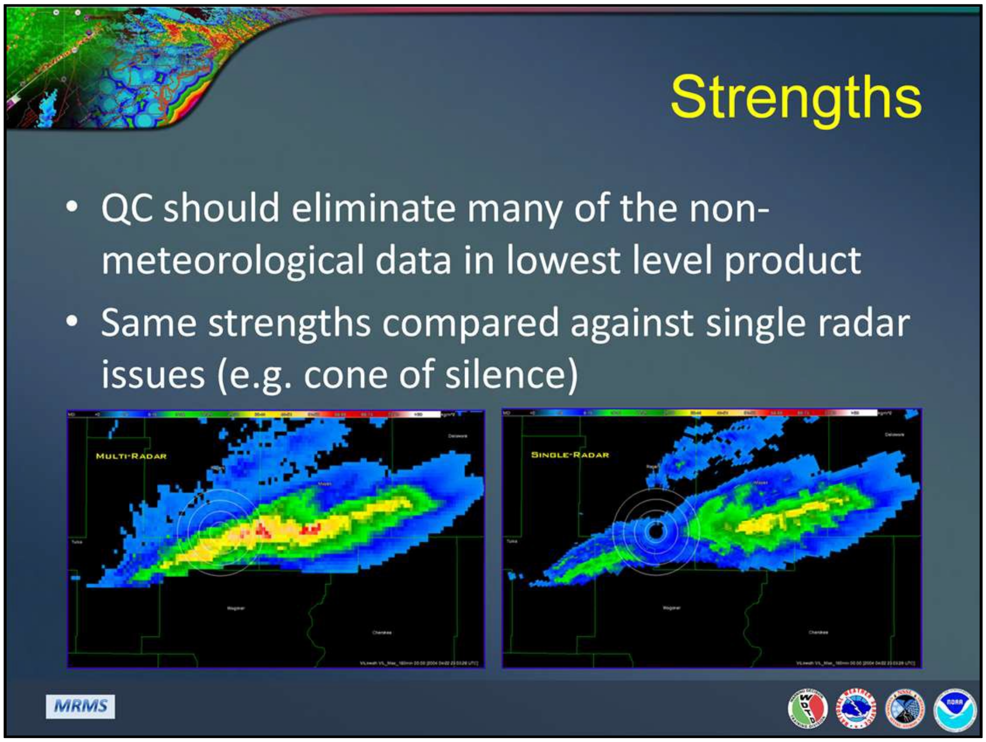


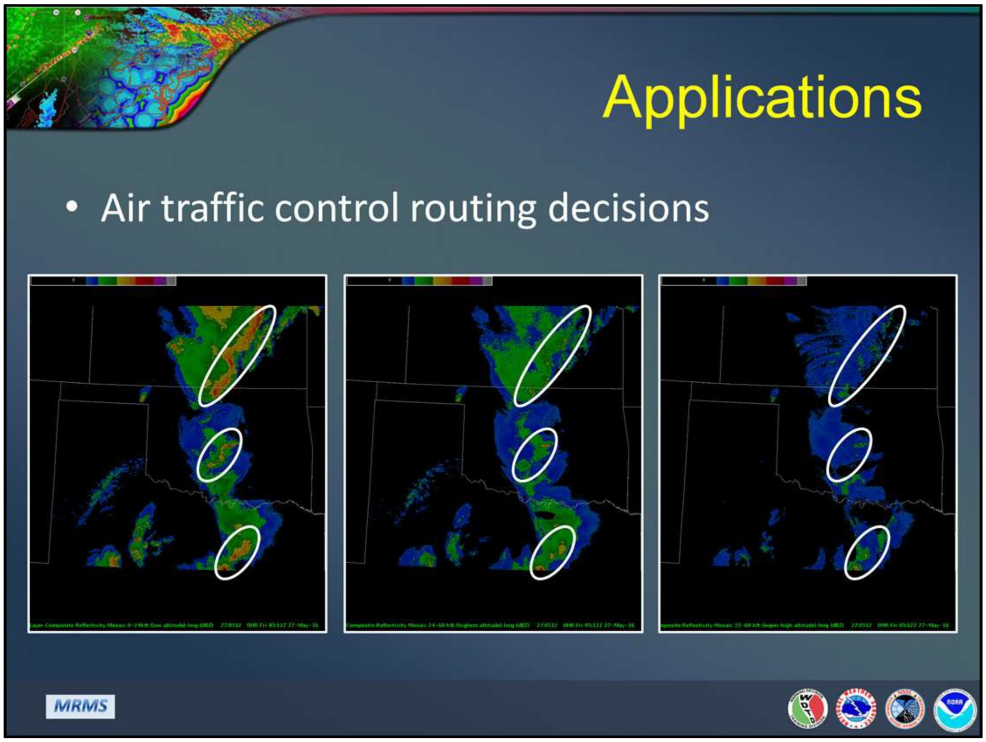
Here are the objectives for this lesson. Take a minute to review them before moving on to the next slide. There will be a quiz at the end of this lesson based on these learning objectives.



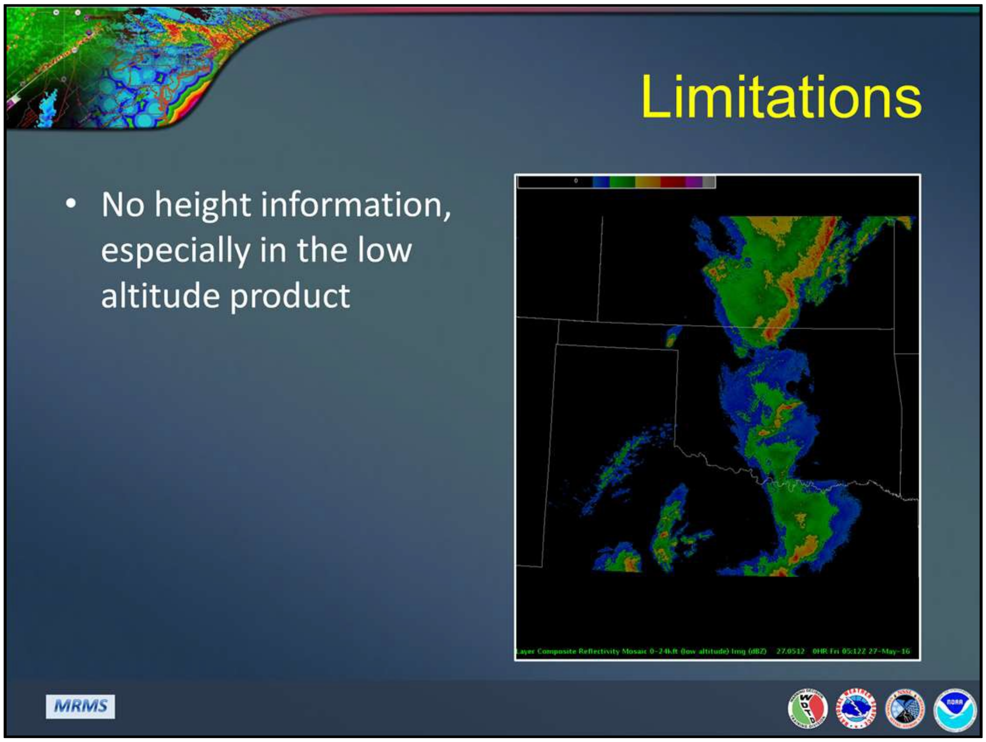
The various layer composite reflectivity products are developed by finding the maximum reflectivity within the various height levels. These height levels are 0-24 kft, 24-60 kft, and 33-60 kft. The spatial resolution is 1 km x 1 km and the temporal resolution is 2 minutes.



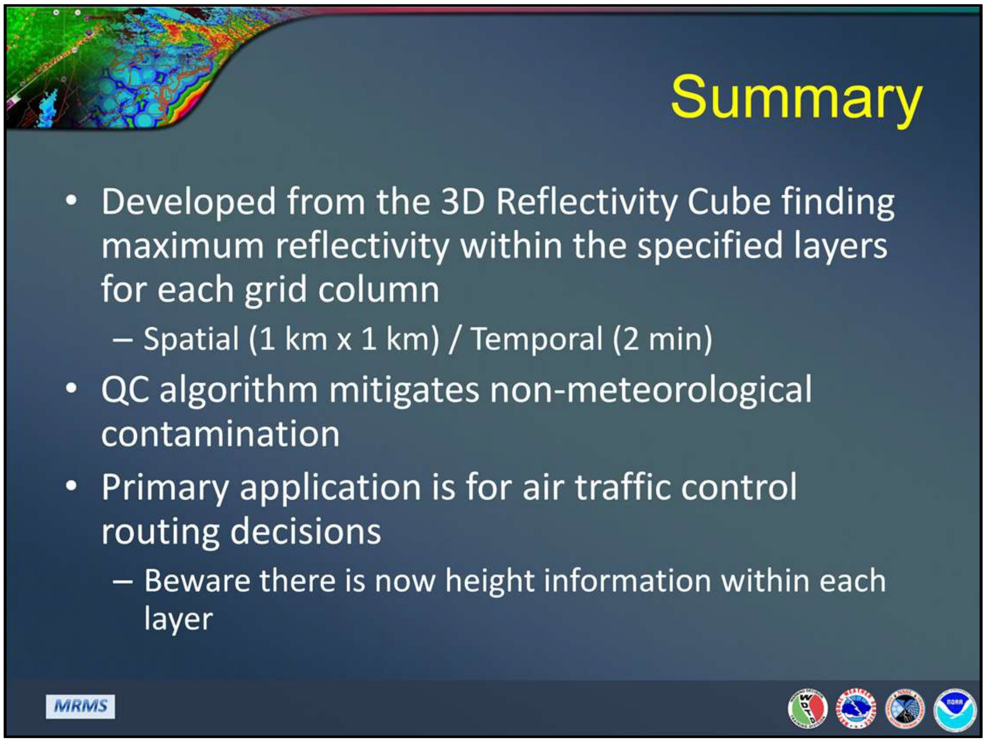
The QC algorithm should eliminate many of the non-meteorological echoes which will most likely reside in the lowest level product. The same general strengths for all MRMS products apply (e.g. cone of silence mitigation).



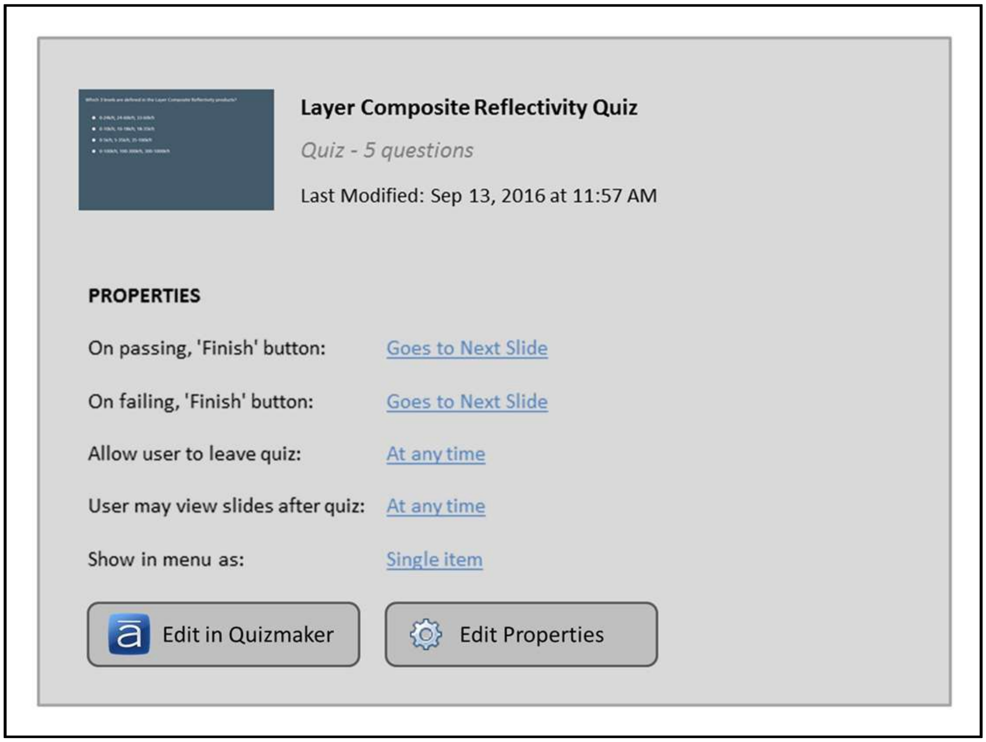
Since these levels are defined in feet, the primary application of these products are for air traffic control routing decisions. Where you see high reflectivity values at low, mid, and upper levels, airplanes most likely do not want to fly though those areas.



One major drawback to these layer products is the exact height level of the reflectivity value is unknown for each grid point. This is most likely to impact decisions made using the low level product.



In summary, the Layer Composite Reflectivity products are derived from the 3D Reflectivity Cube much like the High Resolution Composite reflectivity except using the three specified layers. The spatial resolution is 1 km x 1 km and the temporal resolution is 2 minutes. The QC algorithm attempts to remove most non-meteorological contamination, but sometimes they can slip through. If the non-meteorological echoes do affect any of the Layer Composite Reflectivity products, it will be the lowest level product. The primary application for Layer Composite Reflectivity is for air traffic control routing decisions, but beware that the exact height of each grid point is not known within each layer. Now you are ready for the quiz for this lesson.


Layer Composite Reflectivity Quiz
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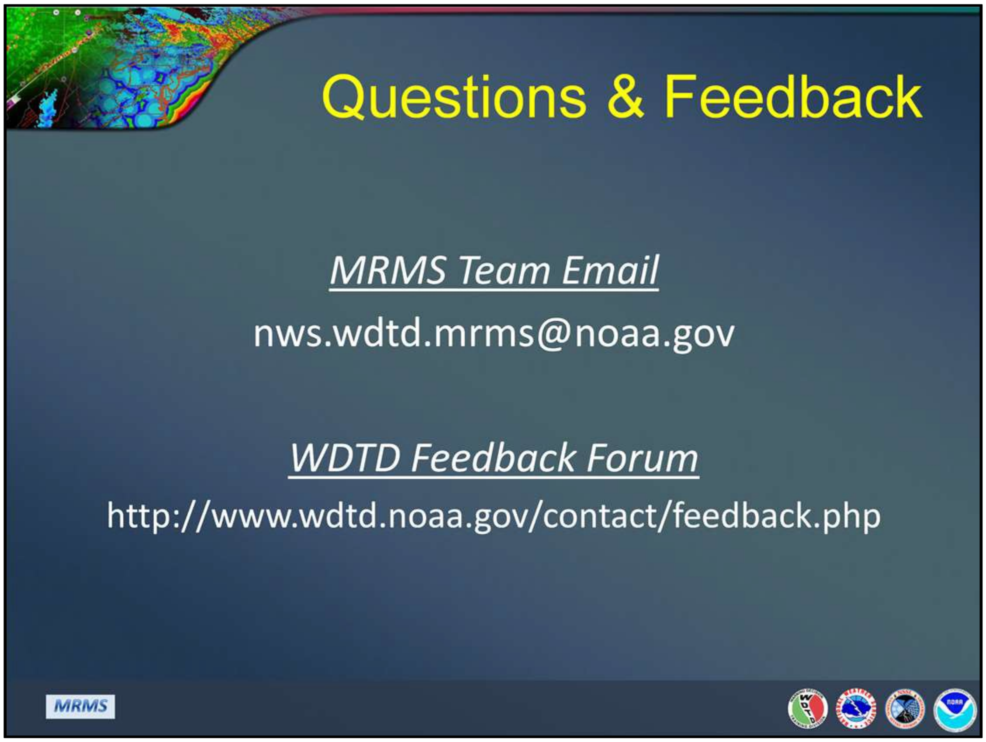
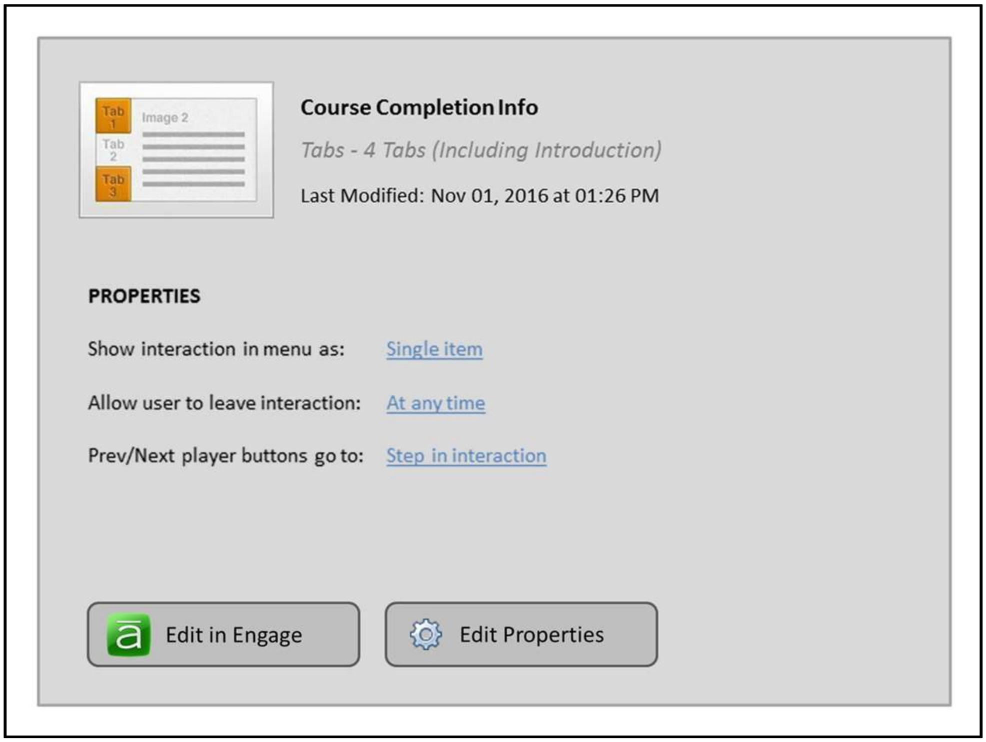


Thanks for completing this module on Layer Composite Reflectivity. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.

Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Constant Altitude Reflectivity (WSR-88D Only & All Radars) developed at the Warning Decision Training Division (WDTD).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Tab 2
Tab 3
Image 2
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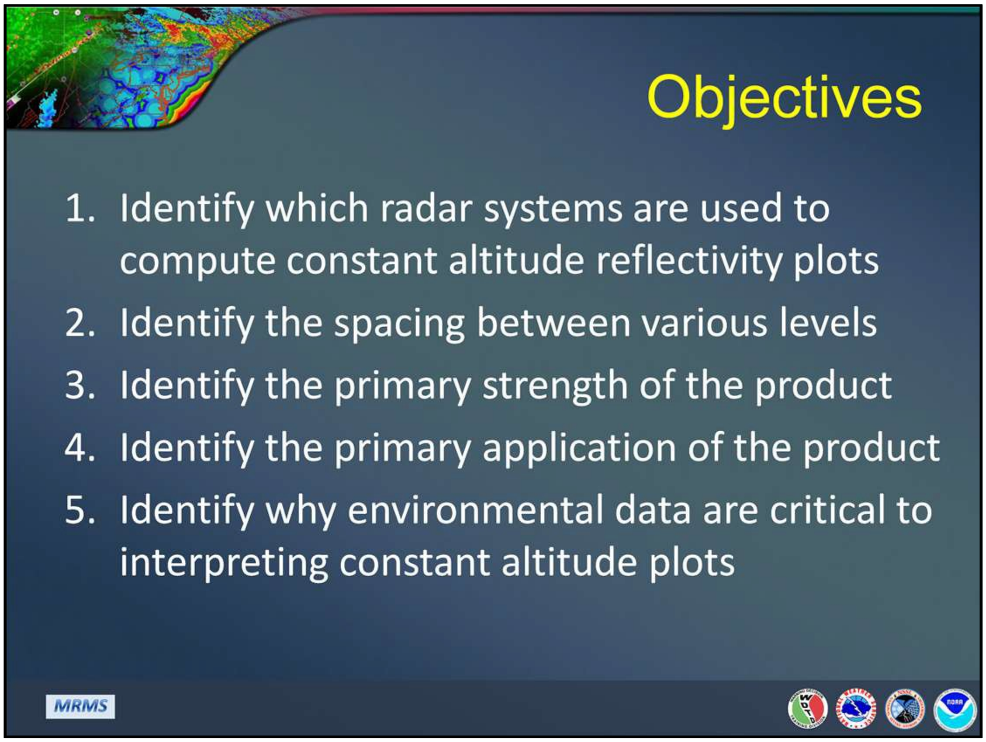
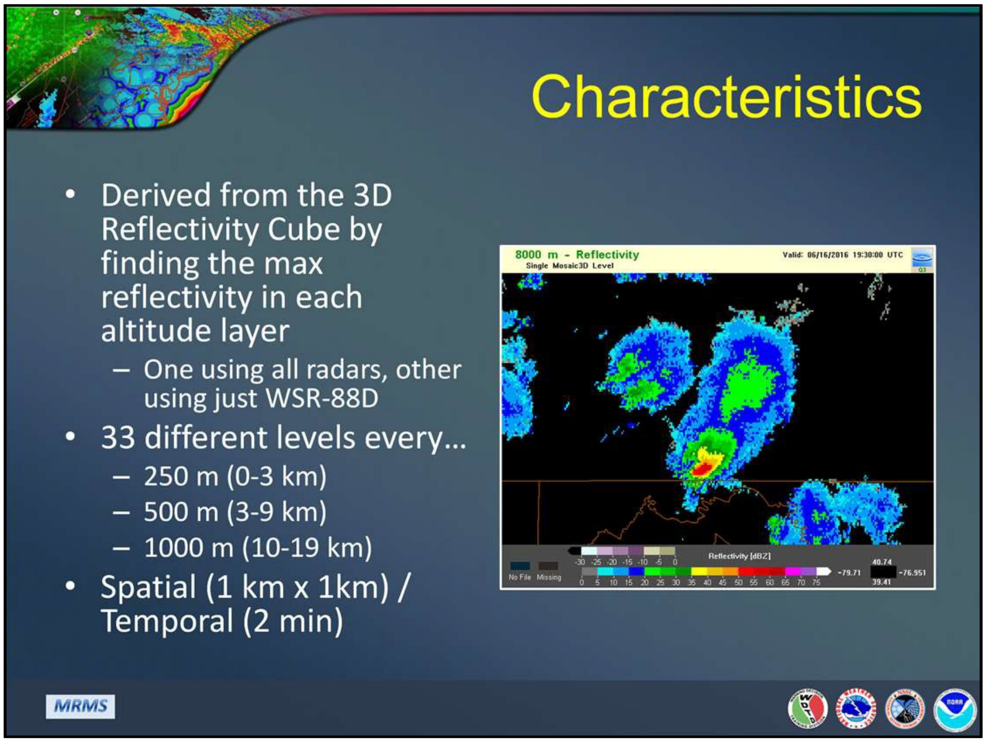
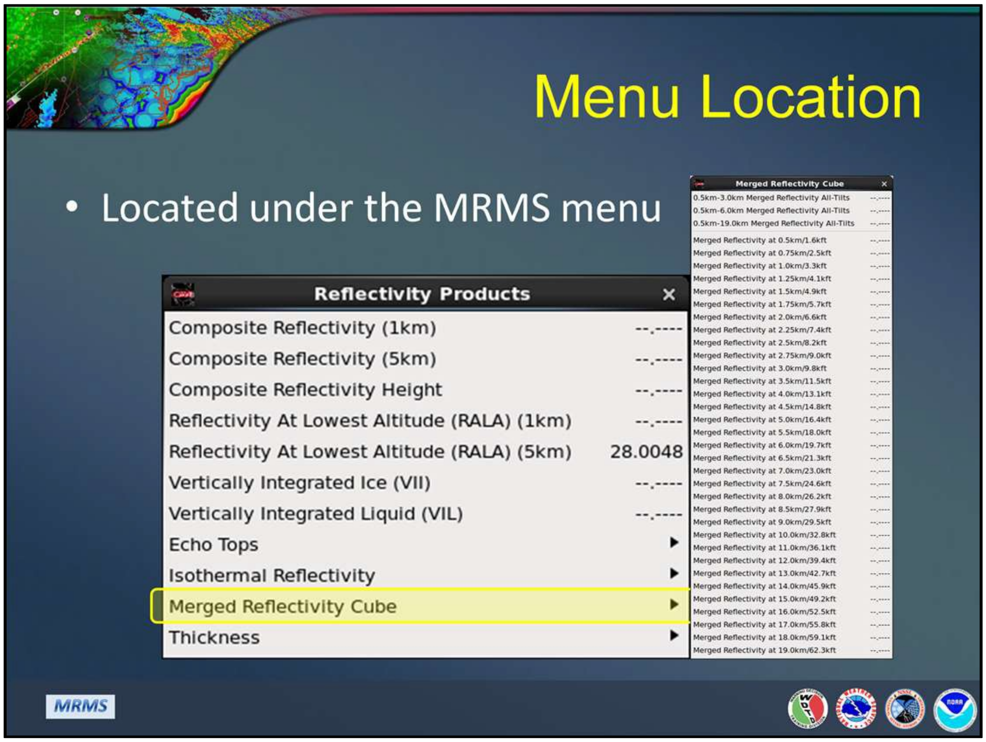


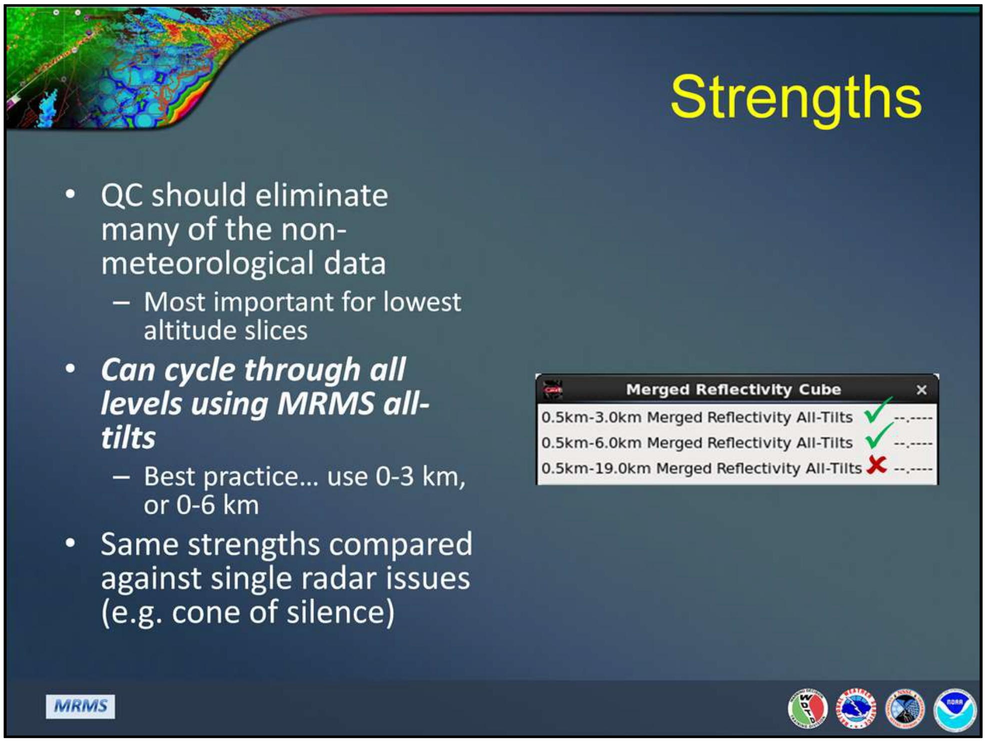
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. The quiz at the end of this lesson is based on these objectives.



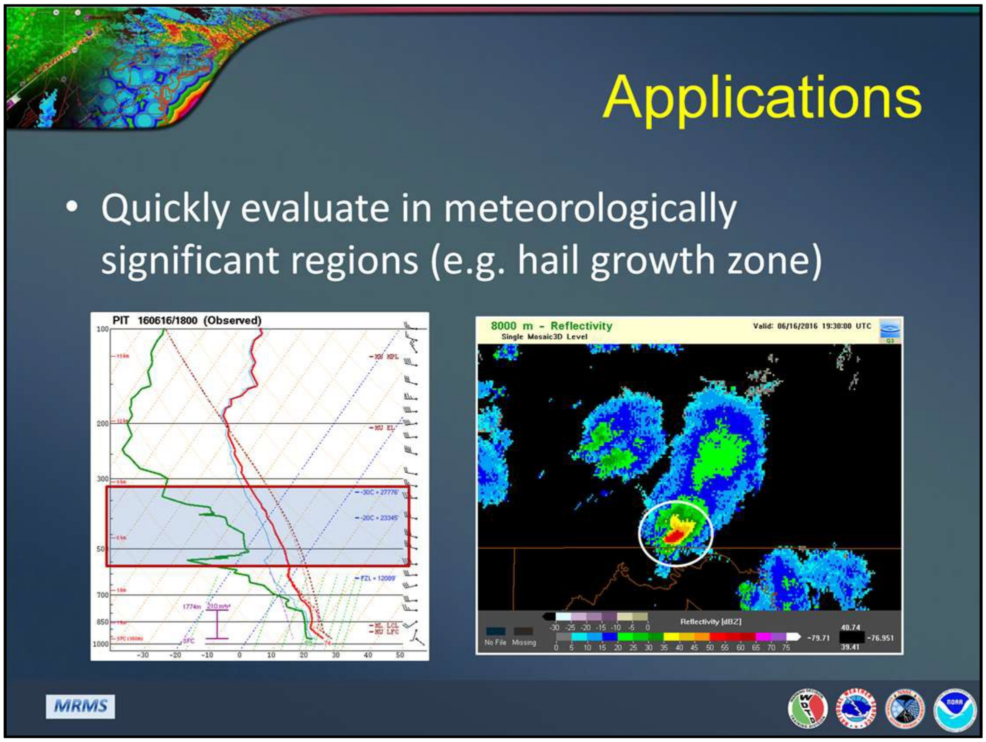
The constant altitude reflectivity product is derived from the 3D Reflectivity Cube by finding the maximum reflectivity in each altitude layer. There are actually two products. The first is based solely on the WSR-88D radars. The other product uses both Canadian and WSR-88D radars as input. There are 33 different layers from 0 through 19 km altitude. At the lowest altitudes, the vertical separation of the layers is 250 meters. Between 3 and 9 km, the separation is 500 meters, and between 10 and 19 km, the separation is 1000 meters. The spatial resolution is 1 km x 1 km, and temporal resolution is 2 minutes.



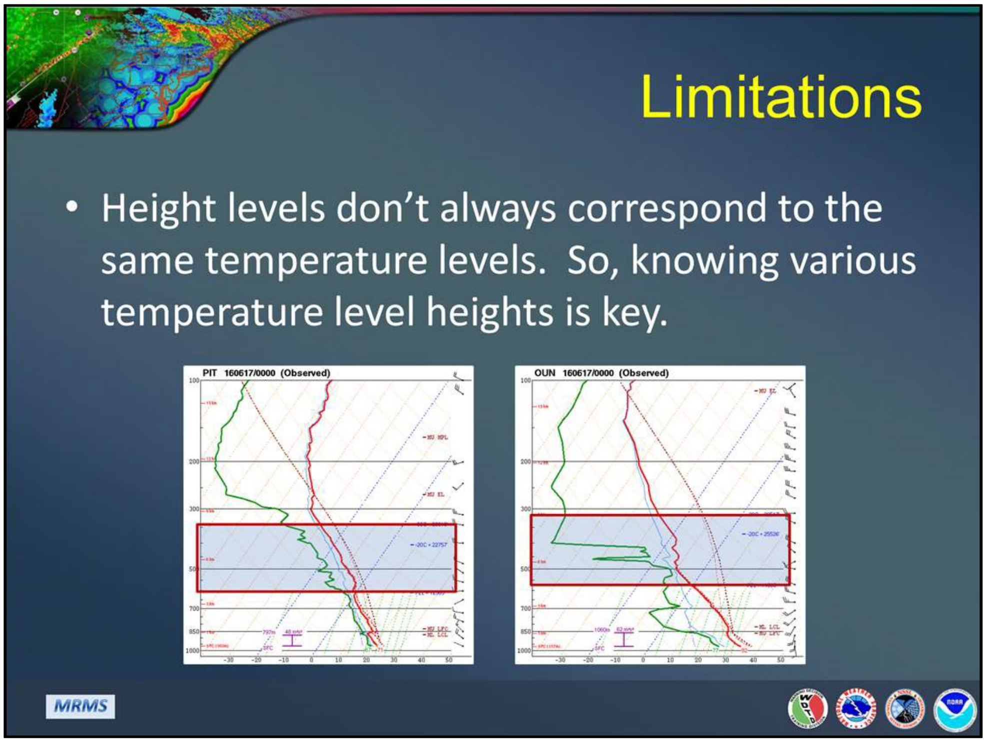
You can find the Constant Altitude Reflectivity products within the MRMS menu inside of CAVE.



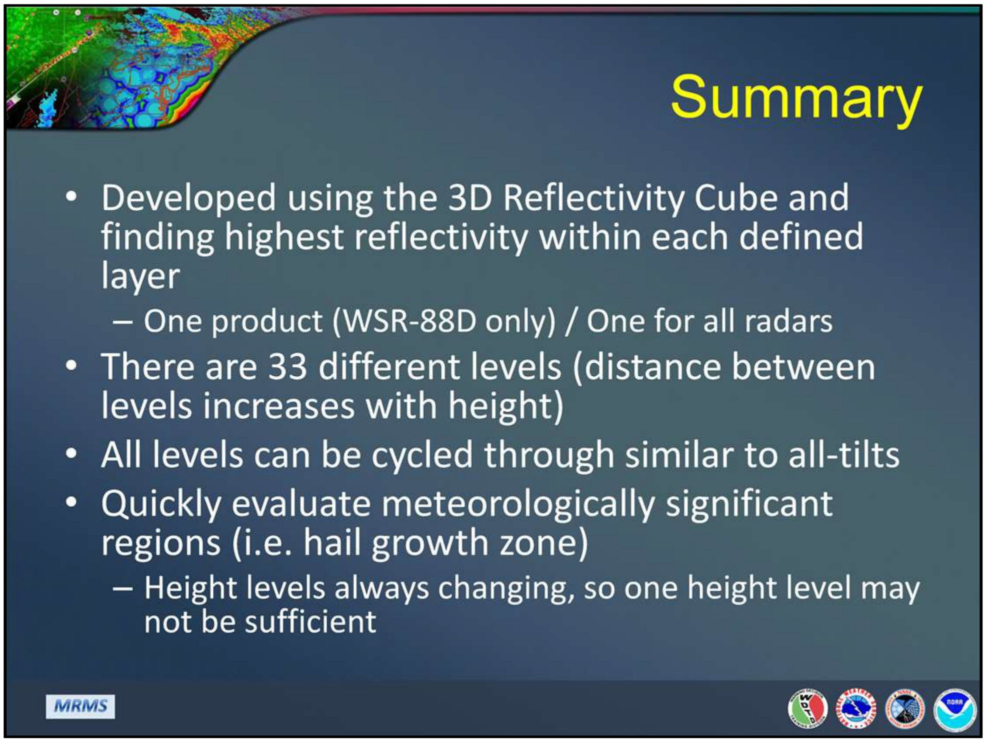
The quality control algorithm should eliminate many of the non-meteorological echoes, but sometimes they can slip through. If this happens, the most likely products to be affected will be the lowest altitude slices. Another major strength of this product (more tied to a strength of AWIPS 2) is the ability to cycle through all levels of this product much like you can cycle through tilts for a single radar. In other words, it's like MRMS all-tilts. Because the full 3D Reflectivity Cube is large in size, loading all 33 levels for all-tilts functionality is not advisable. Therefore, there are sub-products available for 0-3 km and 0-6 km which should be sufficient for most warning needs. Finally, the same strengths compared against single radar (e.g. cone of silence) apply.



The primary application of the constant altitude reflectivity plots are to be able to quickly interrogate reflectivity in regions of meteorological significance such as the hail growth zone. Here is an example from Pennsylvania where there was baseball sized hail. Looking at the sounding, the hail growth zone was between roughly 5 and 9 km. Looking at the 5 through 9 km constant altitude reflectivity plots, the storm to the south that produced the baseball sized hail is showing 50-60 dBZ echoes through the entire hail growth zone. So, we can feel confident there is hail with this storm.



Since the height levels in the product don't always correspond to the same temperature levels, knowing your environment is key to know which height levels are important to look at. Therefore, either have model data loaded to determine important temp/height levels, or look at the latest skew-T diagram to determine height levels of the most important temperature levels. Here are two Skew-T diagrams where the hail growth zones are different depths and occur at different heights.



In summary, the Constant Altitude Reflectivity product is derived from the 3D Reflectivity Cube by finding the highest reflectivity within each defined layer. One product exists where only the WSR-88D radars are used as input. Another product exists where all radars (Canadian and WSR-88D) are used. There are 33 different altitude levels and the distance between each level varies with height. Near the ground the separation is small, but high up the separation is larger. In AWIPS2, there is the capability to cycle through all the various levels in a manner similar to all-tilts for single radar. The main application of this product is to quickly evaluate meteorologically significant regions such as the hail growth zone. But, beware, temperature levels are never at constant altitudes, so one height level will not be sufficient for interpretation.

Constant Altitude Reflectivity Quiz

Quiz - 5 questions

Last Modified: Sep 14, 2016 at 10:35 AM

PROPERTIES

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On failing, 'Finish' button:	Goes to Next Slide
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User may view slides after quiz:	At any time
Show in menu as:	Single item

Edit in Quizmaker

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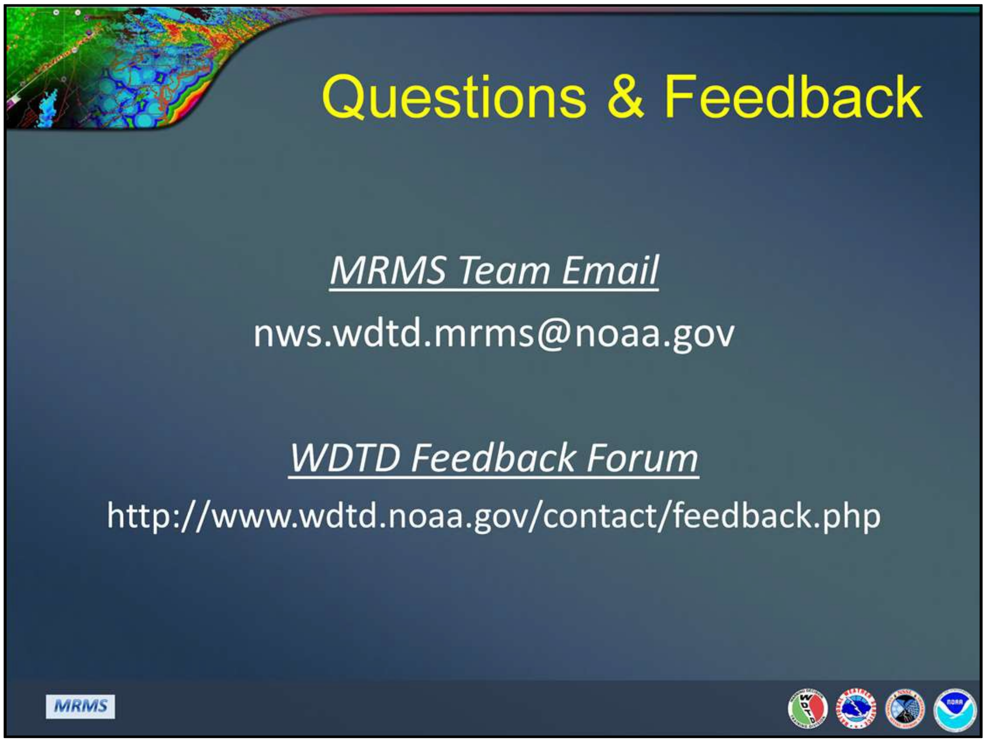
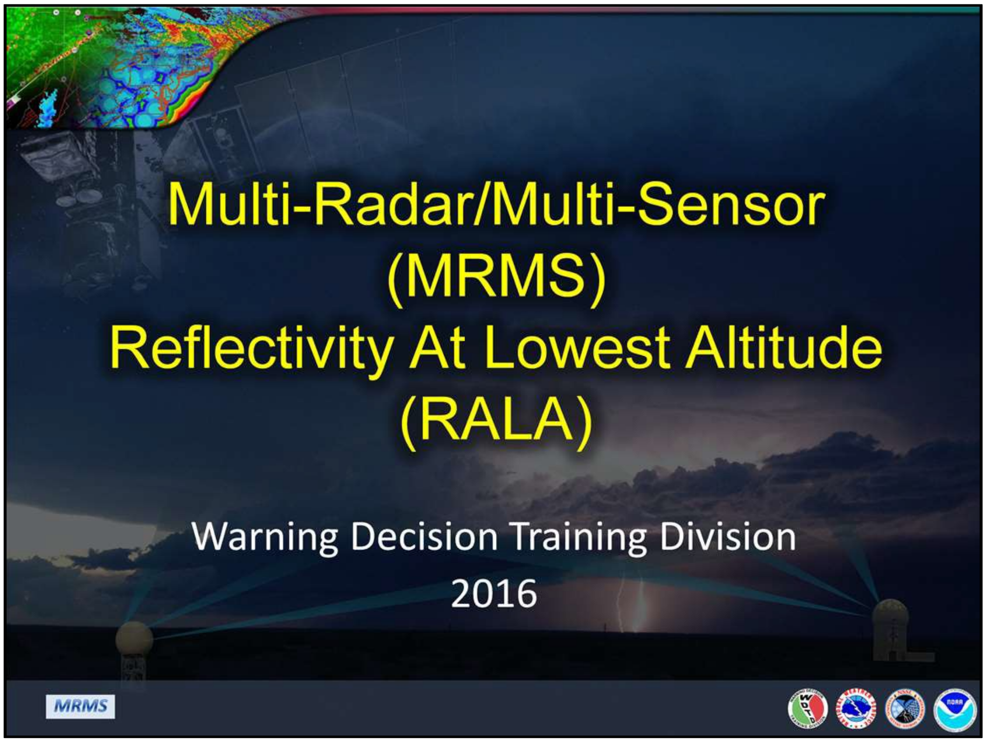
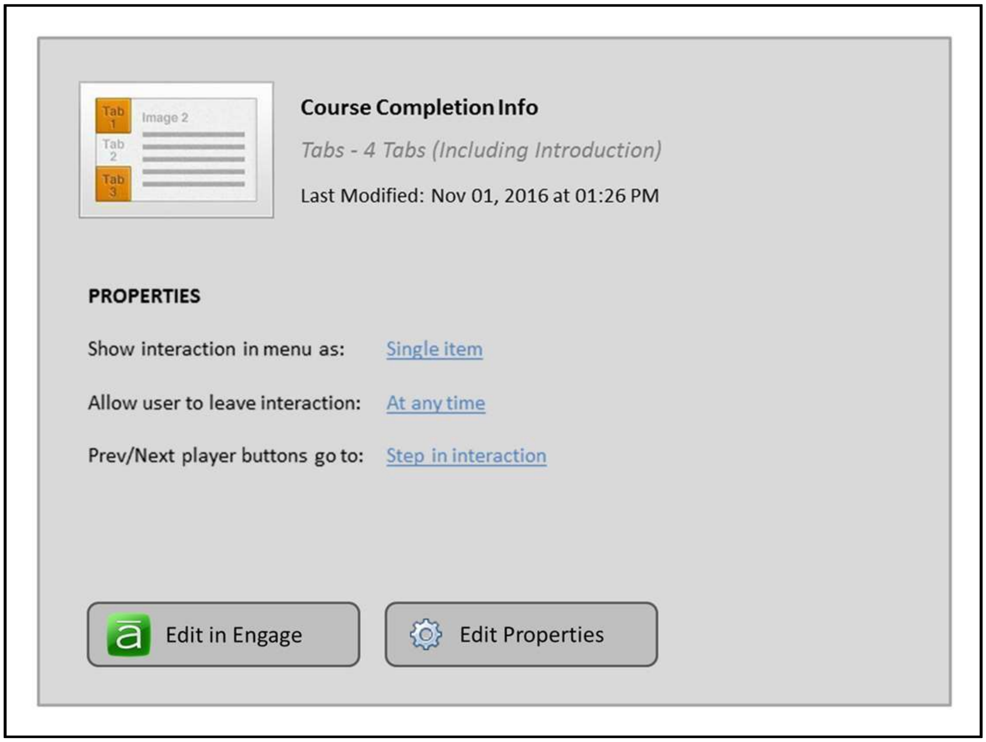


Thanks for completing this module on Constant Altitude Reflectivity. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on the Reflectivity At Lowest Altitude (RALA) product developed here at the Warning Decision Training Division (WDTD).


Tab 1
Image 2
Tab 2
Tab 3
Course Completion Info
Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 01, 2016 at 01:26 PM
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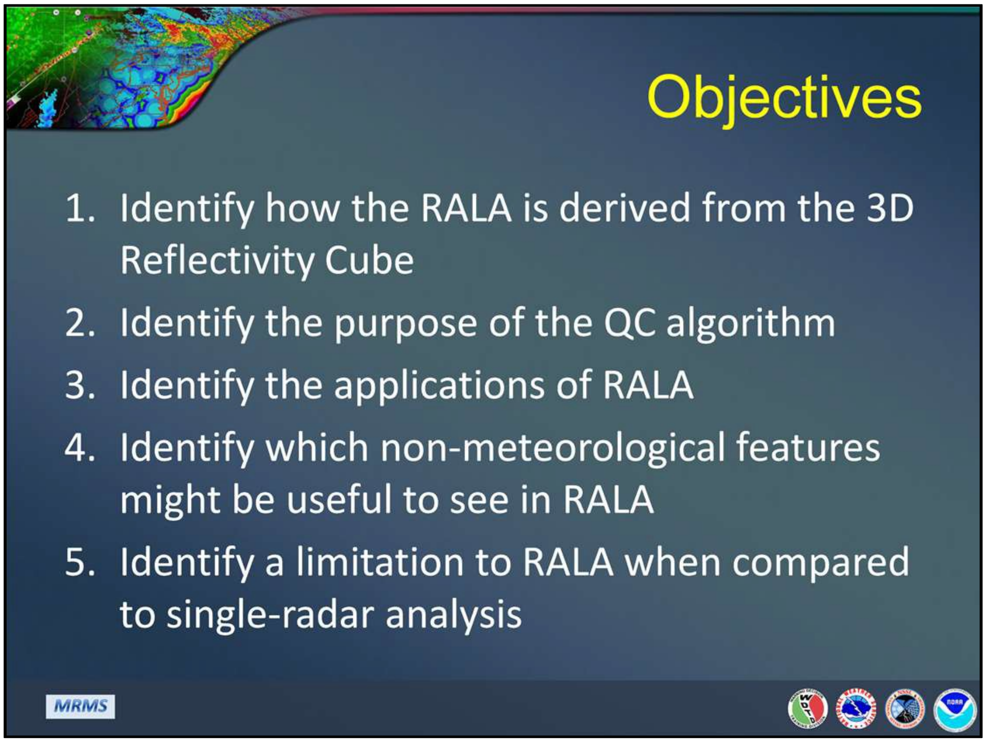
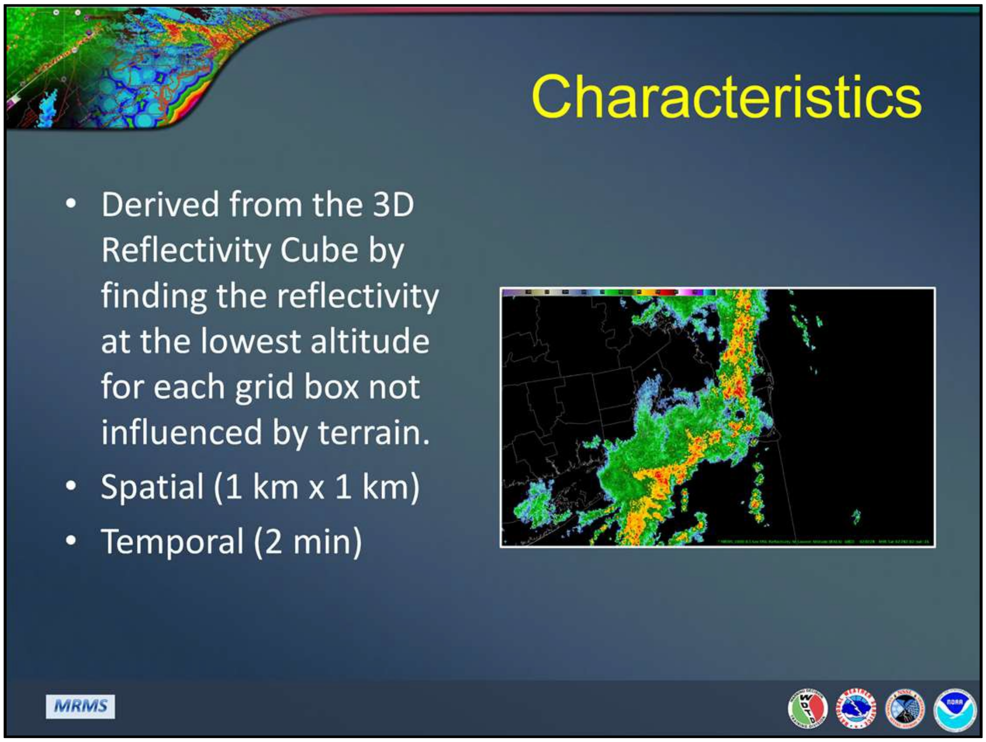
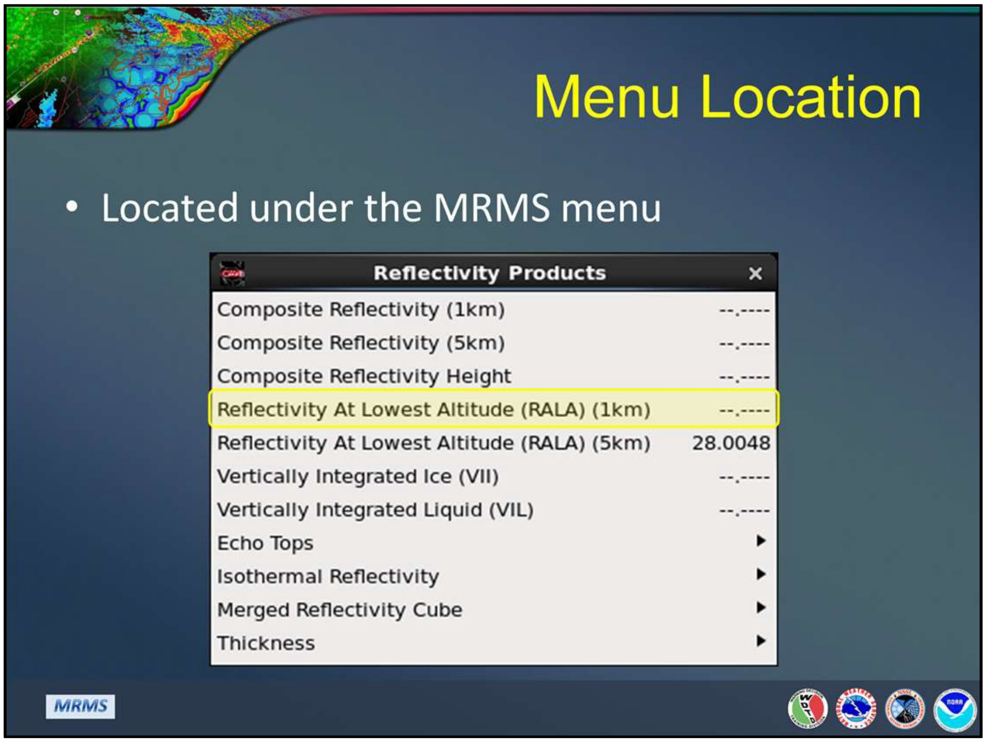


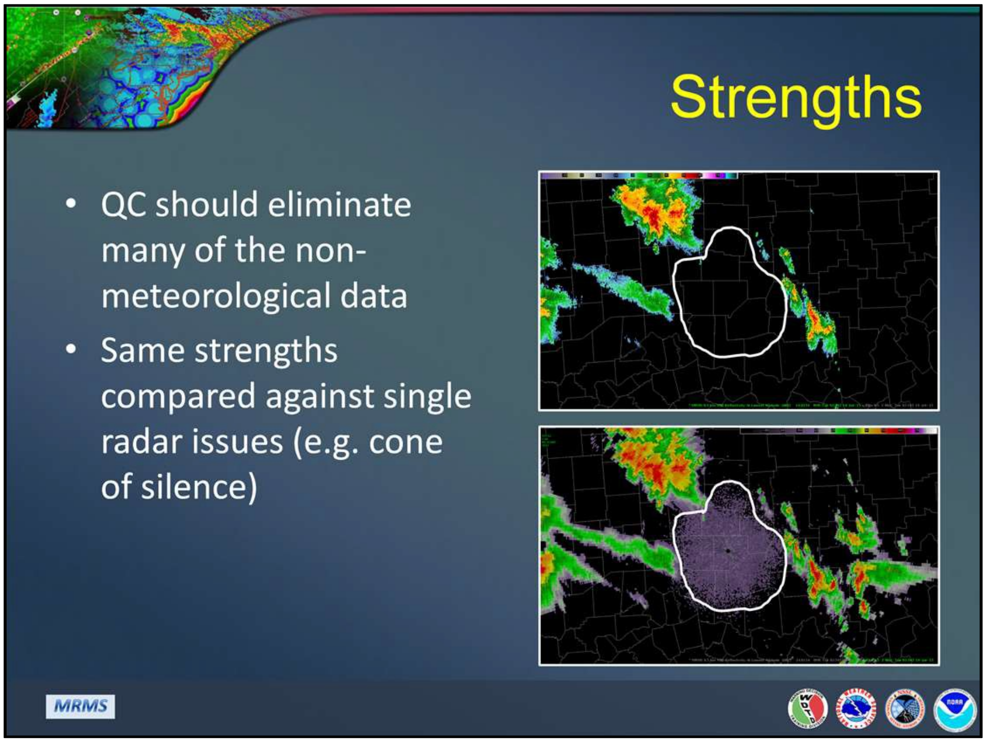
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. You will be tested on these objectives at the end of the lesson.



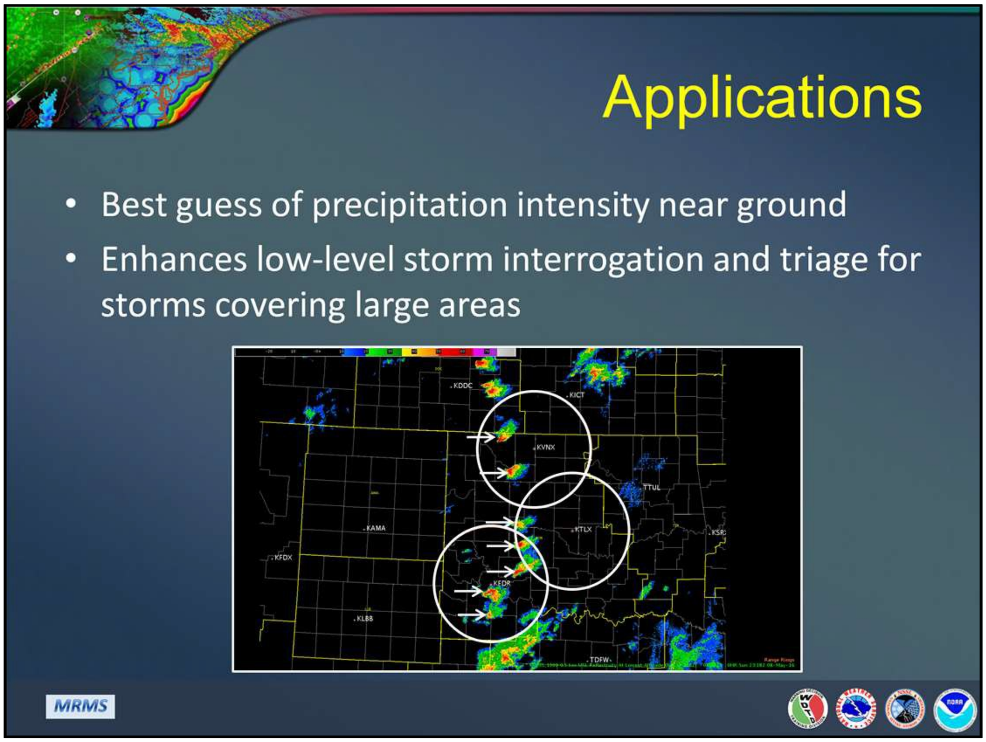
The Reflectivity At Lowest Altitude (RALA) is derived from the 3D Reflectivity Cube by finding the reflectivity at the lowest altitude for each grid box not influenced by terrain. The spatial resolution is 1 km x 1 km and is updated every 2 minutes.



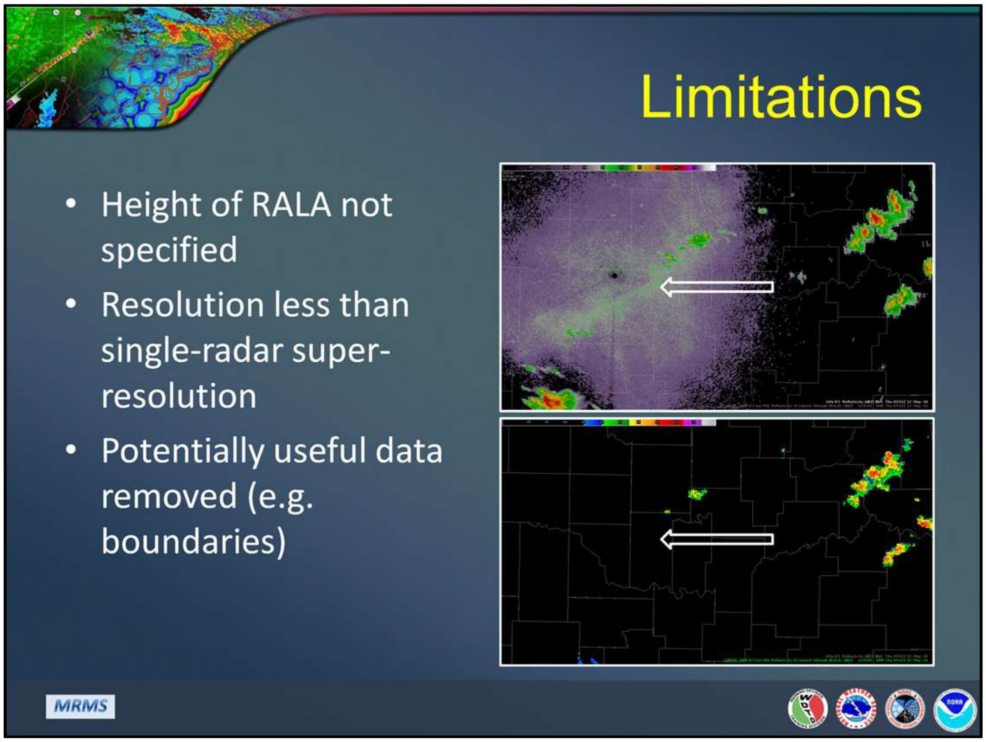
The RALA data can be found within the MRMS menu located within the CAVE display.



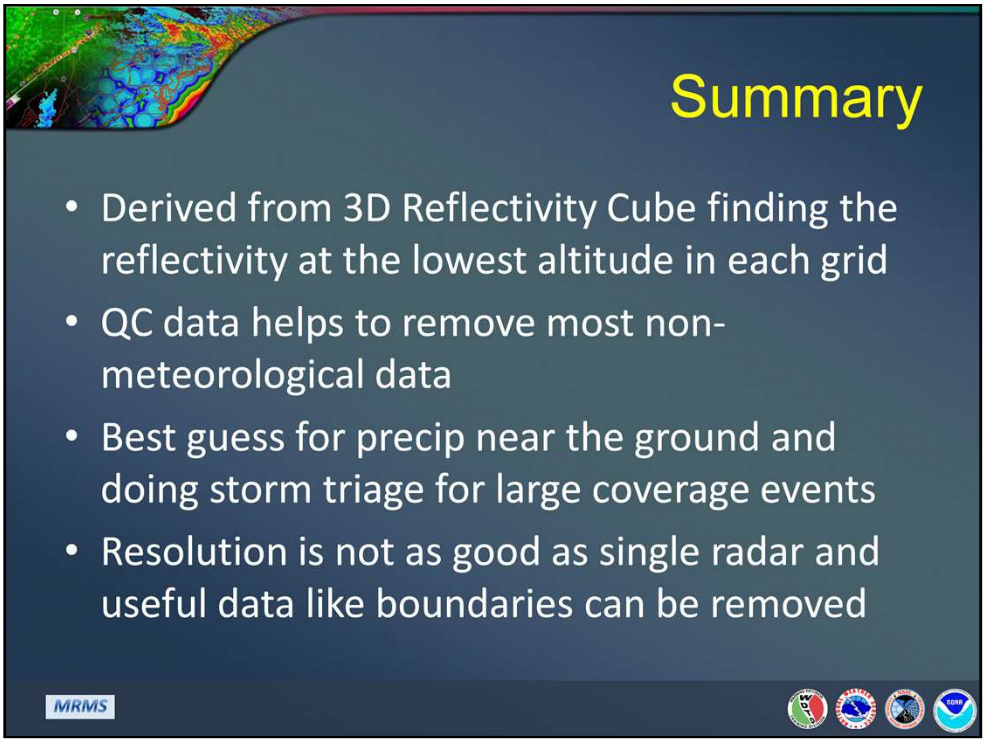
The QC algorithm was developed to help reduce any contamination by non-meteorological echoes in the 3D Reflectivity Cube. Therefore, the QC algorithm should eliminate most the non-meteorological echoes from appearing in RALA. Here is an example from KILN. Notice remnants of the radar bloom as convection is approaching. In the MRMS RALA product, the radar bloom echoes are gone. All of the general strengths of MRMS over single radar analysis still apply (e.g. mitigation of cone of silence).



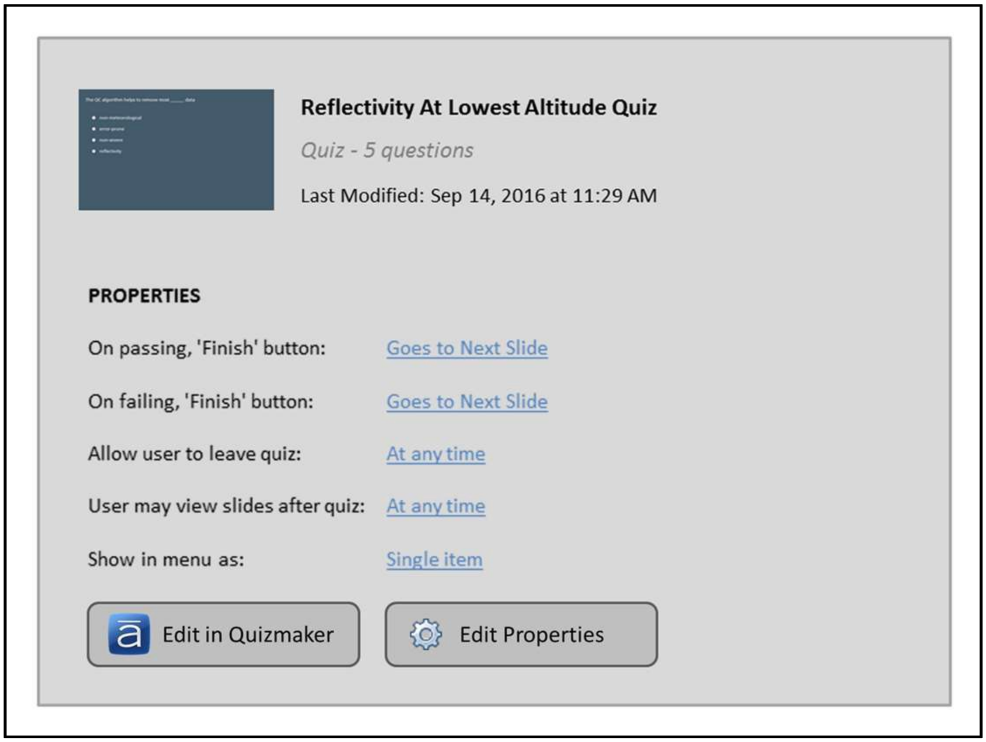
RALA is best used as a first guess at the precipitation intensity near the ground. You can also use RALA to do a storm triage for areas experiencing wide spread coverage of storms. In this example, there are seven different storms spanning the entire CWA from north to south. I've plotted the three different WSR-88Ds available in this CWA and drawn a 60 nm range ring around each one. Notice how each of these storms fall within the 60 nm range ring of different radars. In order to determine which storm you should focus on first using just single radar analysis, you'd need to load up base reflectivity for each radar and switch between the three and mentally keep track of which storm was strongest. With RALA, you can quickly do this screening and ranking process with one product, which can save you valuable time.



The drawbacks to RALA are the height of the RALA is not specified. For the most part, it should be near the ground, but in areas of hilly terrain, it might be higher up. Since the spatial resolution is 1 km x 1 km, the RALA will not show as much detail as single-radar super-resolution reflectivity. This will have the highest impacts in operations when dealing with high-end severe storms. Finally, because some non-meteorological echoes are useful (e.g. boundaries), but the QC algorithm remove most non-meteorological echoes, these features usually never show up in RALA. Here is an example where the radar reflectivity fine line is clearly evident in the single radar display, but MRMS has completely removed it.



In summary, the RALA product is derived from the 3D reflectivity cube by finding the reflectivity at the lowest altitude in each grid box accounting for terrain. The QC algorithm helps to remove most of the non-meteorological data. RALA is best used for getting a good first guess at the precipitation intensity nearest the ground. It is also great for storm triage during events that have a large coverage of storms. Be careful though when using RALA. Remember it is lower resolution than single radar super resolution, so some fine-scale features might be easily overlooked, and useful non-meteorological data like boundaries may be removed. Now, you are ready to take the quiz for this lesson.


Reflectivity At Lowest Altitude Quiz
Quiz - 5 questions
Last Modified: Sep 14, 2016 at 11:29 AM
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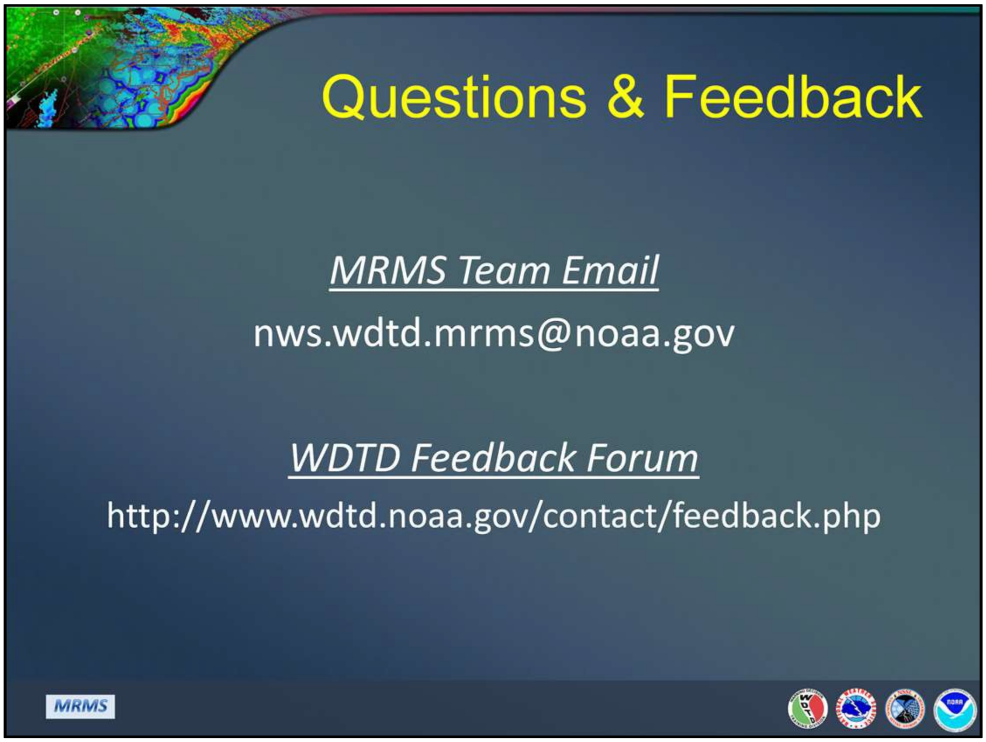
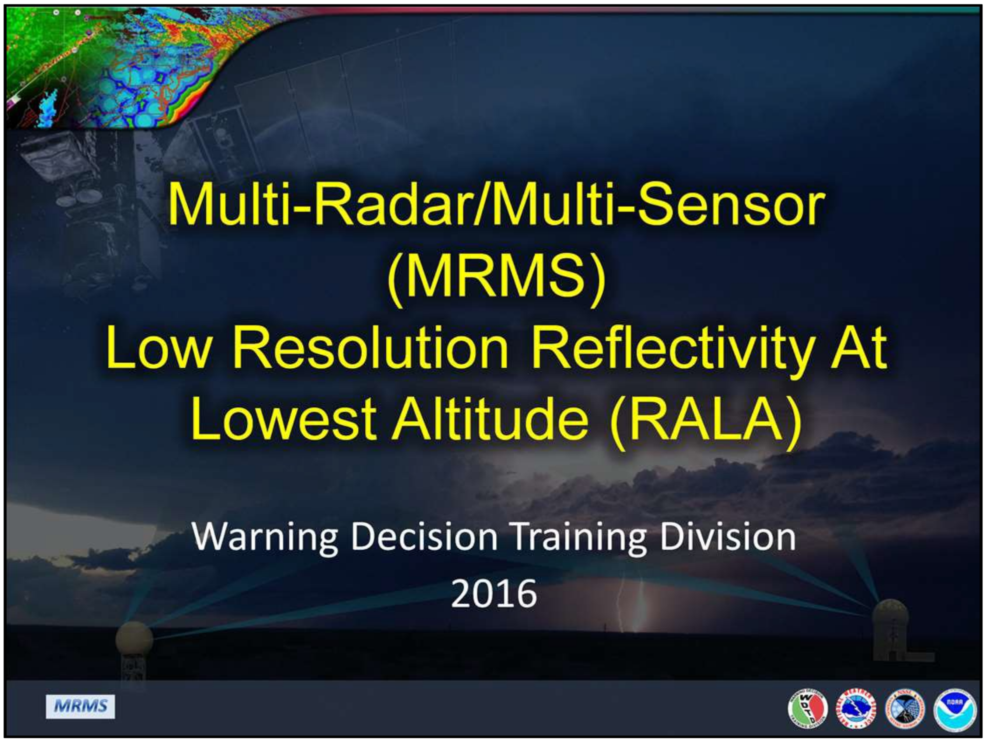
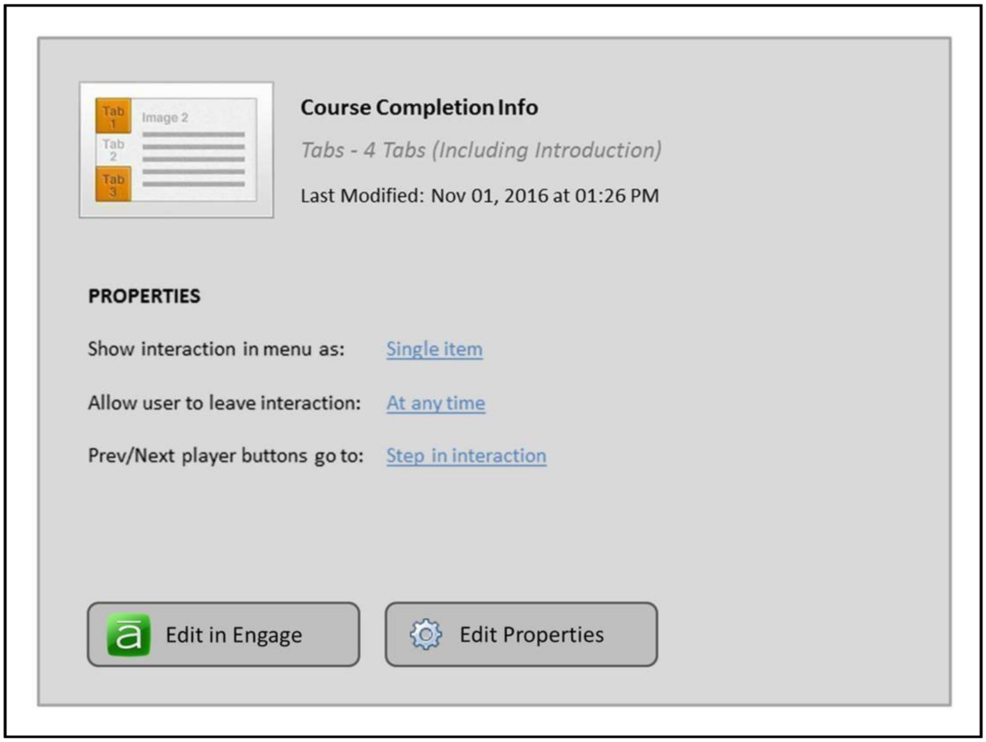


Thanks for completing this module on Reflectivity At Lowest Altitude (RALA). If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Low Resolution Reflectivity At Lowest Altitude (Low Res RALA) developed at the Warning Decision Training Division (WDTD).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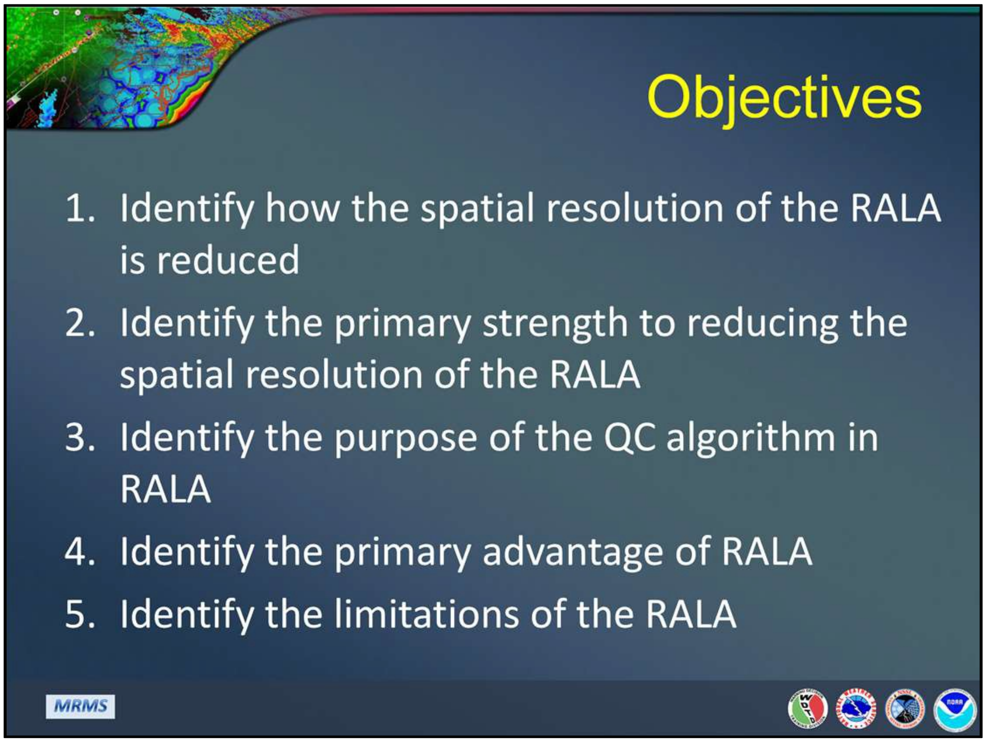
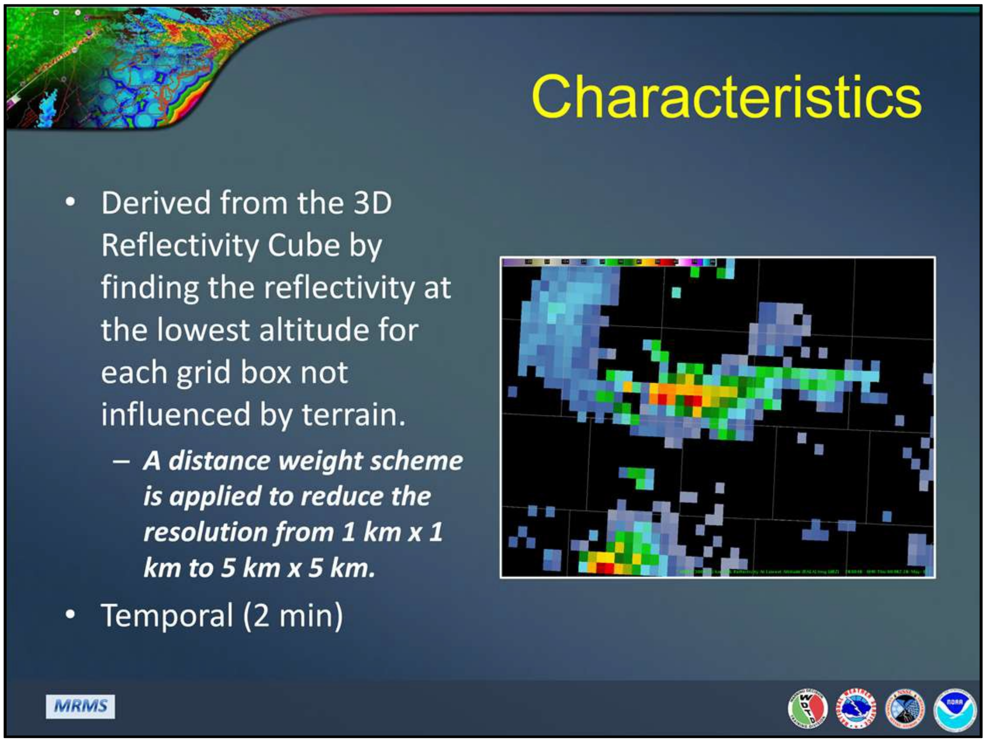
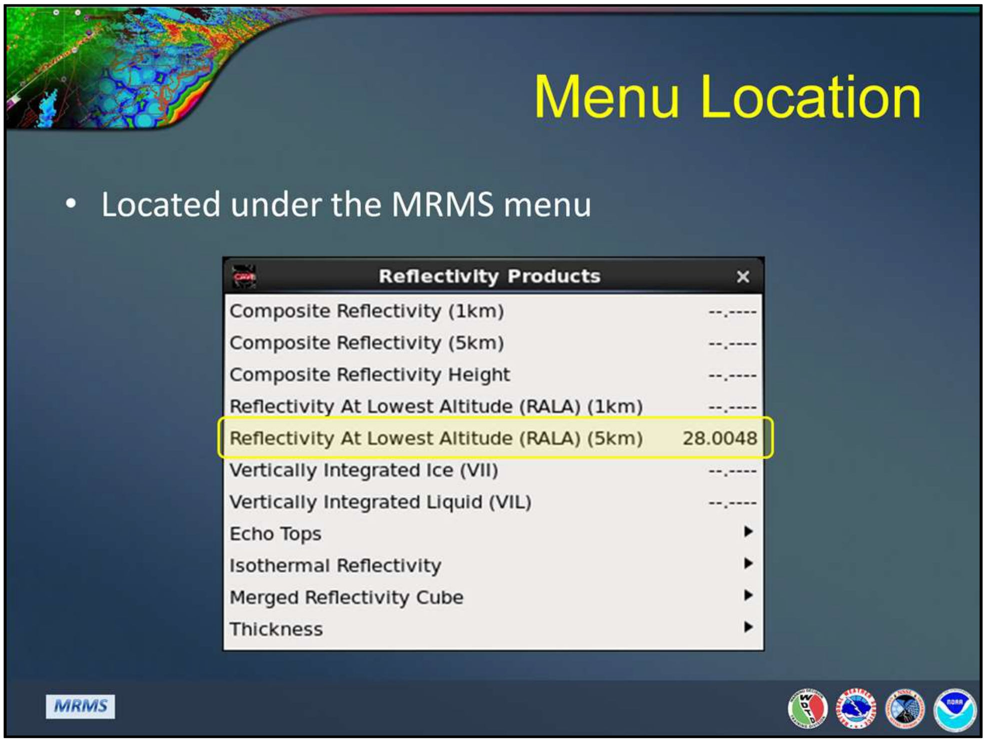


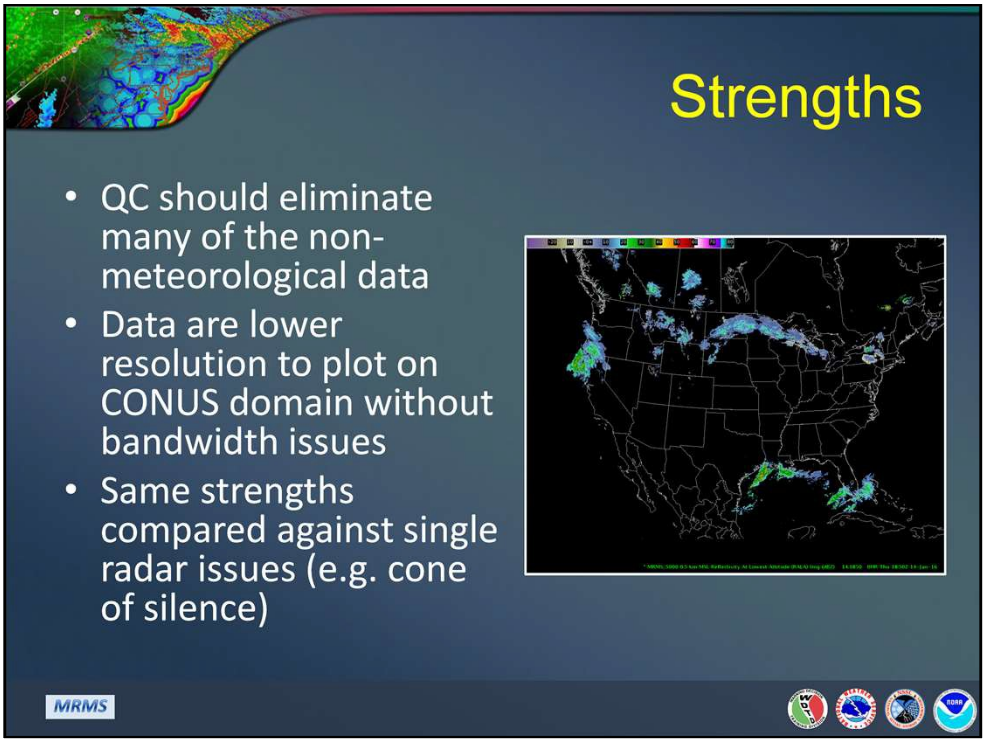
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. The quiz at the end of this lesson will be based on these objectives.



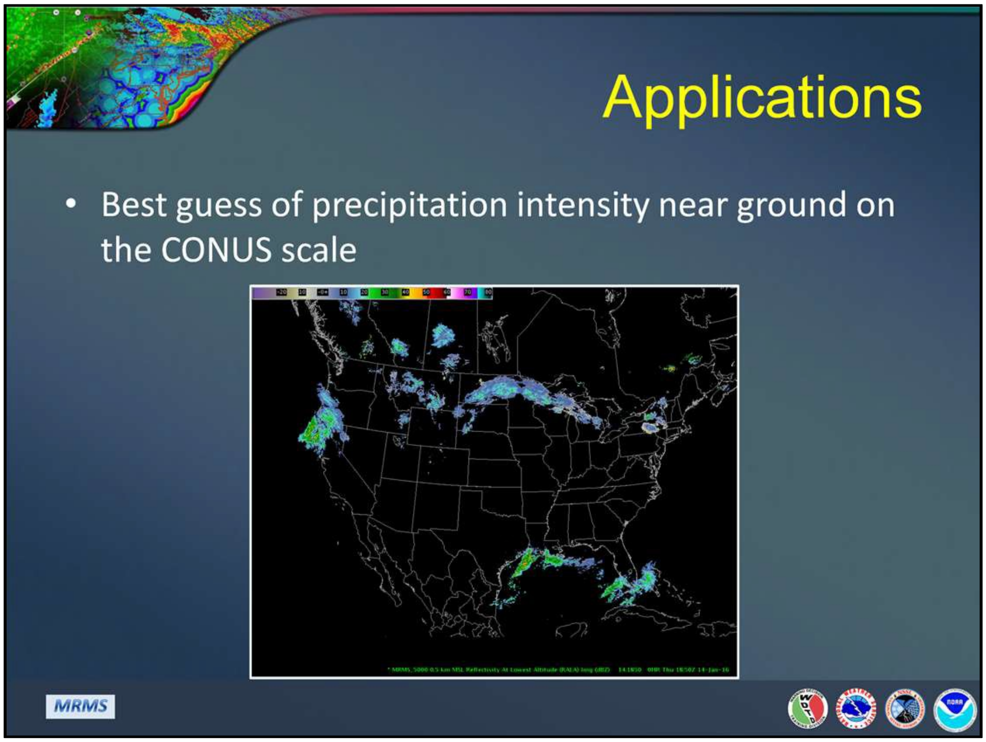
The Low Resolution Reflectivity At Lowest Altitude (RALA) is derived from the 3D Reflectivity Cube by finding the reflectivity at the lowest altitude for each grid box not influenced by terrain. A distance weighting scheme is then applied to reduce the resolution from 1 km x 1 km to 5 km x 5 km. The product is updated every 2 minutes.



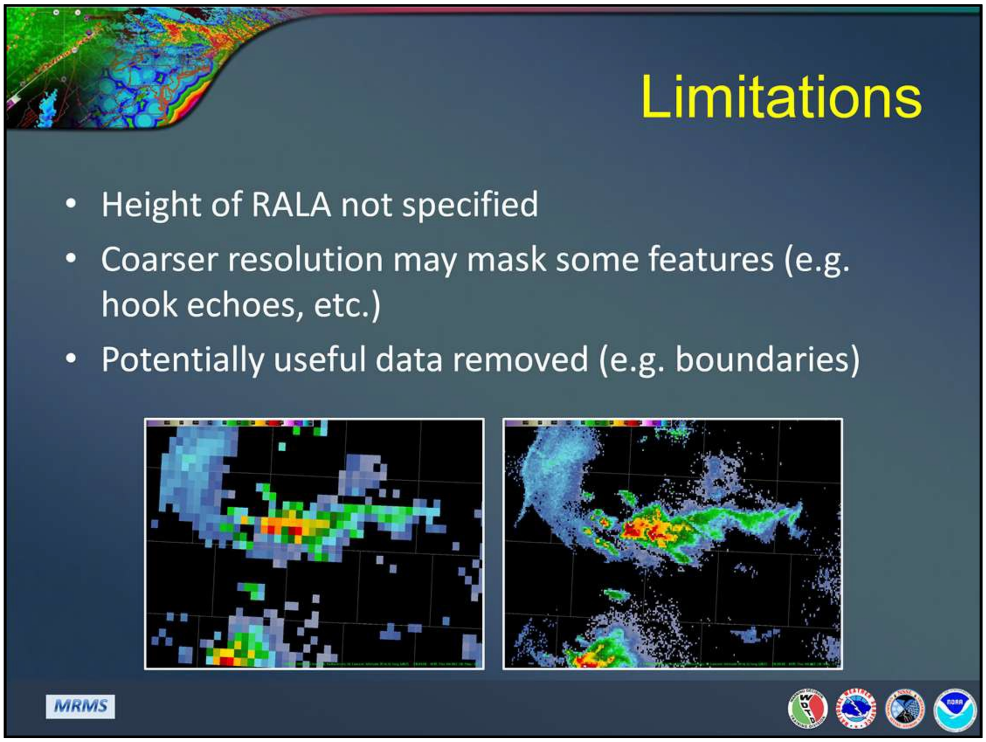
The Low Resolution RALA data can be found within the MRMS menu located within CAVE toolbar.



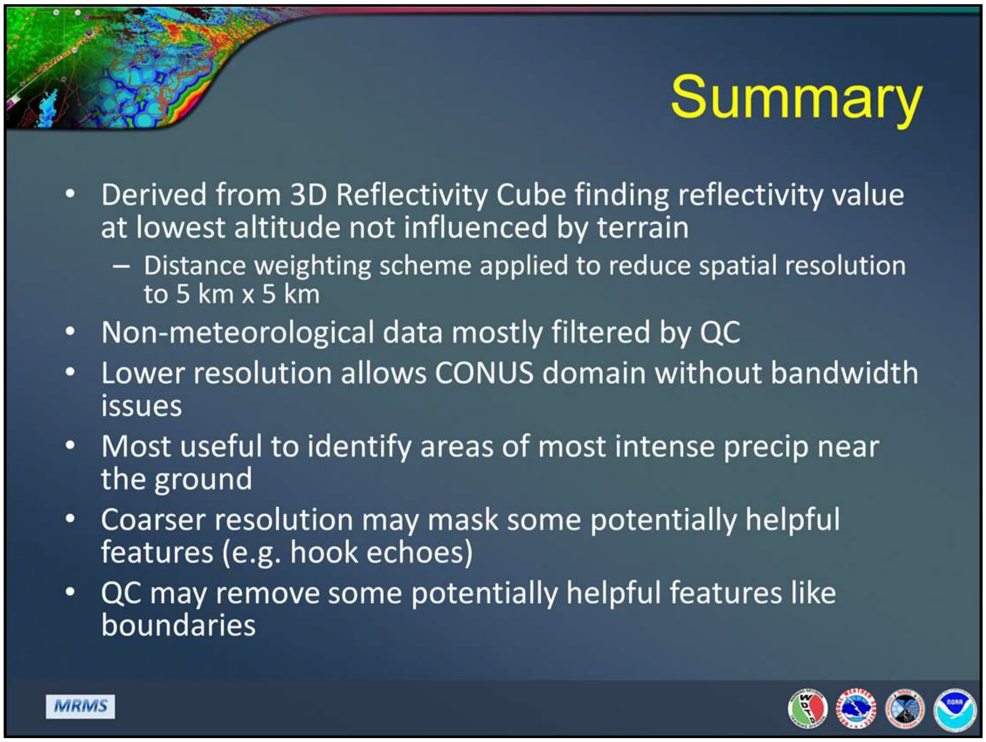
The QC algorithm should eliminate many of the non-meteorological data from contaminating this product. Since the data are lower resolution, this allows for a CONUS domain without compromising bandwidth. Finally, the same general strengths of MRMS over single radar analysis still apply (e.g. mitigation of cone of silence).



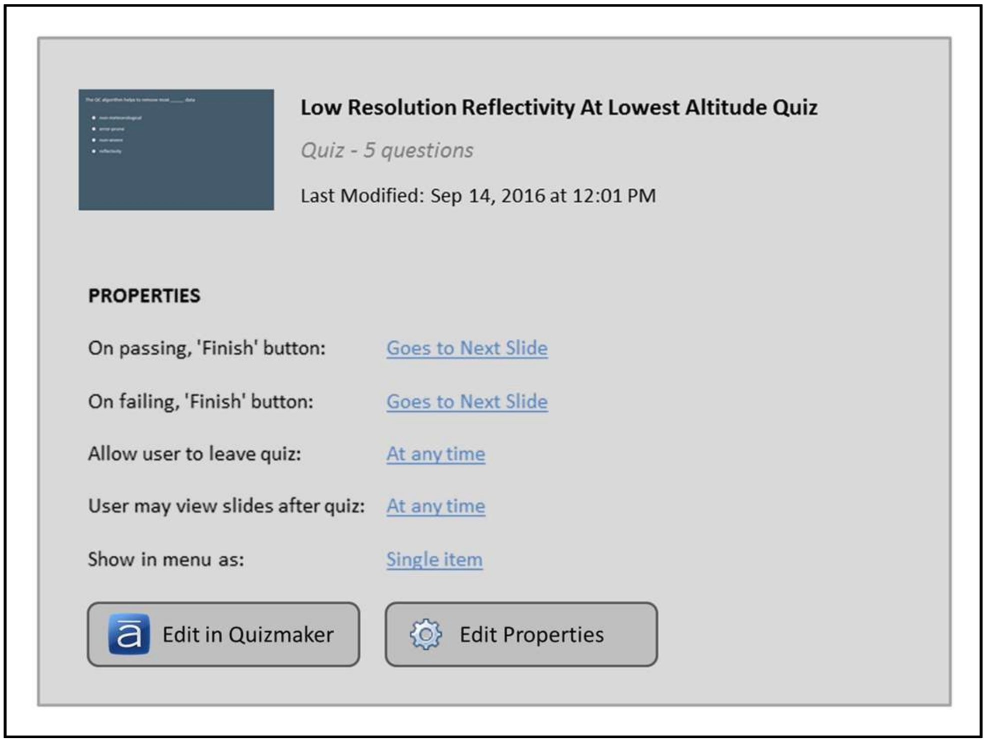
The primary application of the low resolution RALA is to provide a best guess for the precipitation intensity near the ground on the CONUS scale. At any other smaller scale, the 5 km resolution is just too coarse for any useful information.



The height of the low resolution RALA is not specified, but this limitation should not be to limiting because for the most part, the height should be fairly close to the ground except maybe in areas of hilly terrain. The coarser resolution may mask some important features (e.g. hook echoes, inflow notches). Here is an example of the 5 km product versus the 1 km product. You can definitely see the loss in detail in the 5 km product. Finally, because of the QC algorithm, potentially useful data are removed such as boundaries.



In summary, the low resolution RALA is derived from the High Resolution RALA by applying a distance weighting scheme to reduce the resolution down from 1 km x 1 km to 5 km x 5 km. Most of the non-meteorological data is filtered out by the QC algorithm, and the lower resolution allows for a CONUS level domain without affecting bandwidth. The primary application of the low resolution RALA is to identify areas of most intense precipitation near the ground. Some things to watch out for is the coarser resolution may mask some potentially useful features like a hook echo, and QC may remove some potentially useful signals like boundaries. Now you are ready for the quiz!


Low Resolution Reflectivity At Lowest Altitude Quiz
Quiz - 5 questions
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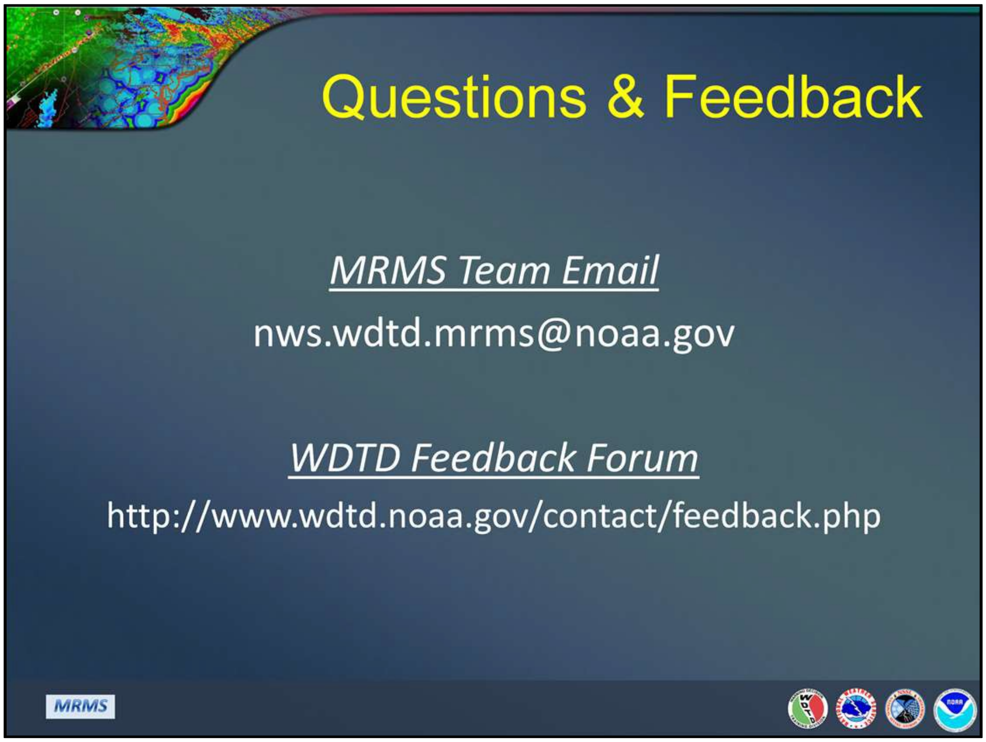
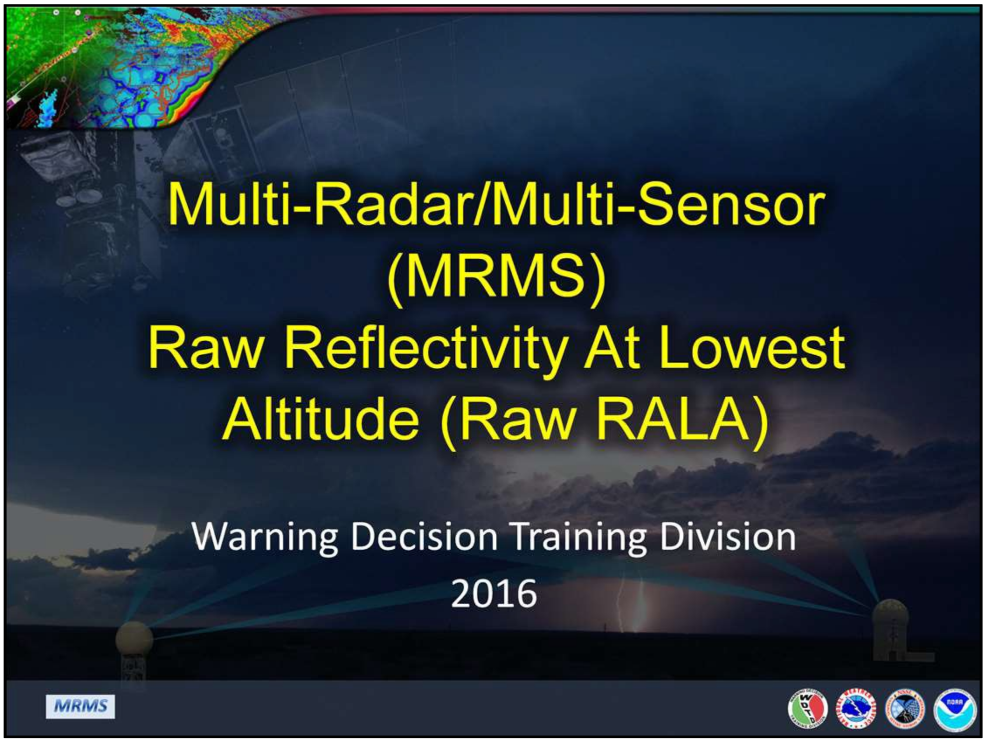
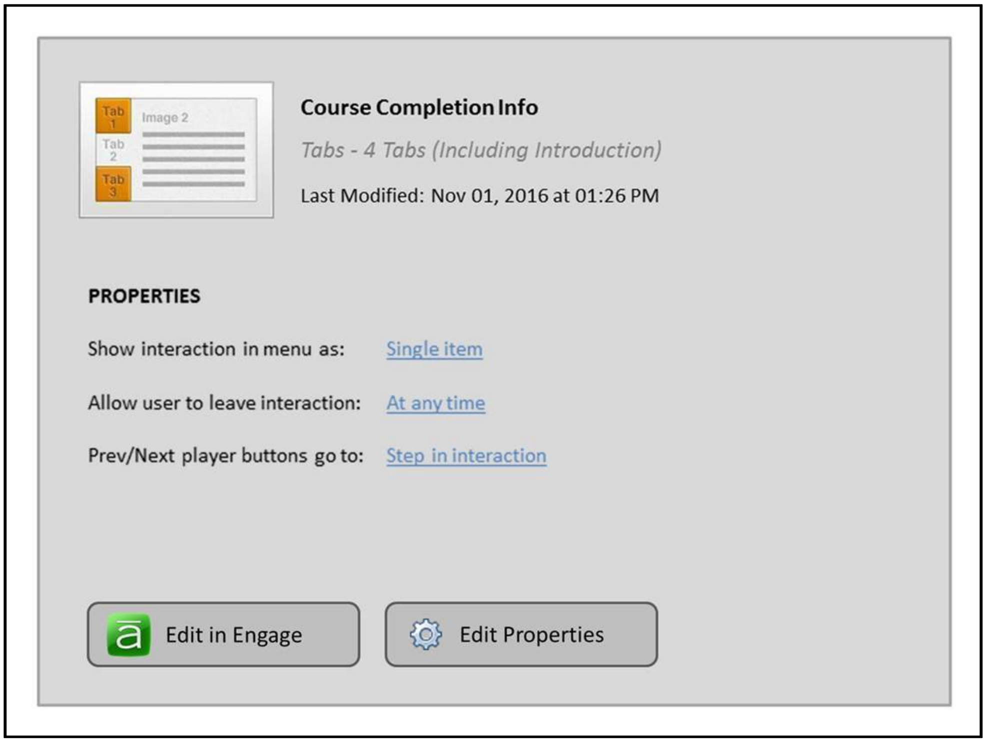


Thanks for completing this module on Low Resolution Reflectivity At Lowest Altitude (RALA). If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Raw Reflectivity At Lowest Altitude (Raw RALA) developed at the Warning Decision Training Division (WDTD).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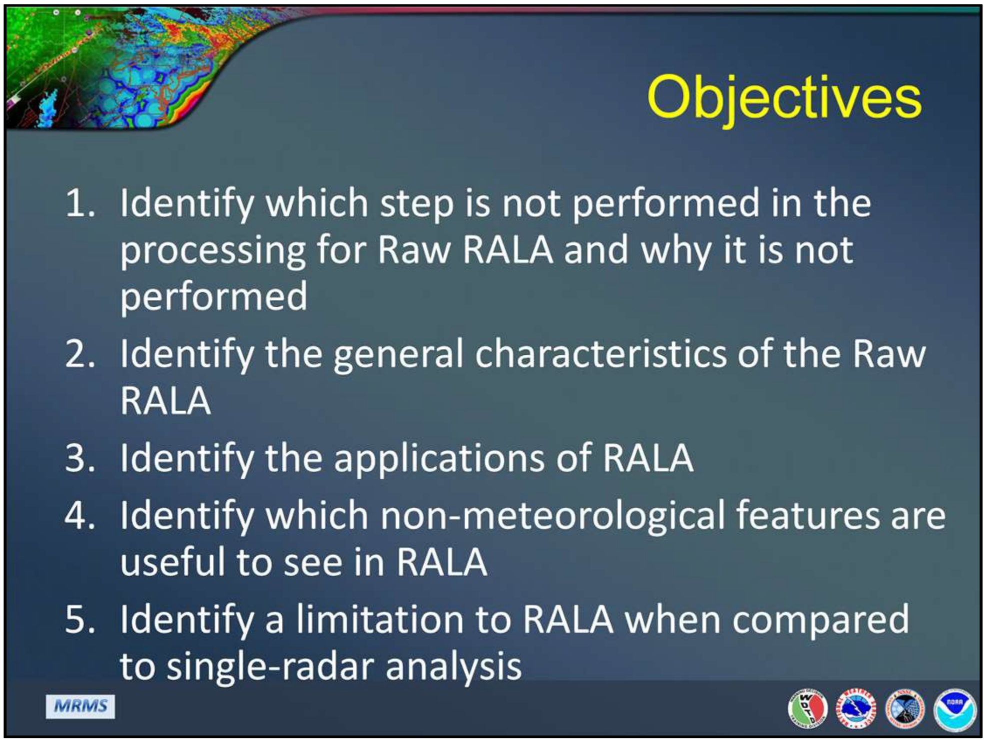
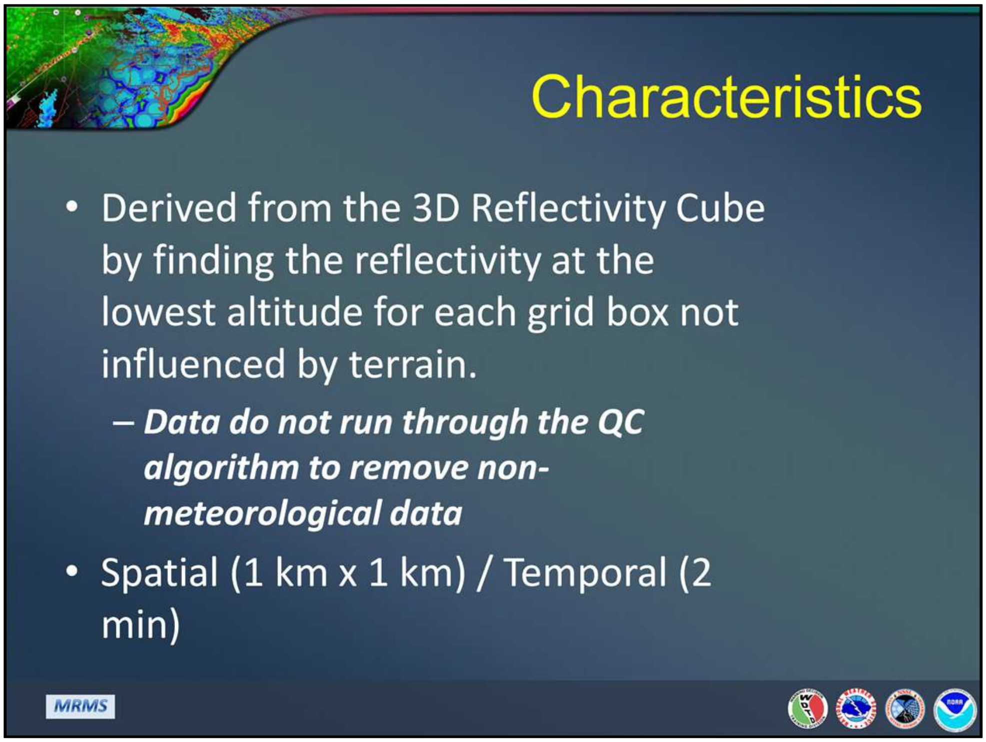
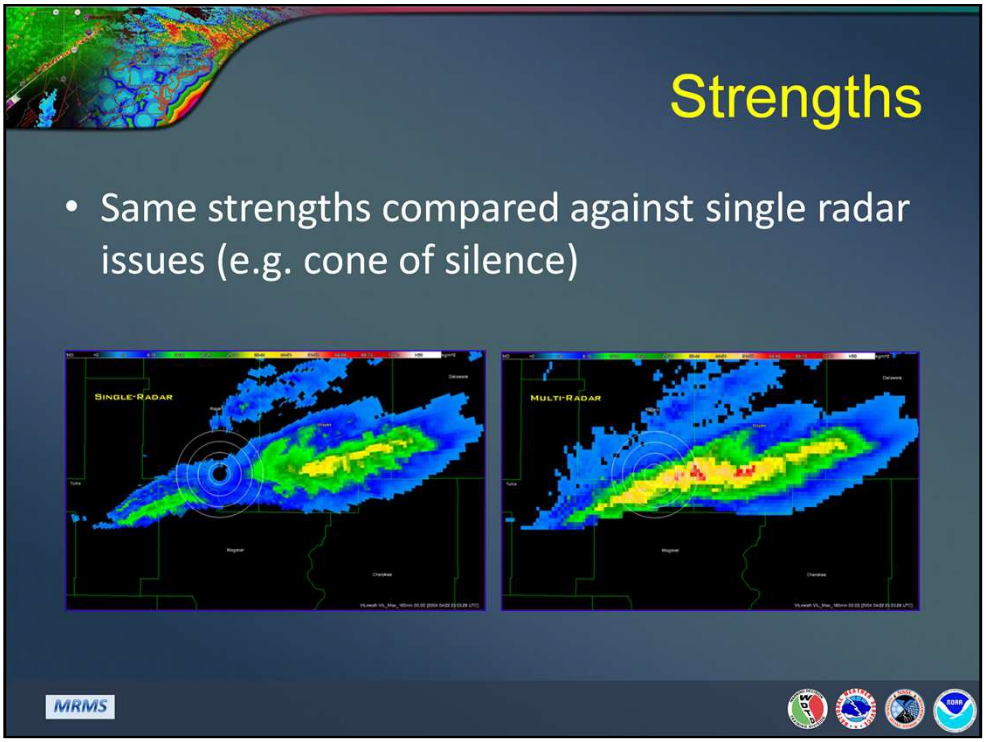


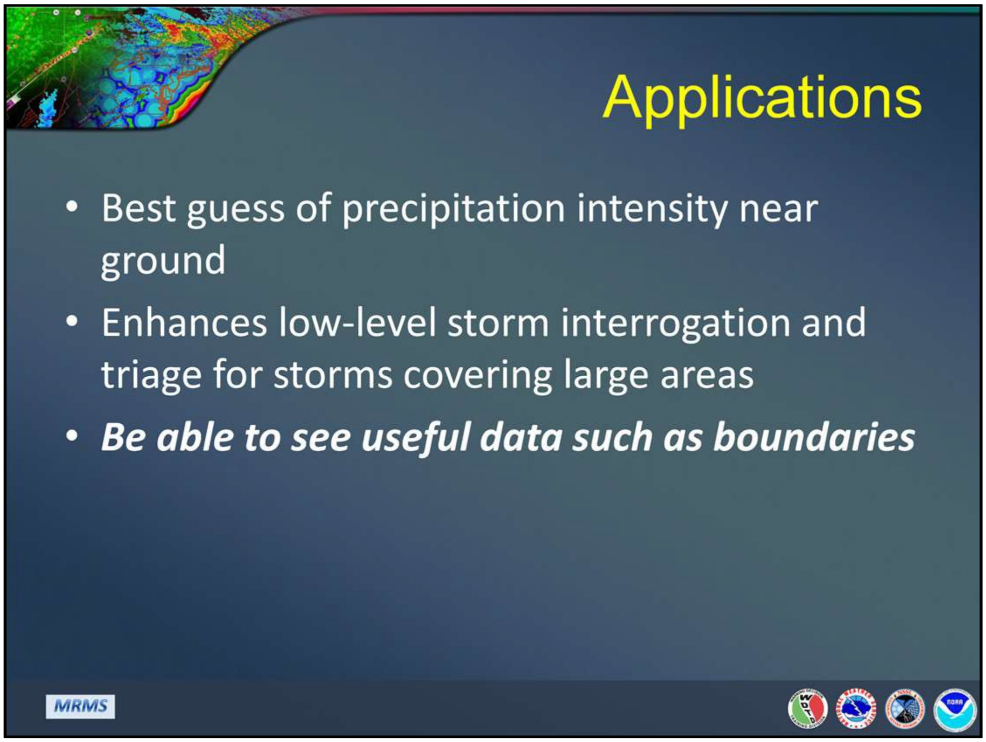
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. The quiz at the end of this lesson are based on these objectives.



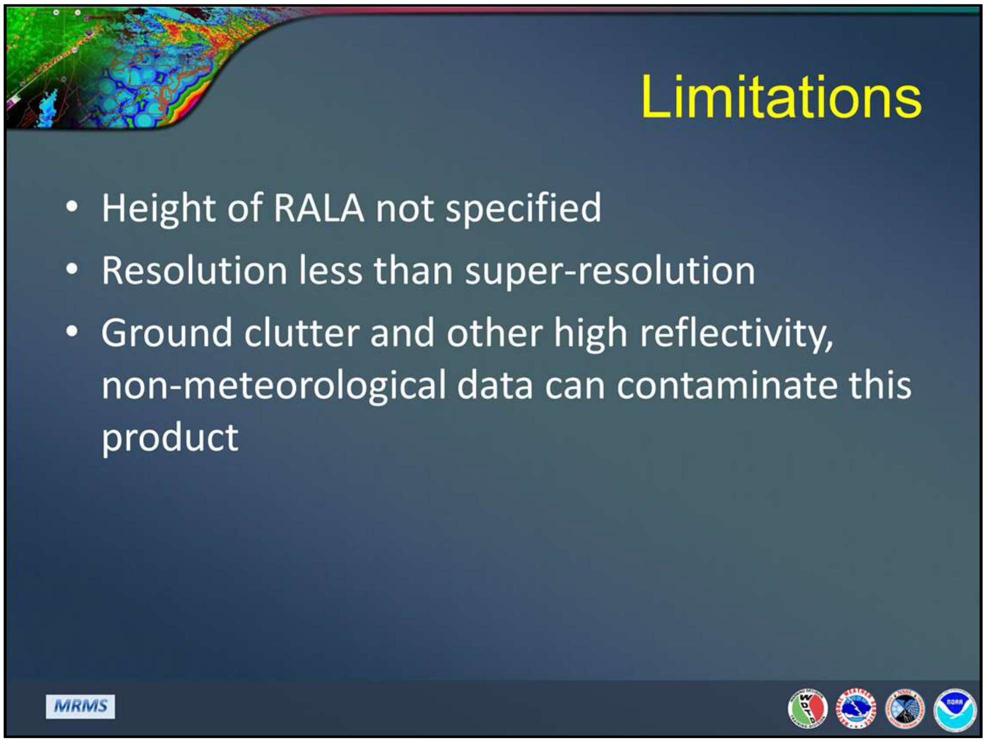
The Raw Reflectivity At Lowest Altitude (RALA) is derived from the 3D Reflectivity Cube by finding the reflectivity at the lowest altitude for each grid box not influence by terrain. Additionally, there is no QC algorithm run on this data to remove the non-meteorological data. The spatial resolution is 1 km x 1 km and is updated every 2 minutes.



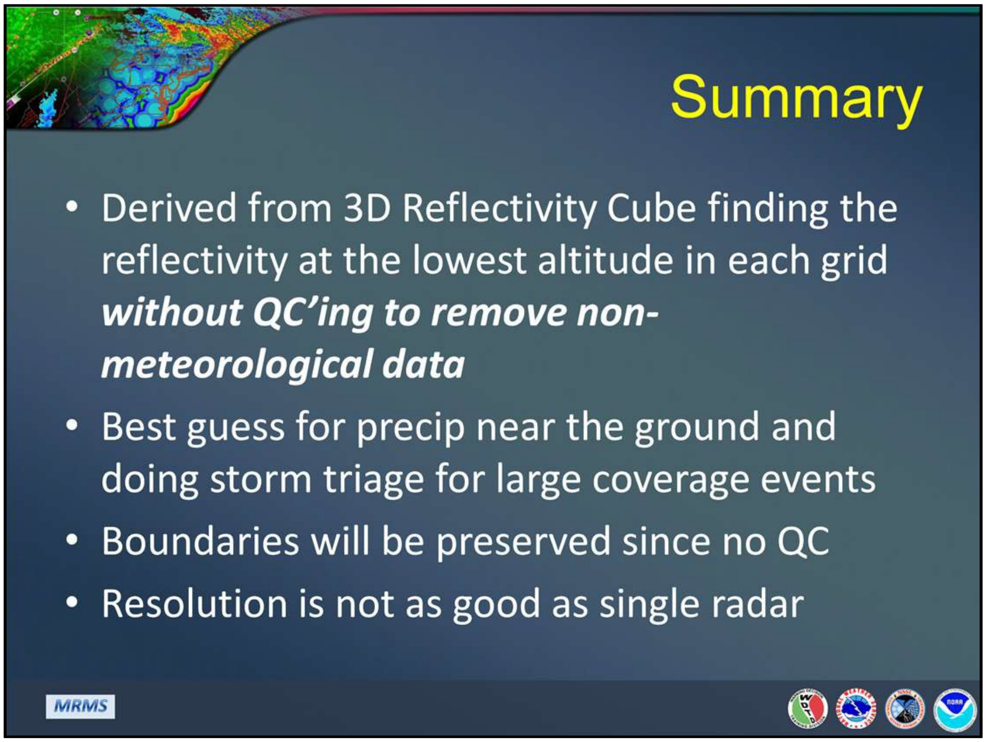
All of the general strengths of MRMS over single radar analysis still apply (e.g. mitigation of cone of silence).



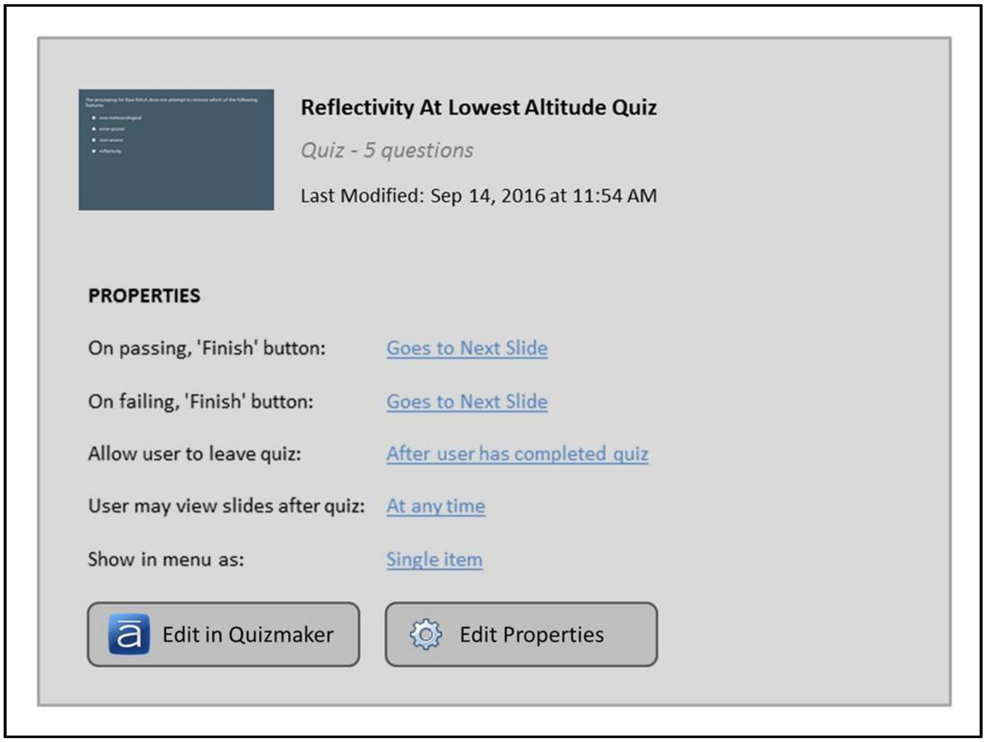
Raw RALA is best used as a first guess at the precipitation intensity near the ground. You can also use Raw RALA to do a storm triage for areas experiencing wide spread coverage of storms. Additionally, since non-meteorological data are not filtered in this product, useful signatures like boundaries should appear in Raw RALA.



The drawbacks to Raw RALA are the height of the Raw RALA is not specified. For the most part, it should be near the ground, but in areas of hilly terrain, it might be higher up. Since the resolution is only 1 km x 1 km, the Raw RALA will still not show as much detail as single-radar super-resolution reflectivity. Finally, be careful of ground clutter and other high reflectivity contamination from non-meteorological data since the QC algorithm is not performed on the data.



In summary, the Raw RALA is derived from the reflectivity cube by finding the reflectivity at the lowest altitude in each grid box without using the QC algorithm to remove most of the non-meteorological data. Raw RALA is best used for getting a good first guess at the precipitation intensity nearest the ground. It is also great for storm triage during events that have a large coverage of storms. Because of the lack of removing non-meteorological data, some useful features like boundaries will be preserved. Be careful though when using RALA. Remember it is lower resolution than single radar super resolution, so some fine-scale features might be easily overlooked.


Reflectivity At Lowest Altitude Quiz
Quiz - 5 questions
Last Modified: Sep 14, 2016 at 11:54 AM
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On failing, 'Finish' button:
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After user has completed quiz
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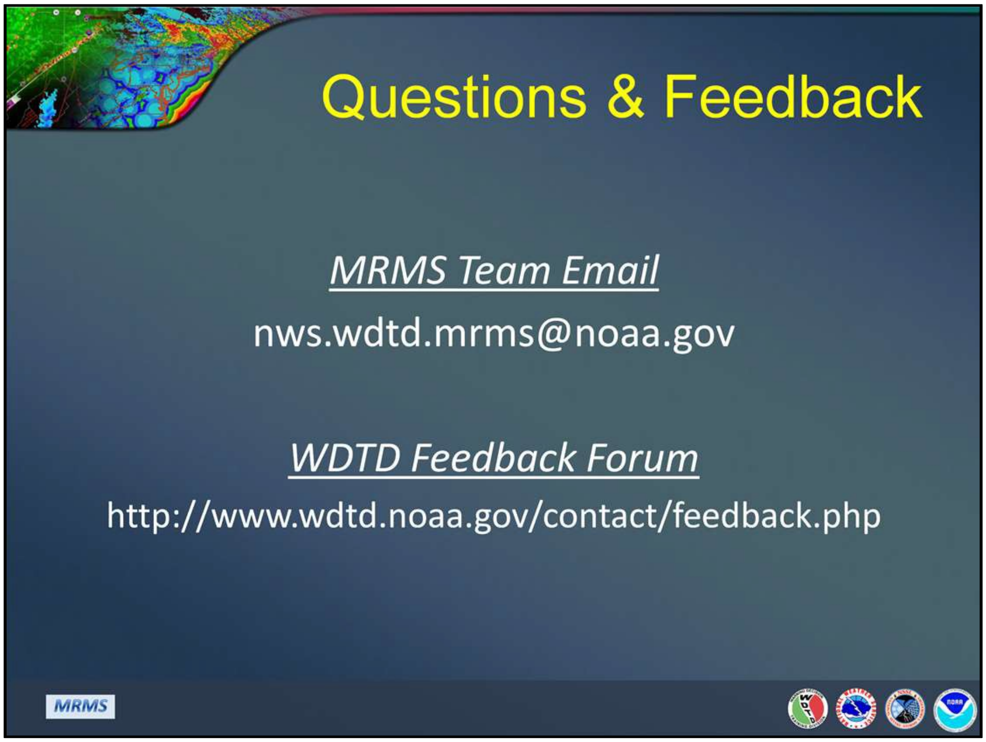
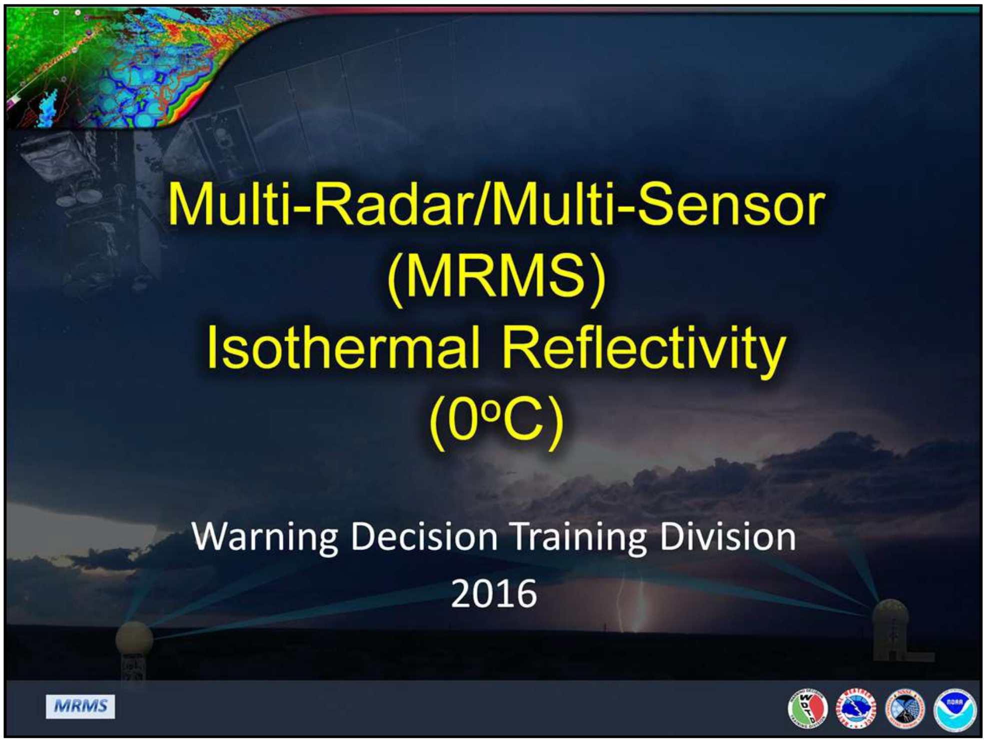
Edit Properties



Thanks for completing this module on Raw Reflectivity At Lowest Altitude (RALA). If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Isothermal Reflectivity (0°C) developed at the Warning Decision Training Division (WDTD).

Course Completion Info

Tabs - 4 Tabs (Including Introduction)

Last Modified: Nov 01, 2016 at 01:26 PM

PROPERTIES

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Prev/Next player buttons go to: Step in interaction

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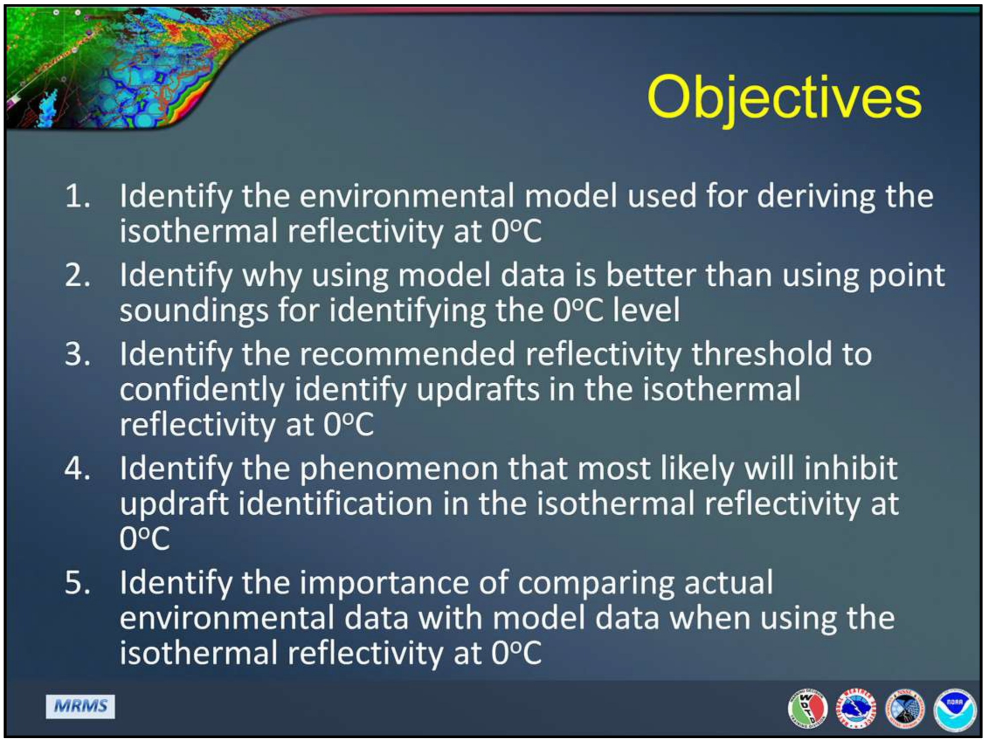
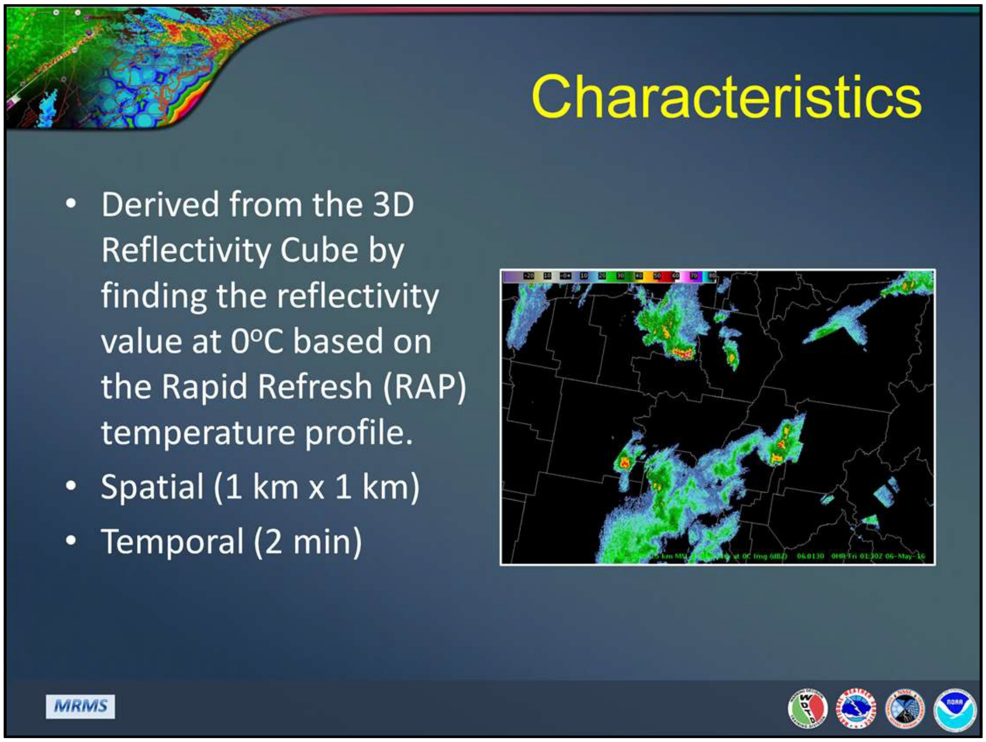
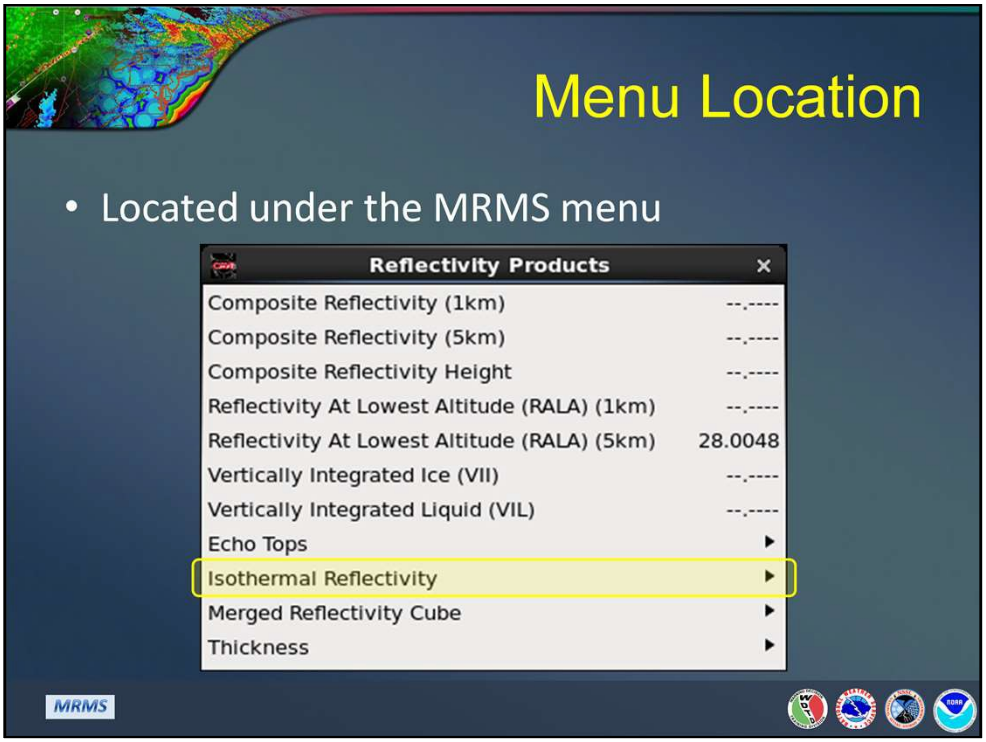
Edit Properties



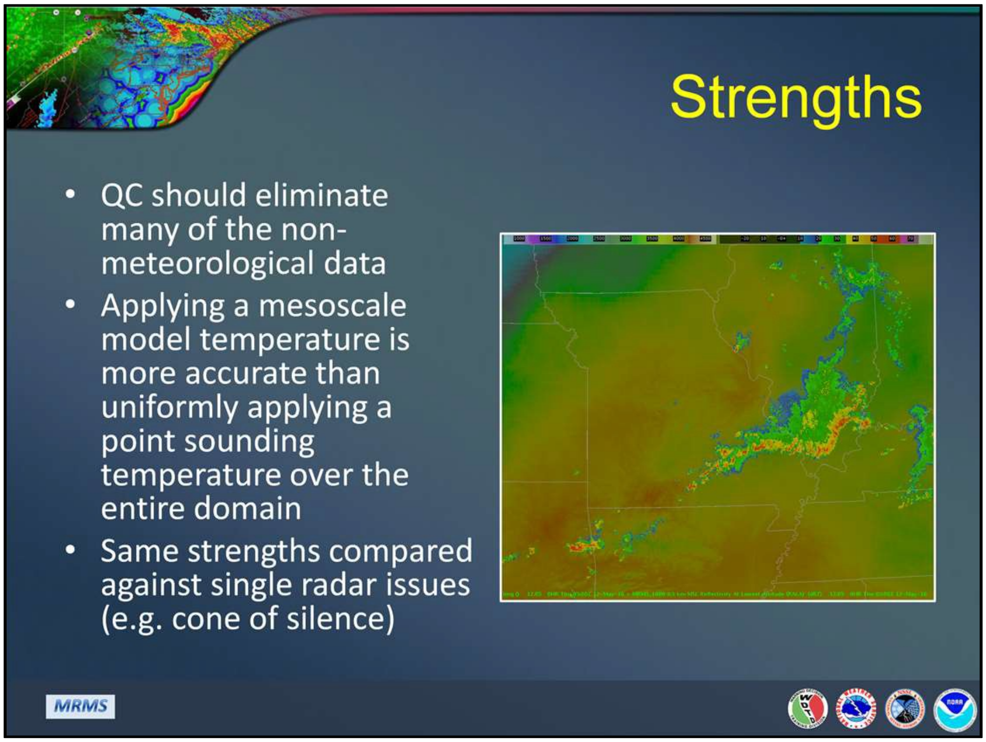
Here are the objectives for this lesson. Please take a minute to review them before moving on to the next slide. You will be quizzed on these objectives at the end of this lesson.



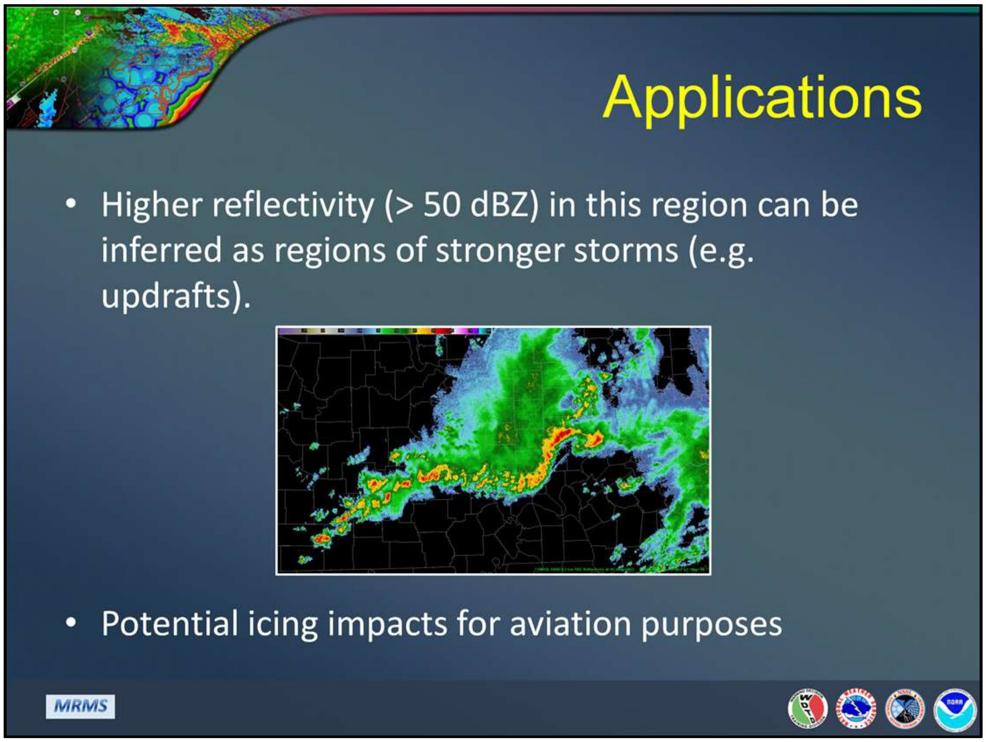
The isothermal reflectivity product at 0°C is derived from the 3D reflectivity cube by finding the reflectivity value within the cube that resides at 0°C based on the RAP temperature profile. Its spatial resolution is 1 km x 1 km and is updated every 2 minutes.



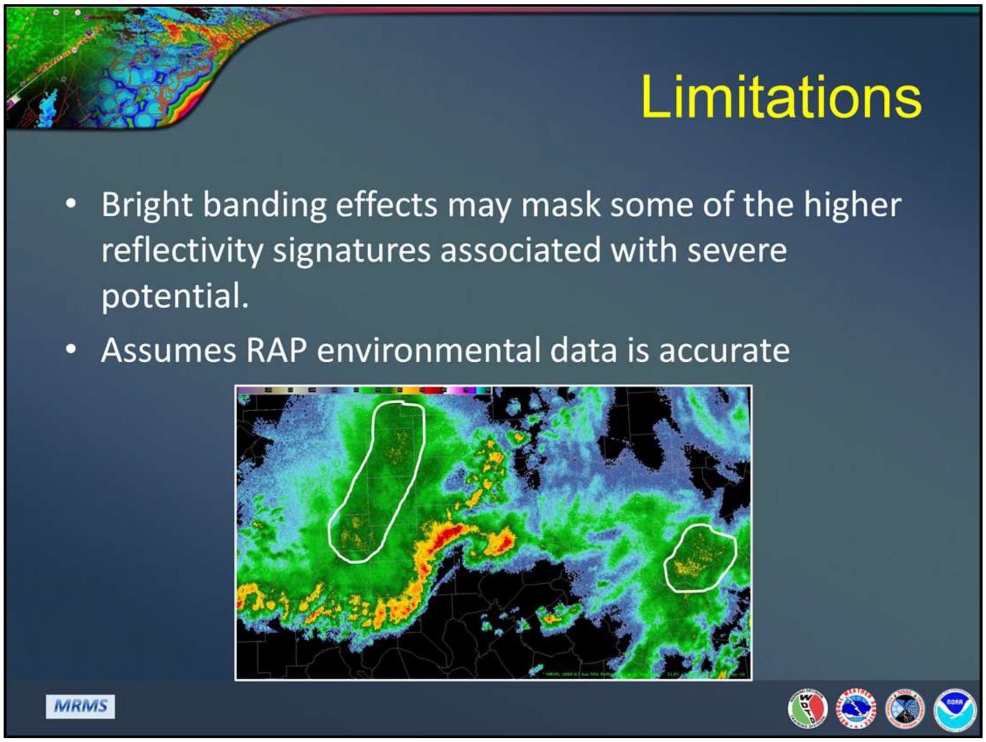
The product can be found within the MRMS menu located in your CAVE toolbar.



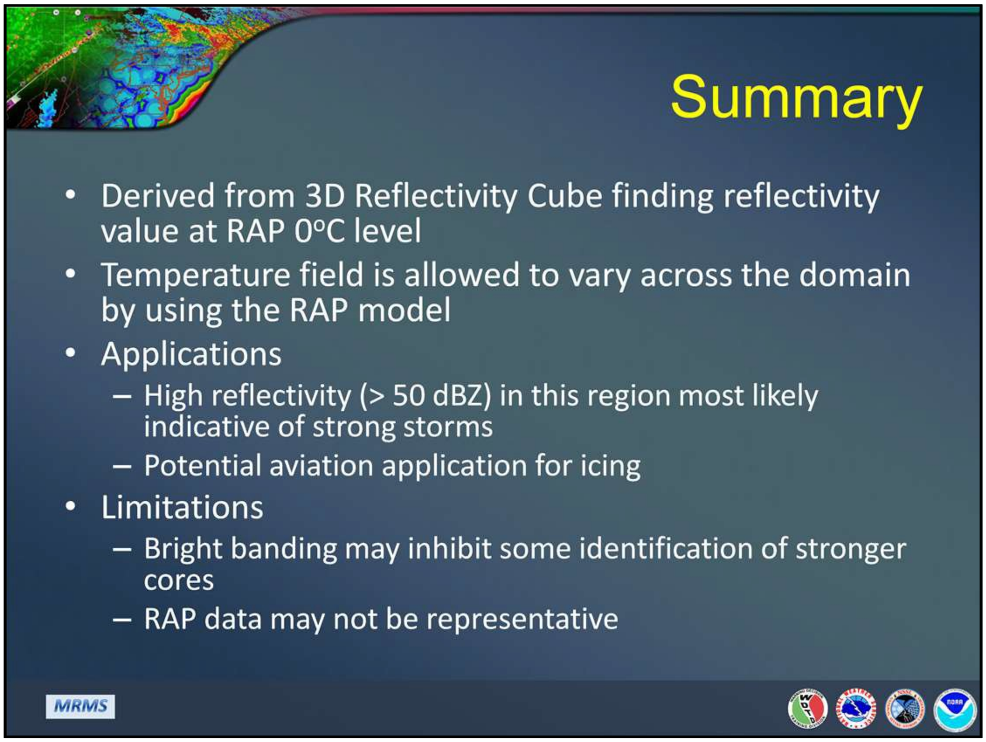
While most non-meteorological data will not contaminate echoes at or above the freezing level, it is still worth noting that non-meteorological data is still filtered out by the QC algorithm. During cold season events when the 0^{o}C level resides near the ground, this will become more important. Because temperature heights are never constant across a particular domain (as is shown here in this example where I have plotted the bright banding height across the MRMS domain), applying a mesoscale temperature field instead of uniformly applying a point sounding results in more accurate interpretations. Notice how the bright banding heights vary by as much as 1,000 feet. Finally, all strengths associated with MRMS vs single radar analysis are still valid (e.g. mitigating cone of silence).



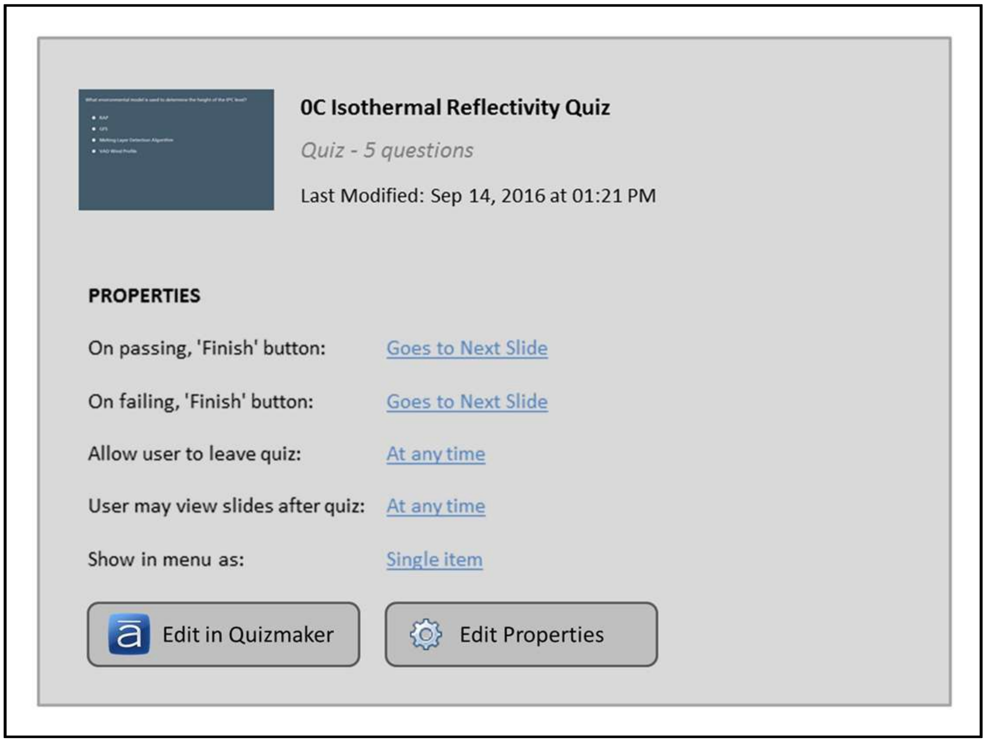
Higher reflectivity cores, typically greater than 50 dBZ, in this temperature level can be inferred as regions of stronger storms due to updrafts being able to loft larger rain drops above the environmental freezing level. In this example, we see a broken line of intense reflectivity. Each core above 50 dBZ is likely an area of updraft along this line of storms. Another application might be the potential icing impacts for aviation during winter-time events.



Because the 0^{o}C level is where bright banding occurs, be careful interpreting large reflectivity regions as updrafts. Typically, bright banding only increases Z to around 45-50 dBZ. Therefore, any values above this level are more likely to be updraft driven rather than bright band driven. Here's an example where two broad regions of reflectivity are approaching 50 dBZ, but they are behind lines of stronger reflectivity in the stratiform region. Another limitation to be aware of is the RAP data may not be representative of the actual environment. This could lead to some faulty interpretations.



In summary, this isothermal reflectivity product is derived from the 3D Reflectivity Cube by finding the reflectivity value at the 0°C using the RAP model. Using the RAP model allows for temperature to vary across the MRMS domain, whereas using a single point sounding does not allow for this temperature variation. High reflectivity values in this region most likely indicate strong updrafts, and therefore strong storms. Additionally, reflectivity in this temperature range can have potential uses in identifying icing regions for aviation. A couple drawbacks to using this product is bright banding can inhibit the identification of these stronger cores, and the RAP data may not be representative.
Next up is the quiz!


0C Isothermal Reflectivity Quiz
Quiz - 5 questions
Last Modified: Sep 14, 2016 at 01:21 PM
PROPERTIES
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Goes to Next Slide
On failing, 'Finish' button:
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At any time
Show in menu as:
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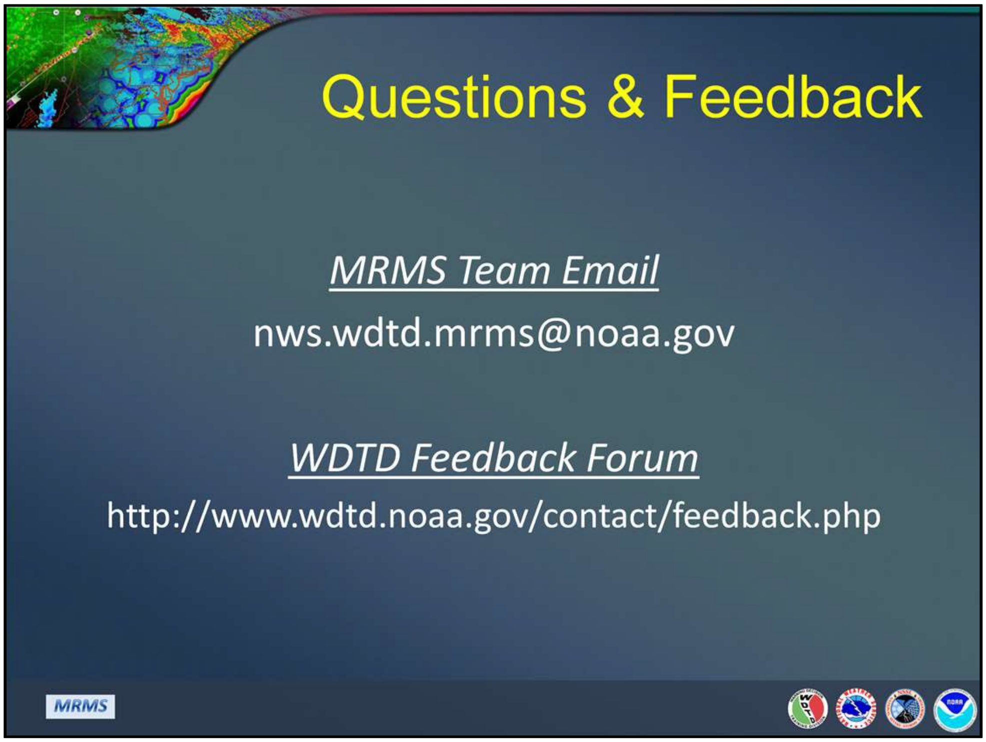
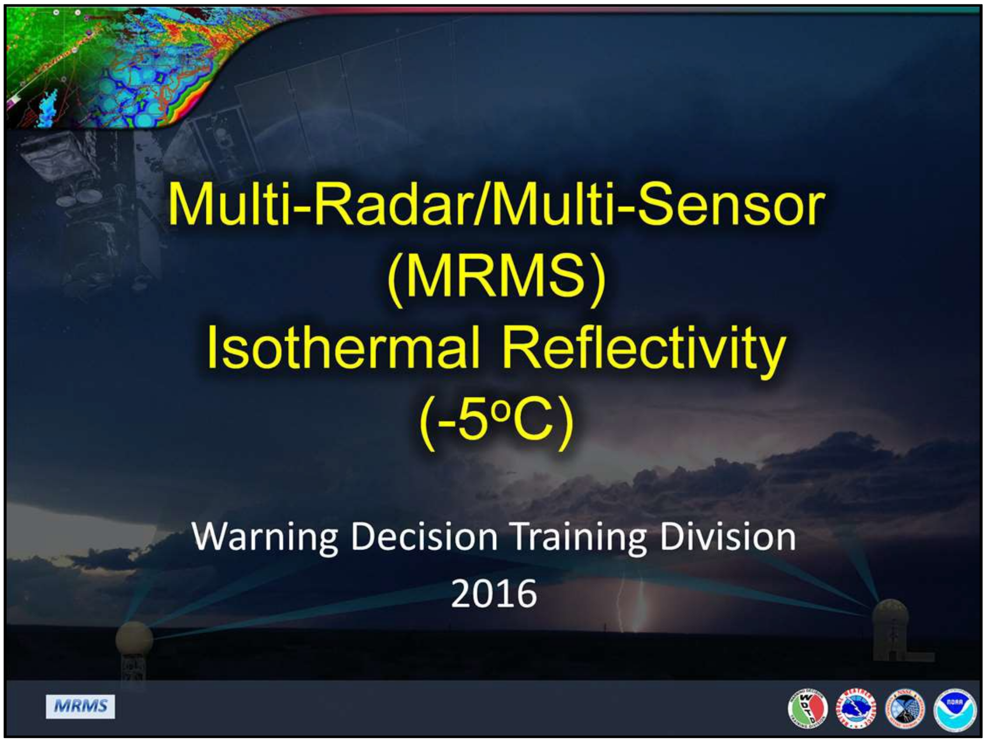
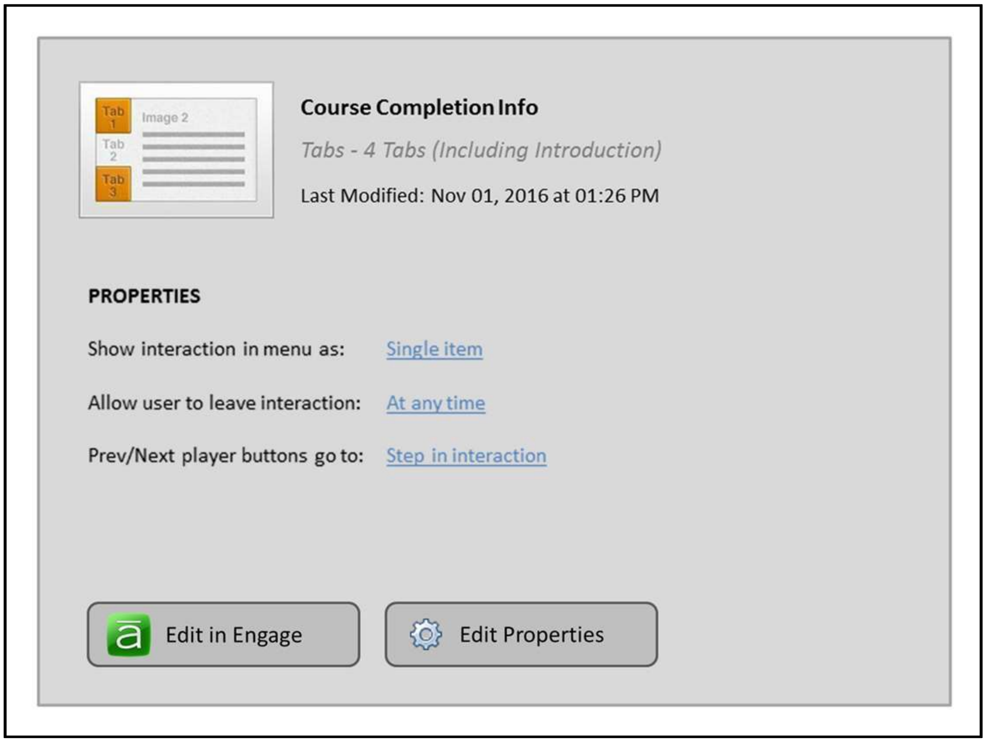
Edit Properties



Thanks for completing this module on Isothermal Reflectivity at 0°C. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Isothermal Reflectivity (-5^{o}C) developed here at the Warning Decision Training Division (WDTD).


Course Completion Info
Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 01, 2016 at 01:26 PM
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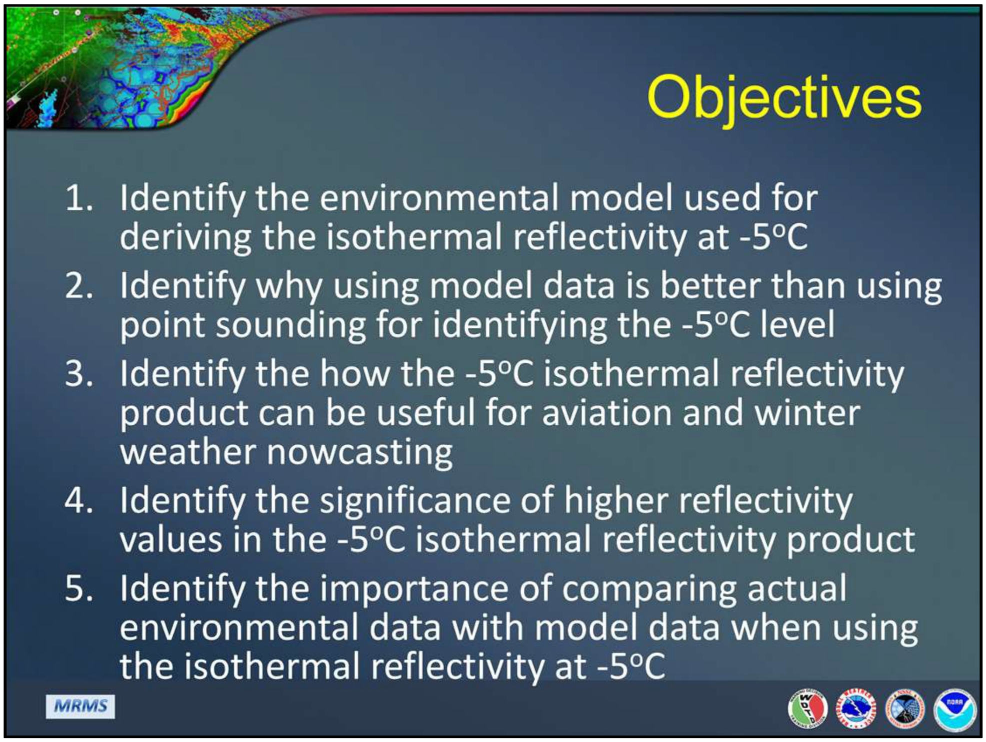
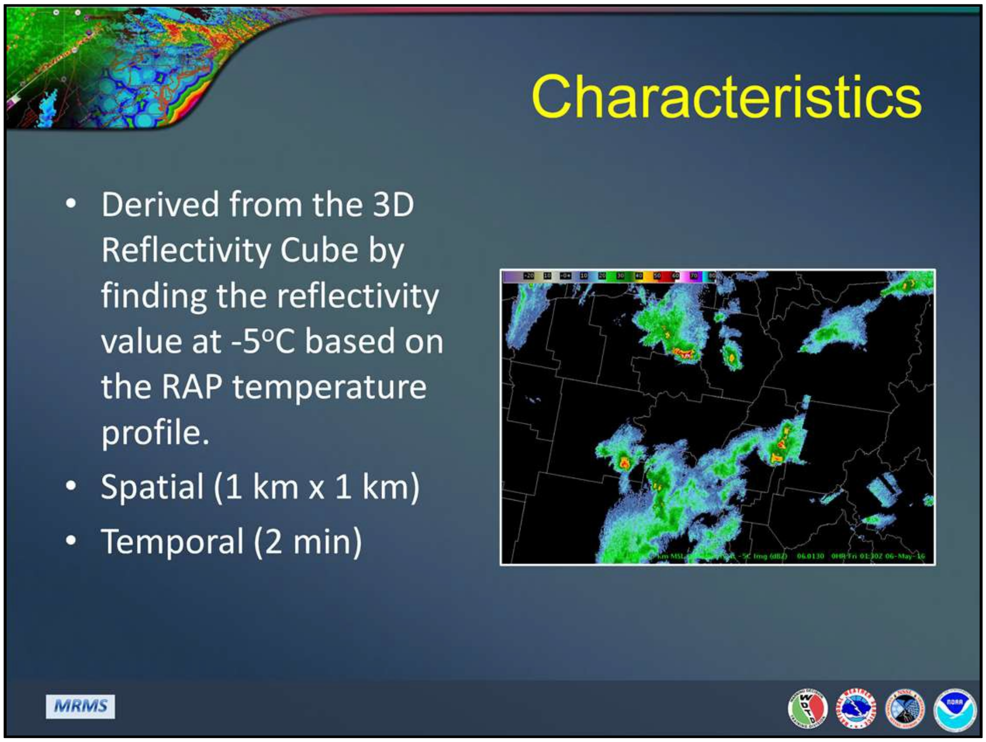
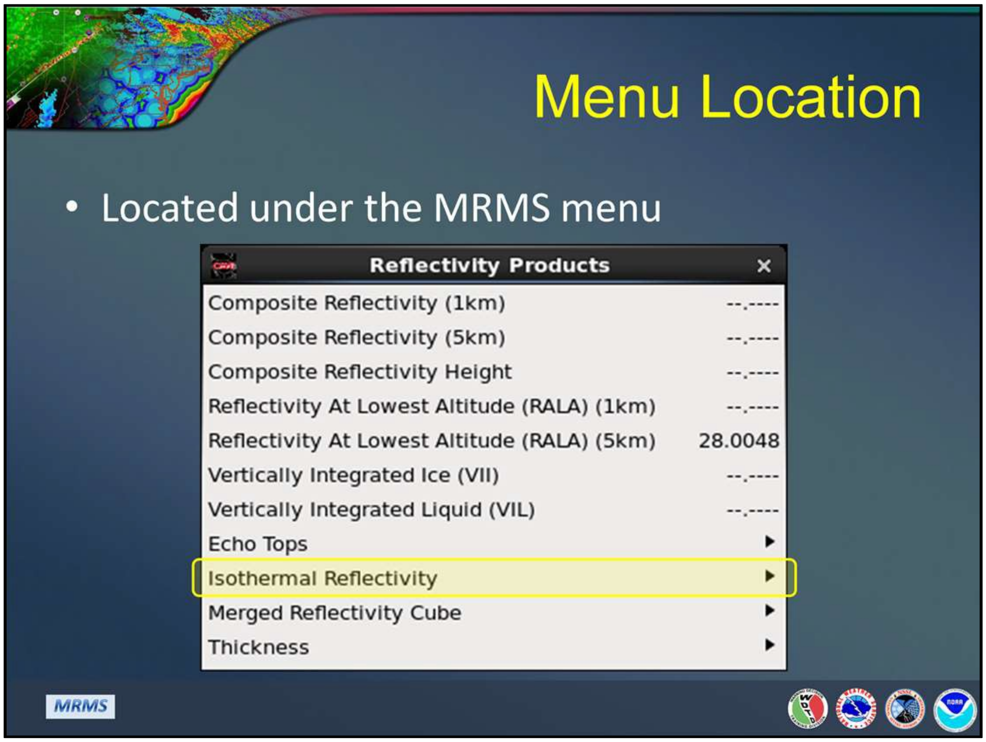
Edit in Engage
Edit Properties



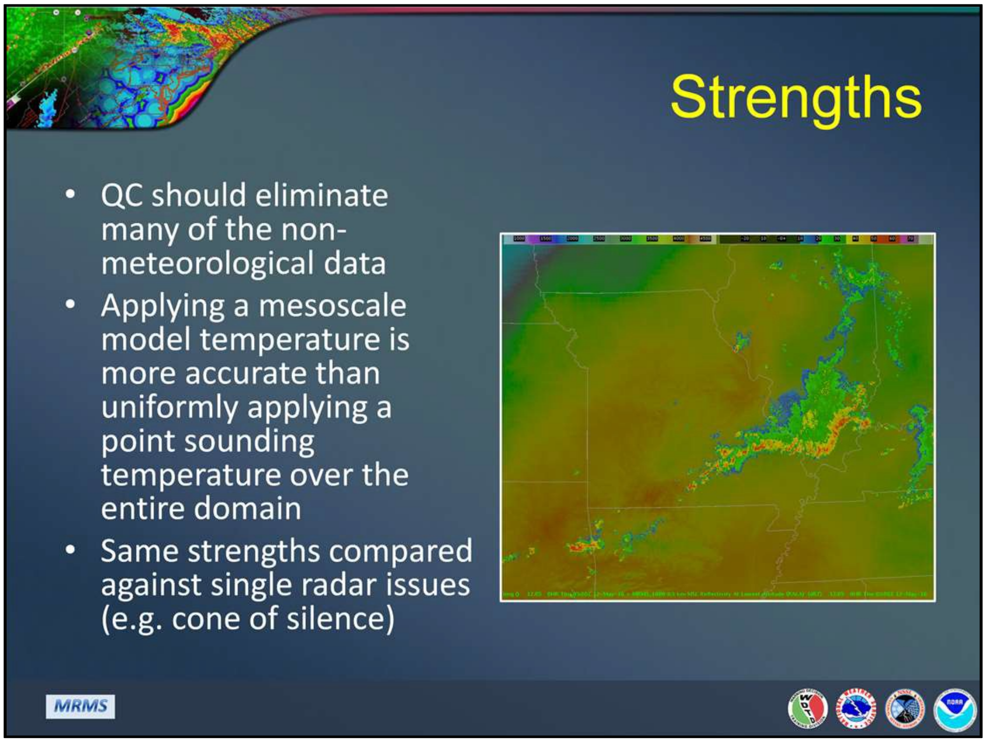
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. There will be quiz at the end of this lesson based on these objectives.



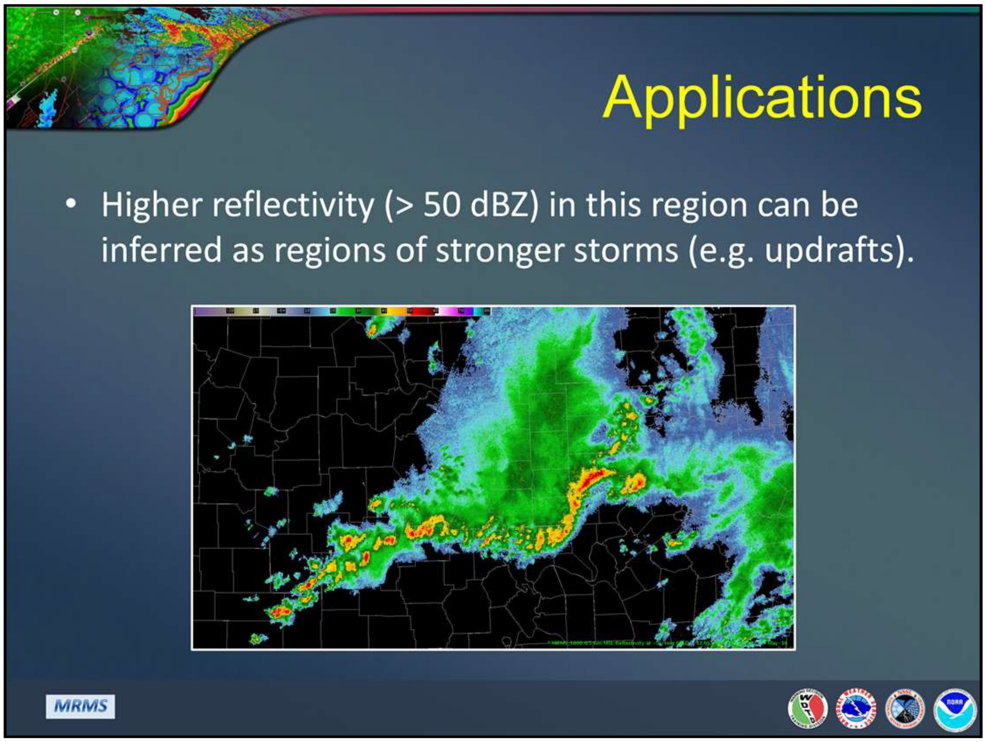
The isothermal reflectivity product at -5°C is derived from the 3D reflectivity cube by finding the reflectivity value within the cube that resides at -5°C based on the RAP temperature profile. Its spatial resolution is 1 km x 1 km and is updated every 2 minutes.



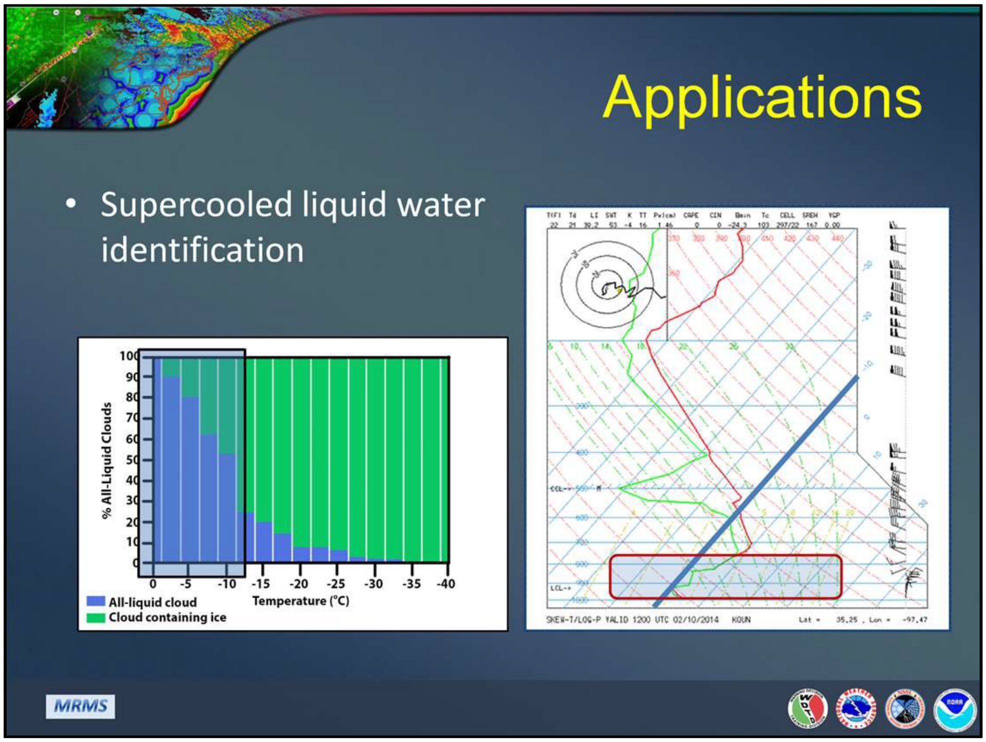
This isothermal reflectivity product can be found with in the MRMS menu located in your CAVE display.



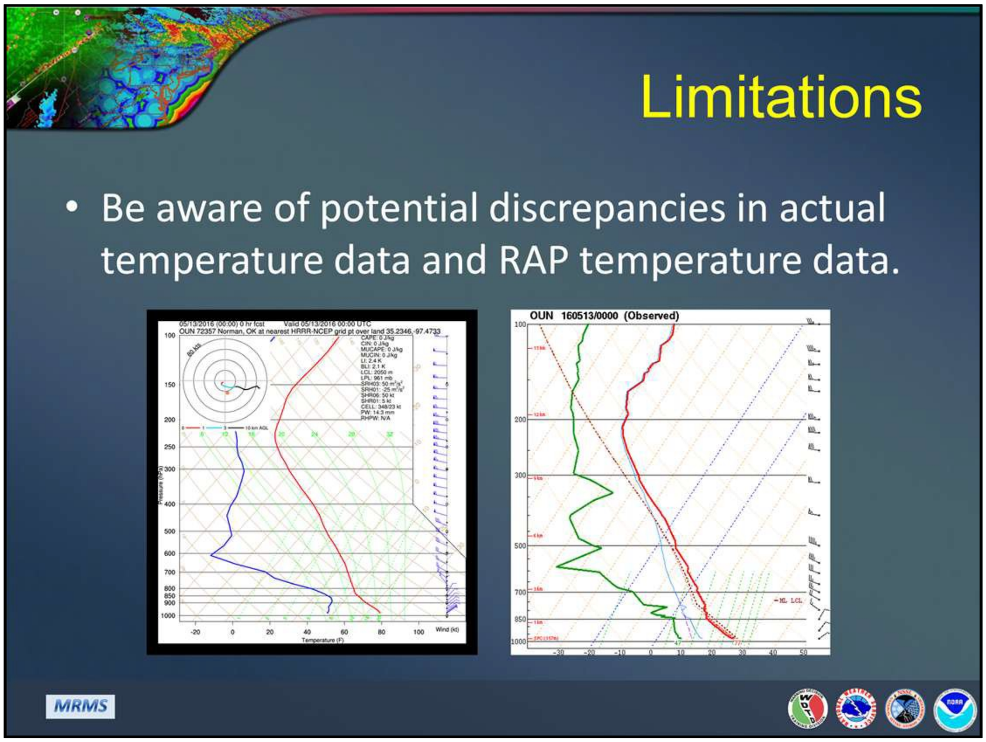
While most non-meteorological data will not contaminate echoes at or above the -5^{o}C level, it is still worth noting that non-meteorological data is still filtered out by the QC algorithm. During cold season events when the -5^{o}C level resides near the ground, this will become more important. Because temperature heights are never constant across a particular domain (as is shown here in this example where I have plotted the bright banding height across the MRMS domain), applying a mesoscale temperature field instead of uniformly applying a point sounding results in more accurate interpretations. Notice how the bright banding heights vary by as much as 1,000 feet. Finally, all strengths associated with MRMS vs single radar analysis are still valid (e.g. mitigating cone of silence).



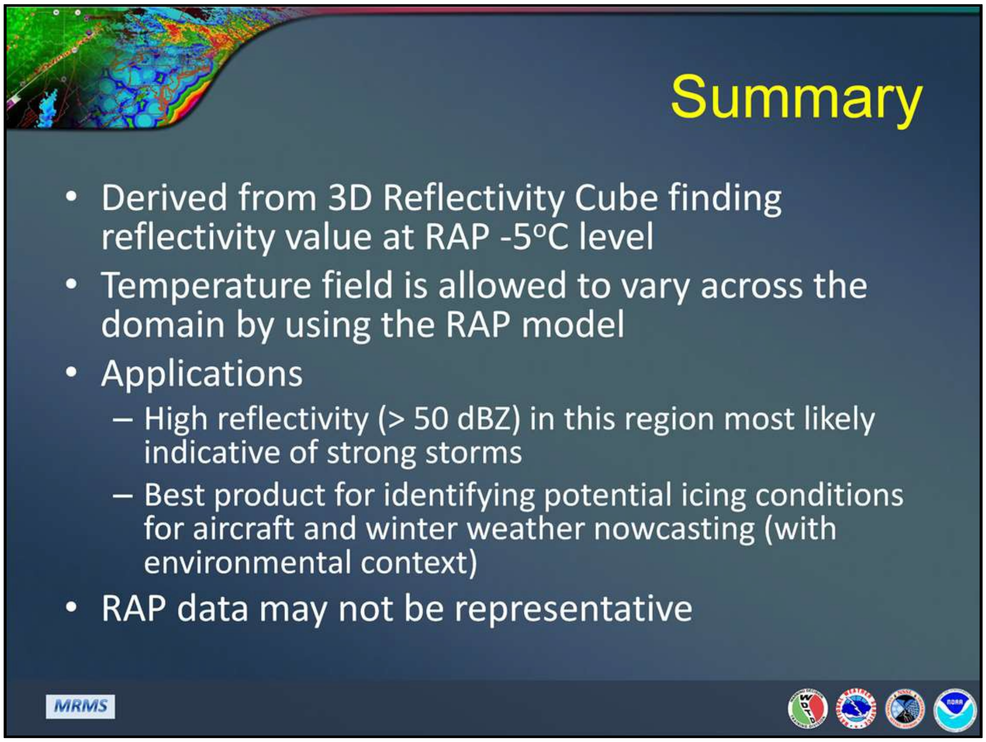
Higher reflectivity cores, typically greater than 50 dBZ, in this temperature level can be inferred as regions of stronger storms due to updrafts being able to loft larger rain drops above the environmental freezing level. In this example, we see a broken line of intense reflectivity. Each core above 50 dBZ is likely an area of updraft along this line of storms.



With environmental context, this product can also be very useful for identifying regions of potentially super cooled liquid water which can greatly aid in alerting aircraft to potential icing issues, or with winter weather nowcasting for potentially dangerous icing conditions at the surface. If the saturated column of air all exists below -10^{o}C, there is a high likelihood the cloud is mostly made up of liquid droplets (as seen by the graph on the left). The best way to identify if the column is mostly saturated below the -10^{o}C height is to analyze a representative sounding (as noted in the image on the right). Therefore, if you have a sounding like what is shown, then you can load the isothermal reflectivity at -5^{o}C and assume most of the returns are liquid in nature and have a high likelihood of being supercooled and causing aircraft icing issues, or may lead to icing issues at the surface if surface temperatures are below freezing.



The only limitation to using the -5^{o}C isothermal reflectivity product is to be aware of the potential discrepancies in actual temperature data vs. the RAP temperature data. There can be model biases that may inhibit your interpretations. This example shows an initial RAP sounding (left) and actual sounding (right). You can see they pretty well agree, but it's always good to make sure the model matches reality.



In summary, this isothermal reflectivity product is derived from the 3D Reflectivity Cube by finding the reflectivity value at the -5^{o}C using the RAP model. Using the RAP model allows for temperature to vary across the MRMS domain, whereas using a single point sounding does not allow for this temperature variation. High reflectivity values in this region most likely indicate strong updrafts, and therefore strong storms. Additionally, with environmental context, reflectivity in this temperature range are most likely to be best at identifying icing regions for aviation and even winter weather nowcasting in general. One caveat with this product is the RAP data may not be representative due to potential model biases, etc. Next up will be the quiz!


-5C Isothermal Reflectivity Quiz
Quiz - 5 questions
Last Modified: Sep 14, 2016 at 01:44 PM
PROPERTIES
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On failing, 'Finish' button: Goes to Next Slide
Allow user to leave quiz: At any time
User may view slides after quiz: At any time
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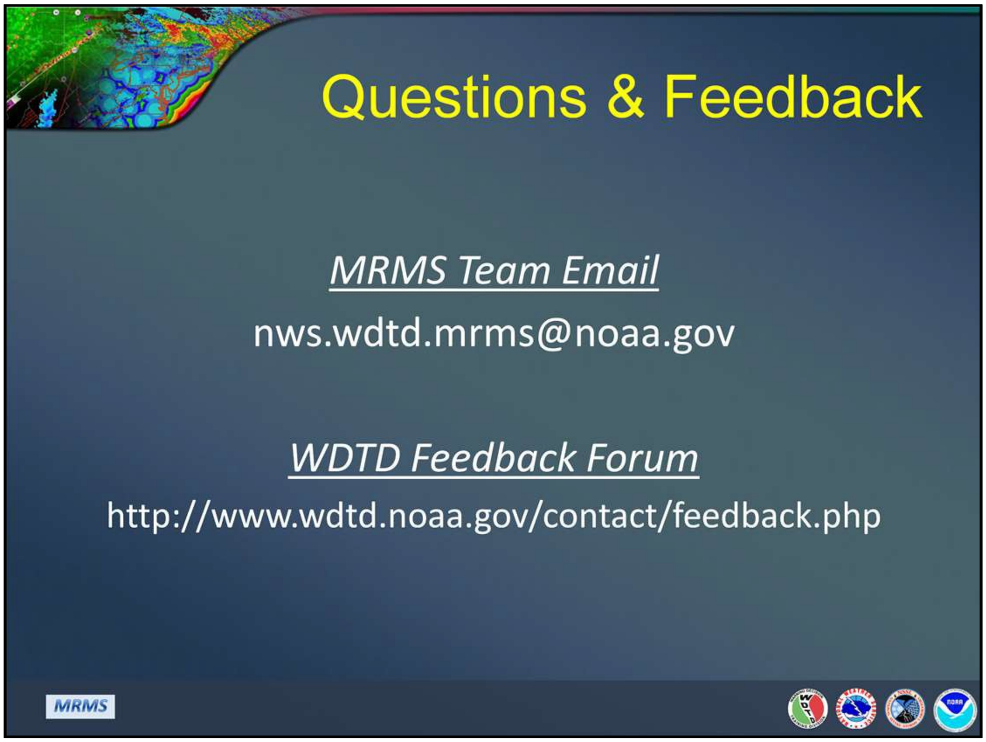
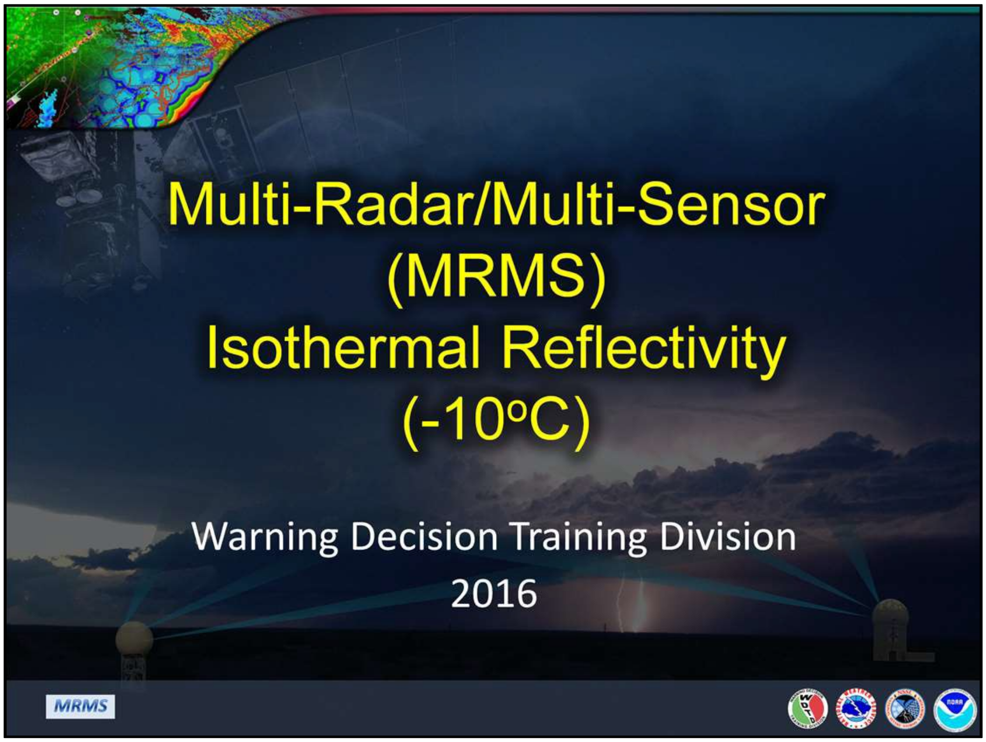
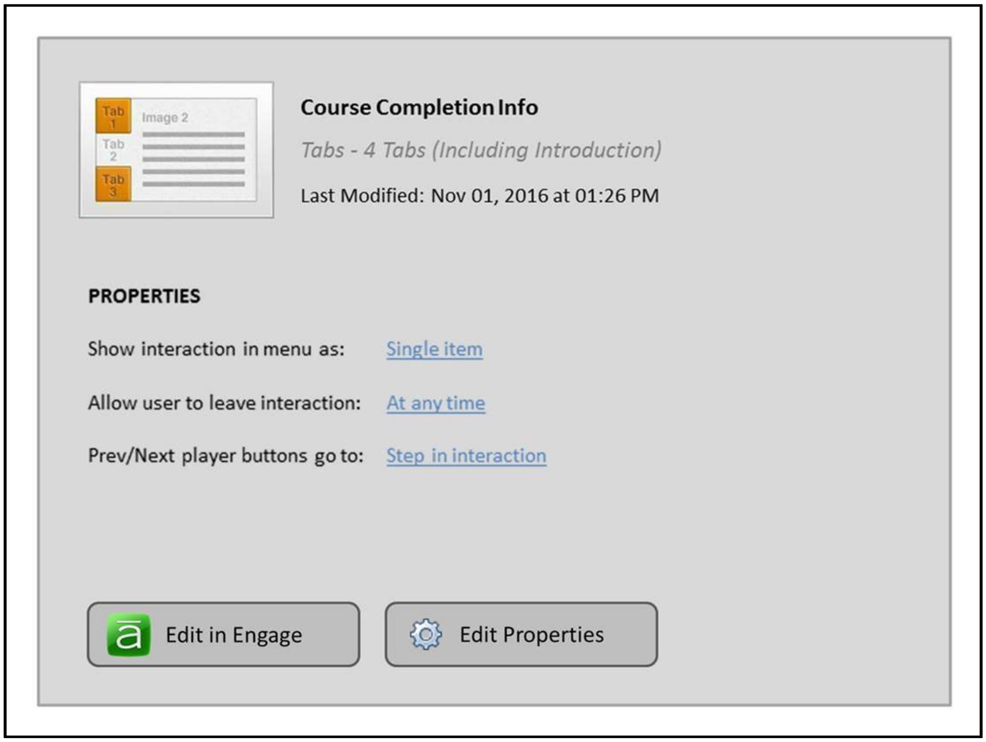
Edit Properties



Thanks for completing this module on Isothermal Reflectivity at -5^{o}C. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Isothermal Reflectivity (-10^{o}C) developed at the Warning Decision Training Division (WDTD).


Tab 1
Image 2
Tab 2
Tab 3
Course Completion Info
Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 01, 2016 at 01:26 PM
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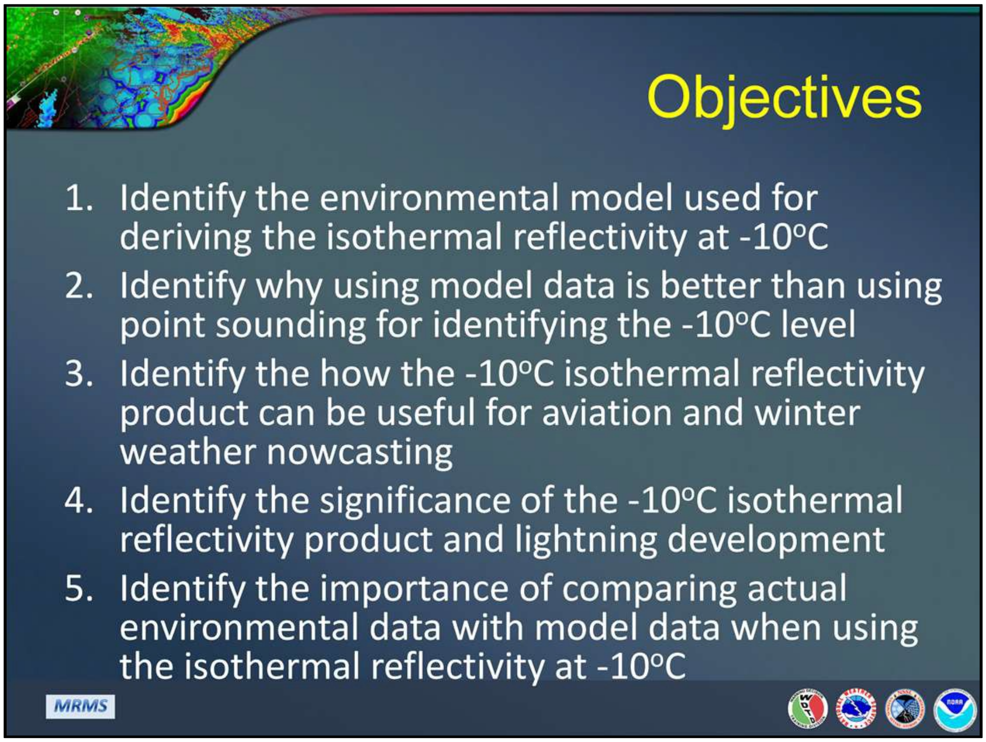
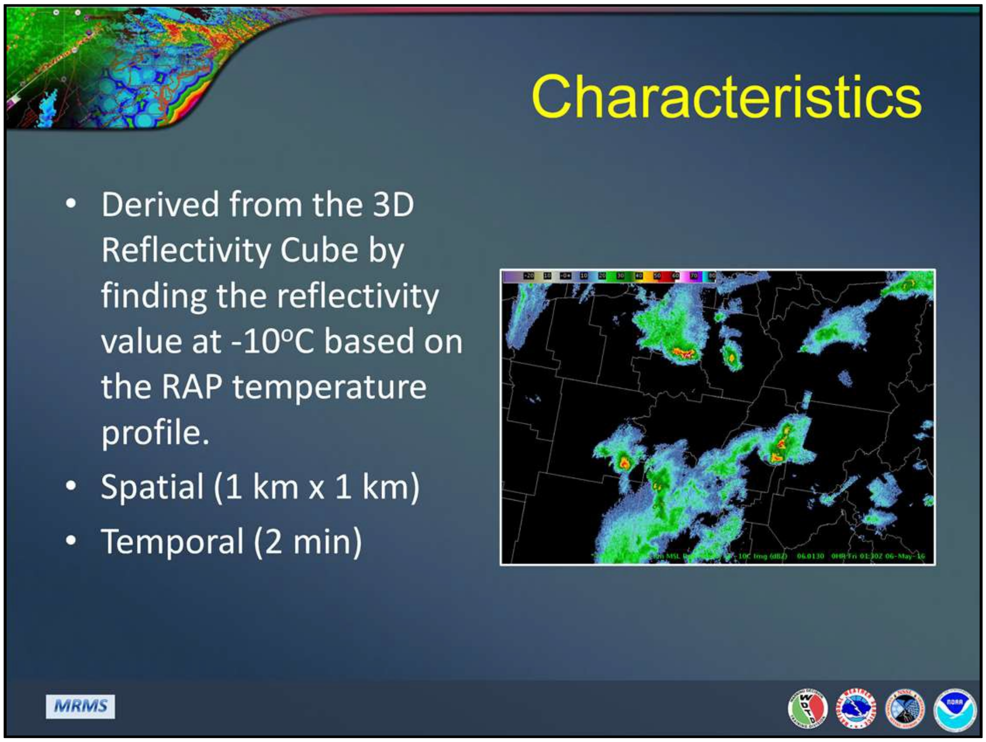
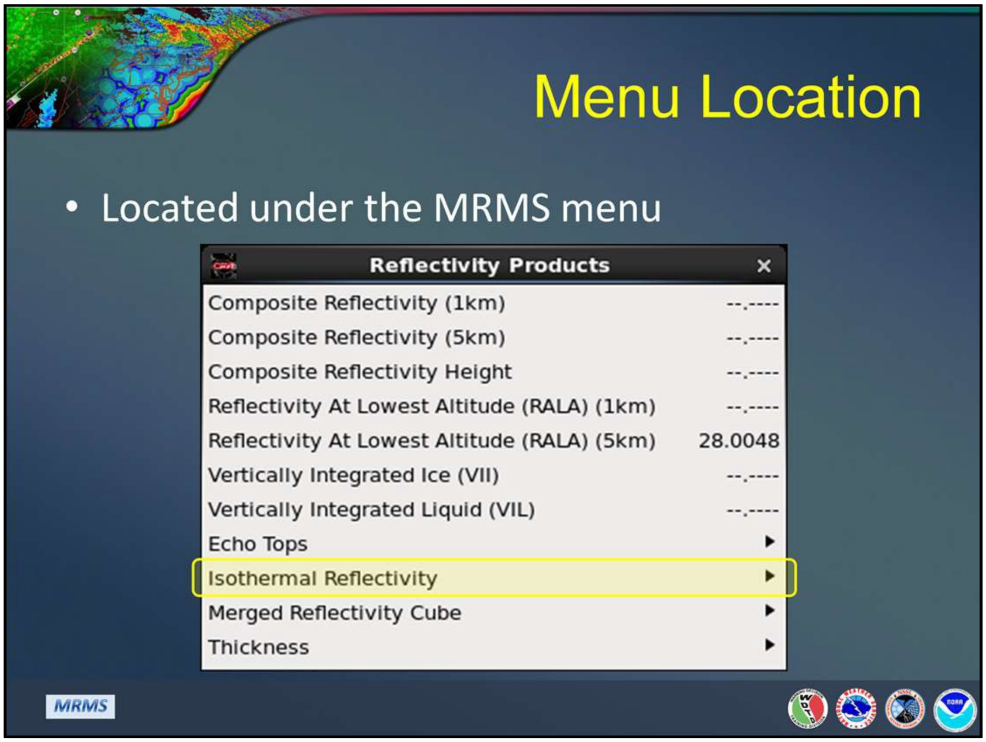


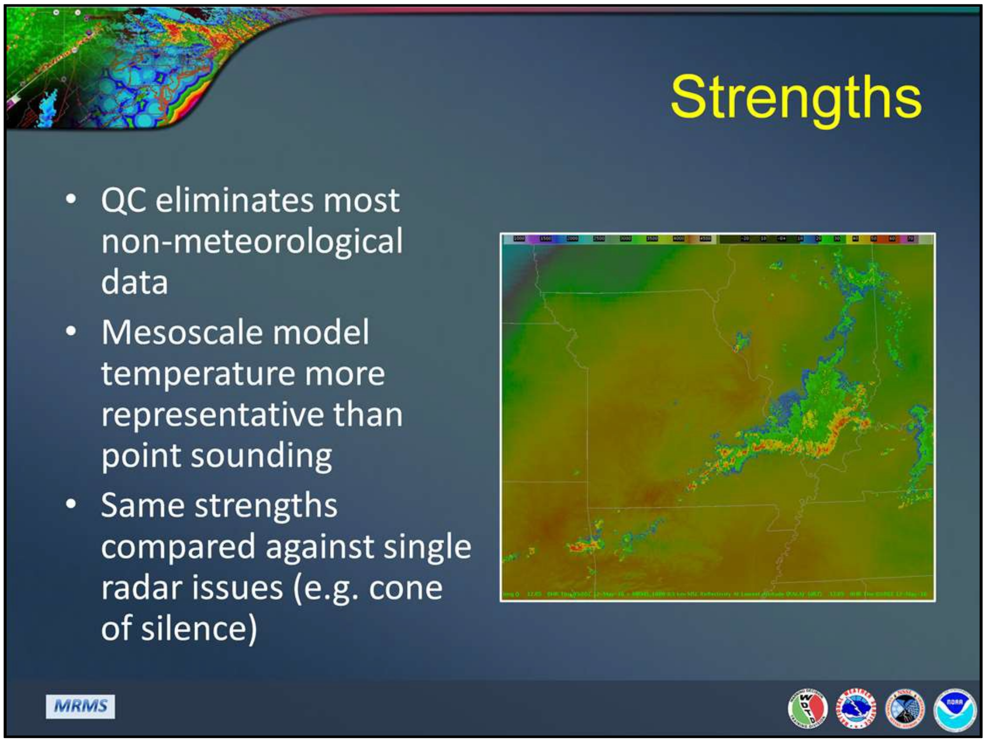
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. There will be a quiz at the end of this lesson based on these objectives.



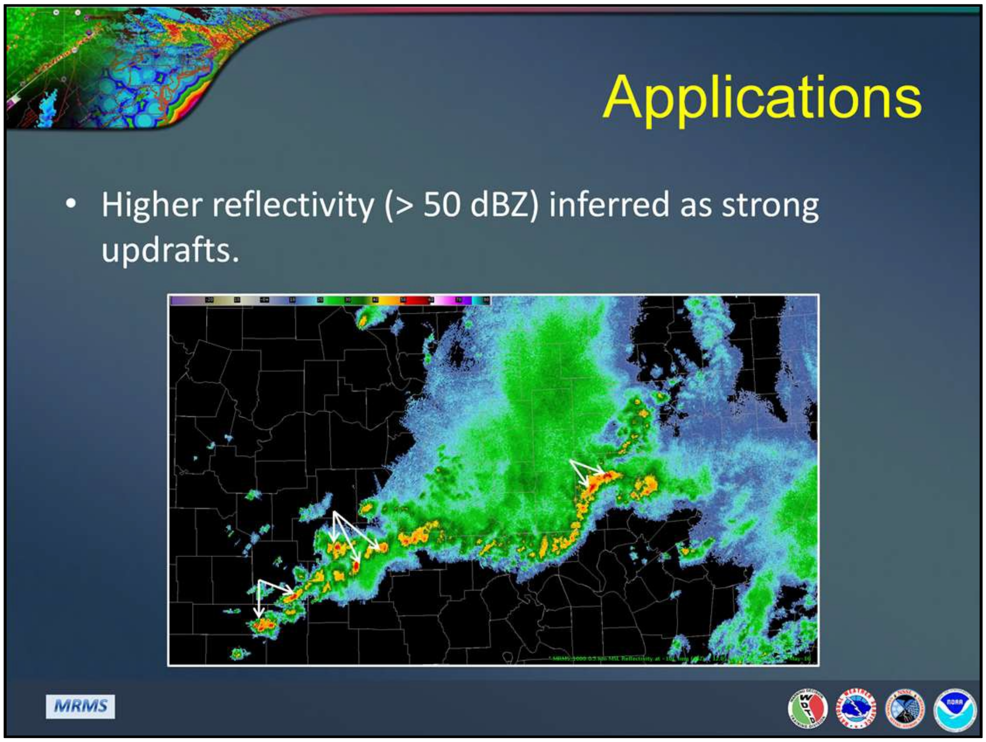
The isothermal reflectivity product at -10^{o}C is derived from the 3D reflectivity cube by finding the reflectivity value within the cube that resides at -10^{o}C based on the RAP temperature profile. Its spatial resolution is 1 km x 1 km and is updated every 2 minutes.



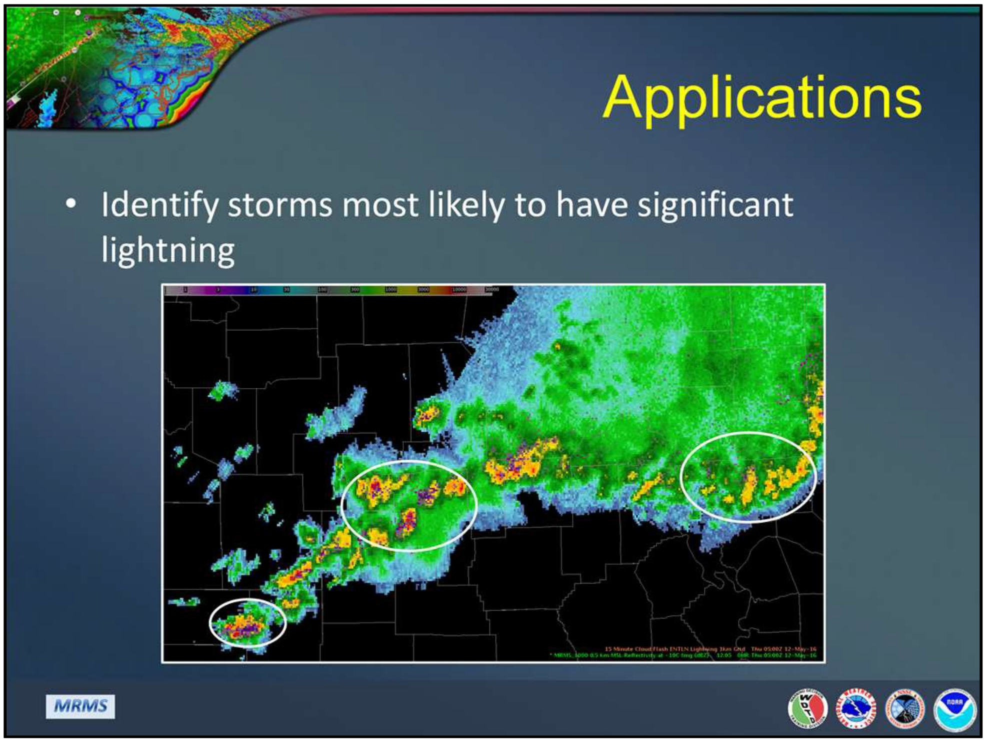
This isothermal reflectivity product can be found with in the MRMS menu located in your CAVE display.



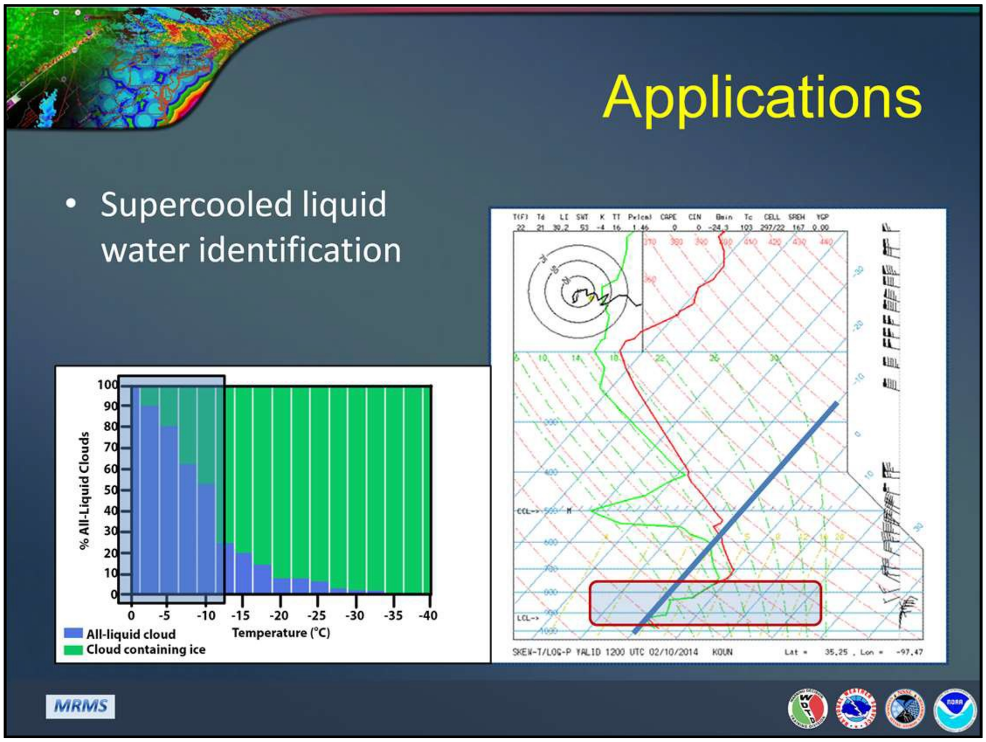
While most non-meteorological data will not contaminate echoes at or above the -10^{o}C level, it is still worth noting that non-meteorological data is still filtered out by the QC algorithm. Because temperature heights are never constant across a particular domain (as is shown here in this example where I have plotted the bright banding height across the MRMS domain), applying a mesoscale temperature field instead of uniformly applying a point sounding results in more accurate interpretations. Notice how the bright banding heights vary by as much as 1,000 feet. Finally, all strengths associated with MRMS vs single radar analysis are still valid (e.g. mitigating cone of silence).



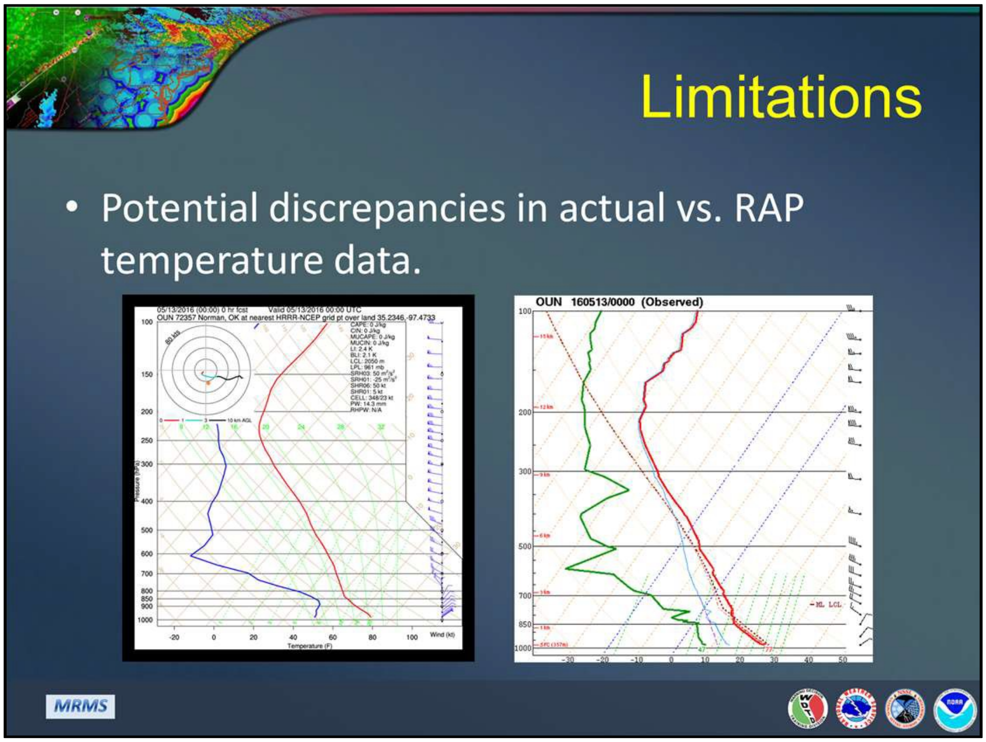
Beginning at this temperature level, higher reflectivity, especially above 50 dBZ, will more likely indicate very strong storms (e.g. updrafts) with increasing likelihood of severe hail. In this example, the eastern portion of the line is showing a few pockets of Z greater than 50 dBZ, and there are some more well-defined, isolated storms further southwest of the main line that appear to have broader areas of greater than 50 dBZ echoes. Each of these sections of the line are the most likely areas where updrafts are strongest and the biggest potential exists for severe weather or continued development.



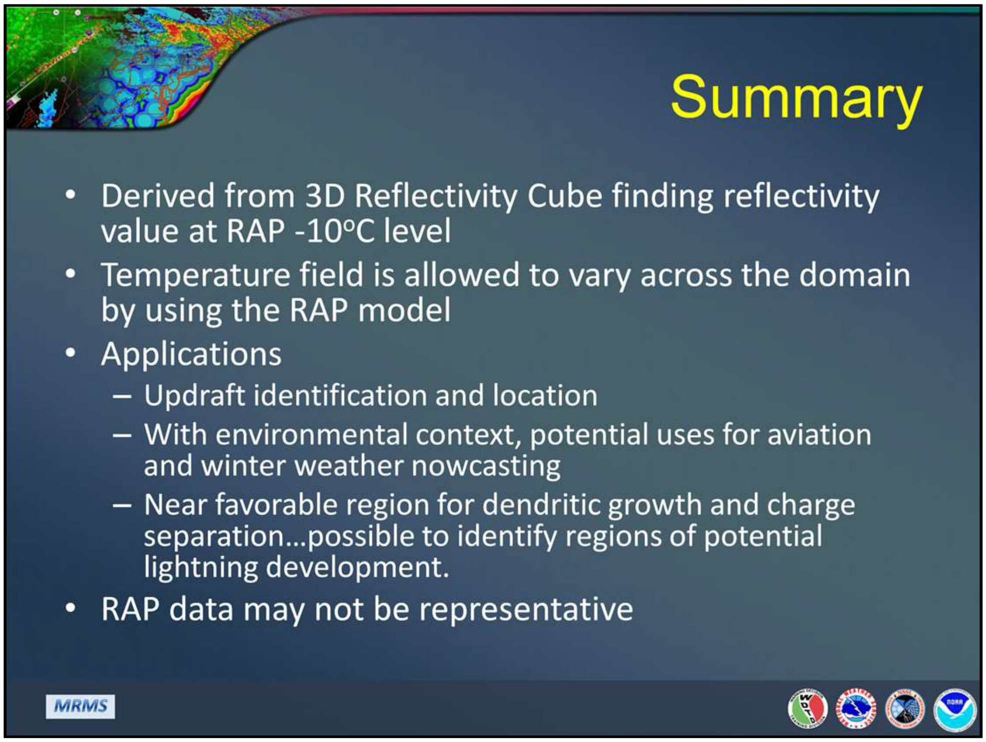
The -12°C level is a region of favorable dendritic growth, and this dendritic growth is partially responsible for charge separation. Therefore, this product might be useful for identifying regions of potential lightning development. In this example, the stronger cores to the south show reflectivity values between 45-55 dBZ in the most intense lightning regions. Areas to the east where there are significant reflectivity between 40-45 dBZ, there is some lightning activity, but not as much as to the west.



With environmental context, this product can also be very useful for identifying regions of potentially super cooled liquid water which can greatly aid in alerting aircraft to potential icing issues, or with winter weather nowcasting for potentially dangerous icing conditions at the surface. If the saturated column of air all exists below -10°C, there is a high likelihood the cloud is mostly made up of liquid droplets (as seen by the graph on the left). The best way to identify if the column is mostly saturated below the -10°C height is to analyze a representative sounding (as noted in the image on the right). Therefore, if you have a sounding like what is shown, then you can load the isothermal reflectivity at -10°C and assume most of the returns are liquid in nature and have a high likelihood of being supercooled and causing aircraft icing issues, or may lead to icing issues at the surface if surface temperatures are below freezing.



The only limitation to using the -10°C isothermal reflectivity product is to be aware of the potential discrepancies in actual temperature data vs. the RAP temperature data. There can be model biases that may inhibit your interpretations. This example shows an initial RAP sounding (left) and actual sounding (right). You can see they pretty well agree, but it's always good to make sure the model matches reality.



In summary, this isothermal reflectivity product is derived from the 3D Reflectivity Cube by finding the reflectivity value at the -10°C using the RAP model. Using the RAP model allows for temperature to vary across the MRMS domain, whereas using a single point sounding does not allow for this temperature variation. One of its applications include updraft identification and location. Also, with environmental context, reflectivity in this temperature range are most likely to be best at identifying icing regions for aviation and even winter weather nowcasting in general. Additionally, this temperature level is near the -12°C level which is favorable for dendritic growth which is often tied to charge separation and lightning development. One caveat with this product is the RAP data may not be representative due to potential model biases, etc. Now, it is on to the quiz!


-10C Isothermal Reflectivity Quiz
Quiz - 5 questions
Last Modified: Sep 14, 2016 at 03:24 PM
PROPERTIES
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On failing, 'Finish' button: Goes to Next Slide
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User may view slides after quiz: At any time
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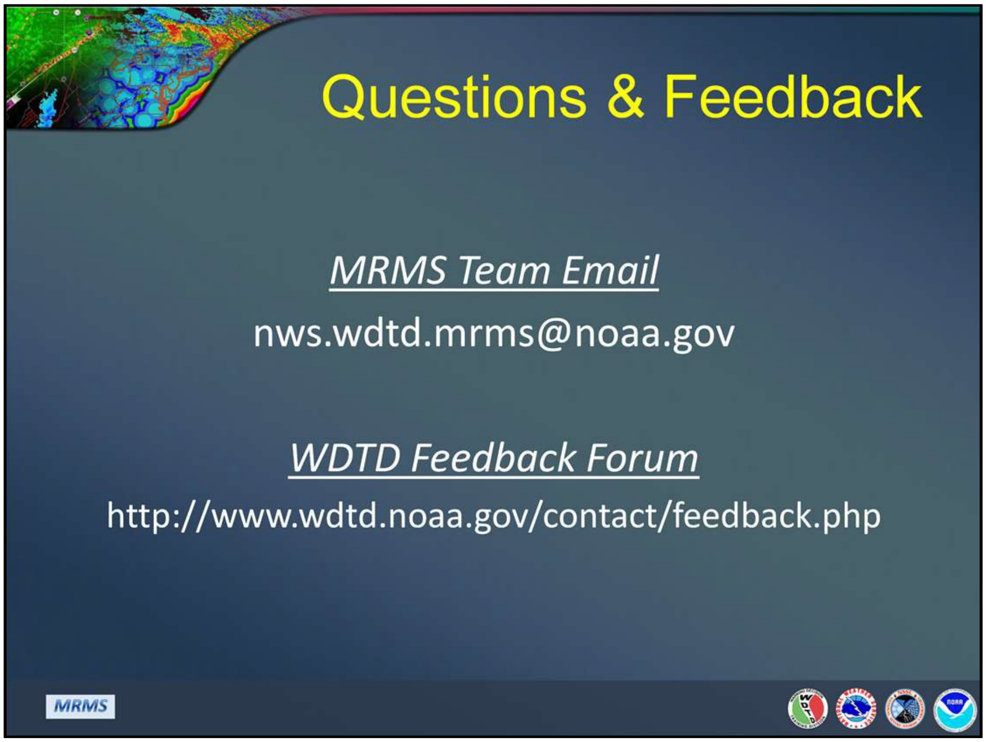
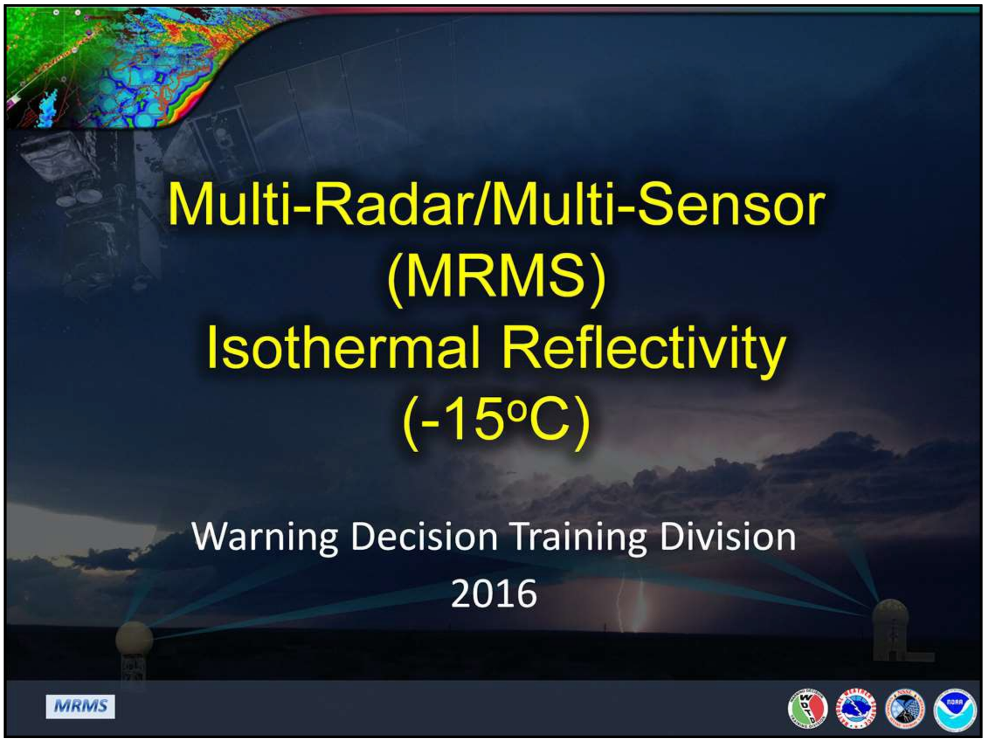
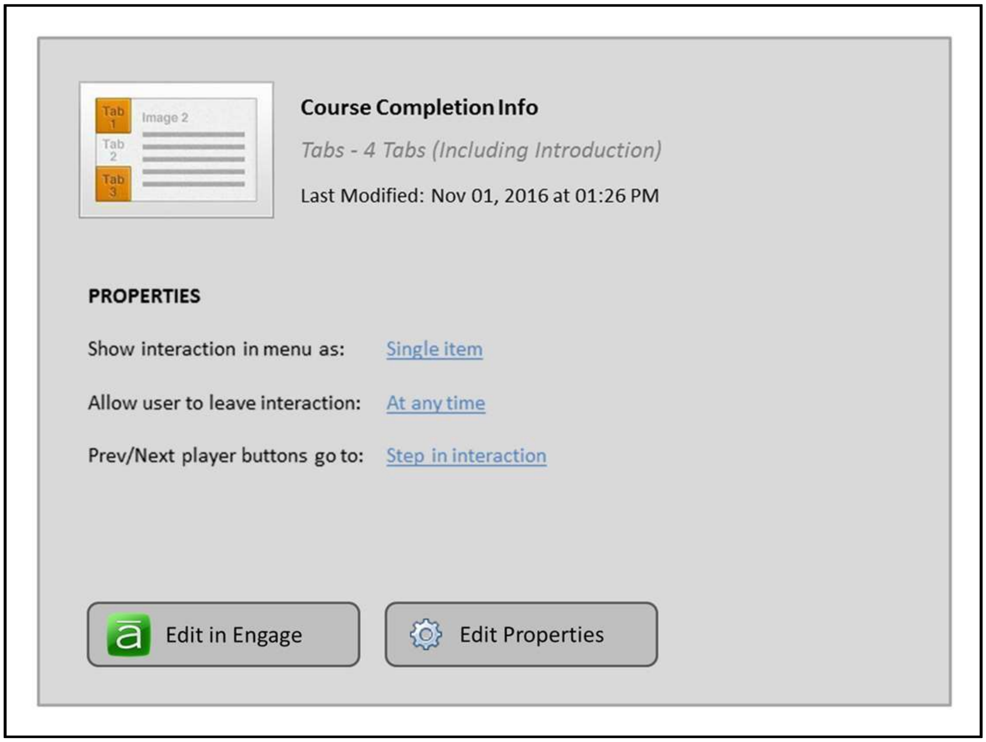
Edit Properties



Thanks for completing this module on Isothermal Reflectivity at -10ºC. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Isothermal Reflectivity (-15°C) developed at the Warning Decision Training Division (WDTD).


Tab 1
Tab 2
Tab 3
Image 2
Course Completion Info
Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 01, 2016 at 01:26 PM
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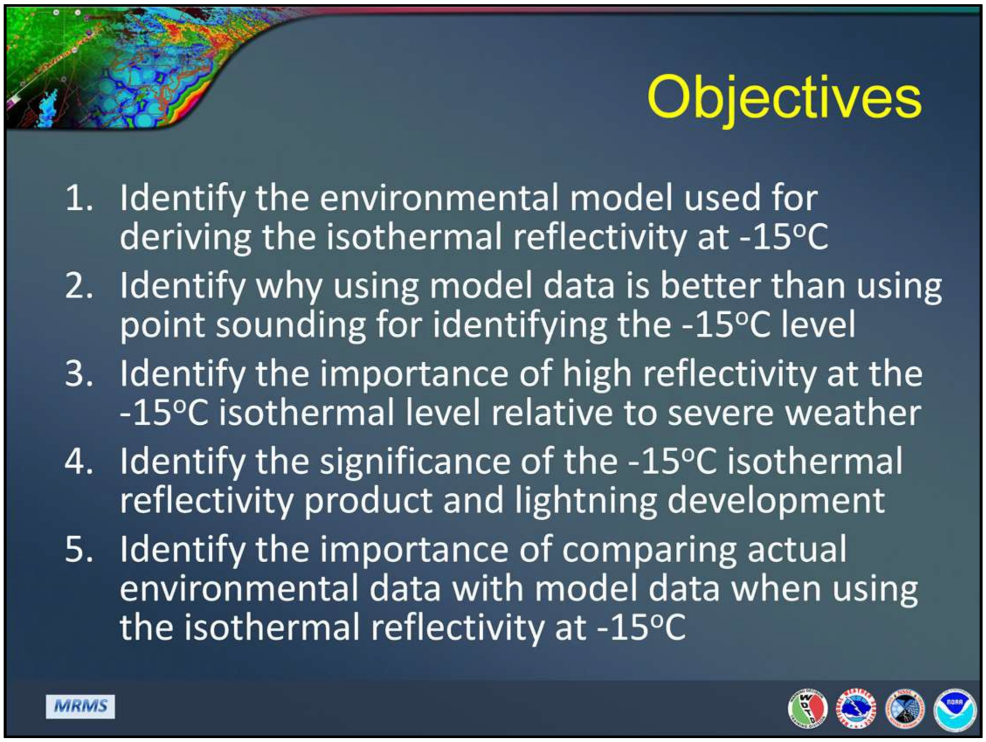
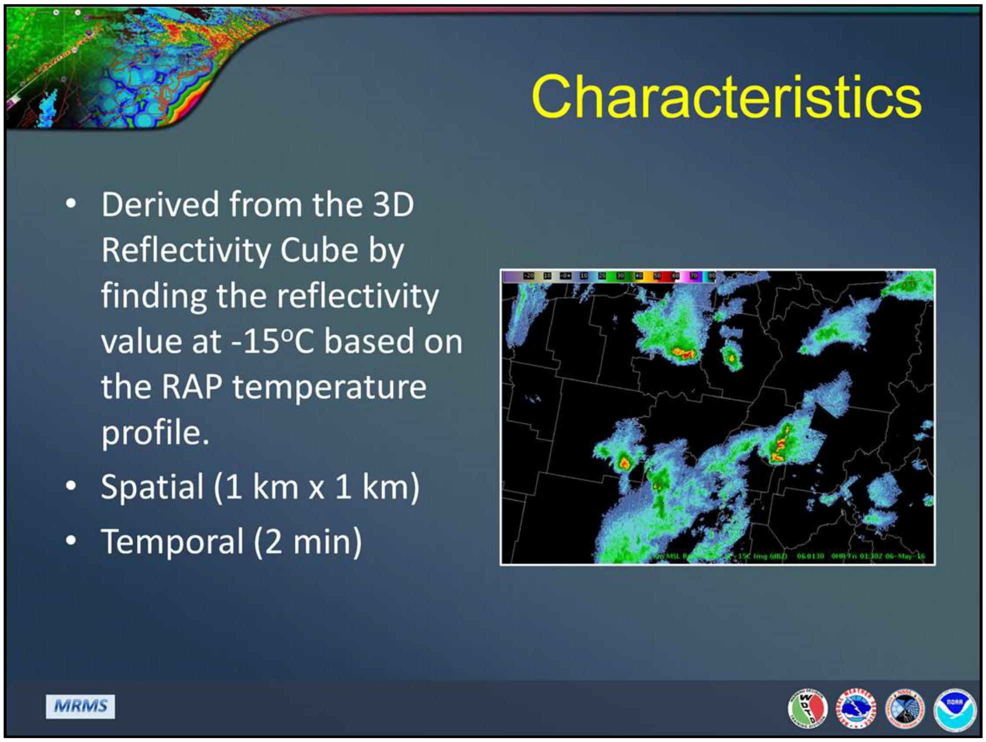
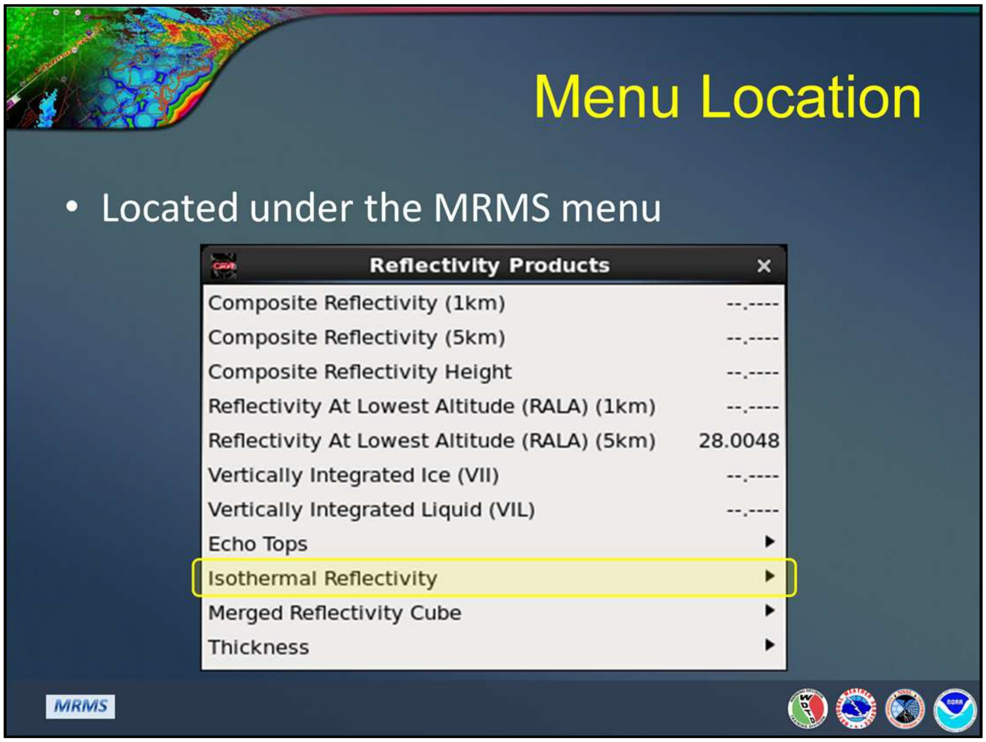


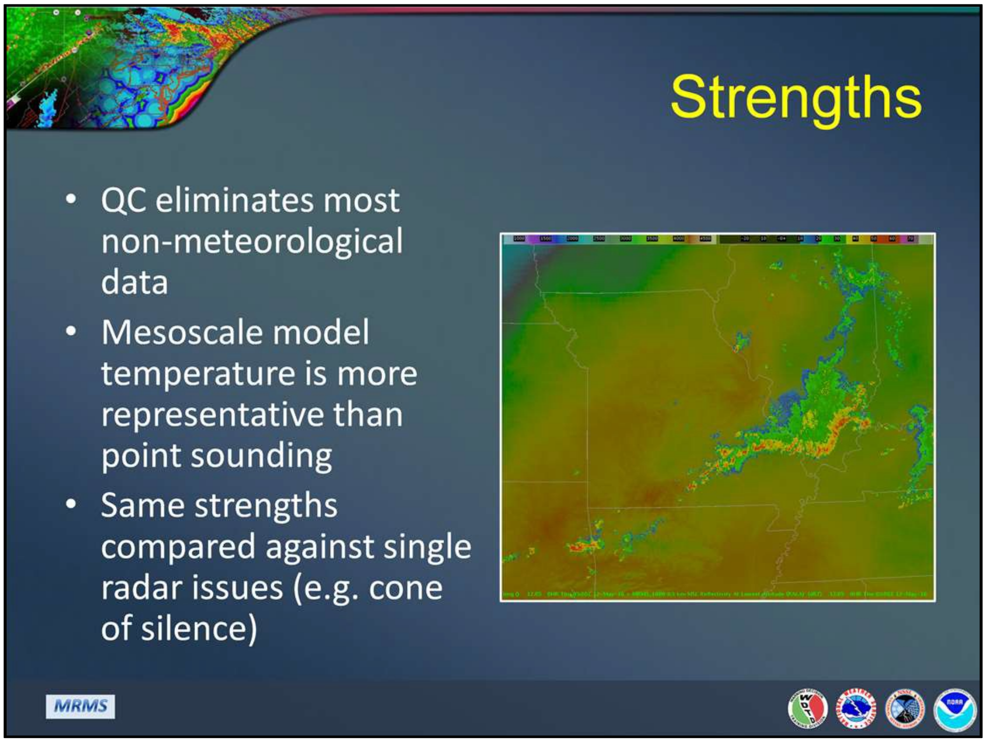
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. There will be a quiz at the end of this lesson based on these objectives.



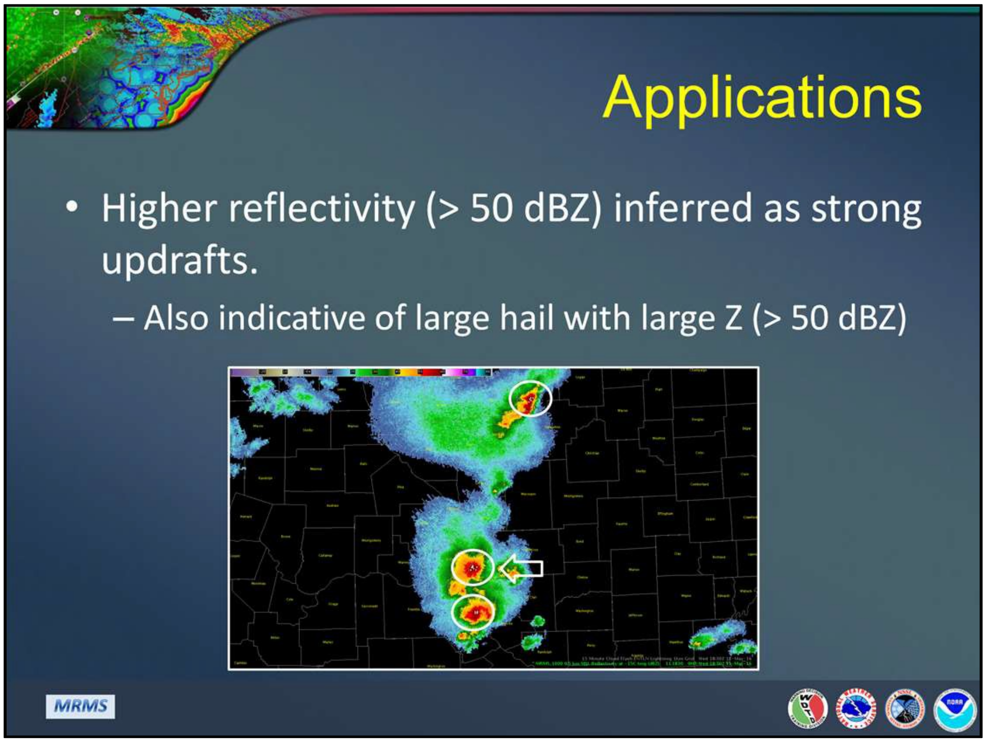
The isothermal reflectivity product at -15°C is derived from the 3D reflectivity cube by finding the reflectivity value within the cube that resides at -15°C based on the RAP temperature profile. Its spatial resolution is 1 km x 1 km and is updated every 2 minutes.



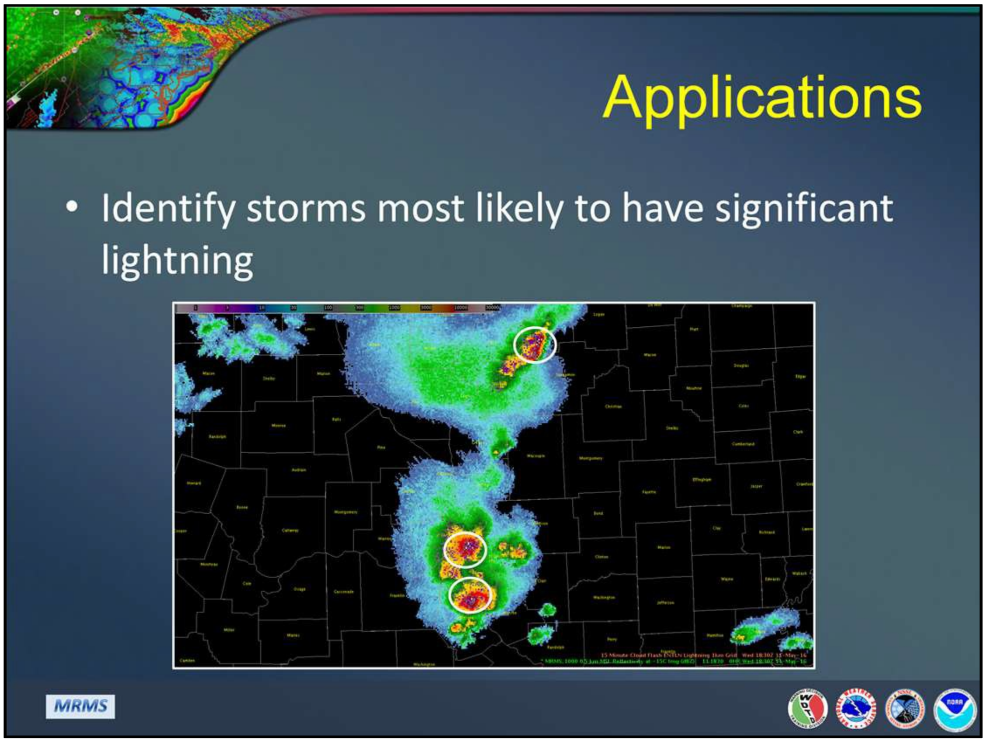
This isothermal reflectivity product can be found within the MRMS menu located in your CAVE display.



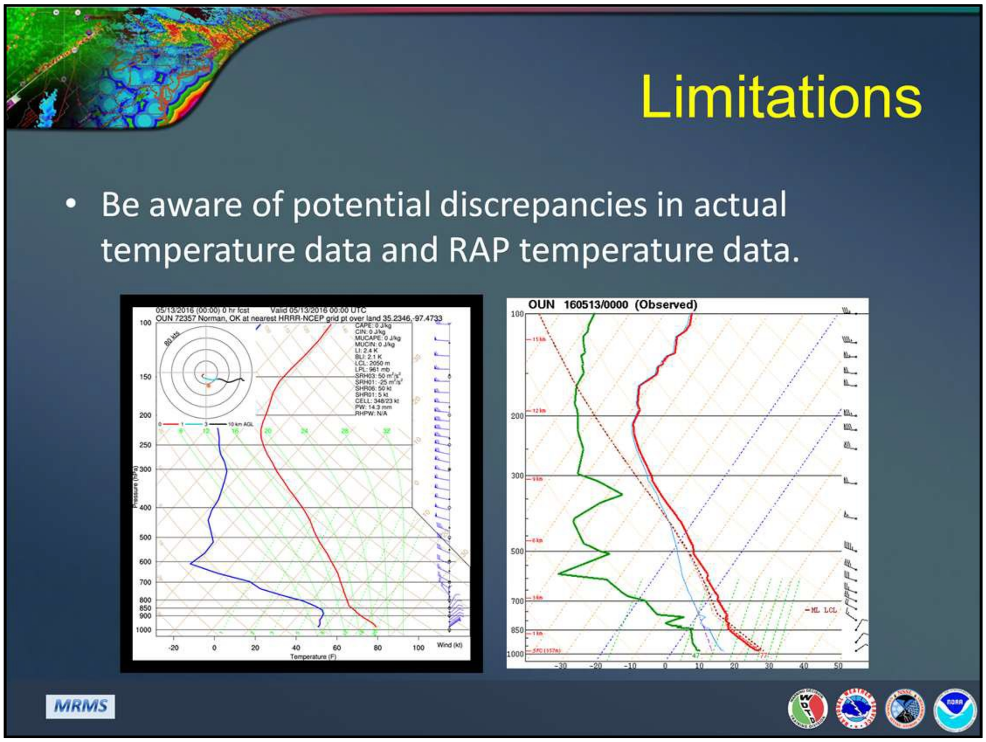
While most non-meteorological data will not contaminate echoes at or above the -15^{o}C level, it is still worth noting that non-meteorological data is still filtered out by the QC algorithm. Because temperature heights are never constant across a particular domain (as is shown here in this example where I have plotted the bright banding height across the MRMS domain), applying a mesoscale temperature field instead of uniformly applying a point sounding results in more accurate interpretations. Notice how the bright banding heights vary by as much as 1,000 feet. Finally, all strengths associated with MRMS vs single radar analysis are still valid (e.g. mitigating cone of silence).



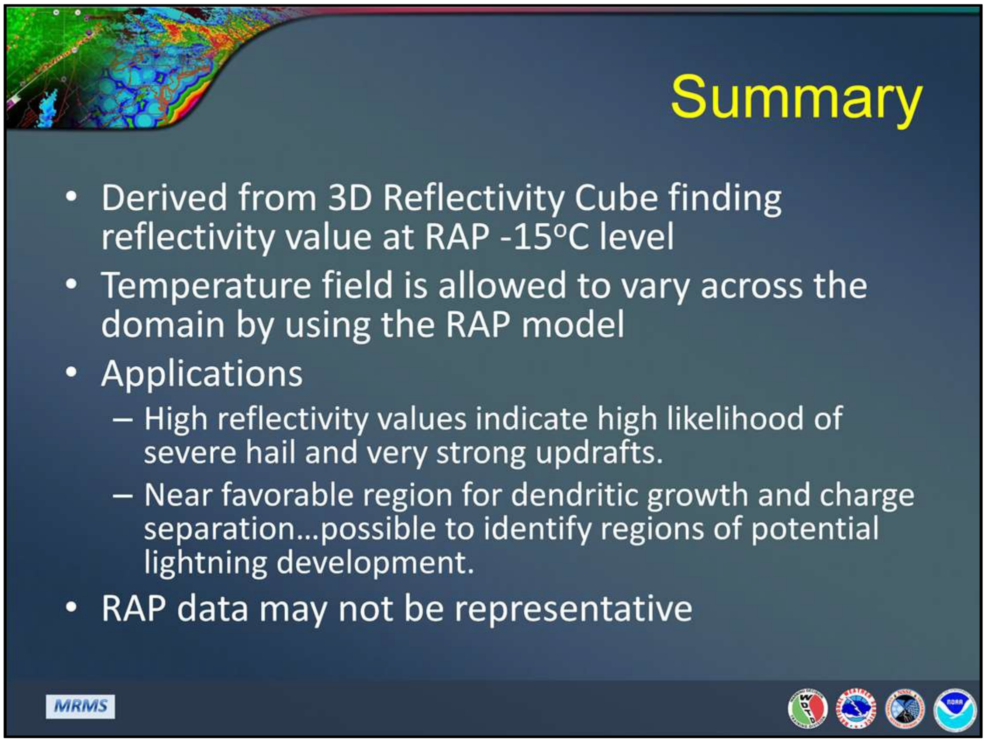
In order for significant reflectivity values to occur at this temperature level, either very large supercooled liquid drops or significantly large hail must be present. Both of these are evidence of very strong updrafts. In this example, there are three areas with Z > 60 dBZ at -15^{o}C. These three areas are most likely experiencing the strongest updrafts and most likely generating significant hail. In fact, the middle storm has produced 4-inch hail in the past 10-15 minutes.



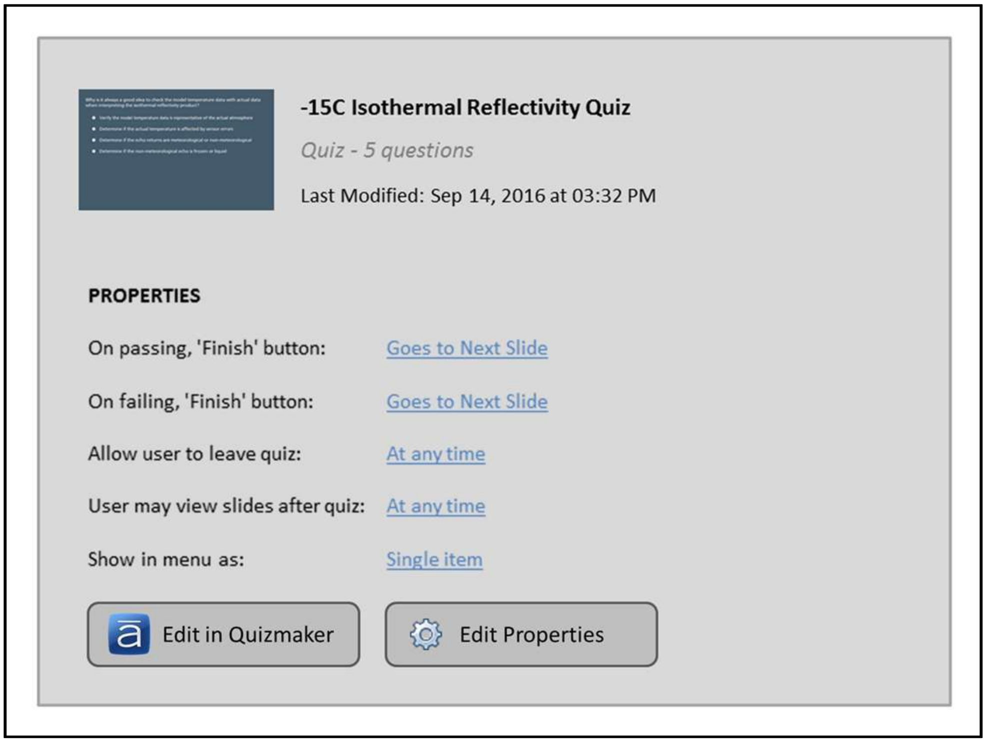
Additionally, the -12°C level is a region of favorable dendritic growth, and this dendritic growth is partially responsible for charge separation. Therefore, this product might be useful for identifying regions of potential lightning development. Notice in this example, the lightning (as denoted by the purple dots) is very well correlated with the higher Z.



The only limitation to using the -15ºC isothermal reflectivity product is to be aware of the potential discrepancies in actual temperature data vs. the RAP temperature data. There can be model biases that may inhibit your interpretations. This example shows a RAP sounding on the left and the corresponding actual sounding on the right. You can see they pretty well agree, but it is always to good to double check.



In summary, this isothermal reflectivity product is derived from the 3D Reflectivity Cube by finding the reflectivity value at the -15°C using the RAP model. Using the RAP model allows for temperature to vary across the MRMS domain, whereas using a single point sounding does not allow for this temperature variation. High reflectivity values in this region most likely indicate very strong updrafts, and likely severe hail. Additionally, this temperature level is near the -12°C level which is favorable for dendritic growth which is often tied to charge separation and lightning development. One caveat with this product is the RAP data may not be representative due to potential model biases, etc. Alright, now up next is the quiz!


-15C Isothermal Reflectivity Quiz
Quiz - 5 questions
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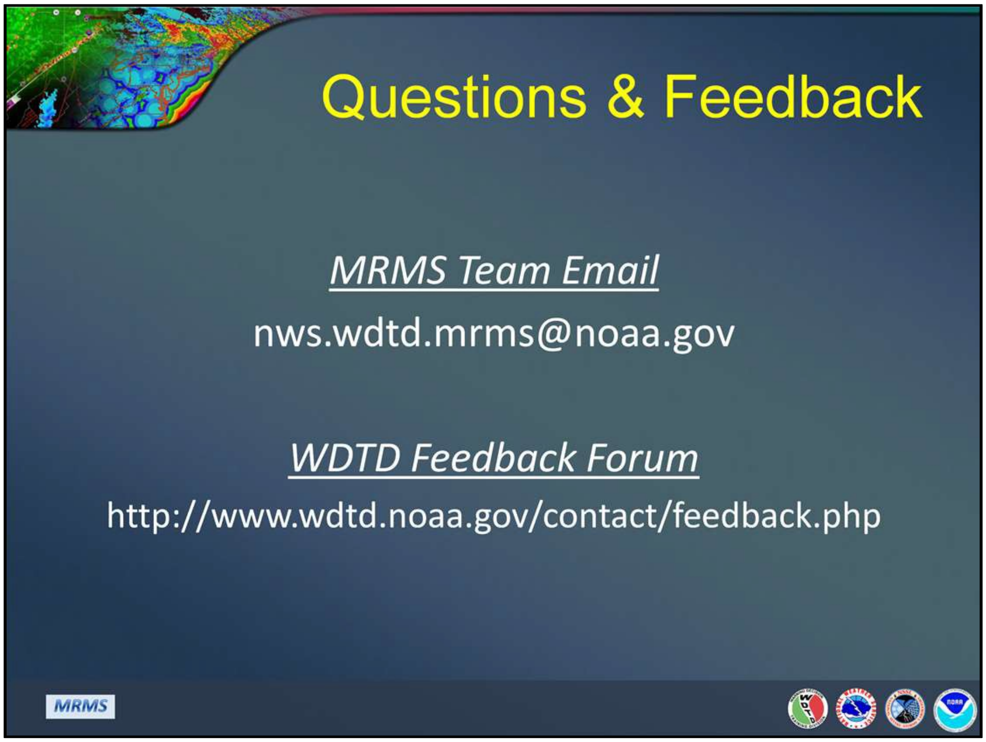
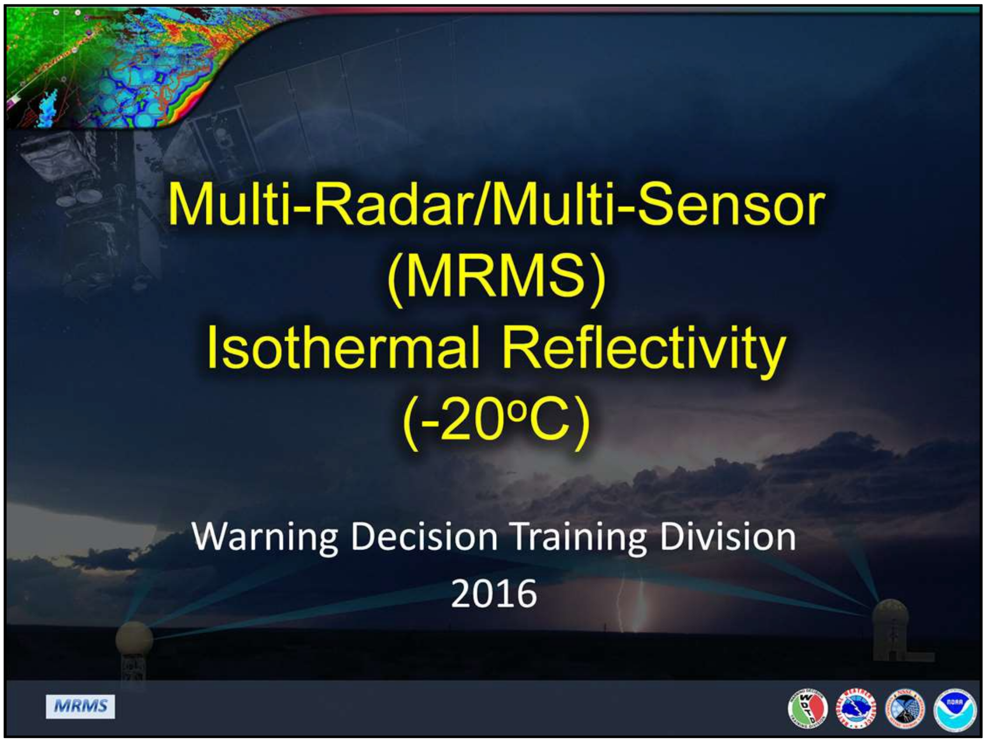
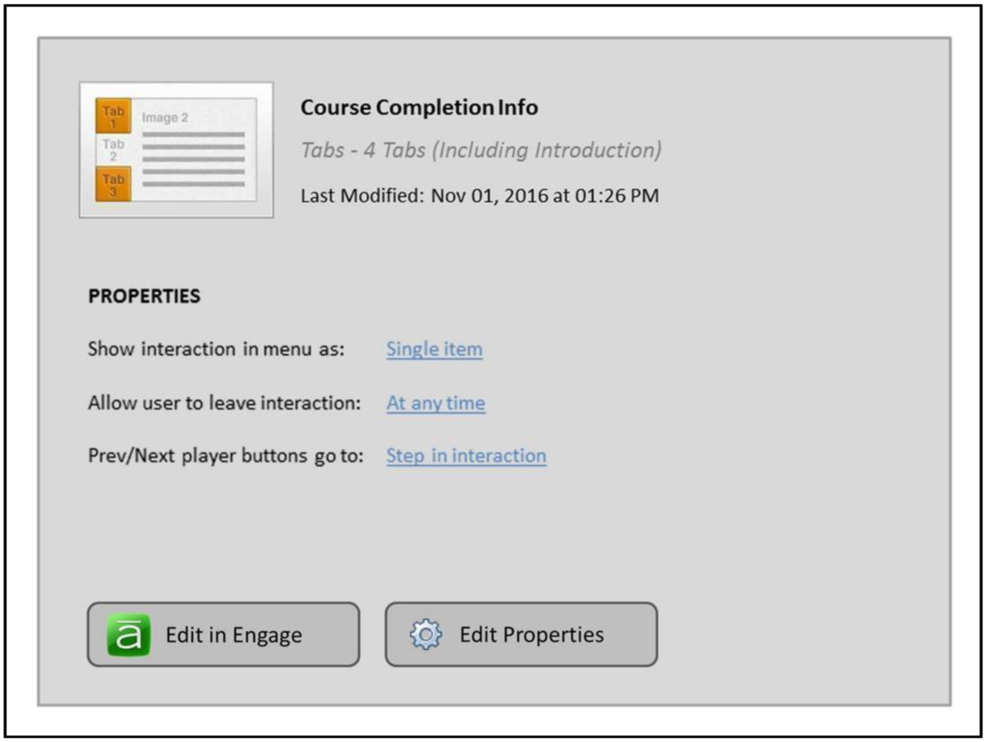


Thanks for completing this module on Isothermal Reflectivity at -15°C. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Isothermal Reflectivity (-20°C) developed at the Warning Decision Training Division (WDTD).


Tab 1
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Tab 3
Course Completion Info
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Last Modified: Nov 01, 2016 at 01:26 PM
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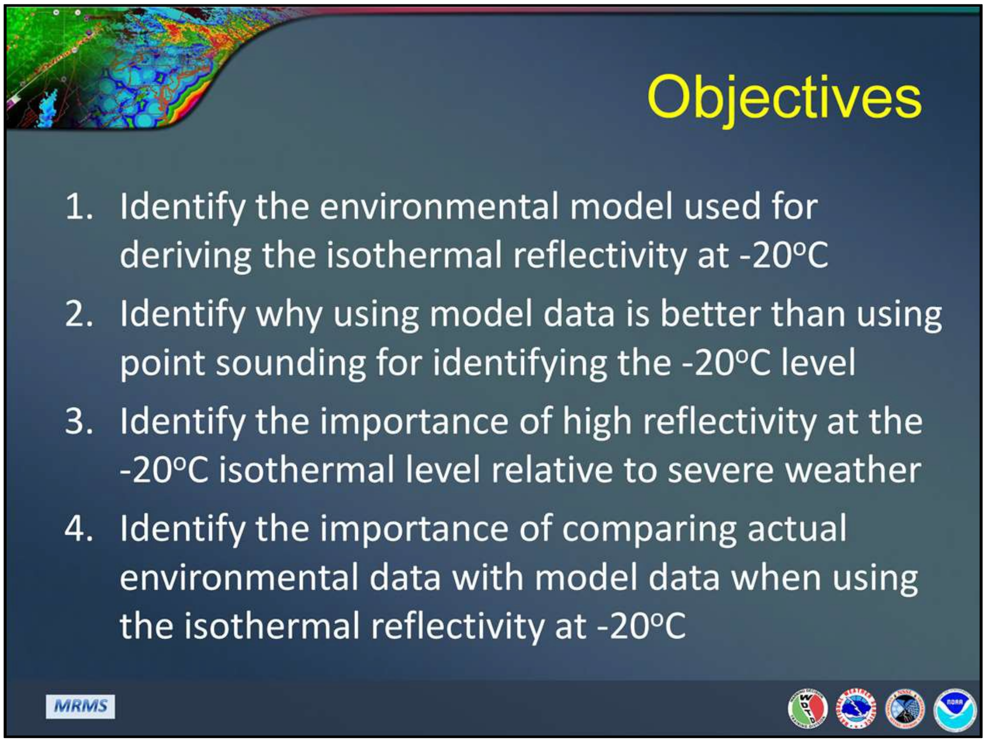
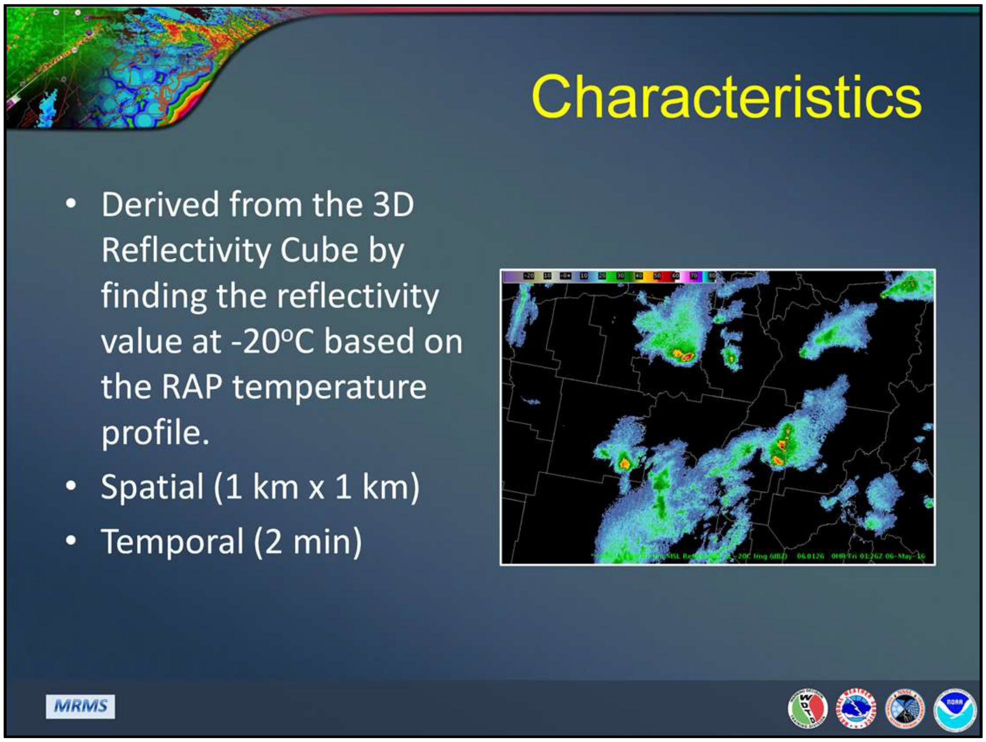
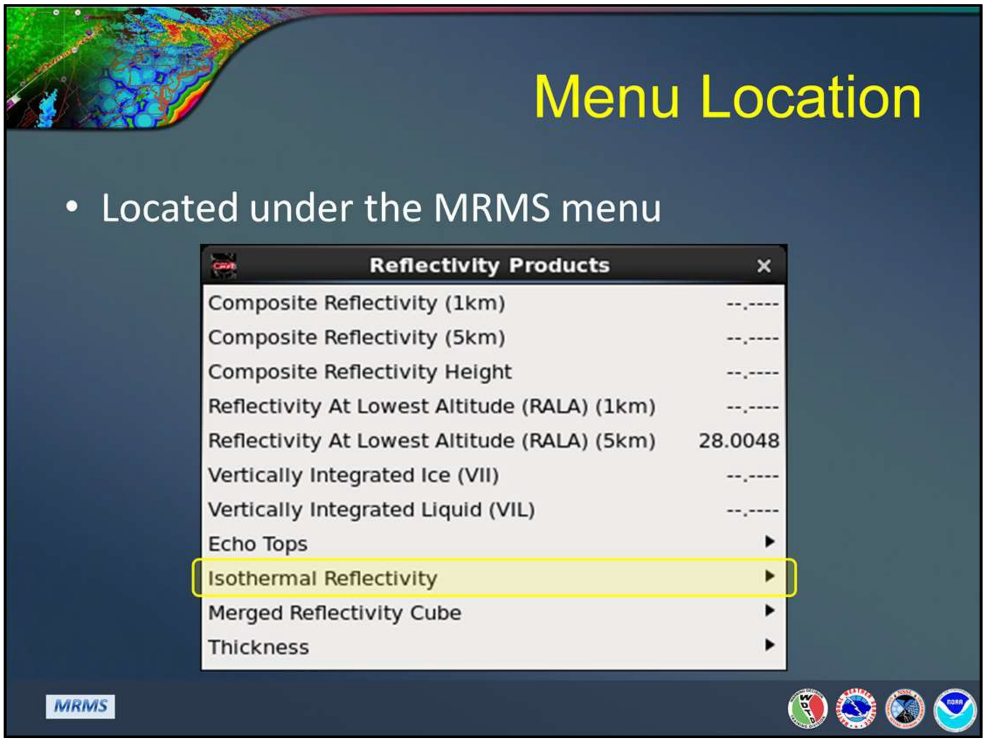


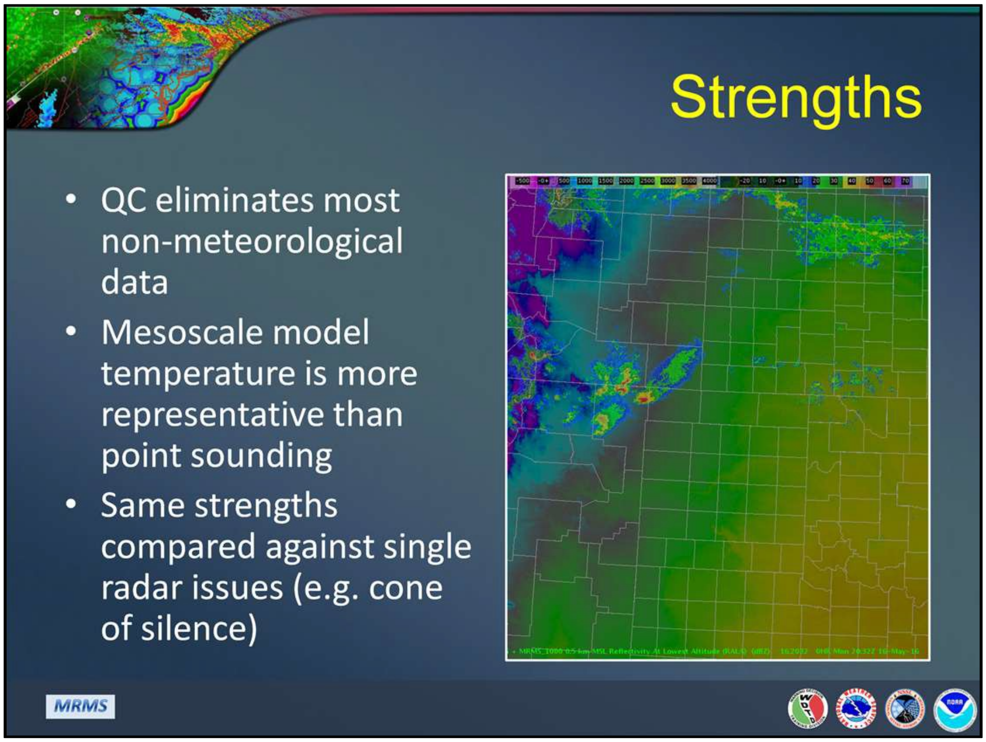
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. There will be a quiz at the end of this lesson based on these objectives.



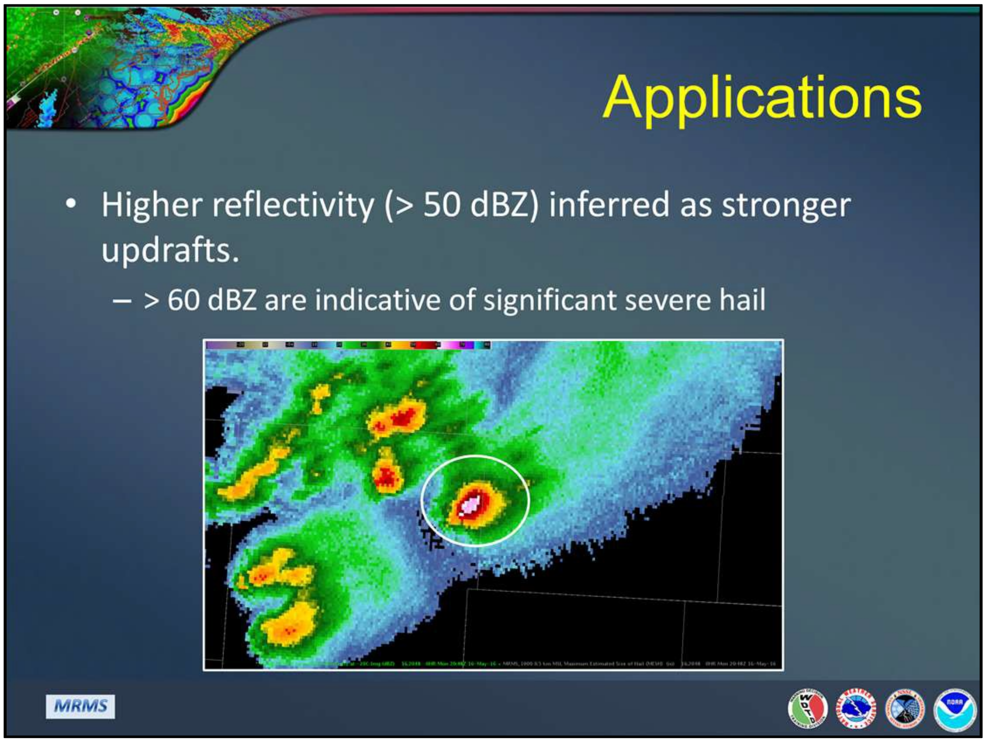
The isothermal reflectivity product at -20°C is derived from the 3D reflectivity cube by finding the reflectivity value within the cube that resides at -20°C based on the RAP temperature profile. Its spatial resolution is 1 km x 1 km and is updated every 2 minutes.



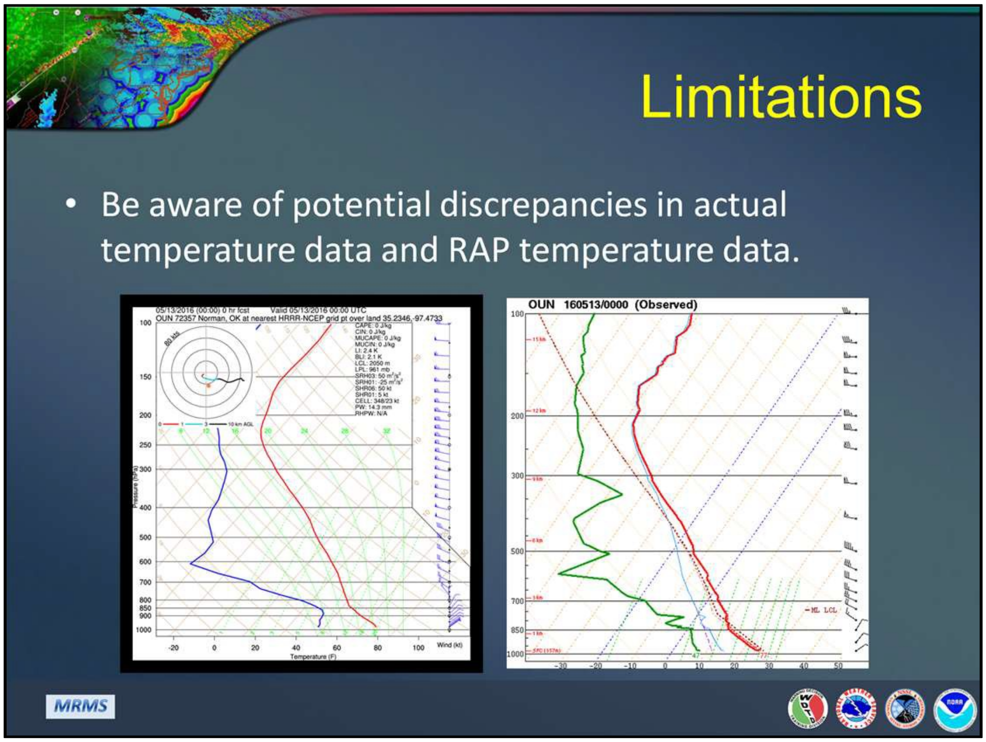
This isothermal reflectivity product can be found within the MRMS menu located in your CAVE display.



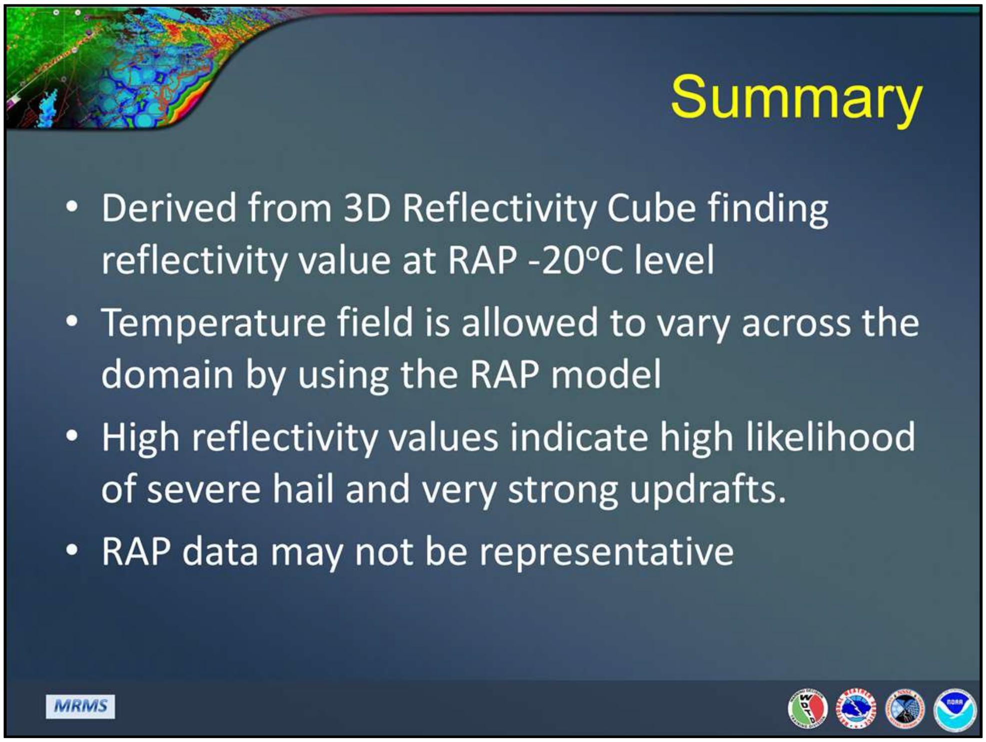
While most non-meteorological data will not contaminate echoes at or above the -20^{o}C level, it is still worth noting that non-meteorological data is still filtered out by the QC algorithm. Because temperature heights are never constant across a particular domain (as is shown here in this example where I have plotted the bright banding height across the MRMS domain), applying a mesoscale temperature field instead of uniformly applying a point sounding results in more accurate interpretations. Notice how the bright banding heights vary by as much as 2,000 feet. Finally, all strengths associated with MRMS vs single radar analysis are still valid (e.g. mitigating cone of silence).



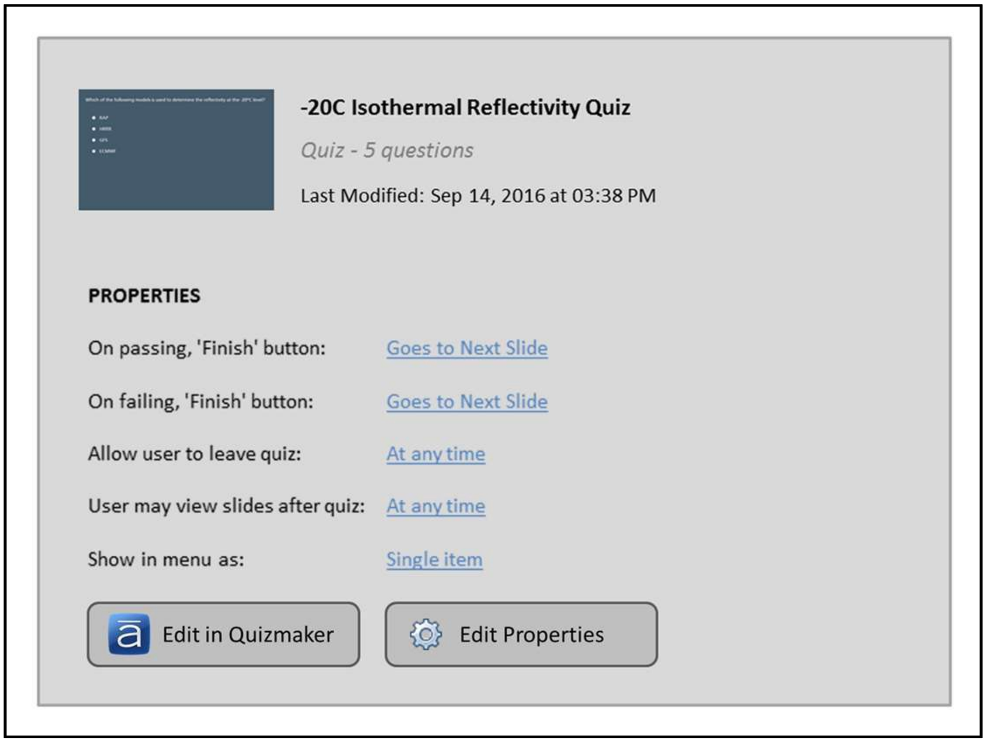
At this temperature level, higher reflectivity, especially above 50 dBZ, will more likely indicate very strong storms (e.g. updrafts) with increasing likelihood of severe hail. In fact, reflectivity values greater than 60 dBZ are indicative of significant severe hail (greater than golf ball sized). Here is an example from a few storms in New Mexico. The most intense storm in the middle of the image has a significant area of Z > 60 dBZ at -20^{o}C. This suggests there is likely significant hail in this storm and this storm has the strongest updraft of all the storms present.



The only limitation to using the -20^{o}C isothermal reflectivity product is to be aware of the potential discrepancies in actual temperature data vs. the RAP temperature data. There can be model biases that may inhibit your interpretations. This example here shows a RAP sounding on the left and the corresponding actual sounding on the right. Notice that they agree pretty well all the way through, but it's still good to double check.



In summary, this isothermal reflectivity product is derived from the 3D Reflectivity Cube by finding the reflectivity value at the -20°C using the RAP model. Using the RAP model allows for temperature to vary across the MRMS domain, whereas using a single point sounding does not allow for this temperature variation. High reflectivity values in this region most likely indicate strong updrafts, and likely severe hail. One caveat with this product is the RAP data may not be representative due to potential model biases, etc. Up next will be the quiz.


-20C Isothermal Reflectivity Quiz
Quiz - 5 questions
Last Modified: Sep 14, 2016 at 03:38 PM
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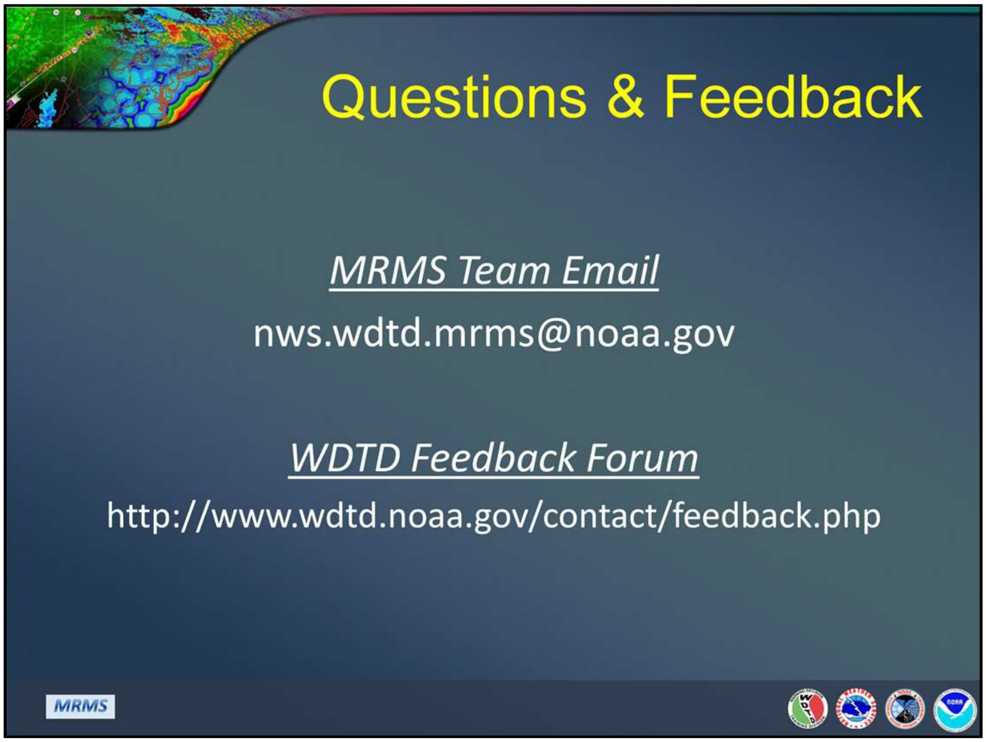
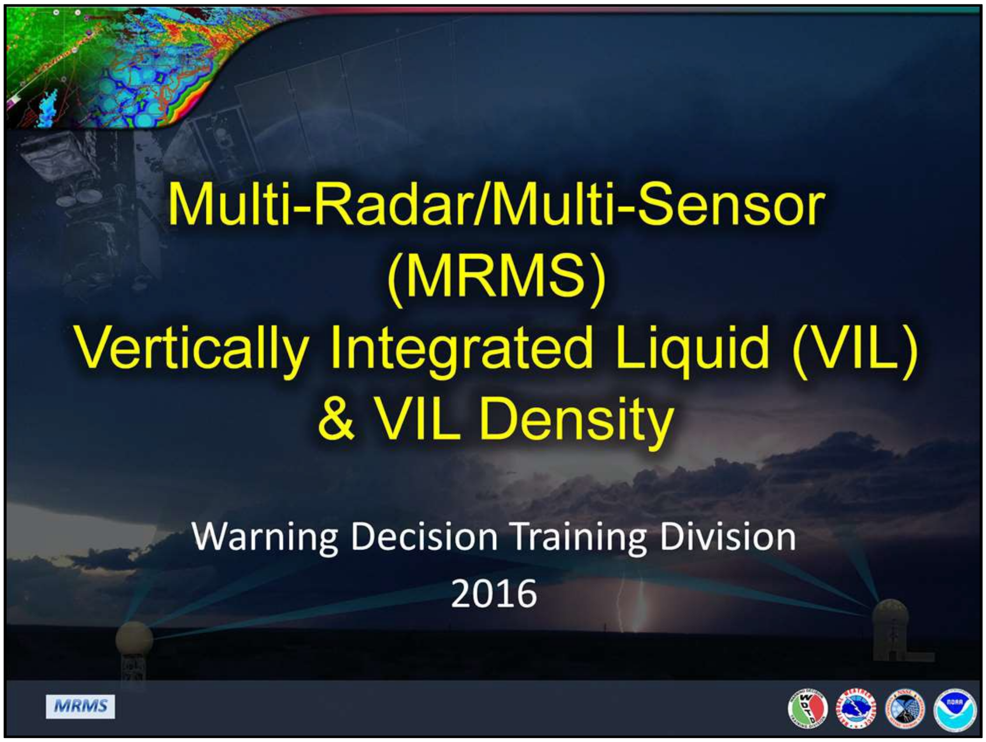
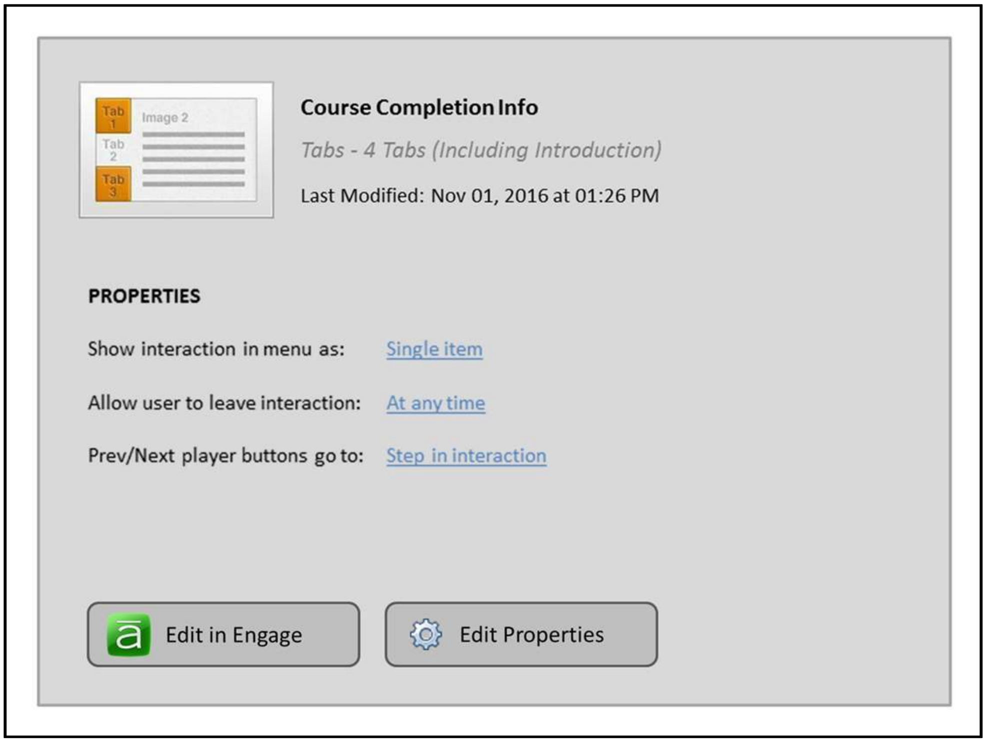


Thanks for completing this module on Isothermal Reflectivity at -20^{o}C. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Vertically Integrated Liquid (VIL) and VIL Density developed at the Warning Decision Training Division (WDTD).



Tab 1
Image 2
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Tab 3
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Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 01, 2016 at 01:26 PM
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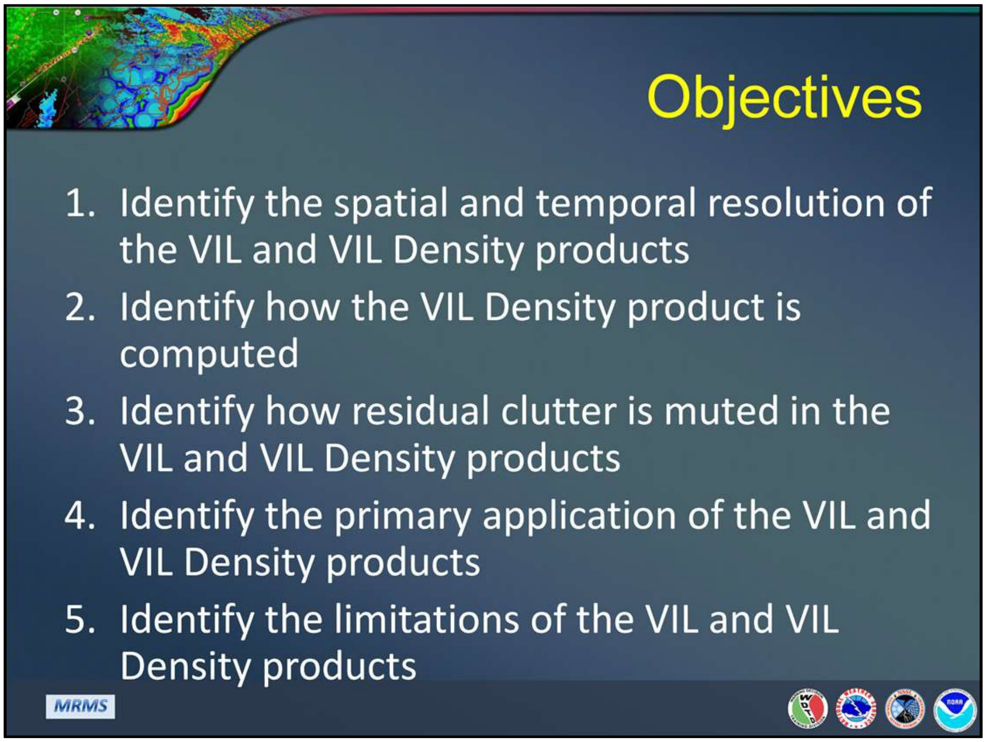
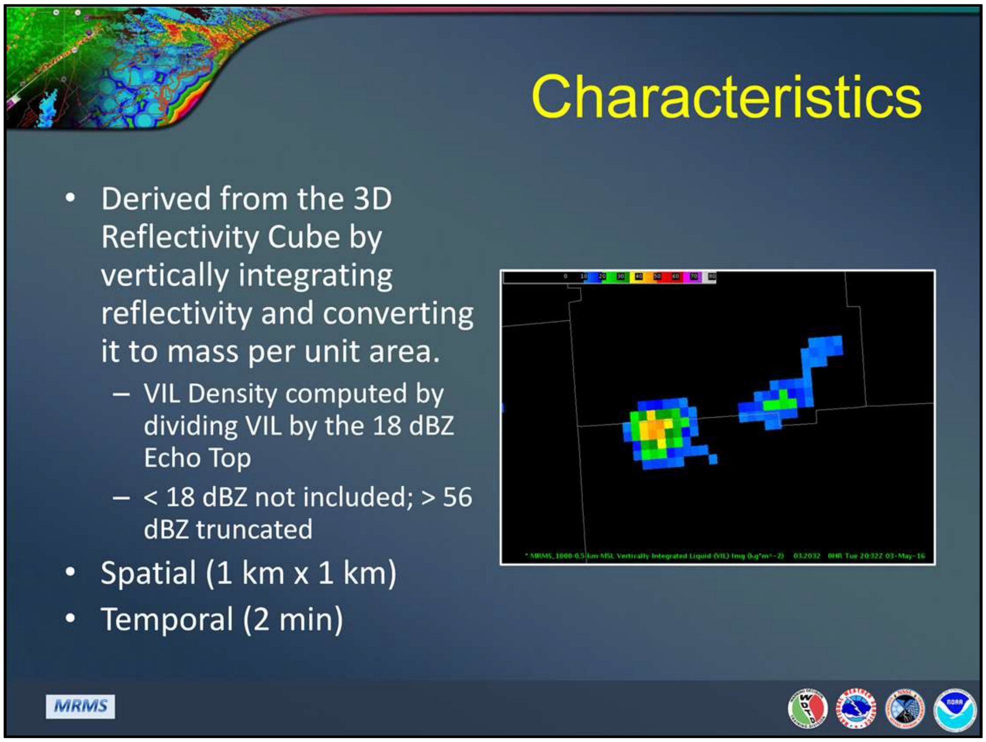
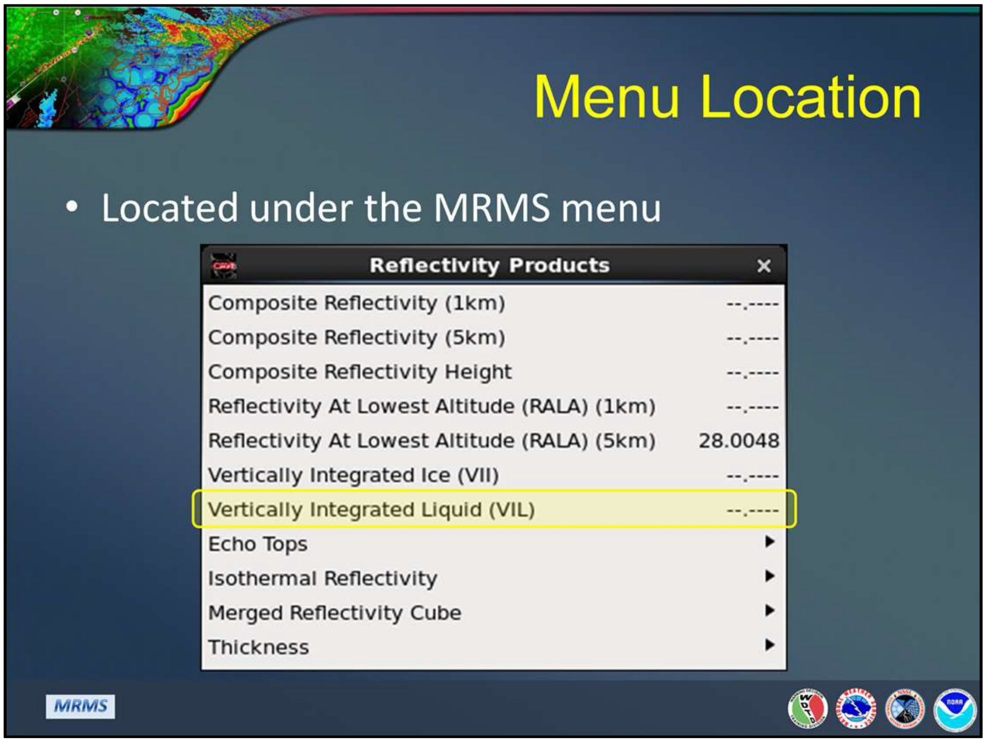


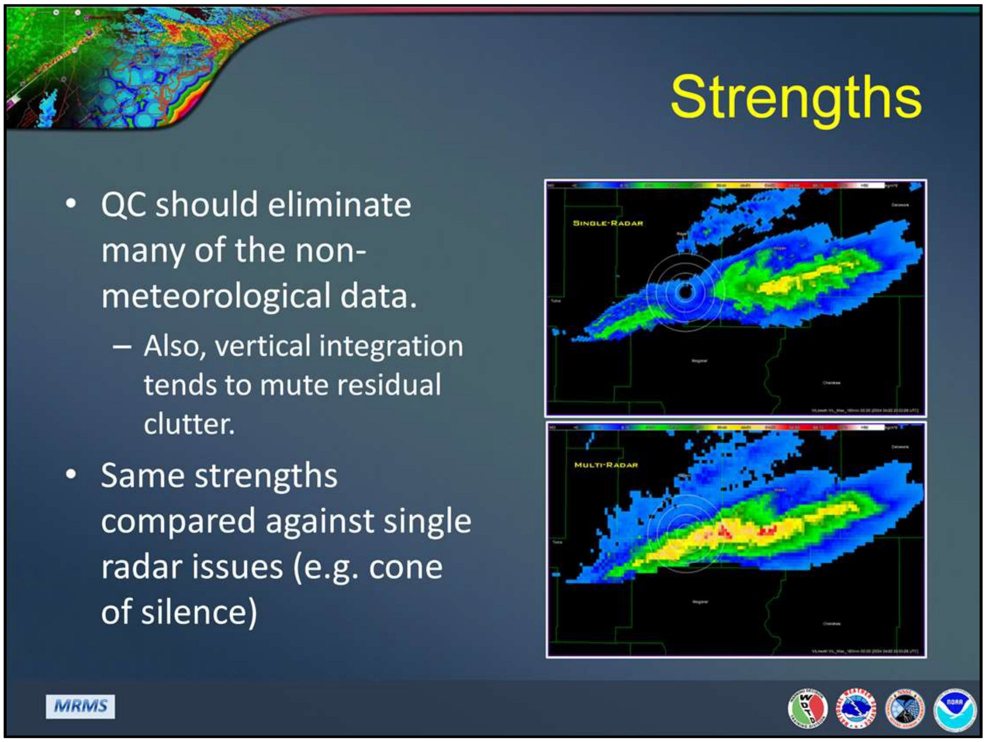
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. There will be a quiz at the end of this lesson based on these objectives.



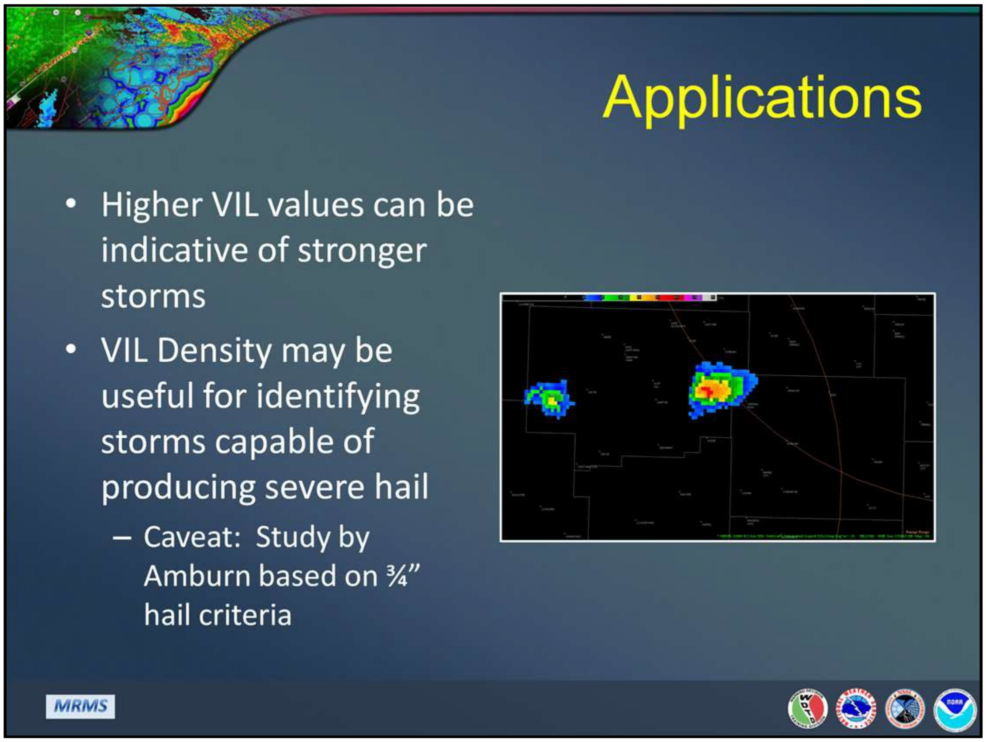
The VIL product is derived from the 3D Reflectivity Cube by vertically integrating the reflectivity and converting it into a mass per unit area. To help account for strong storms that are not deep (e.g. mini supercells), the VIL Density product was born, which is just the VIL value divided by the 18 dBZ Echo Top. Recall for VIL, values of reflectivity less than 18 dBZ are not included and values of reflectivity greater than 56 dBZ are truncated to 56 dBZ. The spatial resolution is 1 km x 1 km and the products are updated every 2 minutes.



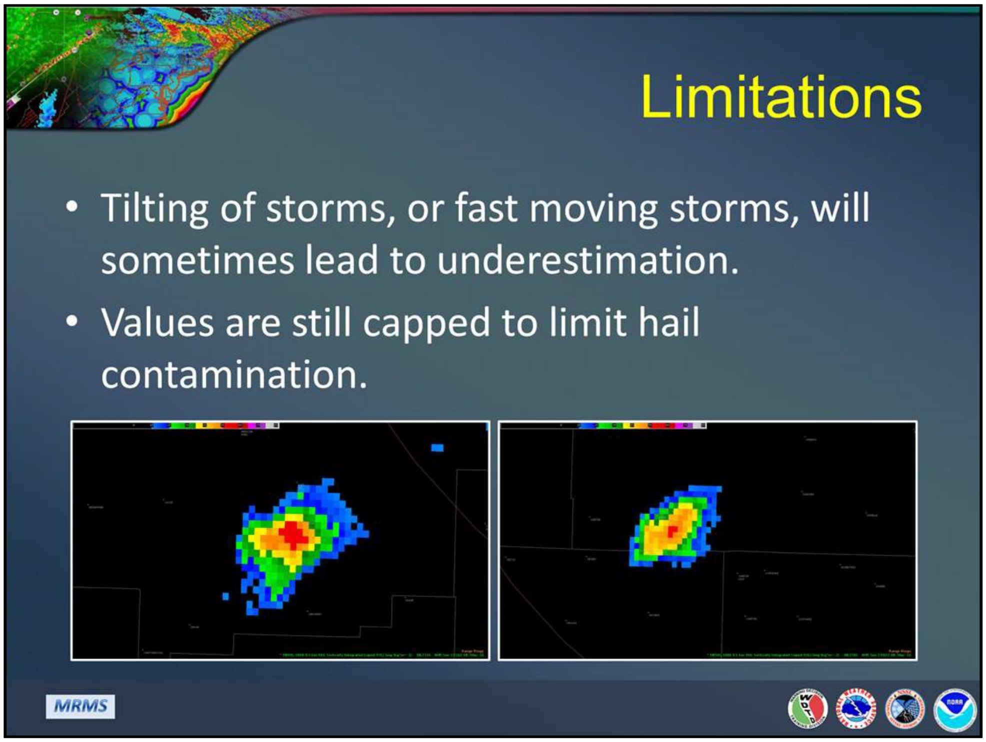
The VIL and VIL Density products can be found within the CAVE toolbar underneath the MRMS menu.



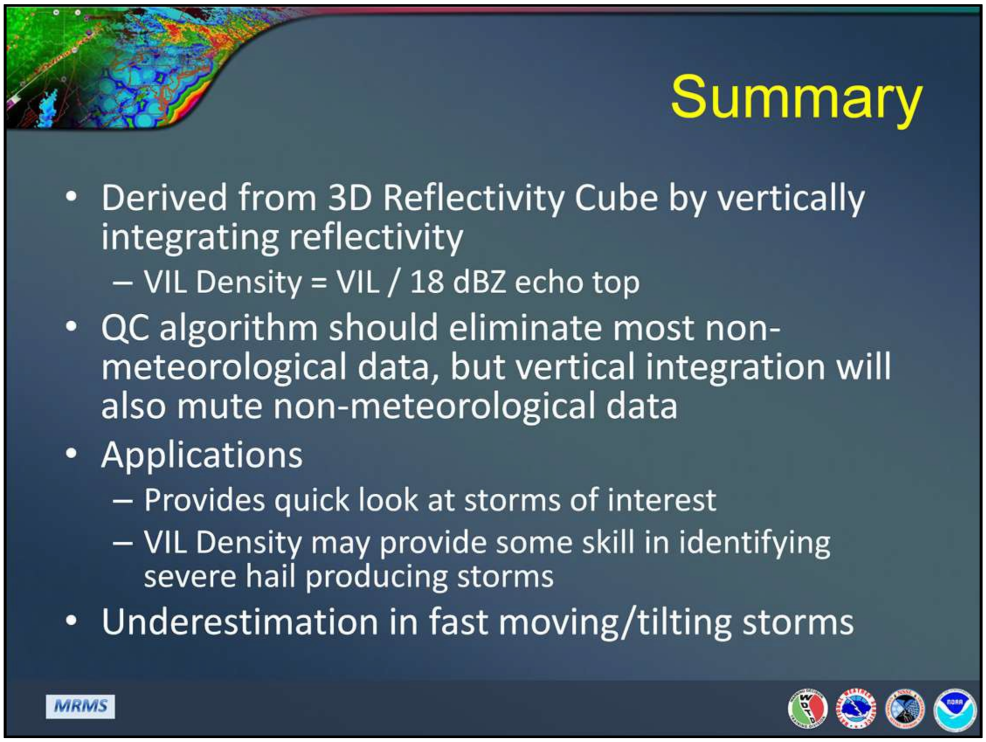
A major strength of the 3D Reflectivity Cube is the QC algorithm which attempts to remove any contamination by non-meteorological echoes. However, some non-meteorological data do make it through the QC. In the case of VIL and VIL Density, because there is vertical integration, these products will tend to mute any residual clutter since the vertical integration over most non-meteorological echoes (e.g. clutter) will tend to be very low. Finally, the same strengths compared against single radar analysis will be valid (e.g. cone of silence).



Higher VIL values result from higher reflectivity values throughout the vertical column. Therefore, higher VIL values can be a good indicator of stronger storms. So, VIL can be useful for quickly identifying storms of interest. For hail producing storms, a study by Amburn and Wolf in 1997 showed that by using VIL Density, there is some skill in delineating severe vs non-severe hail producing thunderstorms. This study was based on ¾” hail being the severe threshold, and no work since has been done to update the thresholds derived by Amburn and Wolf.



Because VIL is a vertical integration, if a storm is moving fast or highly tilted, the vertical integration may not capture the highest reflectivity values throughout the depth of the actual storm resulting in underestimation of VIL. Here are a couple examples. The image on the left is from a storm that was moving slowly to the east, and the image on the right is from a left split that was moving much faster to the northeast. Notice how the slower moving storm had slightly higher values that were over a larger area, where the fast moving storm had slightly lower values over a smaller area. Additionally, remember that VIL truncates all reflectivity values above 56 dBZ to limit the contamination from hail.



In summary, the VIL product is created by vertically integrating reflectivity through the depths of each grid column. The VIL Density product is created by dividing VIL by the 18 dBZ echo top height. The QC algorithm eliminates most non-meteorological data, but for the residual clutter, vertical integration will tend to mute that residual clutter. The primary application of VIL is to quickly identify storms of interest without having to do a full all-tilts analysis. VIL Density has shown some skill in identifying severe hail producing storms. Finally, remember that VIL can be underestimated in fast moving or tilting storms. Up next will be your quiz!


VIL and VIL Density Quiz
Quiz - 5 questions
Last Modified: Sep 14, 2016 at 04:04 PM
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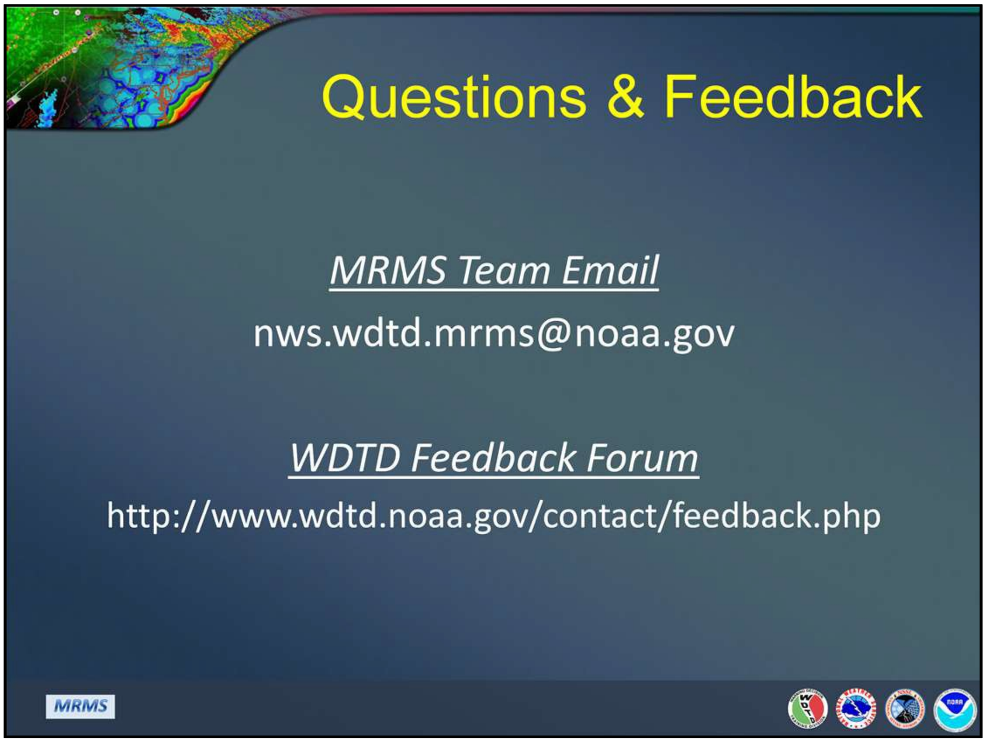
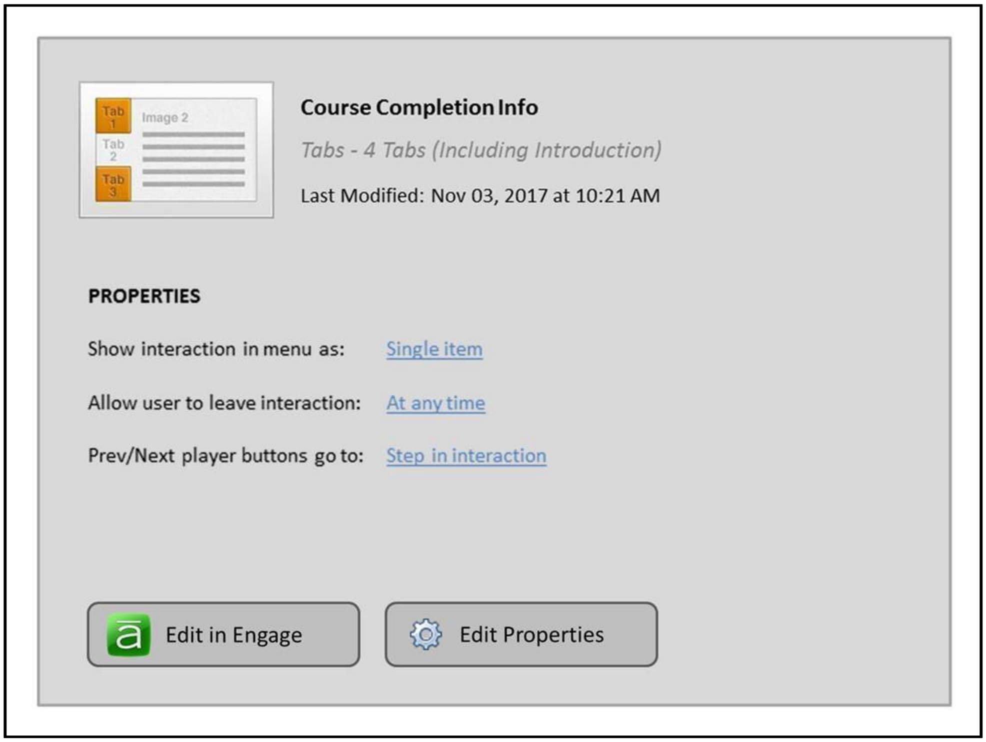


Thanks for completing this module on VIL and VIL Density. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.

Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Vertically Integrated Ice (VII) developed at the Warning Decision Training Division (WDTD).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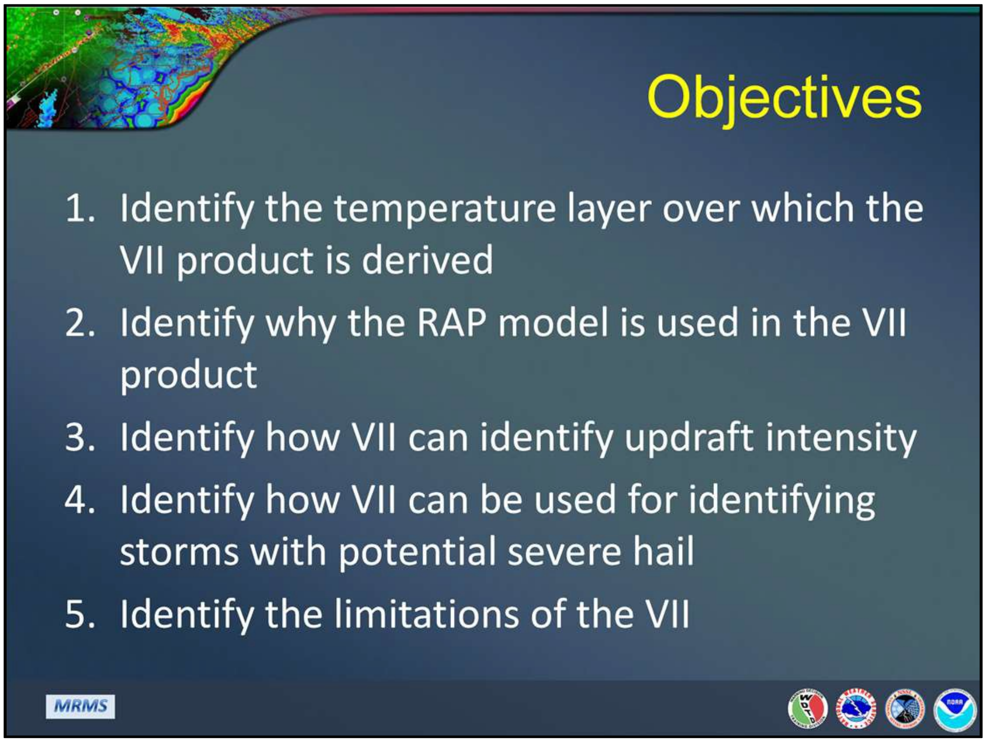
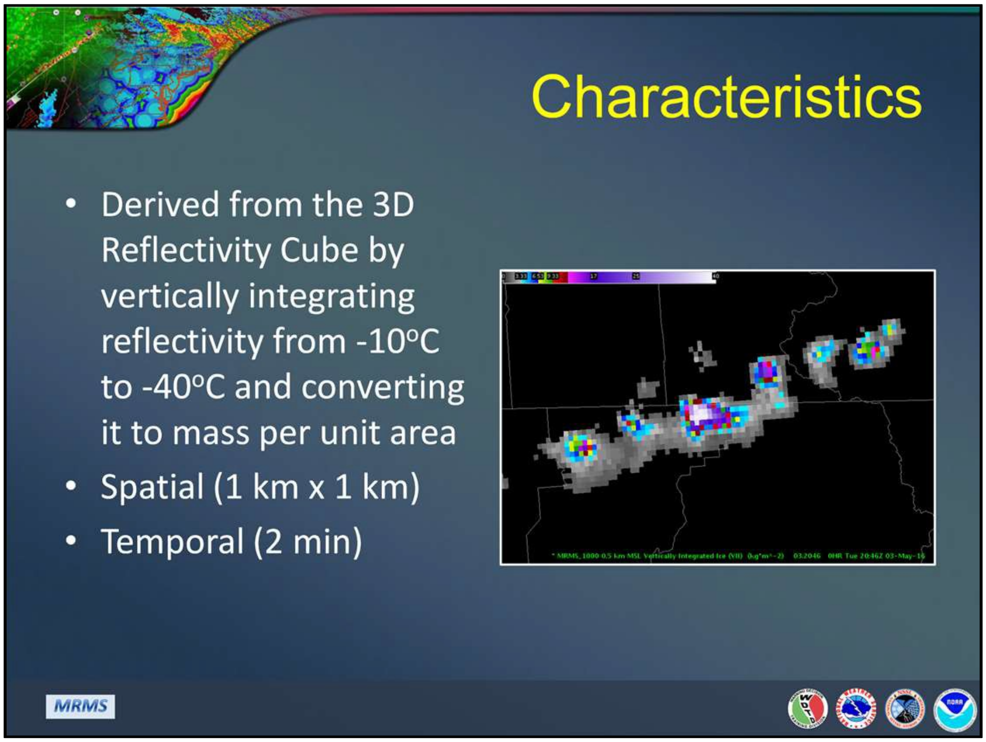
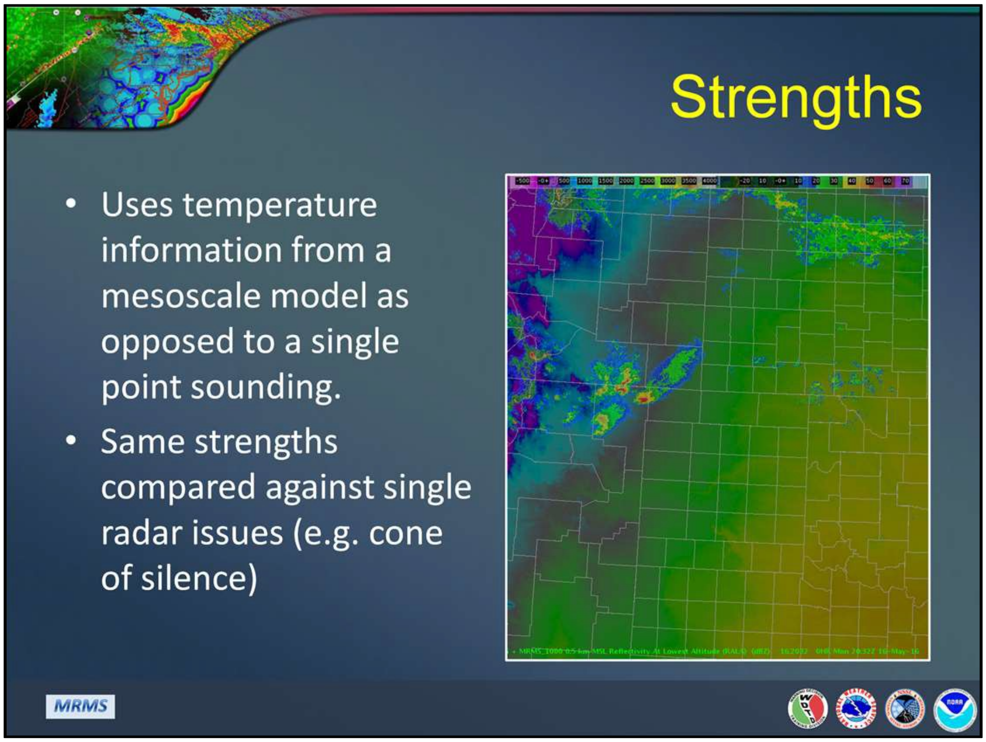


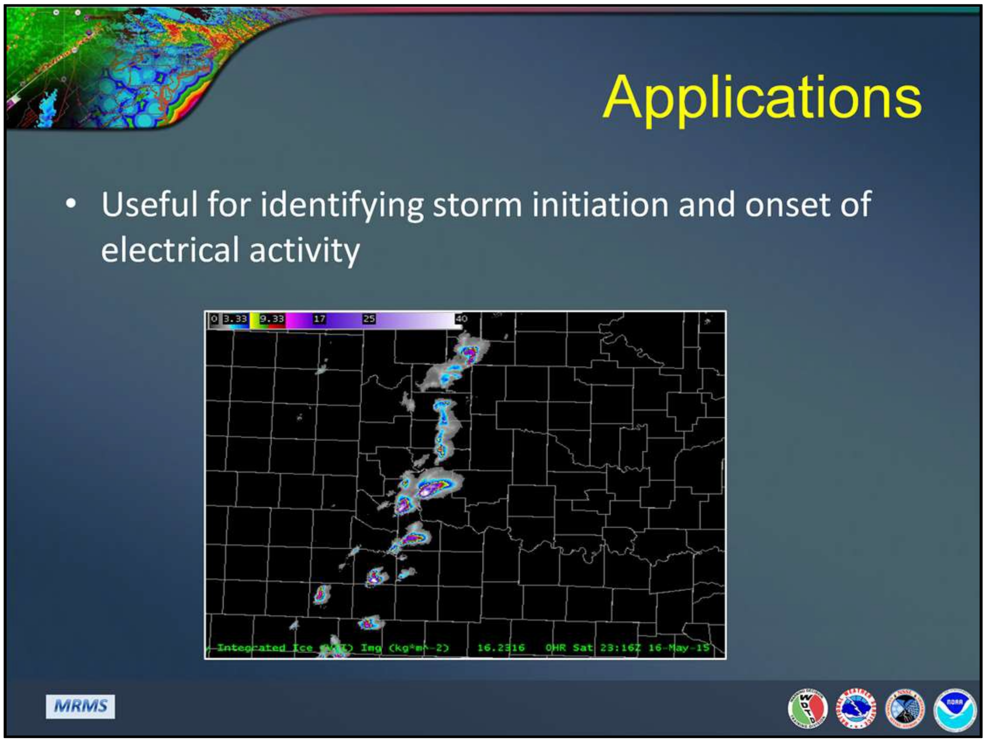
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. The quiz at the end of this lesson is based on these objectives.



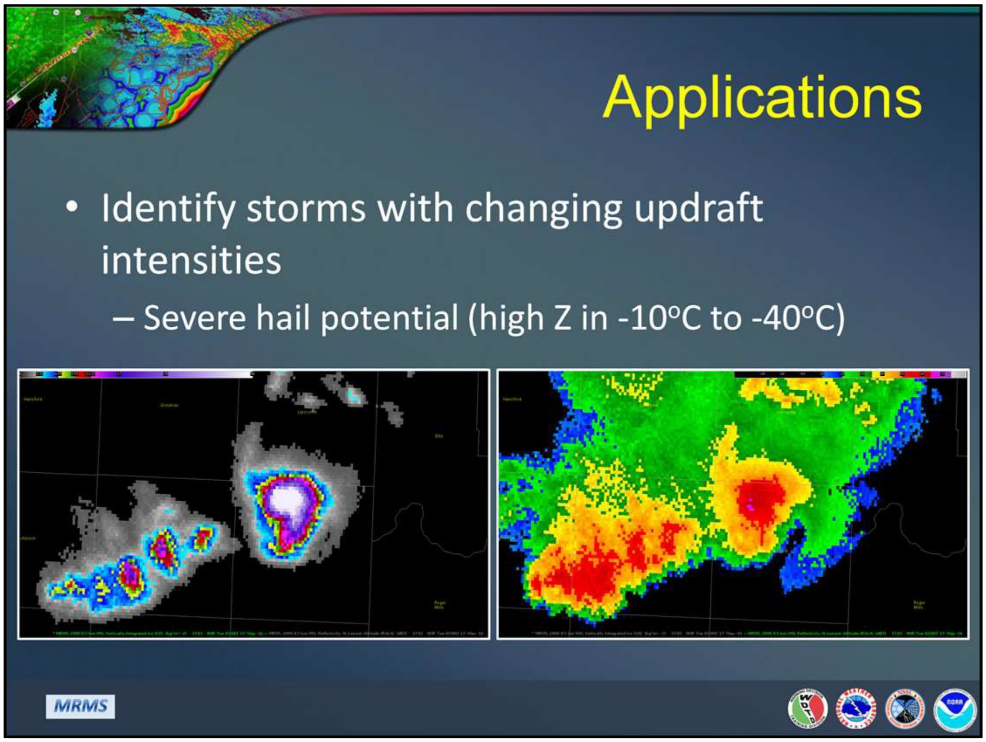
The VII product is derived from the 3D Reflectivity Cube by vertically integrating the reflectivity in the temperature region of -10^{o}C and -40^{o}C, as defined in the RAP model, and converting it into a mass per unit area. The spatial resolution is 1 km x 1 km and the products are updated every 2 minutes.



The temperature layer used for integration comes from the RAP model so the temperatures applied are allowed to vary across the domain and not tied to a single point sounding. In the example on the right, notice how the melting level height varies by as much as 2,000 feet across the domain. Therefore, applying a uniform temperature from a point sounding would not make much sense in this case. Additionally, the same strengths of MRMS compared to single radar still apply (e.g. cone of silence).

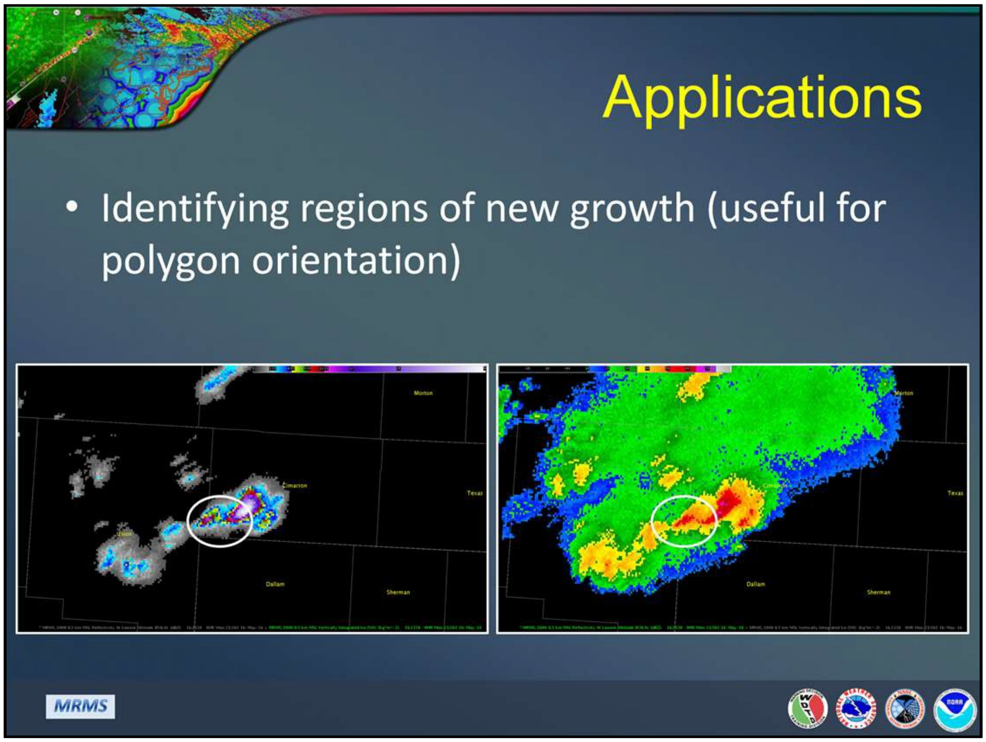


The VII product has many uses in operations. First, it is great for identifying convective initiation and storms at the onset of electrical activity. Here is an example from western Kansas. On the left is VII, and on the right is Reflectivity at Lowest Altitude (RALA). Notice in the first time period, VII values begin to appear and there are some moderate reflectivity in the low levels. Stepping forward about 15 minutes later and now VII has increased in value and coverage. Notice how RALA has also increased in value and coverage. And, if we step forward another 30-40 minutes, this storm has become severe. In 2017, the lowest VII value threshold was lowered to 0.5 kg*m^-2. This permits even earlier detection of deep convection initiation.

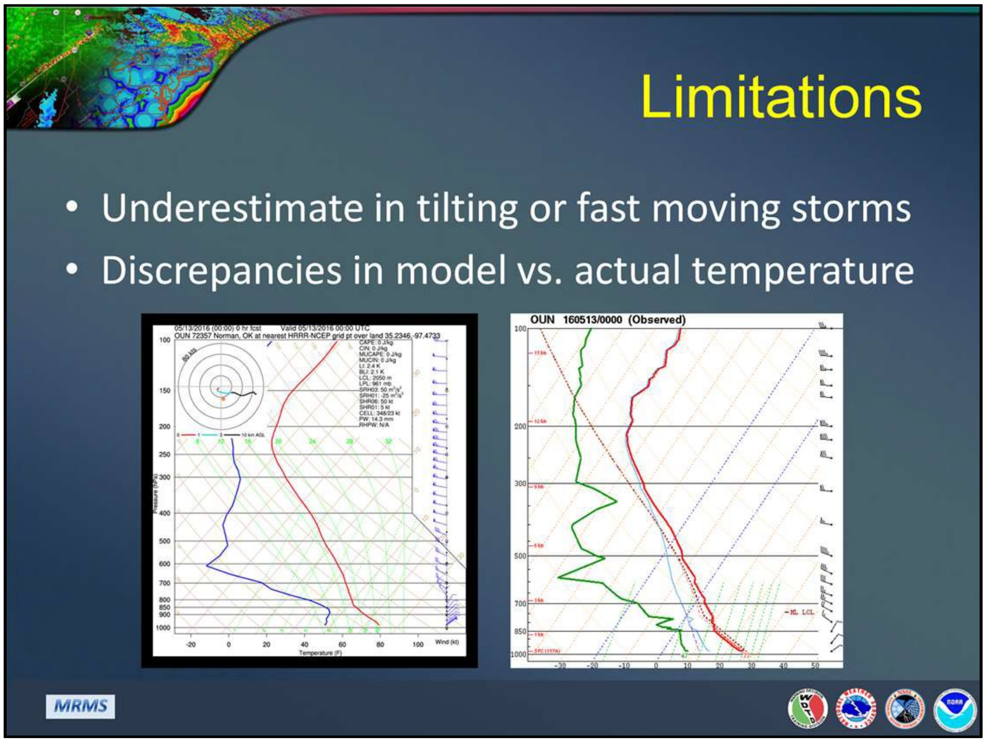


Rapid increases in VII can be used as a proxy for identifying intensifying updrafts. A dramatic decrease in VII can also indicate decreasing intensity in updrafts. Here is an example of two storms in the Texas panhandle. The western-most storm appears strongest in the RALA product and if we look at VII, the values are fairly similar between the two. However, as we step forward in time, we can see the eastern-most storm develops much larger VII values, and by the last frame, the eastern-most storm now appears stronger. Therefore, we might want to interrogate this storm a little further to identify possibly large hail, etc.

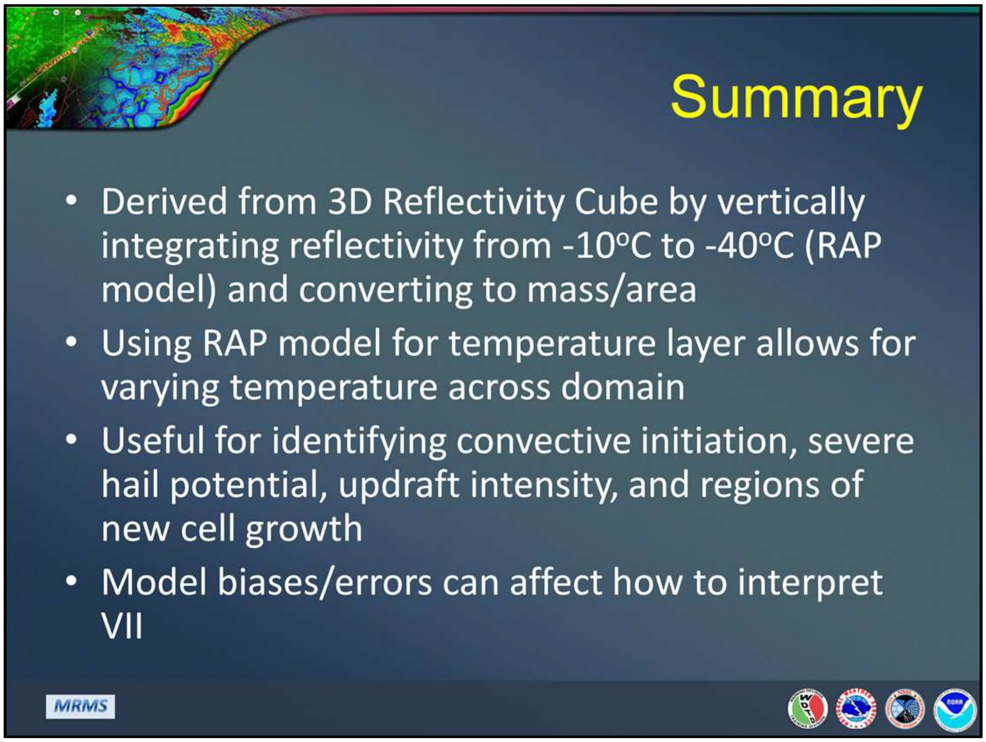
One other application tied to updraft intensity is severe hail potential. Because the integration of reflectivity is between -10°C and -40°C, and high reflectivity in this temperature range is often associated with severe hail, then high VII values might be a good indicator of increased severe hail potential.



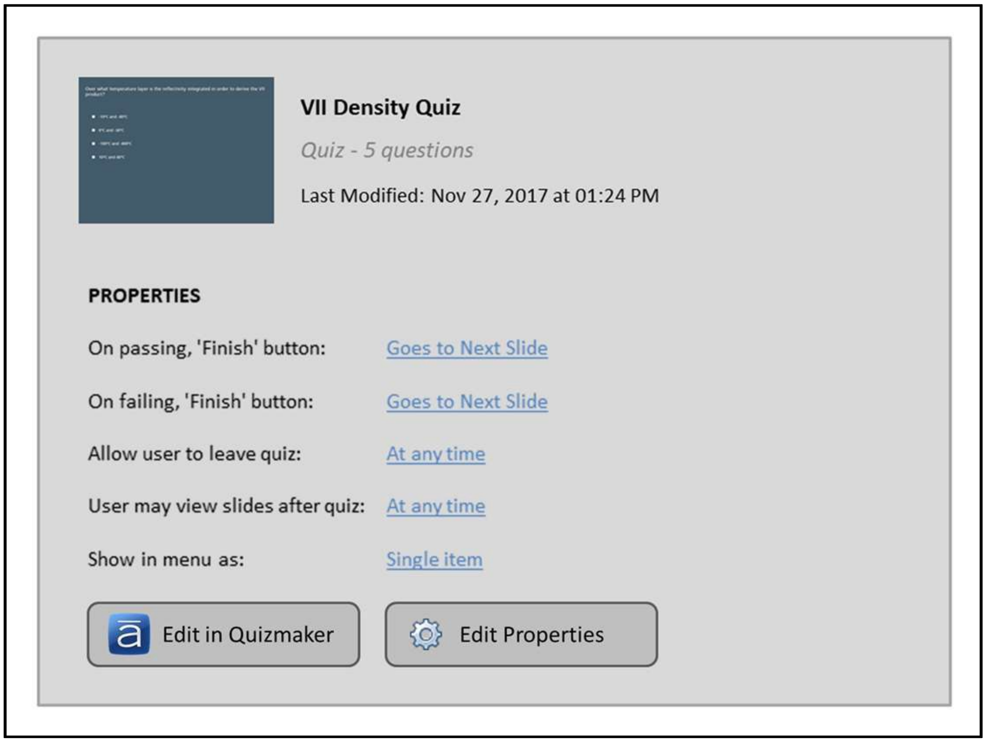
Finally, VII can be used to identify new regions of updrafts and help orient warning polygons to better follow the threats. In this example, notice how it appears there is new development to the southwest of the main storm. Being able to identify this new development before low level features reflect this new development can help you better orient polygons so that new development does not occur outside your polygon.



Just like the VIL product, fast moving storms may result in underestimation of the VII. However, this limitation is less of a factor because of the shorter depth of integration. And, stay aware of the fact the temperature layer used for integration comes from the RAP model. If they RAP model is not representative of the actual atmosphere, then there could be some errors in interpreting the VII product.



In summary, the VII product is created by vertically integrating reflectivity through the depths of each grid column from -10°C to -40°C using the RAP model for the temperature layers. Using the RAP model allows for varying temperature across the domain which is more representative than a single point sounding. Some of the applications of VII are identifying areas experiencing convective initiation, severe hail potential, and regions of new cell growth useful for polygon orientation. Finally, remember RAP model biases/errors can affect how to interpret VII.


VII Density Quiz
Quiz - 5 questions
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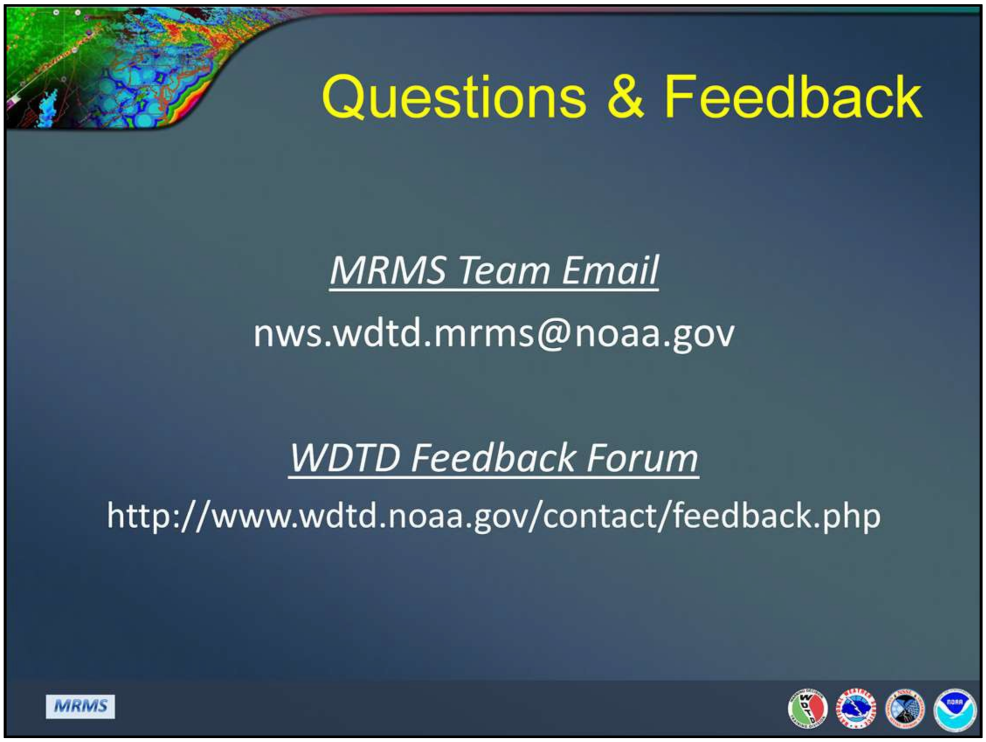
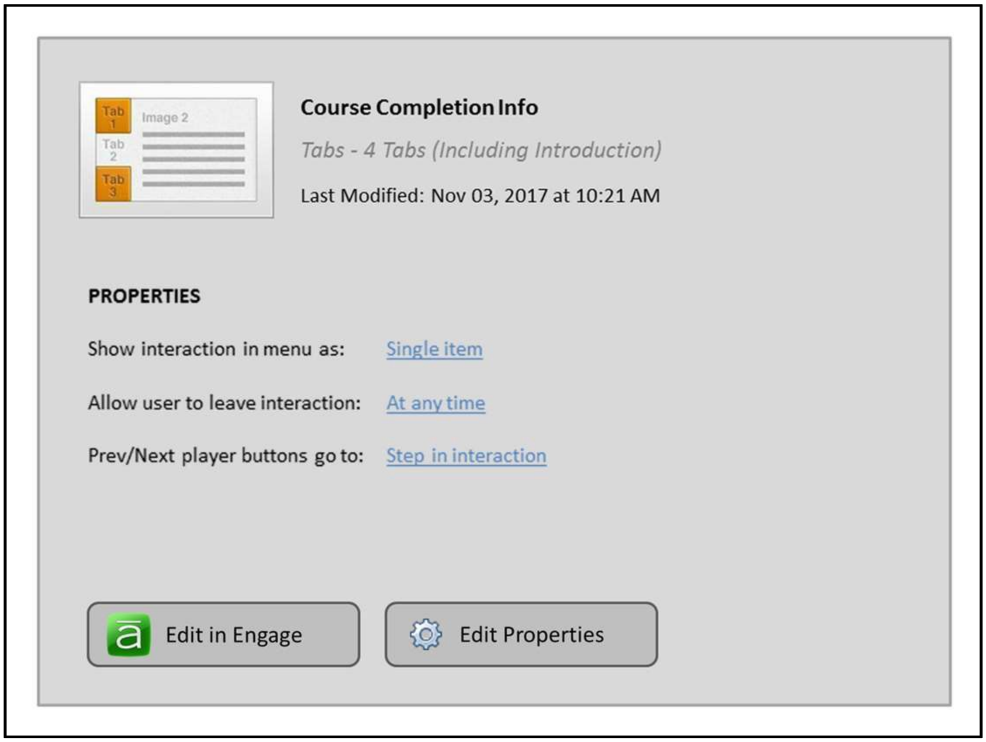


Thanks for completing this module. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses here.

Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Echo Tops (ETs) developed at the Warning Decision Training Division (WDTD).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Last Modified: Nov 03, 2017 at 10:21 AM
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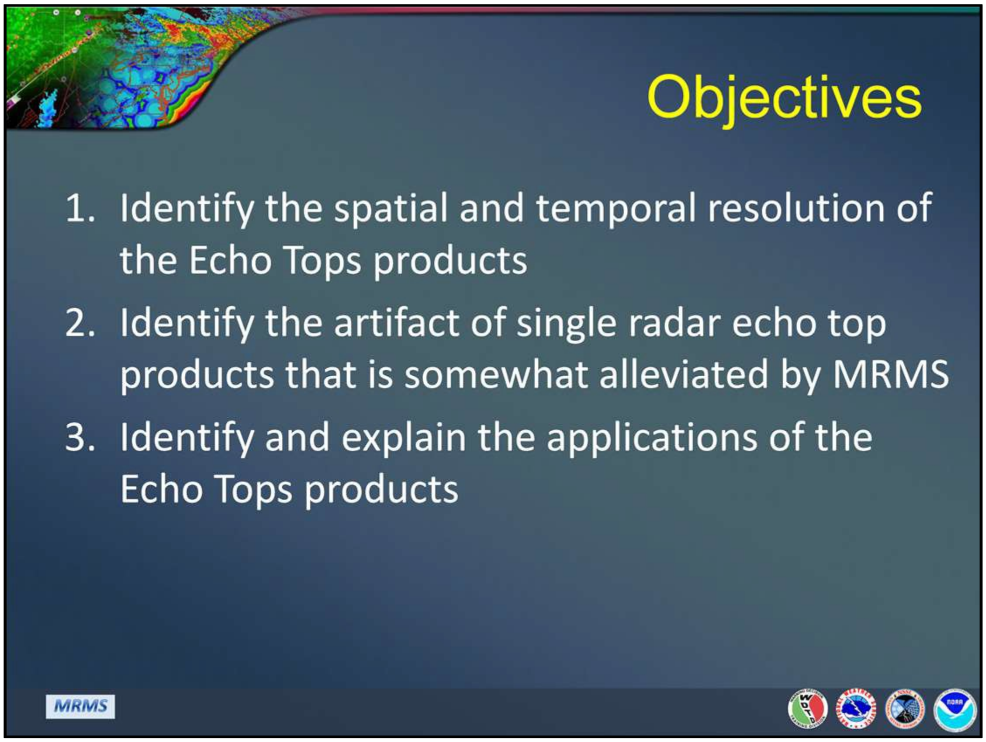
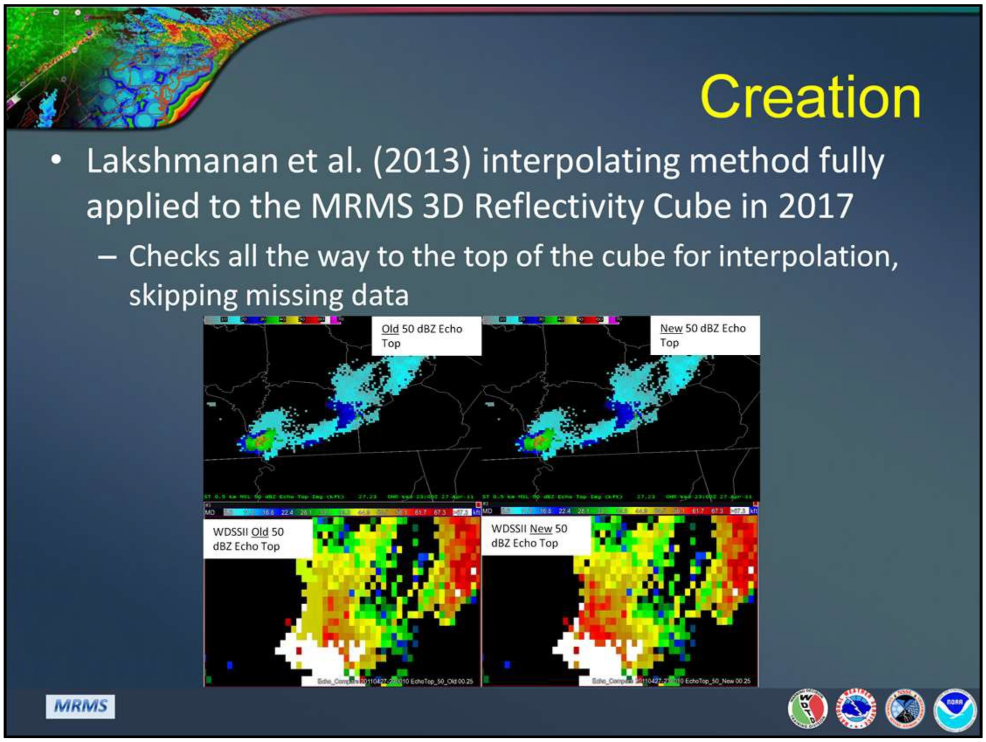
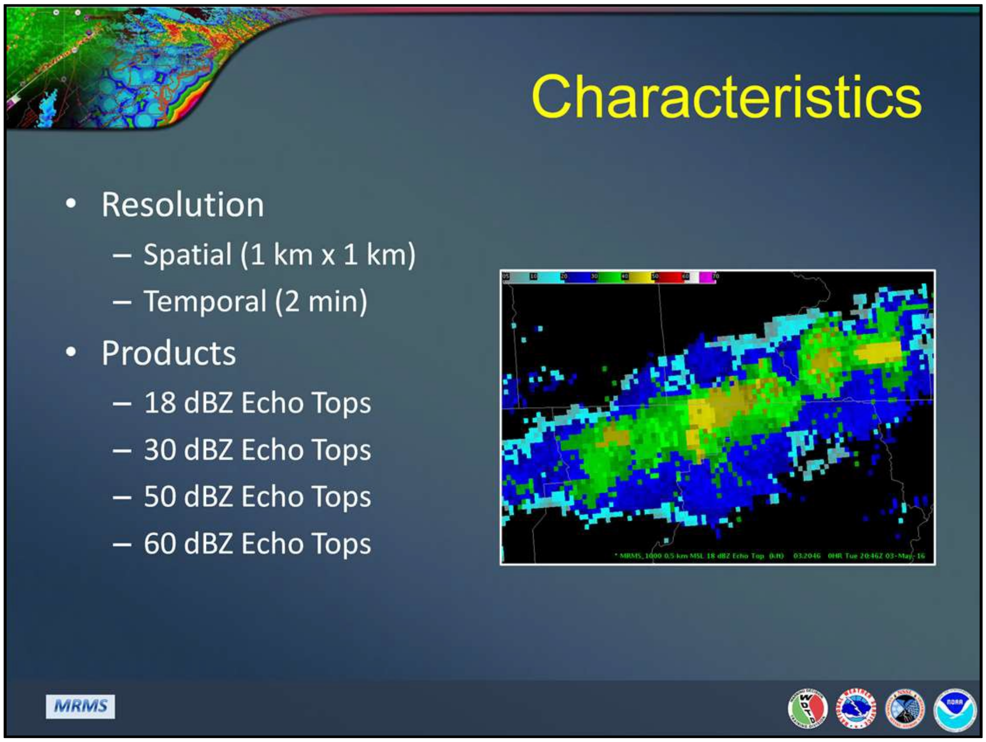


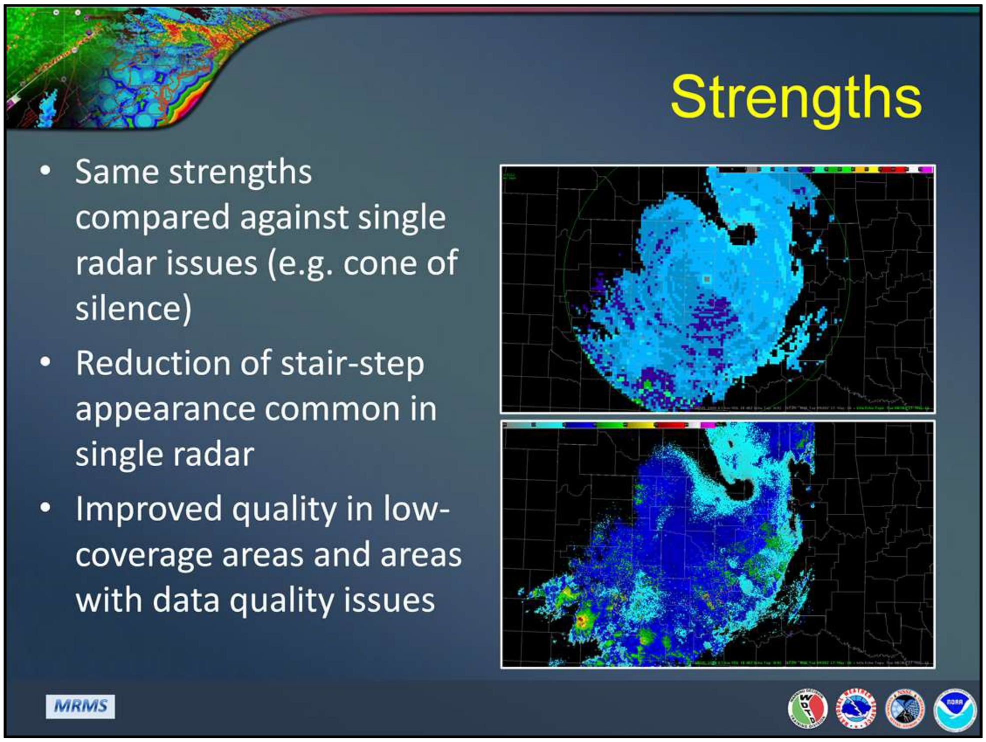
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. You will be tested on these objectives at the end of the lesson.



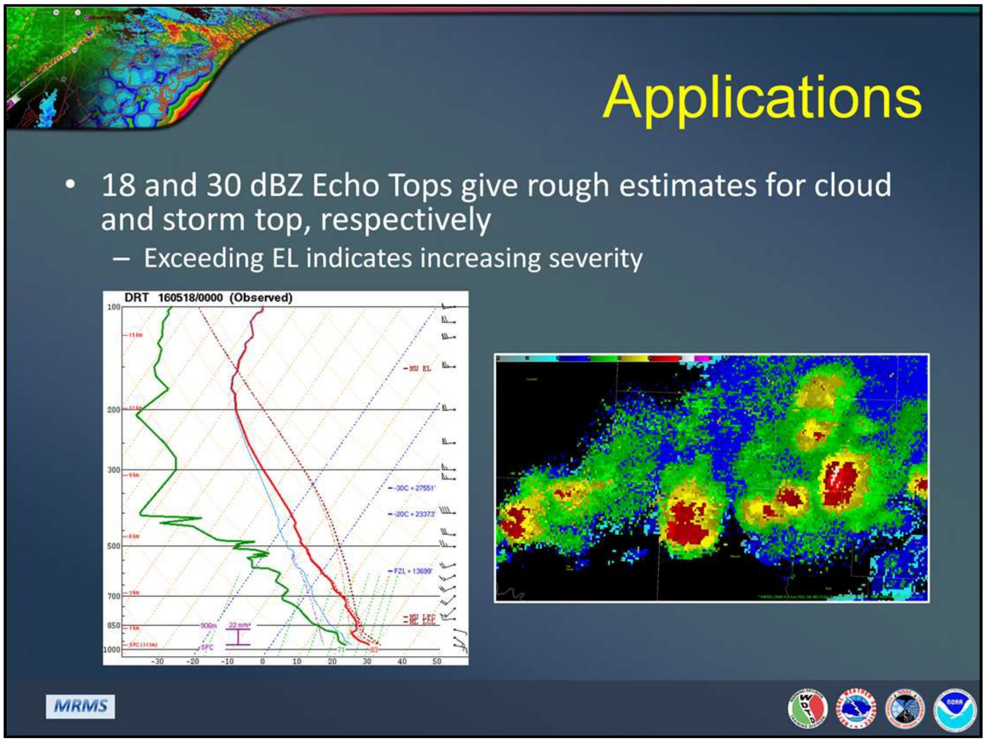
As of 2017, the echo top products are created using the elevation angle interpolation method detailed in Lakshmanan et al. (2013). Instead of simply selecting the highest elevation within a volume, this method interpolates between elevation scans to get a more accurate estimate of the echo top. Additionally, the MRMS algorithm now checks the entire 3-D cube to find elevation scans to interpolate. If an elevation angle above a certain threshold is missing, it will keep checking until it finds another, then will interpolate between the two, and so on. This figure compares the new product with the old method that did not look for non-missing data. The AWIPS dsiplay is on the top and the National Severe Storms Lab Warning Decision Support System: Integrated Information display, whose color curve more markedly shows the improvement, is on the bottom.



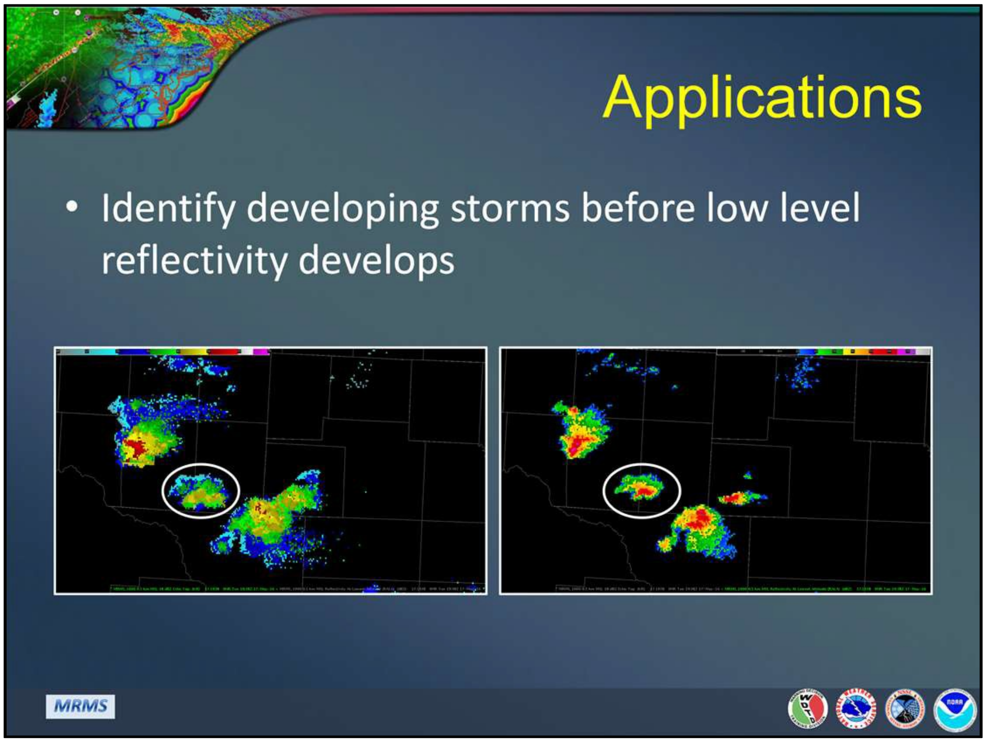
The spatial resolution of the echo top products is 1 km x 1 km and is updated every 2 minutes. 18, 30, 50, and 60 dBZ echo tops are available via the MRMS menu in CAVE.



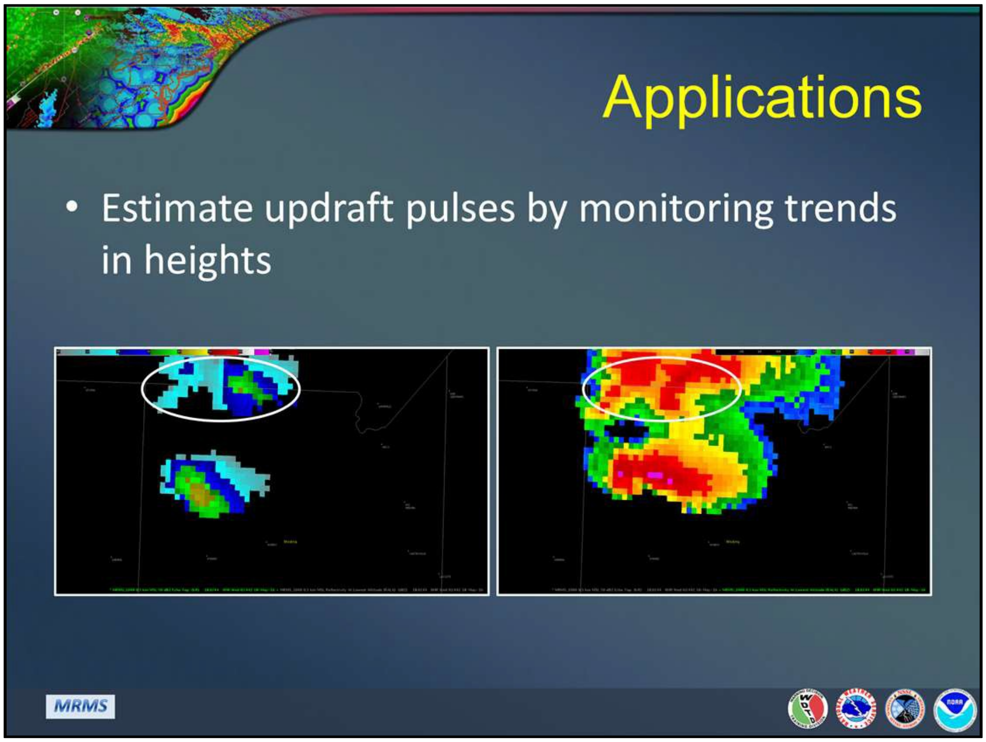
The same general strengths for MRMS also apply to the Echo Top products (e.g. cone of silence). One particular strength to mention is in single radar echo top products there is the stair step appearance due to the scanning strategy. With multiple radars scanning the same areas in MRMS, the stair step appearance is somewhat mitigated. In addition, the 2017 interpolation method improves quality in low-coverage and low-data quality areas.



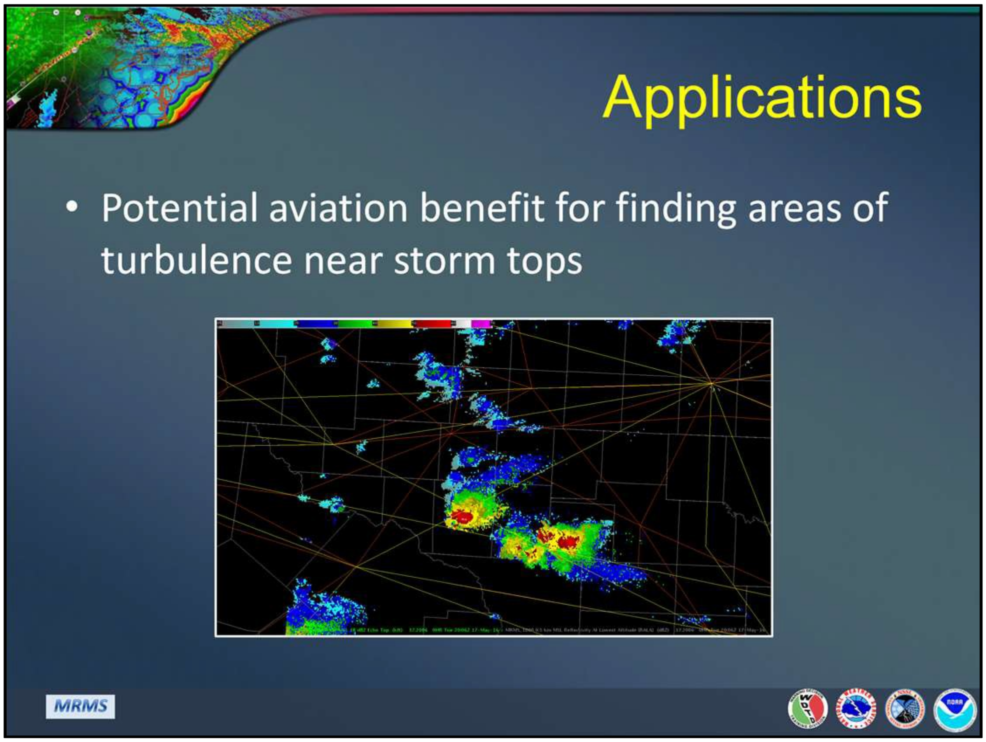
The lower dBZ Echo Top products can give rough estimates of cloud and storm tops, respectively. Here's an example of how 18 dBZ ET can be used to estimate a cloud top. If these echo top values exceed the equilibrium level height, then you can confidently say those storms are experiencing overshooting tops, indicating more severity. Here is an example from south Texas where the EL from the sounding was approximately 45,000 feet. The 18 dBZ Echo Tops were exceeding 50-55 kft.



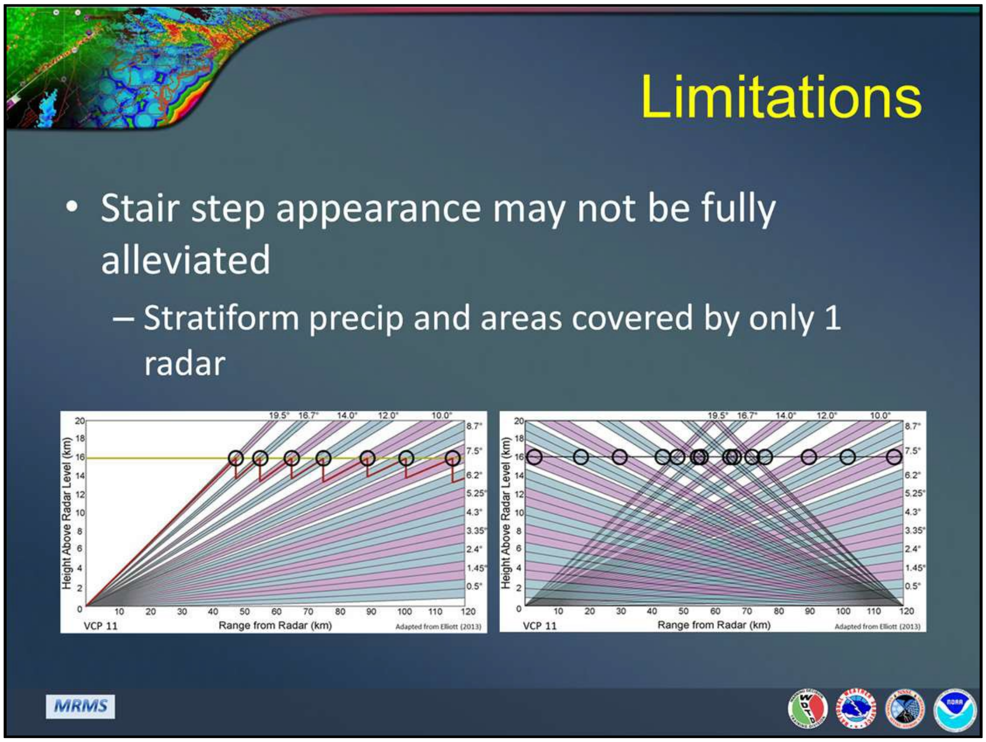
Again the lower dBZ echo tops can come in handy. They can detect echoes that occur aloft before reaching the ground early on in a storm's lifecycle. Therefore, for example, the 18 dBZ Echo Top may appear aloft before any echoes show up in the low levels. Here's an example in SW Texas. Notice in the 18 dBZ echo tops (left) there are values approaching 20 kft in an environment favorable for thunderstorm development, and yet there is no corresponding reflectivity at the lowest levels. If we step through the next few frames, we see the 18 dBZ echo top increase in value and areal coverage and the low level reflectivity responds in intensity. By monitoring the 18 dBZ echo tops, this product could have given you a few extra minutes lead time for any potential warning considerations.



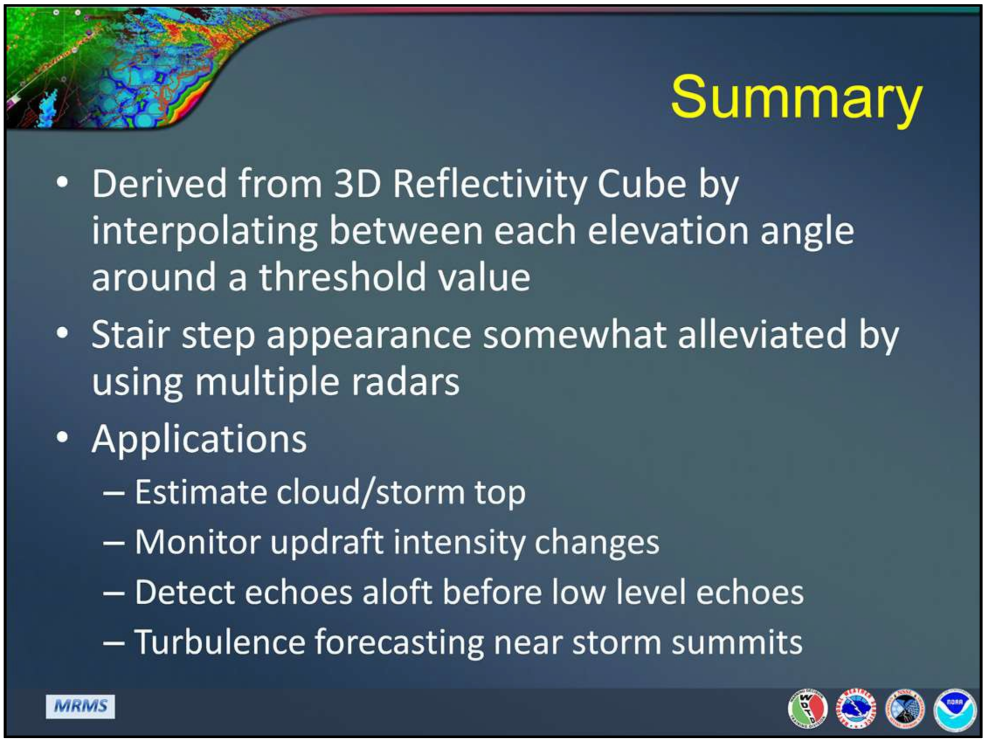
All the ET products can be used to detect updraft pulses at various levels. For instance, updraft pulses will often result in increased 50 dBZ Echo Top heights, so monitoring trends in 50 dBZ echo top heights may help with anticipating updraft pulses and storm propagation. In this example, the southern storm already has some significant low level reflectivity at around 0222 UTC with 50 dBZ echo tops reaching near 20 kft. However, as we step through roughly the next 20-25 minutes, the 50 dBZ echo tops increase to over 40 kft, and the low level reflectivity increases dramatically. If we look to the north, the 50 dBZ echo tops attempted to reach higher heights but never as much as the southern storm, and the low level reflectivity reflected this trend.



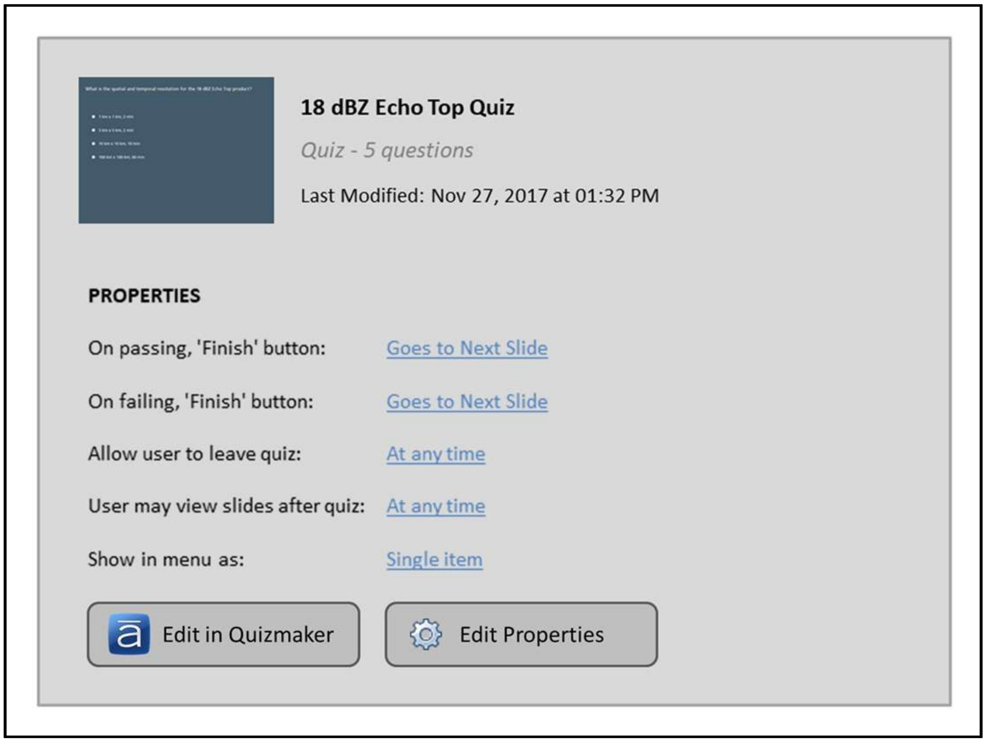
In aviation, the 18 dBZ Echo Top can be used as a proxy for areas of turbulence near storm tops and anvil layers. Here is an example where aviation routes are overlaid with the 18 dBZ echo tops. Some of these routes pass right through the maximum echo tops, therefore, a route change may be in order.



Even with the advantage of having multiple radars with these Echo Top products, the stair step appearance does not fully go away. This is especially true in areas of the country where only 1 radar covers the area, or in regions of stratiform precipitation.



In summary, the Echo Top products are derived from the 3D Reflectivity Cube by interpolating between each elevation angle. With single radar echo tops, there was always a stair step appearance due to the scanning strategy. This artifact is somewhat alleviated with MRMS but is not completely alleviated because some areas are not covered by multiple radars. The major applications of these products are the lower dBZ ETs are a good estimate for cloud and storm tops. By monitoring height trends, you can estimate regions experiencing updraft intensity changes with any ET product. Early on in convective initiation, echoes will occur aloft before any low level echoes develop and can be seen on the lower dBZ ETs. Finally, aviation uses the 18 dBZ ET product to estimate regions of turbulence near storm summits. Up next will be the quiz!


18 dBZ Echo Top Quiz
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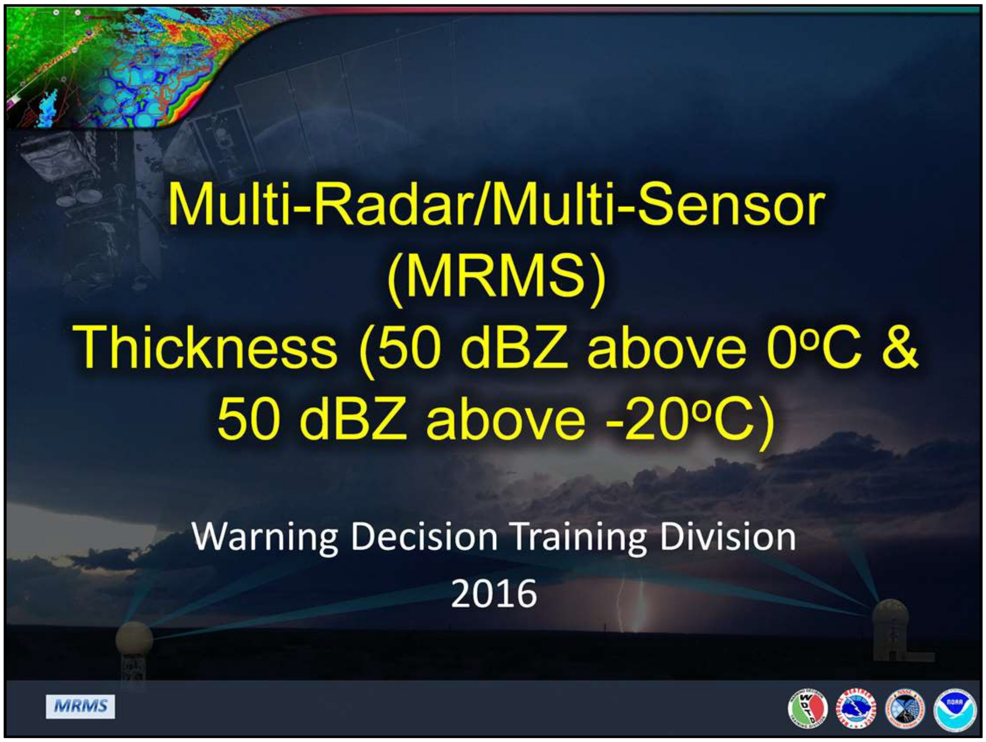
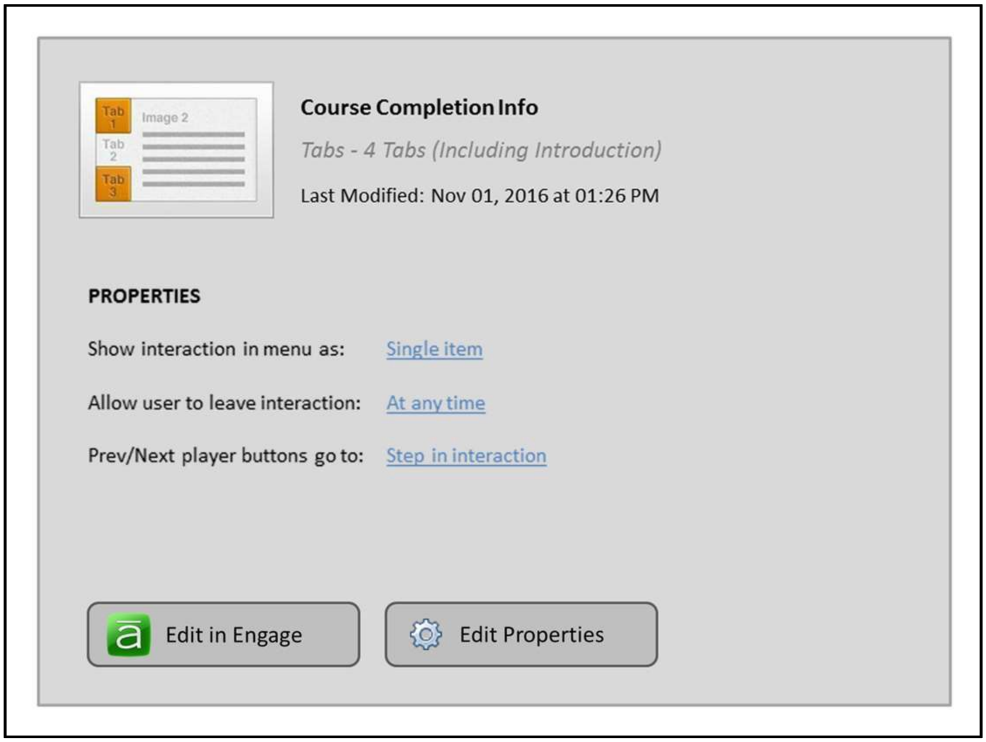
Thanks for completing this module on Echo Tops. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses listed here.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Reflectivity Thickness (50 dBZ above 0°C and 50 dBZ above -20°C) developed at the Warning Decision Training Division (WDTD).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Tab 2
Tab 3
Image 2
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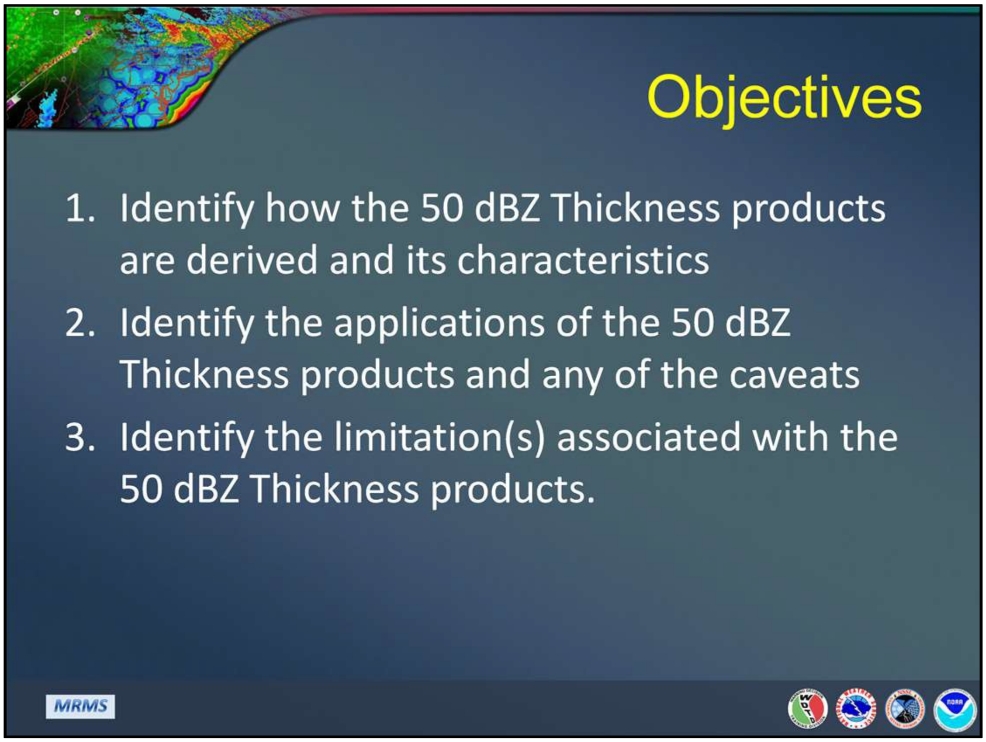
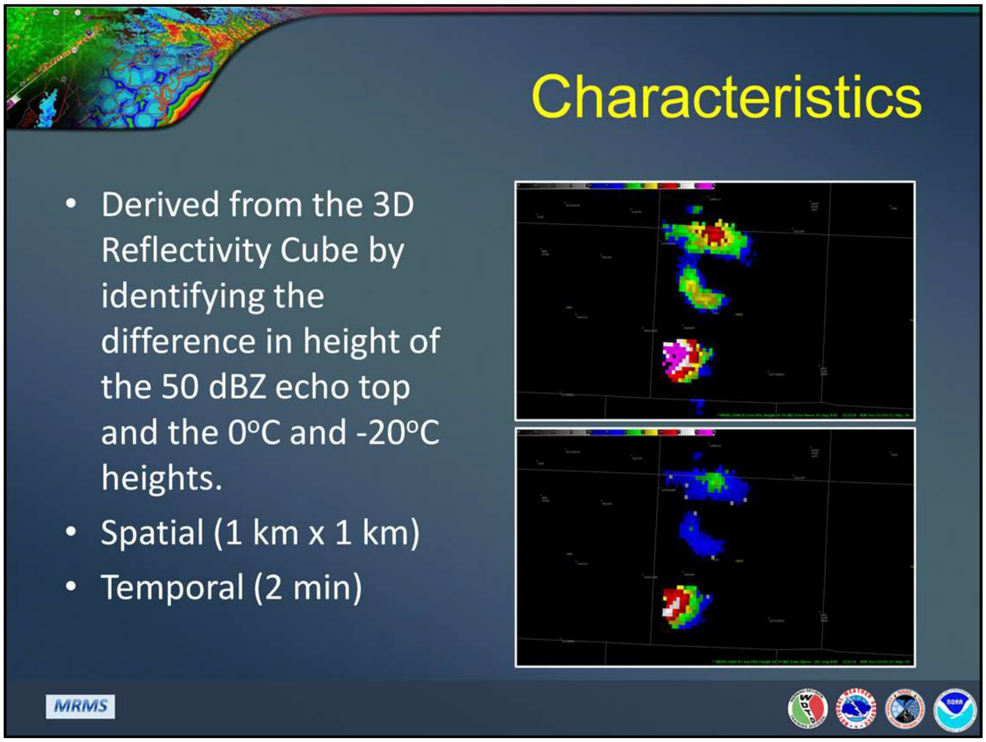
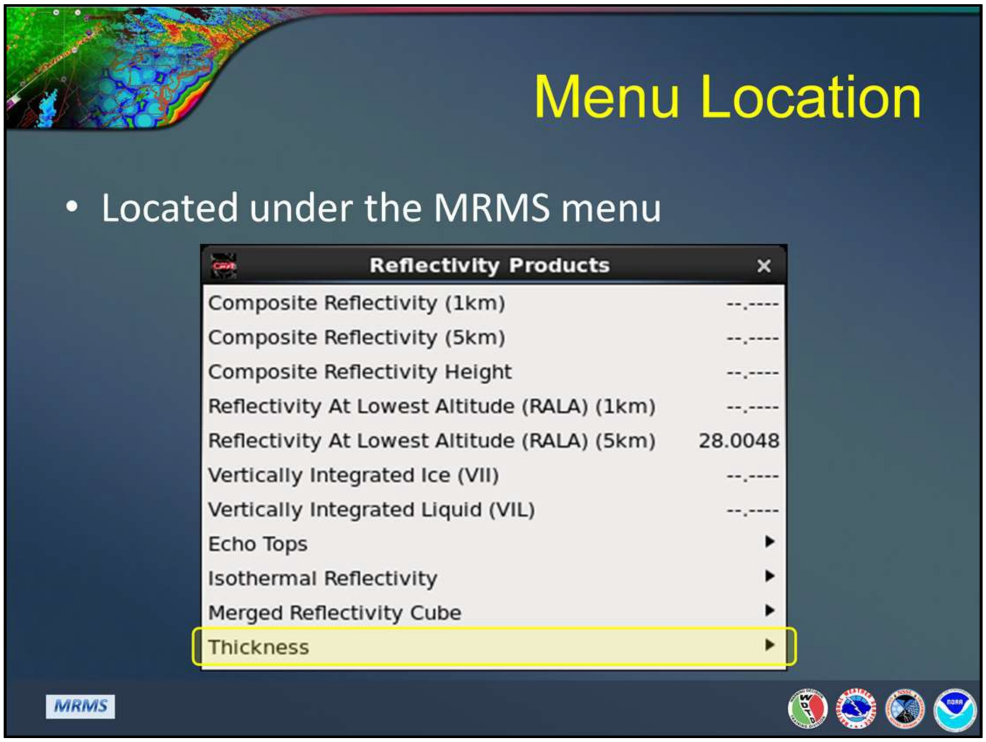


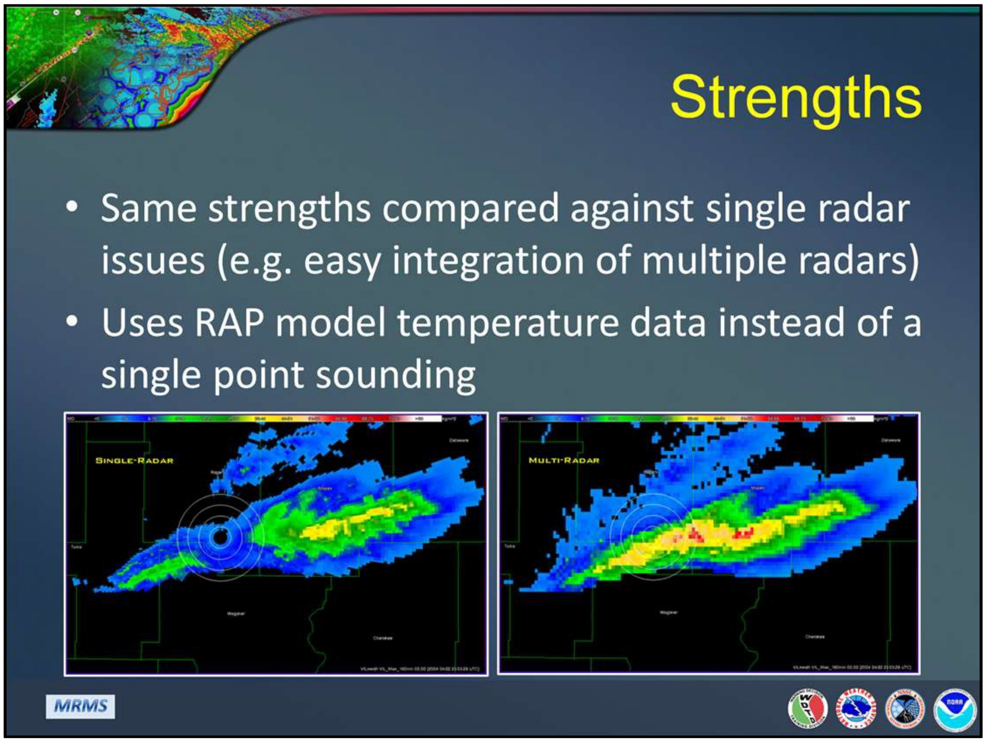
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. The quiz at the end of this lesson will be based on these objectives.



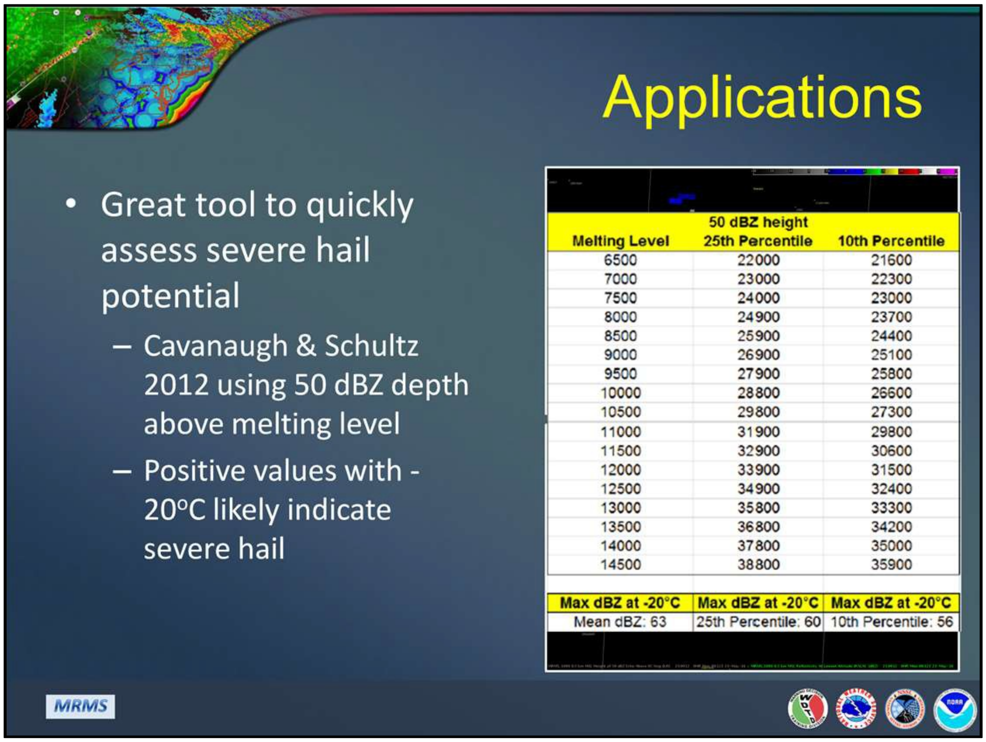
The two products here are derived from the 3D Reflectivity Cube by identifying the difference in height between the 50 dBZ echo top height and the 0^{o}C and -20^{o}C heights. Each product has a spatial resolution of 1 km by 1 km and updates every 2 minutes.



Each product can be found underneath the MRMS menu inside the CAVE toolbar.



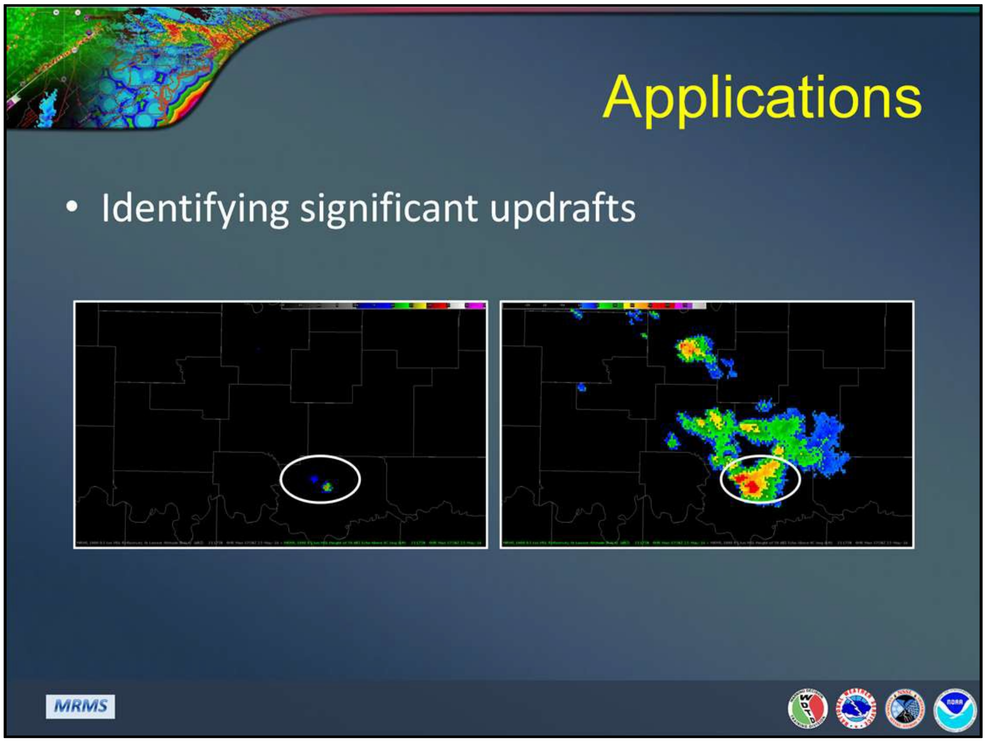
The primary strengths of this product are those general strengths associated with all MRMS products such as easily integrating multiple radars to overcome issues such as cone of silence. Additionally, the use of RAP model temperature data allows for a more representative analysis of the varying temperature across the domain instead of uniformly applying a single point sounding.



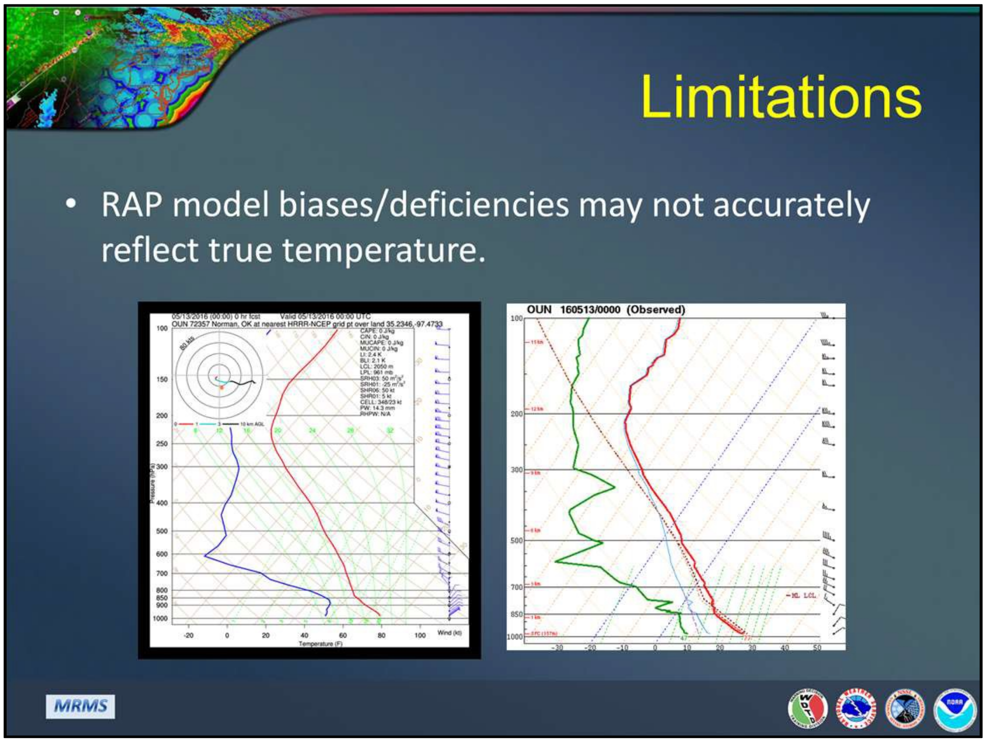
Melting Level	50 dBZ height 25th Percentile	10th Percentile
6500	22000	21600
7000	23000	22300
7500	24000	23000
8000	24900	23700
8500	25900	24400
9000	26900	25100
9500	27900	25800
10000	28800	26600
10500	29800	27300
11000	31900	29800
11500	32900	30600
12000	33900	31500
12500	34900	32400
13000	35800	33300
13500	36800	34200
14000	37800	35000
14500	38800	35900

Max dBZ at -20°C	Max dBZ at -20°C	Max dBZ at -20°C
Mean dBZ: 63	25th Percentile: 60	10th Percentile: 56

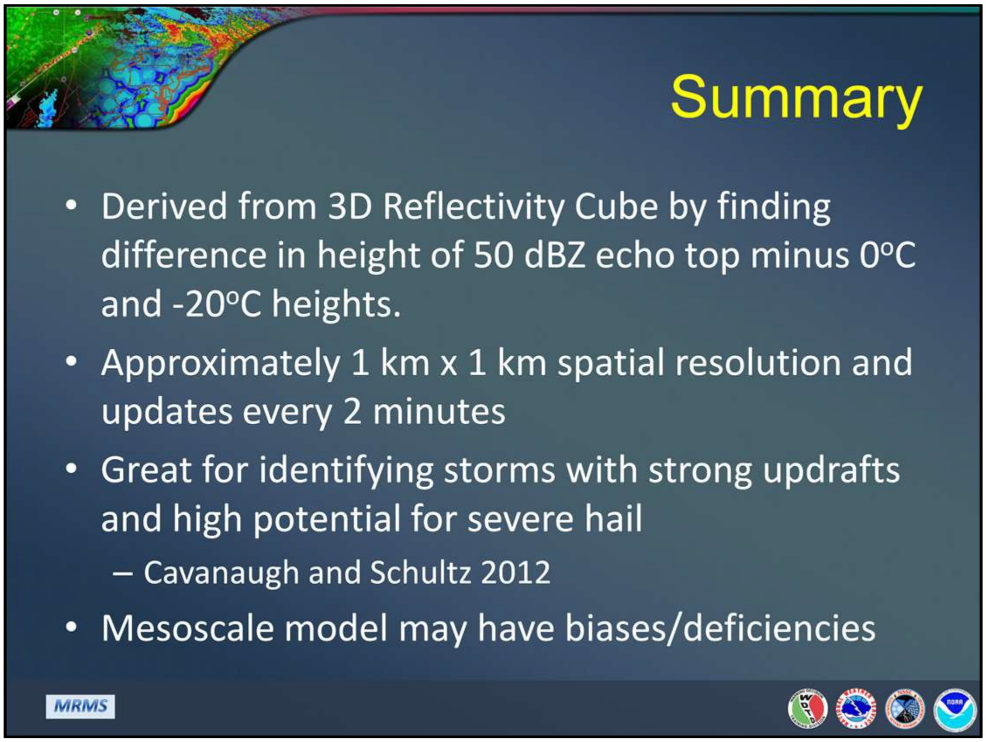
The primary application of these two height products is to quickly identify severe hail. Cavanaugh and Schultz 2012 used the depth of the 50 dBZ echo top height above the melting level to assess severe hail potential. The following chart shows the heights that maximized POD and minimized false positives. Note, AWIPS plots the 0°C height using MSL, and the study used AGL, so there may be some small discrepancies. It is also known that 50 dBZ or higher above the -20°C indicates severe hail is very likely occurring, therefore, positive height values in the -20°C product indicates severe hail is likely. Here is an example from west Texas. The storm produced up to golf ball sized hail and we can see significant 50 dBZ heights above the 0°C and -20°C levels.



Outside hail detection, these two products can also be used to assess significant updraft potential. Larger positive values will indicate stronger updrafts. In this example from southern OK, notice how only the southern storm shows any updraft potential in the 50 dBZ thickness products. So, we can confidently say that this storm right now is the only storm realizing any convective potential.



The primary limitation is the temperature levels are determined using a mesoscale model which has its own biases and deficiencies. Therefore, be mindful of the model temperature data compared to actual data to make sure the model is representative.



In summary, these two products are derived from the 3D Reflectivity Cube by finding the difference in the height of the 50 dBZ Echo Top and the 0^{o}C and -20^{o}C heights. The spatial resolution is approximately 1 km x 1 km and updates every 2 minutes. The products are great for identifying storms with strong updrafts and consequently high potential for severe hail. Cavanaugh and Schultz used the 50 dBZ echo top height above 0^{o}C to identify a technique that maximizes POD and reduces false positives when warning for 1-inch hail. And, whenever reflectivity above 50 dBZ extends above the -20^{o}C level, the higher it extends, the more likely severe hail is present. Due to dependency on the melting level height from the RAP model, deficiencies or biases in this model may lead to inaccurate heights which could affect interpretation. Up next will be your quiz.

50 dBZ Thickness Quiz

Quiz - 5 questions

Last Modified: Sep 14, 2016 at 04:50 PM

PROPERTIES

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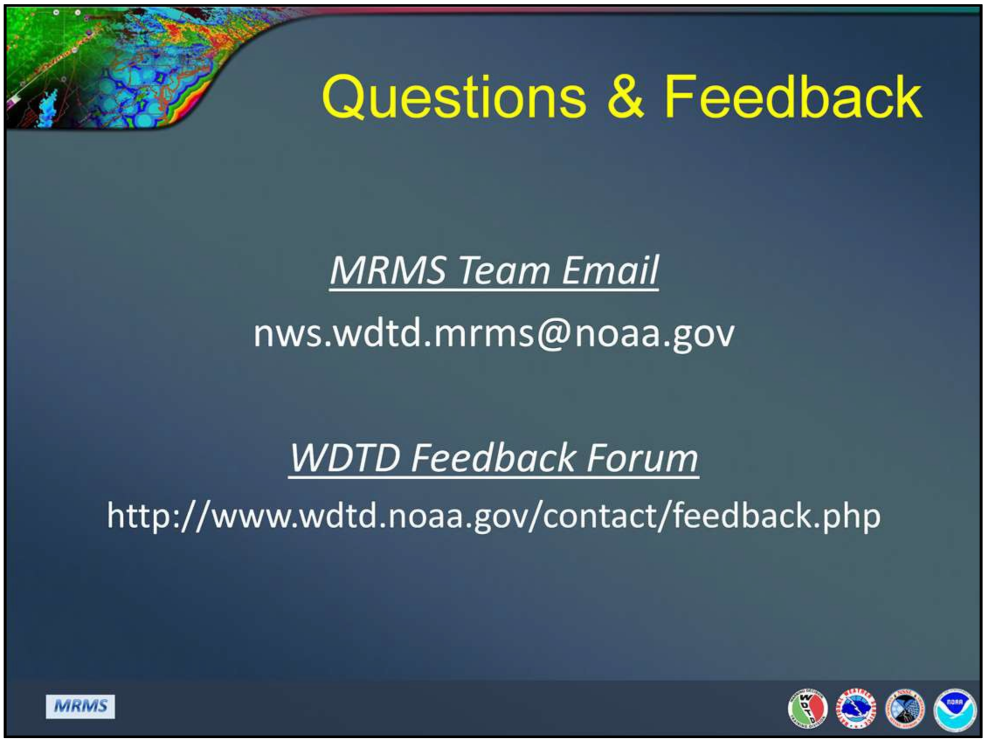
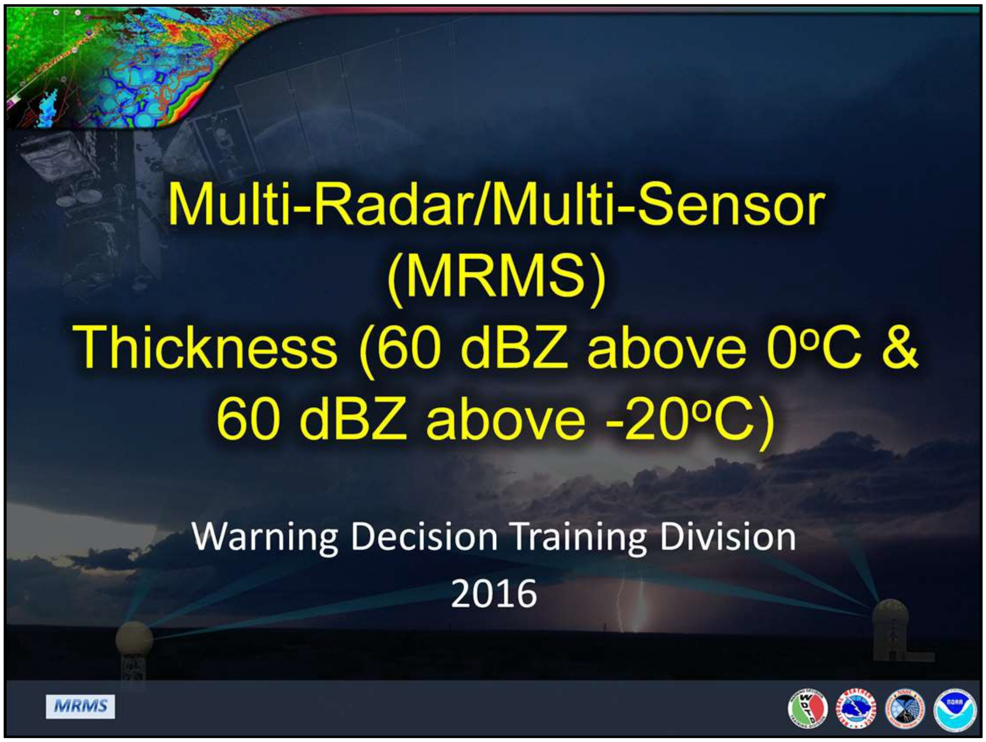
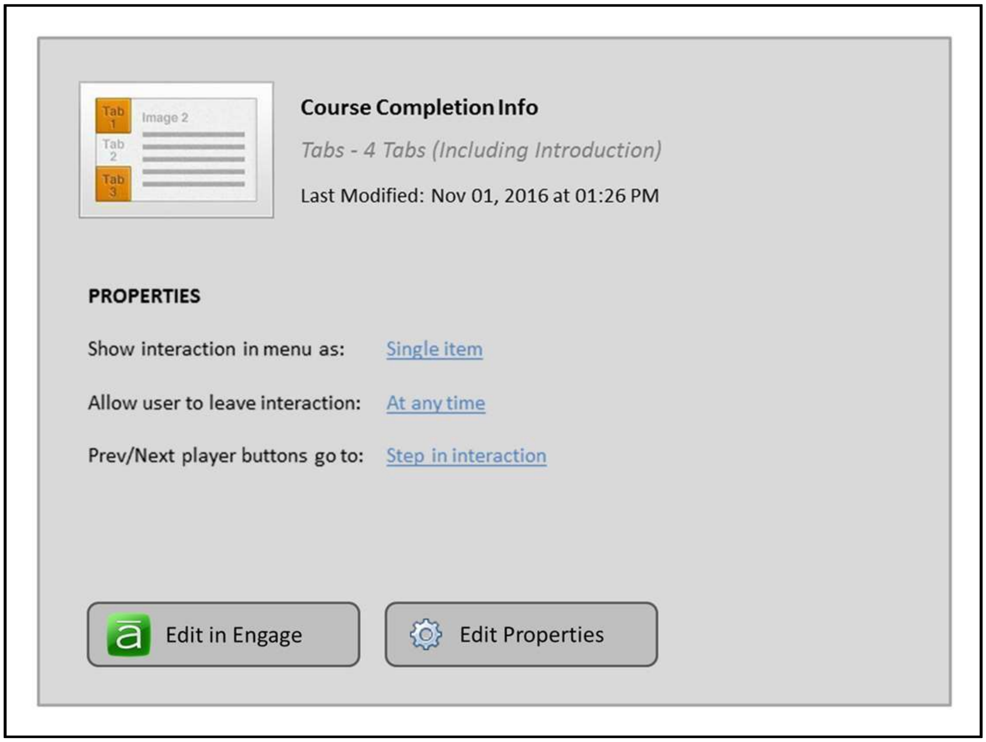


Thanks for completing this module on Reflectivity Thickness @ 50 dBZ. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Reflectivity Thickness (60 dBZ above 0°C and 60 dBZ above -20°C) developed at the Warning Decision Training Division (WDTD).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Tab 2
Tab 3
Image 2
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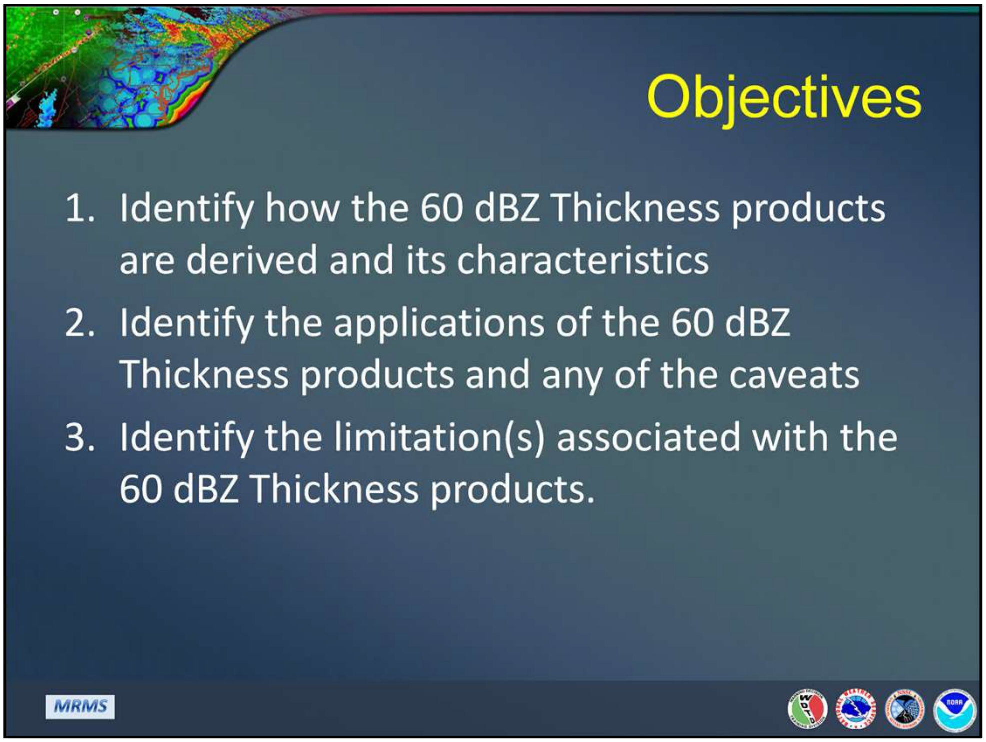

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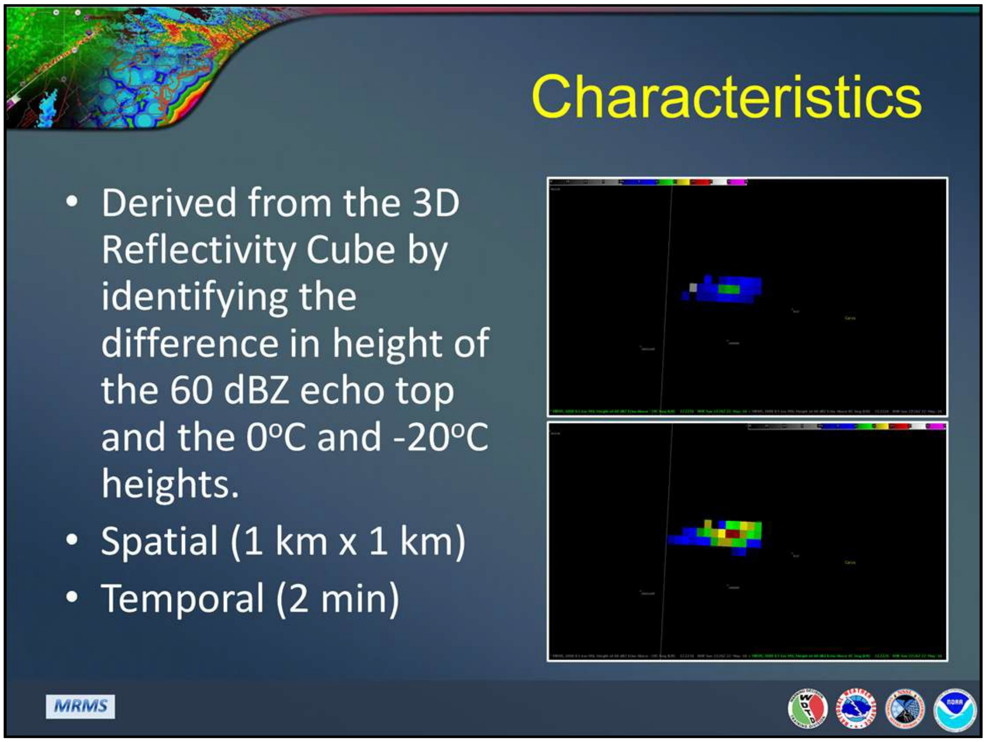
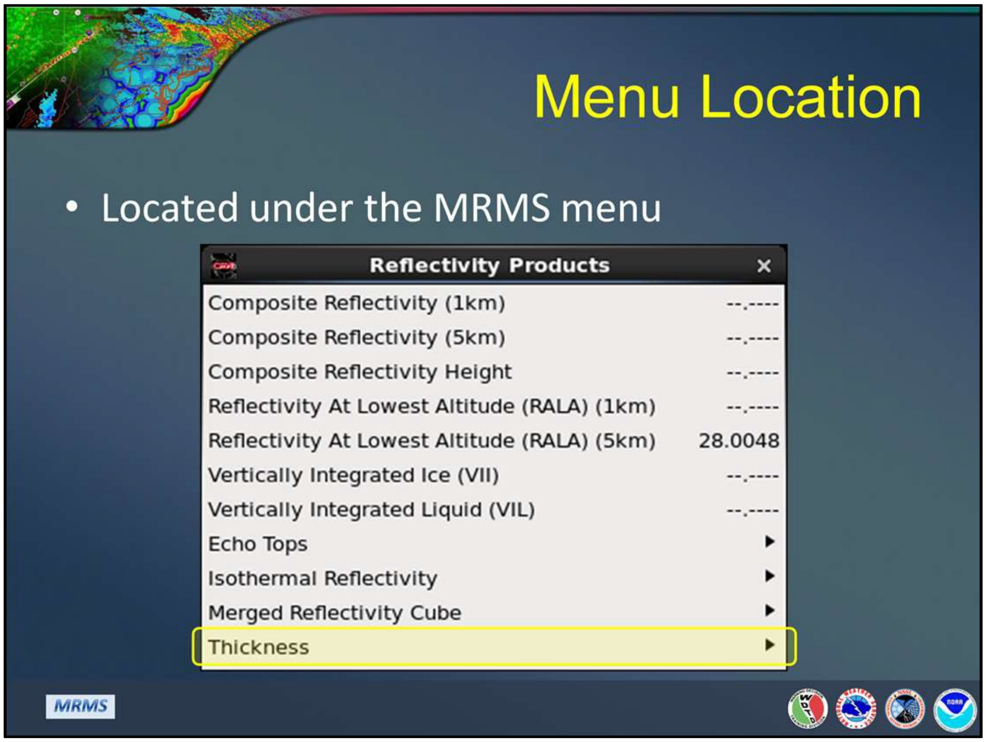
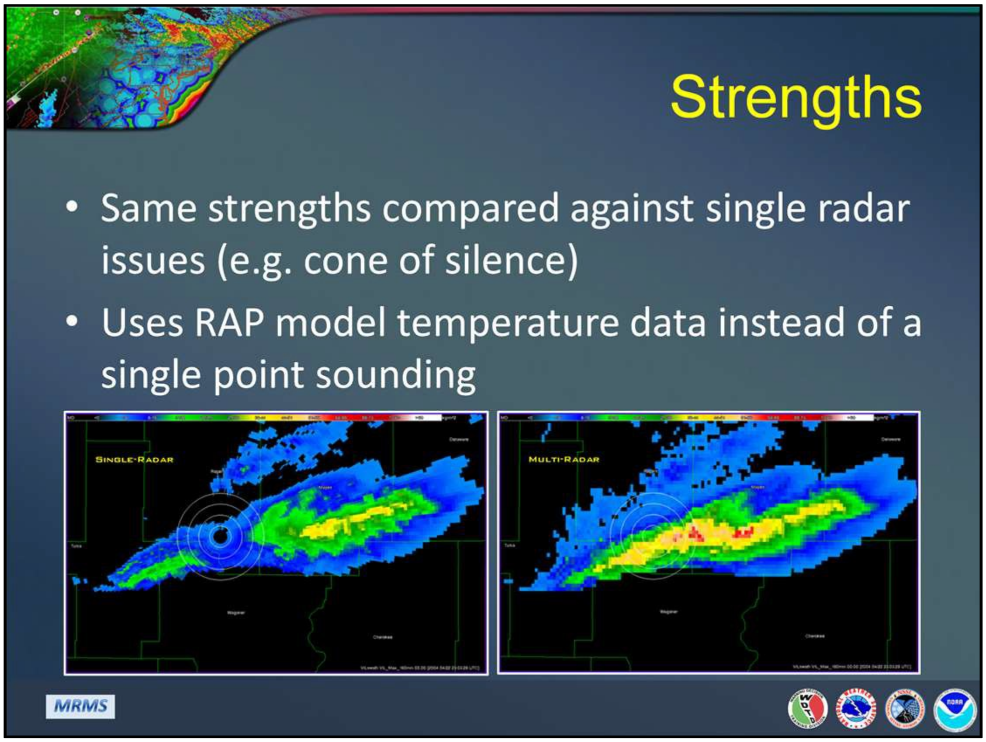


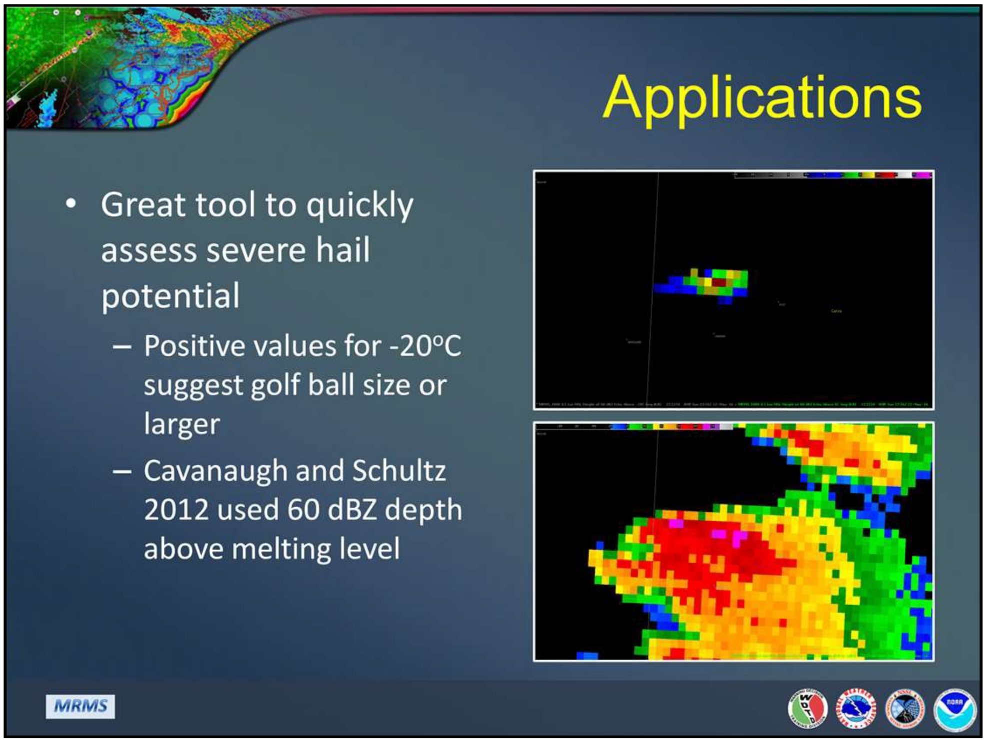
The two products here are derived from the 3D Reflectivity Cube by identifying the difference in height between the 60 dBZ echo top height and the 0^{o}C and -20^{o}C heights. Each product has a spatial resolution of 1 km by 1 km and updates every 2 minutes.



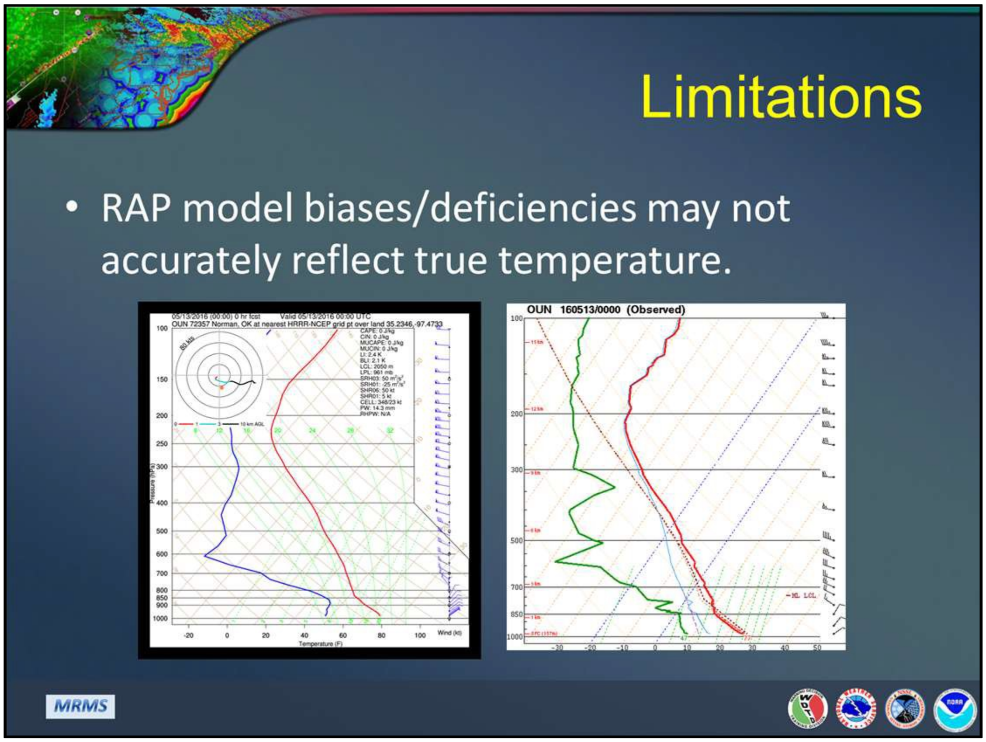
Each product can be found underneath the MRMS menu inside the CAVE toolbar.



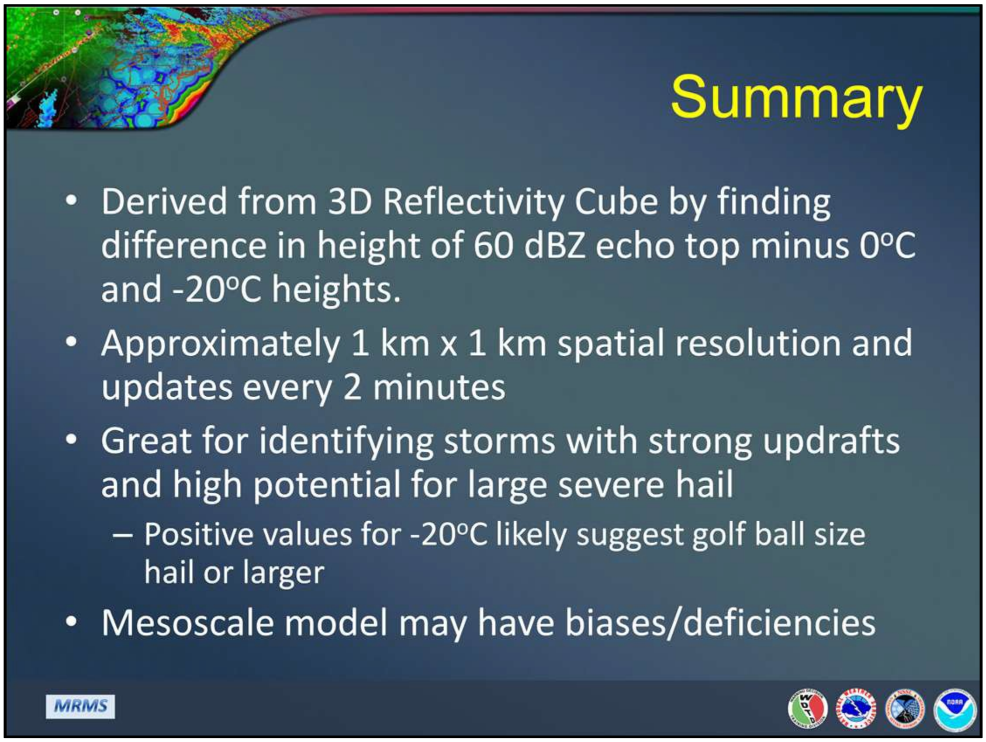
The primary strengths of this product are those general strengths associated with all MRMS products such as easily integrating multiple radars to overcome issues such as cone of silence. Additionally, the use of RAP model temperature data allows for a more representative analysis of the varying temperature across the domain instead of uniformly applying a single point sounding.



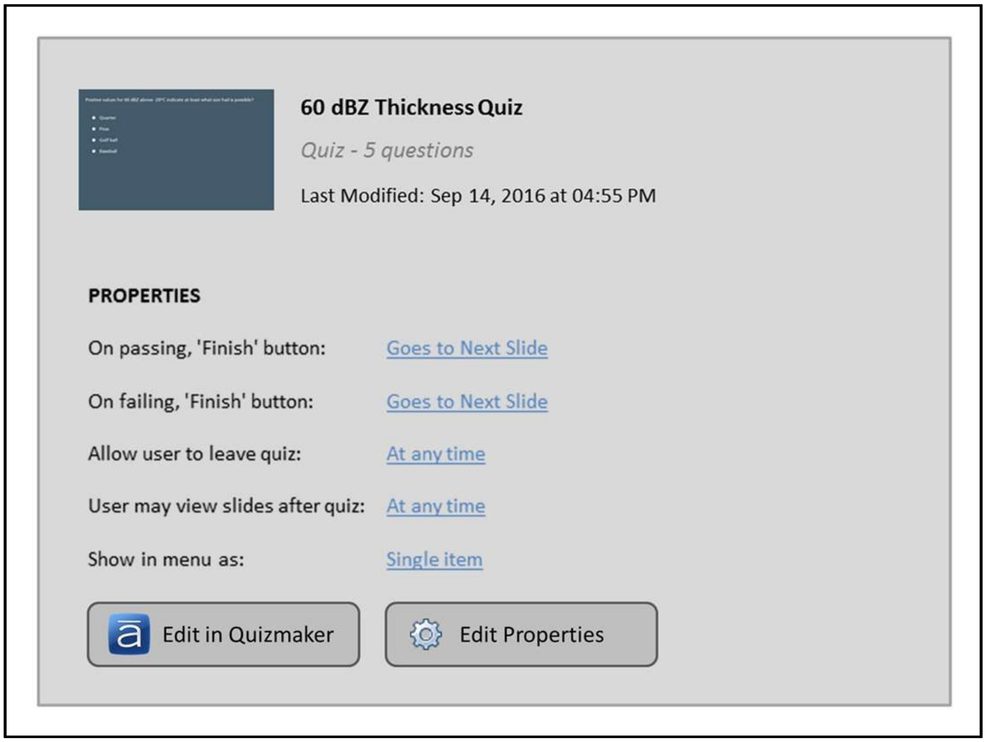
The primary application of these two height products is to quickly identify severe hail. Values of 60 dBZ extending above the -20°C level indicate golf ball sized hail, or larger, is very likely occurring, therefore, look for increasingly larger positive values in these products. Cavanaugh and Schultz 2012 used the depth of the 60 dBZ echo top height above the melting level to assess severe hail potential. In this example shown here, a report of baseball sized hail was reported with this storm.



The primary limitation is the temperature levels are determined using a mesoscale model which has its own biases and deficiencies. Therefore, be mindful of the model temperature data compared to actual data to make sure the model is representative.



In summary, these two products are derived from the 3D Reflectivity Cube by finding the difference in the height of the 60 dBZ Echo Top and the 0°C and -20°C heights. The spatial resolution is approximately 1 km x 1 km and updates every 2 minutes. The products are great for identifying storms with strong updrafts and consequently high potential for large severe hail. Whenever reflectivity above 60 dBZ extends above the -20°C level, the higher it extends, the more likely large severe hail is present. Cavanaugh and Schultz used the 60 dBZ echo top height above 0°C to identify a technique that maximizes POD and reduces false positives when warning for 1-inch hail. Due to dependency on the melting level height from the RAP model, deficiencies or biases in this model may lead to inaccurate heights which could affect interpretation.


60 dBZ Thickness Quiz
Quiz - 5 questions
Last Modified: Sep 14, 2016 at 04:55 PM
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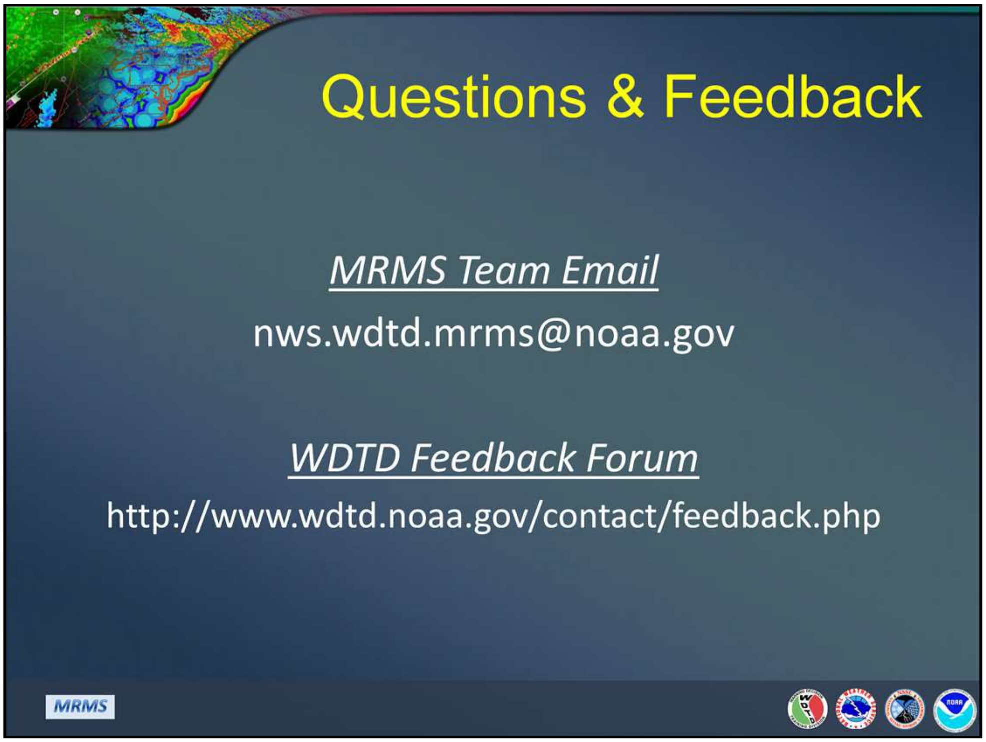
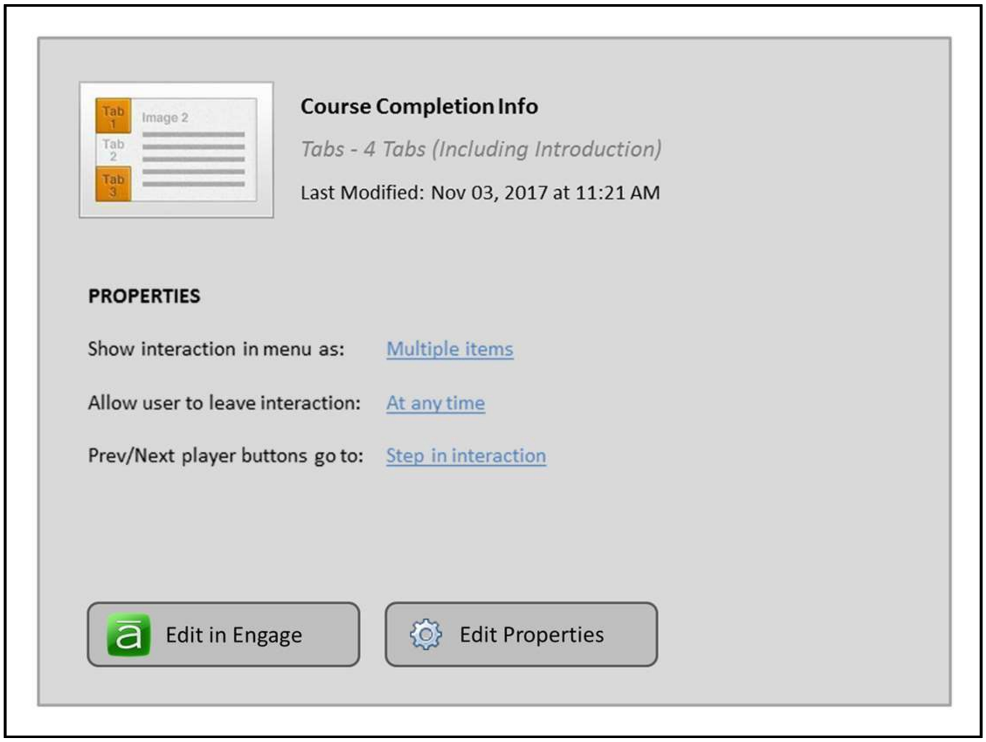


Thanks for completing this module on Reflectivity Thickness @ 60 dBZ. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.

Welcome to the Multi-Radar/Multi-Sensor (MRMS) Products Course Lesson on Hail Products! I am Alyssa Bates with the Warning Decision Training Division (WDTD), but the content of this lesson was created by Matt Elliott, former WDTD.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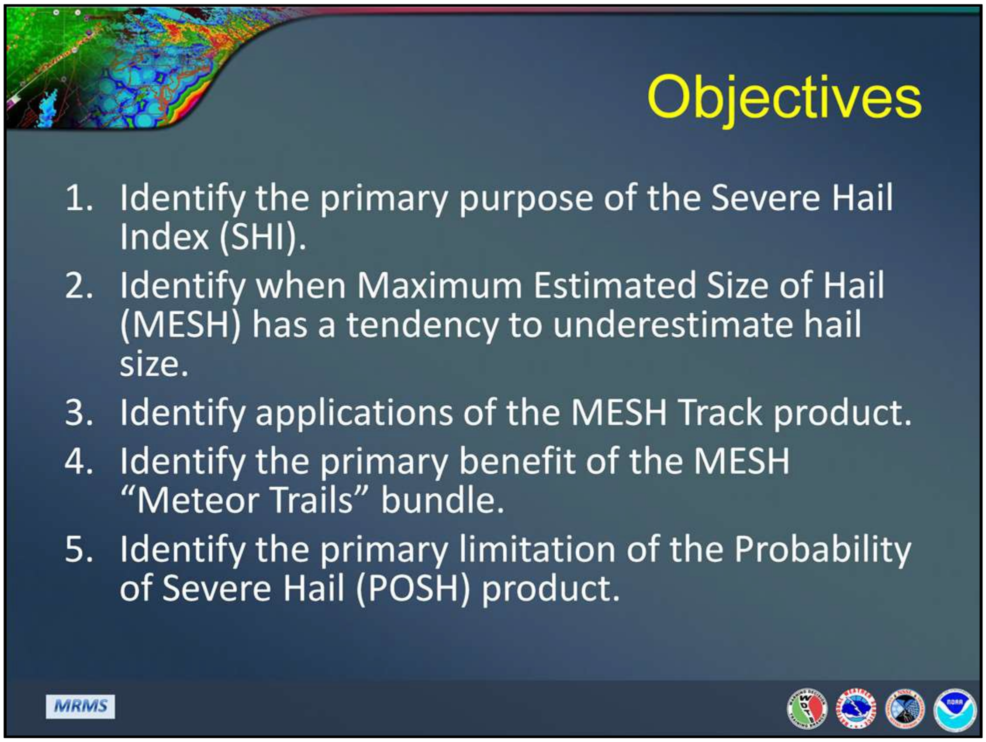
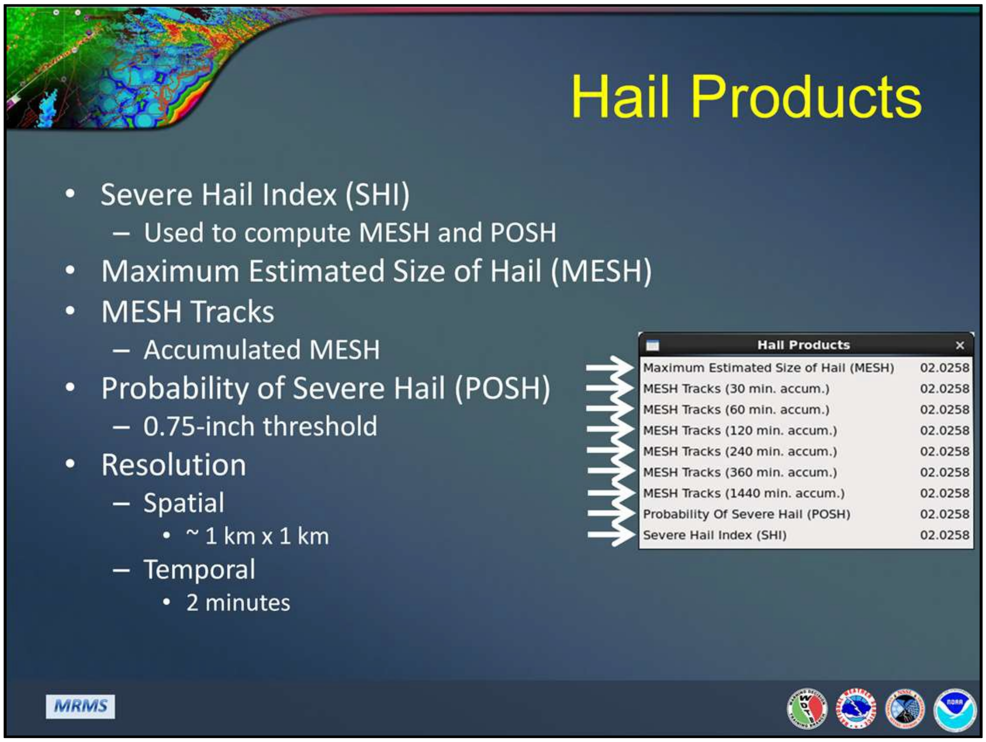


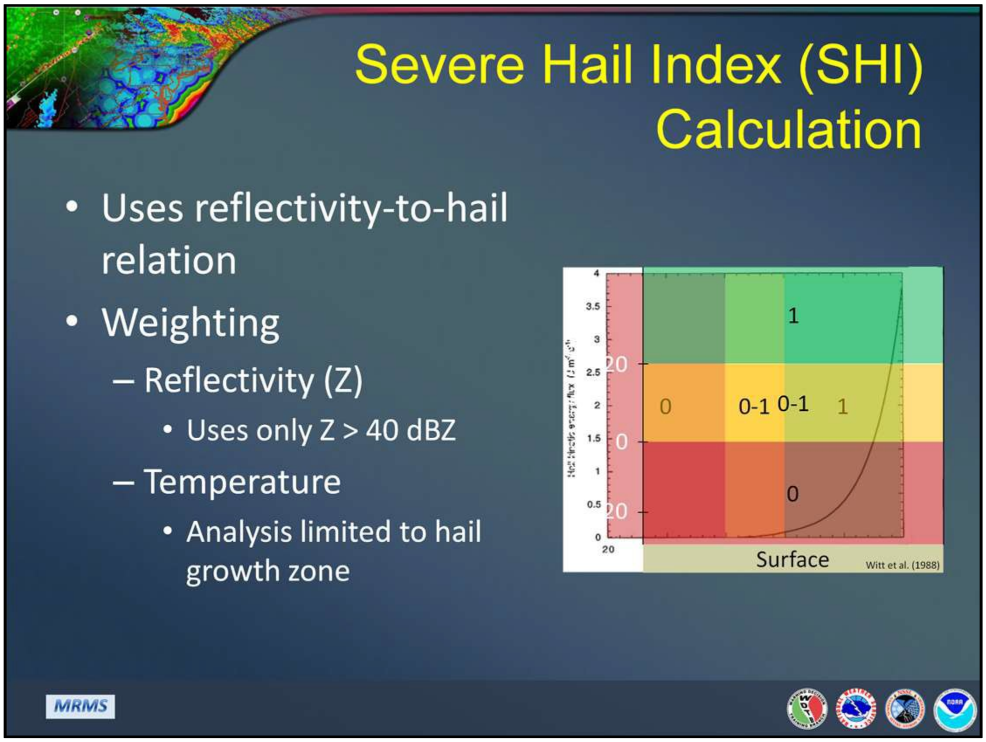
Here are the objectives for this lesson. Take a minute to review them before moving on to the next slide.



There are four MRMS hail products:

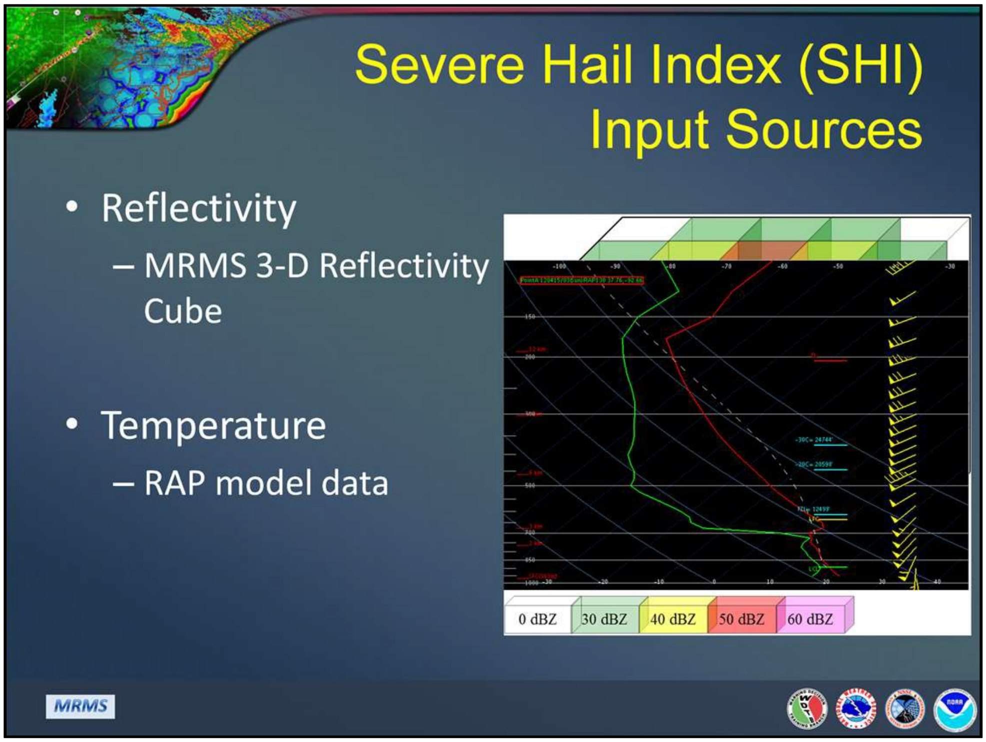
- The Severe Hail Index or SHI is used to calculate the Maximum Estimated Size of Hail and the Probability of Severe Hail.
- The Maximum Estimated Size of Hail or MESH provides an estimate of the maximum hail size that can be expected.
- MESH Tracks display the maximum MESH value during a specified time period. Available intervals include 30, 60, 120, 240, 360, and 1440 minutes.
- Lastly, the Probability of Severe Hail or POSH is the probability of 0.75-inch diameter hail occurring.

The spatial resolution of these products is approximately 1 km by 1 km and the temporal resolution is 2 minutes.

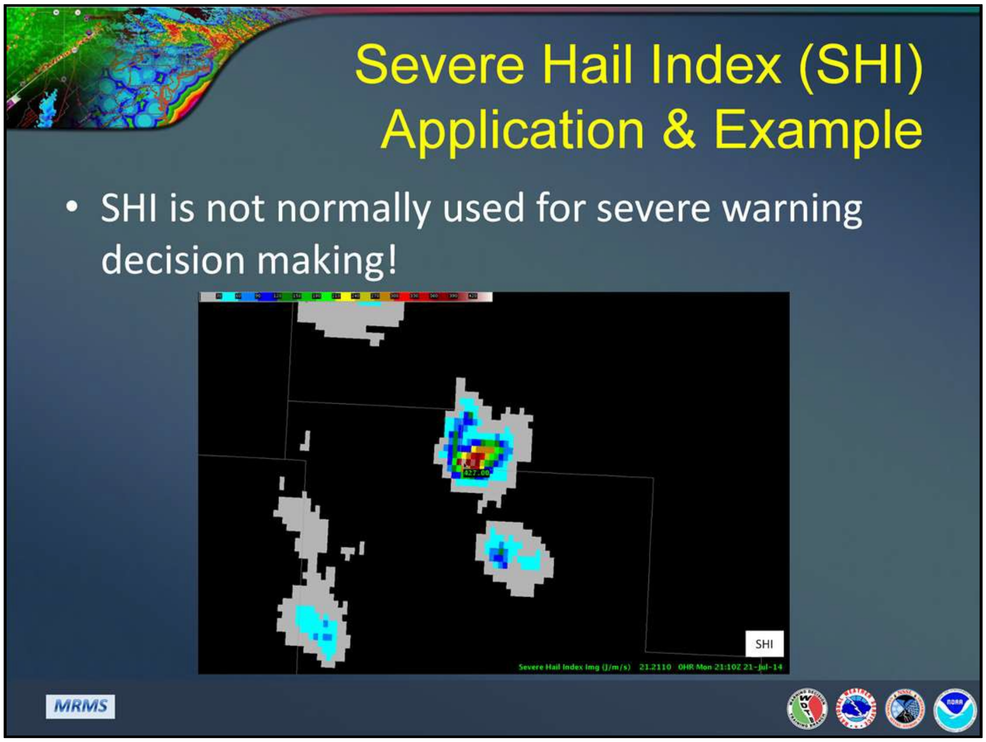


The Severe Hail Index (SHI) uses a reflectivity-to-hail relation to detect the presence of severe hail. A weighting function is used to filter out liquid water and isolate for hail. Reflectivities less than 40 dBZ are assumed to be associated with liquid water and are thrown out, in other words they are given a weight of zero. Between 40 and 50 dBZ is the transition zone between rain and hail reflectivities with weights increasing from 0 at 40 dBZ to 1 at 50 dBZ. This reflects the increasing chances of hail as reflectivities approach 50 dBZ. Reflectivities above 50 dBZ are assumed to be associated with hail and are fully retained, in other words they are given a weight of one.

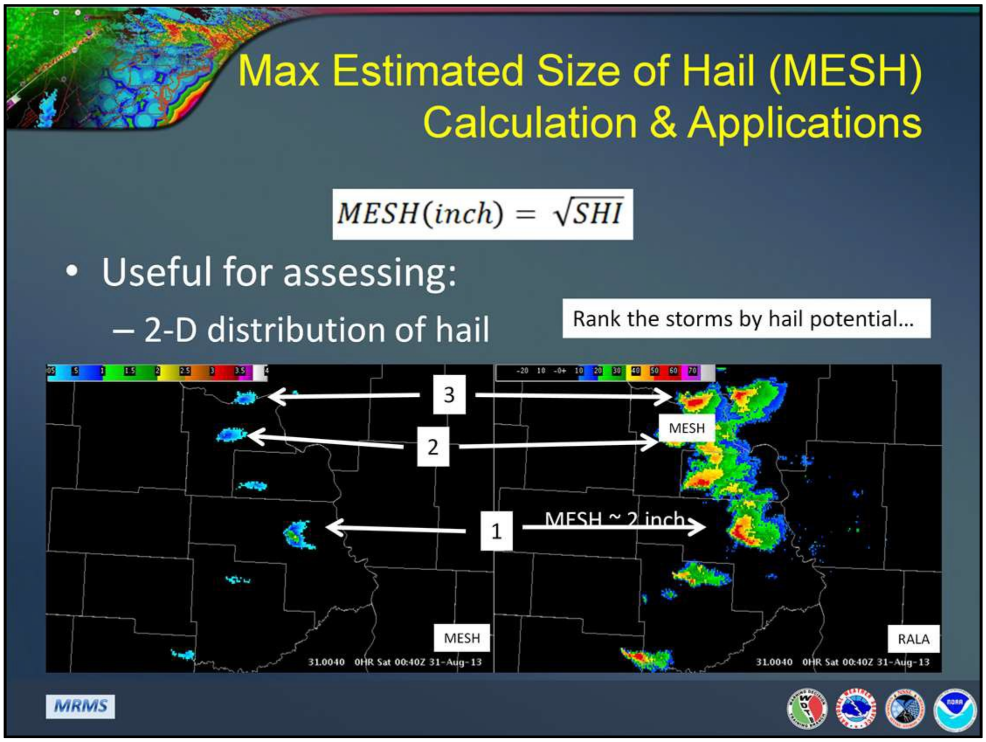
Since hail growth occurs primarily at temperatures less than 0°C, reflectivities at temperatures greater than 0°C are given a weight of zero. Between 0 and -20°C is the transition zone with weights increasing from 0 at 0°C to 1 at -20°C. This reflects the increasing chances of hail as temperatures approach -20°C. Most growth for severe hail occurs at temperatures near -20°C or colder, so reflectivities at temperatures less than -20°C are fully retained.



SHI receives reflectivity input from the 3D Reflectivity Cube and vertical temperature profiles from the Rapid Refresh (RAP) model.



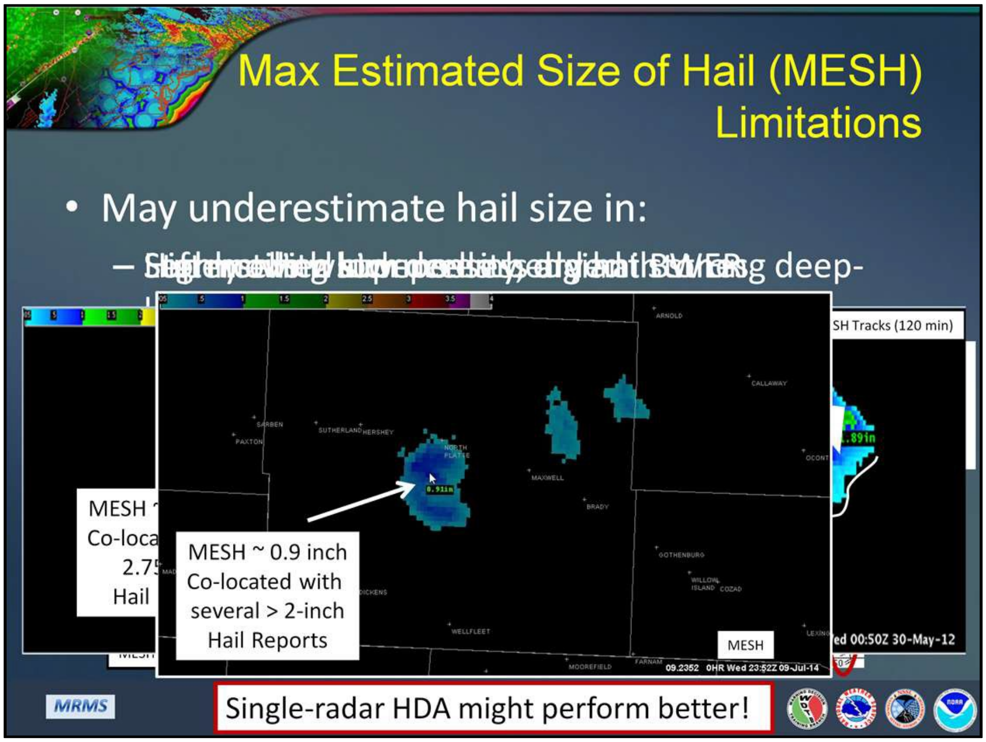
It is important to note that SHI is not normally used alone for severe warning decision making. It’s primarily used to compute the Probability of Severe Hail (POSH) and Maximum Estimated Size of Hail (MESH).



The MESH calculation is simple; just take the square root of the Severe Hail Index.

MESH has shown to be very useful for assessing the 2D distribution of hail. Can you quickly rank these storms by their potential to produce severe hail? It's easy with MESH!

MESH is also useful for assessing the largest hailstone size associated with a storm.

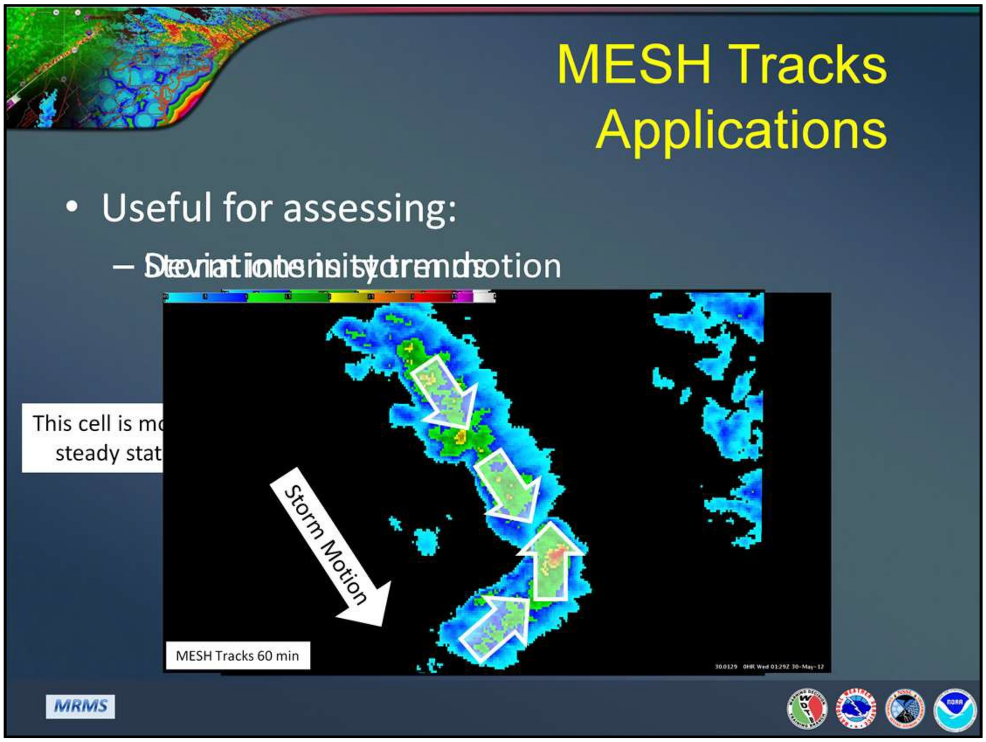


Like many other hail size estimation techniques, which use reflectivity and vertical temperature input, MESH has a tendency to underestimate hail size in highly-tilted storms embedded in strong, deep-layer shear. In these cases, the traditional single-radar hail detection algorithm might perform better than the multi-radar product.

MESH also tends to underestimate hail size in Left-moving supercells.

MESH may also underestimate hail size in supercells that possess a giant Bounded Weak Echo Region. As shown in this example, a low MESH value hole is sometimes co-located with the bounded weak echo region. The presence of a "MESH hole" is a strong indicator that MESH is underestimating hail size! As was the case with highly-tilted storms, the traditional single-radar hail detection algorithm might perform better than the multi-radar product in these cases.

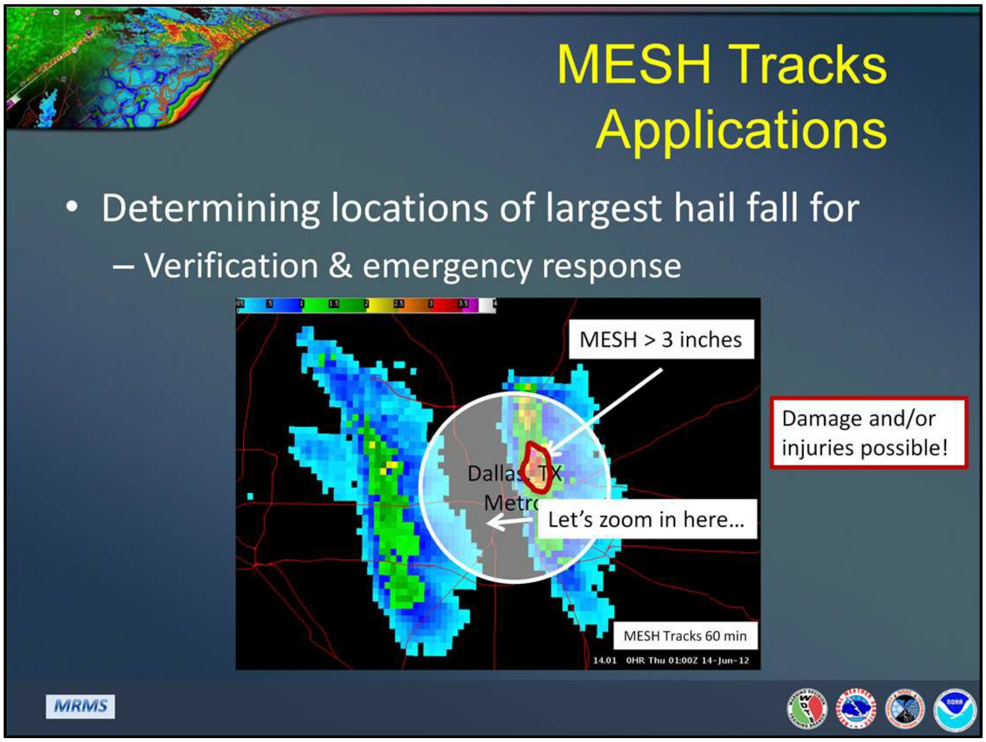
Lastly, MESH may underestimate hail size in storms with low-density, dry hailstones.



MESH Tracks are useful for assessing storm intensity trends.

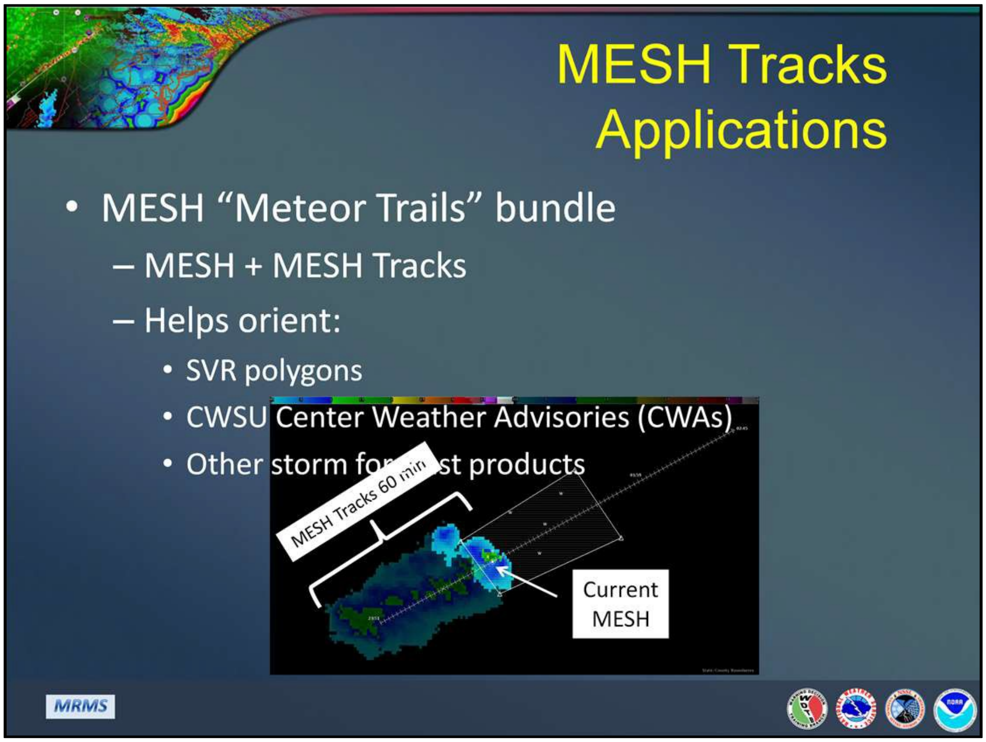
A quick look at MESH tracks with these storms reveals the eastern cell cycled in intensity before steadying, while the western cell remained intense throughout.

MESH tracks can also help identify deviations in storm motion. The arrows here indicate the direction of movement of the two cells. As they approach each other, the southern cell takes a sharp left turn. This is easy to identify using MESH tracks.

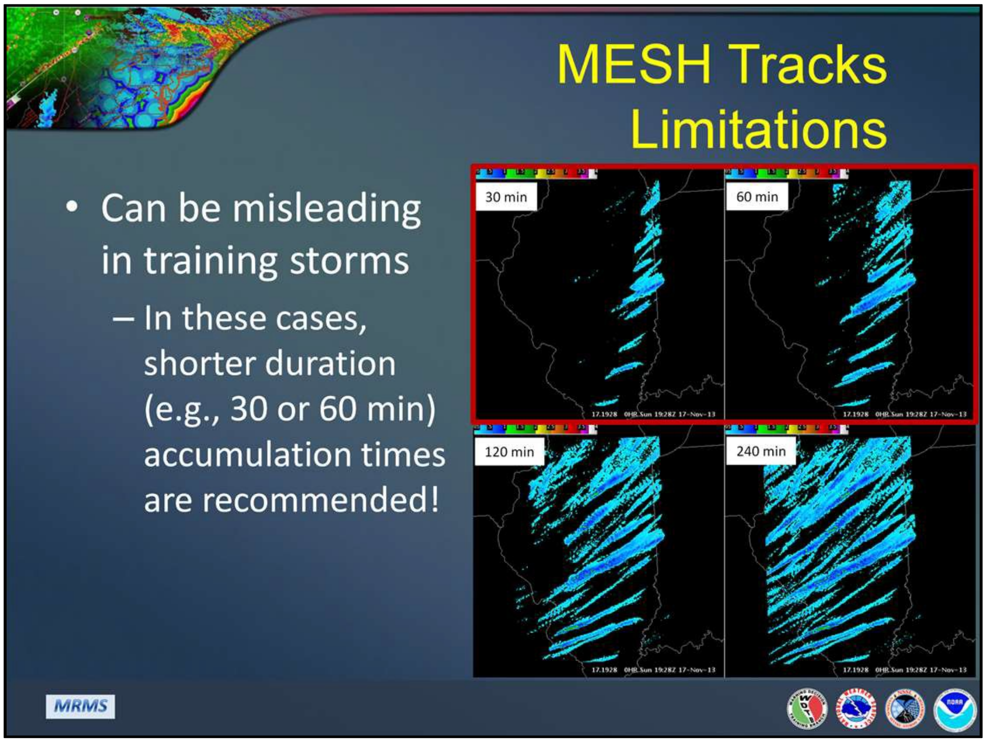


MESH tracks can help forecasters define an area for verification calls during and after severe weather events.

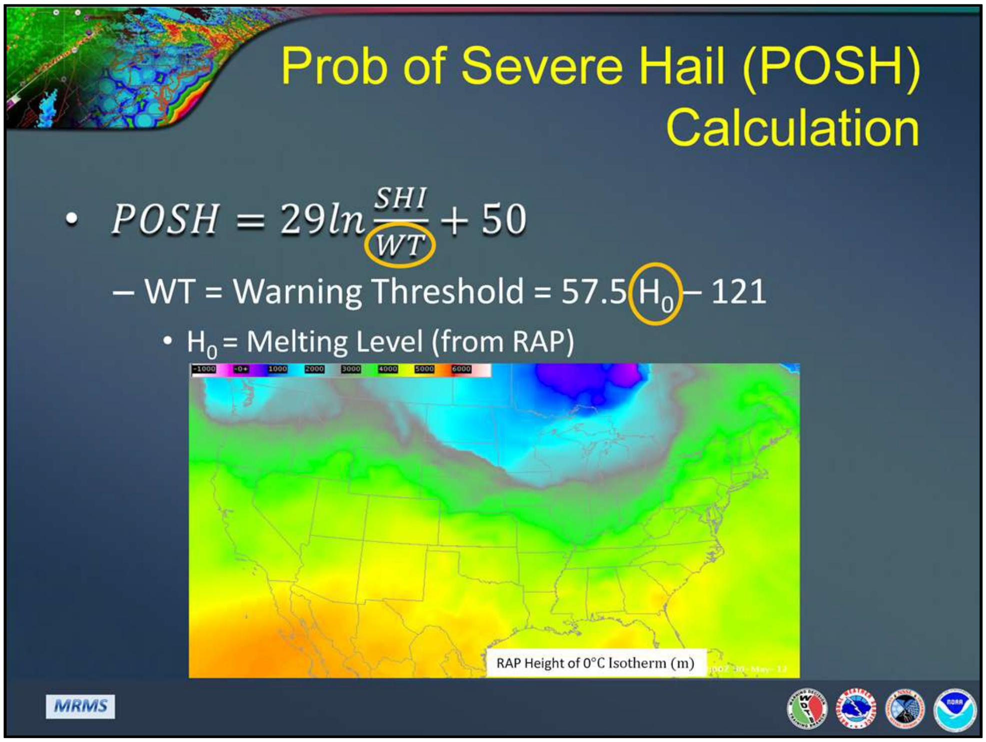
MESH tracks can also aide emergency response by identifying locations with possible damage or injuries.



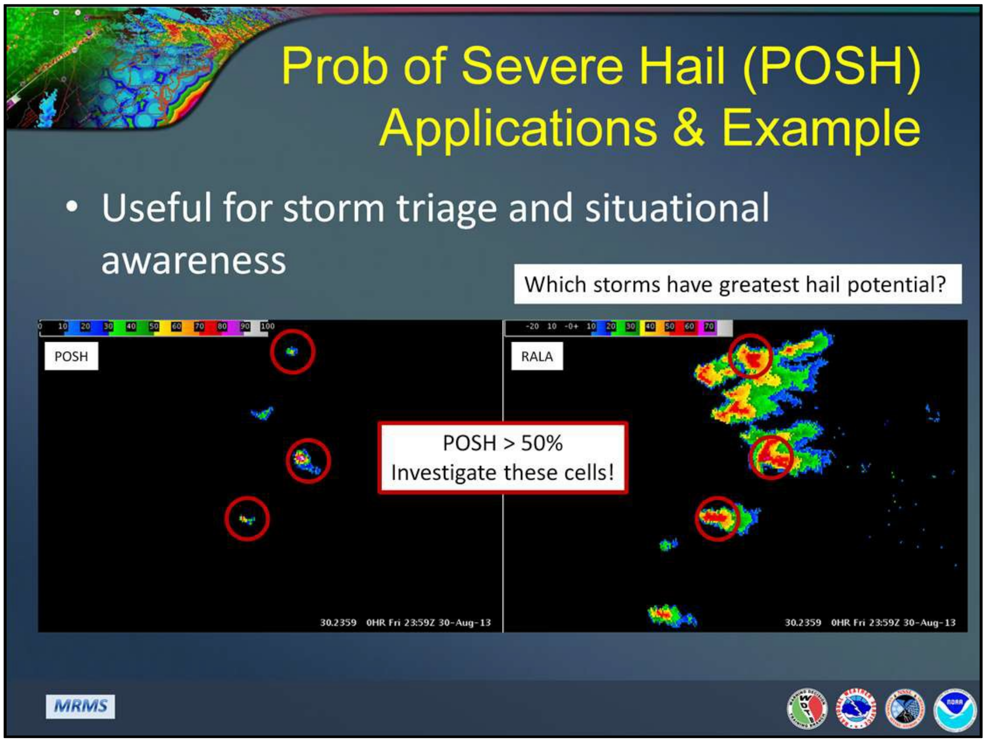
MESH Tracks can be image combined with instantaneous MESH to create a MESH “Meteor Trails” bundle which is very useful for the orientation of NWS WFO Severe Thunderstorm Warning polygons CWSU Center Weather Advisories (CWAs), and other storm forecast track products.



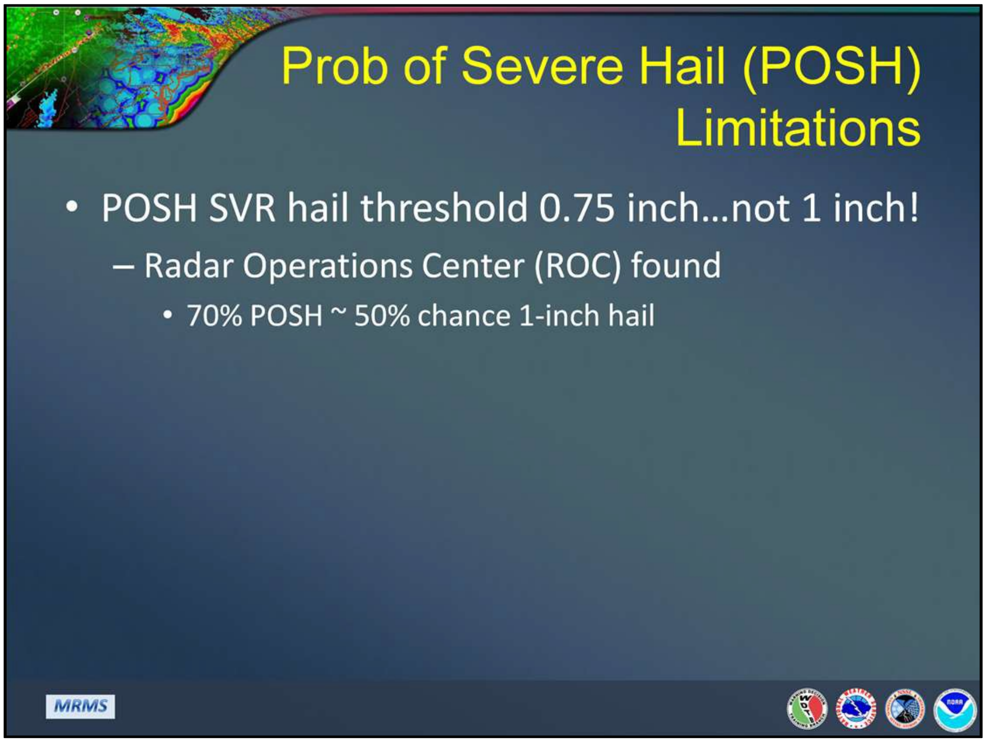
MESH tracks at longer accumulation times can be misleading in training storms, since it is difficult to determine which cell is responsible for the maximum MESH during the period. In these cases, shorter duration accumulation times are recommended.



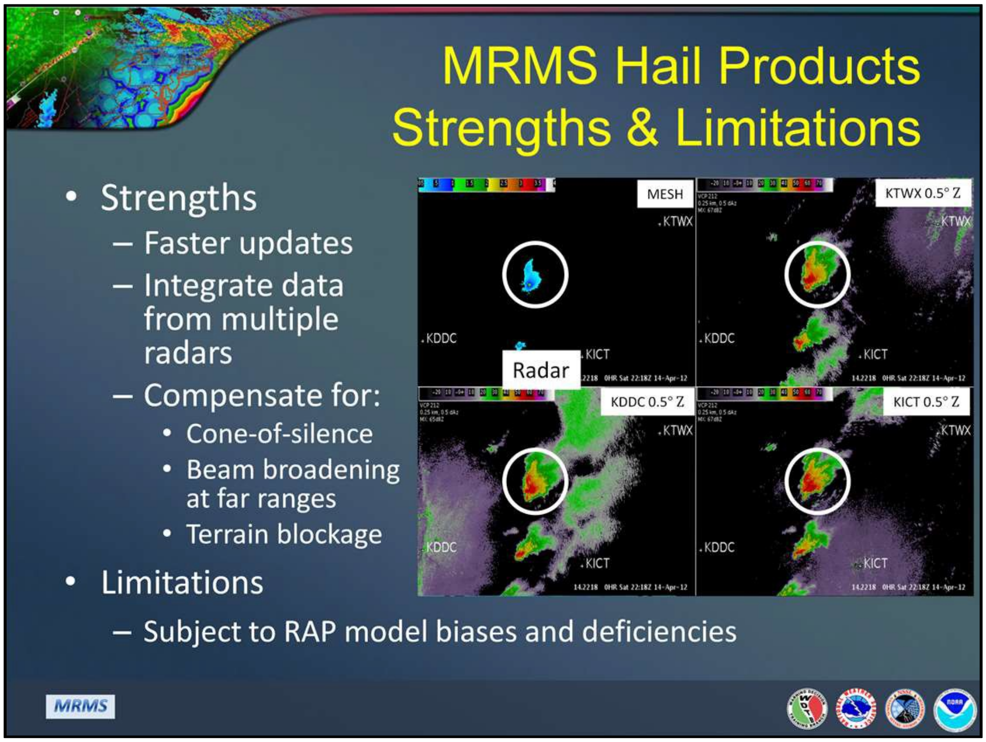
The probability of severe hail product has two inputs in its calculation, the SHI and a warning threshold. The warning threshold is a linear equation with the melting level as the only input.



POSH is useful for storm triage and situational awareness. Can you tell which storms have the greatest hail potential? It's easy with POSH!



But beware! POSH was developed when the NWS severe hail criteria was 0.75-in diameter, rather than the current 1-inch criteria. The NEXRAD Radar Operations Center (ROC) determined that a 70% POSH is approximately the same as a 50% chance of 1-in hail.

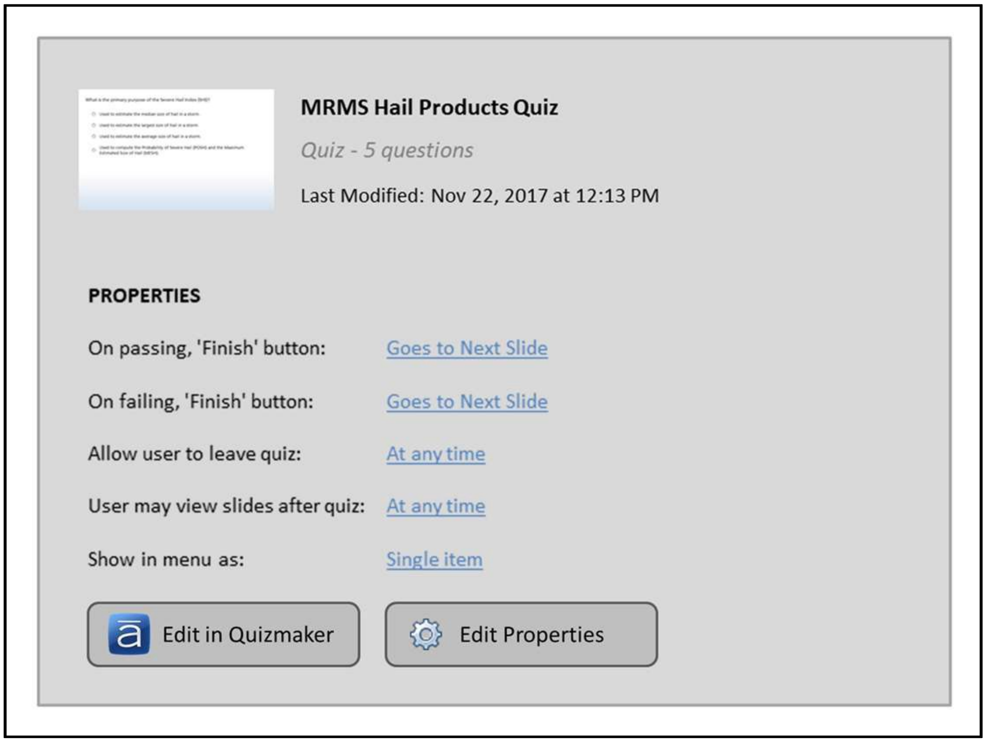


Like all MRMS products, the use of multiple radars is more robust than single-site radar alone.

It provides faster updates and helps the forecaster integrate data from multiple radars. That is illustrated here, with a cell located equidistant between three radars, which radar would you use to analyze the cells hail potential? You could use MESH, it uses data from all of these radars!

The MRMS hail products also compensates for cone-of-silence, beam broadening at far ranges, and terrain blockage.

Do note that the data are subject to the biases and deficiencies of the mesoscale model used to derive the vertical temperature profile.


MRMS Hail Products Quiz
Quiz - 5 questions
Last Modified: Nov 22, 2017 at 12:13 PM
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On failing, 'Finish' button: Goes to Next Slide
Allow user to leave quiz: At any time
User may view slides after quiz: At any time
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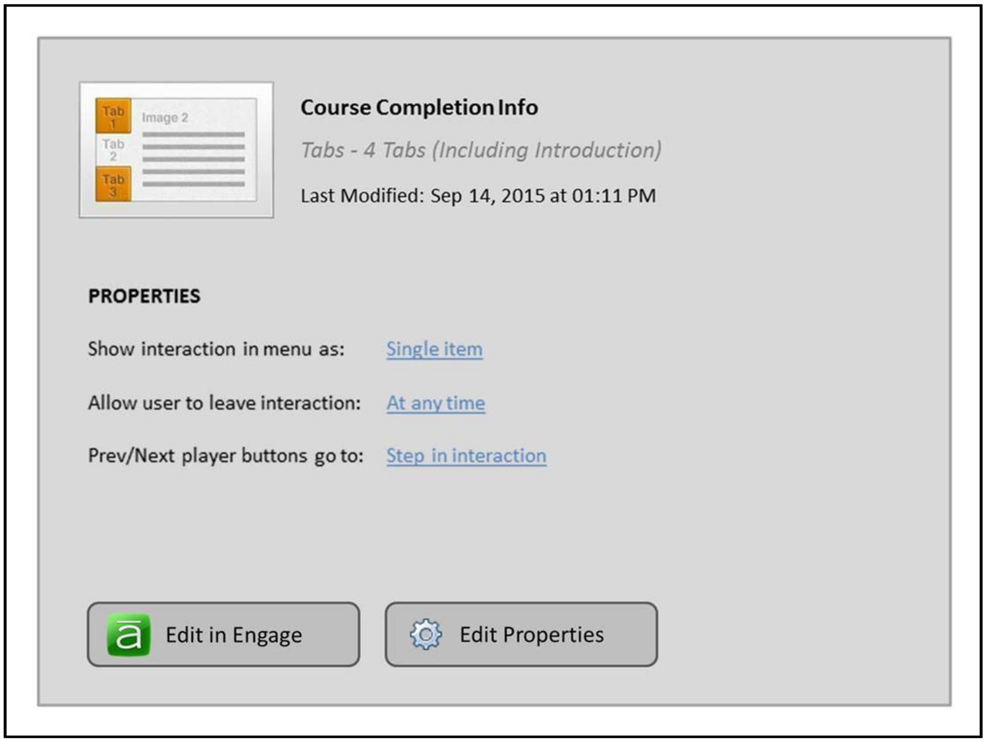
Welcome to the Multi-Radar/Multi-Sensor (MRMS) Products Course Lesson on Velocity-based Products! I am Alyssa Bates with the Warning Decision Training Division (WDTD).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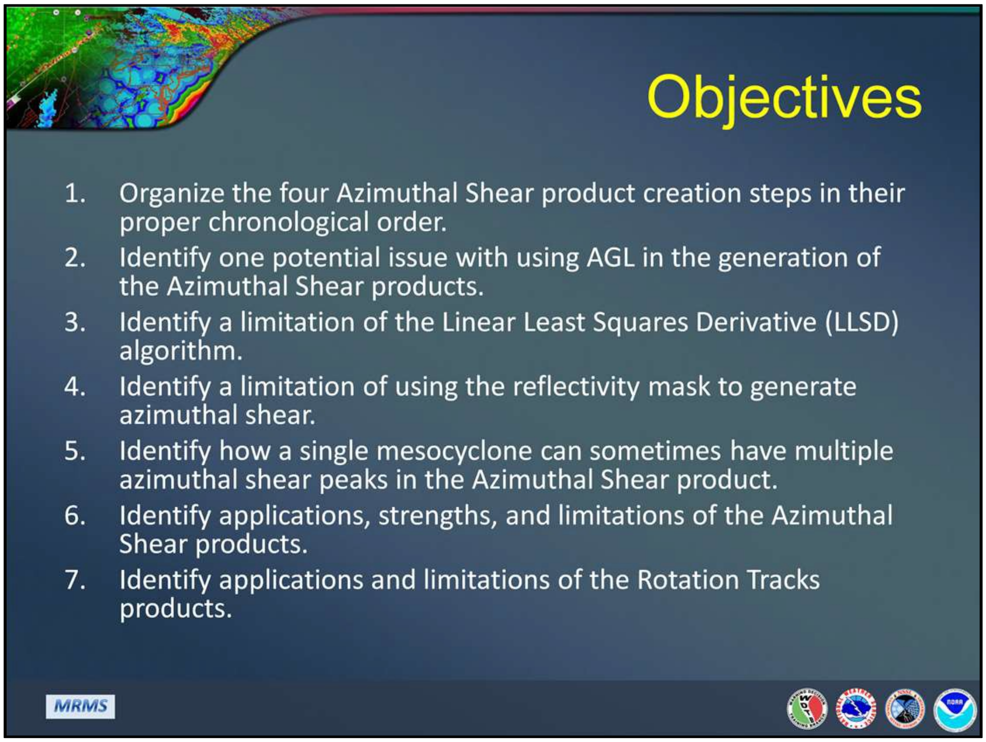
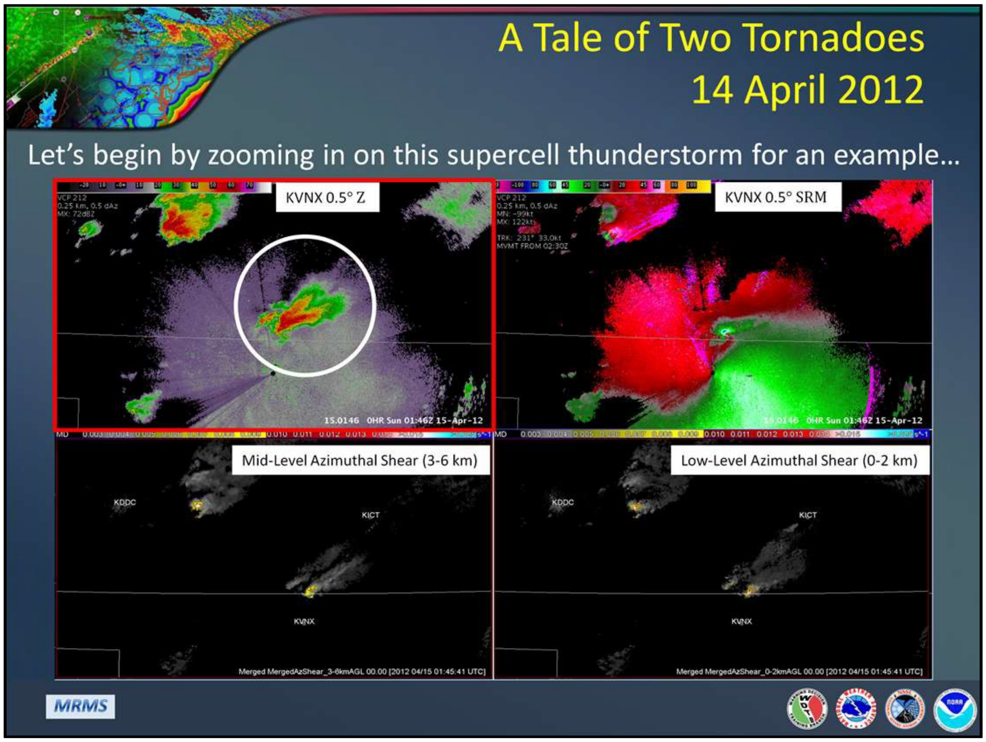
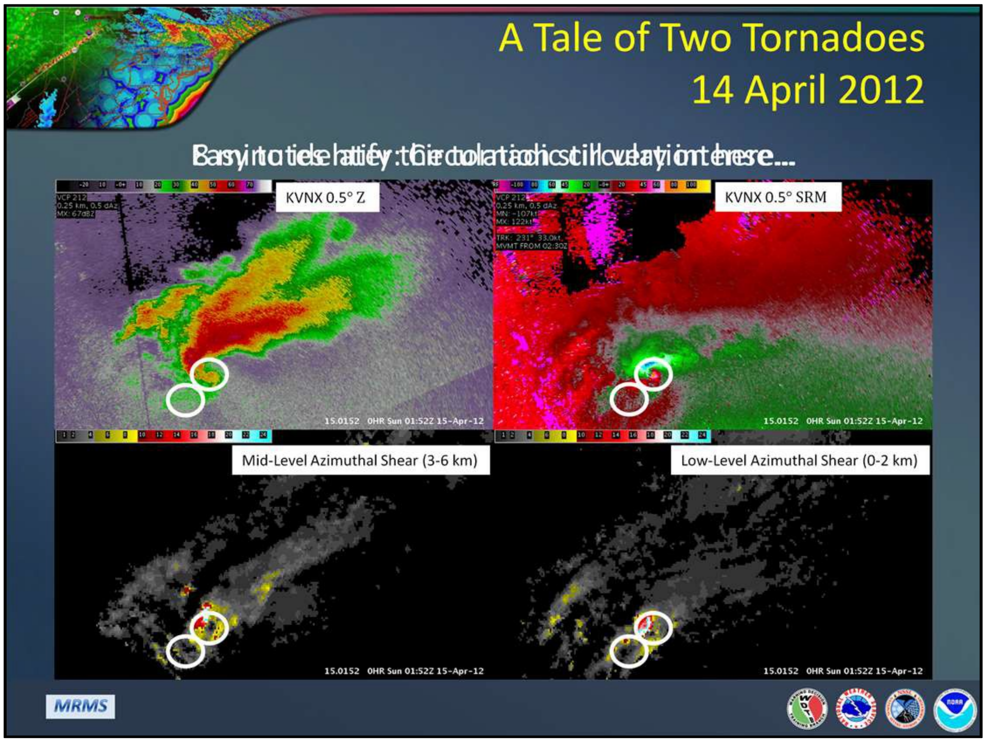


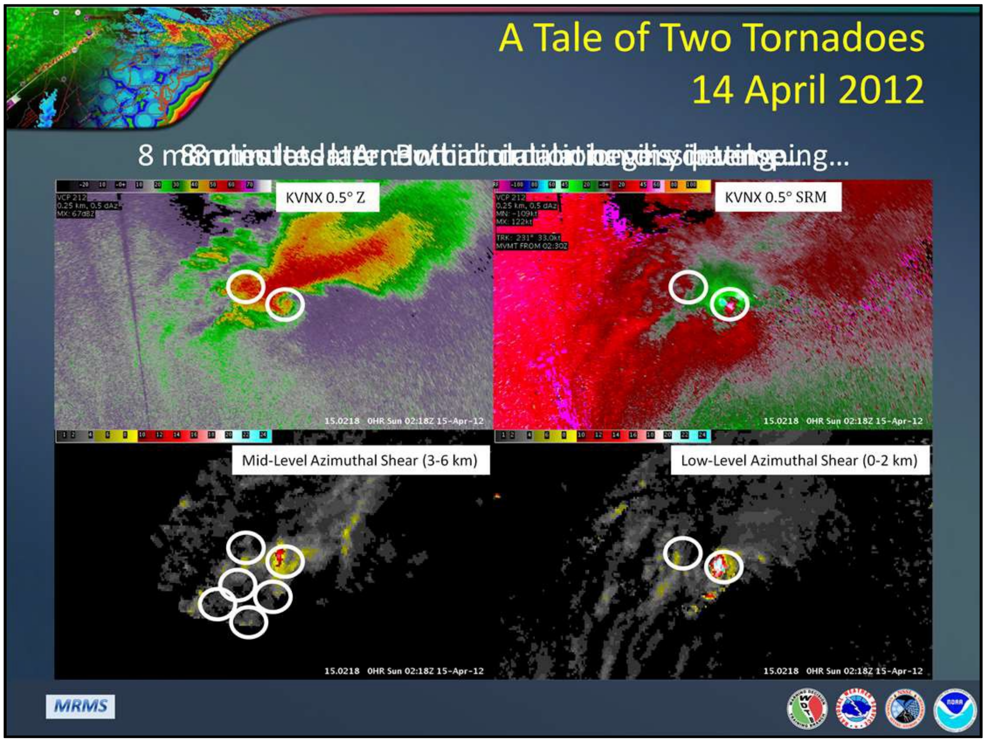
Here are the objectives for this lesson. Take a minute to review them before moving on to the next slide.



Let's begin this module by showing a comparison of MRMS and base radar data. The top two panels are reflectivity and SRM from a single-site, while the bottom two panels are Mid- and Low-Level Azimuthal Shear. Our example will focus on this supercell.

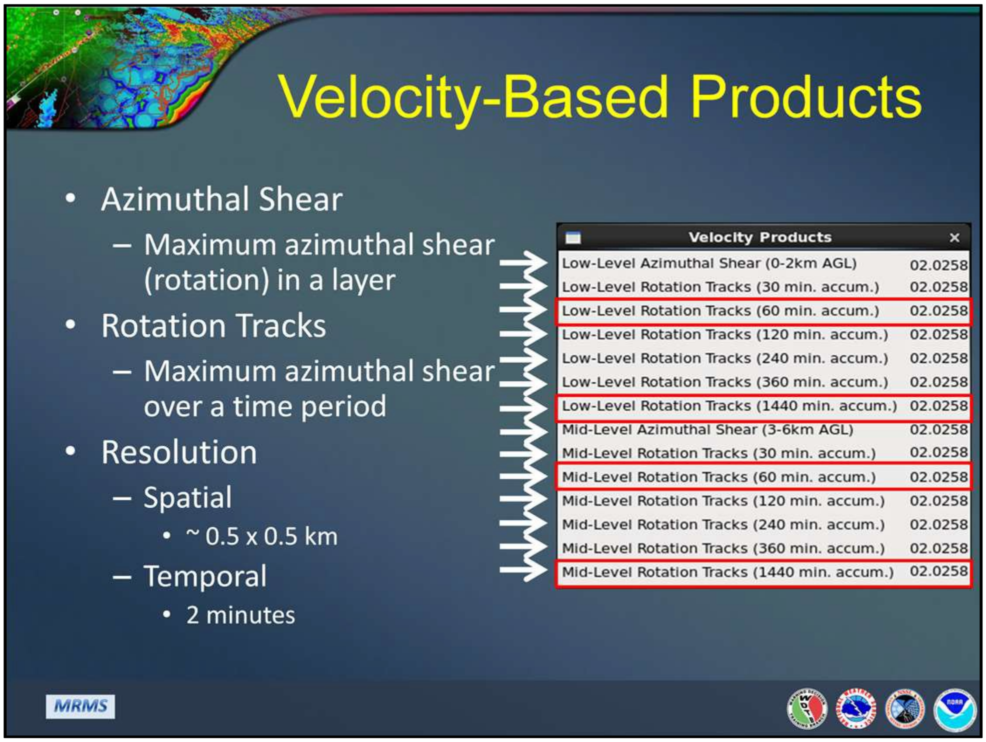


In this case, it's easy to identify the tornadic circulation in both the base and MRMS data. And if we advance eight minutes, we can see that the circulation is remaining very intense.



Advancing 8 more minutes, a new mesocyclone begins to develop to the east. At the same time, MRMS and base data indicate the initial circulation is at its strongest. 8 more minutes and both circulations are now intense with two tornadoes occurring simultaneously. Lastly, if we advance 8 more minutes, we see that the initial tornadic mesocyclone has occluded and been replaced by the secondary mesocyclone.

This example illustrates how MRMS data can complement traditional base radar velocity analysis.

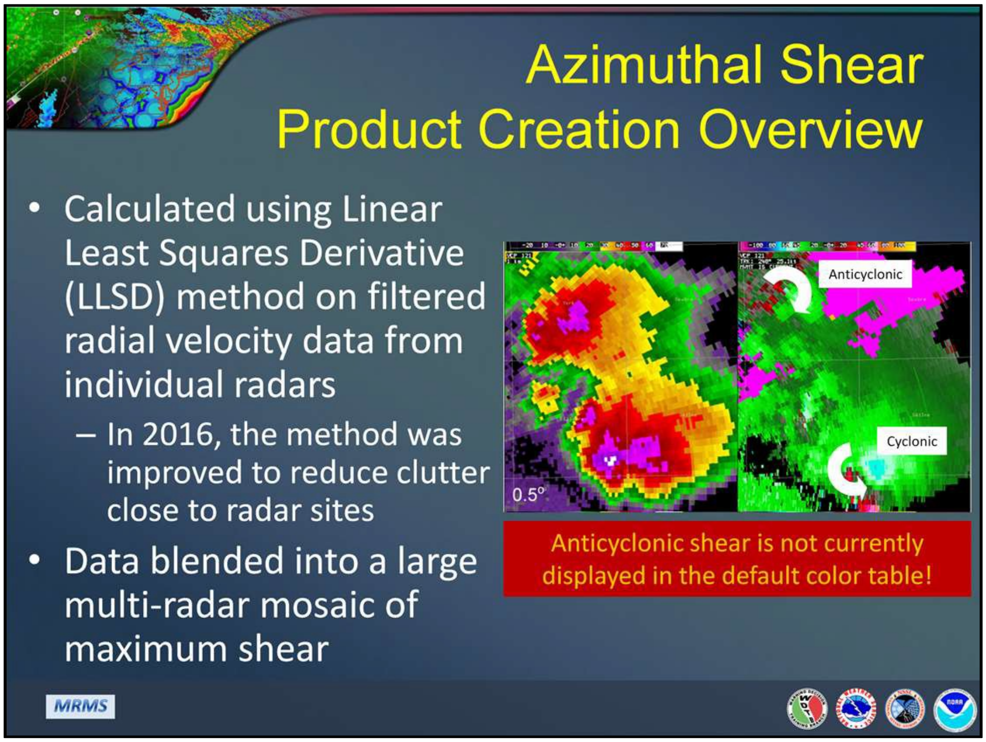


There are two MRMS velocity-based product suites:

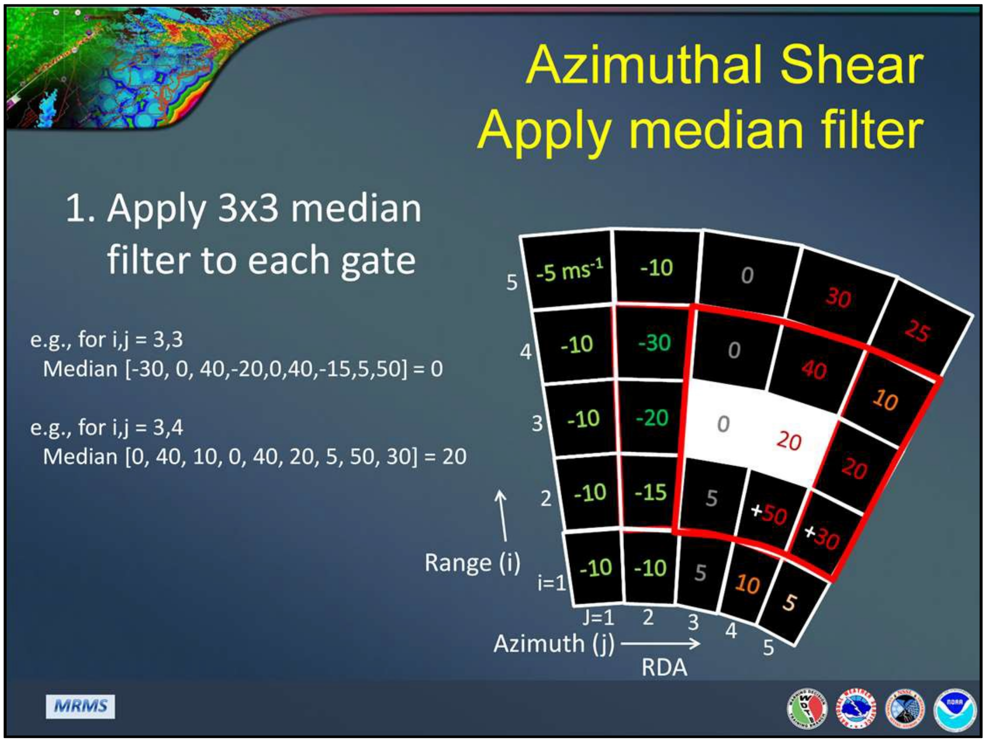
- The Azimuthal Shear products display the maximum azimuthal shear or rotation divided by diameter in units of per second. Available Azimuthal Shear products include Low-Level, which uses the 0-2 km above ground level (AGL) layer and Mid-Level, which uses the 3-6 km above ground level (AGL) layer.

- The Rotation Tracks products display the maximum azimuthal shear in the low-level or mid-level layer for a specified time period. Available intervals include 30, 60, 120, 240, 360, and 1440 minutes.

The spatial resolution of these products is approximately 500 m by 500 m and the temporal resolution is 2 minutes. In addition, only a select few of these products are operational as of June 2016. The rest of the products may become operational in the future.

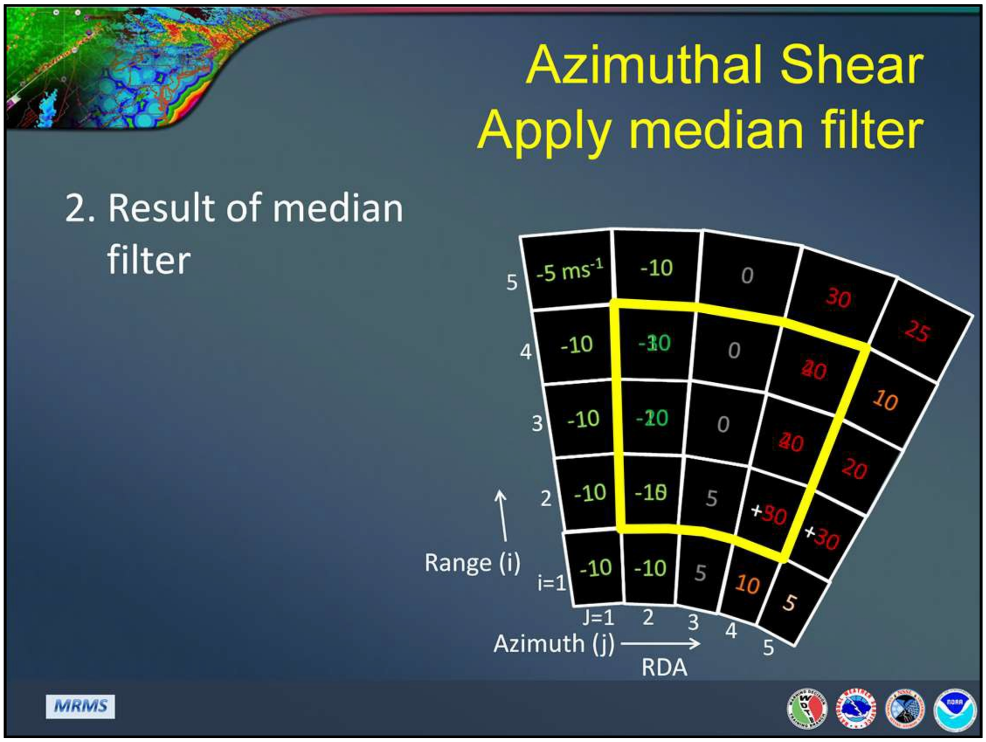


Let's now get into how the Azimuthal Shear product is created. This will help us better understand its applications, strengths and weaknesses. Azimuthal shear is calculated by applying a Linear Least Squares Derivative or LLSD algorithm to the radial velocity data from individual radars. Note that this method was improved in 2016 and significantly reduced clutter close to radar sites. We'll talk about that later. Once this process is complete, the data is then blended to create the multi-radar Azimuthal Shear product. It is important to note that anticyclone shear is not currently displayed in the default color table.

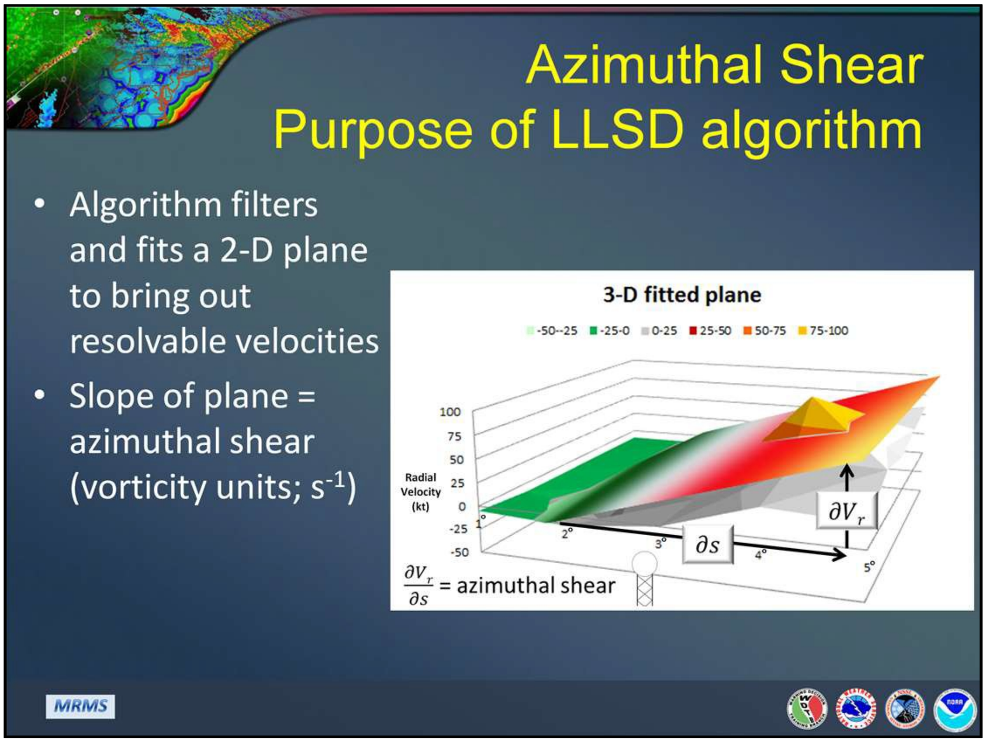


Now, let's discuss this LLSD process in greater depth. The process starts in polar format for each radar's velocity data. In order to reduce spikes or that occasional bad velocity in the data, velocities are smoothed using a 3x3 median filter. For example, let's look at this pie slice of velocity gates where azimuths are represented by 'j' and range increases by 'i'.

Running the median filter at point 3,3, we find the median value of all the velocities in the 3x3 wedge is zero and thus point 3,3 does not change. However, if we run the filter at point 3,4, the velocity is reduced by 20 ms-1.



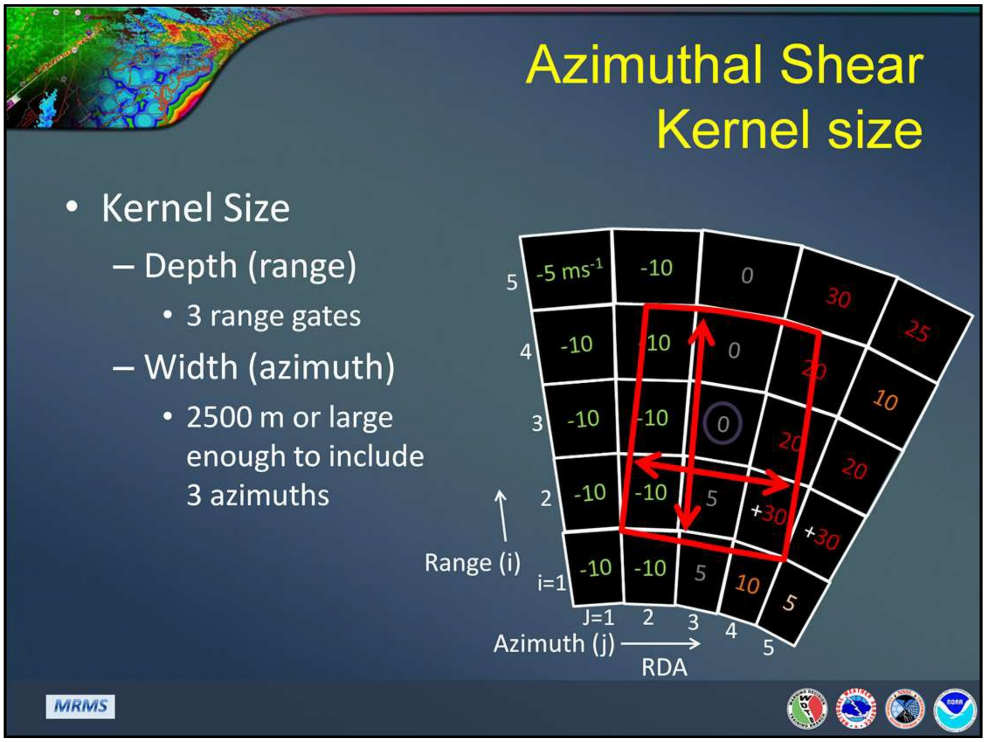
Starting back at the raw velocity data, the result of filtering all the points in the yellow highlighted area may look something like this. Notice how the velocity data becomes smoother. It is important to note that this process might partially or fully remove small tornado vortex signatures. This sacrifice is worthwhile because there are a lot more bad velocity spikes that could corrupt the azimuthal shear product.



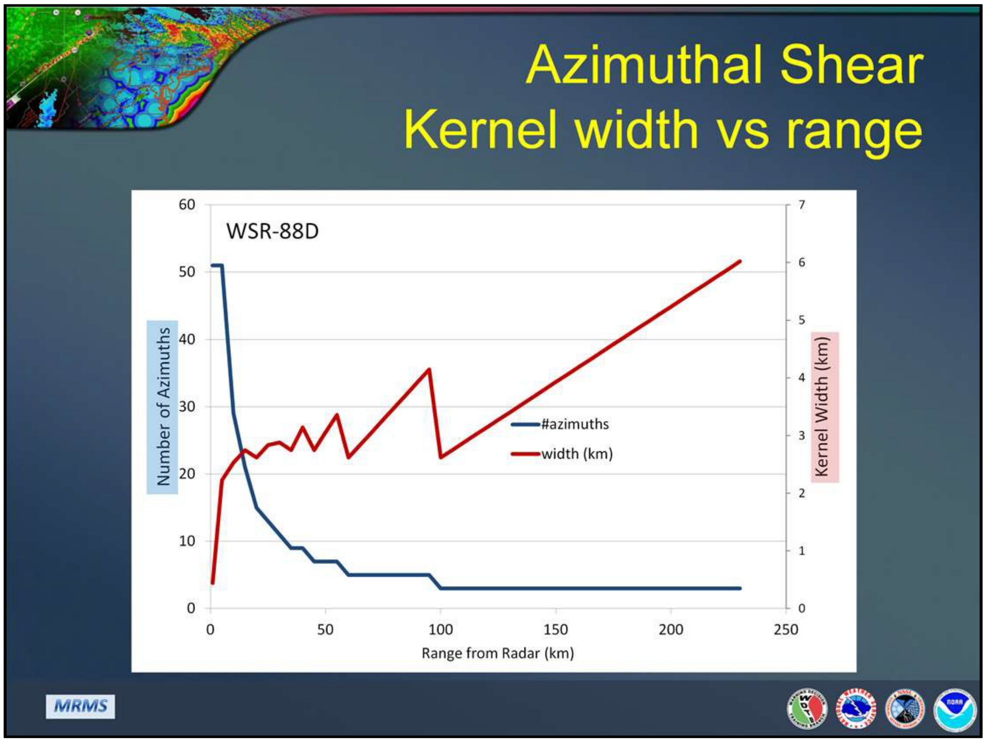
After the 3x3 filter is applied, the LLSD algorithm calculates azimuthal shear.

To illustrate the process, let's look at this 3D graphic where the radar is at the bottom of the image and radial velocity is on the vertical axis. A large, cyclonic circulation is centered in the middle of this 3D graphic with inbound velocities represented by the green valley on the left and outbound velocities represented by the reds and oranges on the right. An outbound peak velocity can be seen on the right.

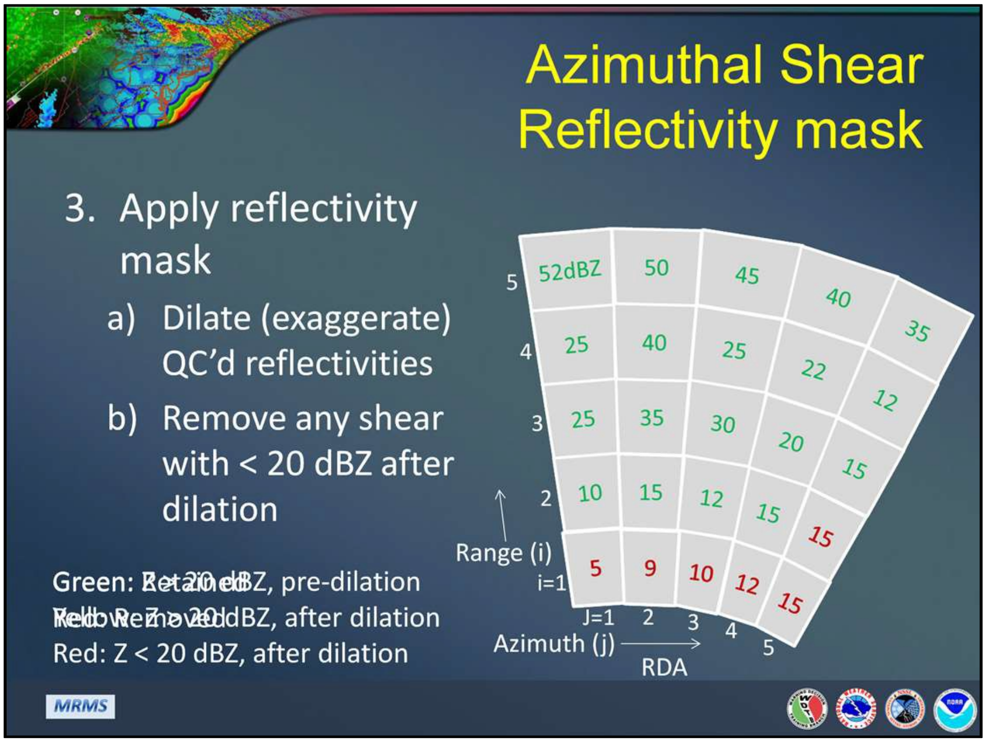
The LLSD algorithm fits a plane three gates deep and at a fixed width to the underlying radial velocity data. It does so in such a way as to minimize the differences between the velocities in the fitted plane and the raw radial velocities. The slope of the plane represents the azimuthal shear. The LLSD algorithm creates an azimuthal shear at every gate and elevation slice for each radar.



The LLSD kernel size must be large enough to produce reliable azimuthal shear values. The kernel depth is always 3 range gates. For the WSR-88D in long pulse mode, this is 1500 m (500 m x 3 = 1500m). The kernel width is 2500 m or for longer ranges wide enough to include at least 3 azimuths. This generally occurs beyond about 90 nautical miles.

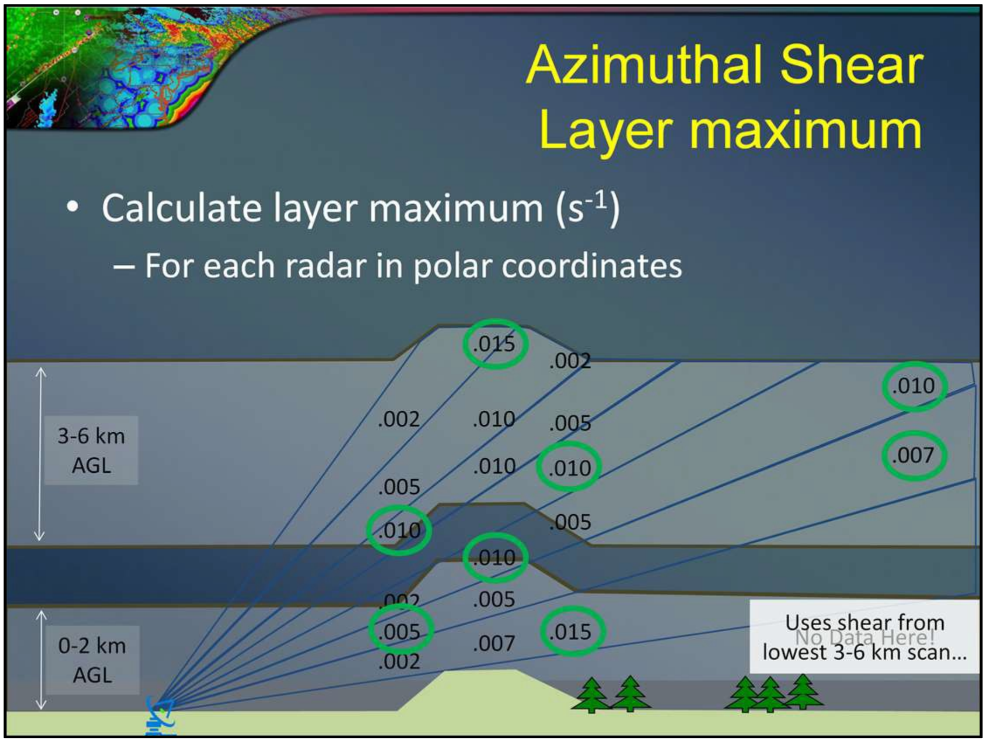


This graph illustrates kernel width and number of azimuths versus range from a radar. Notice the number of azimuths in the kernel, which is the blue line, decreases exponentially as range from the radar increases. The kernel width, which is the red line, doesn't change much between 10 and 100 km, though numerous fluctuations exist. At longer ranges beyond 100 km, the kernel width increases to satisfy the requirement to always maintain at least three azimuths. This means the kernel will respond to vortex signatures of a certain dimension of at least an inner core diameter of 3 km and that smaller vortices will not be well resolved by the LLSD algorithm.



The LLSD algorithm developers are mindful that radial velocities with poor signal may not be reliable. Earlier versions applied a reflectivity mask to remove azimuthal shear values associated with reflectivities less than 20 dBZ. However, such logic proved too harsh, especially for mesocyclones embedded in weak echo regions. So the process was modified to dilate or "exaggerate" the quality controlled polar reflectivities such that the reflectivities in weak echo regions adjacent to storm cores were increased enough that they exceeded the 20 dBZ reflectivity mask threshold. After dilation, data is removed from gates with reflectivity still less than 20 dBZ. The implications of the dilation process are that mesocyclones in weak reflectivity regions such as low precipitation supercells are better preserved. Although some can still be missed.

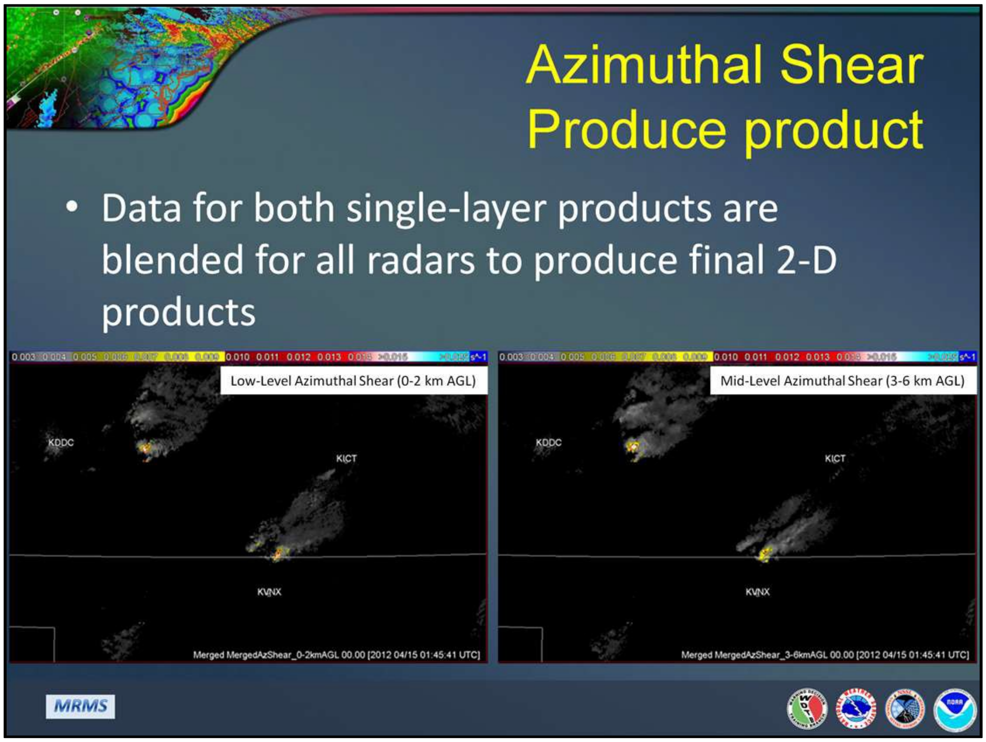
This graphic illustrates the dilation and masking process. Let's assume these gates (green) have a reflectivity greater than 20 dBZ pre-dilation. While the reflectivity in these (yellow) gates exceeds 20 dBZ after dilation. And the reflectivity in these (red) gates is less than 20 dBZ after dilation. The result of the masking process would be to retain the green gates (including the yellow gates) and remove the red gates.



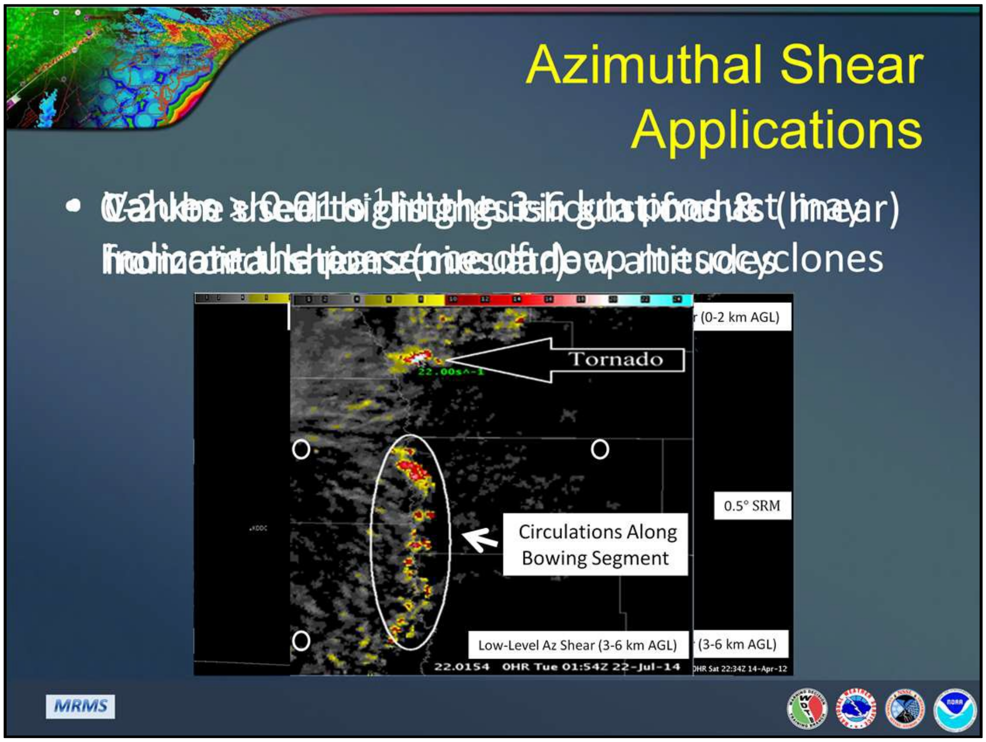
With the reflectivity masked azimuthal shears retained, the next step is to composite them into the 0-2 km and 3-6 km vertical layers. Each layer is a layer maximum composite, in other words, the maximum azimuthal shear found the layer is retained.

Let's overlay some sample azimuthal shear values at different ranges for various elevation angles to help illustrate this process. In this example, these values would be the layer maximum at their respective ranges.

At more distant ranges, there is no data in the 0-2 km layer. In these cases the lowest elevation slice contributes an azimuthal shear to both the 0-2 and 3-6 km layers.



Once the polar azimuthal shear layer products are finalized, they are merged into the MRMS grid, much like the reflectivity-based polar radar data. However in this case, there is no vertical interpolation. This is the final step in the product creation process.

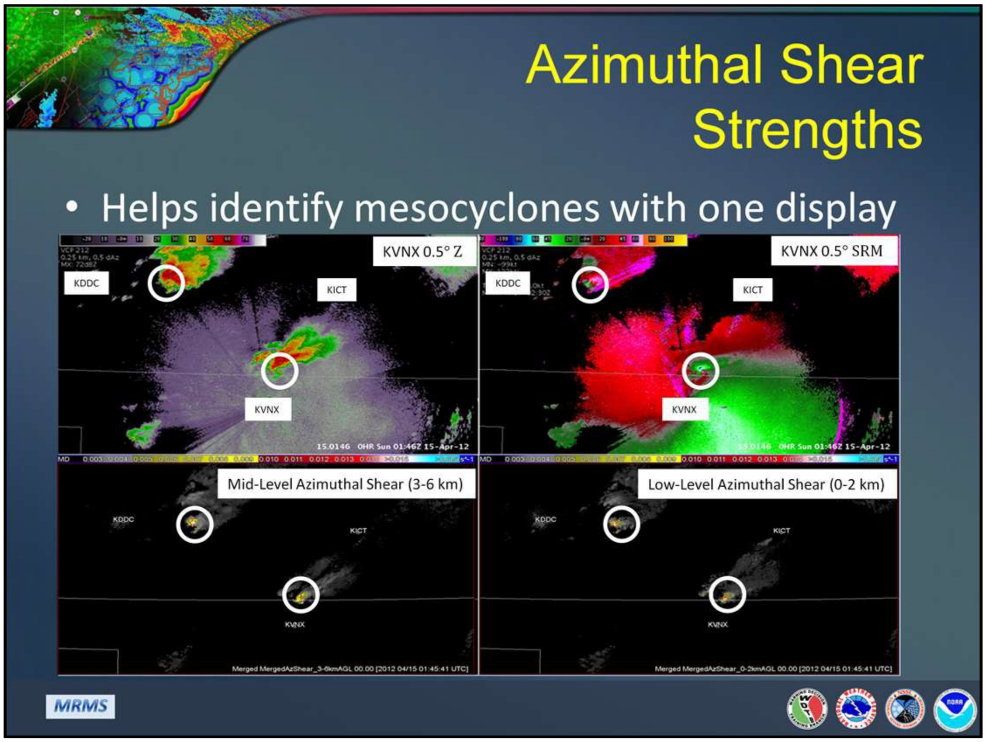


The Azimuthal Shear products have many applications:

- For example, the 0-2 km Azimuthal Shear product highlights circulations and horizontal shear zones in the low altitudes of storms that may be associated with mesocyclones and/or tornadoes.

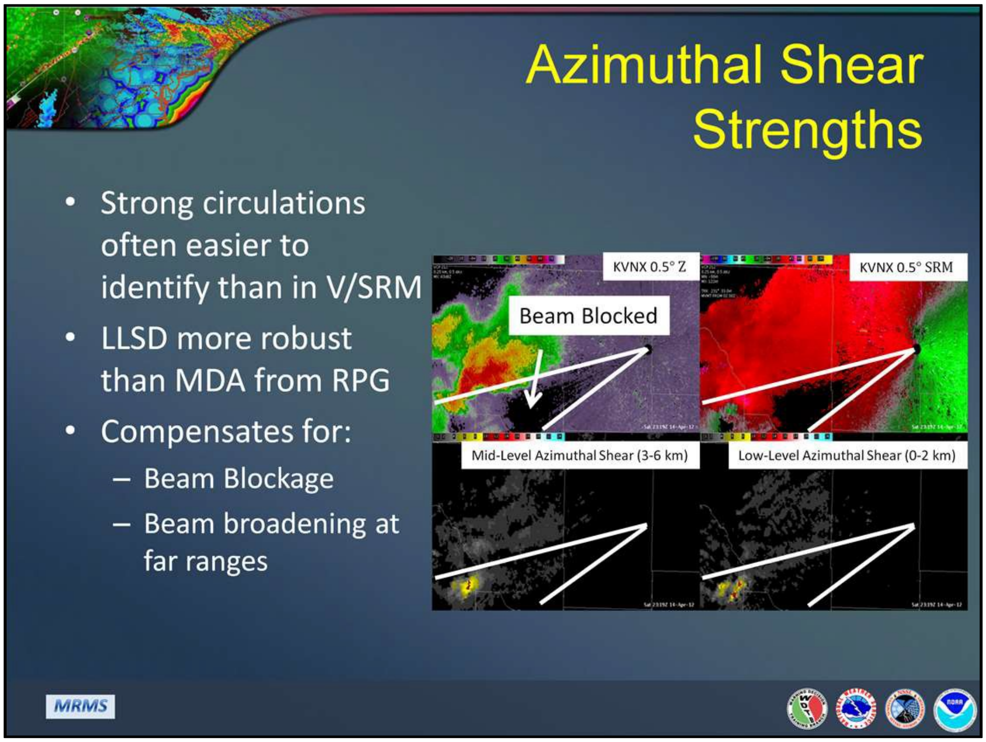
- Additionally, large values in the 3-6 km product may indicate the presence of a deep mesocyclone, indicative of a supercell thunderstorm.

- Lastly, Azimuthal Shear could also be associated with a gust front or another feature, depending on the viewing angle of the nearest radar. Well-sampled circulations generally appearcircular, while gust fronts and shear zones are linear.



Some strengths of the Azimuthal Shear Product are:

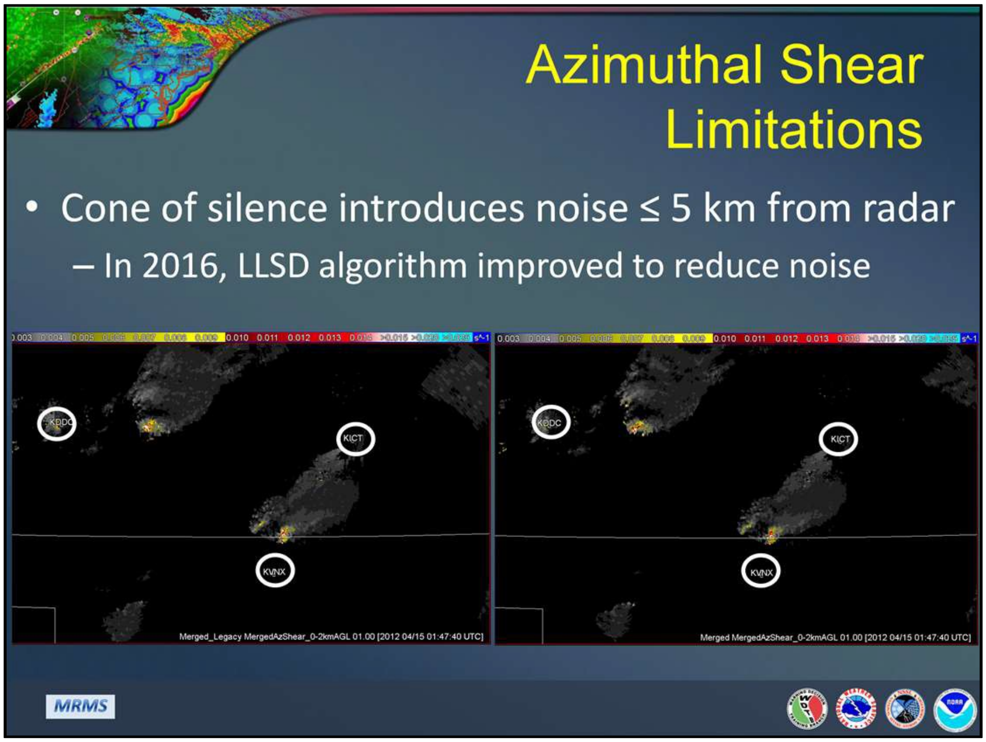
- That it helps identify mesocyclones and tornadoes with one display. In this example, there are three radars that could be used to analyze these storms. Instead of having to flip between radars, you could use Azimuthal Shear! It provides a perspective from all of these radars.



- Also, very strong mesocyclones and tornadoes are usually easier to identify than in WSR-88D Base Velocity or SRM products.

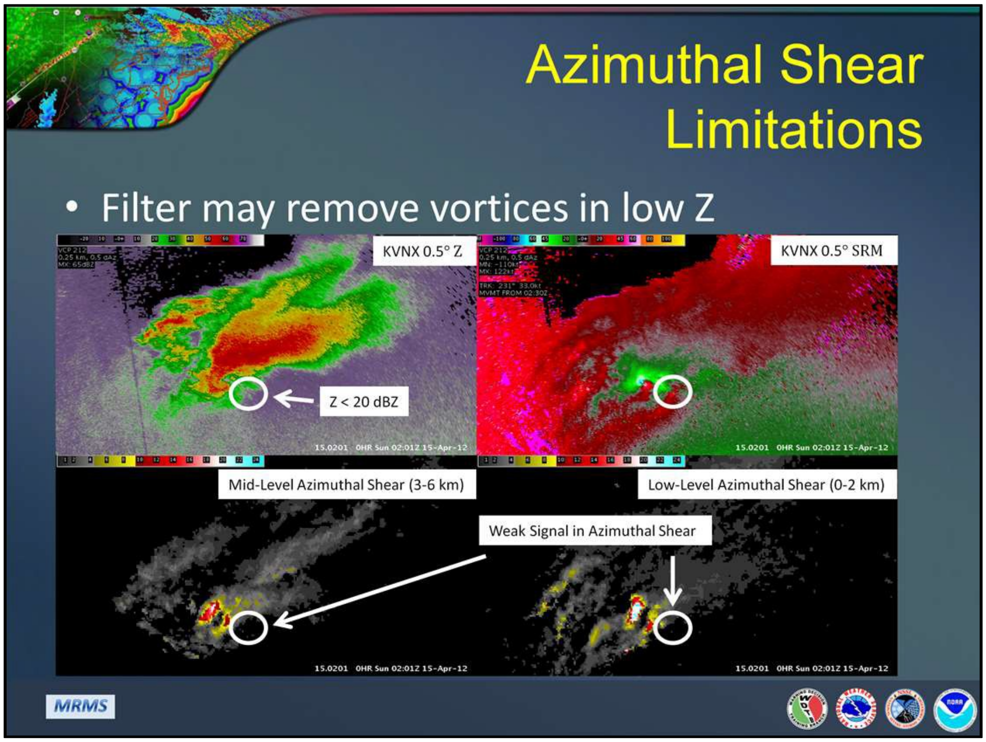
- The Linear Least Squares Derivative algorithm is also more sophisticated than the Mesocyclone Detection Algorithm from the WSR-88D Radar Product Generator.

- Lastly, the Azimuthal Shear product compensates for beam blockage and beam broadening at far ranges.

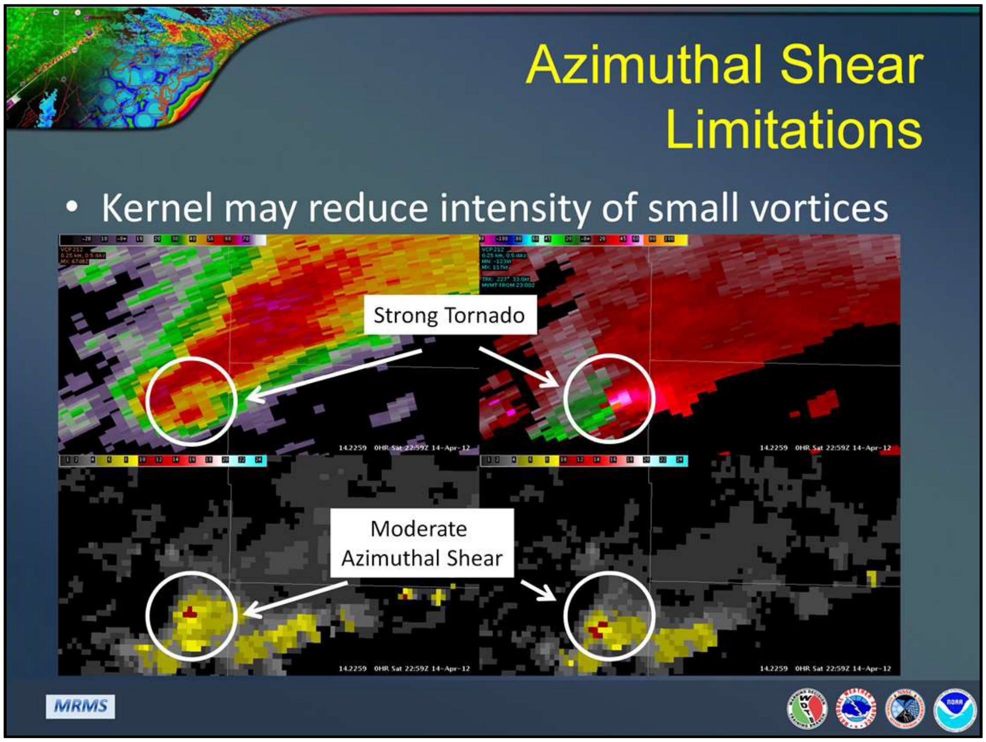


The Azimuthal Shear product does have a few limitations:

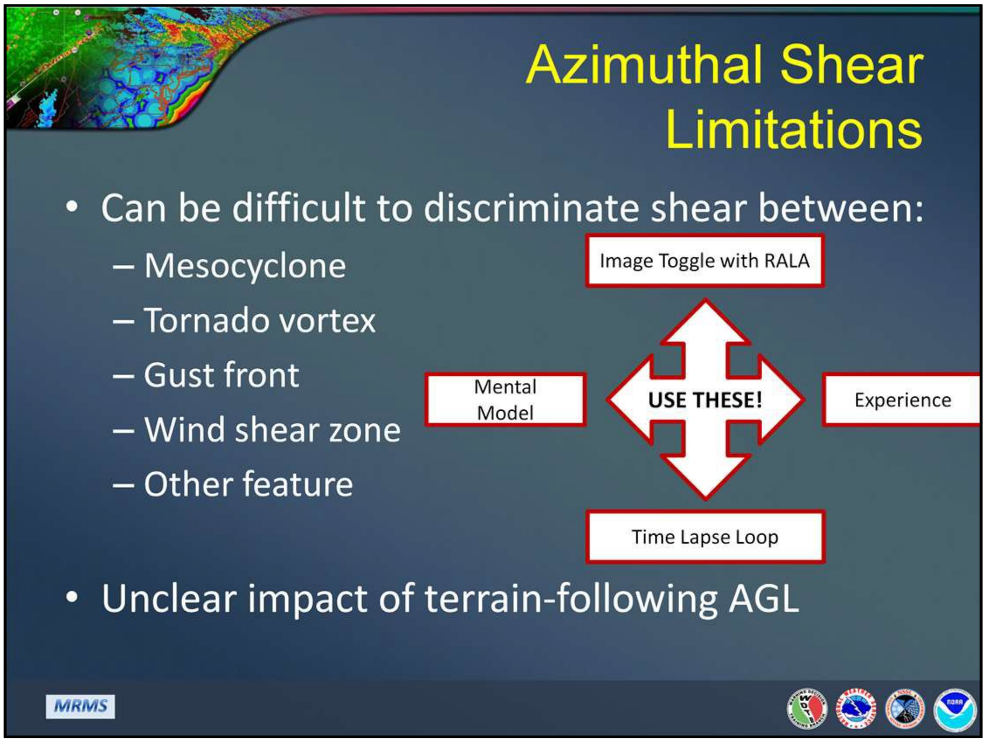
- The Azimuthal Shear calculations break down within 5 mi of a radar, so RDAs can sometimes be ringed with false Azimuthal Shear. In 2016, National Severe Storms Lab researchers improved the LLSD derivation to erase a lot of that erroneous shear, but some will be occasionally evident.



- Valid circulations can also be removed by the reflectivity mask when the dilation process is insufficient to compensate for low-reflectivities. This can occur with tornadoes associated with a low reflectivity hook echo or a non-mesocyclone tornado under a yet-to-be precipitating updraft column.

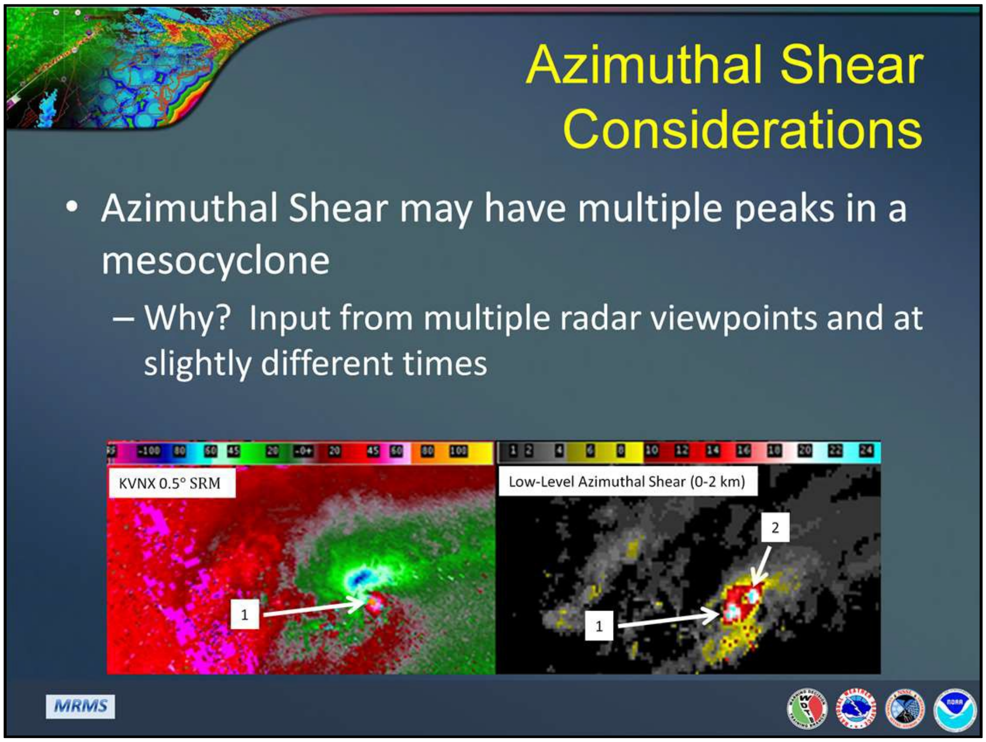


- The Azimuthal Shear kernel may remove or underestimate the full intensity of well sampled vortices, especially when they are small.

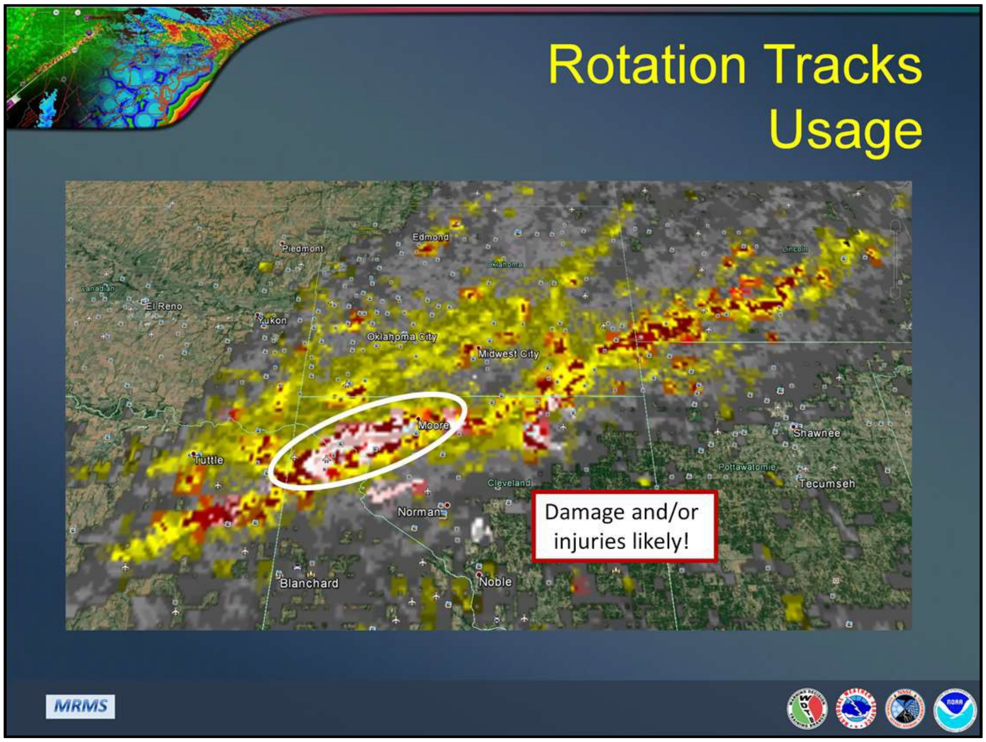


- Also, it can sometimes be difficult to discriminate between shear associated with a mesocyclone, tornado vortex, gust front, wind shear zone, or other feature. In these cases, a time lapse loop, image toggling between Reflectivity at Lowest Altitude and Azimuthal Shear, a mental model of the storm's structure, and experience can all help you make the proper interpretation.

- Note that it is unclear what impact a terrain-following Azimuthal Shear value will have when trying to assess trends in mesocyclone strength for elevation changes. It's possible that a steady state mesocyclone may appear to increase or decrease in intensity as the terrain rises and falls. In other words, changes of altitude may lead to artificial changes of mesocyclone intensity.



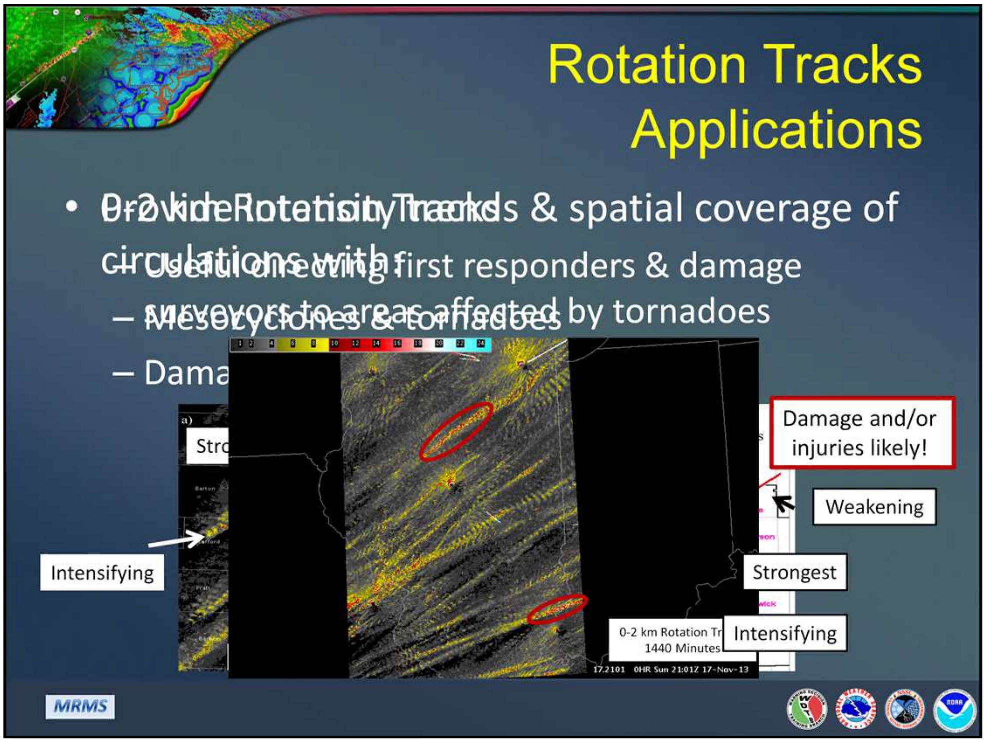
This final azimuthal shear topic is merely a consideration. A single mesocyclone can sometimes have multiple azimuthal shear peaks. This misplacement can occur as a result of input from multiple radar viewpoints and because each radar provides data at slightly different times. Be aware that when a supercell mesocyclone occludes, a new mesocyclone typically forms at the point of occlusion. When this occurs, the dual azimuthal shear couplets are valid.



On May 20, 2013 an EF-5 tornado strikes Moore, Oklahoma. Is there a quick and easy way to provide a first guess of the tornado track to Emergency Managers and First Responders?

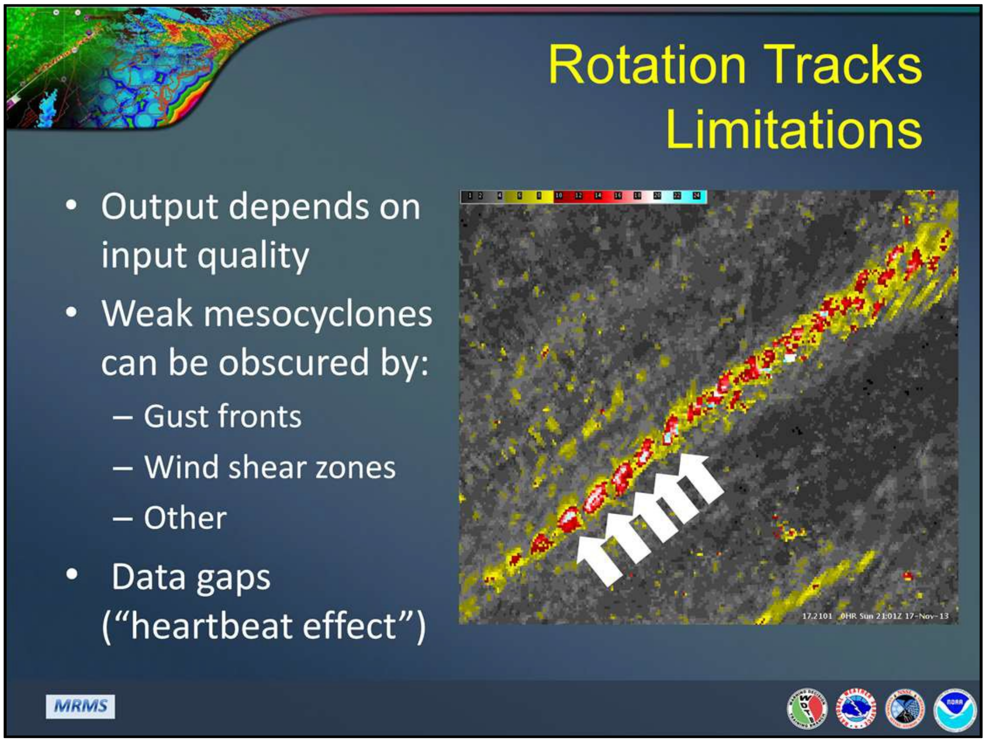
Yeah you can use Rotation Tracks!

You can use the product to quickly disseminate the possible tornado track to National Weather Service partners. Zooming in, here's the surveyed tornado track overlaid on the rotation tracks product.



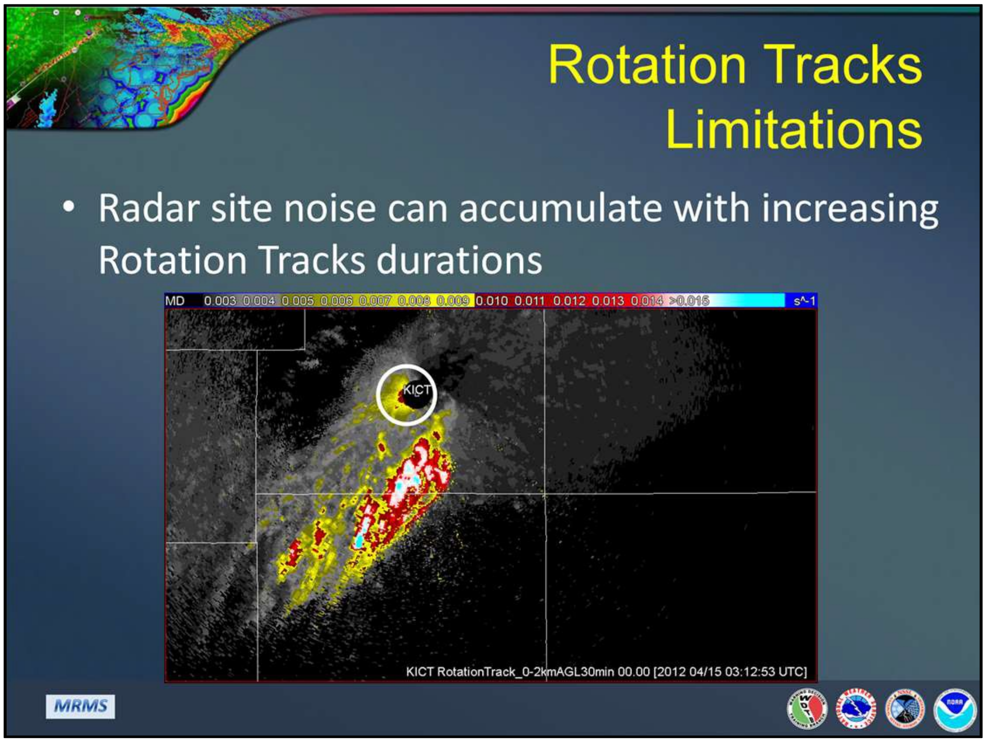
Rotation tracks provide a history of the intensity and spatial coverage of strong storm circulations that may be associated with mesocyclones, tornadoes, and/or damaging winds. This example shows a good correlation between the intensity and location of the rotation track and the associated tornado reports.

Also, as discussed previously, Low-Level Rotation Tracks have shown enormous utility after events in providing guidance to first responders and damage surveyors to direct them to areas most likely affected by tornadoes.

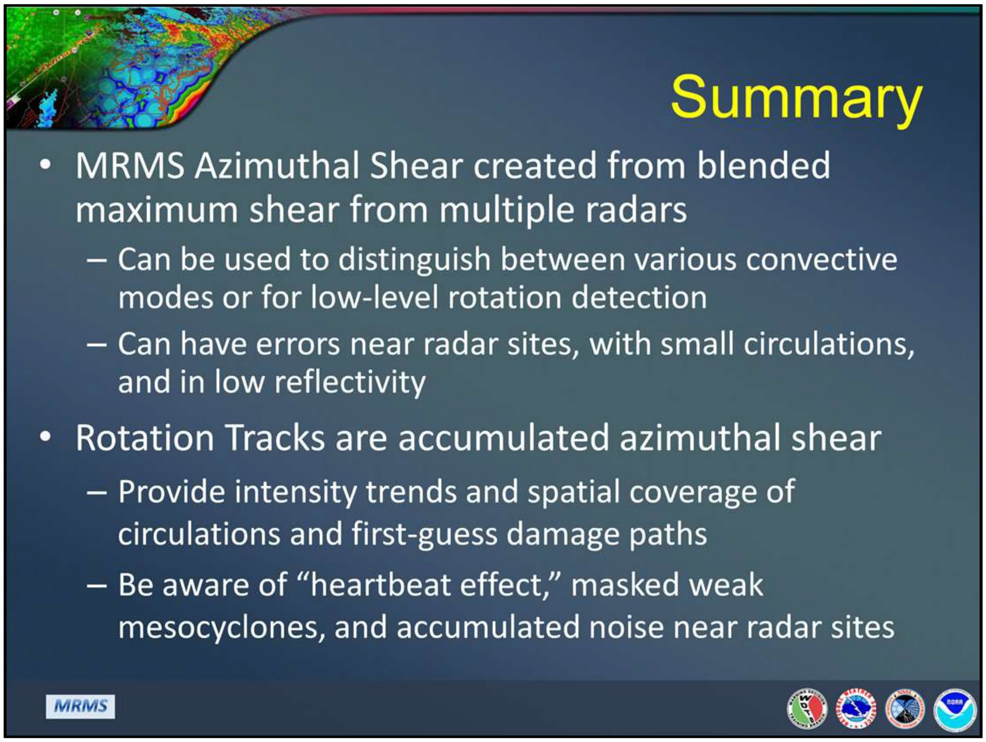


The Rotation Tracks product does have a few limitations:

- For example, if the quality of the Azimuthal Shear data is bad, the quality of the Rotation Tracks will also be bad.
- Some mesocyclones, particularly weaker ones, can be obscured within the noise generated by gust fronts, wind shear zones, and other phenomena.
- Data gaps, which are known as the heartbeat or strobing effect are sometimes observed between product scan times. This effect is most noticeable for fast moving storms and when only one radar samples the storm. Note that some forecasters may consider this a strength because it can provide a sense of the speed of motion of the event.



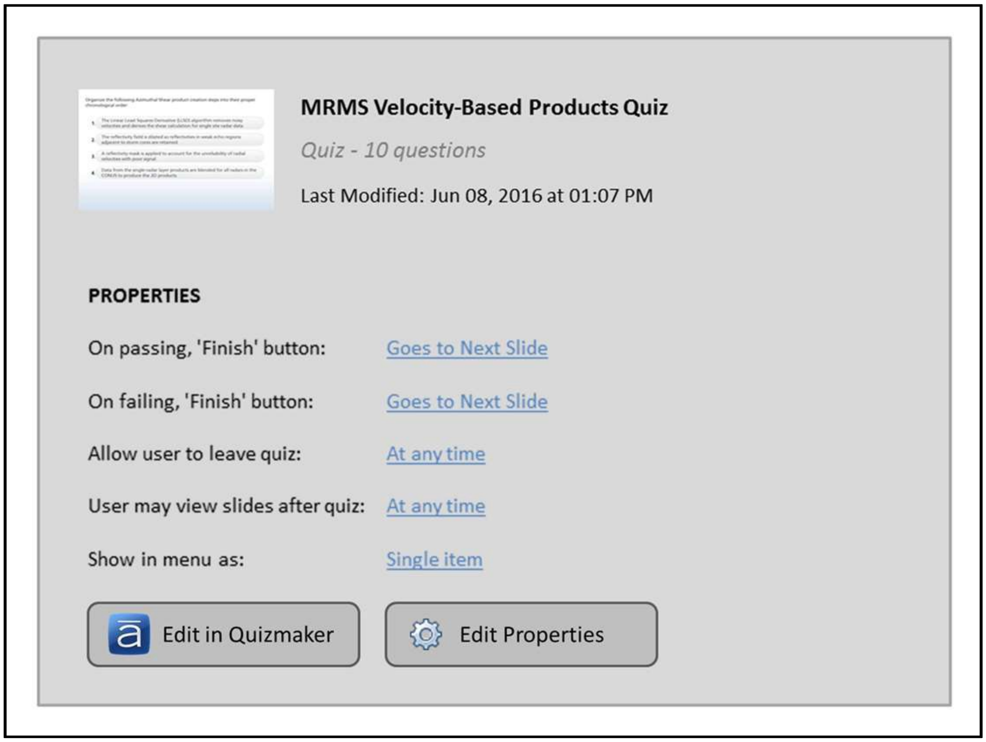
- Finally, be aware that the rings of Azimuthal Shear around RDAs mentioned previously can accumulate with increasing Rotation Tracks durations. Don't mistake these accumulated rings for strong mesocyclones.



In summary, MRMS Azimuthal Shear is created from blended maximum shear from multiple radars. It can be used to distinguish between various convective modes or for low-level rotation detection. However, be mindful that it can have errors near radar sites, with small circulations, and in low reflectivity.

Also, Rotation Tracks are simply accumulated azimuthal shear. They provide intensity trends and spatial coverage of circulations, as well as give first-guesses of damage path locations. Finally, note the Rotation Tracks' limitations of a "heartbeat effect," masked weak mesocyclones, and accumulated noise near radar sites.

Following this slide is a quiz covering what you've learned in this module. Please complete it before moving on.


MRMS Velocity-Based Products Quiz
Quiz - 10 questions
Last Modified: Jun 08, 2016 at 01:07 PM
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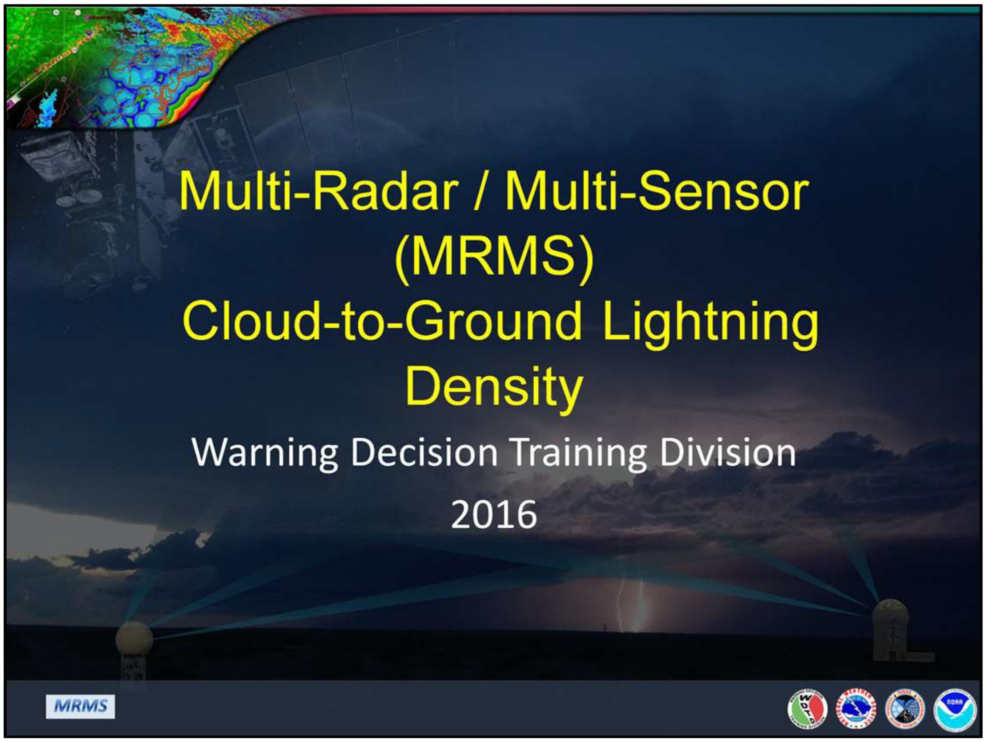
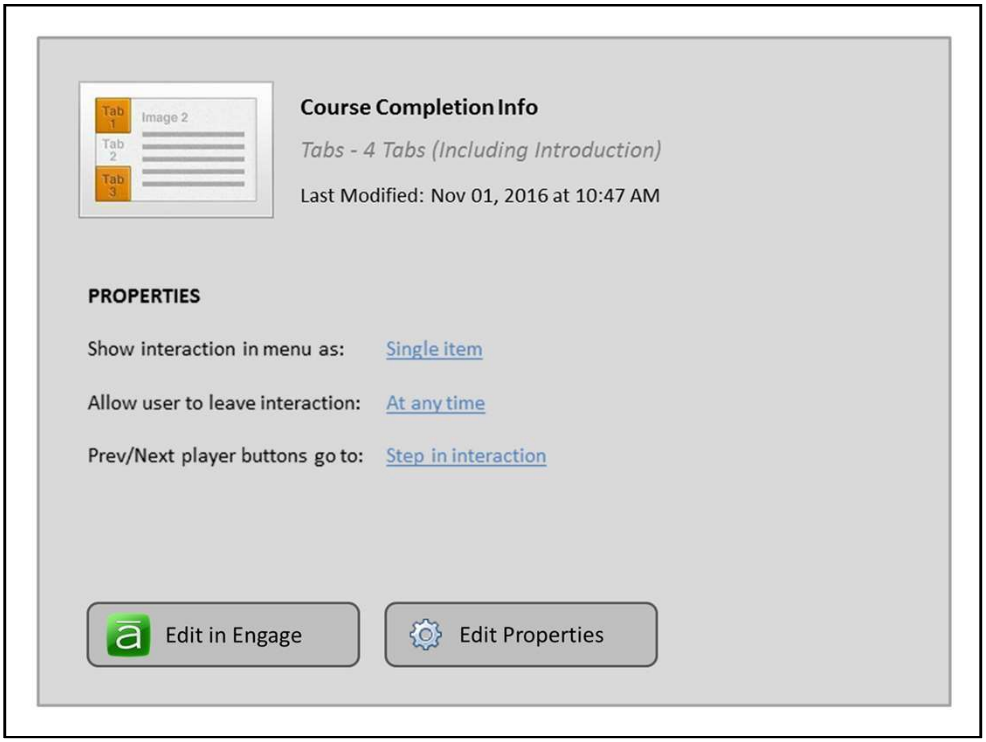
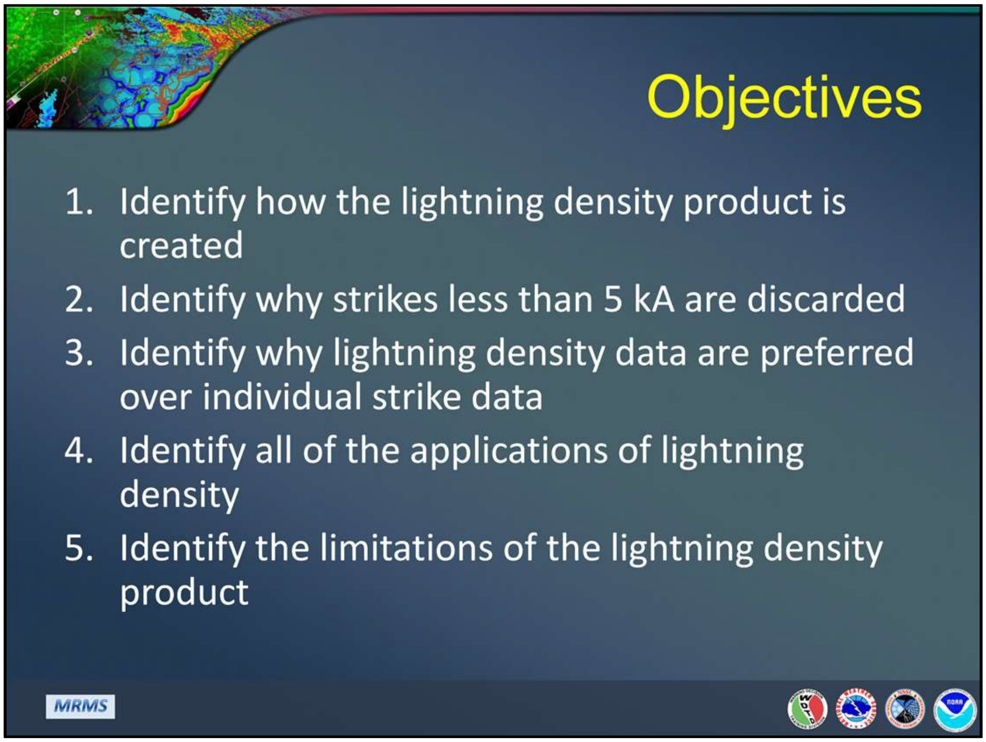


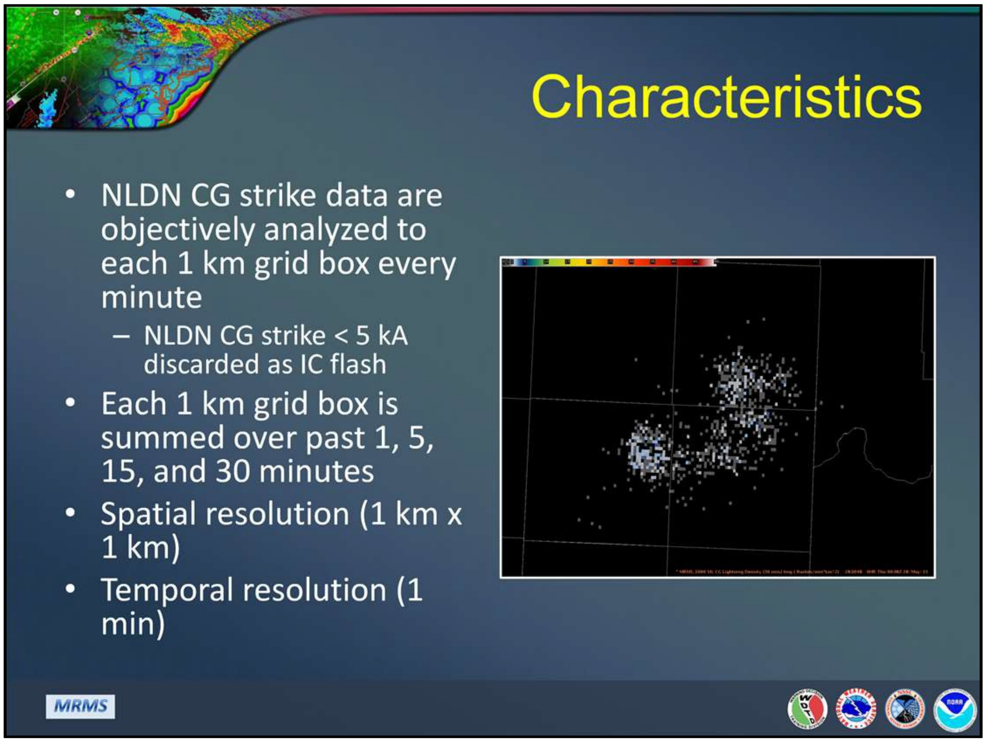
Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Cloud-to-Ground Lightning Density developed at the Warning Decision Training Division (WDTD).



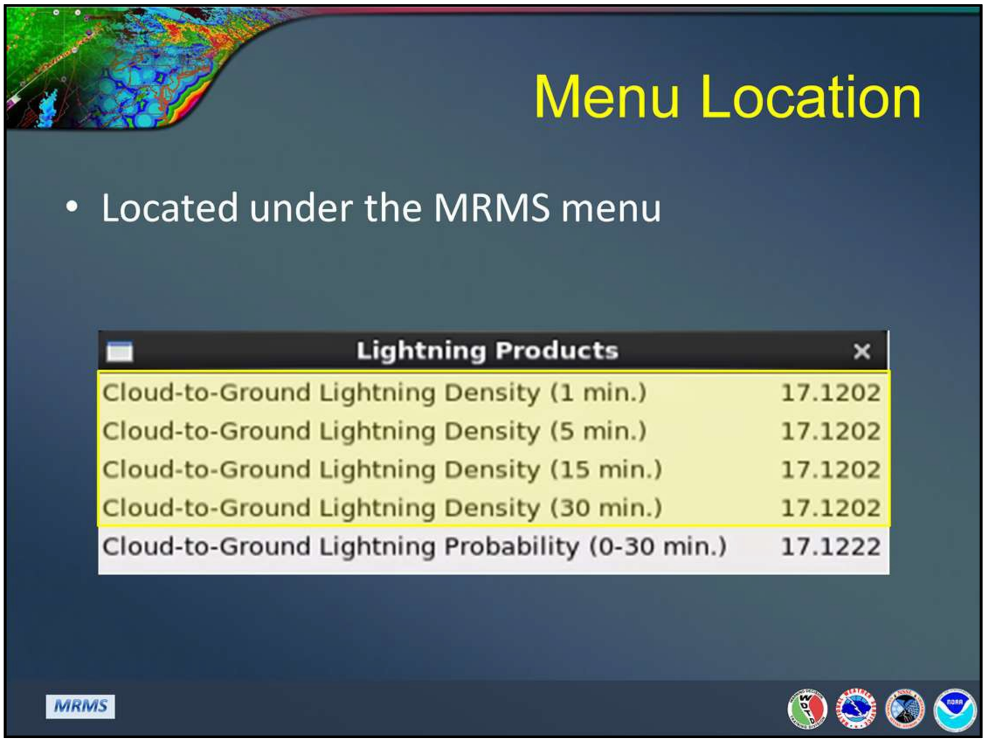
If you are taking this lesson for credit, please review this interaction on how to complete this course.



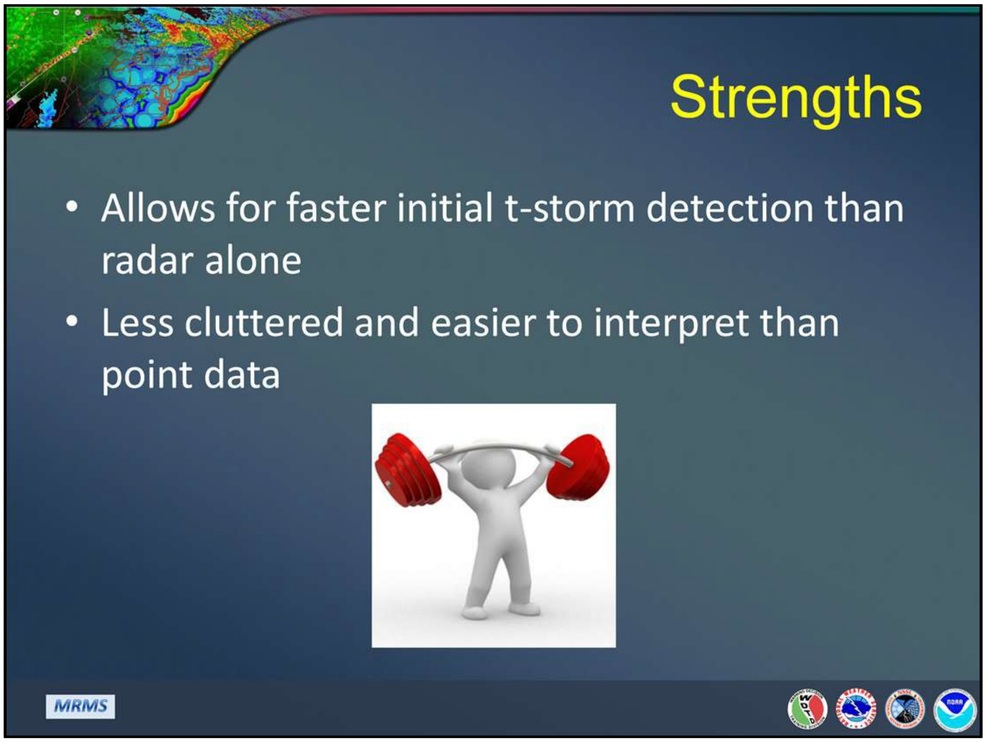
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. The quiz at the end of the lesson is based on these objectives.



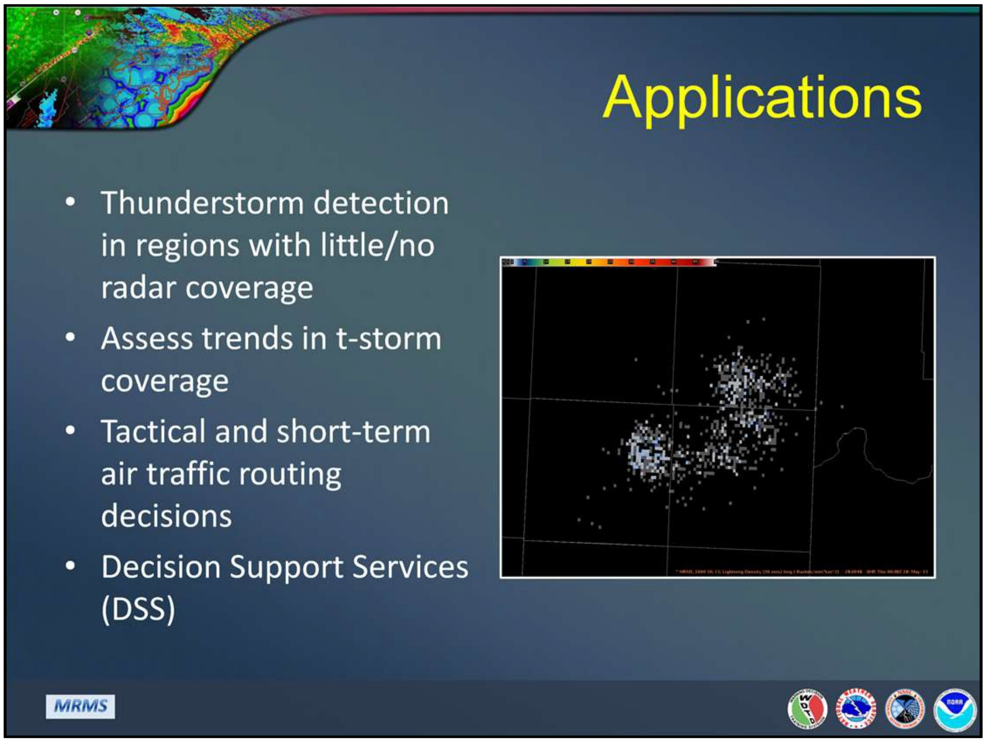
Cloud-to-ground (CG) lightning data from the National Lightning Detection Network (NLDN) are objectively analyzed to a 1 km x 1 km grid box every minute. If the NLDN CG strike data has an absolute value of 5 kA or less, the strike is discarded since research has shown most NLDN CG strike data at 5 kA or less are likely to be intra-cloud (IC). Each 1-km grid box is then summed over 1, 5, 15, and 30 minute time intervals to come up with each time-dependent product. The spatial resolution for each product is 1 km x 1 km with a temporal resolution of 1 minute.



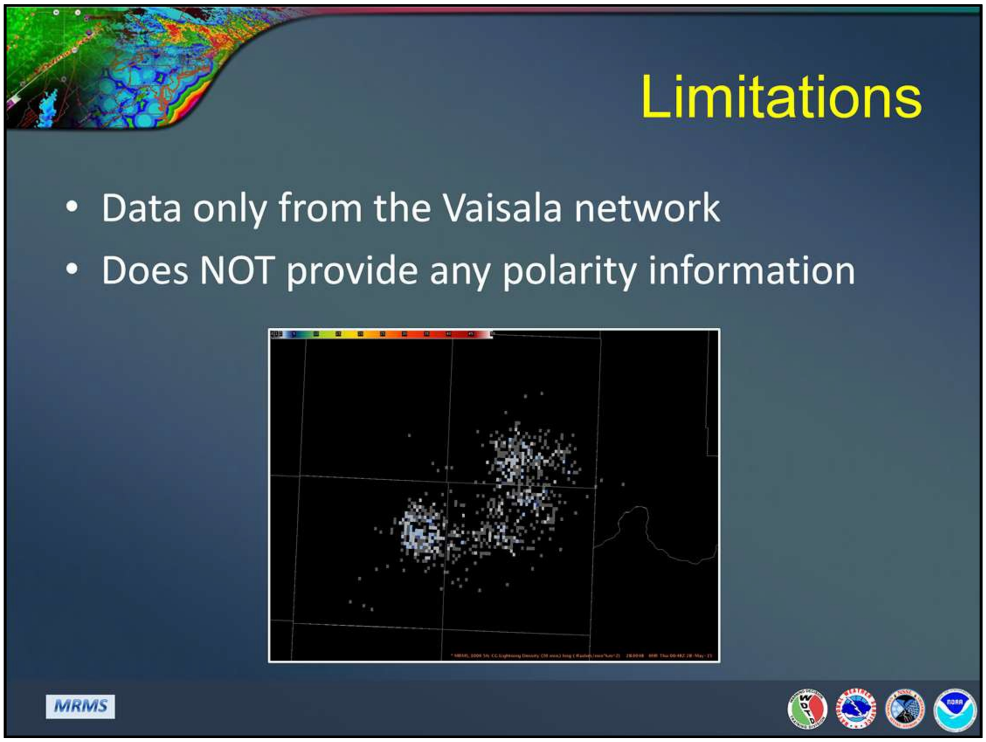
The Lightning Density products can be found within the MRMS menu inside of CAVE.



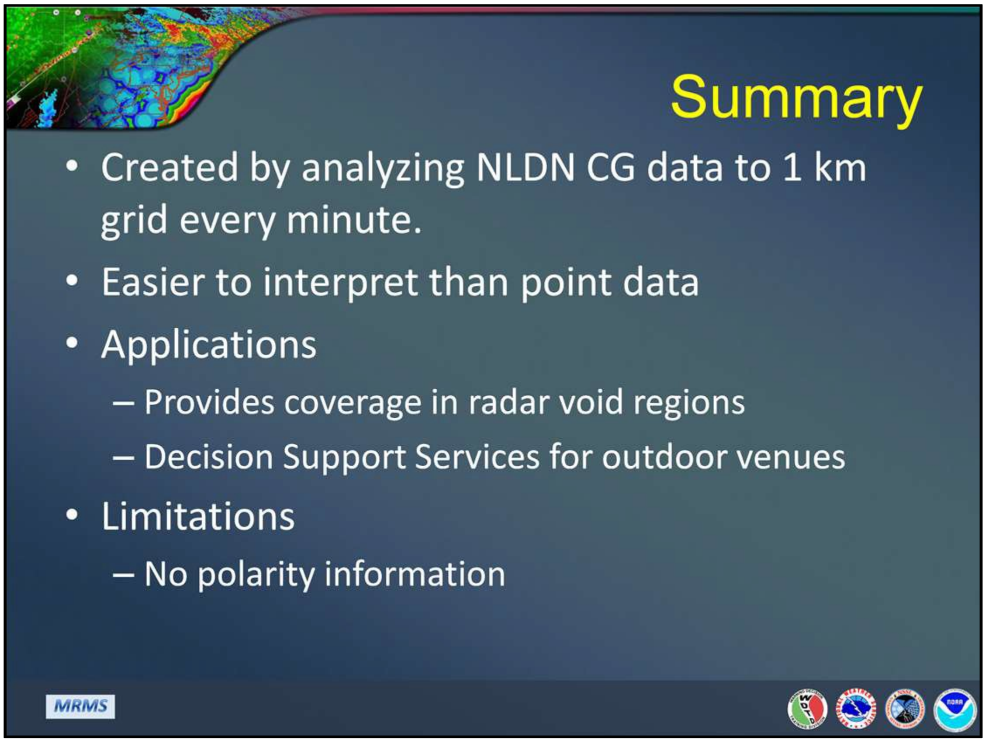
Some of the strengths of lightning density include: 1) CG lightning density often allows for faster initial thunderstorm detection than radar alone and 2) the lightning density grid is often less cluttered and easier to interpret than point lighting data.



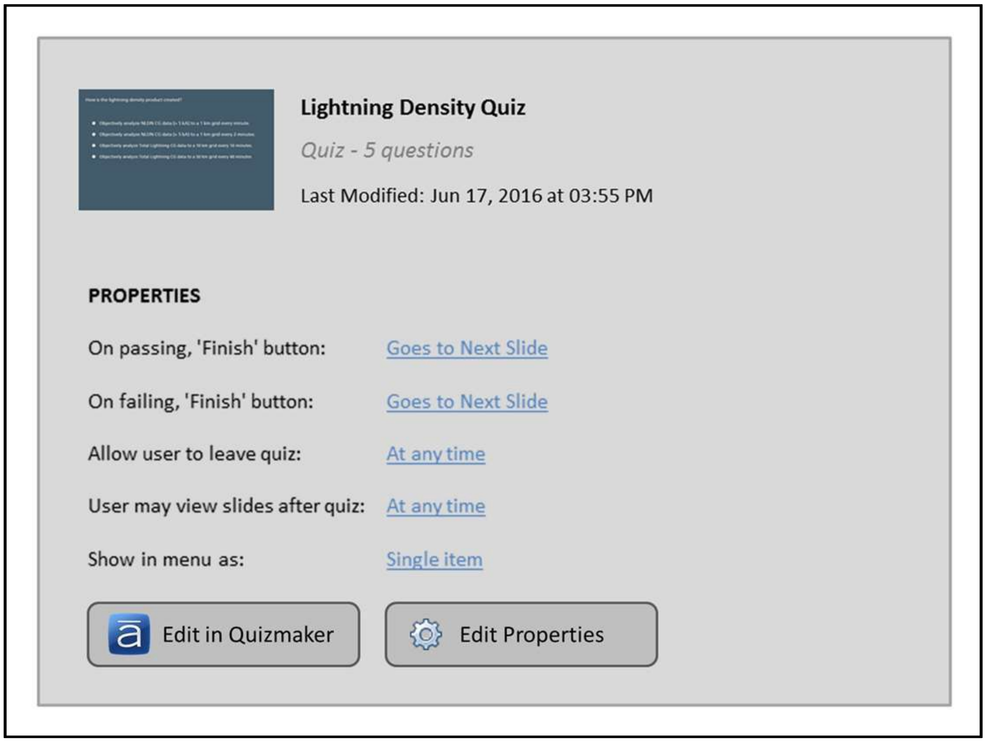
CG Lightning Density can be helpful in several situations. First, it can help to detect thunderstorms in areas with little to no radar coverage. Imagine in this example, if this was all you had because there was no radar coverage, or your radar went down. This product wouldn't be ideal to use, but you would at least have something to work with. It can also be used to assess trends in thunderstorm coverage, or be used for tactical and short-term air traffic routing decisions. Finally, the lightning density product can be useful while providing decision support services (DSS) for outdoor venues and events.



There are multiple sources of lightning CG data, but the lightning density product only uses data from the Vaisala NLDN. Additionally, some research has shown some correlations with polarity information and possible severe weather phenomena, but the Lightning Density product does not delineate CG polarity. The NLDN plots in AWIPS can show you polarity information, but those graphics are harder to read.



In summary, the cloud-to-ground lightning density product is created by analyzing NLDN CG data to a 1 km x 1 km grid every minute. The primary strength of lightning density is it is easier to interpret then traditional point data from the NLDN. The product is most useful in providing coverage in radar void regions and providing decision support services (DSS) for outdoor/large venues. The major limitation is lightning density does not provide polarity information. Up next will be your quiz!


Lightning Density Quiz
Quiz - 5 questions
Last Modified: Jun 17, 2016 at 03:55 PM
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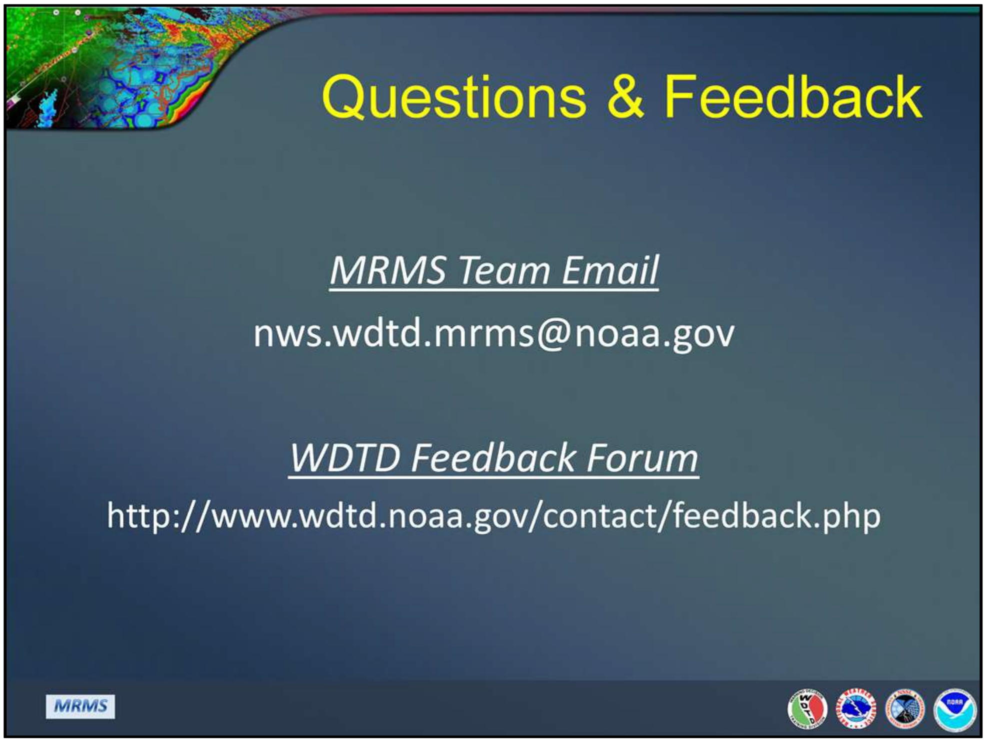
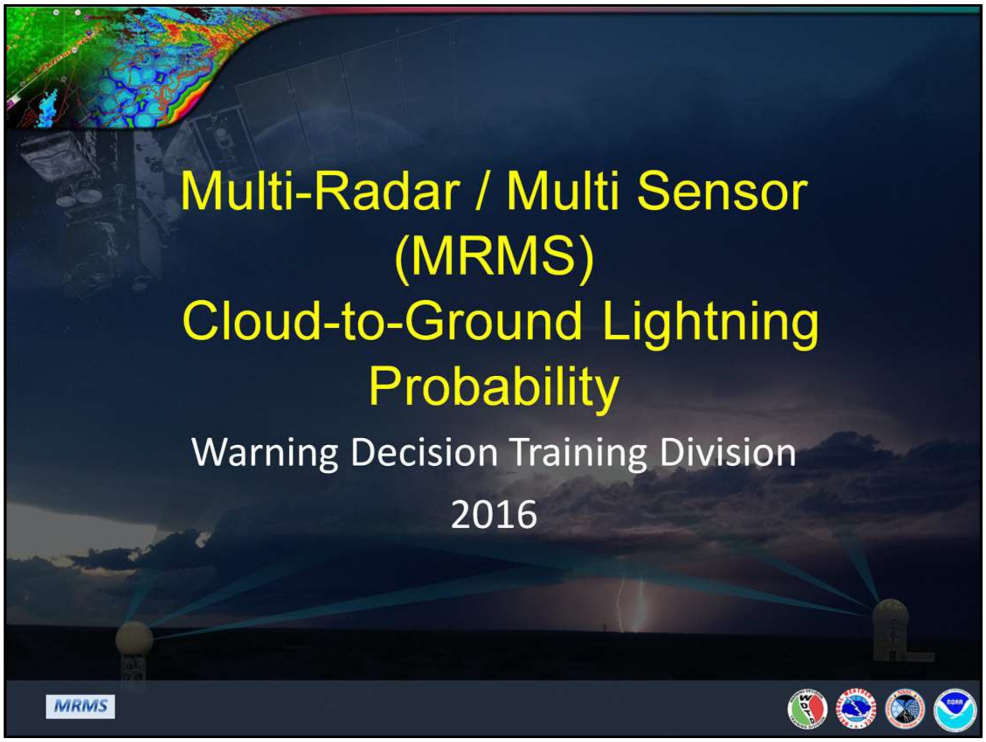
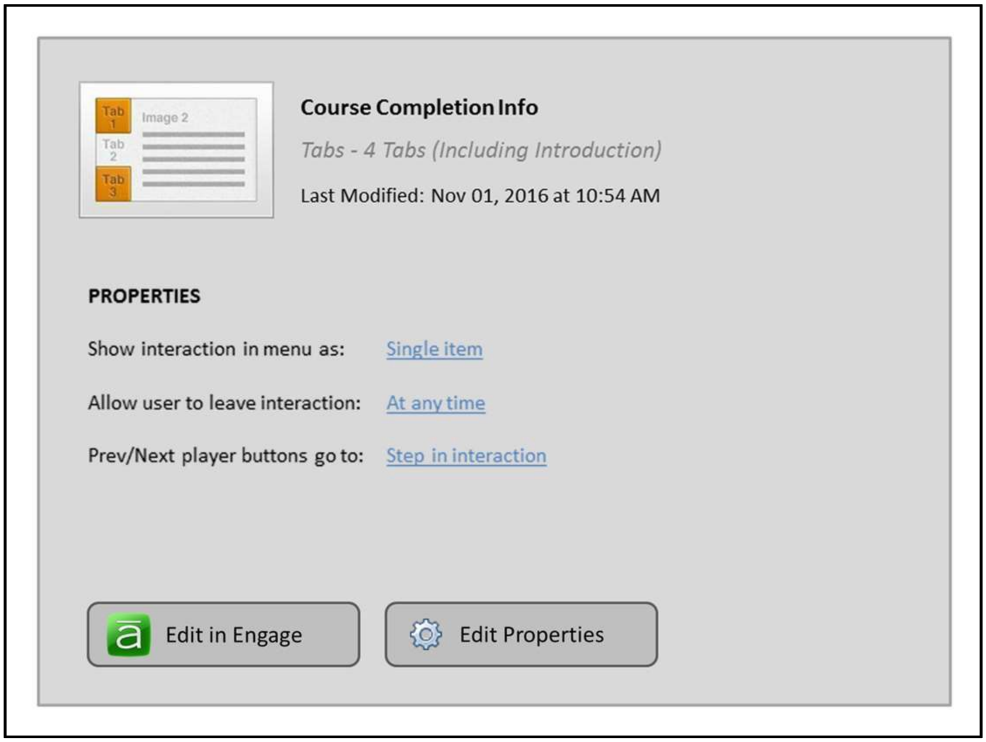


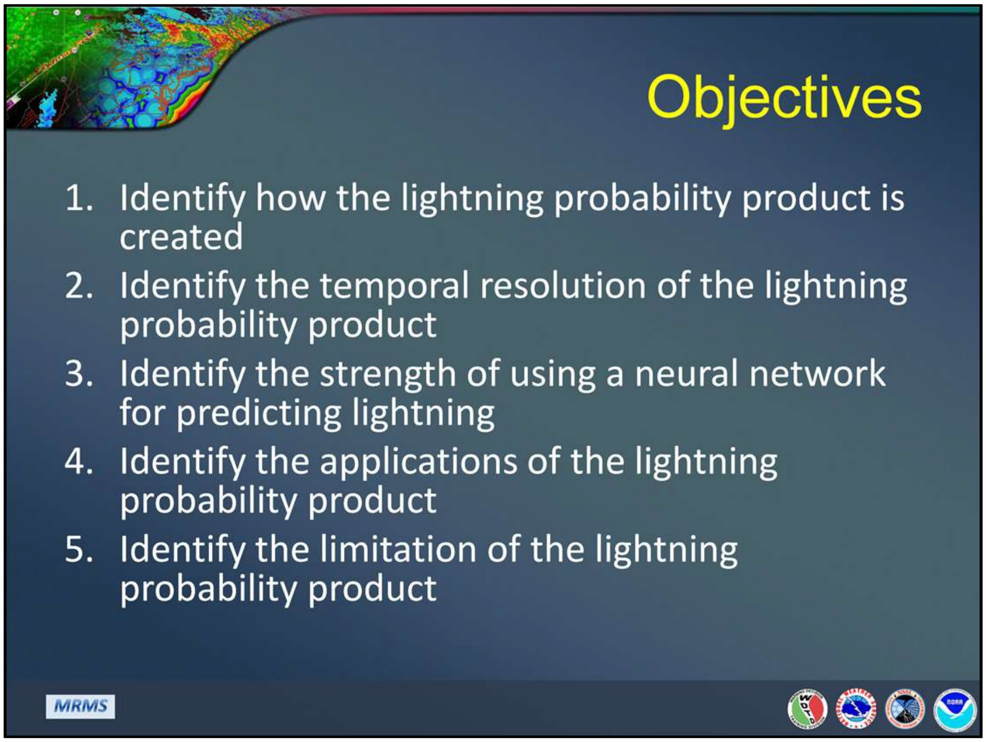
Thanks for completing this module on CG Lightning Density. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.



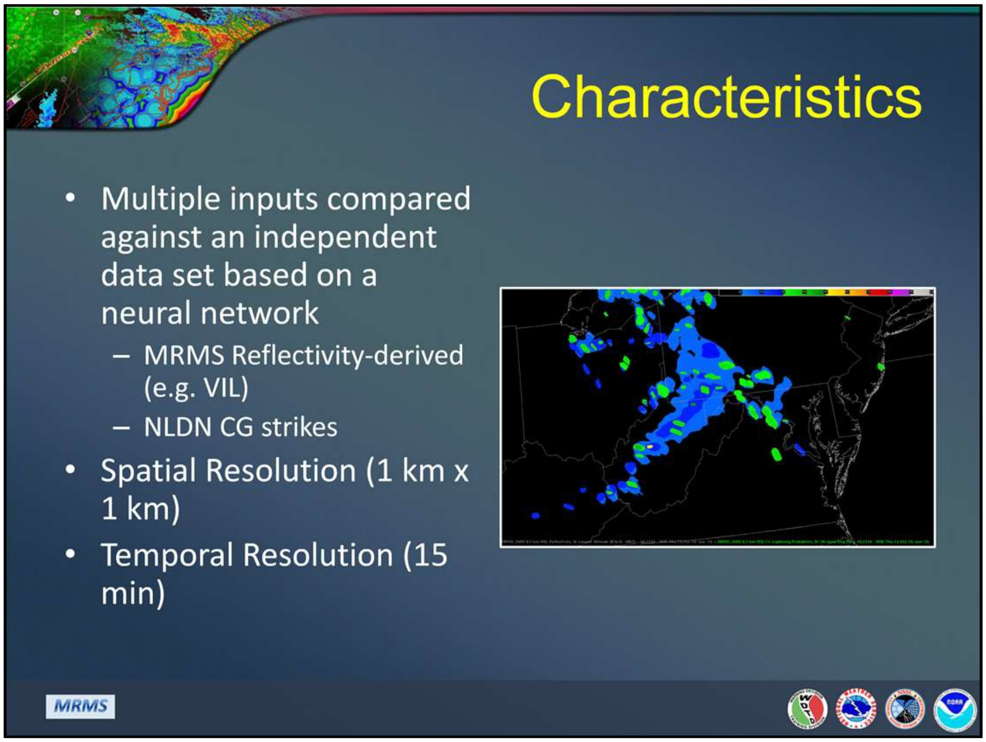
Welcome to the Multi-Radar/Multi-Sensor (MRMS) Training Course Lesson on Cloud-to-Ground Lightning Probability developed at the Warning Decision Training Division (WDTD).



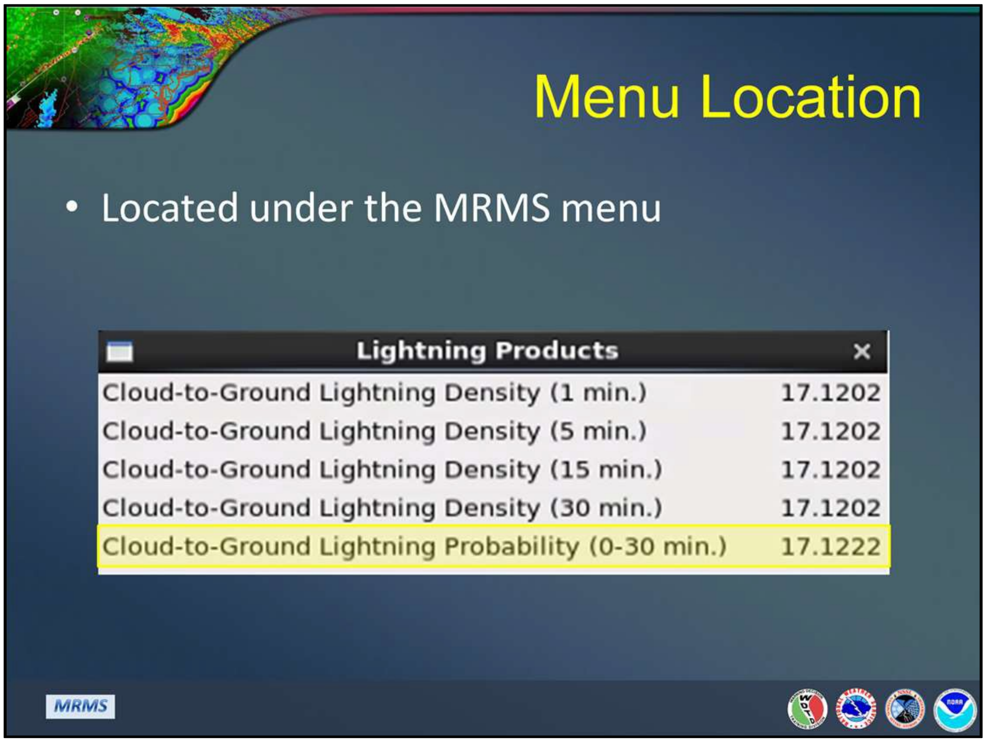
If you are taking this lesson for credit, please review this interaction on how to complete this course.



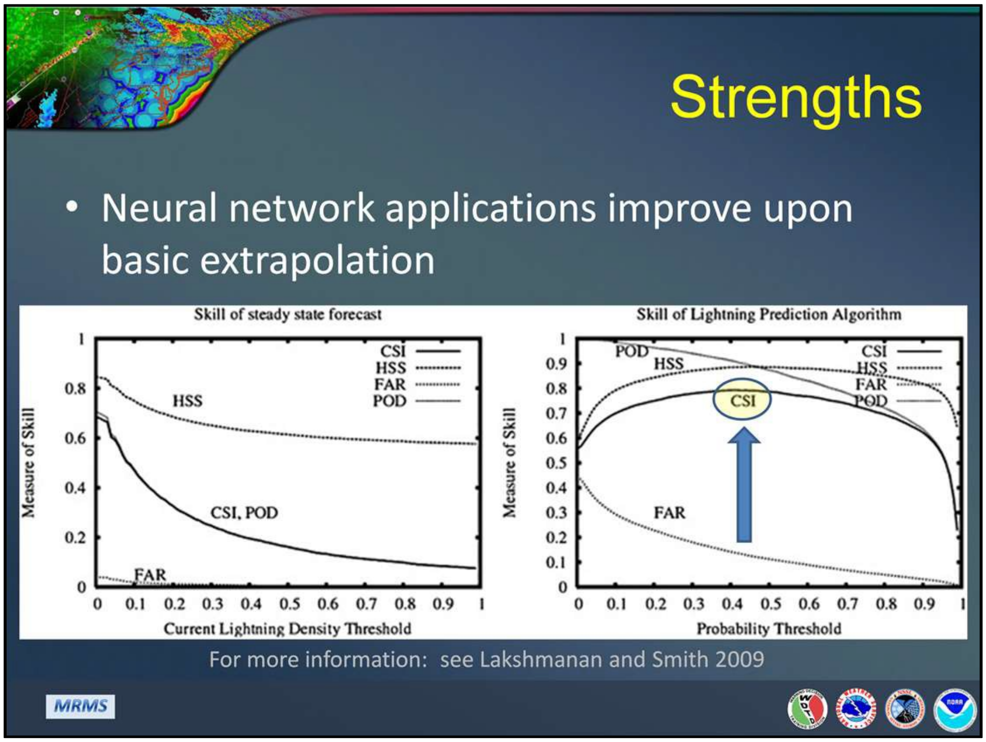
Here are the learning objectives for this lesson. Please take a minute to review them before moving on to the next slide. The quiz at the end of this lesson will be based on these objectives.



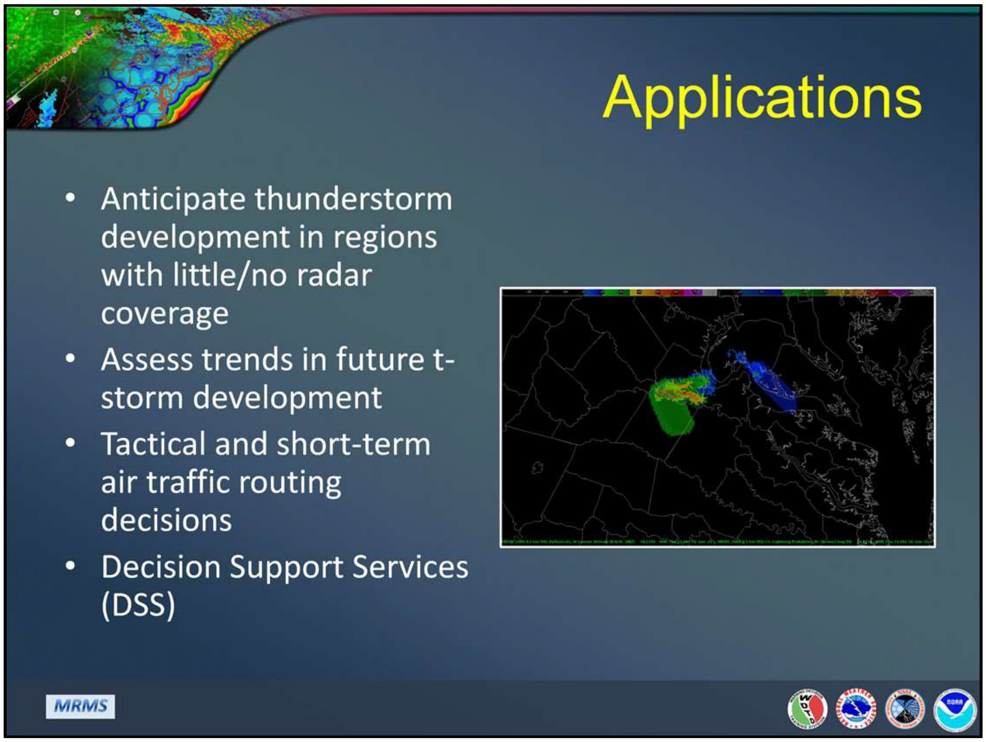
The lightning probability algorithm uses multiple inputs that are compared against an independent data set based on a neural network which then determines the probability of CG lightning over the next 30 minutes for each grid point. These inputs include various MRMS reflectivity-derived products like VIL, and strike data from the National Lightning Detection Network (NLDN). The output is on a 1 km x 1 km grid that is updated every 15 minutes.



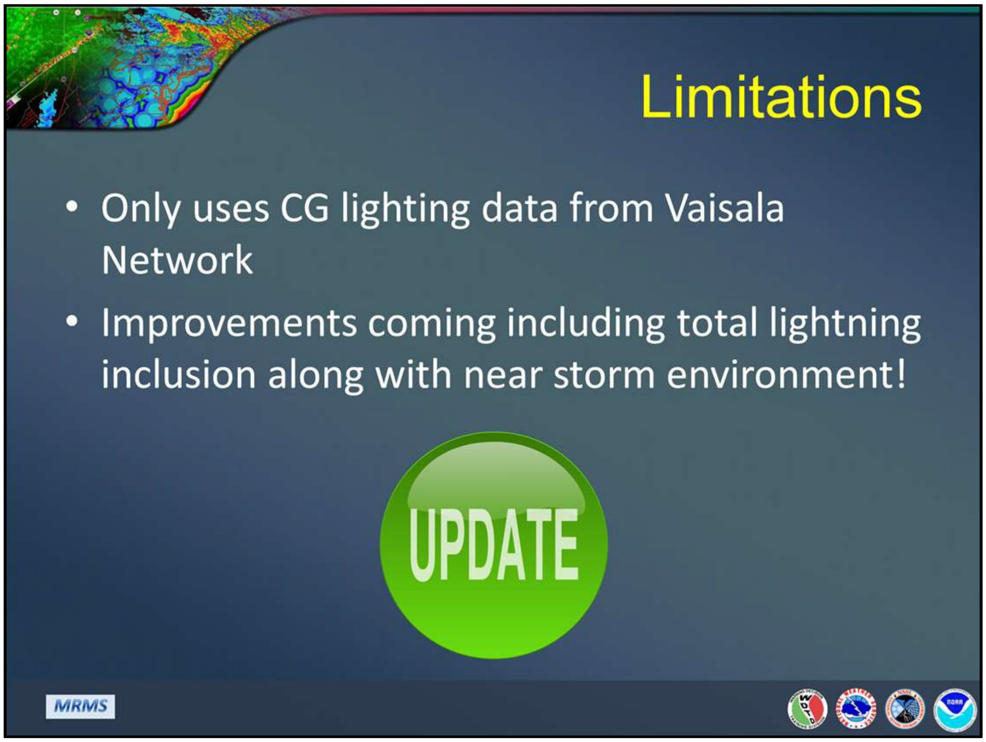
You can find the Lightning Probability product within the MRMS menu inside of CAVE.



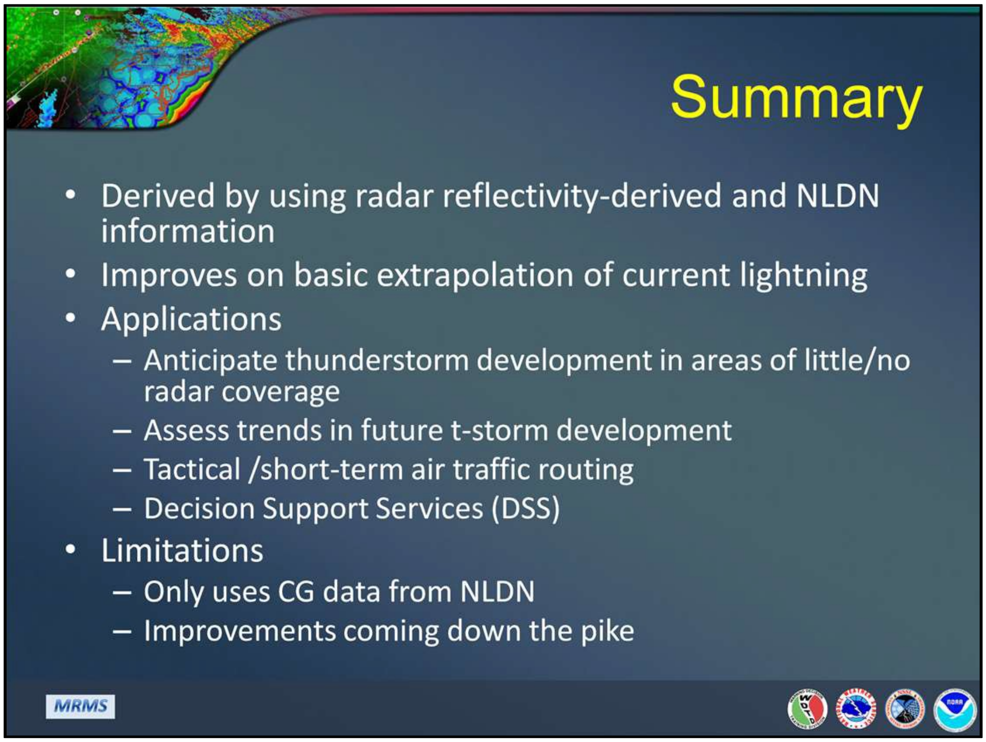
The lightning probability (or prediction) algorithm shows increased skill in CSI for a broader range of probabilities than from just simply extrapolating current lightning clusters forward 30 minutes. The charts show the Heidke Skill Score (HSS), the POD and CSI of the extrapolated lightning density (left) and the lightning probability algorithm (right). Overall the CSI and HSS of the algorithm shows improvement over pure extrapolation in predicting the occurrence of CG lightning 30 minutes in the future. The best skill is when the neural network was thresholded at a 0.41 probability threshold. An additional advantage of the neural network is that it can predict lightning in the future when none occurred at the forecast time, a feature that extrapolation cannot replicate.



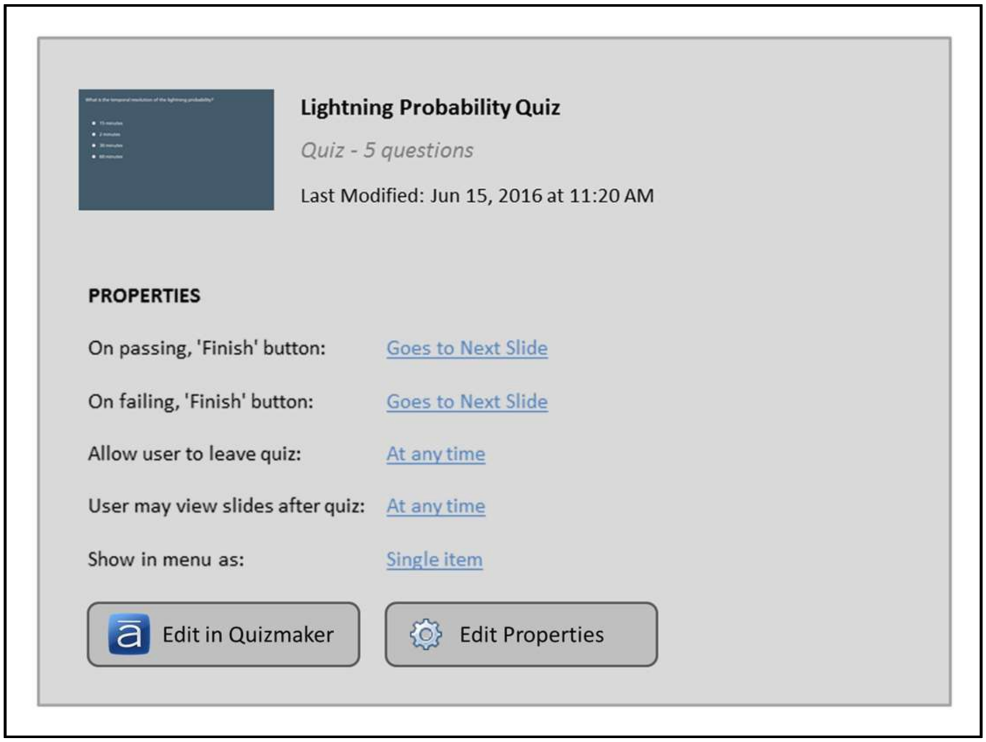
Short-term forecasts of CG Lightning can be helpful in several situations. First, it can help to anticipate thunderstorm development in areas with little to no radar coverage. It can be used to assess trends in future thunderstorm development. It can also be used for tactical and short-term air traffic routing decisions. Finally, the lightning probability product can be useful while providing decision support services (DSS) for outdoor venues and events.



The main limitation to the 0-30 minute Lightning Probability product is that it only uses cloud-to-ground lightning data from the Vaisala Network. There are efforts to update this product by incorporating total lightning and near storm environment data which have shown significant improvements over this current method. So, stay tuned to updates coming down the pike for this product.



In summary, the lightning probability product is derived using mutliple MRMS reflectivity-derived and NLDN data using a neural network. This method has shown considerable improvement in skill over pure extrapolation. The 30 minute forecast can be helpful in anticipating thunderstorm development in areas of little or no radar coverage, or just assessing trends in future thunderstorm development regardless of radar coverage. This anticipation is primarily beneficial for tactical/short-term airtraffic routing and decision support services (DSS). The primary limitation of this product is only CG data from the NLDN is utilized. Other information like Total Lightning and near storm environment are not incorporated. However, improvements to the algorithm are coming down the pike! Up next will be the quiz!


Lightning Probability Quiz
Quiz - 5 questions
Last Modified: Jun 15, 2016 at 11:20 AM
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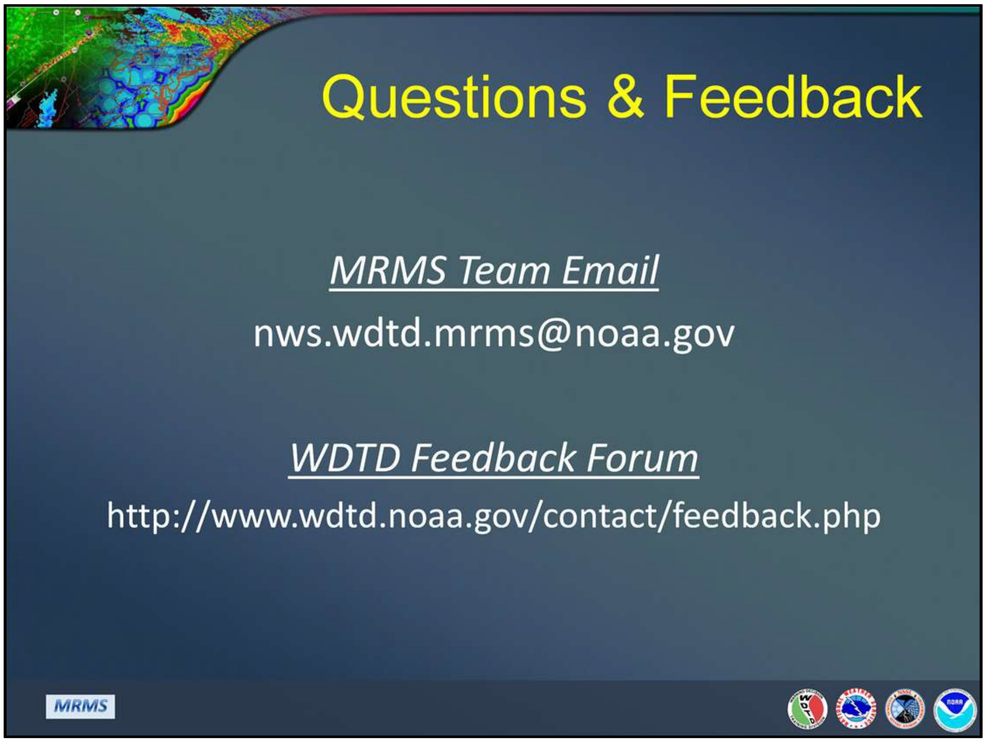
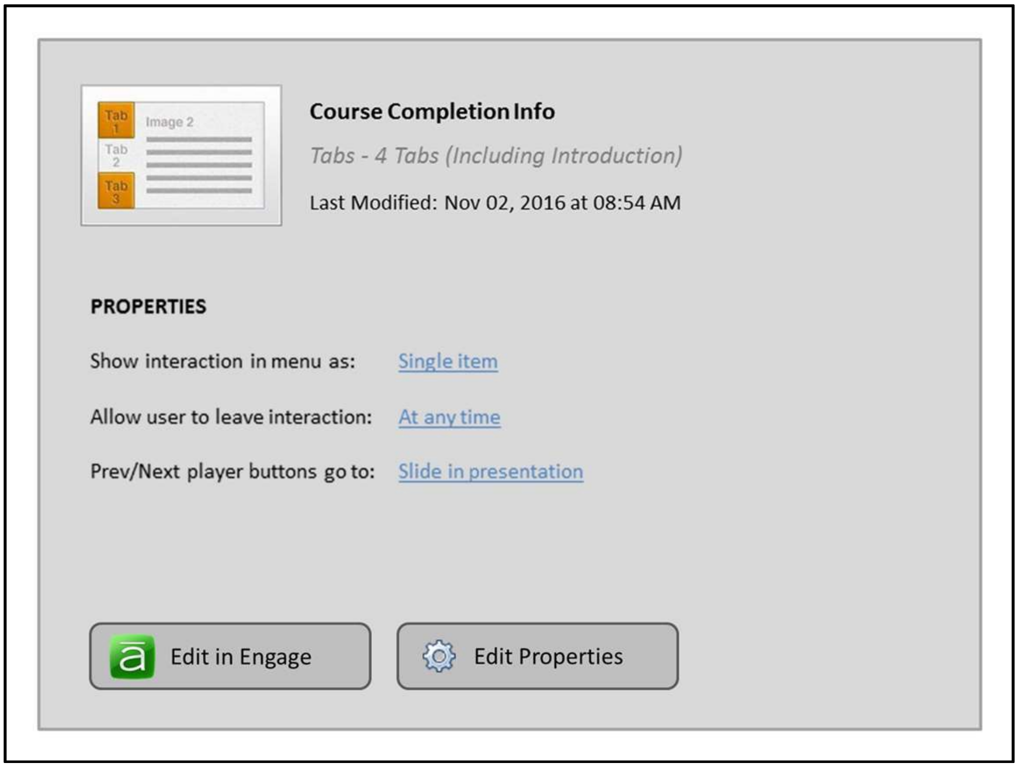


Thanks for completing this module on CG Lightning Probability. If you have any questions or feedback concerning this module, please feel free to contact us at the addresses below.

Hi, my name is Jill Hardy, and welcome to the Hydro Products Overview lesson. This module will give an introduction to the MRMS quantitative precipitation estimation (or QPE) related products, as well as the quality control steps used to create them.


Course Completion Info
Tabs - 4 Tabs (Including Introduction)
Last Modified: Nov 02, 2016 at 08:54 AM
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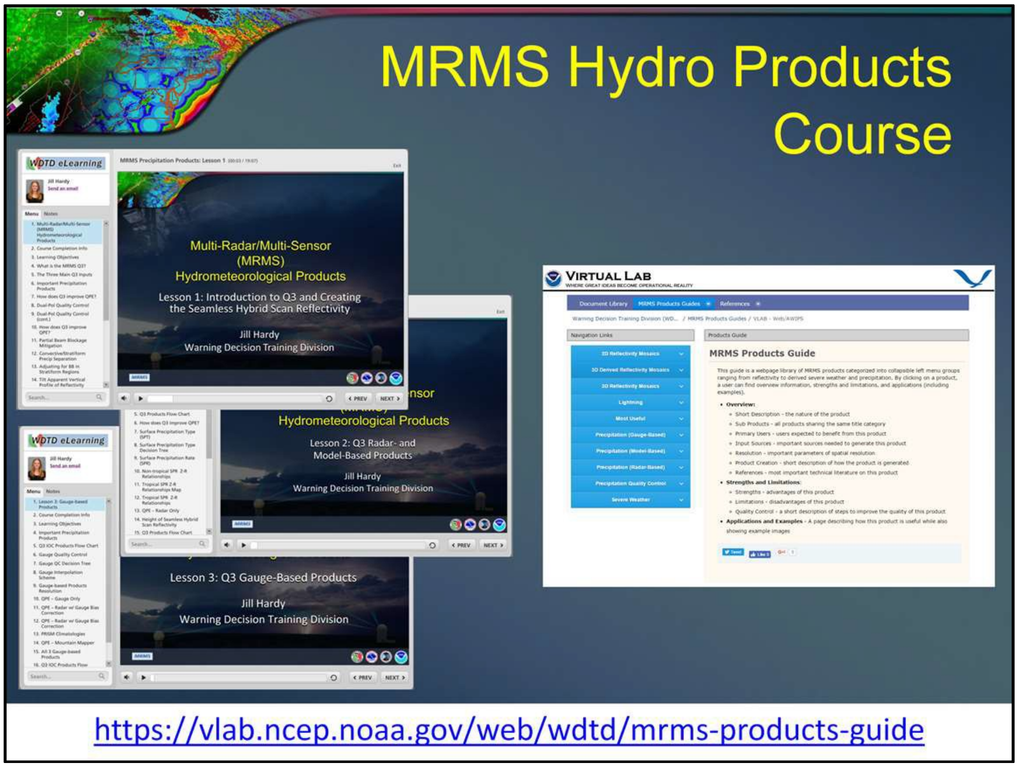
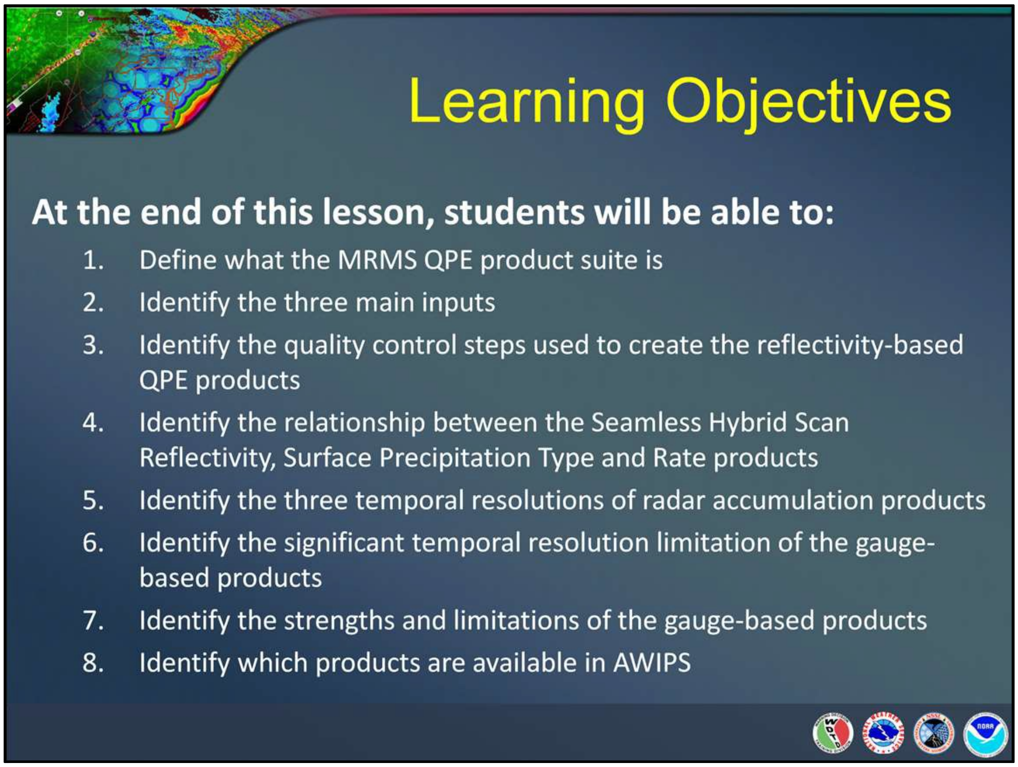


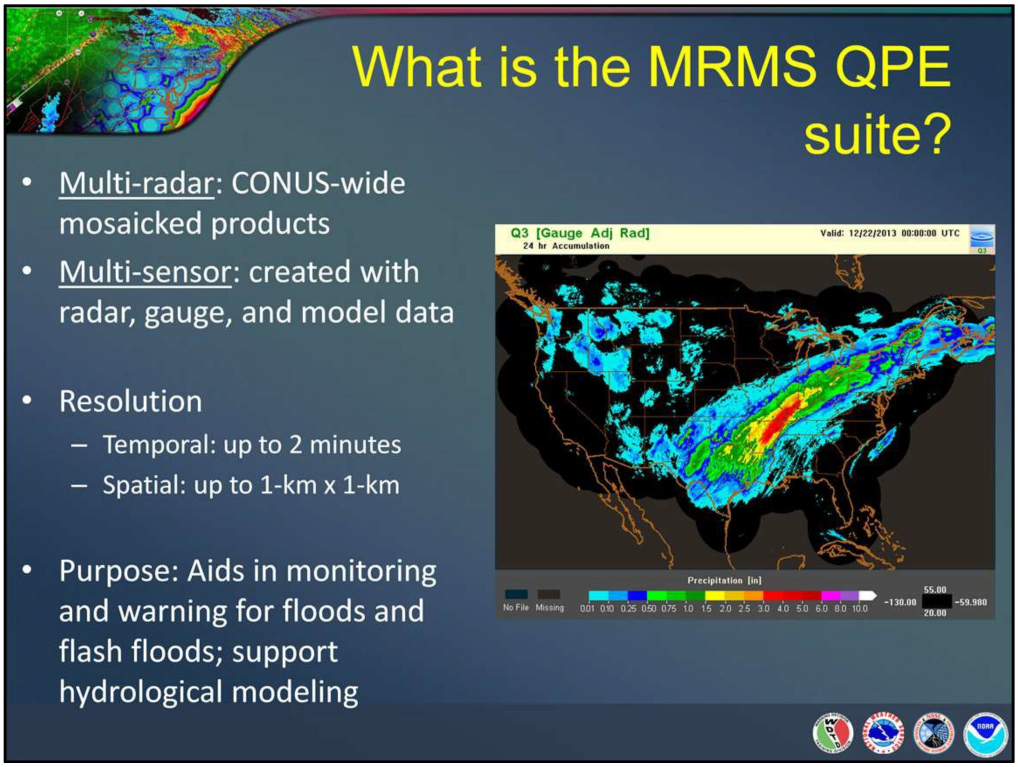
As the name implies, this lesson is meant to be a brief overview of the MRMS hydro products available in AWIPS. If you want more detailed explanations, please refer to the full Hydro Products Course, which contains three lessons that delve deeper into everything introduced here.

Additionally, there is useful reference material on the VLab, including strengths and limitations of each product, resolution information, applications, and examples. The link provided here does not require log-in to view.

Okay, let’s get started…



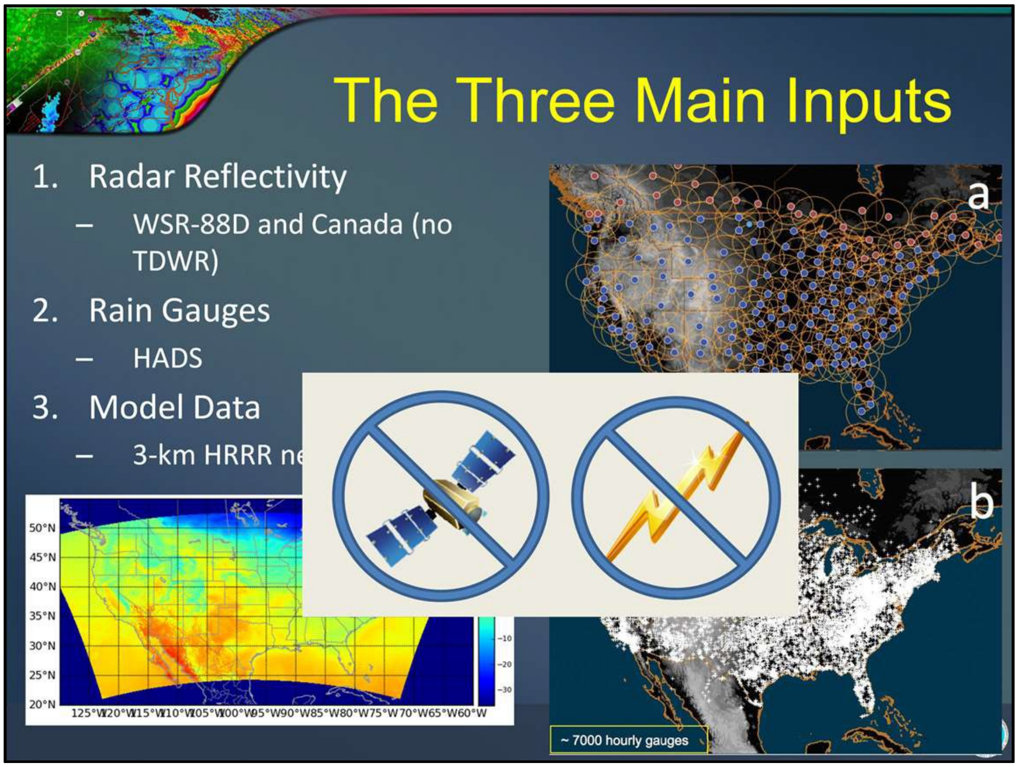
Here are the learning objectives for this lesson. When you have finished reading them, please move onto the next slide.



--As you are probably familiar with at this point, MRMS stands for multi-radar/multi-sensor. In the QPE suite of products, the multi-radar component is highlighted by creating CONUS-wide mosaicked products, such as the image on the right. The multi-sensor component is highlighted by using a variety of inputs to create the products. These will be discussed on the next slide.

--The highest resolution in the QPE suite is 2-minute temporal resolution, and 1-km by 1-km spatial resolution, although not every product is this resolution. In particular, all of the gauge-related products are a minimum of one-hourly. We'll discuss this later.

--The ultimate purpose of the QPE suite is to aid in the monitoring and warning for floods and flash floods, and to support further development of hydrological modeling.



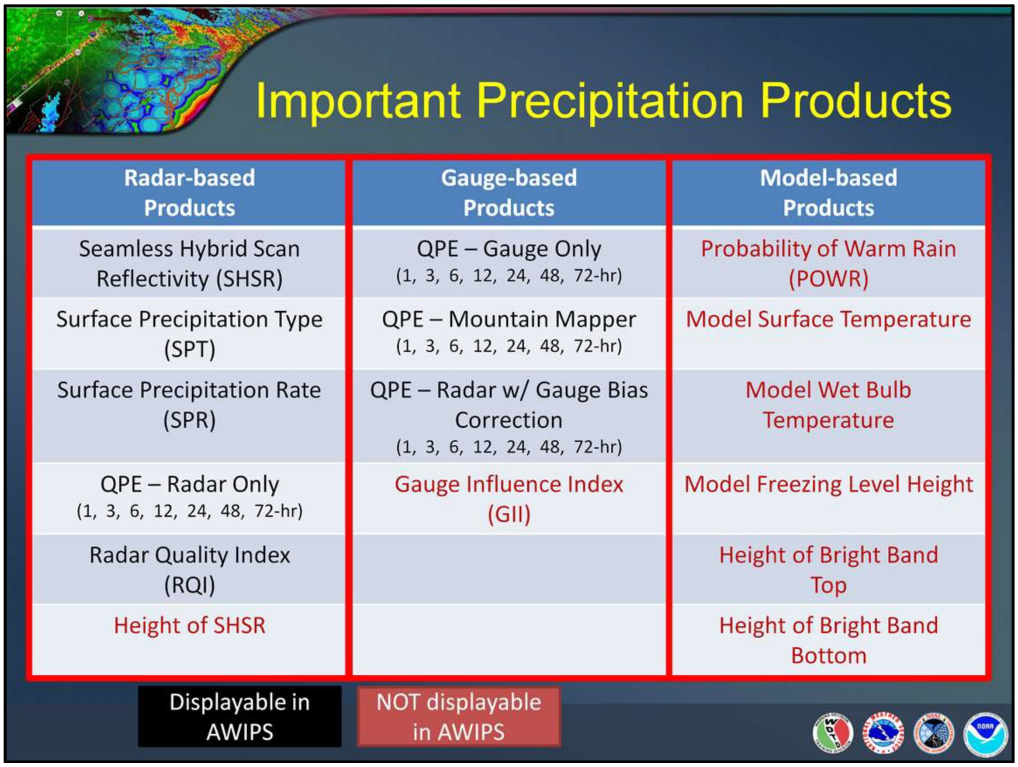
--The QPE system has three main inputs that are used to create the majority of its products.

--Radar reflectivity comes from the national network of WSR-88D radars, as well as the Canadian network, as depicted here. However, there are NO Terminal Doppler Weather Radars.

--Rain gauge data comes from the HADS (or Hydrometeorological Automated Data System) gauge network, as shown here. Gauge data provides valuable ground validation used for bias-correction of precipitation estimates.

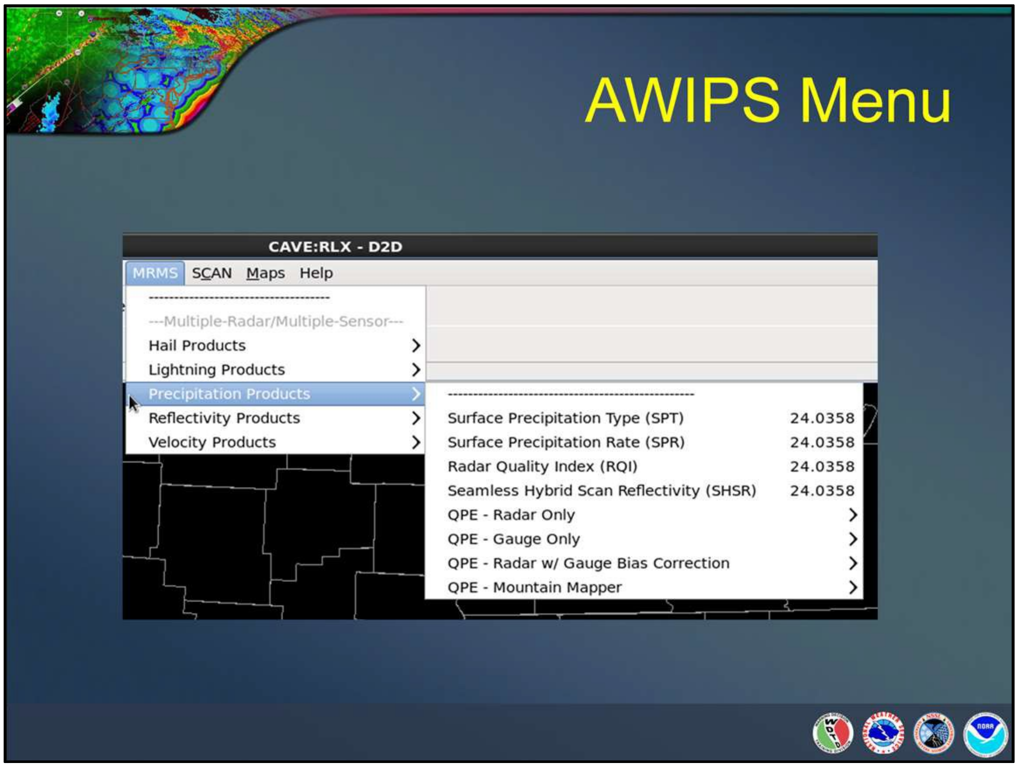
--Finally, model data comes from the 3-km High-Resolution Rapid Refresh (or HRRR), nested within the 13-km RAP domain. Below is the HRRR domain, which covers the entire CONUS. The RAP model is used anywhere the HRRR does not reach, which will mainly affect basins near or within Canada. The models provide environmental data that is incorporated into several QC steps, as well as directly into some products.

--While lightning and satellite data are used in some of the MRMS severe products, it is important to know they are not incorporated into any of the precipitation products at this time.

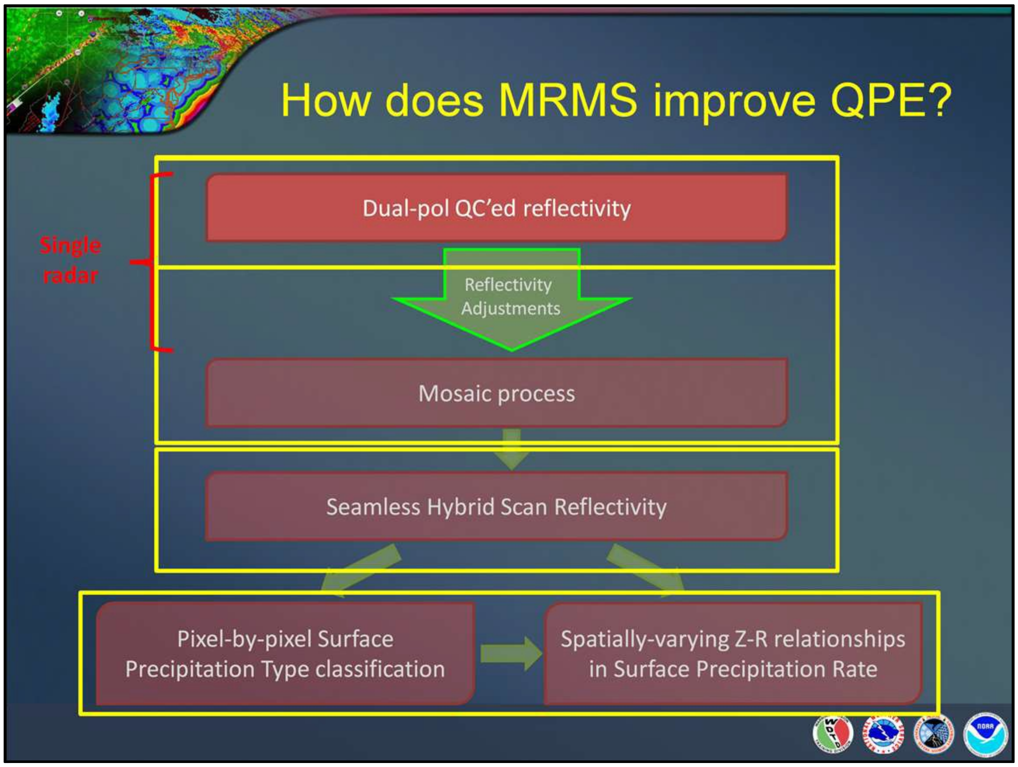


Radar-based Products	Gauge-based Products	Model-based Products
Seamless Hybrid Scan Reflectivity (SHSR)	QPE – Gauge Only (1, 3, 6, 12, 24, 48, 72-hr)	Probability of Warm Rain (POWR)
Surface Precipitation Type (SPT)	QPE – Mountain Mapper (1, 3, 6, 12, 24, 48, 72-hr)	Model Surface Temperature
Surface Precipitation Rate (SPR)	QPE – Radar w/ Gauge Bias Correction (1, 3, 6, 12, 24, 48, 72-hr)	Model Wet Bulb Temperature
QPE – Radar Only (1, 3, 6, 12, 24, 48, 72-hr)	Gauge Influence Index (GII)	Model Freezing Level Height
Radar Quality Index (RQI)		Height of Bright Band Top
Height of SHSR		Height of Bright Band Bottom

This table shows the MRMS products that we will be discussing in this training. The products in black are displayable in AWIPS and will be the focus of this lesson. While the products in red are only available on the experimental website. We include them in this training because they are being sent to the NCO (for creation of the other products), so you may find it useful to look at them on the website to better understand the MRMS suite. There are three main types of products: radar-based, gauge-based, and model-based. The rest of this lesson will step through the process of creating this suite of products, as well as important details of each.

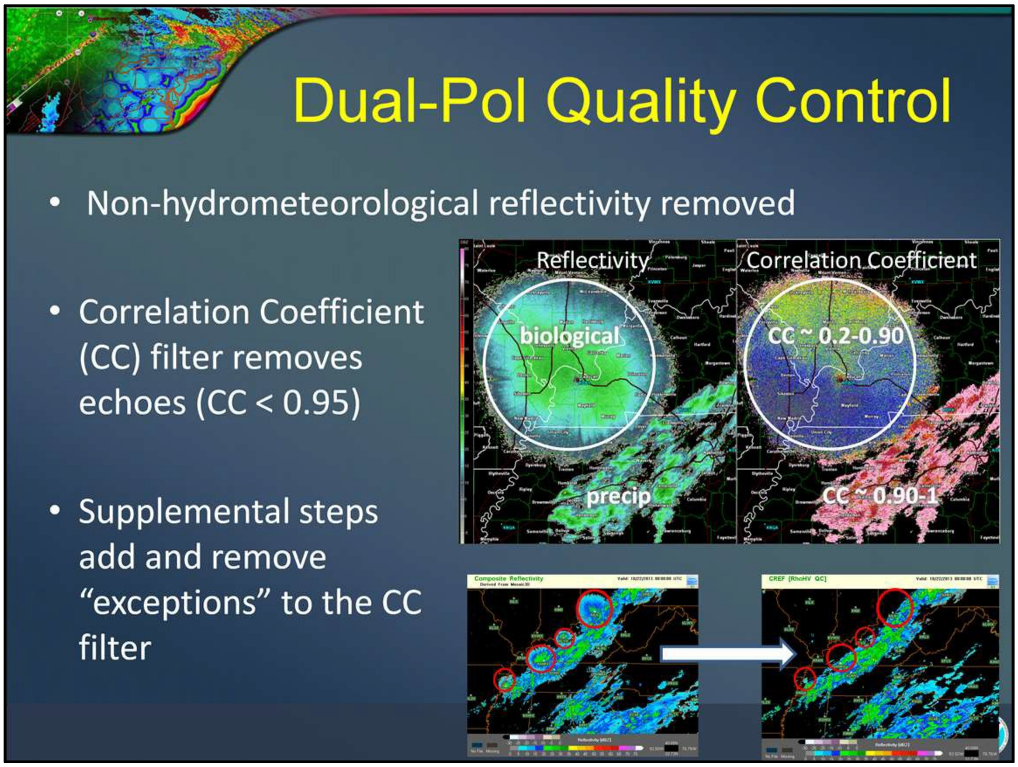


For the products available in AWIPS, the MRMS product suite has its own menu, as shown here, with all of the precip products located together.



The main goal of the MRMS QPE system is to get improved QPE for better prediction of flooding and flash flooding. While the gauge-based and model-based products help achieve this goal, the foundation of the system is the high-resolution, mosaicked reflectivity product, the Seamless Hybrid Scan Reflectivity. The SHSR directly and indirectly feeds into most of the other QPE products, including the important Surface Precipitation Type and Surface Precipitation Rate products.

Therefore, in order to create the SHSR and achieve this improved QPE, the reflectivity data from the network of radars goes through a rigorous series of processes, as shown in this flow chart. Each step will be described in subsequent slides, with the first step being the Dual-Pol quality control. It is important to note that dual-pol variables are currently only incorporated into this first step, the quality control. They are NOT used to calculate rain rates.

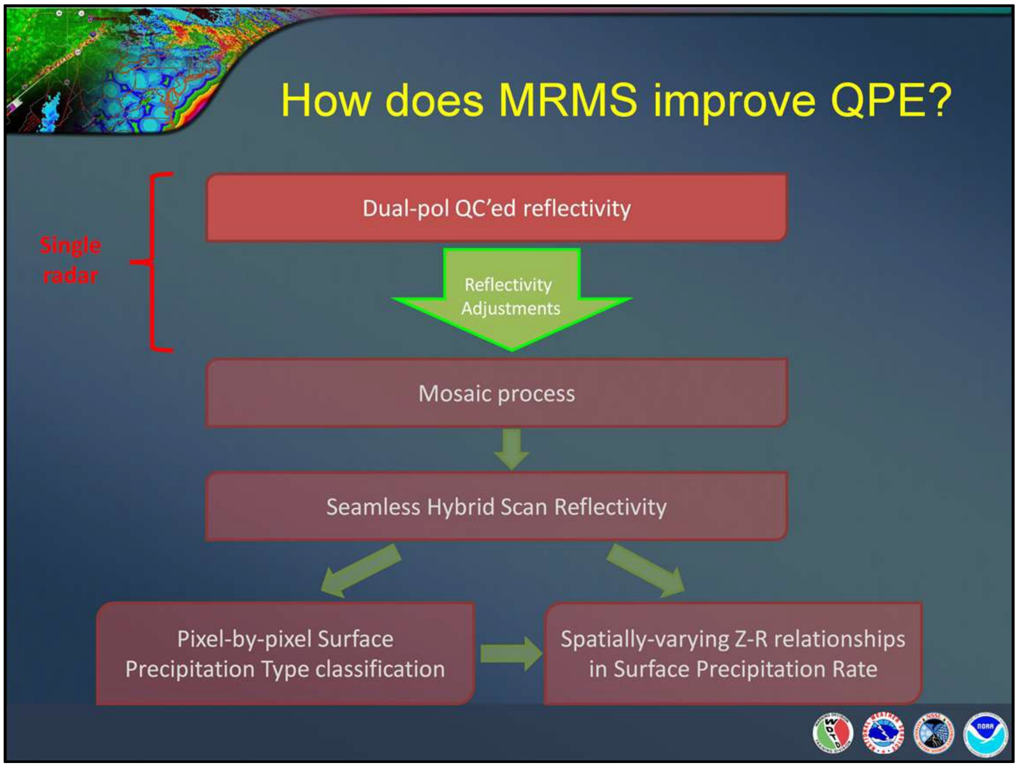


--The dual-pol quality control removes non-hydrometeorological echoes from each volume scan of reflectivity.

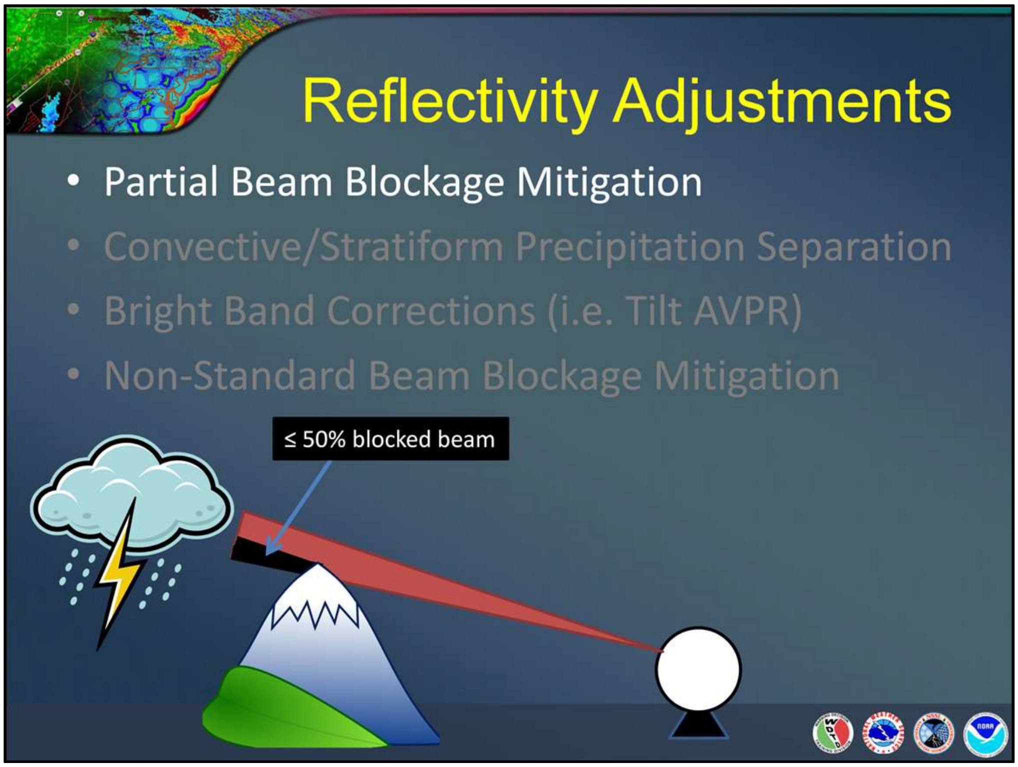
--The main filter in this algorithm is the correlation coefficient filter that removes all echoes below 0.95. While this is a very aggressive initial reflectivity-removal threshold, the algorithm has a number of subsequent steps to reintroduce or further remove reflectivity. For more information about these “exception filters”, please refer to Lesson 1 of the MRMS Hydro Products course.

--On the right is an image of the KPAH radar showing a strong biological bloom signature near the radar, as well as precipitation echoes to the SE. Notice how low CC values exist in the bloom area, generally well below 0.95. However, the precipitation region is returning values generally above 0.95.

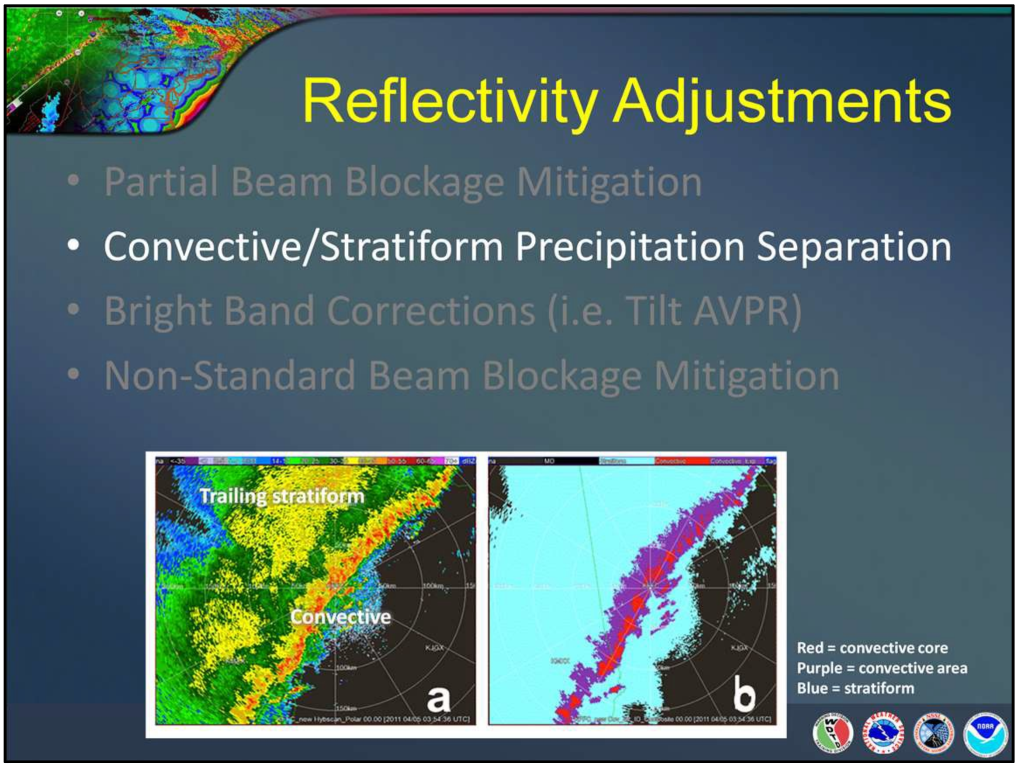
--MRMS uses these CC signals to remove reflectivity in the bloom region, while maintaining the precipitation to the SE of the radar. Below is an example showing what the reflectivity field may look like after the blooms have been removed by the filter.



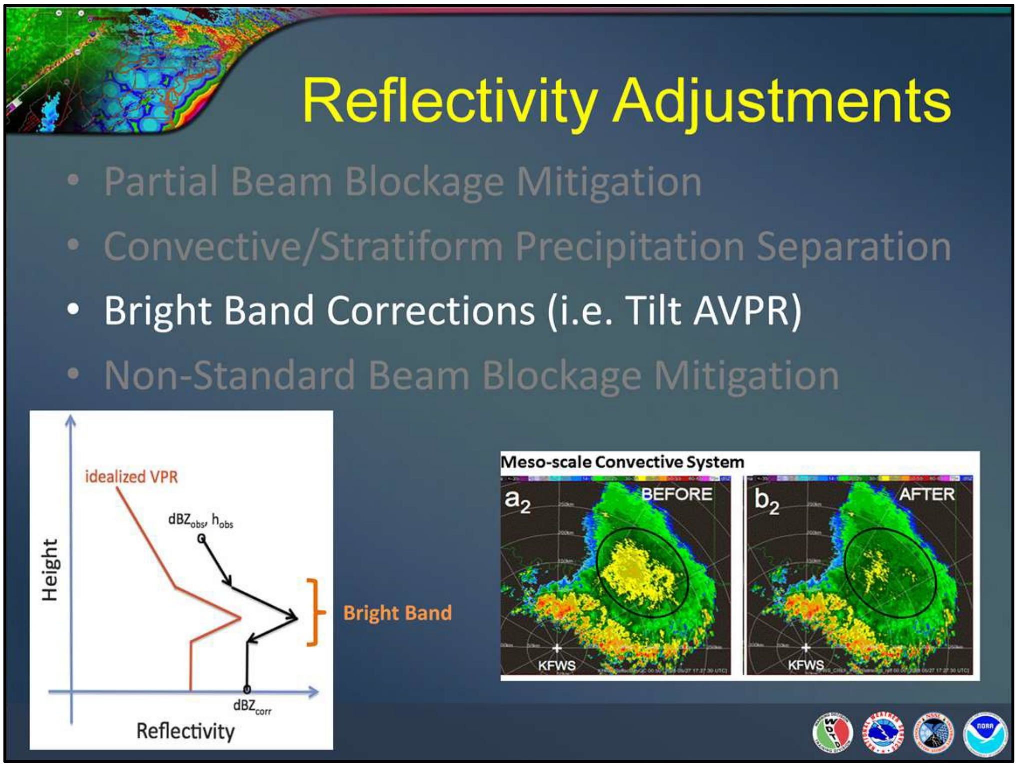
After the Dual Pol Quality Control, the next step is to take the quality-controlled reflectivity data and run it through a set of adjustments that will help correct for various biases in the data.



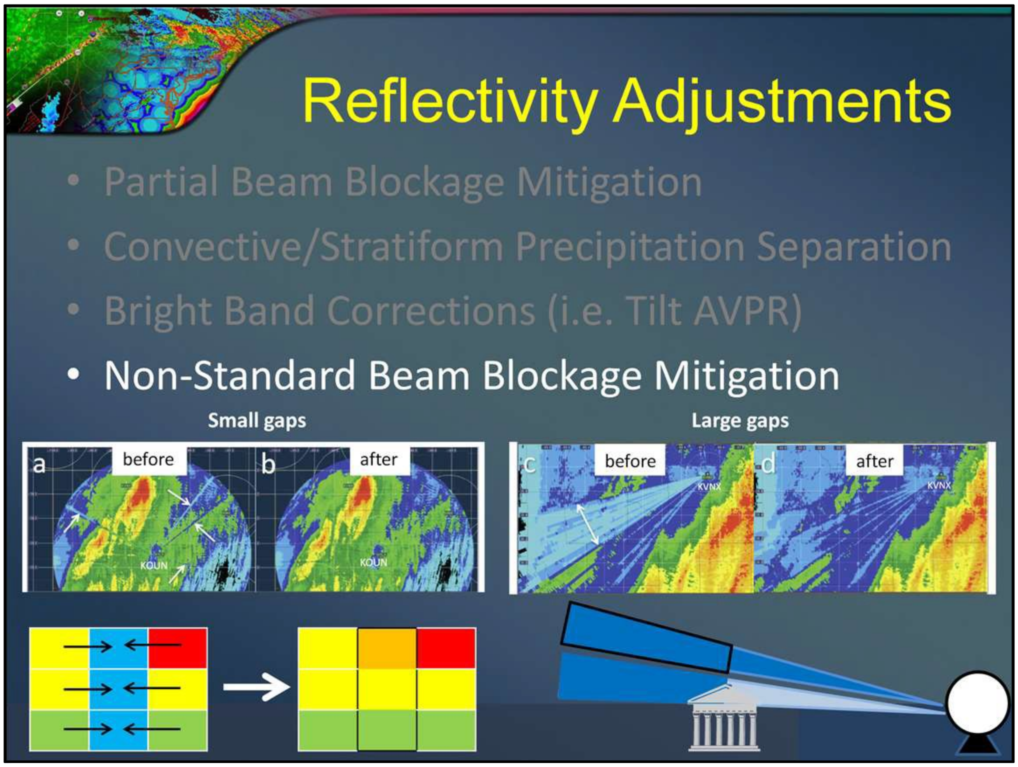
--The first of these adjustment processes is the Partial Beam Blockage Mitigation. This step takes any radar bin that is blocked by 50% or less (such as the situation on the bottom), and adds power back into its reflectivity total, in order to get a more representative value at that bin.



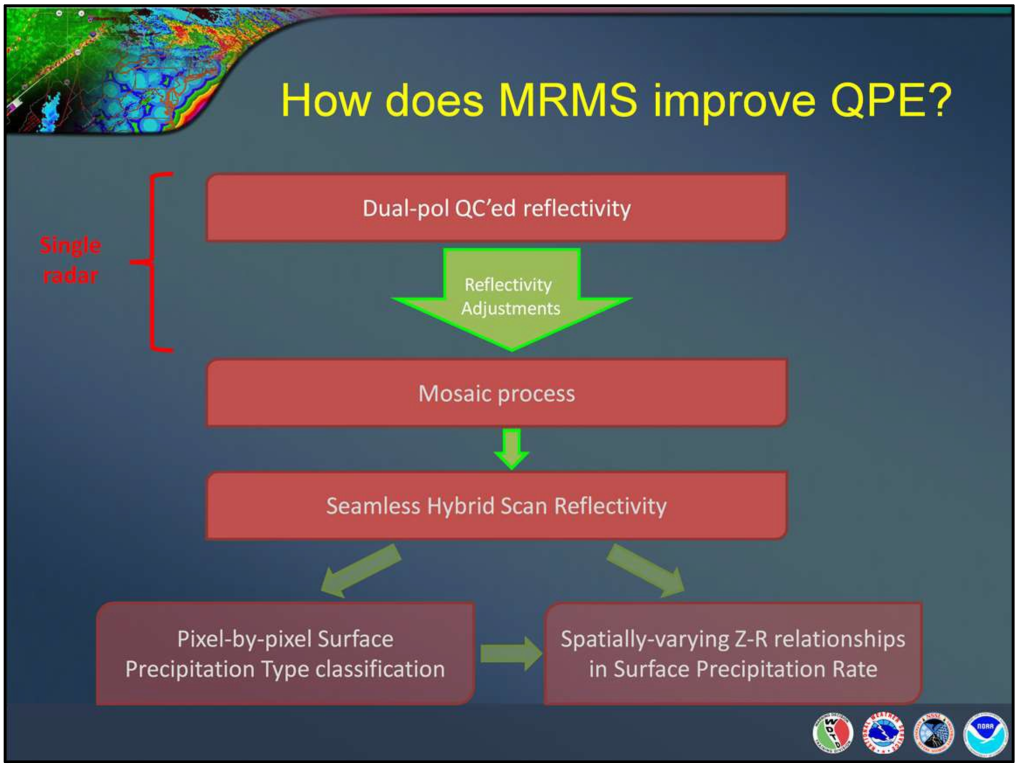
--The next reflectivity adjustment is the Convective/Stratiform Precipitation Separation. Just as the name sounds, this step defines each radar bin as either convective or stratiform.
--It uses the model height levels, VIL, and range dependency of radar sampling to classify the pixels.
--The purpose of the convective/stratiform identification is to aid in adjusting reflectivity values in the melting layer, which will be discussed on the next slide.



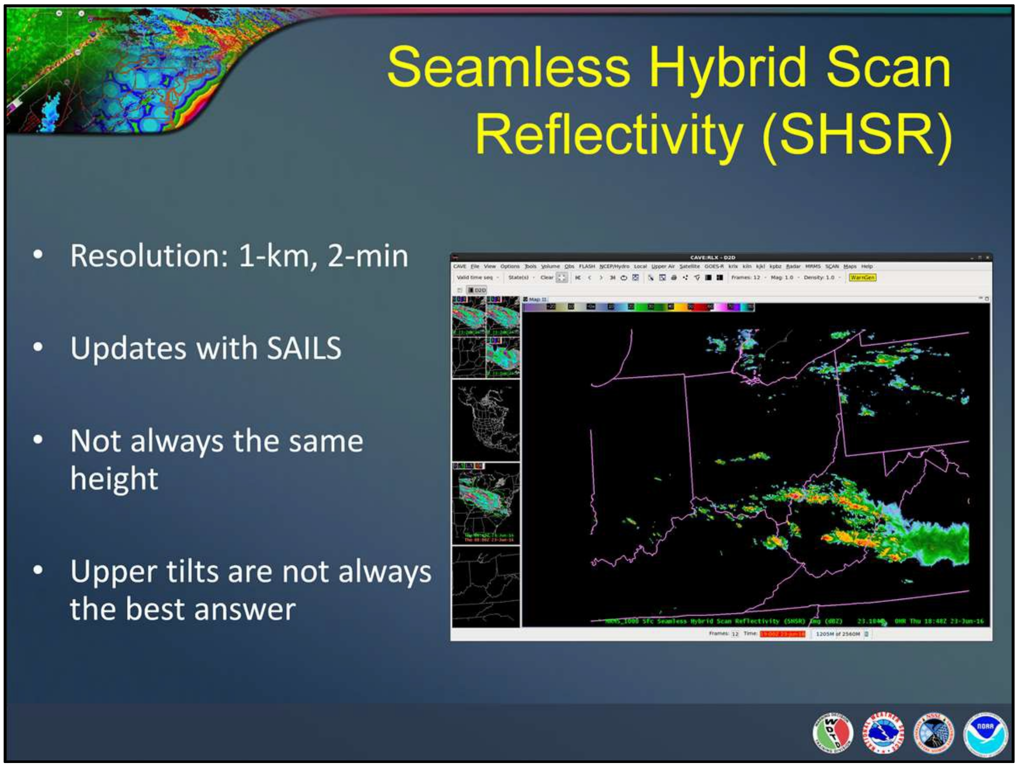
--Once the precip type is classified, the next step is to apply corrections for biases in the "bright band", or the melting layer. This layer can cause QPE overestimation because melting ice particles may appear to the radar as big drops, and thus, get falsely assigned higher reflecitvities in the region.
--A vertical profile of reflectivity (or VPR) correction is used in affected stratiform regions, as well as ice regions above the BB. Saving the details for Lesson 1 of the Hydro Products Course, in general, the VPR, as shown on the left, samples the elevated reflectivities in the bright band, and then, applies an algorithm to reduce the values in these areas.
--The images on the right show a "before and after" instance for an MCS. The BB is likely causing higher reflectivities in the areas that are circled. However, after the correction, the bright banding is significantly reduced.



--Finally, there is the non-standard beam blockage mitigation. The first process (the partial beam blockage) accounted for instances when there was beam blockage associated with known features that block the radar beam (for example, mountains). However, reflectivity fields may still have non-standard beam blockage issues (like, trees and buildings) that are not accounted for in the digital elevation models. That's where this adjustment comes in!
--For small or narrow gaps, like the images on the left, the gaps are filled using horizontal interpolation. MRMS averages the two bins on either side to get the middle value.
--For large or wide gaps, like the images on the right, a horizontal interpolation is not ideal because interpolating over a broad region may not be very representative of what is occurring. Instead, the next elevation scan up that is unblocked is used. This replaces all values in the lower, blocked region. In this case, the dark blue values would be extrapolated to the lower tilt.



Now that the single-site radar reflectivity has been filtered using the Dual-Pol QC and then adjusted for blockage and bright-band effects, the next step is to combine the radars into a mosaic. We will not cover the details of this here, but the algorithm uses logic that considers radar quality, as well as distance and height weighting to get the final reflectivity at each grid point. The result is the Seamless Hybrid Scan Reflectivity.



--All of the previous quality control steps helped to create a more continuous and accurate reflectivity field, as shown on the right.
--Its resolution is 1-km by 1-km, with a 2-minute update time.
--This update time is in conjunction with SAILS data, which updates the lowest tilt more frequently than higher tilts.
--It is important to note that the reflectivity data in the SHSR is not always located at the same height. This is because the non-standard beam blockage mitigation sometimes fills gaps from different elevation angles, as well as the mosaicking process using multiple radars (at different distances from the point) to provide information at one grid cell.
--A caveat of this process is that the inclusion of upper tilts does not always provide better information compared to the lower, partially-blocked tilts. An example of this is if the upper tilt overshoots the precipitating cloud.

Overview Recap 1

Quiz - 3 questions

Last Modified: Nov 07, 2016 at 04:16 PM

PROPERTIES

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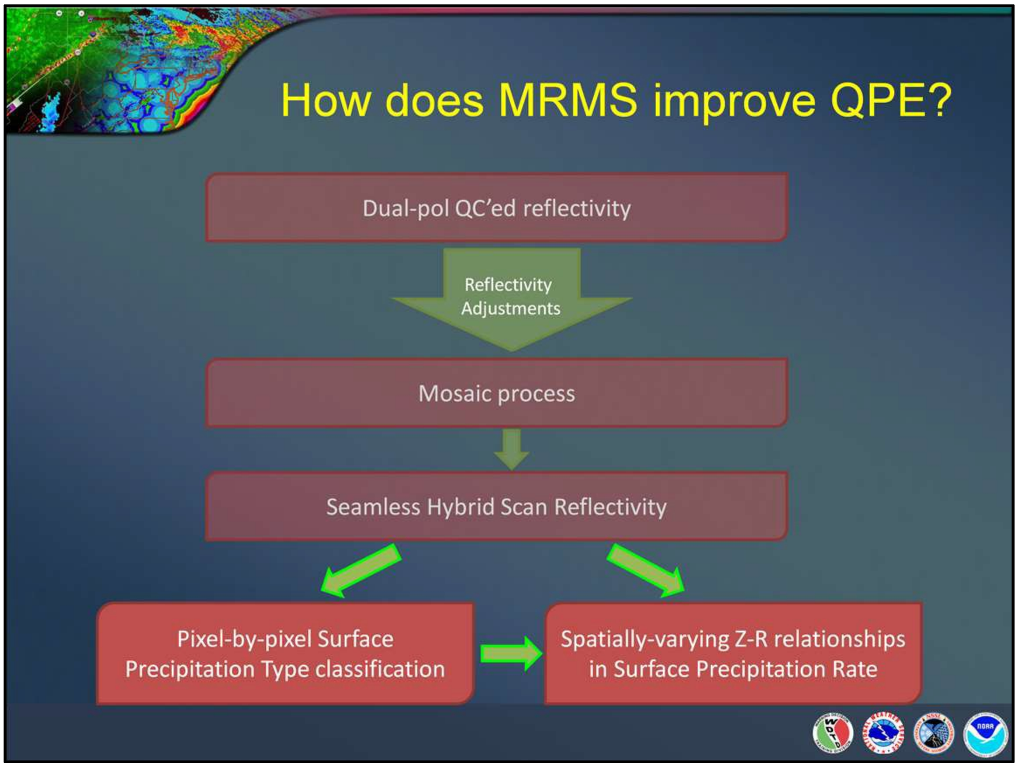
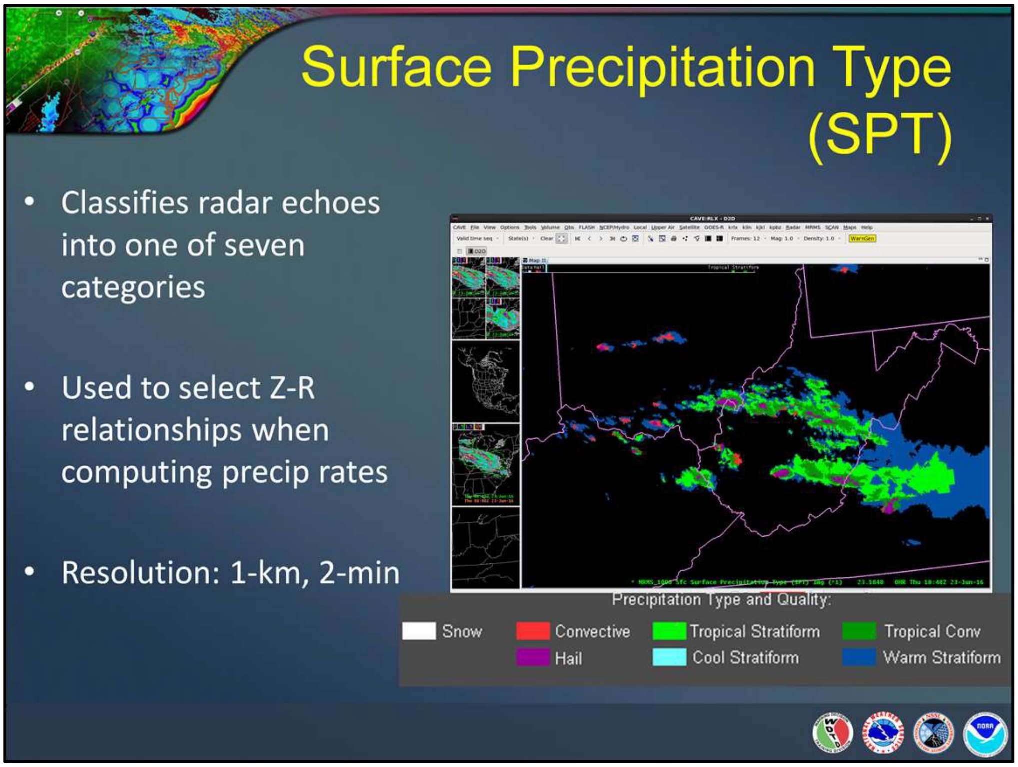


--Now that we have created the mosaicked Seamless Hybrid Scan Reflectivity product, let's look at the two products that directly come from it.

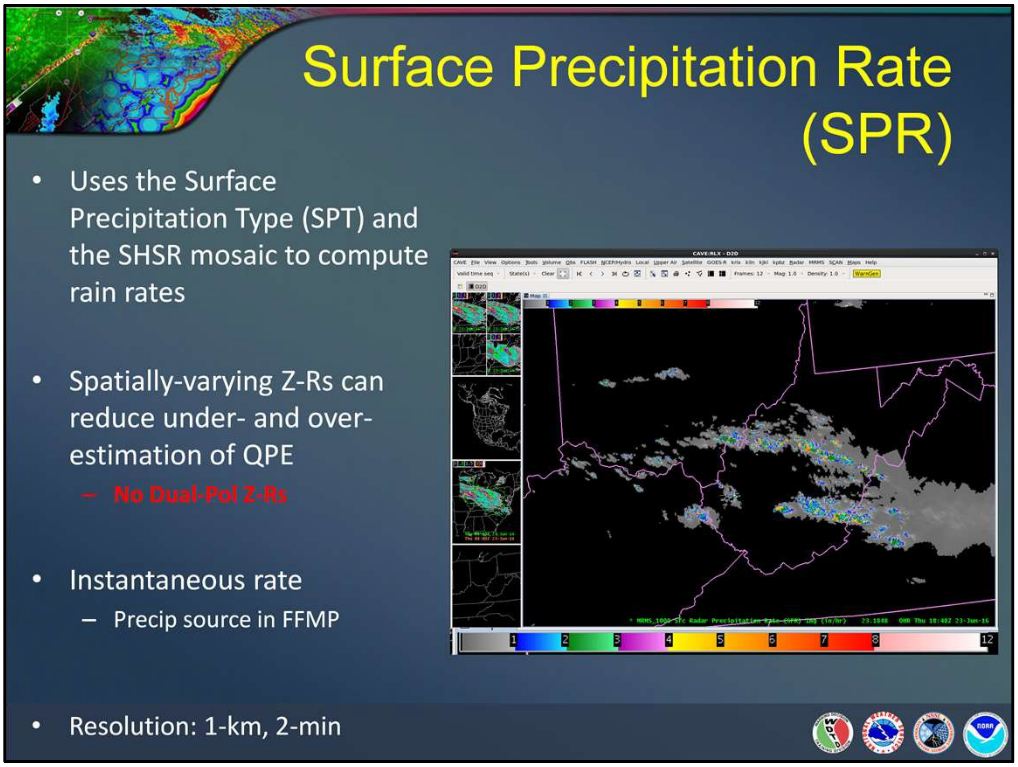
--In brief, the SHSR is used within the Surface Precipitation Type product as a reflectivity criteria to define precip type at each pixel.

--The defined precipitation type is then used within the Surface Precipitation Rate product to determine which Z-R relationship to assign the pixel. Here, the SHSR is also used as the reflectivity value within the Z-R calculation, in order to get the precip rate.

--Combined, these two products display the novelty of the MRMS QPE system, with pixel-by-pixel values that are updated every 2 minutes. Let's look into these products in more detail.



--The Surface Precipitation Type (or SPT) product is an algorithm that classifies radar echoes into one of seven categories. These categories are snow, convective rain, hail, tropical stratiform, tropical convective, cool stratiform, and warm stratiform.
--Its primary use is for the selection of Z-R relationships, in order to compute the Surface Precipitation Rate at each grid point.
--The image on the right is an example of the SPT product. You can see how there are little pockets of convective and hail embedded in a broader stratiform system. Please refer to Lesson 2 of the Hydro Products Course for a full description of how these classifications are made.



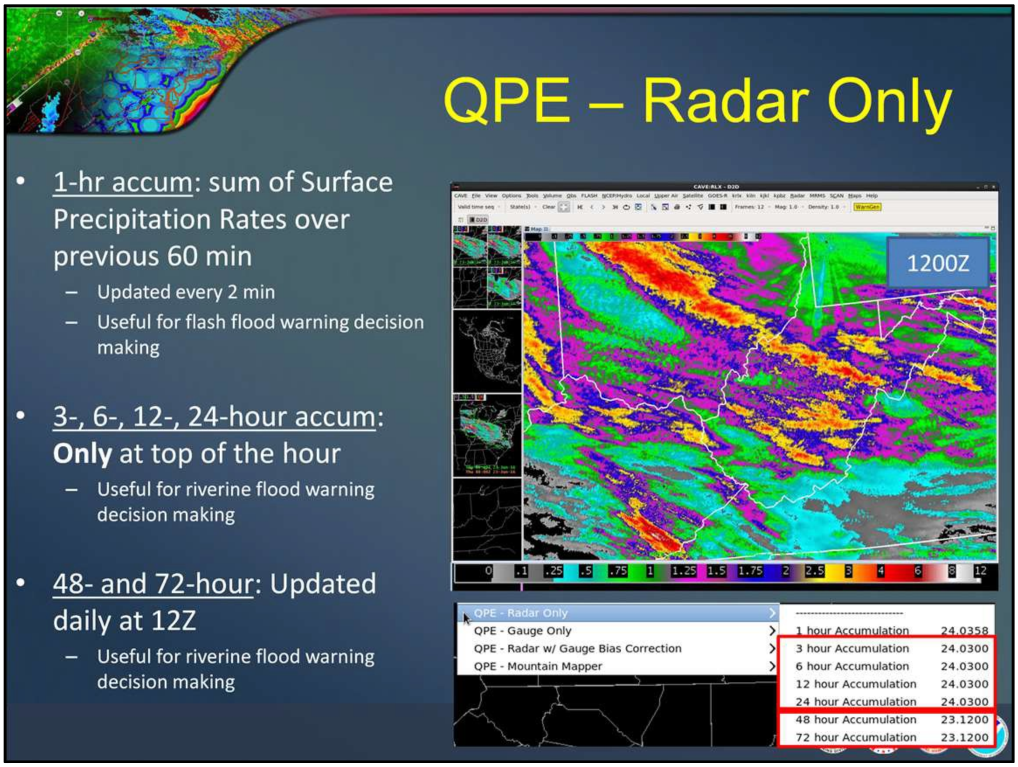
--Once the Surface Precipitation Type product classifies each pixel, it is used within the Surface Precipitation Rate (or SPR) to assign a Z-R relationship at each pixel. The Seamless Hybrid Scan Reflectivity provides the reflectivity value as the input to the calculation.

--Allowing the Z-R relationships to vary per grid cell is a great strength of the MRMS system because it can help reduce under- and over-estimation of QPE. However, it is important to note that the current MRMS system does NOT use dual-pol Z-R relationships. Please refer to Lesson 2 for more information about the Z-Rs used.

--One essential concept to understand is that this is an instantaneous rain rate product. This product can be interpreted as a stand-alone product (to identify areas of locally heavy rainfall), or can be integrated over time to create a longer duration precip accumulation.

--It is a precip source in FFMP, and should be considered alongside your other options (like DPR and DHR).

-And since it updates every 2 minutes, it has the fastest update time of any precip source available in AWIPS.



--Directly from the Surface Precipitation Rate product comes the QPE – Radar Only product. The one-hour accumulation is a summation of the rate product over the previous 60 minutes. This is updated every 2 minutes, as shown by the example on the right which is valid at 1848.

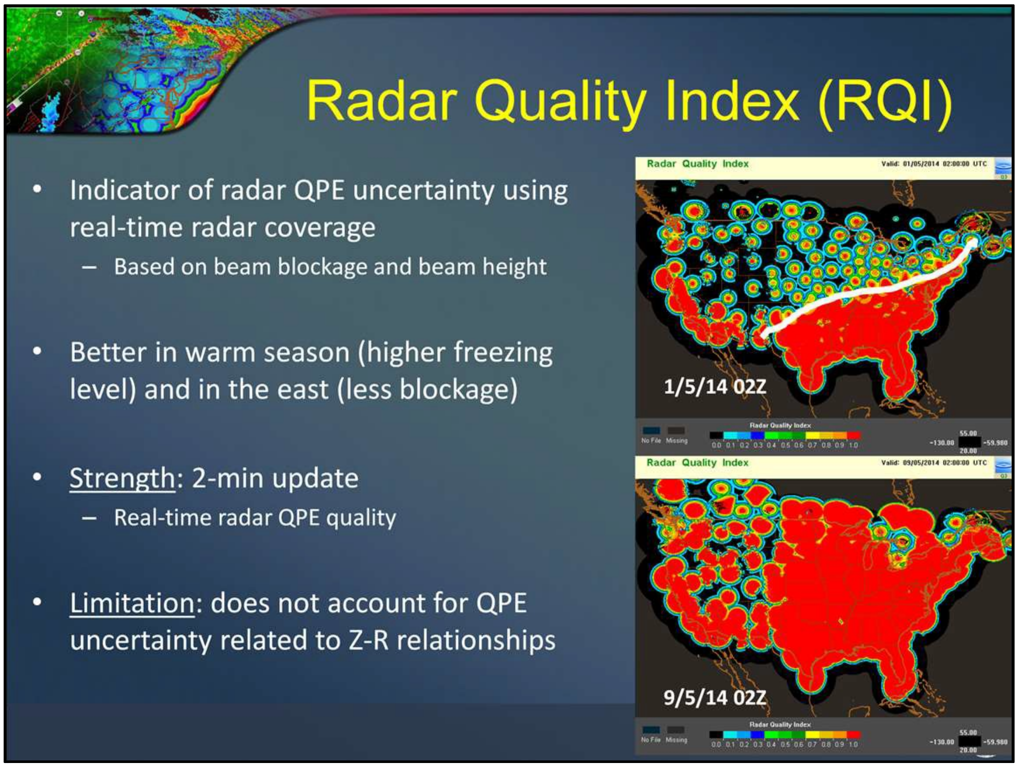
--Because of its quick update time, this product is useful for short-fuse flash flood events.

--3, 6, 12 and 24 hour accumulations are only created every hour, at the top of the hour. Here is a 3-hour accumulation, and it is valid at 19Z.

--Finally, the 48 and 72 hour totals are only updated at 12Z each day. Here is an example of a 72-hour product, valid at 12Z.

--All of these longer duration products may prove more useful for flood events, rather than flash flood events, due to the timeliness of the accumulations.

--Below is the AWIPS menu for these products. From this, it is easy to see how the update times differ and how that can affect interpretation. In this menu, the 3- to 24-hour accumulations are missing almost an hour's worth of data since they were last updated at 3Z and it's now 0358. Whereas, the 48- and 72-hour totals do not include any precip since 12Z, almost 16 hours ago! So be careful when using these longer duration products, as they could end up being quite outdated.



--The final radar-based product available in AWIPS is the Radar Quality Index (or RQI). It is an indicator of single-site radar QPE uncertainty using real-time radar coverage.

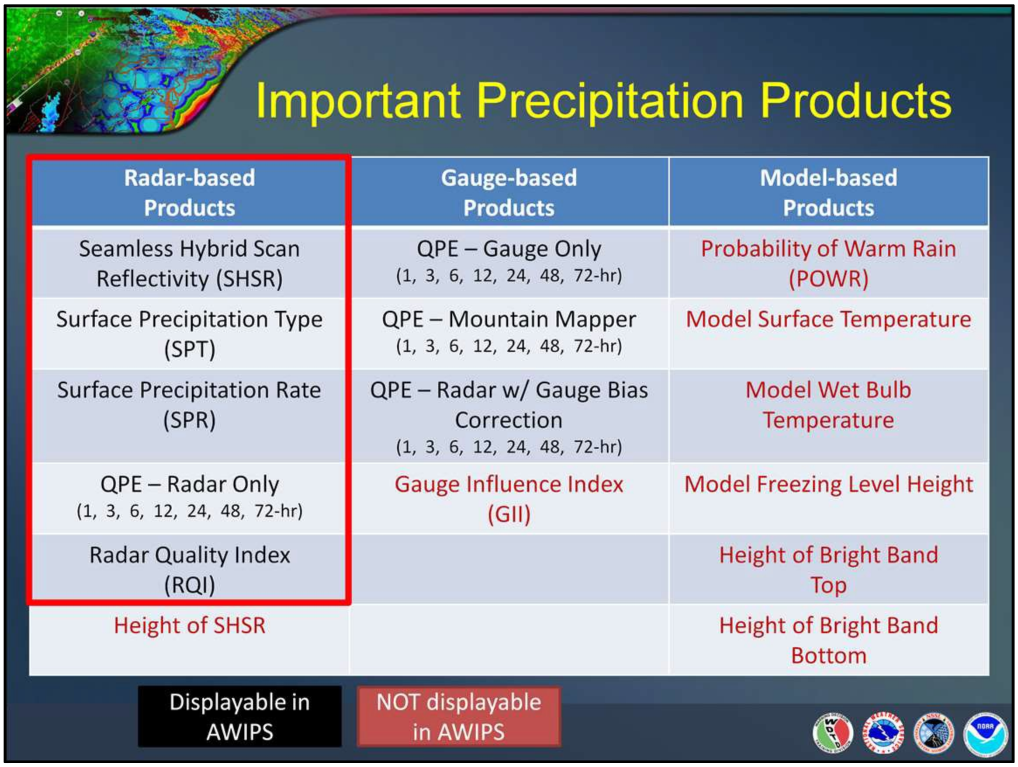
--It is based on uncertainty related to beam blockage (from terrain) and beam height (related to the melting layer).

--The images on the right show RQI maps for both the cool and the warm seasons, with red showing areas where there is no blockage, as well as sampling below the melting layer.

--In general, the RQI is better in the warm season, when there are higher freezing level heights, and in the east, where there is less beam blockage. We see this in the images here because the January map shows very low values throughout much of the north where a winter storm is moving through, roughly along the white line. While the September map clearly shows that the western US has issues even in warmer temperatures.

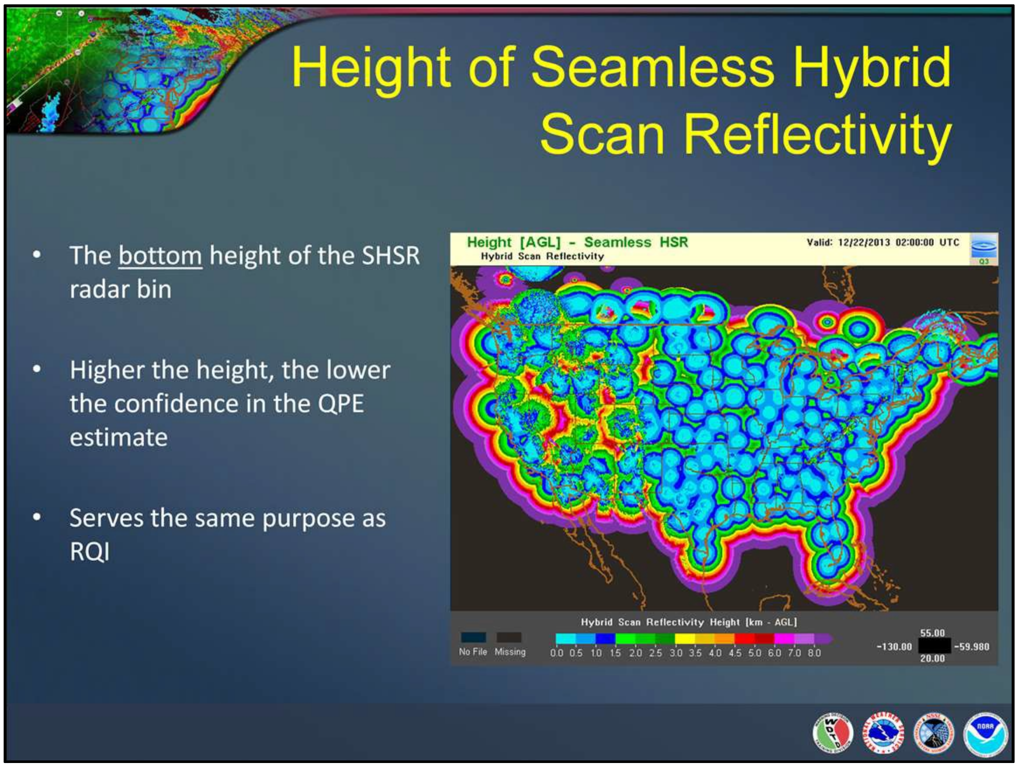
--A strength of the product is that the RQI field is updated every 2 minutes and represents the real-time radar QPE quality distribution across the CONUS.

--However, the main limitation is that the RQI does not account for QPE uncertainties related to Z-R relationships. So don’t look at this product to assess TOTAL QPE uncertainty, don’t say “Hey, RQI is 1, so my QPEs are perfect!” No. Rather use it to get a sense for where you can trust the radar’s coverage in the QPE calculation.

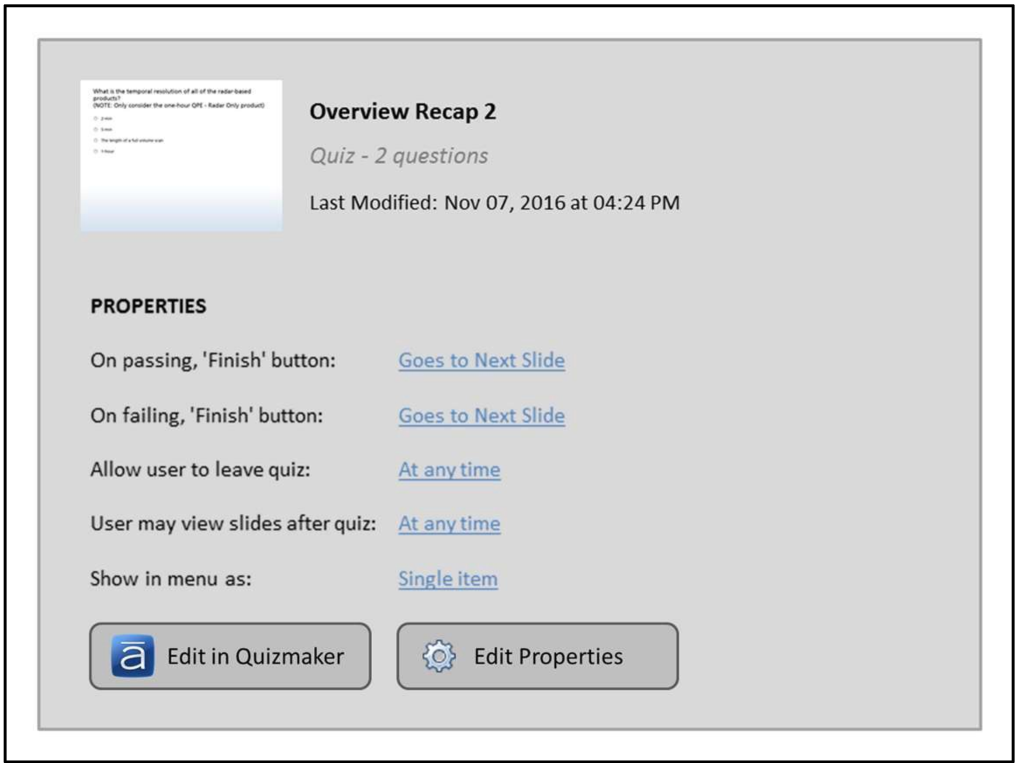


Radar-based Products	Gauge-based Products	Model-based Products
Seamless Hybrid Scan Reflectivity (SHSR)	QPE – Gauge Only (1, 3, 6, 12, 24, 48, 72-hr)	Probability of Warm Rain (POWR)
Surface Precipitation Type (SPT)	QPE – Mountain Mapper (1, 3, 6, 12, 24, 48, 72-hr)	Model Surface Temperature
Surface Precipitation Rate (SPR)	QPE – Radar w/ Gauge Bias Correction (1, 3, 6, 12, 24, 48, 72-hr)	Model Wet Bulb Temperature
QPE – Radar Only (1, 3, 6, 12, 24, 48, 72-hr)	Gauge Influence Index (GII)	Model Freezing Level Height
Radar Quality Index (RQI)		Height of Bright Band Top
Height of SHSR		Height of Bright Band Bottom

So we have covered all of the radar-based products that are available in AWIPS. The last product is the Height of the SHSR. Let's briefly cover that on the next slide.



--This product is simply the bottom height of the SHSR radar bin at each point.
--Basically, it shows you the height at which radar reflectivity was sampled for every grid point where QPE was derived.
--Generally, the higher off the ground, the less representative the QPE estimate of what is happening at the surface. Therefore, this height field can help clarify where you my have less confidence in your estimates.
--This product serves a similar purpose as the previously-mentioned RQI since they both give a sense of the quality of QPE estimates, as it relates to radar coverage.


Overview Recap 2
Quiz - 2 questions
Last Modified: Nov 07, 2016 at 04:24 PM
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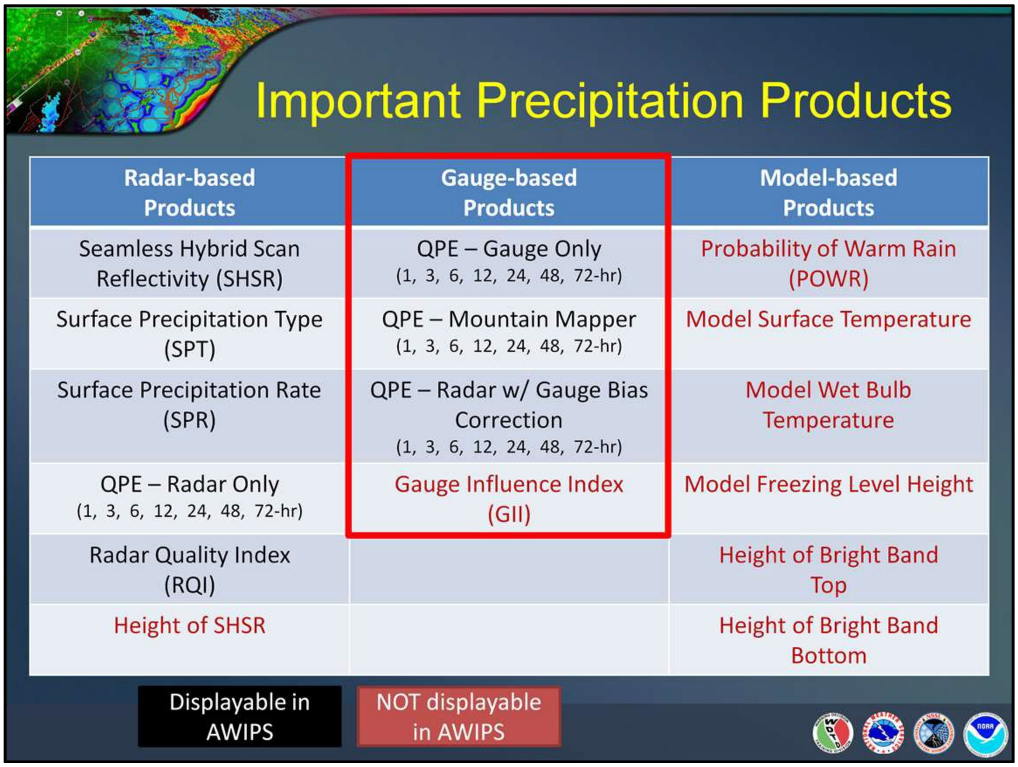
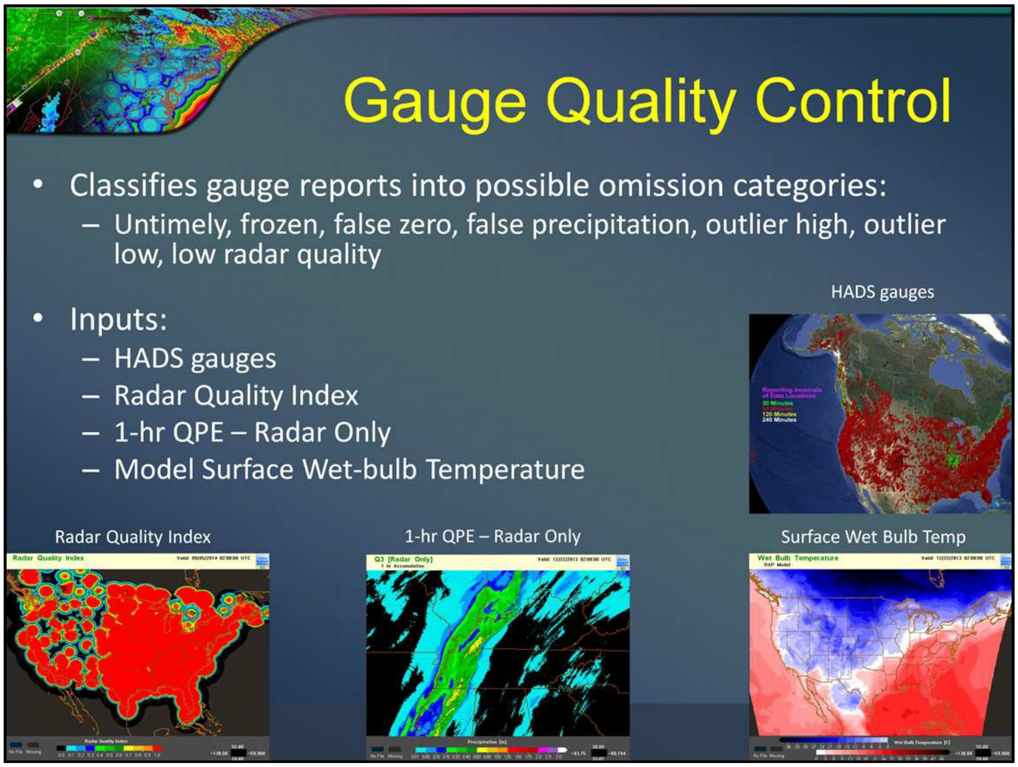


Radar-based Products	Gauge-based Products	Model-based Products
Seamless Hybrid Scan Reflectivity (SHSR)	QPE – Gauge Only (1, 3, 6, 12, 24, 48, 72-hr)	Probability of Warm Rain (POWR)
Surface Precipitation Type (SPT)	QPE – Mountain Mapper (1, 3, 6, 12, 24, 48, 72-hr)	Model Surface Temperature
Surface Precipitation Rate (SPR)	QPE – Radar w/ Gauge Bias Correction (1, 3, 6, 12, 24, 48, 72-hr)	Model Wet Bulb Temperature
QPE – Radar Only (1, 3, 6, 12, 24, 48, 72-hr)	Gauge Influence Index (GII)	Model Freezing Level Height
Radar Quality Index (RQI)		Height of Bright Band Top
Height of SHSR		Height of Bright Band Bottom

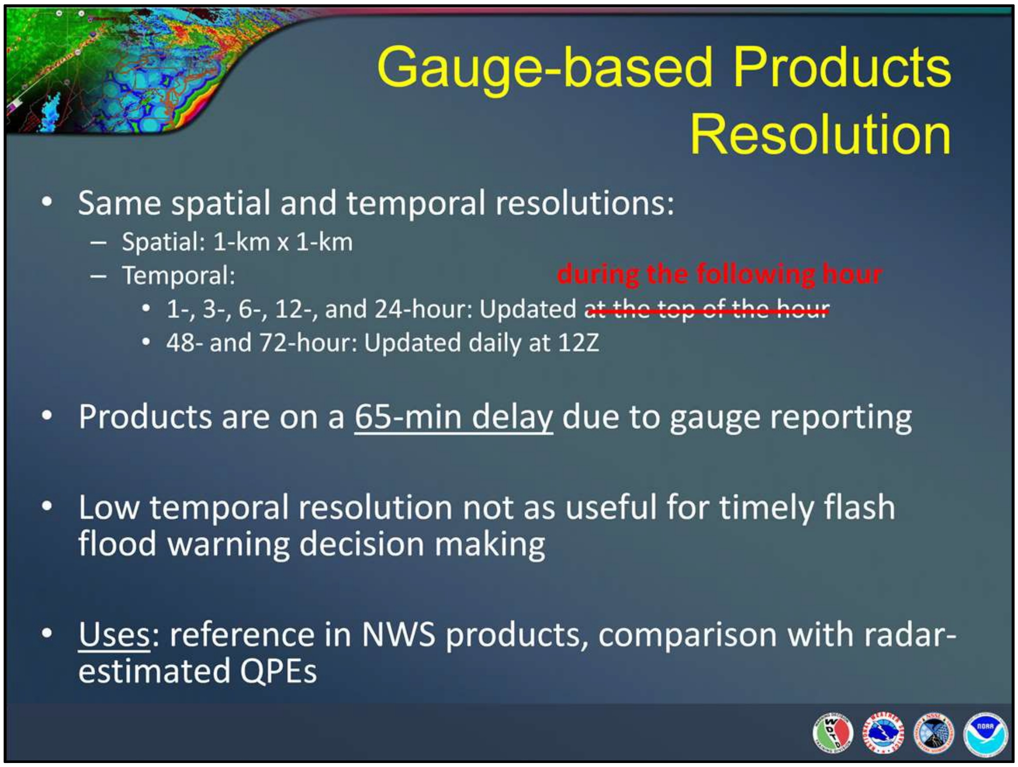
--Next up are the gauge-based products. All of these products have the same spatial and temporal resolutions, however, they differ slightly in their inputs and calculations. Let’s go into more detail, beginning with the Gauge Quality Control.



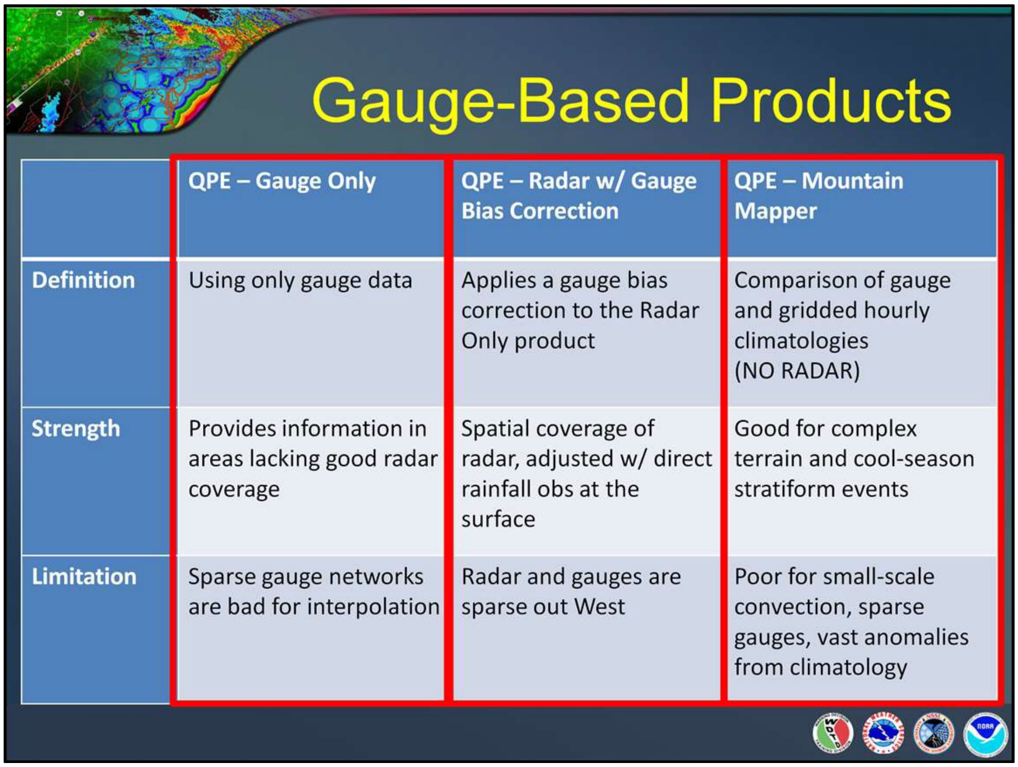
--Each of these products begins from the same foundation, which is the raw gauge data going through the Gauge Quality Control. The algorithm goes through a series of steps to determine if a gauge report falls into one of the categories that could cause it to be omitted in gauge-based product generations.

--These categories are: untimely, may be frozen due to winter precipitation, report "false zero" or "false precipitation", are considered outliers that are either too high or too low, or those that may be deemed questionable in areas of low radar quality.

--The QC uses a variety of inputs to go through the decision tree. The raw hourly gauge data that is being QC'ed comes from the HADS network. The Radar Quality Index, one-hour QPE – Radar Only, and hourly surface wet-bulb temperature are all used to classify the gauge reports. How they are used is covered in Lesson 3 of the Hydro Products Course. Additionally, Lesson 3 includes information about how the gauge interpolation scheme works, so please refer to that lesson for more details.



--All of the gauge-derived products have the same spatial and temporal resolutions.
--The spatial resolution is the same 1-km by 1-km grid as used throughout the MRMS QPE system.
--For the temporal resolution, the smallest accumulation available is the one-hour product. The 1-, 3-, 6-, 12-, and 24-hour accumulations are updated every hour, at the top of the hour.
--The 48- and 72-hour products are updated each day at 12Z.
--Currently, all of the gauge products are on a delay of ~65 min, due to gauge reporting. For example, a product that is valid from 00Z to 01Z will collect its gauge information after 01Z. The data comes in incrementally, so that product (again, valid at 01Z) will not be released until 0205. So I annotate the previous bullet to say, the products are available during the FOLLOWING hour, to take into account this lag.
--Since these products are currently experiencing this lag, they are not as useful for flash flood warning decision making. However, they may be referenced in NWS products to have a more accurate QPE. Additionally, these products are useful to compare with radar estimates of QPE, to see how the gauge information affects the QPE amounts.



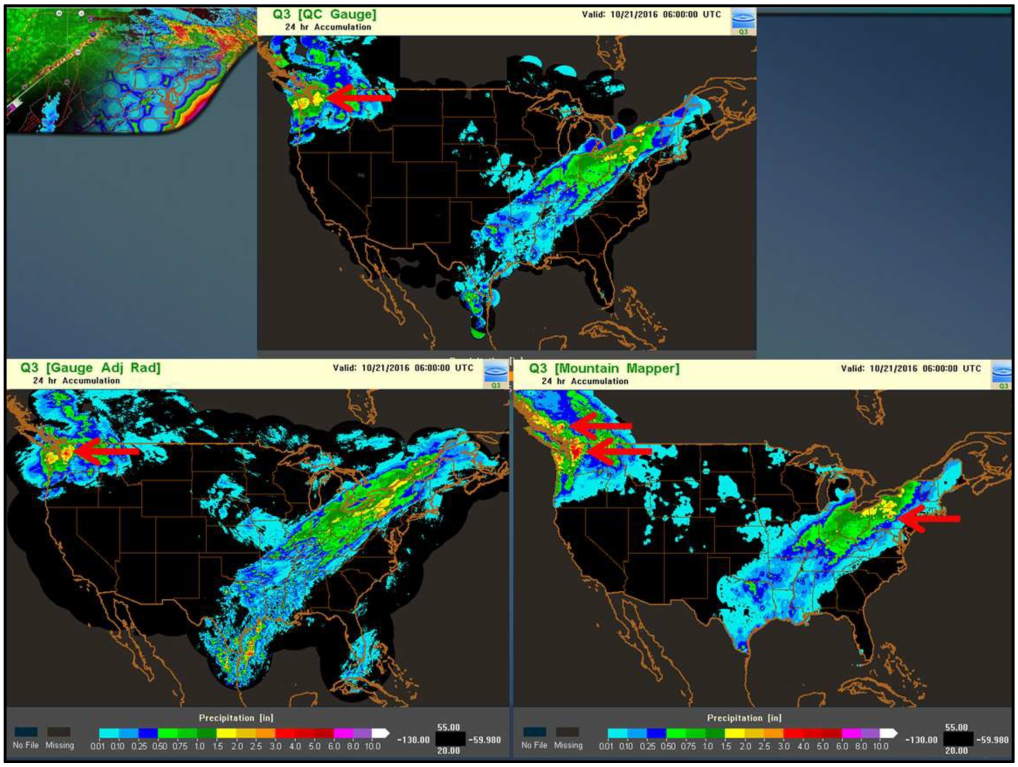
Gauge-Based Products

	QPE – Gauge Only	QPE – Radar w/ Gauge Bias Correction	QPE – Mountain Mapper
Definition	Using only gauge data	Applies a gauge bias correction to the Radar Only product	Comparison of gauge and gridded hourly climatologies (NO RADAR)
Strength	Provides information in areas lacking good radar coverage	Spatial coverage of radar, adjusted w/ direct rainfall obs at the surface	Good for complex terrain and cool-season stratiform events
Limitation	Sparse gauge networks are bad for interpolation	Radar and gauges are sparse out West	Poor for small-scale convection, sparse gauges, vast anomalies from climatology

--Now let's summarize the three gauge-derived QPE products.
--As the name implies, the QPE - Gauge Only product is a precip accumulation product that ONLY uses top-of-the-hour gauge data.
--A strength is that gauges in poor radar coverage regions can provide surface precip information when radar is unavailable (for example, the West).
--However, a limitation of the product is that since it is based solely on available rain gauges (that pass the QC), the product may suffer when gauges are sparse and interpolations must be made that are far-reaching.

--The QPE - Radar w/ Gauge Bias Correction product applies a bias correction to the Radar Only accumulation product.
--This product is particularly useful because it leverages the spatial coverage of radar data, but adjusts it using direct rainfall observations at the surface.
--Since complex terrain and sparse gauge densities impact the product, it suffers in the west.

--That brings us to the final product, the QPE - Mountain Mapper. There is NO radar data used in this product! It is simply a comparison between gauge information and gridded estimates of hourly climatologies.
--This product is meant for precipitation estimation in complex terrain, particularly along the Pacific coast in the Western U.S.
--Due to MM using no radar data, it performs poorly for small-scale convective precipitation; it does better with cool-season stratiform precipitation. Additionally, when the gauge network is sparse, the interpolation is far-reaching and can cause errors. Finally, when the real-time precipitation distribution strongly differs from the climatology, large errors can occur and atmospheric environmental data may be better suited.

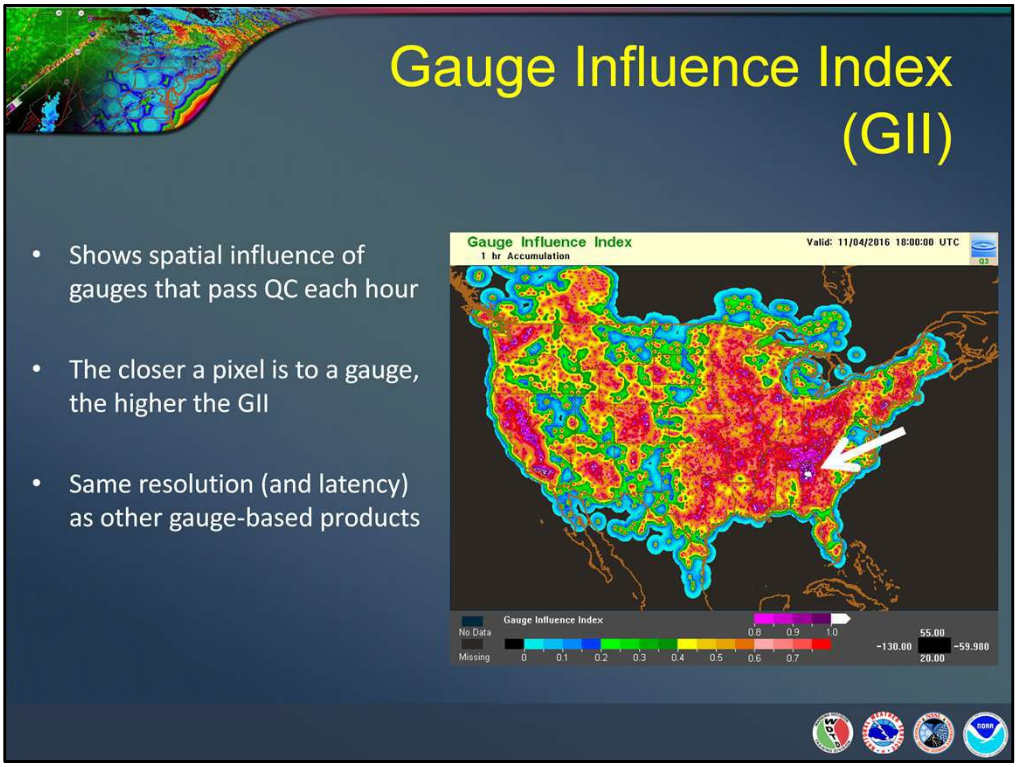


--Here is a comparison of all three gauge-based QPE products, valid at the same time for a 24-hour accumulation.

--You can use the Gauge-Only product, however, there will be issues in areas where gauge networks are sparse. For instance, look at the rainfall occurring in Washington state, which happens to be over a mountainous state forest. The Gauge-Only product has noticeably less precip accumulated as compared to the other two products in this area.

--Next, there's the Radar with Gauge Bias Correction product. This product provides the most coverage because it is radar- and gauge-based.

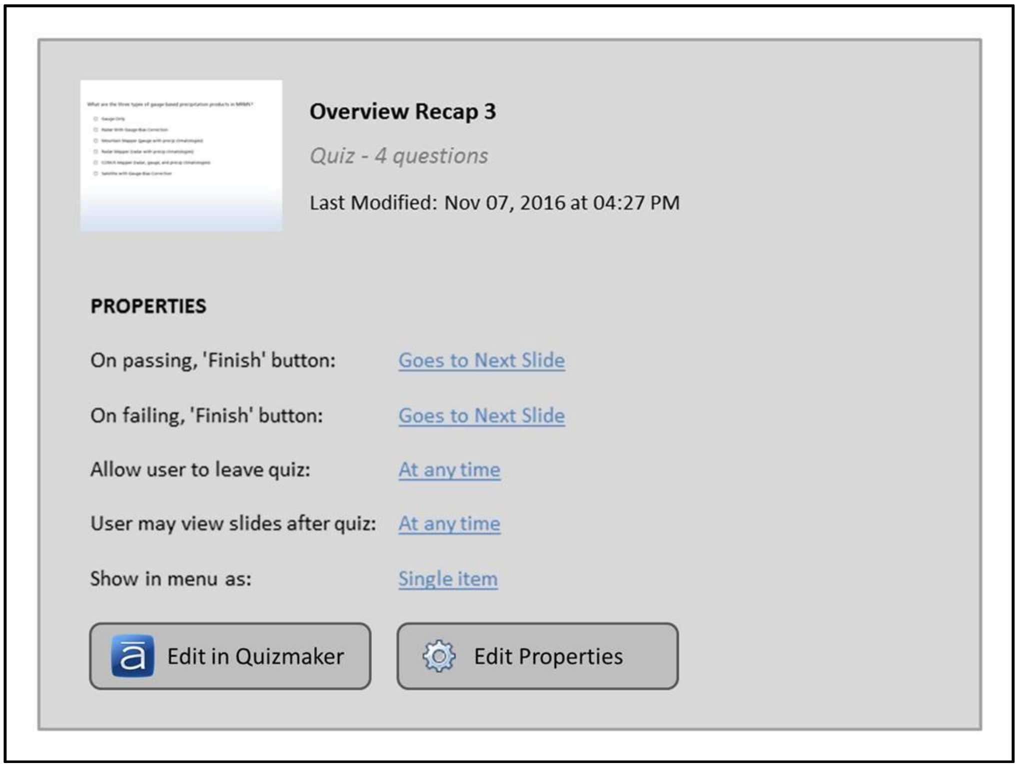
--Finally, you can use the Mountain Mapper, which blends precip climatologies to adjust gauge data. Its usefulness is perhaps most noticeable in the Pacific Northwest where we see high resolution details that are not available via gauges or radar in this region of complex terrain. On the other hand, it smoothes out the small-scale convection occurring across the east since it does not include radar estimates. Also, notice how its spatial coverage is limited to the US and British Columbia, Canada.



--The final gauge-based product, which is only available on the experimental website, is the Gauge Influence Index. It is a dimensionless index that simply shows the spatial influence of the gauges that pass the qualitycontrol each hour.

--It can be interpreted as: the closer a pixel is to a gauge or multiple gauges, the higher the GII will be. So in this image, Atlanta must have a dense network of gauges because many of the pixels in that area have the maximum GII value of one.

--This product has the same resolution, and therefore, latency issues as the other gauge-based products.


Overview Recap 3
Quiz - 4 questions
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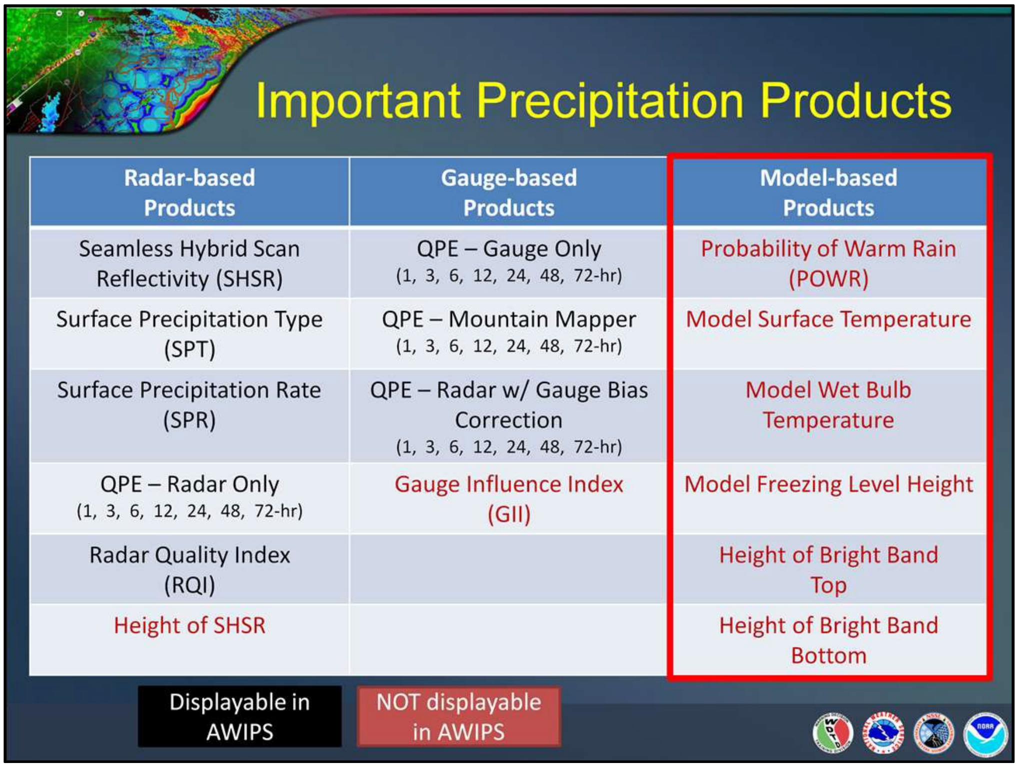
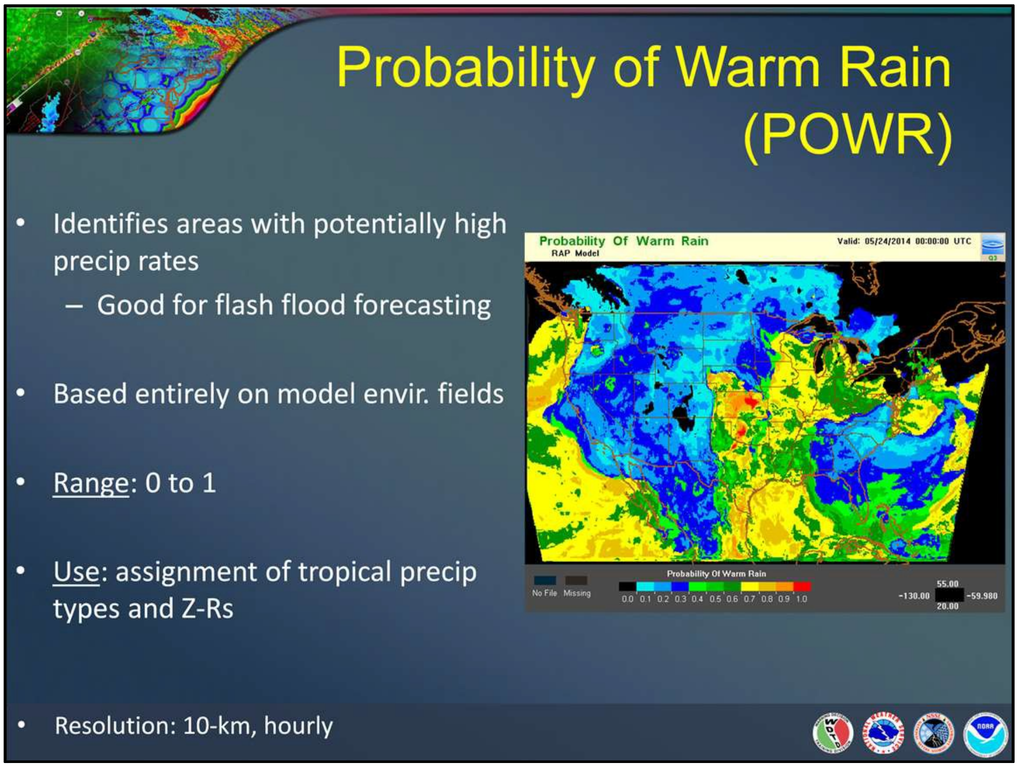
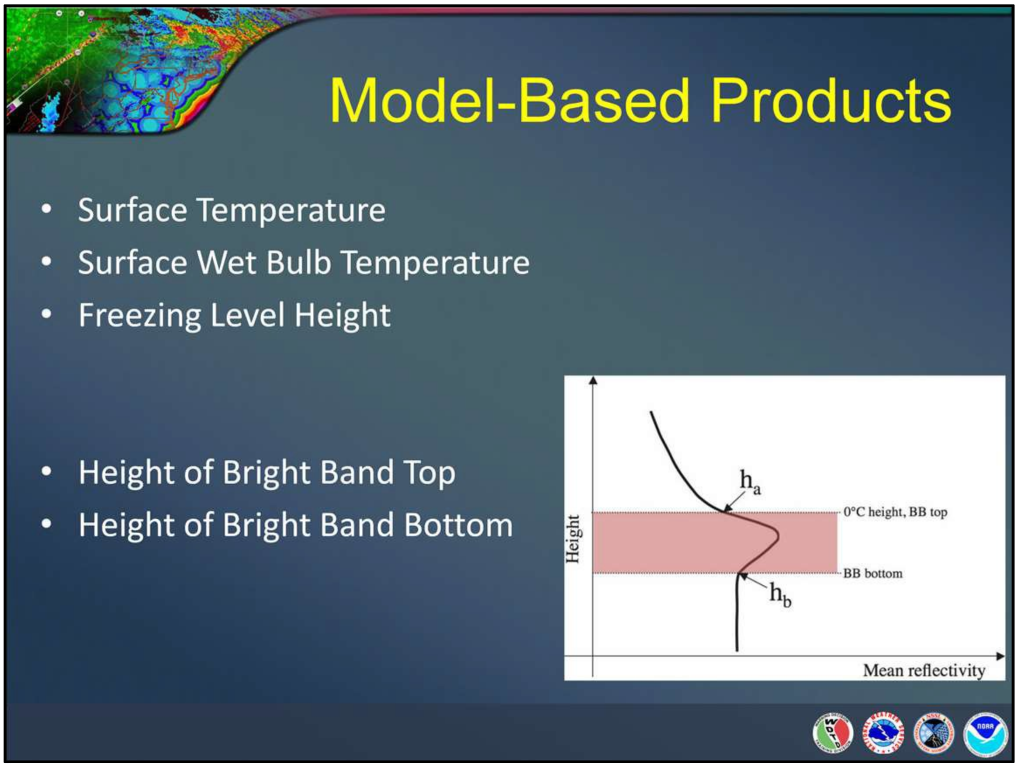


--Finally, there are the model-based products. None of these products are available in AWIPS, but rather are used to create the other products already described. We will very briefly discuss them now, but encourage you to look into them more on the experimental website.

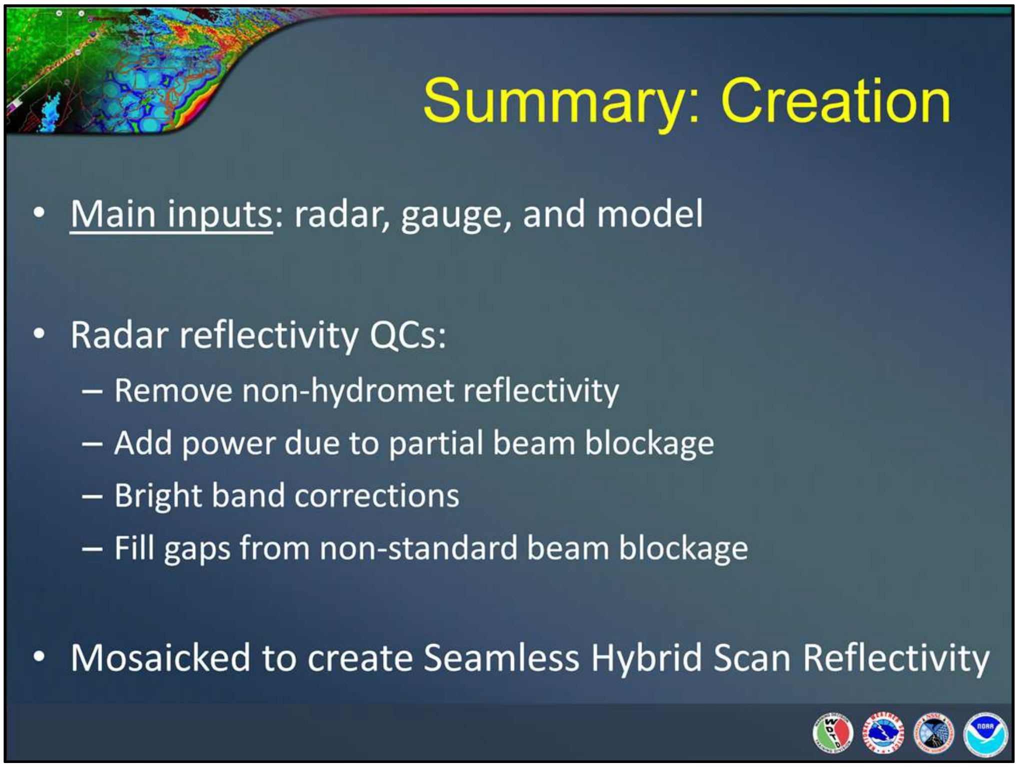


--The Probability of Warm Rain (or POWR) identifies areas where enhanced warm rain processes and potentially high rain rates can be occurring, which is important for flash flood forecasting.
--It is based entirely on model environmental fields related to moisture content, instability, and temperature.
--It ranges from zero to one, with high values indicating an environment with a moist adiabatic profile, a high freezing level, and a lot of low- to mid-level moisture.
--In the MRMS suite, POWR is incorporated into the assignment of tropical precip types and Z-R relationships, since it is a proxy for warm rain processes.



Here are the rest of the model-based products. The first three are pretty self-explanatory, and can be viewed online.

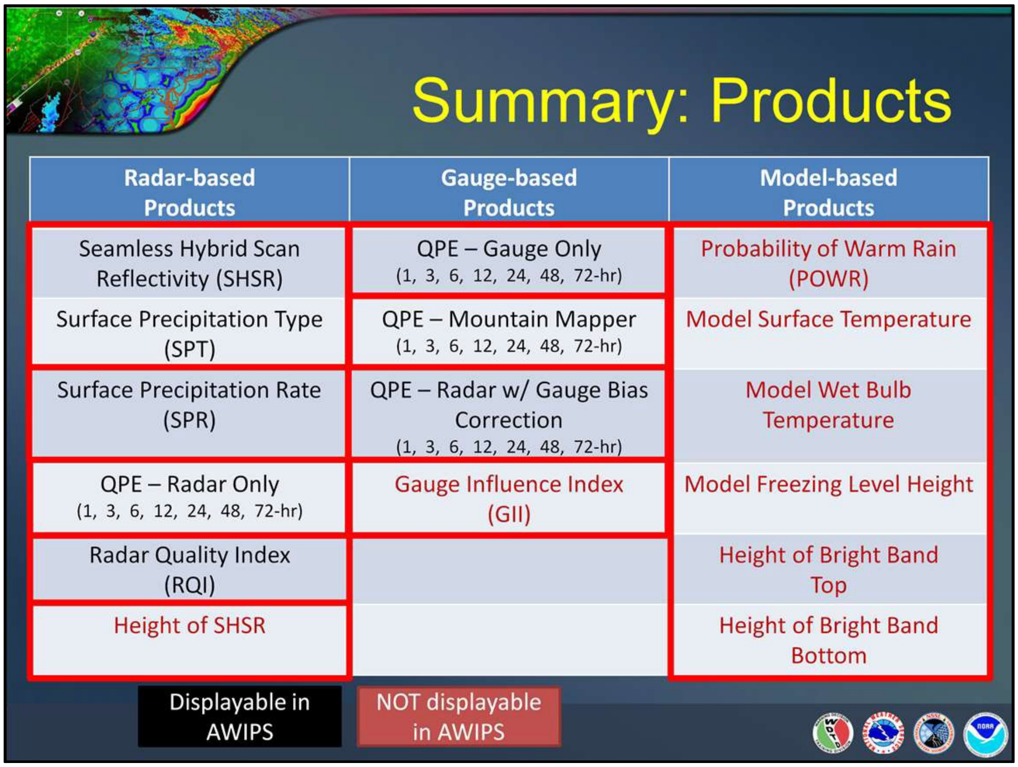
The last two products are the Heights of the Bright Band Top and Bottom. As introduced earlier, the bright band can cause overestimation in radar QPE because melting ice particles may be falsely assigned higher reflectivities, which are then used in rate calculations. So understanding the vertical extent of this layer is useful to know where QPE uncertainty may occur.



--In summary, there are three main inputs to the MRMS QPE suite: radar, gauge, and model.

--The radar reflectivity is the core of the system, and it goes through several quality control steps including: the removal of non-hydrometeorological reflectivity, adding power back due to partial beam blockage, bright band corrections, and the filling of gaps related to non-standard beam blockages.

--This adjusted reflectivity is then mosaicked to create the Seamless Hybrid Scan Reflectivity.

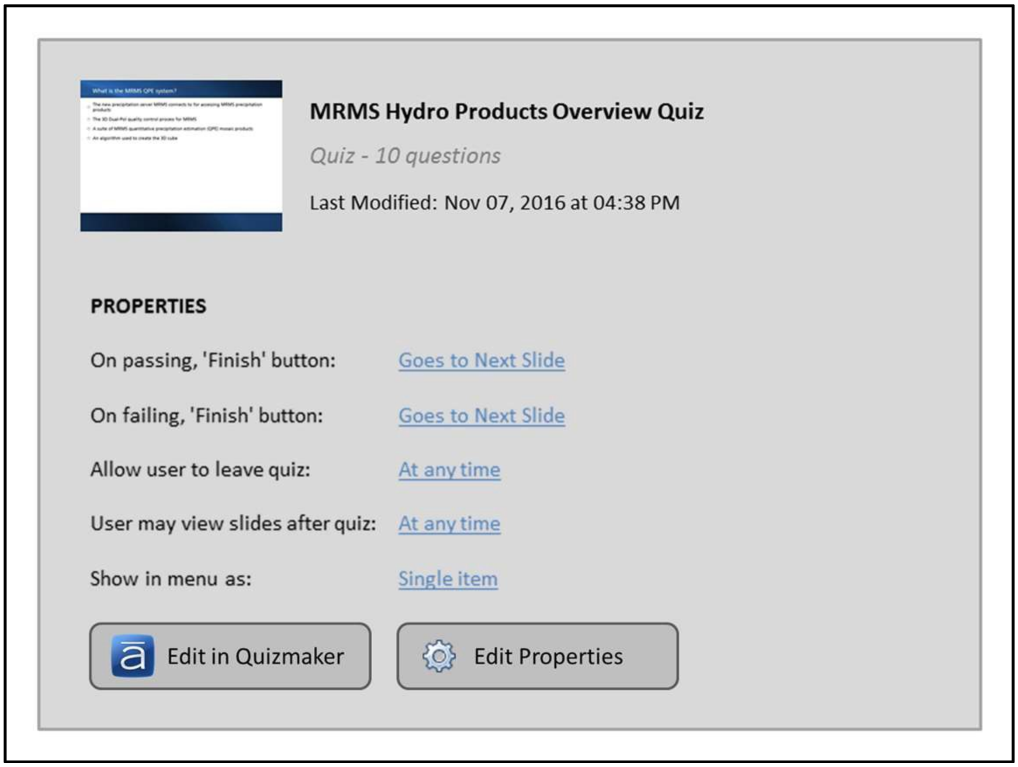


--The Seamless Hybrid Scan Reflectivity is combined with Surface Precipitation Type classifications, to create an instantaneous rate product that has spatially-varying Z-R relationships. The rate is used to create the longer accumulation products, with only the 1-hour accumulation being created every 2 minutes; the rest are once per hour or even less frequent. The Radar Quality Index can be used to get a sense of real-time QPE uncertainty based on beam blockage and beam height. The Height of the SHSR can do the same by showing the height at which the QPEs were derived.

--The gauge-based products are all created using quality-controlled gauges. The Gauge-Only product is created by just interpolating gauge data onto the MRMS grid. The Mountain Mapper uses precip climatologies to help in areas of sparse radar coverage, and the Radar w/ Gauge Bias Correction product uses the Radar Only QPE product as a base to blend radar and gauge observations. The Gauge Influence Index is a good way to quickly assess the influence of gauges on each grid point during each hour's analysis. Remember, all of these gauge products are only updated at the top-of-the-hour, and even then, have latencies associated with them.

--Finally, there are several model-based products that are not available at your AWIPS workstation, but can be viewed online for follow-on analyses.

--Alright, this concludes the MRMS Hydro Products Overview lesson. Remember, there is the Full Hydro course which goes into more detail of all of these products and procedures, and should be considered for all Hydro Focal Points. When you are ready, please move onto the next slide to take the quiz and receive credit on the LMS.


MRMS Hydro Products Overview Quiz
Quiz - 10 questions
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PROPERTIES
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