1. Correlation Coefficient (CC)

Instructor Notes: This lesson will cover the correlation coefficient product (or CC).

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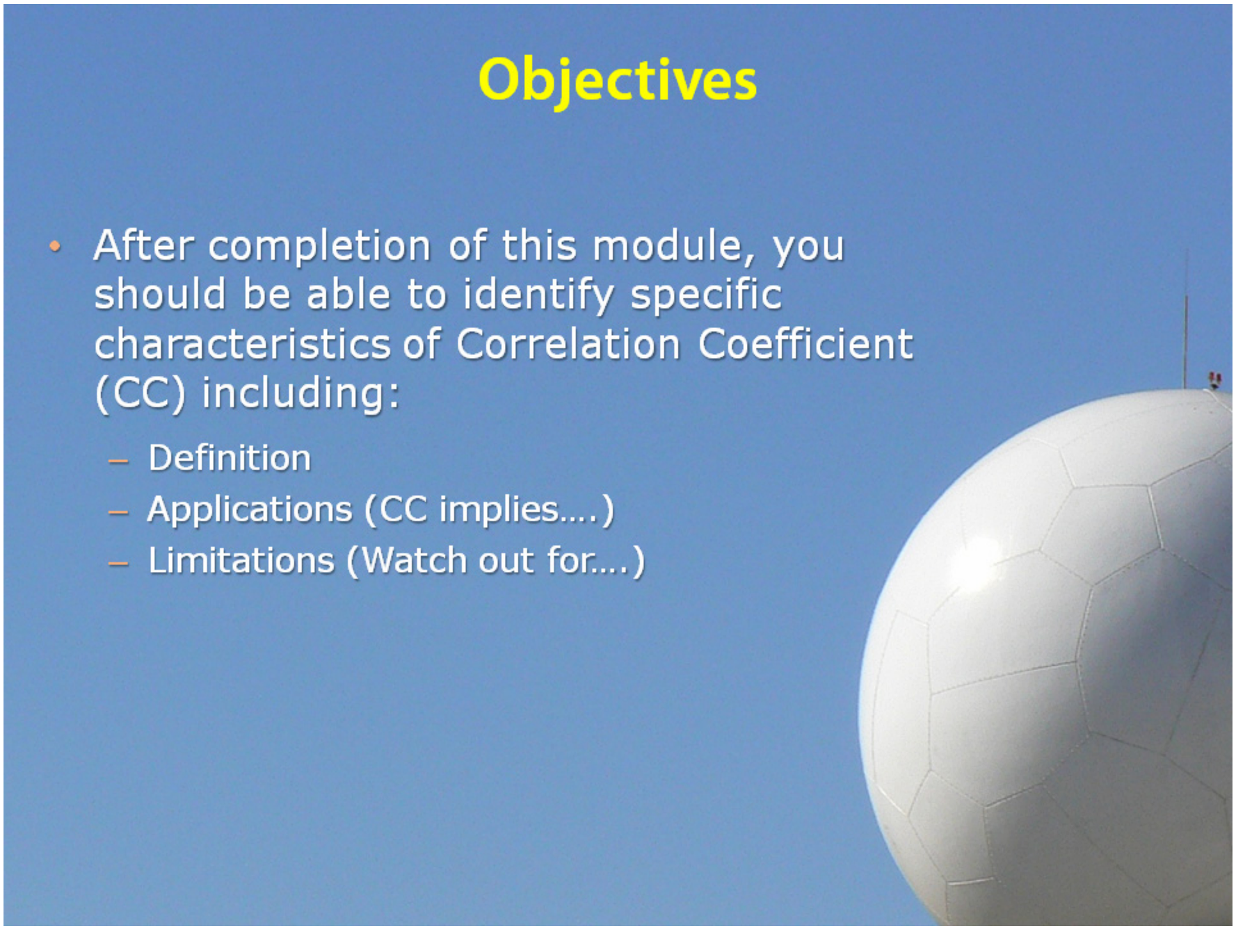

2. Objectives

Instructor Notes: After completing this module, you should be able to define correlation coefficient and recognize situations where correlation coefficient can be useful operationally and when correlation coefficient might be suspect.

Student Notes:

Correlation Coefficient (CC)

Definition	Possible Range of Values	Units	Abbreviated Name
Measure of how similarly the horizontally and vertically polarized pulses are behaving within a pulse volume	0.2 to 1.05	None	CC (AWIPS) RHO (GR Analyst) ρ_{HV} (Literature)

$$CC = \frac{\langle S_{vv} S_{hh}^{*} \rangle}{\left(\langle S_{hh}^{2} \rangle^{1/2} \langle S_{vv}^{2} \rangle^{1/2} \right)}$$

3. Correlation Coefficient (CC)

Instructor Notes: The correlation coefficient is a measure of how similarly the horizontally and vertically polarized pulses are behaving within a pulse volume. Its values can range from 0.2 to 1.05 and are unitless. In AWIPS and the RPG, this variable is referred to as CC, but in research papers you will see it referred to as rhoHV. In GR Analyst it's labeled "RHO". Here is the equation for computing the correlation coefficient as reference only. One thing to note is that it is an absolute value, thus negative values of correlation coefficient are impossible.

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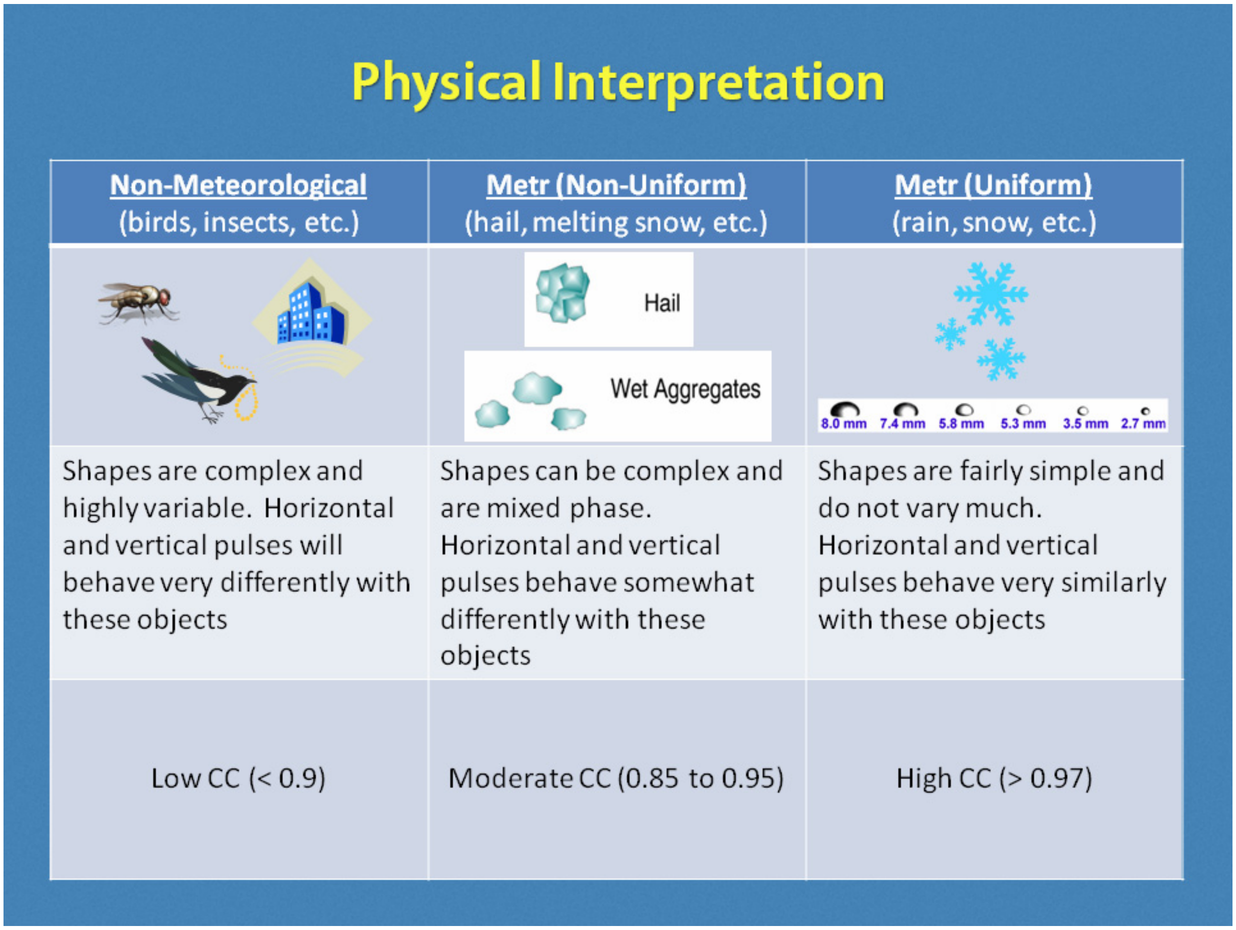

4. Physical Interpretation

Instructor Notes: This chart here summarizes the general physical interpretations of CC. Non-meteorological echoes such as birds and insects have complex and highly variable shapes which result in the horizontal and vertical pulses behaving very differently. This causes CC to be less than 0.9 but more often less than 0.75. For meteorological echoes that have complex shapes, mixed phases, etc., the horizontal and vertical pulses behave somewhat differently, but more similarly than non-meteorological echoes resulting in CC between 0.85 and 0.95. Finally, for meteorological echoes that are fairly uniform in shape and size, such as rain and snow, the horizontal and vertical pulses behave very similarly resulting in CC greater than 0.97. In a sense, CC is somewhat analogous to spectrum width in that CC can tell you whether or not all the radar targets are similar in shape, size, orientation, and phase, or if they widely vary.

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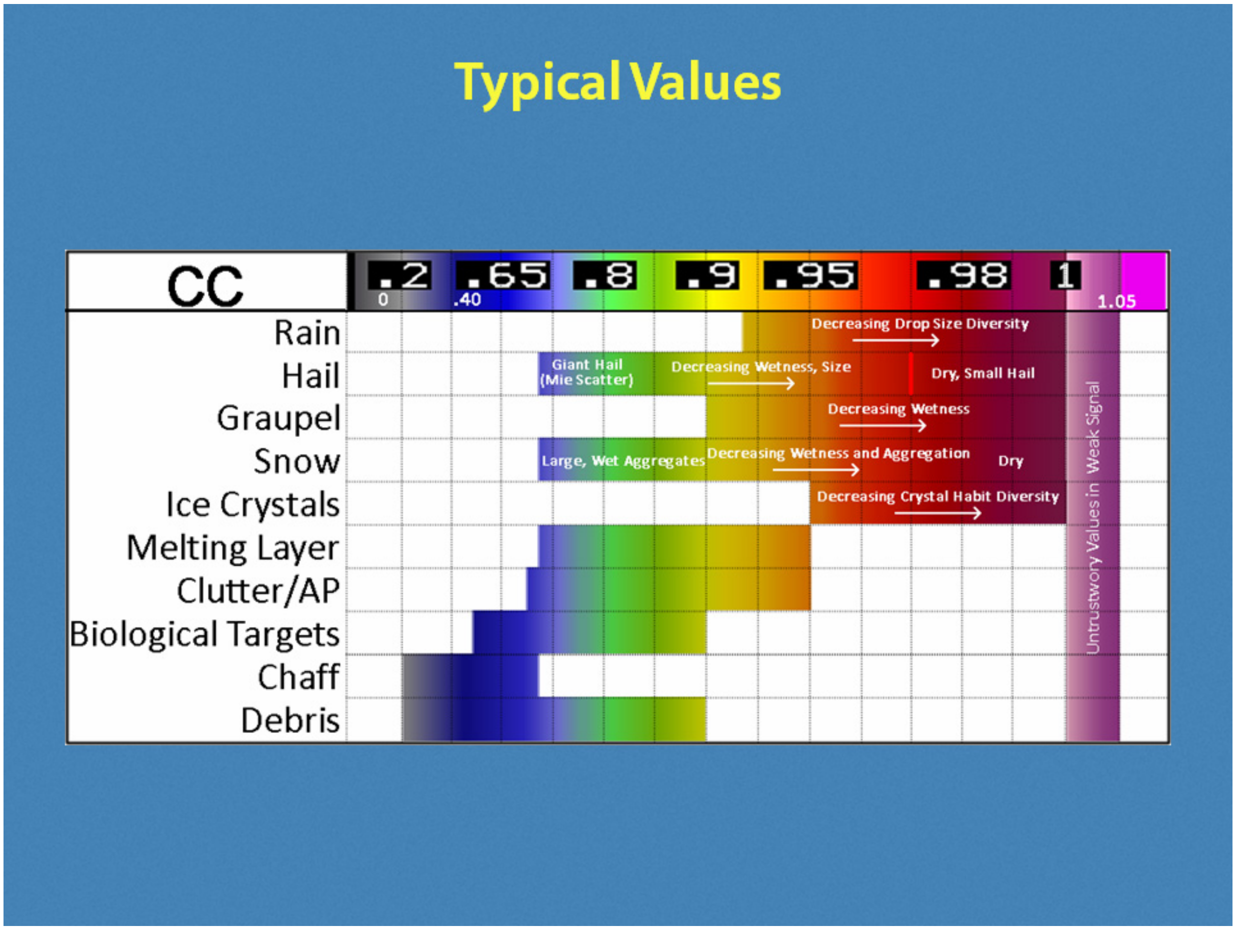
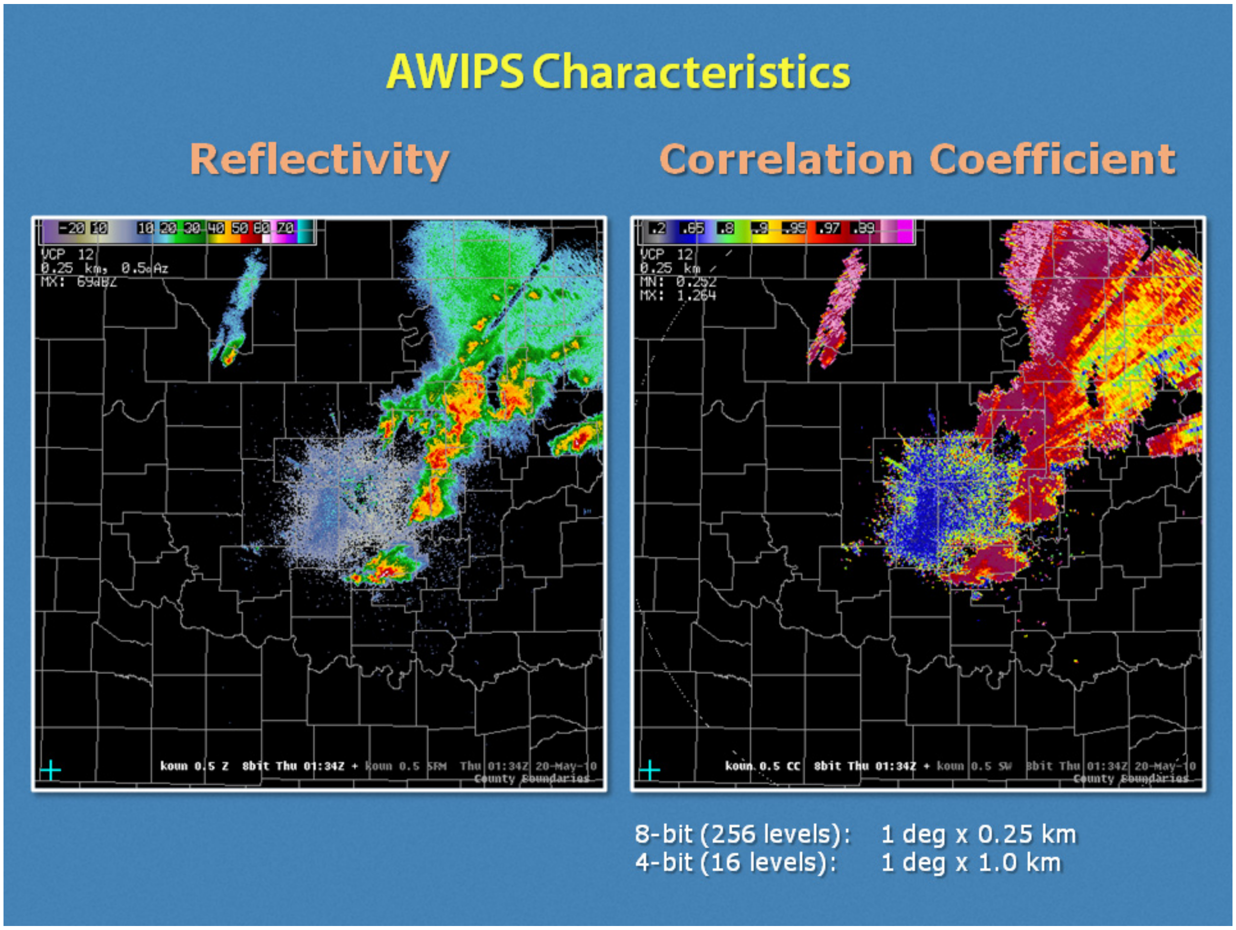


5. Typical Values

Instructor Notes: Here is a chart of the typical values for correlation coefficient for the various echoes listed on the left side of the chart. This same chart is also available with the training aid off the Tools menu on your WES for the dual-pol exercises. At the top of the chart is the default AWIPS color bar. Meteorological echoes are listed at the top, and non-meteorological echoes are listed at the bottom. Note that most meteorological echoes tend to be greater than 0.9 except for giant hail and melting snow flakes which, on very rare occasions, can dip to as low as 0.7. For non-meteorological echoes, the correlation coefficient very rarely is greater than 0.90 except for ground clutter which can get as high as 0.95 in some cases. In weak signal, such as along the fringes of precipitation, you'll see CC get noisy and larger than 1.

Student Notes:



6. AWIPS Characteristics

Instructor Notes: The CC product will appear on your D-2D screen just like the image on the right. A reflectivity image has been provided on the left for reference. CC will be provided in two data levels/resolutions: 8-bit at 1 deg x 0.25 km and 4-bit at 1 deg x 1 km. CC products are available at these resolutions on all elevation angles.

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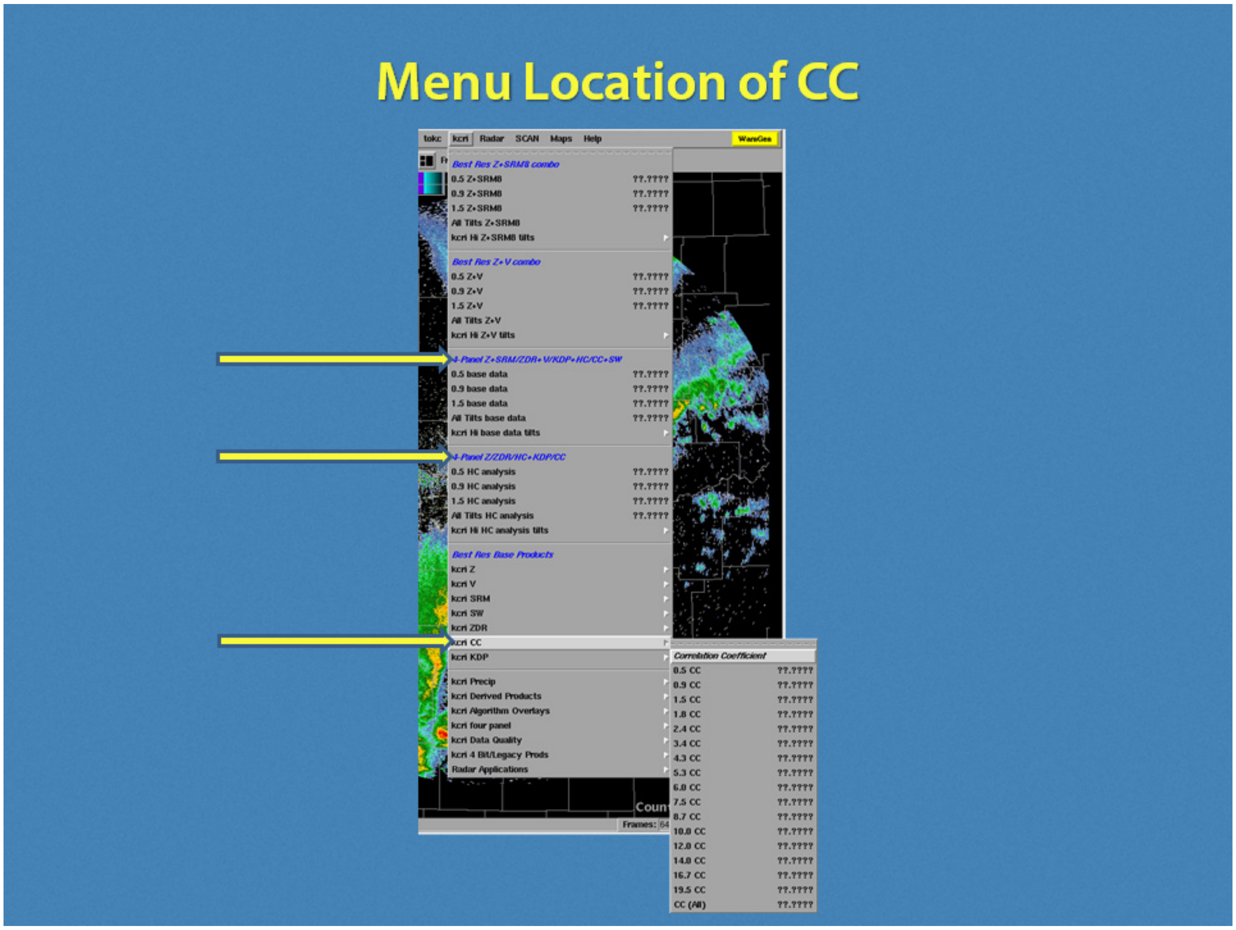
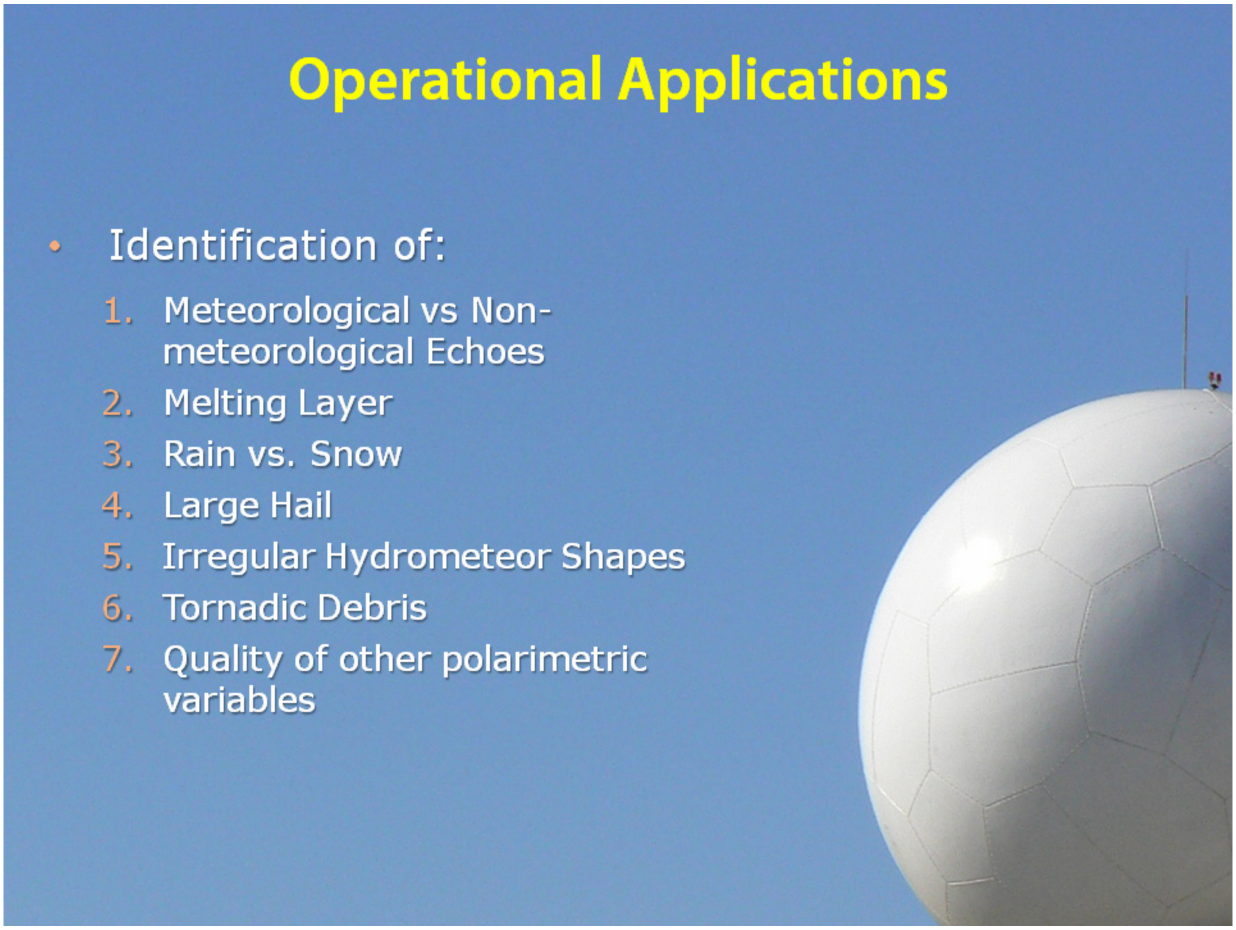


7. Menu Location of CC

Instructor Notes: The CC product can be found inside your dedicated radar's drop down menu at the locations denoted by the yellow arrows.

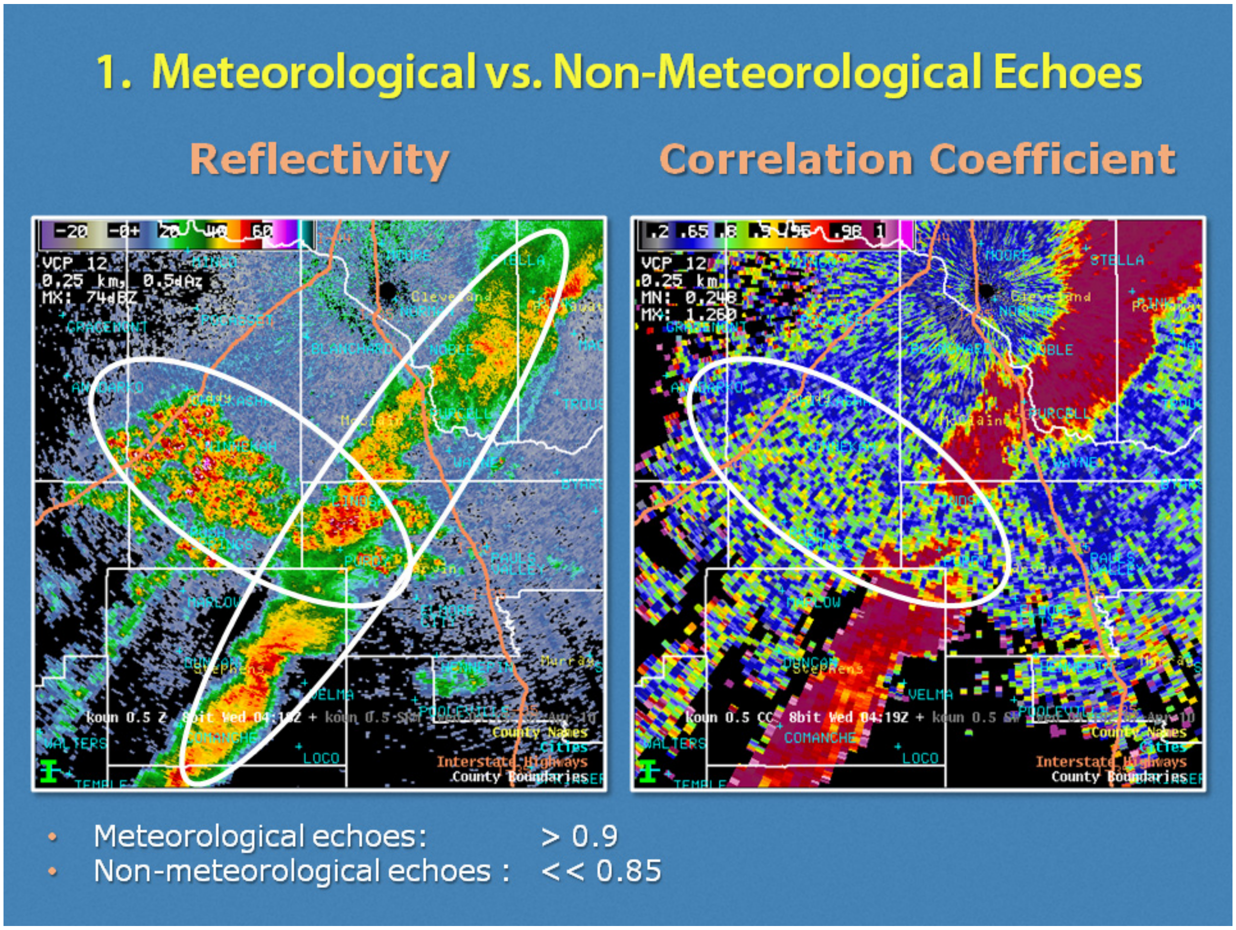
Student Notes:



8. Operational Applications

Instructor Notes: Here is a non-exhaustive list of how CC can be used operationally. I will show examples of these signatures in the coming slides.

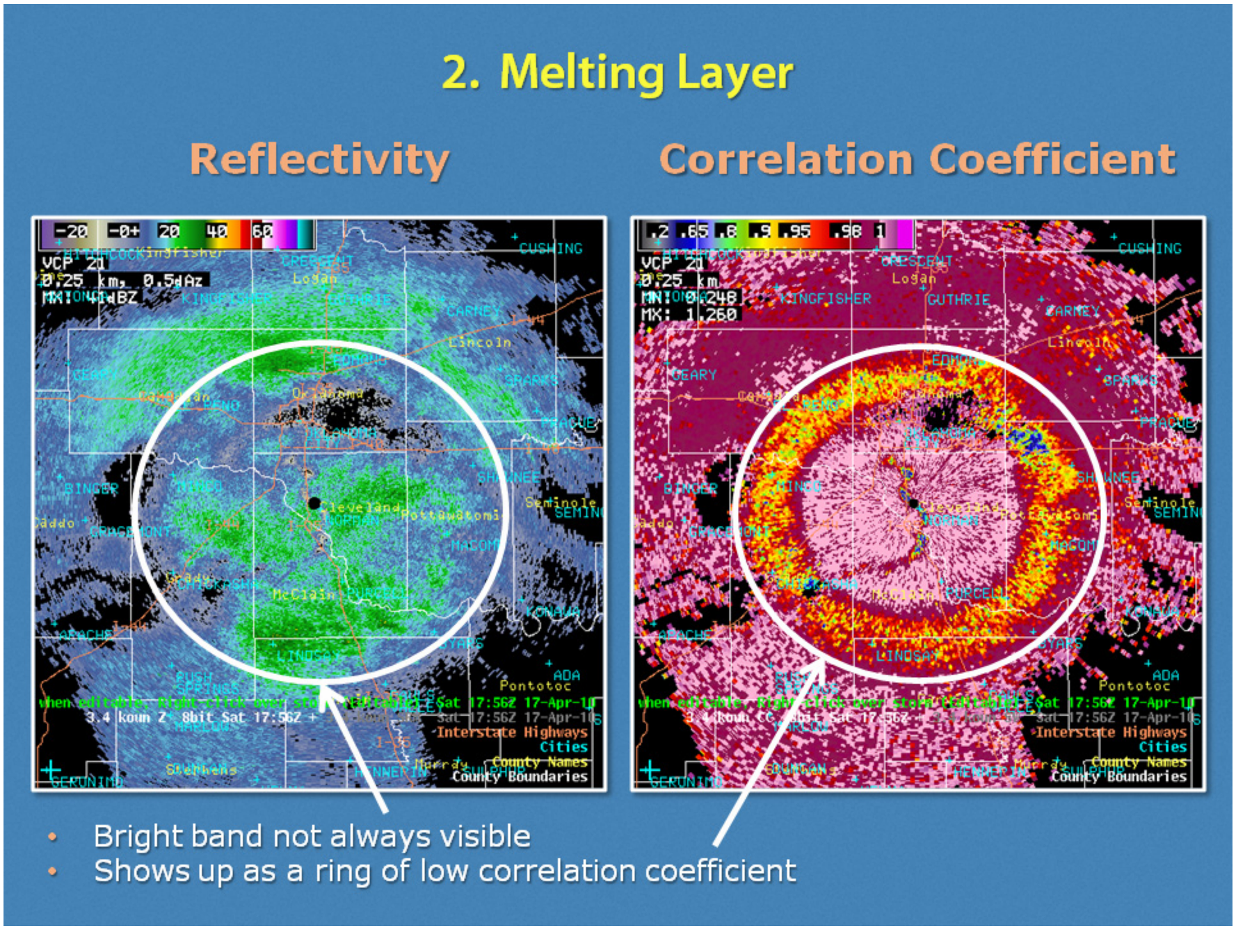
Student Notes:



9. 1. Meteorological vs. Non-Meteorological Echoes

Instructor Notes: The biggest advantage of correlation coefficient is its ability to discriminate between meteorological and non-meteorological echoes. Here is an example. In reflectivity, we see a line of storms oriented SW to NE just south of the radar. Just behind this line we see high reflectivity echoes but something does not look right about it. If we were to loop it or look at velocity we could tell instantly that it is AP. However, we see that this AP extends right into the line of precipitation and there we can't tell from reflectivity that it is AP anymore, and non-zero velocities are starting to show up (not shown). If we toggle to CC, the AP shows up instantly as low CC whether it is by itself or embedded in precipitation. As shown in the typical values slide, the majority of meteorological echoes tend to be above 0.9 CC, and non-meteorological echoes are well below 0.85 CC. In practice, look for smooth fields of CC greater than 0.9, which show up as yellow and maroon, to identify areas of precipitation. Areas of noisy CC less than 0.85, which show up as greens and blues, most likely indicate just about any echo that is not precipitation: chaff, volcanic ash, smoke, insects, bats, birds, and UFOs. Just kidding about that last one.

Student Notes:



10. 2. Melting Layer

Instructor Notes: Another big advantage of correlation coefficient is identification of the melting layer. In reflectivity the melting layer is sometimes identifiable as a bright band, but not always. In this reflectivity example it would be quite a stretch to identify a bright band. With correlation coefficient, it almost always stands out like a sore thumb. It is characterized by a ring of low correlation coefficient (~0.85) surrounded by higher correlation coefficient (~0.98). This signature is due to the presence of mixed-phase hydrometeors which decrease CC below 0.95.

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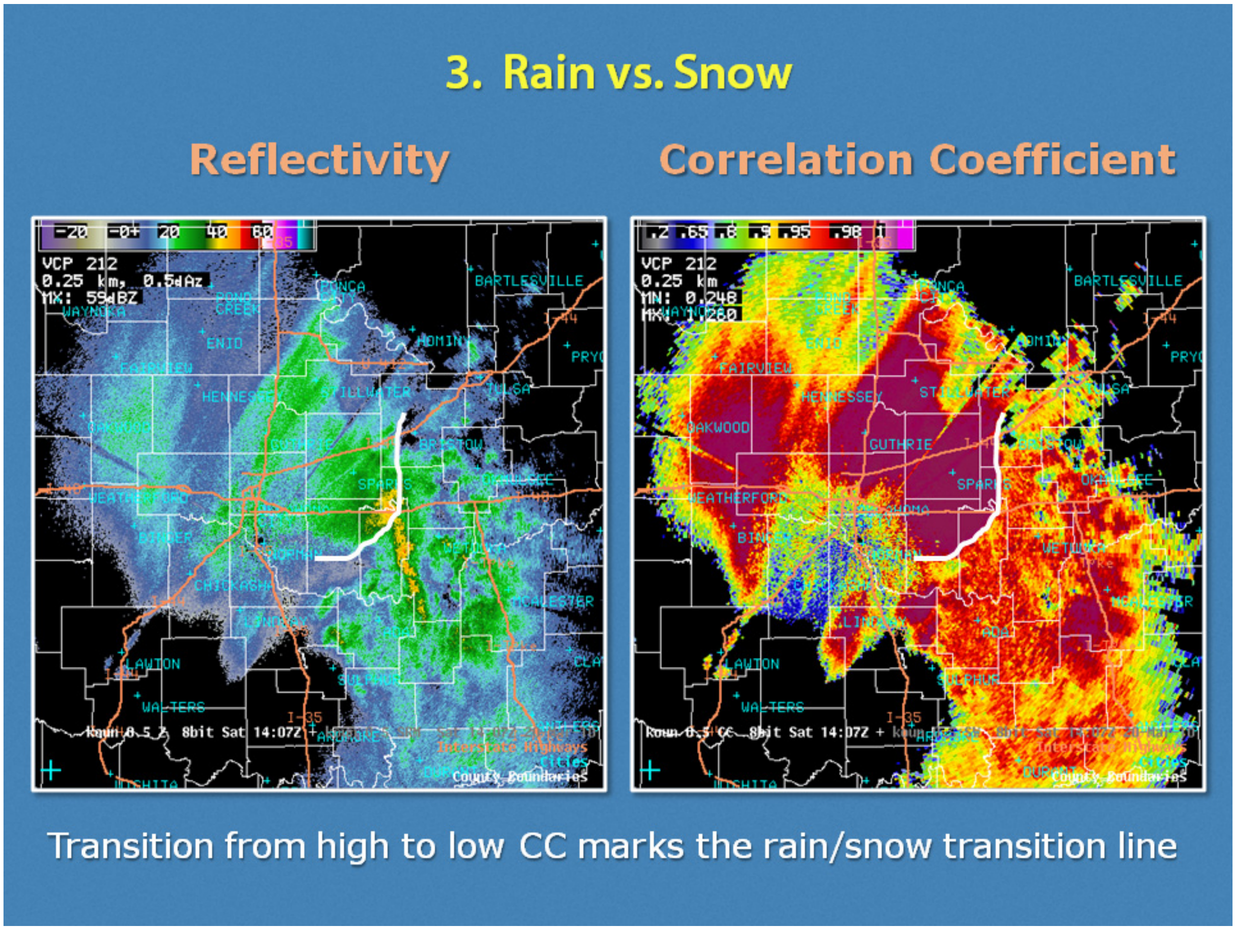

11. 3. Rain vs. Snow

Instructor Notes: During the transition period of rain to snow at the ground, the CC can help a forecaster better locate where the transition from rain to snow is occurring. It is simply the manifestation of the melting layer signature near the ground. Therefore, look for a drop in CC associated with the melting of snow to rain near the surface. It is highly recommended to overlay surface observations (if available) when trying to identify this feature and to look at other polarimetric variables (i.e. differential reflectivity (to be discussed later)) to help in delineating rain vs. snow at the ground. Here is an example from 20 March 2010 at 1407 UTC. East of the radar we see some strong returns and surface temperatures that are near freezing (32 C). However, in reflectivity we do not see clear-cut evidence that there is snow, or rain, or a mixture occurring at the ground. However, if we look at CC, it becomes readily apparent where the transition from rain to snow is occurring. This transition area is noted by the white line. East of the white line, CC are between 0.9 and 0.95 where surface temperatures are just above freezing, and METAR data in these areas indicated rain. To the west of the white line, we see CC of 0.99 where surface temperatures are below freezing. METAR data in these regions were reporting snow. Therefore, the white line separating the lower CC from the higher CC is a good indication where the rain/snow line was occurring.

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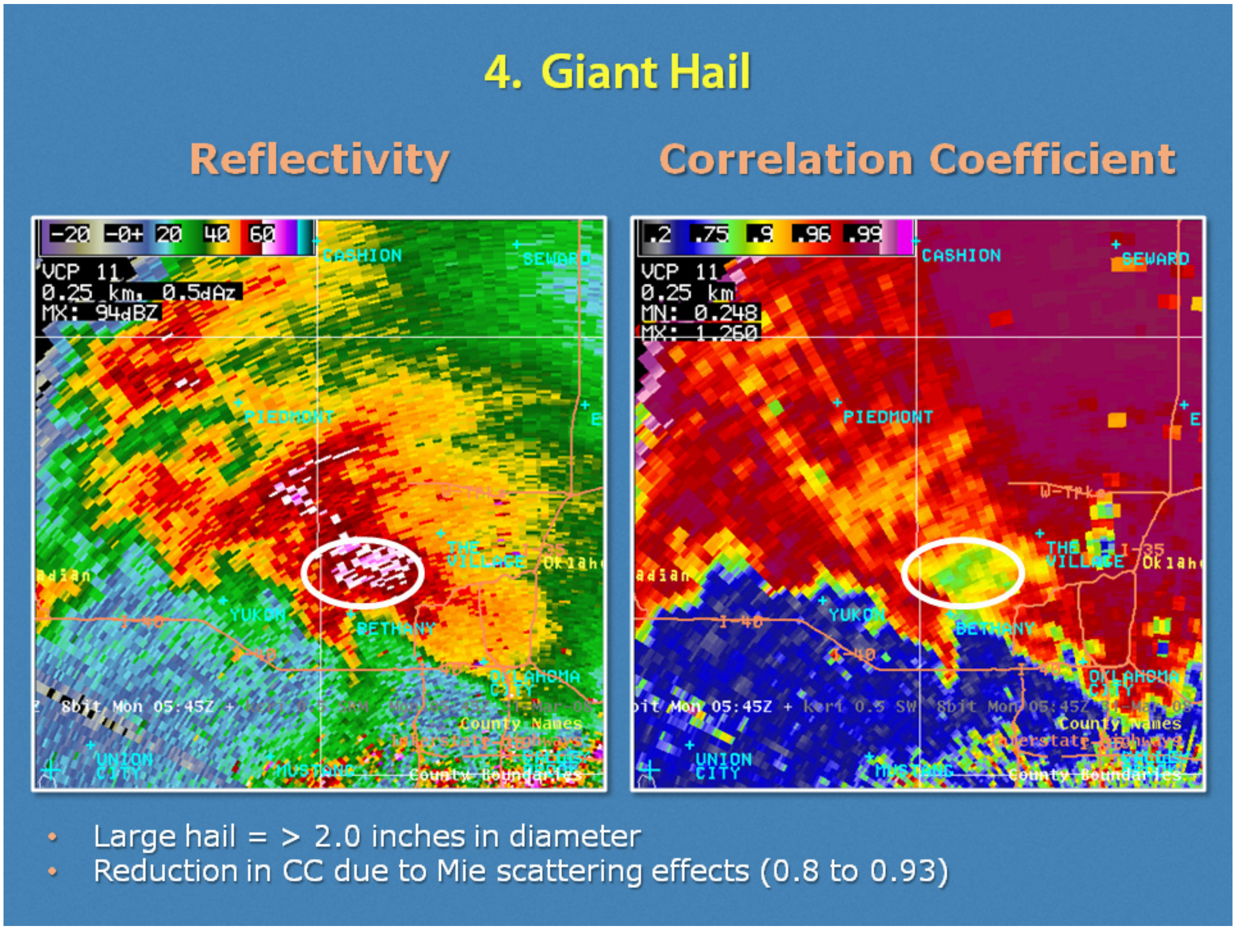
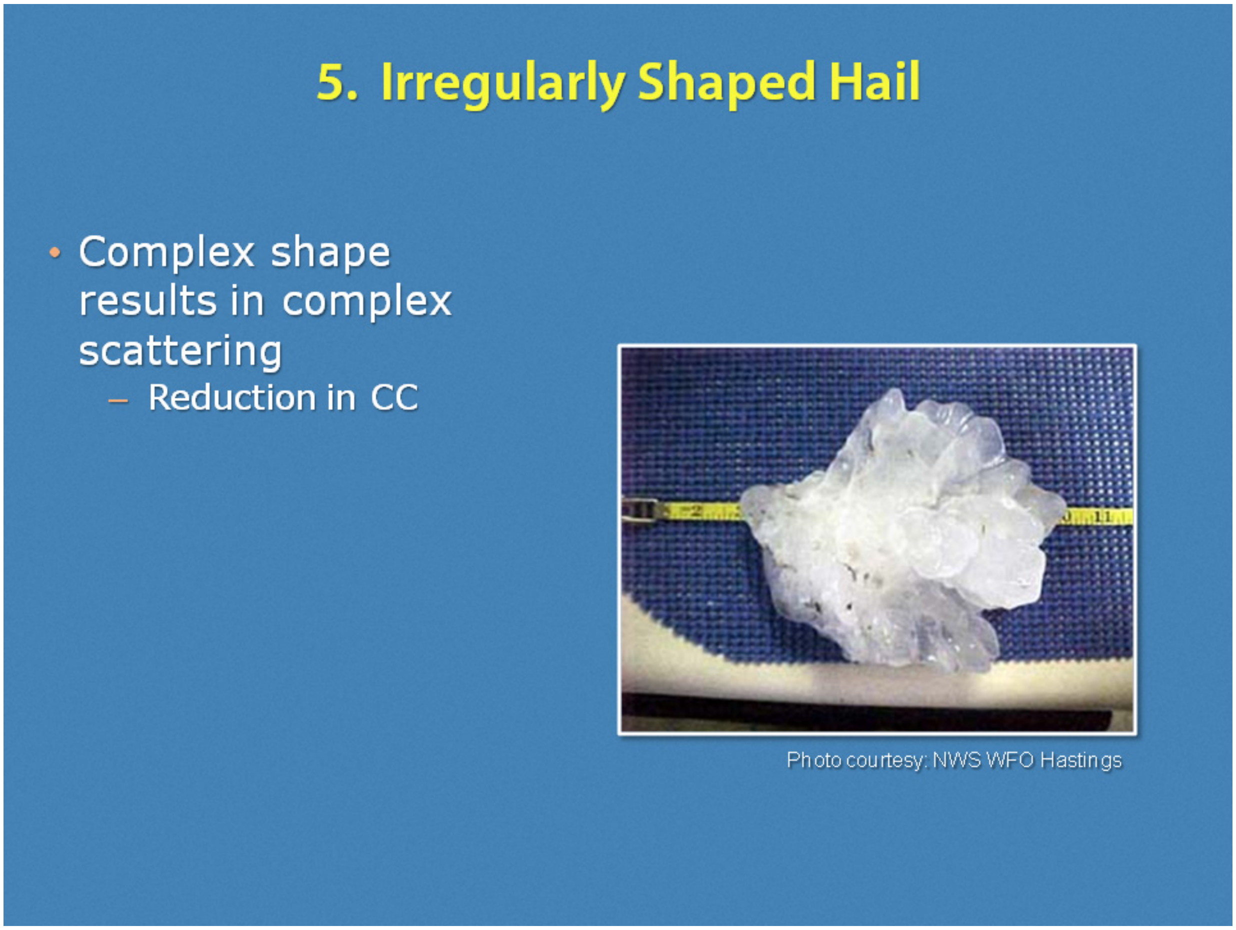


12. 4. Giant Hail

Instructor Notes: Giant hail, which is defined here as greater than approximately 2 inches in diameter, will have noticeably reduced correlation coefficient due to Mie scattering effects. Typical values will start out around 0.93 and decrease to as low as 0.8 as the hail becomes significantly large (> 3.5 inches in diameter). Some cases have had CC as low as 0.7, though this is rare! Here are reflectivity and correlation coefficient screenshots of a supercell in NW Oklahoma City. The white circle denotes where 2.5 inch hail was reported at the ground. Note the high reflectivity and low CC.

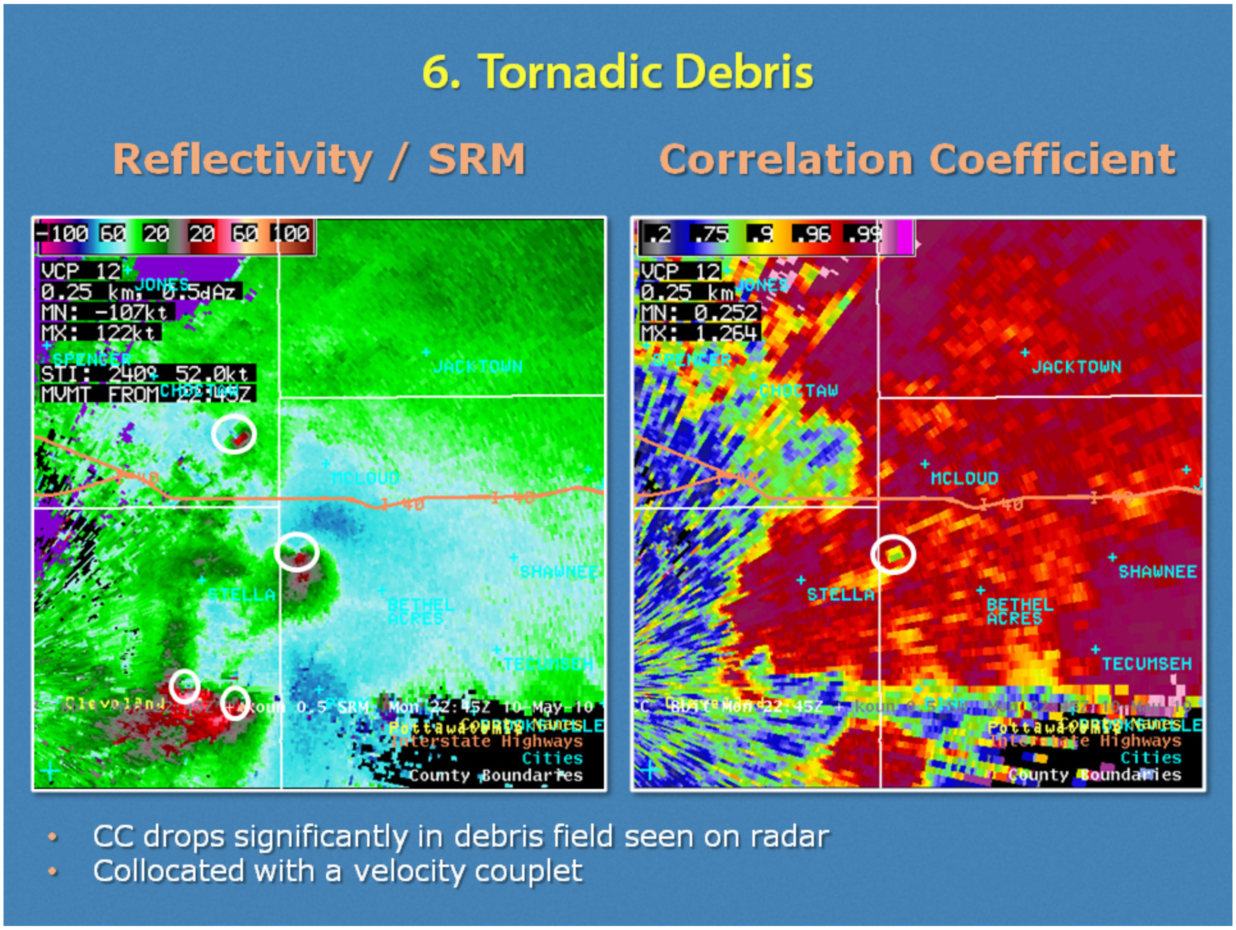
Student Notes:



13. 5. Irregularly Shaped Hail

Instructor Notes: As an extension to the giant hail slide, if giant hail has a complex shape (i.e. many protuberances), the correlation coefficient will decrease even further due to the complex scattering nature of the hail in addition to the CC decreasing because of Mie scattering effects. Here is the hailstone with many protuberances from Aurora, NE that was measured at approximately 7 inches. If measured by dual-pol radar, this hailstone most likely would have had very low CC (somewhere around 0.8).

Student Notes:



14. 6. Tornadic Debris

Instructor Notes: When a tornado is located near a radar (within 75 km) and is able to loft debris high enough that the radar can sample it, dual-pol radar has a very a distinct debris signature. In correlation coefficient it is marked by a significant drop due to complex scattering by the debris field and must be collocated with a velocity couplet. Here is an example from 10 May 2010 where there were 4 tornadoes occurring simultaneously. One is located in SE Oklahoma County and two in Eastern Cleveland County. However, the one to note here is located in far Western Pottawatomie County. In the reflectivity for this storm (not shown), there is no well-defined hook or debris ball. If we look at SRM, there is a noticeable couplet which should (and did) prompt a tornado warning, but no spotter report was available to indicate whether the circulation was on the ground. However, in CC we see a localized region of low correlation coefficient that is collocated with the SRM couplet. This signature automatically tells the forecaster that there is a tornado causing damage, and so this can be reflected in the follow-up statements or warning text. It implies a tornado is already doing damage and is NOT a precursor to a tornado. This is especially useful for nighttime or rain wrapped tornadoes where spotter reports are very difficult to obtain.

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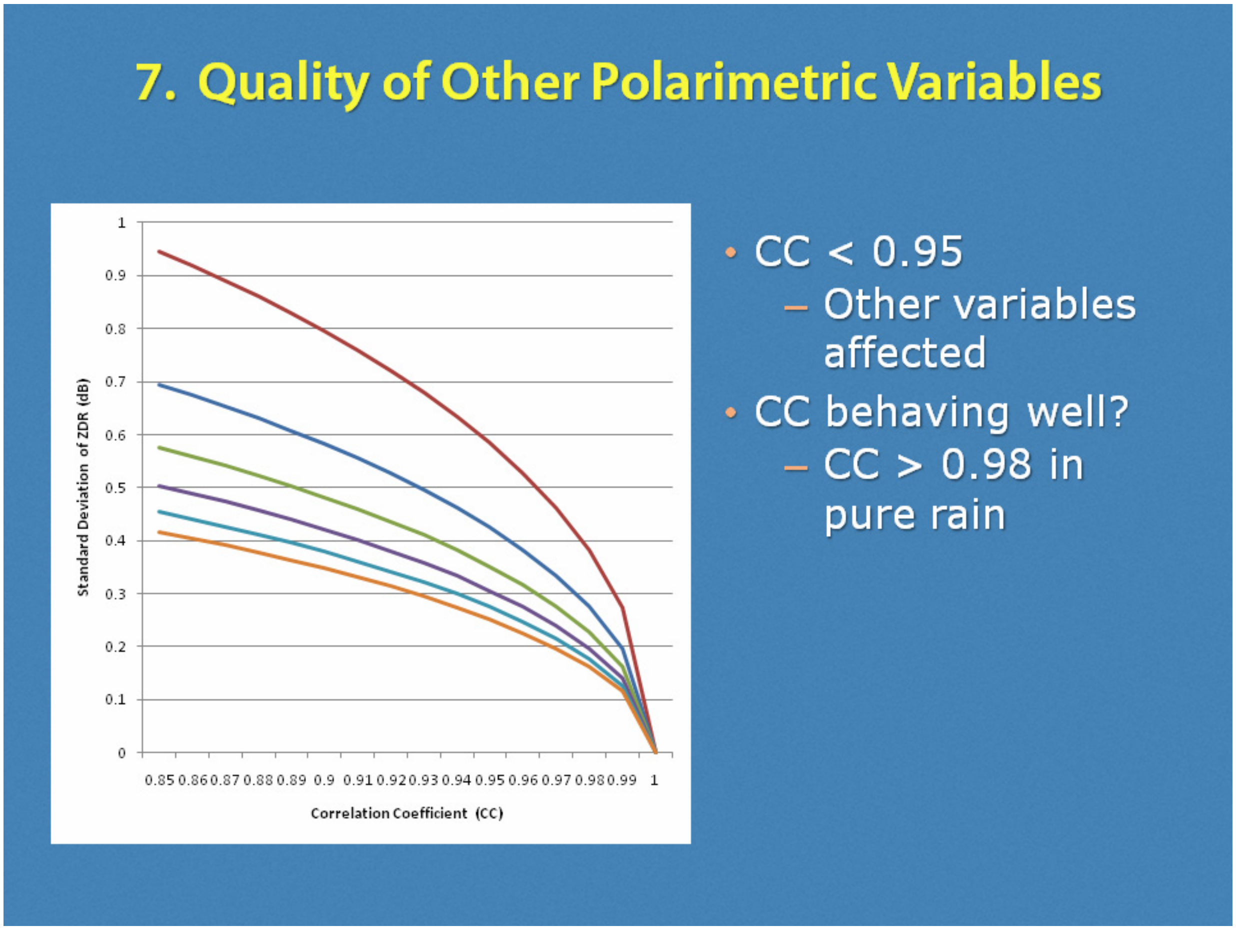
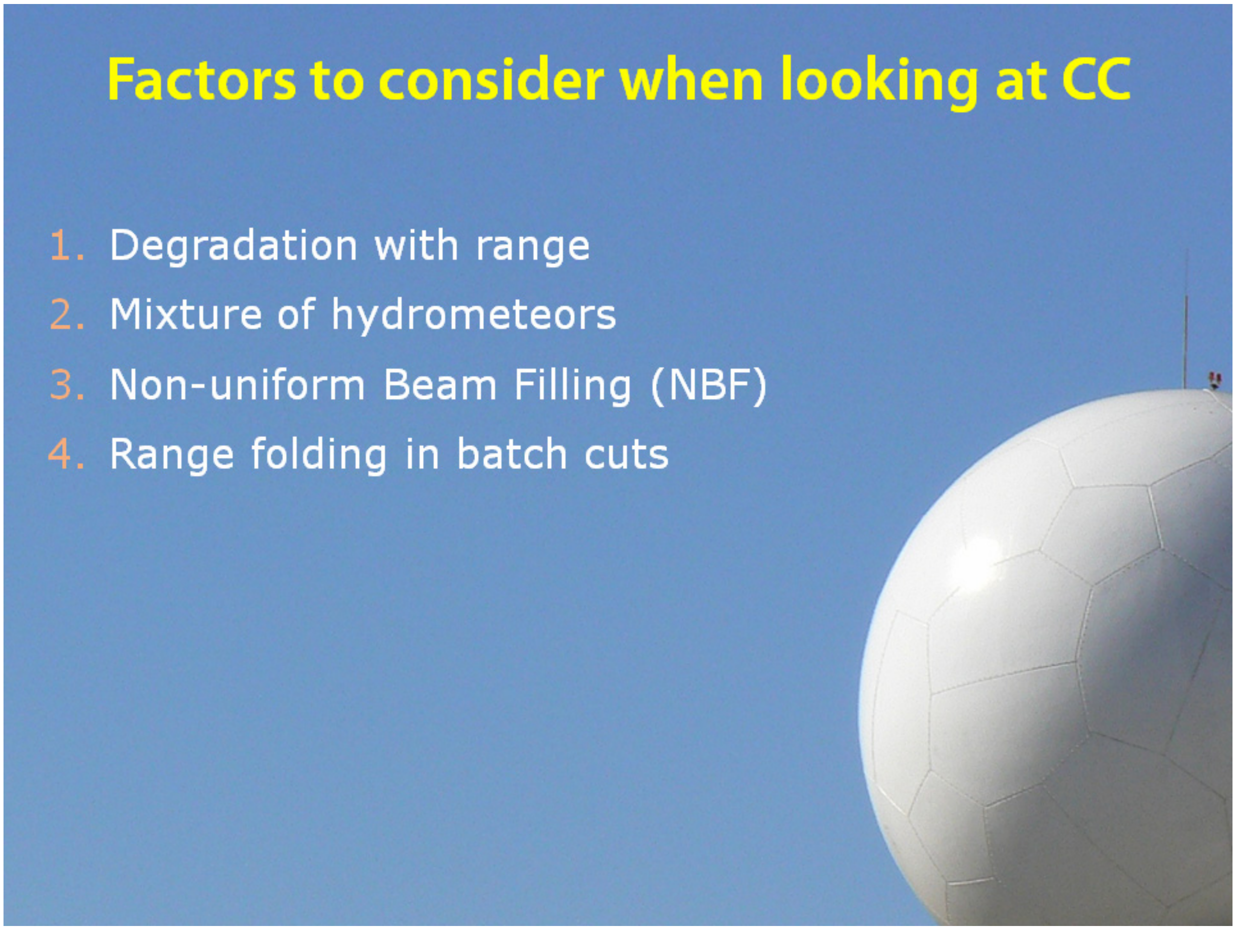


15. 7. Quality of Other Polarimetric Variables

Instructor Notes: When the correlation coefficient drops below 0.95, the quality of the other polarimetric variables will decrease as well. As an example, the graphic here illustrates that when CC drops below 0.9, significant errors in differential reflectivity can occur on the order of 0.4 dB up to almost 1 dB! Each curve represents a different normalized spectrum width value with higher normalized spectrum width values represented by the bottom curves. To tell if correlation coefficient is behaving well, it is best to see if correlation coefficient is greater than 0.98 in regions of light to moderate rain.

Student Notes:



16. Factors to consider when looking at CC

Instructor Notes: Here are some of the limitations to keep in mind when looking at the CC product. We'll look at each one on the following slides.

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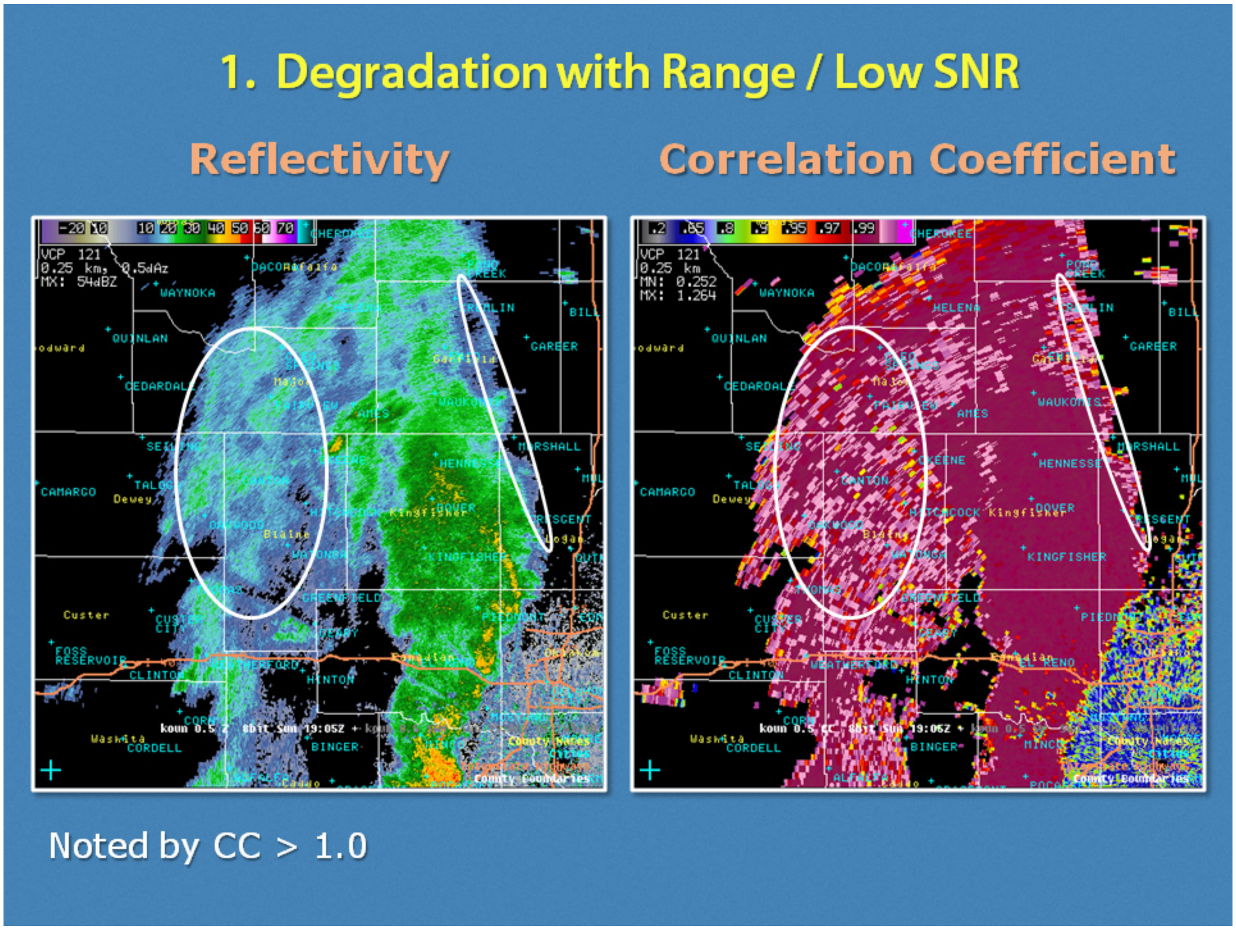
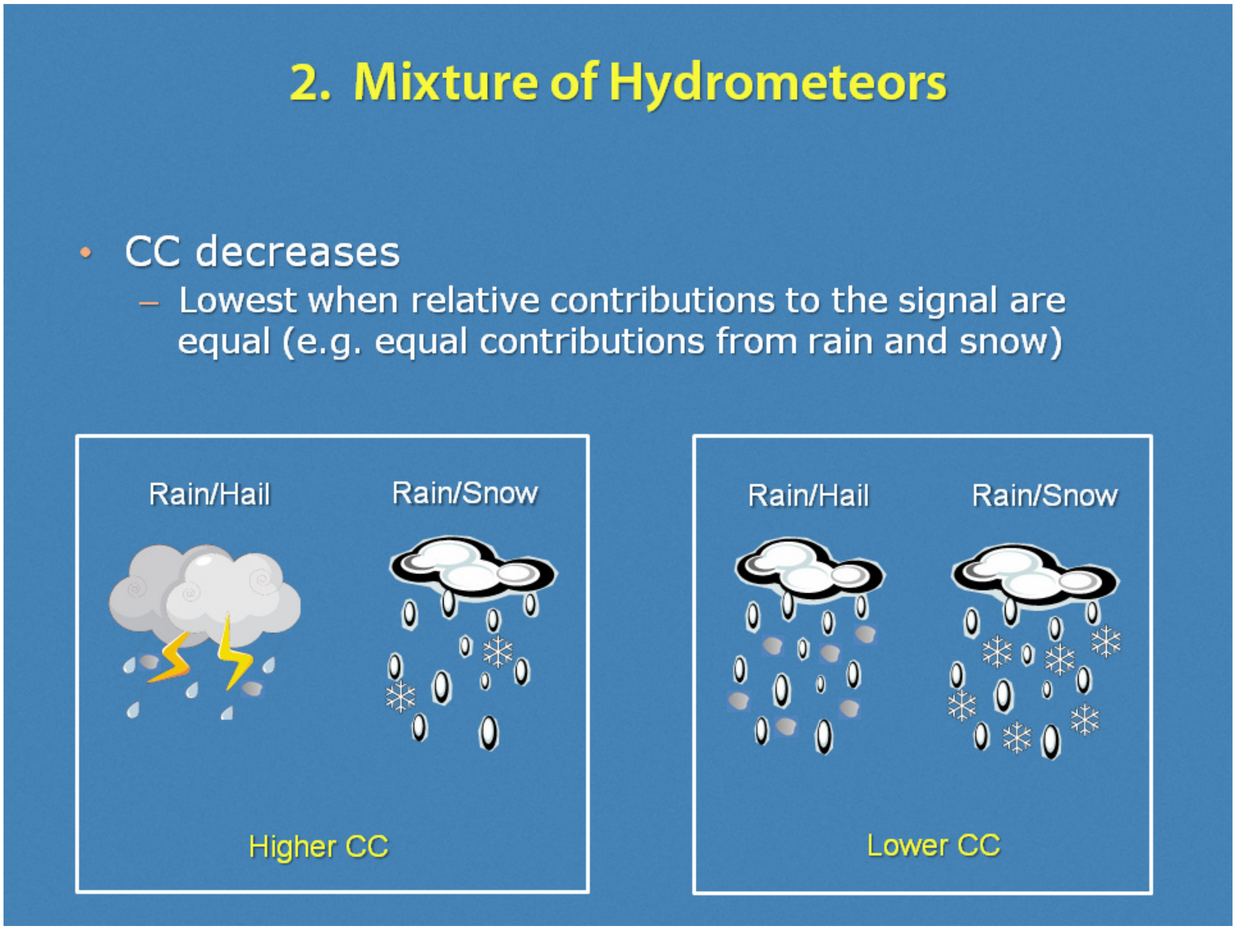


17. 1. Degradation with Range / Low SNR

Instructor Notes: The estimation of the CC degrades with range due to decreasing SNR and/or beam broadening. Another area where low SNR will degrade CC is along the fringes of precipitation. You can note these regions of degraded CC by looking for noisy CC > 1.0, or pink values in AWIPS. Here is an example from 4 July 2010. Note the weak reflectivity values to the NW of the radar. Reflectivity values are less than 20 dBZ at a range of approximately 75 nm. Since this is fairly weak returns at this range, you can bet the SNR is low and looking at CC, we see very noisy data that is mostly greater than 1.0 (or pink). The same thing is occurring along the fringes of the precipitation to the east, noted here.

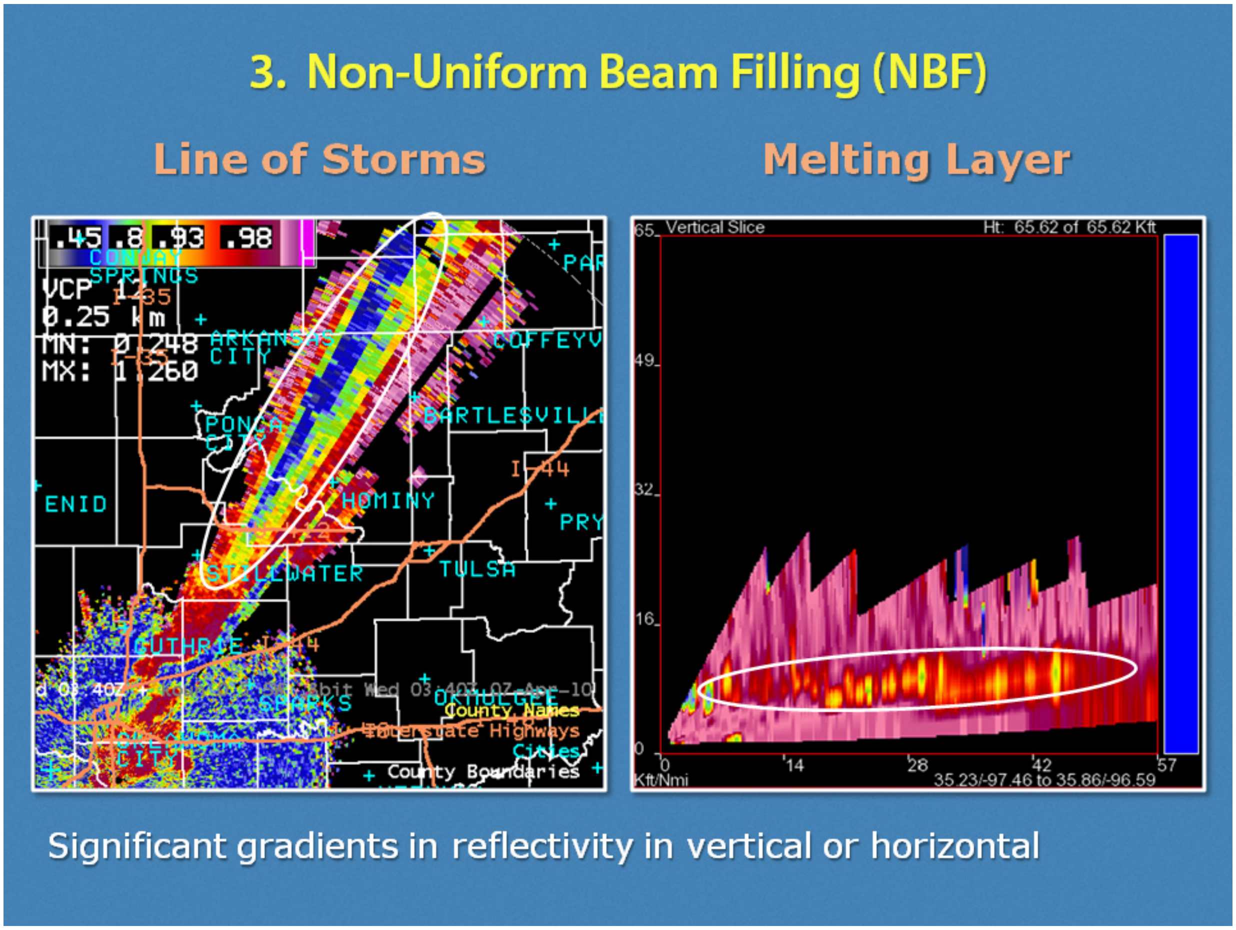
Student Notes:



18. 2. Mixture of Hydrometeors

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

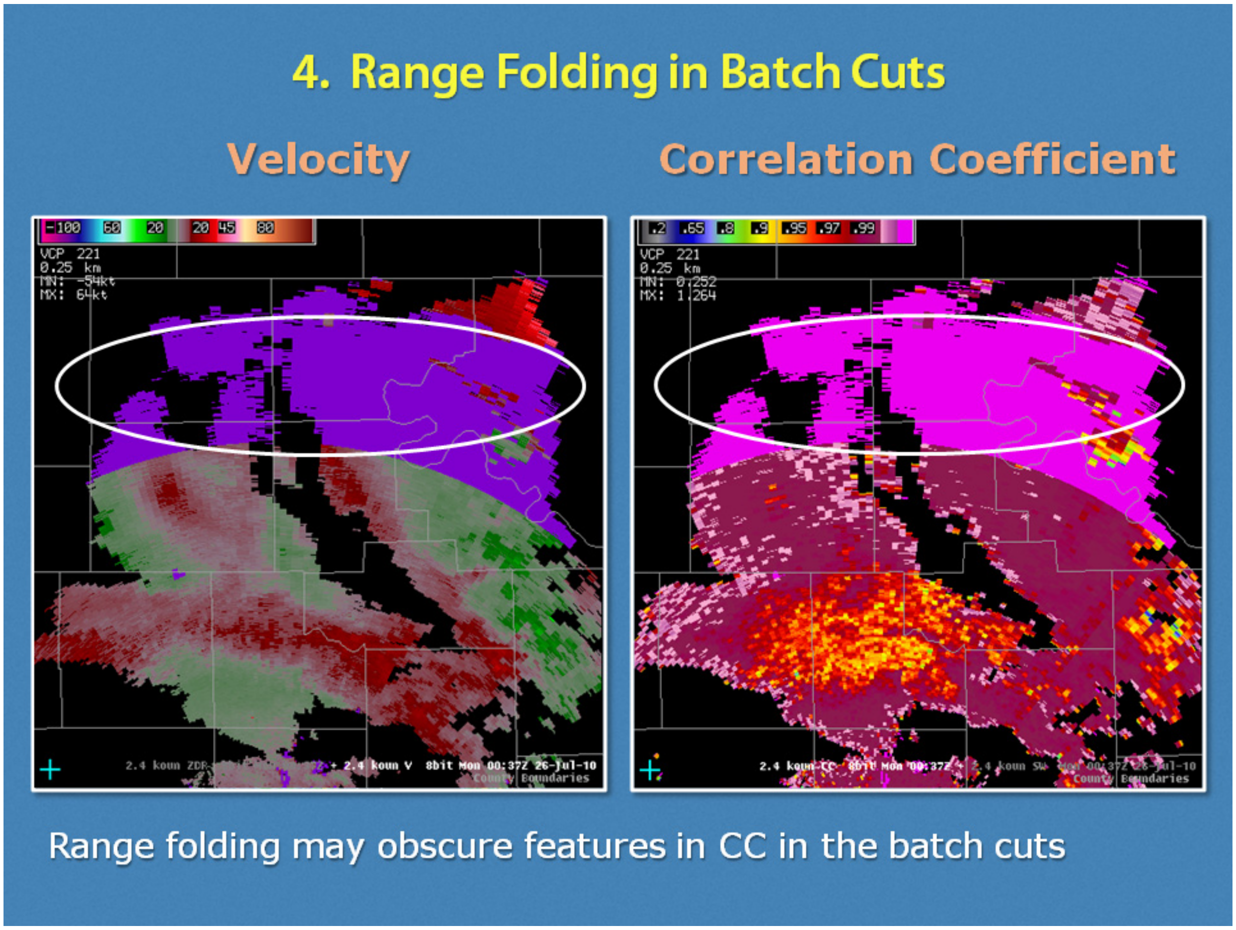
Student Notes:



19. 3. Non-Uniform Beam Filling (NBF)

Instructor Notes: Non-uniform beam filling occurs when significant gradients of differential phase (to be discussed in the lesson on KDP) occur within a pulse volume. This gradient can either be in the horizontal or vertical. This will cause a decrease in correlation coefficient which is purely an artifact. An example where the gradient occurs in the horizontal is represented by the graphic on the left. This occurred when a line of storms became oriented along a radial, resulting in maximum non-uniform beam filling which caused CC to drop. An example where the gradient occurs in the vertical is represented by the graphic on the right. This is a cross-section through a stratiform rain region. Notice the drop in CC near the melting layer around 8 thousand feet. This is due partially to melting and partially to NBF.

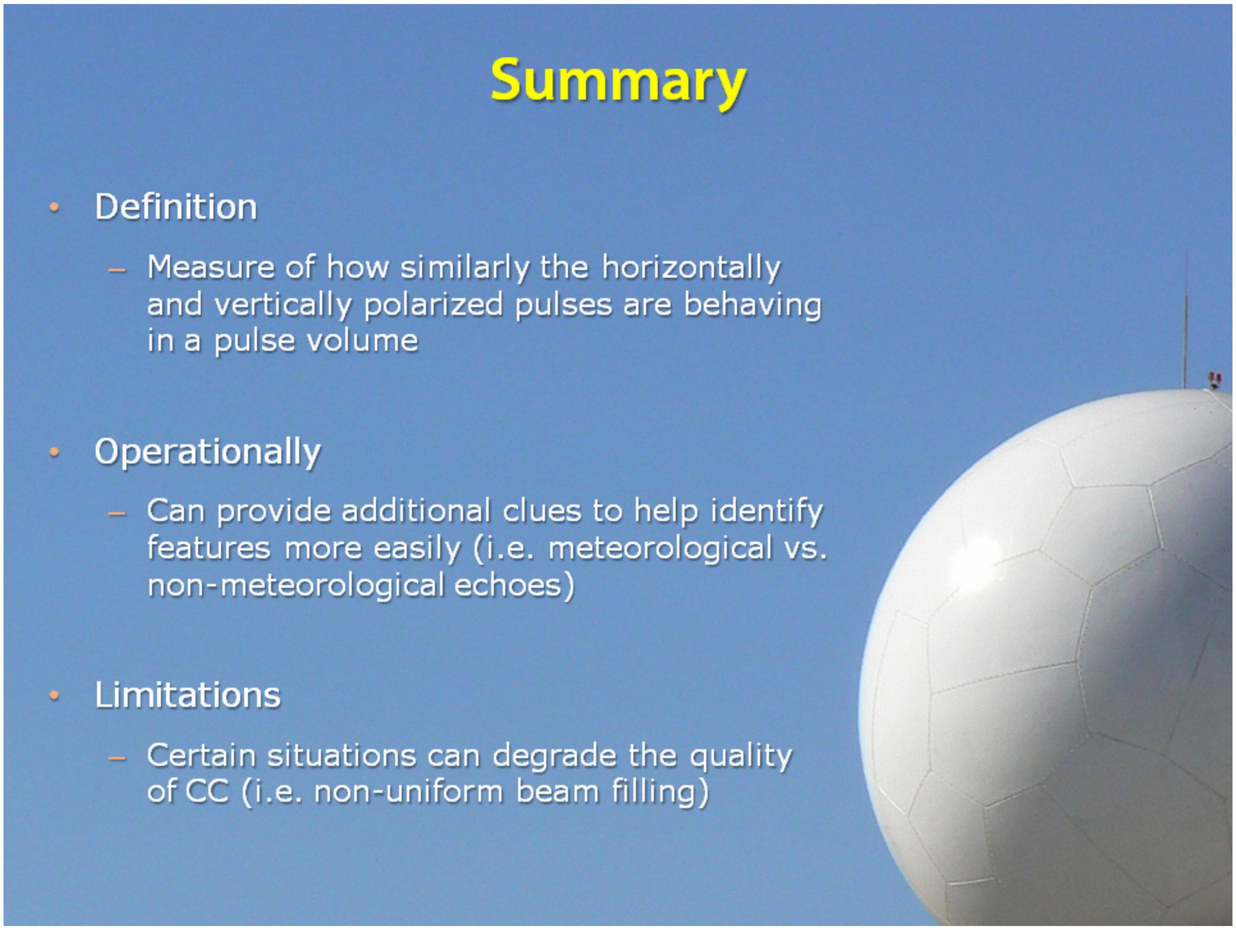
Student Notes:



20. 4. Range Folding in Batch Cuts

Instructor Notes: The last limitation with CC that we'll look at is that in the batch cuts, range folding may obscure some signatures in CC. Here is an example from 26 July 2010 at 0037 UTC from the 2.4 degree elevation scan. Note that where there is range folding in velocity, there is range folding in CC.

Student Notes:



21. Summary

Instructor Notes: In summary, we have learned that the CC is a measure of how similarly the horizontally and vertically polarized pulses are behaving within a pulse volume. Operationally, we saw some examples of how this product can help us more easily identify features that were more difficult to note prior to dual-pol. Lastly we looked at situations where the quality of the CC is degraded.

Student Notes:

22. Conclusion

Instructor Notes: This concludes the lesson on CC, and thanks for your attention. If you have any questions, you can send an email to the dual polarization operations course help list (dualpol_list@wdtb.noaa.gov).

Student Notes: