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Topic: Velocity Interpretation

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Hi, my name is Jill Hardy and welcome to this Topic on Velocity Interpretation. This lesson will cover large-scale Doppler velocity patterns, while the next lesson will focus on storm-scale patterns.

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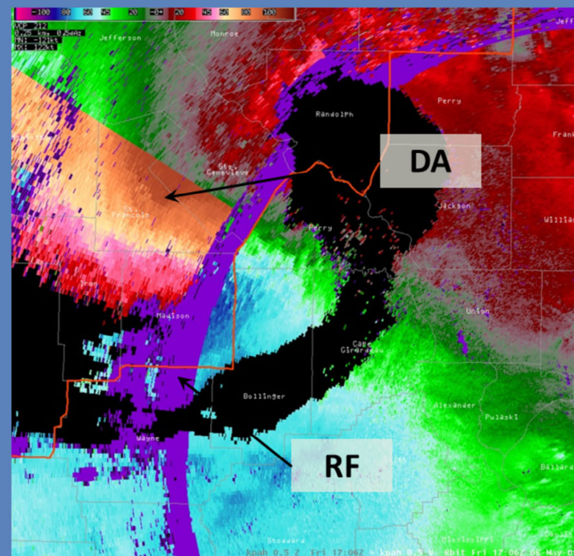
Review from Previous Topic

- When interpreting velocities products, radial velocities are displayed, which are not the true velocities
- Improperly dealiased velocities and range folding can inhibit velocity interpretation



Let’s start with a brief review. When interpreting velocity data, the radial velocities are displayed, which are not the true velocities. Also, the RPG dealiases velocities while the RDA performs range folding. These tasks are effective most of the time, but failures do occur, which can inhibit your ability to interpret velocity products.

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Learning Objectives

- Basic principles used to identify radial velocity signatures
- Relation of velocity displays to the vertical wind profile
- How to use velocity interpretation principles with WSR-88D velocity products

There are three learning objectives for this lesson. By the end of the lesson, you should be able to understand the basic principles used to identify radial velocity signatures, relate the velocity display to the vertical wind profile, and apply velocity interpretation principles to the WSR-88D velocity products.

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Performance Objectives

1. Interpret Doppler velocity patterns under uniform, non-uniform, ambiguous, and meteorologically complex conditions identifying:

- Inbound vs. Outbound Velocities
- Constant Wind Speed and Direction
- Wind Speed and Direction Changing with Height
- Velocity Maxima
- Confluence and Diffluence
- Vertical Discontinuities
- Boundaries

There are also three performance objectives with this lesson. The first objective is to be able to interpret Doppler velocity patterns under uniform, non-uniform, ambiguous, and meteorologically complex conditions. These are listed below. Move on when you are ready.

Performance Objectives

2. Construct vertical wind profiles for uniform and non-uniform horizontal wind conditions

3. Assess the meteorological conditions associated with the identified velocity patterns

The second performance objective is the ability to construct vertical wind profiles for uniform and non-uniform horizontal wind conditions. And the final performance objective is to assess the meteorological conditions associated with the identified velocity patterns.

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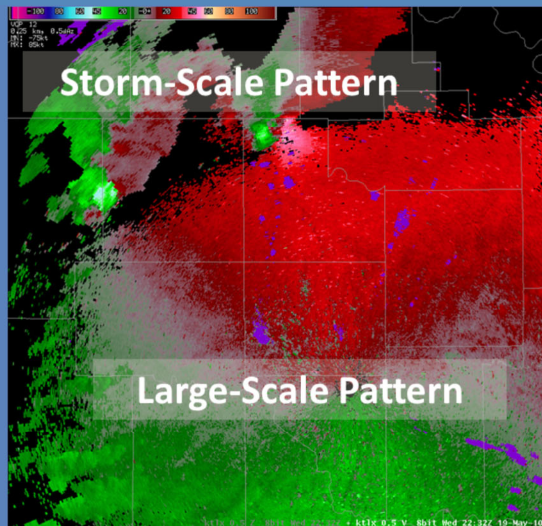
Doppler Velocity Patterns



In this lesson, we will be discussing large scale velocity patterns. The second lesson will then focus on storm-scale velocity signatures.

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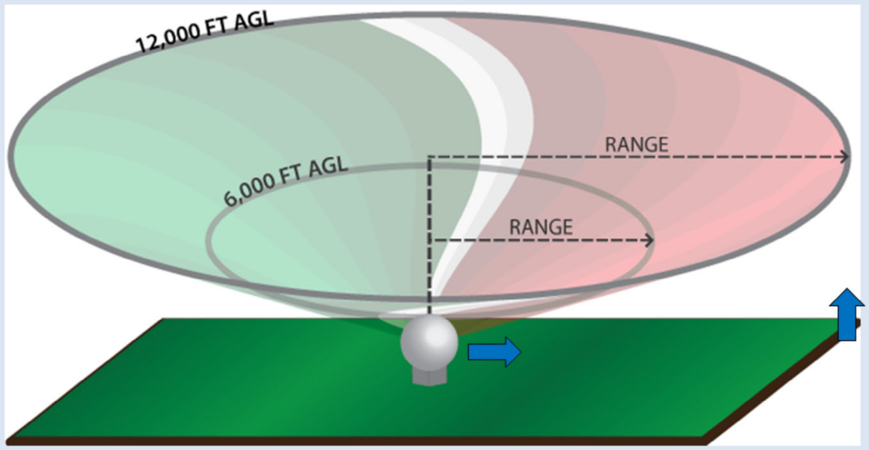
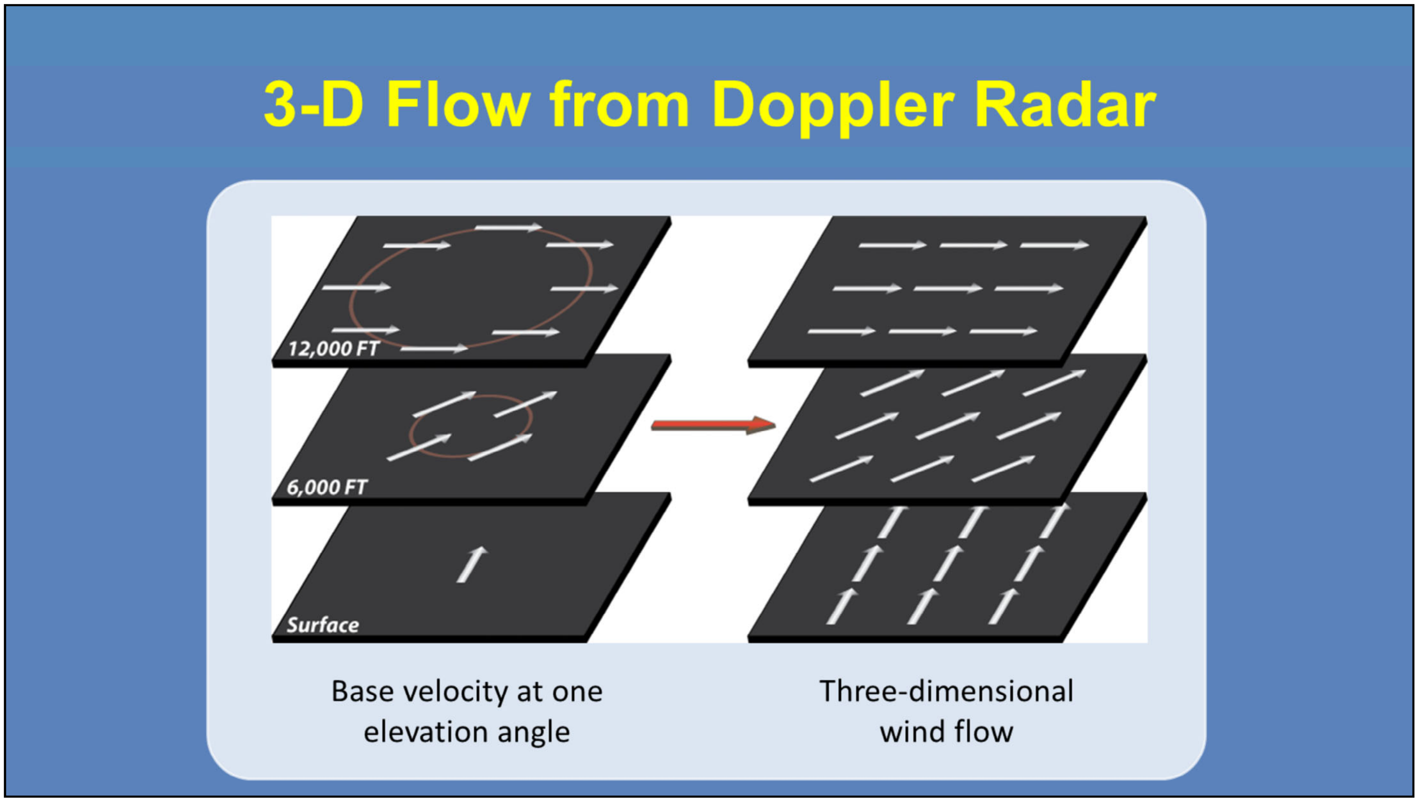
Doppler Radar Viewing Configuration



When you are looking at a velocity product, you are viewing the display from above looking into a cone. As you move farther away from the RDA, you are also increasing in height above the ground.



By using this concept, you can determine the wind flow at various levels and construct a three-dimensional wind profile of the atmosphere around the RDA. In this graphic here, you can see that with one elevation scan, the flow can be determined at different ranges, which are proportional to different heights. The flow at each range can then be assumed for a constant altitude.

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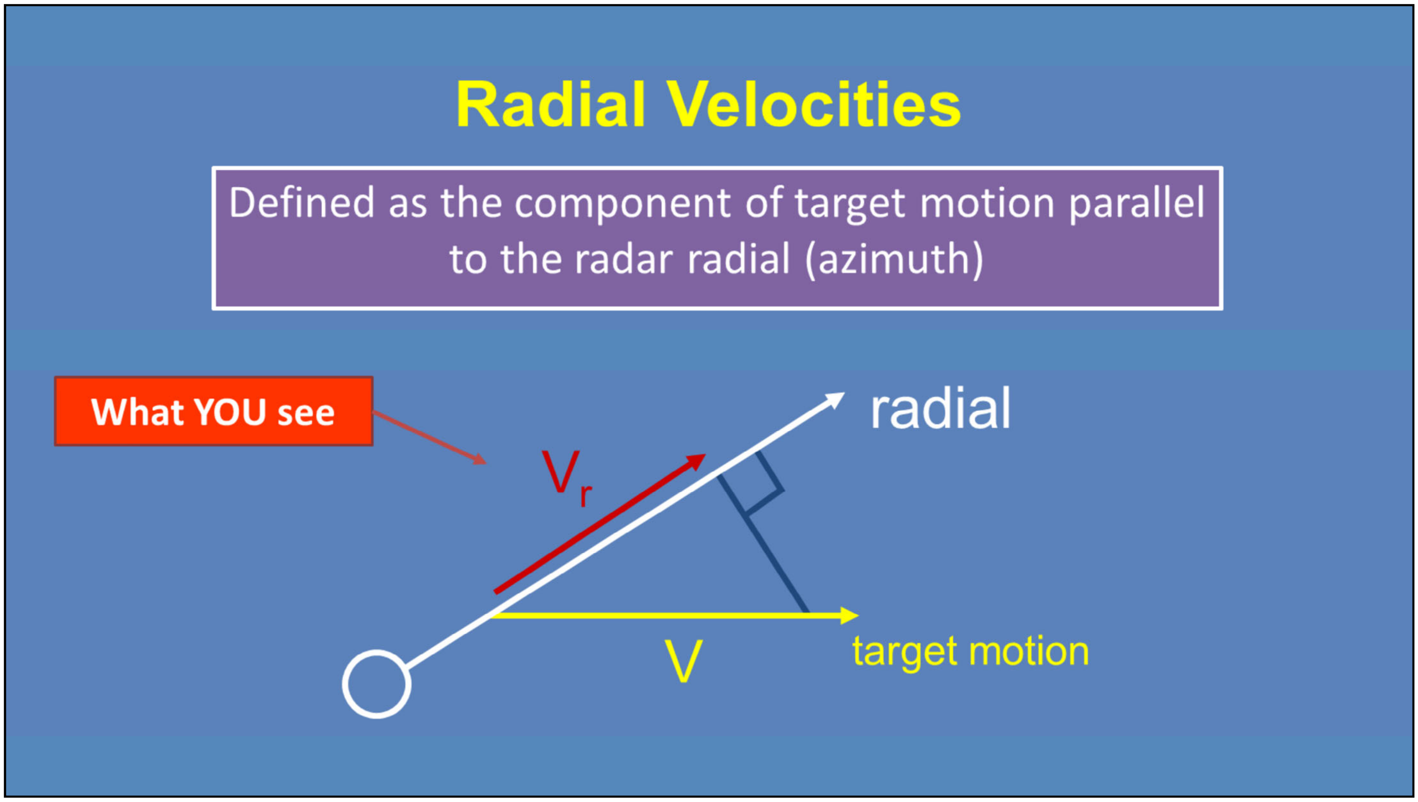

Before we begin to look at conceptual models of velocity patterns, we need to discuss radial velocities. A radial velocity is defined as the component of target motion parallel to the radar radial, or azimuth. In this diagram, you can see the actual target motion (yellow arrow) and the radial velocity target motion (red arrow) along the radial (white arrow).

The most important thing to remember as we move forward is that the radial velocity is the velocity that the radar, and therefore YOU, see. It is not the true target motion.

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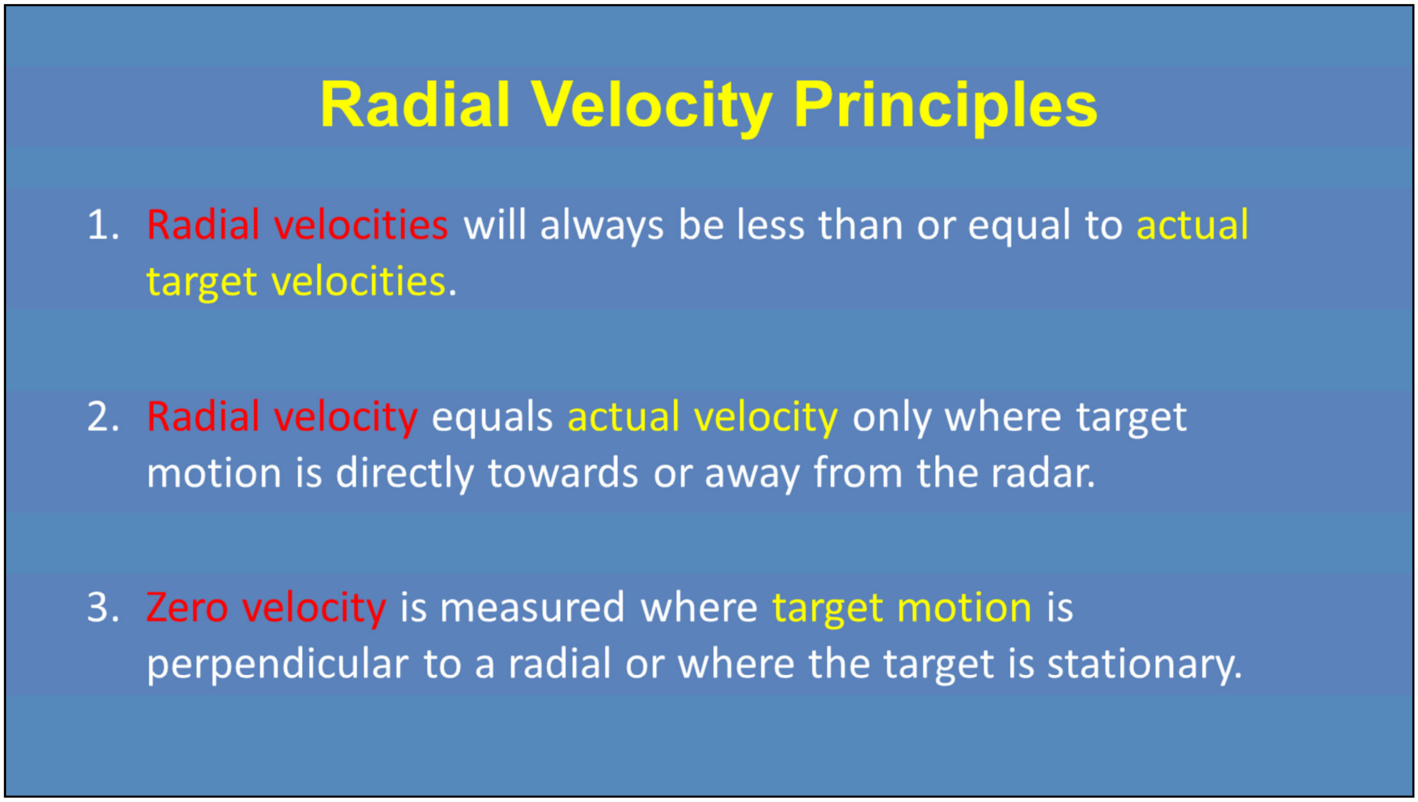

There are three basic principles with regards to radial velocities. The first principle is that radial velocities will always be less than or equal to actual target velocities. The second principle is that the radial velocity equals the actual velocity only when the target motion is directly towards or away from the radar. The third principle is that a radial velocity of zero is measured when the target motion is perpendicular to a radial or when the target is stationary.

You will see why in the following slides.

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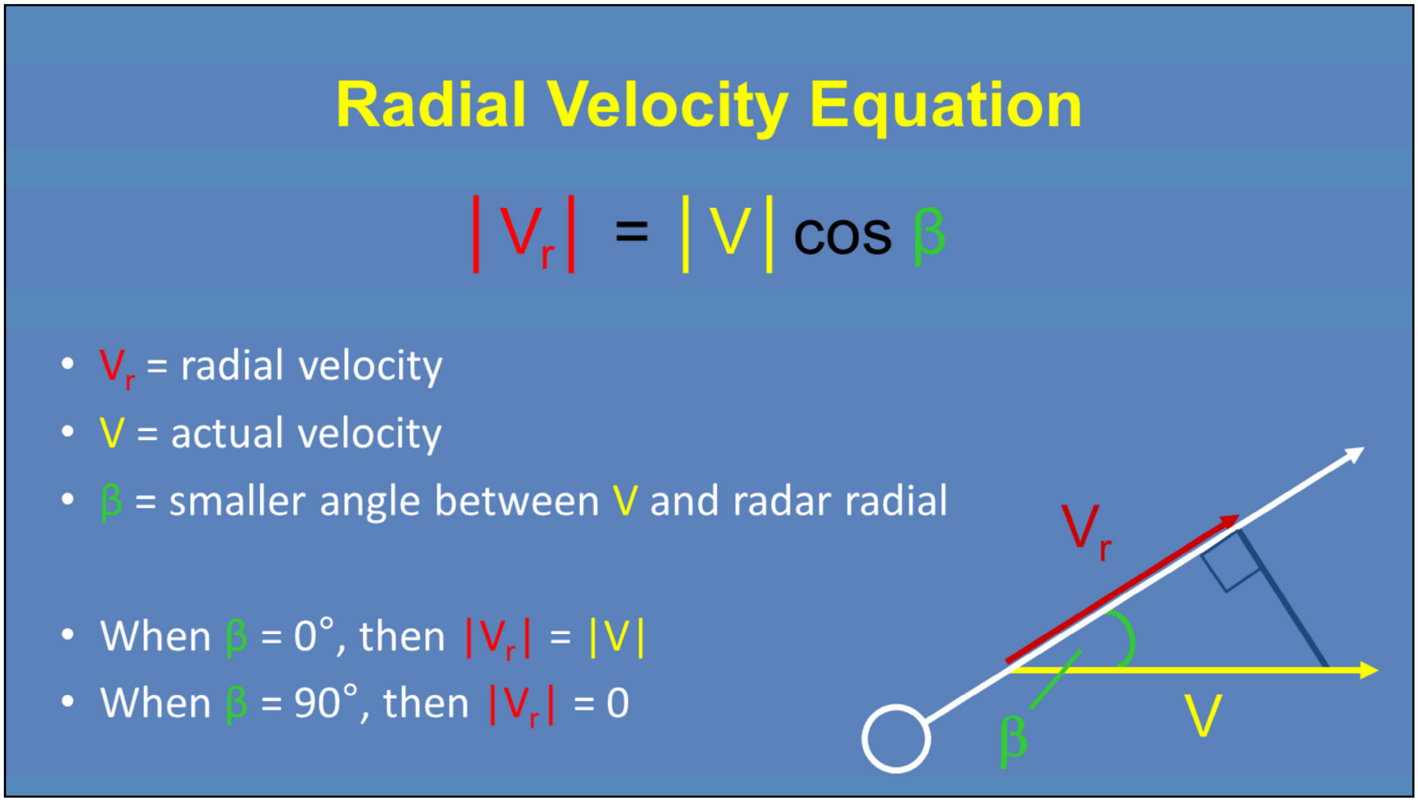

The relationship between a target's actual velocity and the radial velocity depicted by the RDA can be described using the Radial Velocity Equation. Here, the absolute value of the radial velocity is equal to the actual velocity multiplied by the cosine of the angle β. The angle β represents the smaller angle between the actual velocity and the radar radial. When β equals 0°, then the radial velocity is equal to the actual velocity. When β is at 90°, then the radial velocity is zero.

This helps us understand radial velocity principle #1, that radial velocities will always be less than or equal to the actual target velocities. Intuitively, this makes sense. The radar is never going to see a portion of the target's motion (in red) to be larger than the actual target's motion (in yellow). Now, let's take a look at principles 2 and 3…

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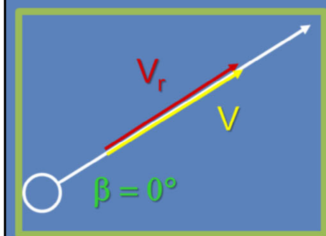
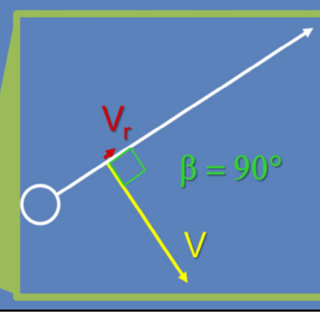
Percentage of Actual Velocity

$$|V_r| = |V| \cos \beta$$



β (degrees)	Cosine β	% Measured
0	1	100 %
5	0.996	99.6 %
10	0.985	98.5 %
15	0.966	96.6 %
30	0.866	86.6 %
45	0.707	70.7 %
60	0.500	50.0 %
75	0.259	25.9 %
90	0	0 %



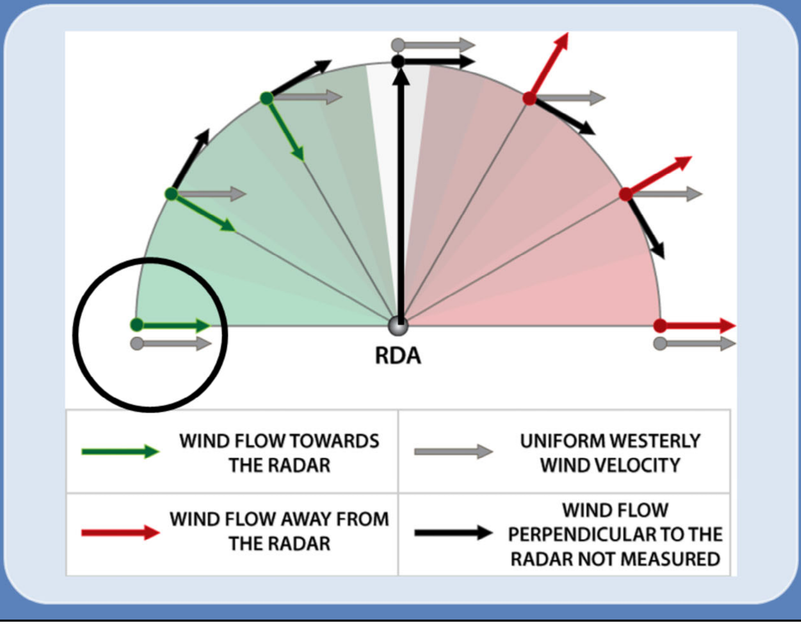
The table here compares various angles of β and the percentage of the actual target motion measured at each radial. The greater the angle between the target's velocity vector and the radar azimuth, the smaller the percentage of the target's actual velocity that will be measured and depicted on the velocity products.

So for principle #2, it says that the "radial velocity equals the actual velocity only when the target motion is directly towards or away from the radar." This is depicted here, where the two vectors are identical.

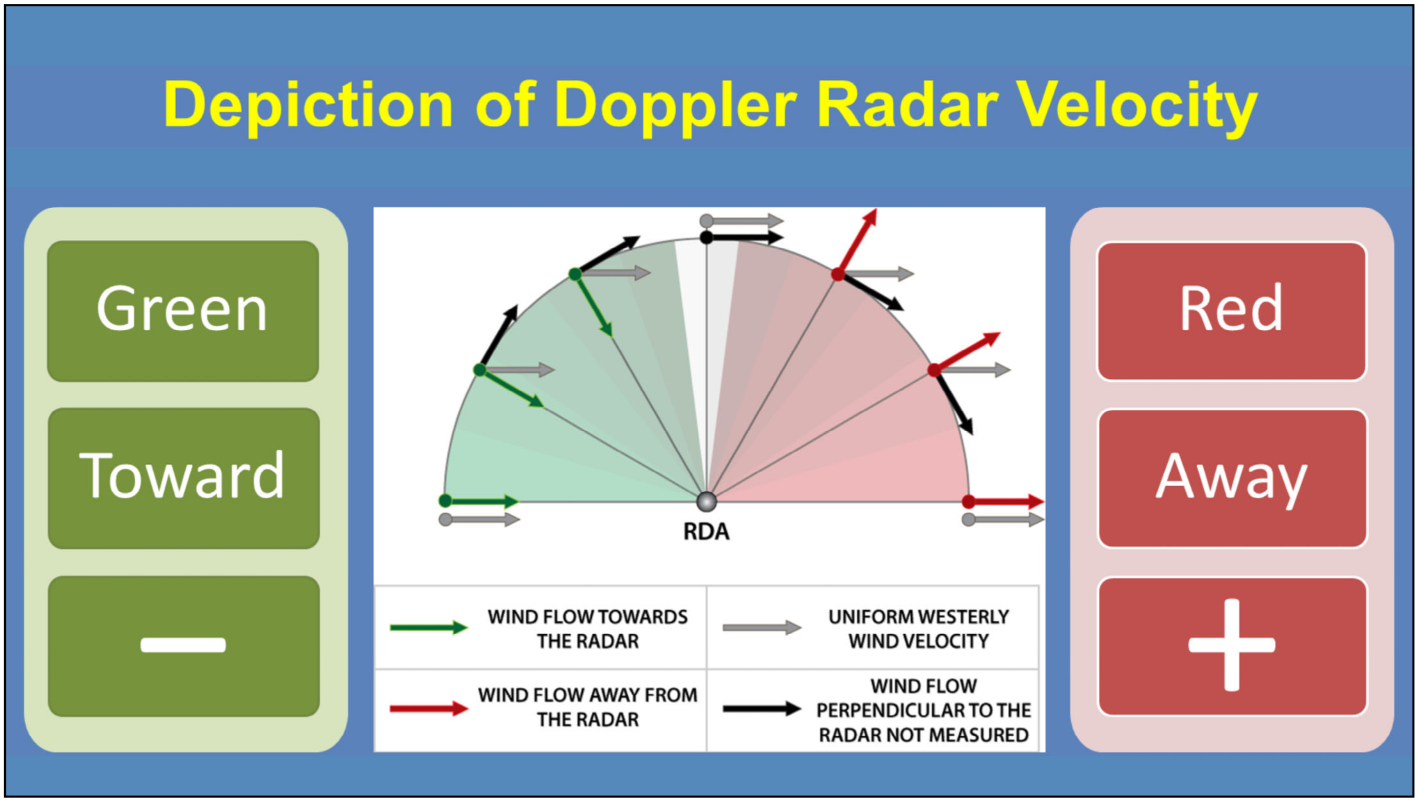
Principle #3 says "zero velocity is measured where the target motion is perpendicular to a radial or where the target is stationary". This is shown here, where beta is 90 degrees.

Note that at a 45° angle, the radar is measuring approximately 70% of the motion, not 50%. This is because of the cosine function within the equation, which creates a non-linear relationship.

Depiction of Doppler Radar Velocity



This graphic depicts the radar's ability to measure velocities and what the operator sees. When the actual wind (in gray) is parallel to radial, the full component of the wind is measured. As the radial becomes more perpendicular to the actual wind, the radial velocity decreases, all the way until the radar displays zero velocity. This occurs when the actual wind is at a 90-degree angle from the radial. However, notice that the actual velocity (in gray) has not changed. It's uniform westerly flow. This change in angle explains why the colors change or speed seems to decrease as you move away from the actual wind direction/speed.



Here, you can also see that inbound velocities are depicted by cool colors (green) and outbound velocities are depicted by warm colors (red). Ever wonder why that is? The reason is that the first Doppler radar pointed straight up, so downdrafts (or negative vertical motion) pointed towards the radar.

But I wanted to share with you a brief rap that helps me remember the differences. And don't worry, I won't *actually* be rapping (you're welcome). But I think of RAP: red, away, positive. Once you can remember that, then you can easily remember the opposites: green, toward, negative. Hope that helps!

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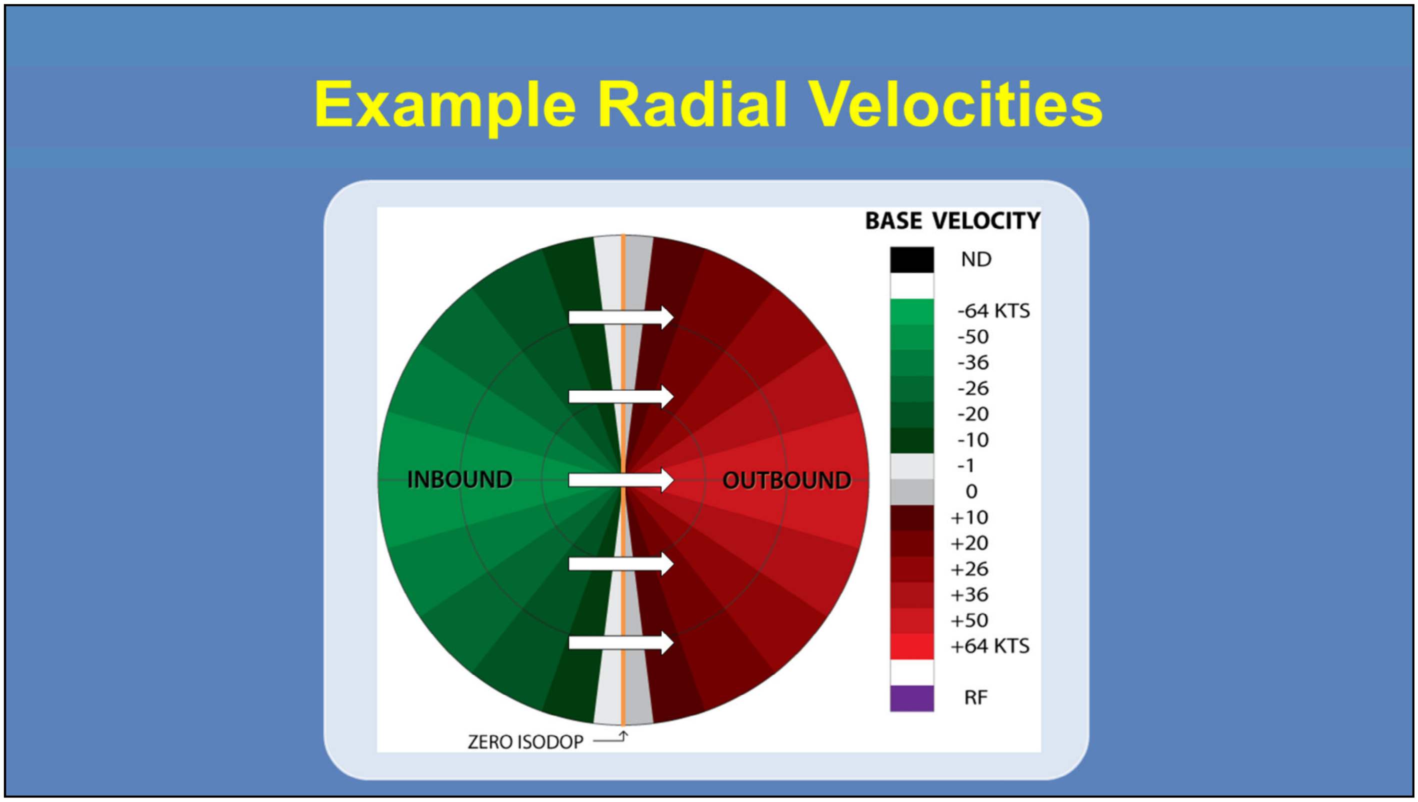
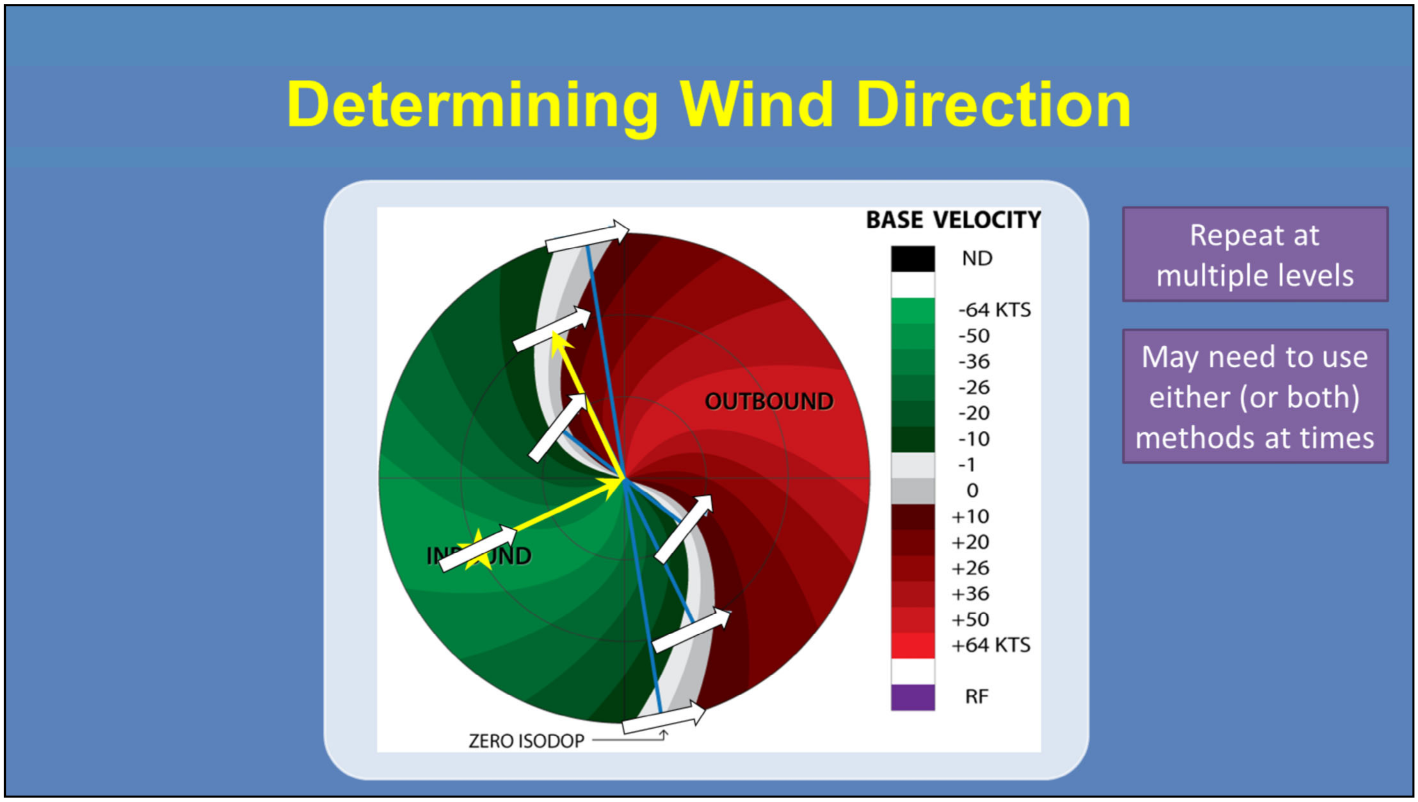
Mean Radial Velocity Terms

- *Zero Velocity* – Actual speed is zero or the direction is perpendicular to the beam (i.e. zero radial velocity)
- *Isodop* – Line of constant Doppler (radial) velocity
- *Zero Isodop* – Line of constant zero Doppler (radial) velocity

Before we go on, it is important that we define a few terms here. Zero velocity is when the actual speed is zero or the direction is perpendicular to the radar beam (which can also be described as zero radial velocity). An isodop is a line of constant Doppler (or radial) velocity. Finally, a zero isodop is a line of constant zero Doppler (radial) velocity.



Here is an example of radial velocities. The inbound velocities are in green while the outbound velocities are in red. The zero isodop represents the line of constant zero radial velocity. A straight zero isodop, as seen here, represents a uniformly directional flow at all levels (because, remember, you are increasing with height as you move away from the radar). Along the zero isodop, the wind direction is simply perpendicular to the radar beam and is always from the inbound to the outbound side. In this example, a homogeneous westerly flow exists over this area.



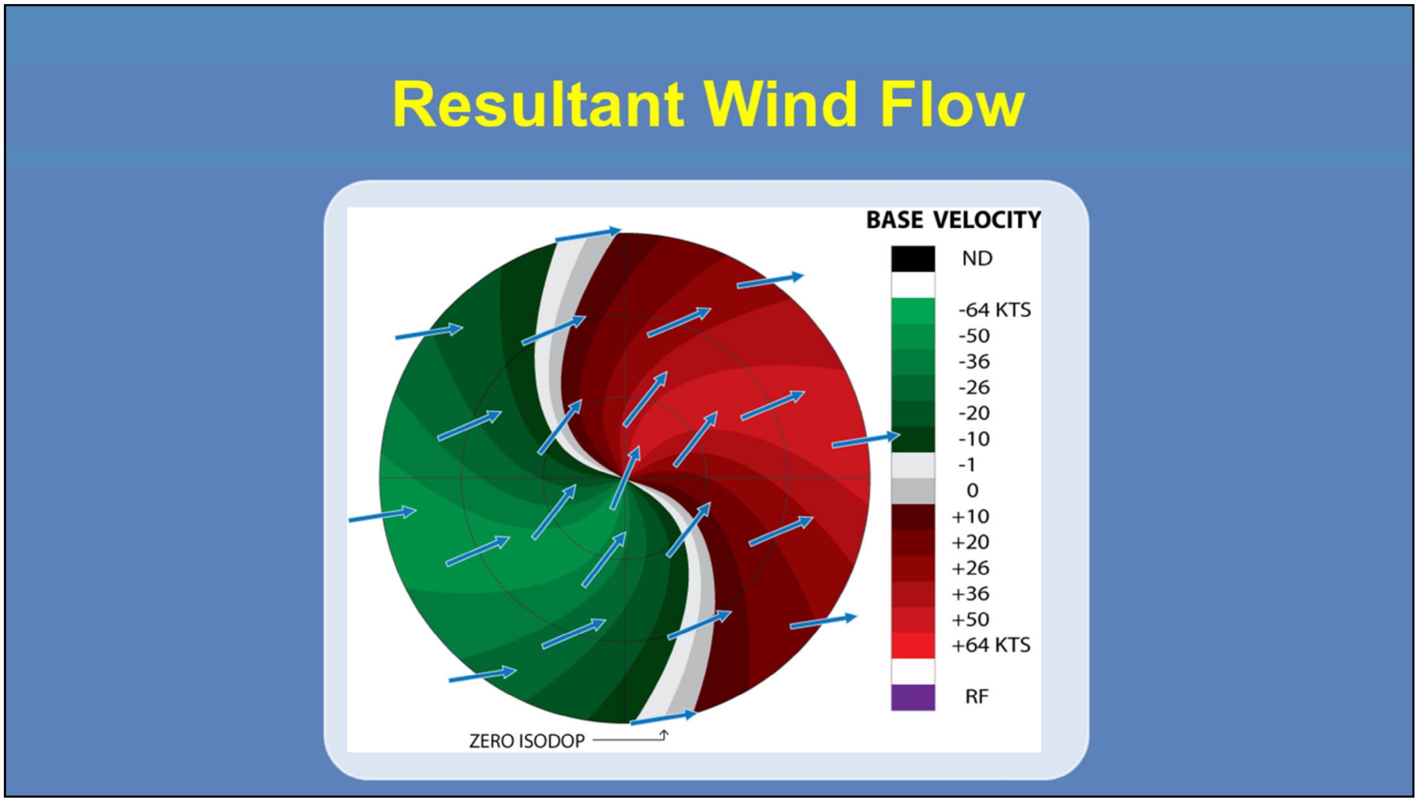
There are two methods for determining wind direction. However, both of these methods carry with it the assumption that the flow over the entire area is homogeneous for each level.

The first method uses the zero isodop to determine wind direction. First draw a line along a radial from the RDA to some point along the zero isodop. Next, draw an arrow perpendicular to the *line along the radial* (here, the yellow arrow, not the isodop). The arrow should be pointing from inbound to outbound velocities. Assuming homogeneous flow, the arrow represents the wind direction at that range (height).

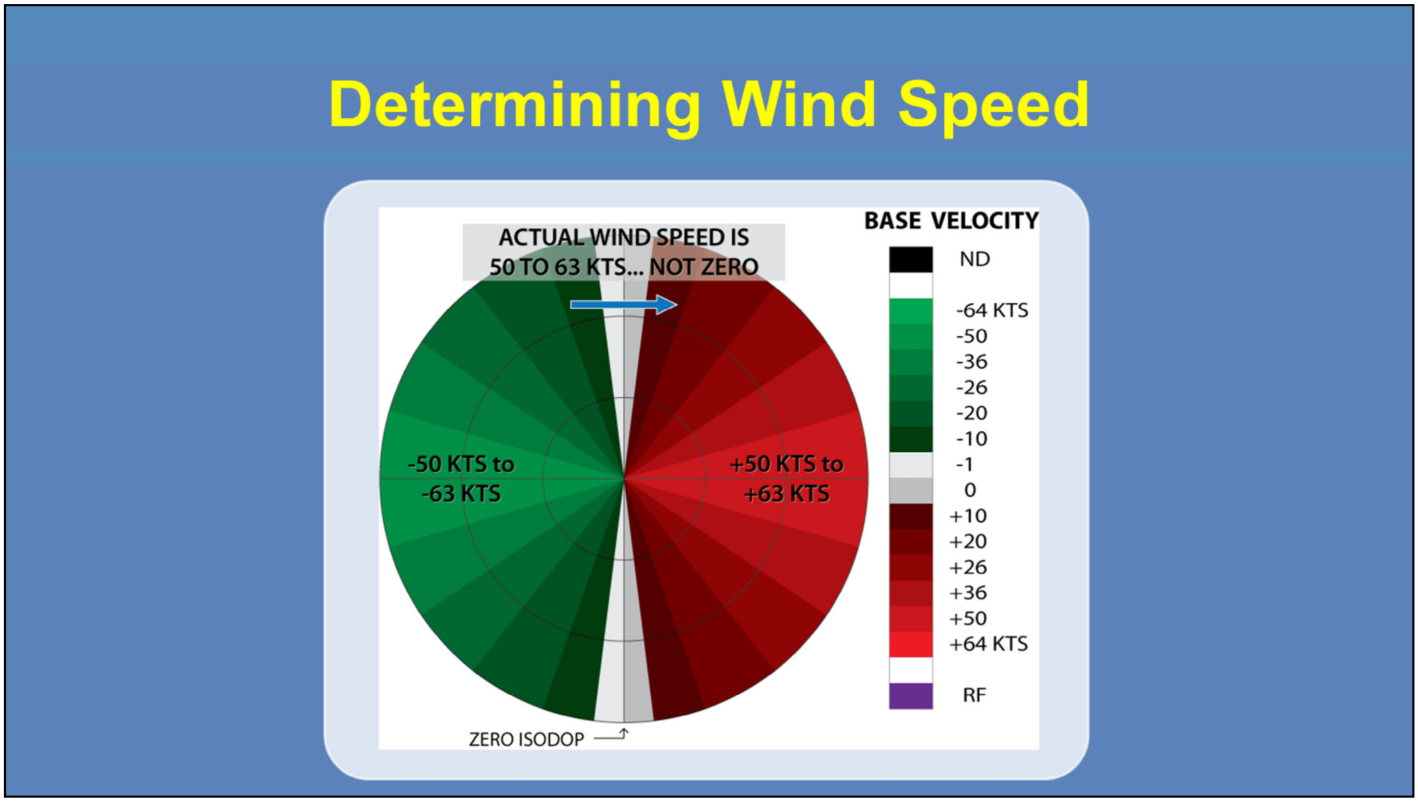
The second method uses the direction of the maximum inbound and outbound velocities from the radar. At a certain range, find the maximum inbound velocity, and then draw an arrow pointing towards the RDA. That's the direction of your wind at that level.

For both methods, note that the wind direction changes at each level, so you'll need to repeat for multiple levels. You may need to use either method to estimate the wind direction. The flow may be horizontally homogeneous over just a part of the radar, so you may need to determine the wind direction for more than one region.

Also, there will be many cases when one of these methods will not work. At times, you may have to use a combination of the two methods.

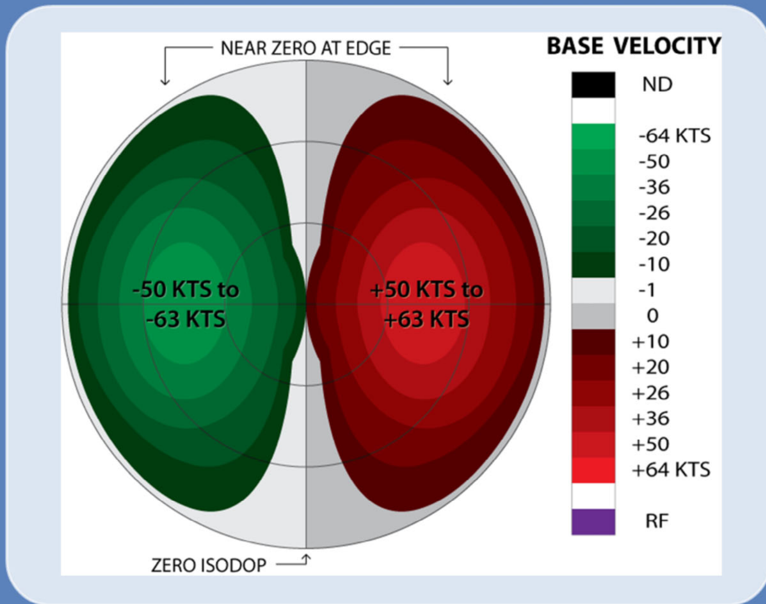


By using the methods described previously, we can determine the wind direction at any range (or height).



Now that we have seen how wind direction is determined, it is time to look at wind speed. Staying with the homogenous westerly flow example, we can easily tell the maximum wind speed from the radar either looking into or directly away from the wind. This example shows a constant wind speed with height of 50-63 kts. Even though the radial velocity is zero at the zero isodop, the actual velocity is still 50-63 kts.

Wind Speed Maximum



A wind speed maximum is identified by closed isodops surrounding a maximum velocity value. Here is a depiction of a low-level wind speed maximum (within the first and second range rings). Starting near the RDA, you can see winds increase up to a closed area of 50-63 kts. From there, they decrease to near zero at the edge of the display.

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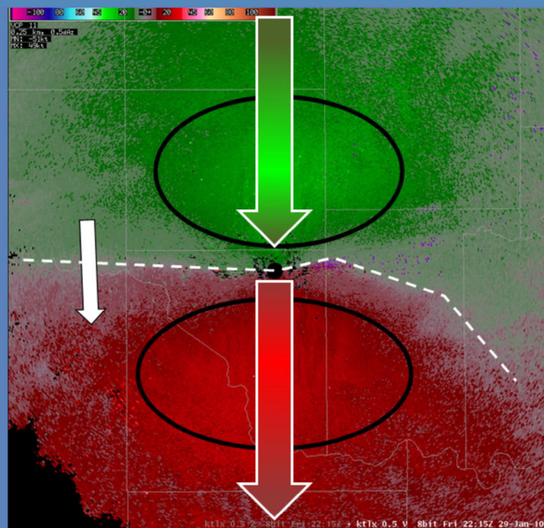
Example Velocity Image



Here is a velocity example that represents some of the concepts learned in the previous slides. First, you can see a fairly straight zero isodop extend from east to west across the display. With the inbound velocities north of the RDA, the general flow is from north to south. You can also see that the wind speed maximum is close to the radar. As you move farther away from the radar in the N-S direction, the maximum velocity values decrease, signifying a low-level wind maximum.

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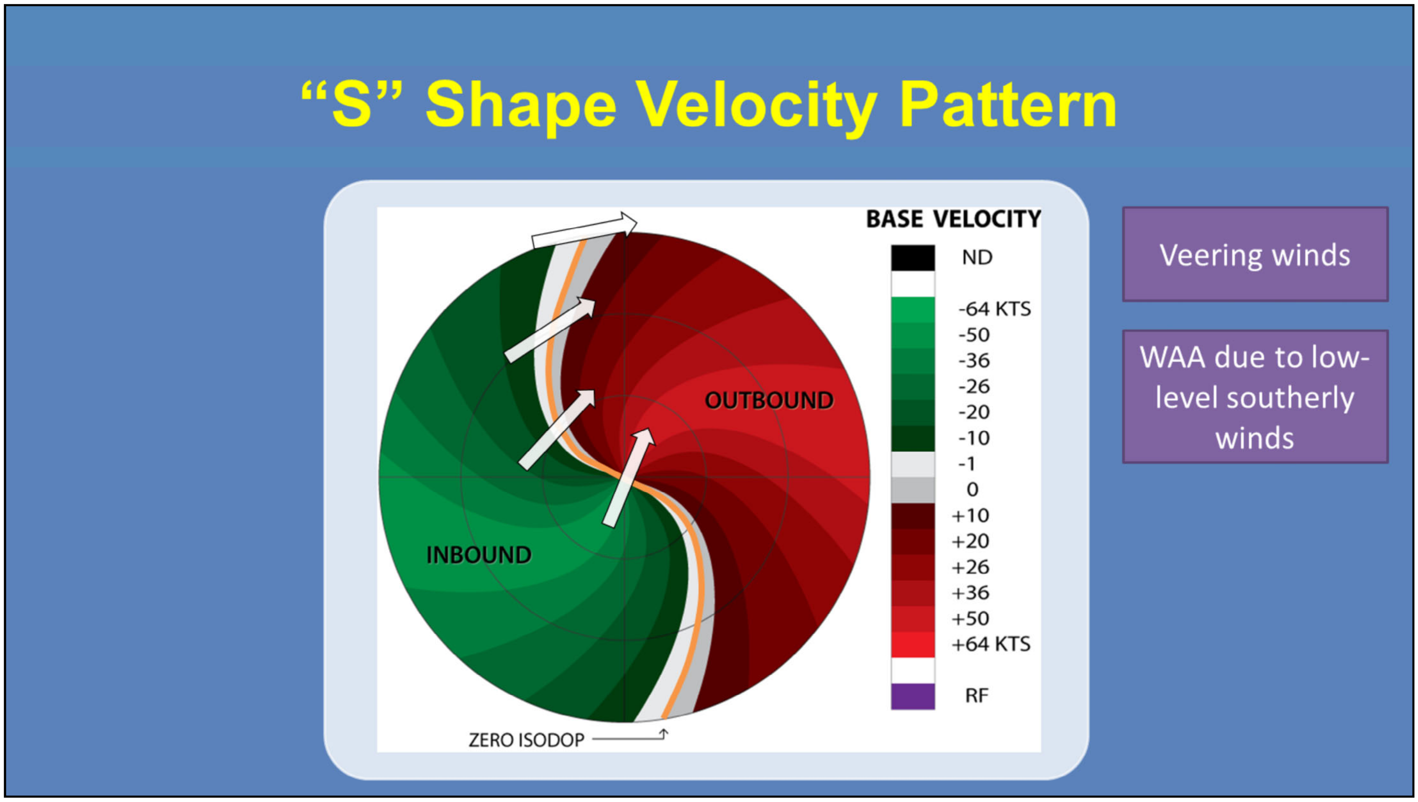

Now, we will begin looking at more complex velocity patterns.

Curvature of the zero isodop represents changing wind direction with height. In this case here, the zero isodop is shaped like the letter “S.” The wind direction near the RDA is from the south-southwest while the wind direction is from the west-southwest near the edge of the display. The associated vertical wind profile shown here indicates that the winds are turning clockwise with height. The meteorological term for this is veering. Veering generally indicates that warm air advection is occurring due to the low-level southerly winds.

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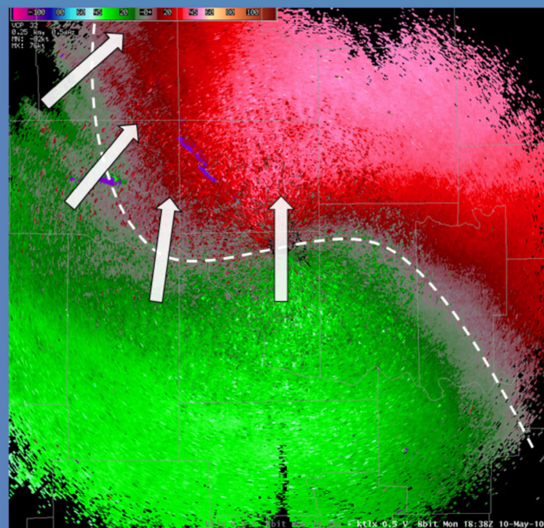
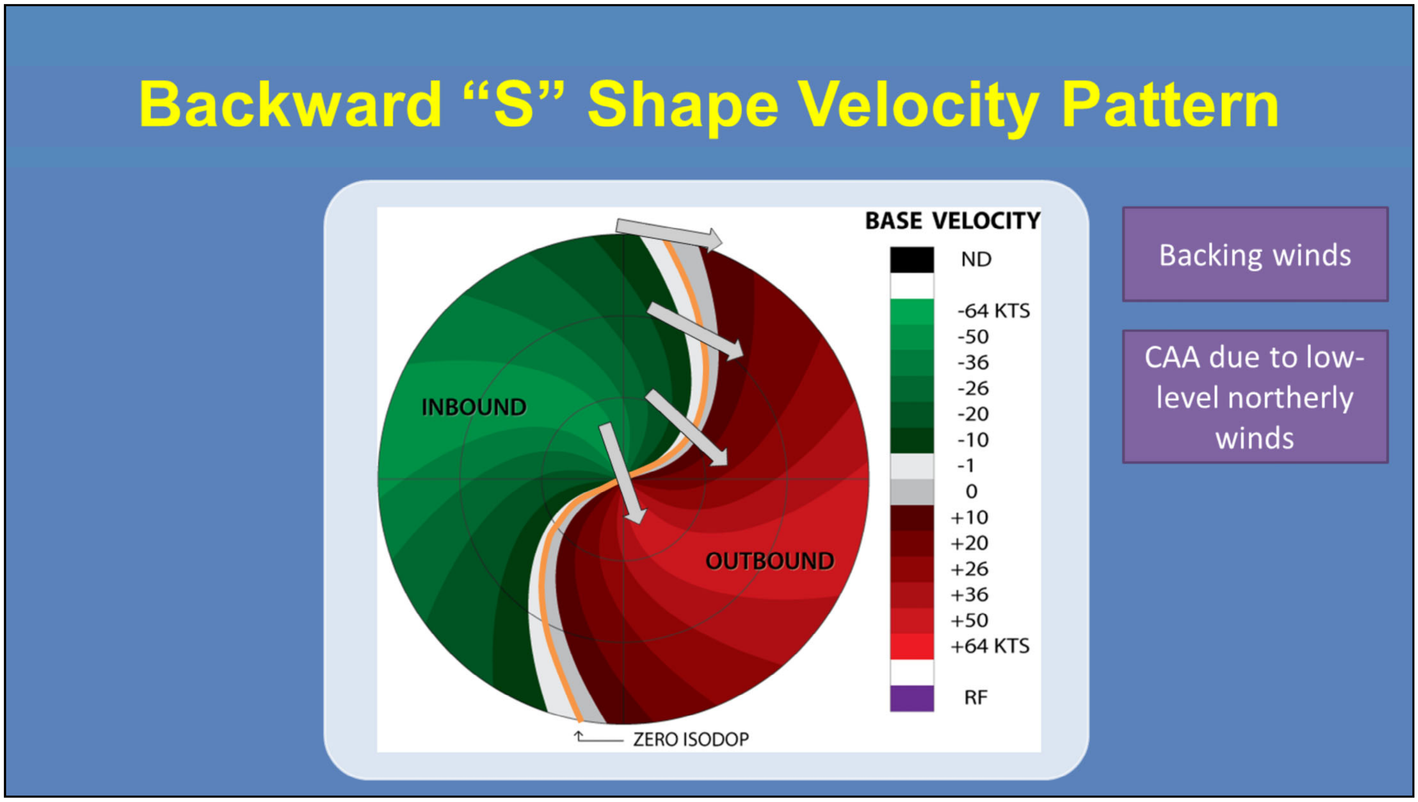
“S” Shape Velocity Example



Here is a real-world example of veering winds with height. There is a “S” shape to the zero isodop, with winds from the south near the surface to winds from the southwest near the edge of the display. Thus, the winds are veering with height throughout the layer.



Some velocity patterns can exhibit a backward "S" shape pattern. In this case, the winds are turning counterclockwise with height, which is completely opposite of the standard "S" shape profile you saw earlier. In this graphic, the winds are from the north-northwest near the RDA and from the west-northwest near the edge of the display. When the vertical wind profile is turning counterclockwise with height, as seen here, it is referred to as backing. Backing winds are generally associated with cold air advection.

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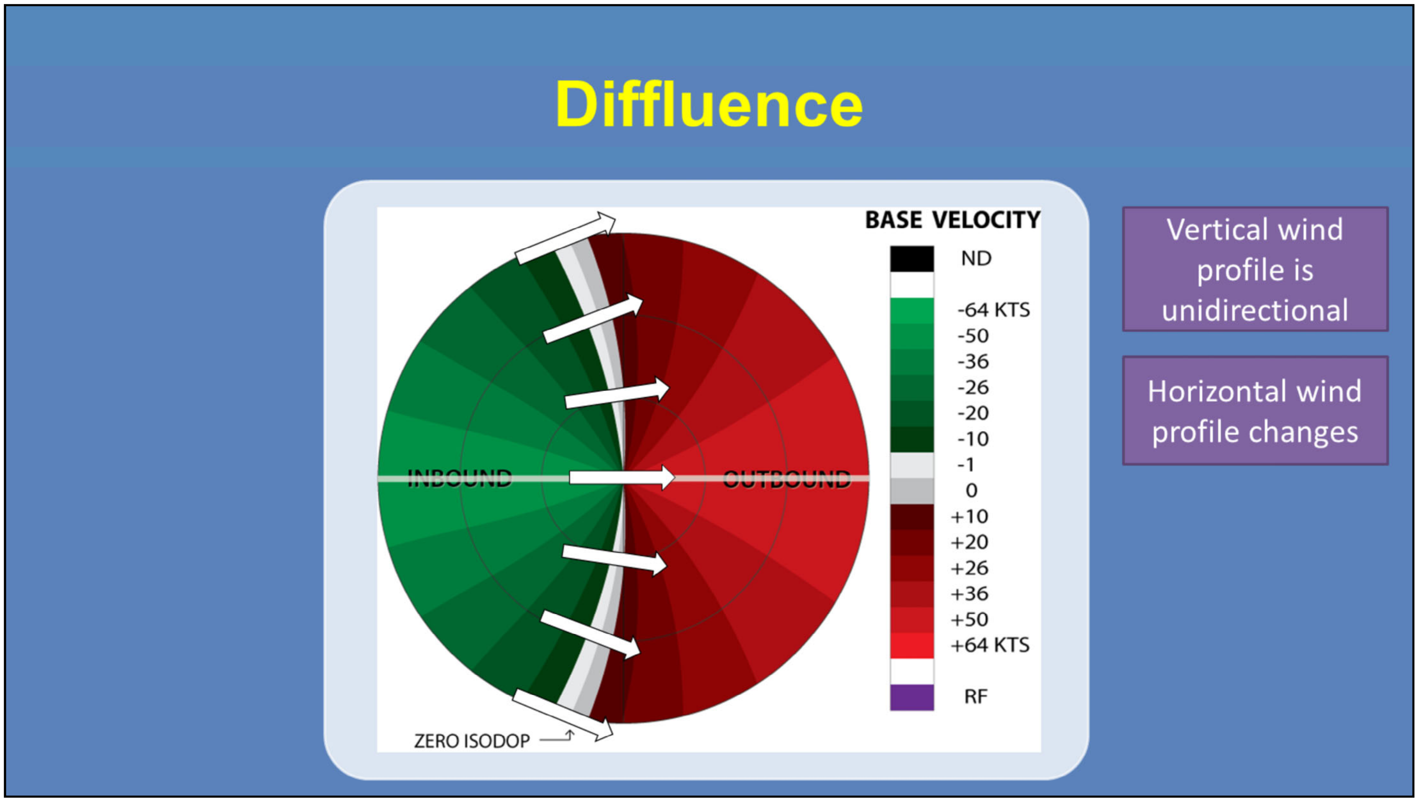

We will now move away from pure homogeneous wind fields and talk about diffluent and convergent wind fields. The best way to examine these kinds of wind fields is to split the display into two parts. Starting with the top half, the wind direction changes from the west near the surface to west-southwest at the edge of the display. Looking at the bottom half of the display, the wind direction is westerly near the RDA but changes to west-northwest at the southern edge of the display. This associated pattern shows the air spreading out as it passes over the RDA.

Note that the zero isodop has a bowing shape to it and that the inbound velocities are within the bow. Now, at any one point, the *vertical* wind profile is still going to be unidirectional; however, we now add that complexity of the wind field changing over horizontal distances (not horizontally homogeneous).

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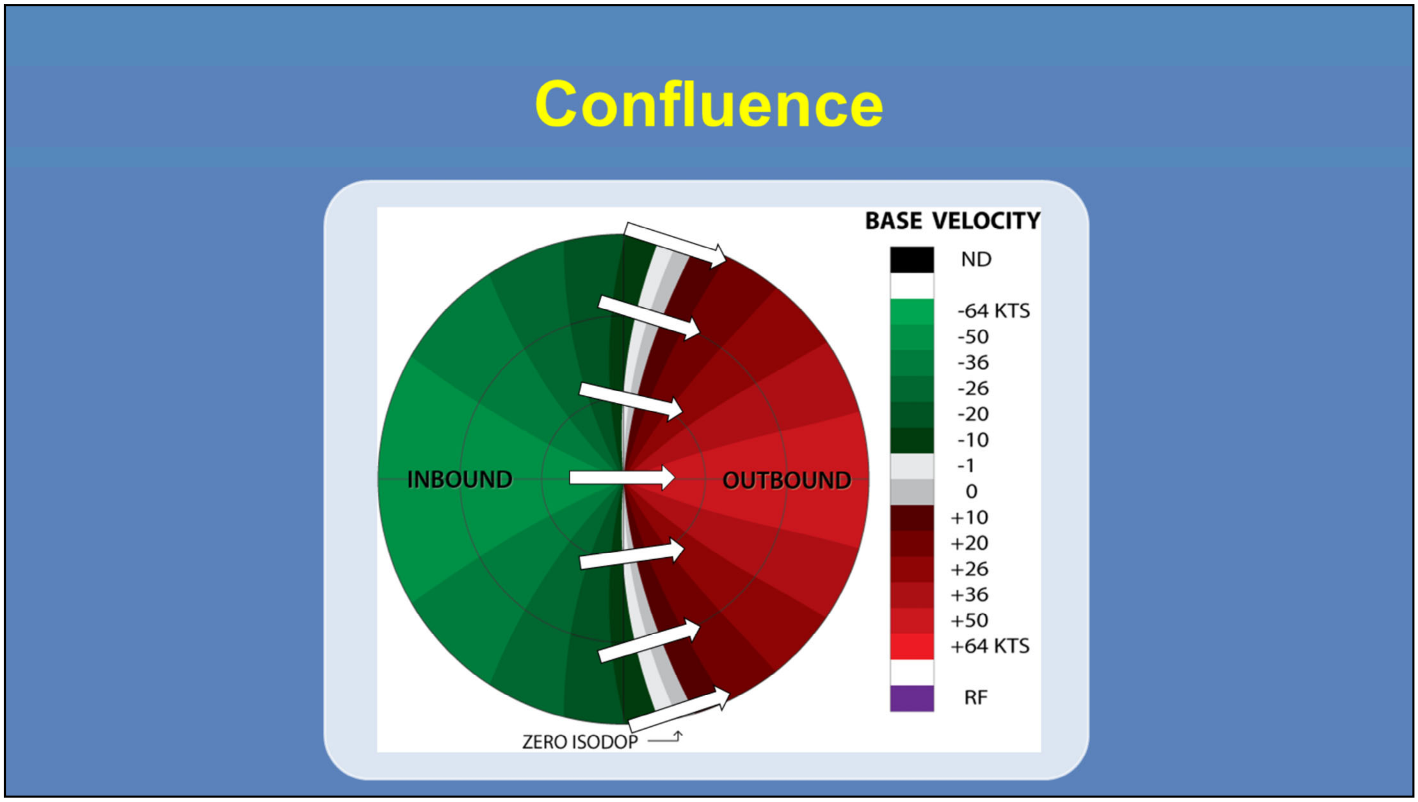

Looking at a diagram at what a confluent wind flow would be, you can see that the outbound velocities are now on the inside of the bow-shaped zero isodop. Here, the winds are coming together over the RDA.

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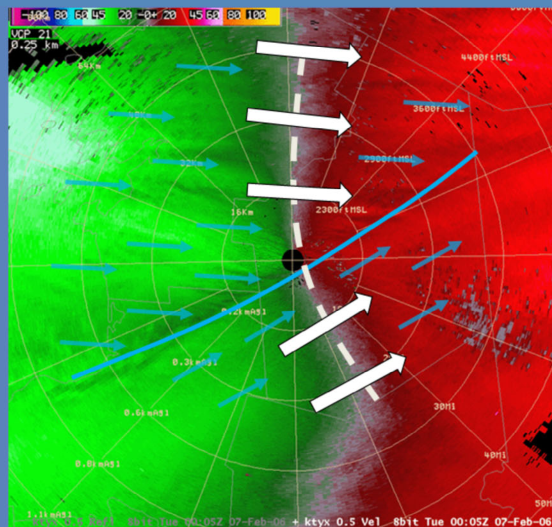
Confluence Velocity Example



Here is a real-life example of a confluence zone. A lake effect snow band is passing over this radar from southwest to northeast. You can see that the zero isodop bends in a way that the outbound velocities are on the inside of the bowing shape.

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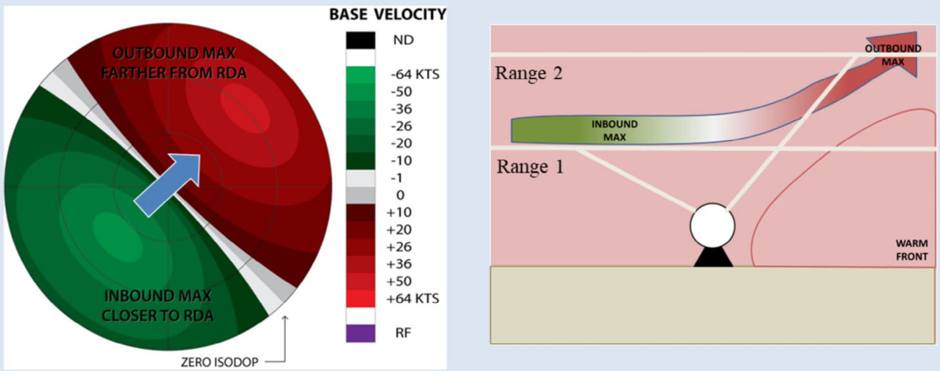
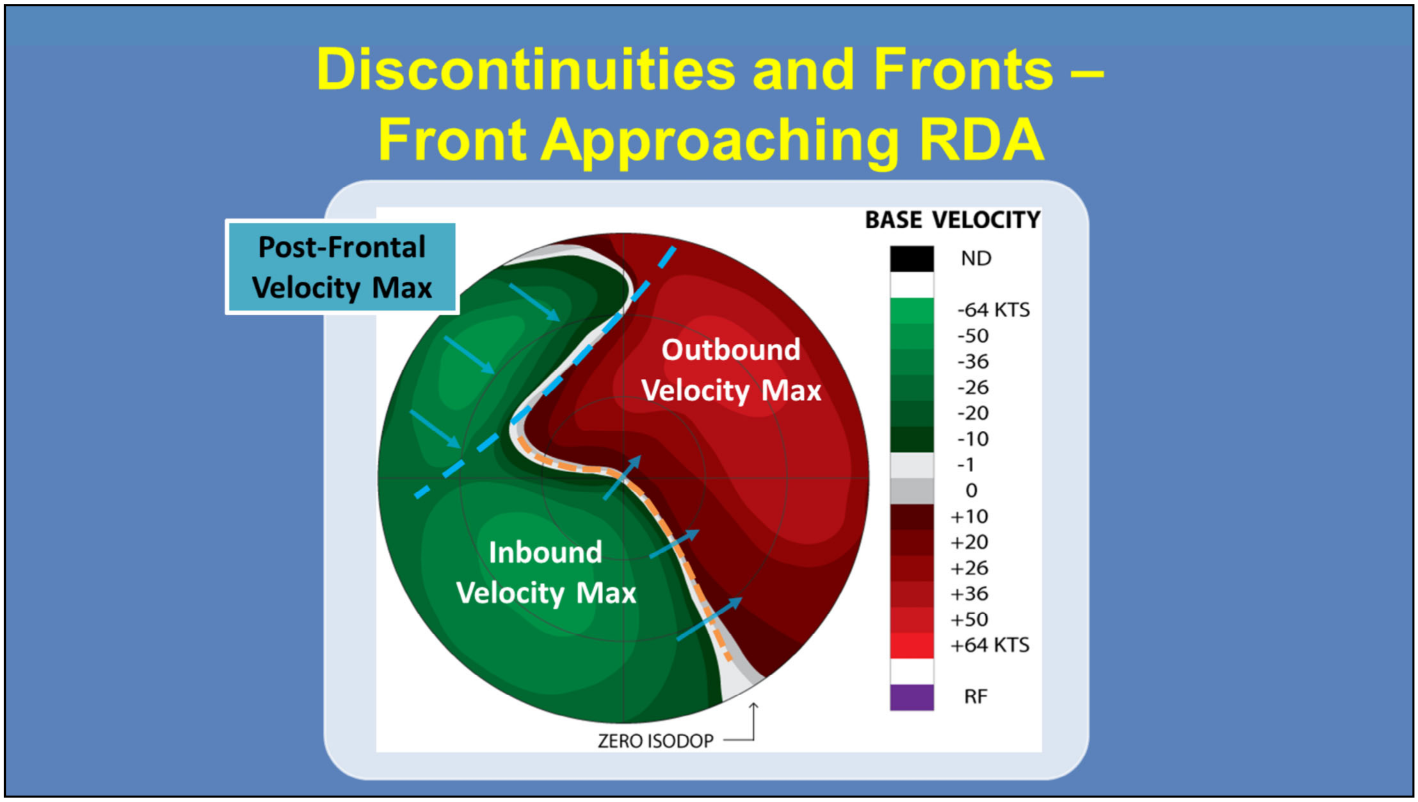
Sloping Wind Maximum



Sometimes, you might run into a situation where you have a sloping wind maximum, like a low-level jet moving over a warm front. In this graphic here, the general flow at all levels is from the southwest to the northeast. If you were to look at the location of the velocity maximum for the inbound winds, you can see it is just beyond the first range ring. Now looking at the velocity maximum on the outbound side, you can see it is over the second range ring. This indicates that the wind maximum is increasing with height as it moves across the display.



Now let's move on to an even more complicated wind pattern. The following examples will show a frontal boundary moving through the display area, and the expected wind patterns at various stages of the passage. First, we will start with the front approaching the RDA, in this case, from the northwest. Here, you can see that the southeastern 2/3 of the display has an "S" shaped pattern, with velocity maxima located to the northeast and southwest of the RDA. Behind the front, located here, you can see a secondary inbound wind maximum to the northwest, which is not "connected" with any of the other two maxima on this display.

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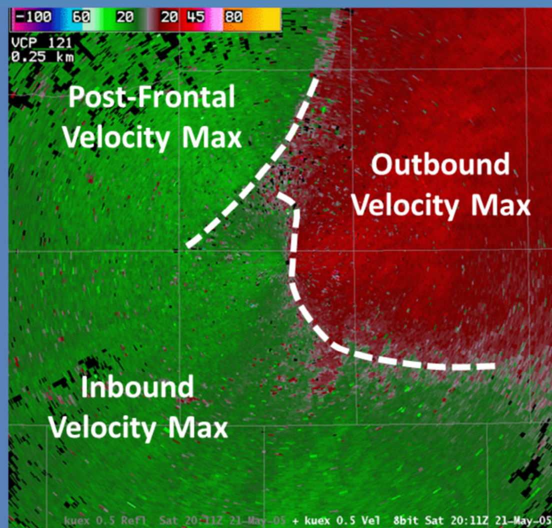
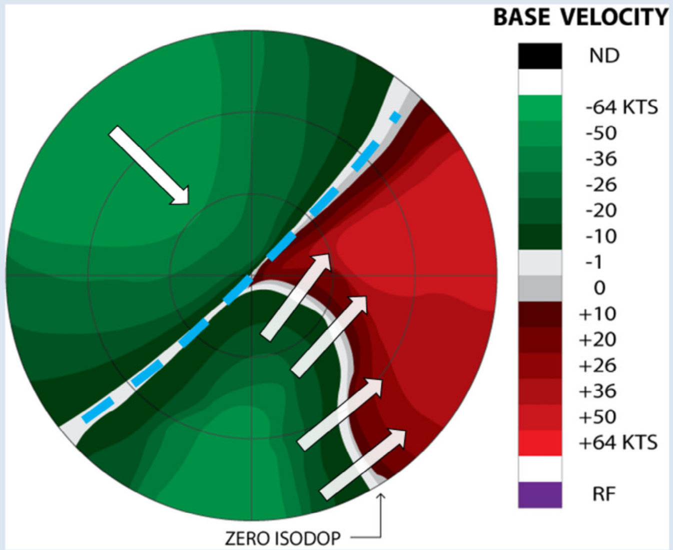
Front Approaching RDA Example



This real world example also has a front approaching the RDA. In the real world, it is not always easy to see frontal boundaries, especially in just one volume scan. Using the static image here, you can see the where the front is located via the cutoff between the inbounds and outbounds to the north, and the velocity minimum to the west. A backing wind pattern is seen south of the boundary. The two connected wind maxima are located to the west-southwest and east-northeast of the RDA, while the disconnected post-frontal velocity maximum is located to the northwest of the RDA. Note that this boundary is aloft in this display. That is, the radar beam is sampling the elevated portion of the boundary.

Discontinuities and Fronts – Front Over RDA



Moving forward in time, here is a graphical representation of a frontal boundary now located over the RDA. The boundary is still oriented from southwest to northeast, as seen by the zero isodop. The winds are from the northwest behind the boundary, while they are generally from the southwest in a veering pattern ahead of the front.

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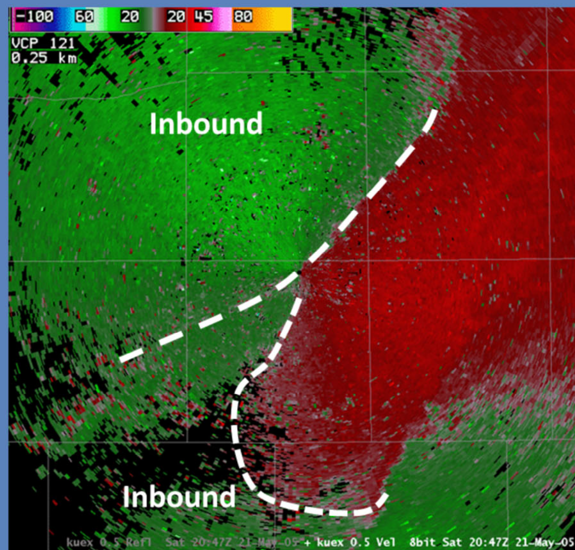
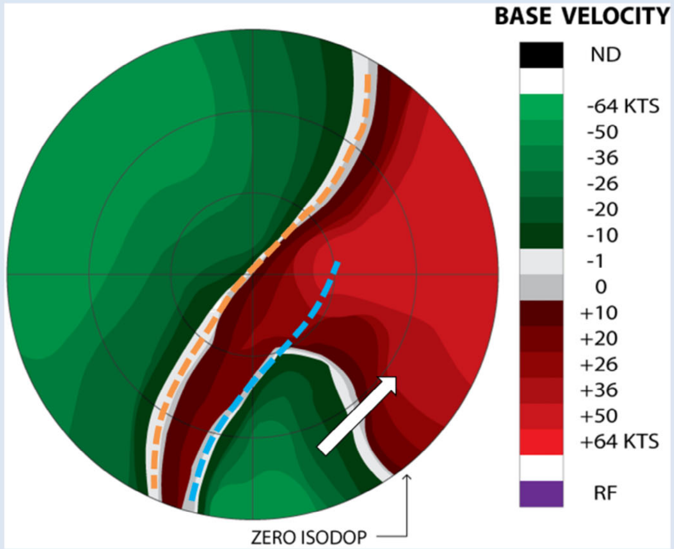
Front Over RDA Example



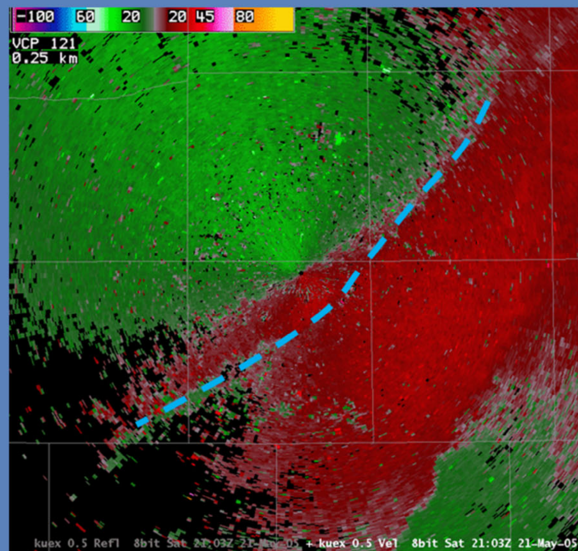
Now moving forward in time with the real-world example, the frontal boundary is now at the RDA. The inbound velocities are located to the southwest of the RDA ahead of the boundary and to the northwest of the RDA behind the boundary. A sharp change in speeds indicates the location of the boundary. Also, in this example, note the backing wind profile ahead of the front.

Discontinuities and Fronts – Front After Passing RDA



The front has now passed over the RDA and is now located to its southeast. The winds ahead of the front are still from the southwest. Behind the front, the winds are now backing with height.

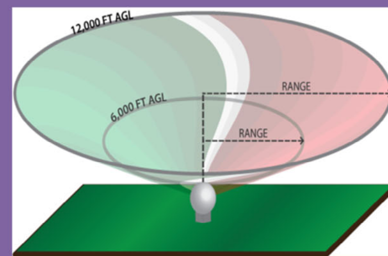
Front After Passing RDA Example

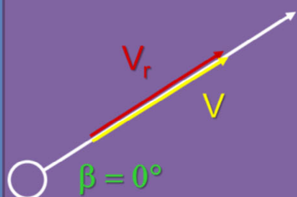


Back to the real world example, the front is now located to the southeast of the RDA, which is denoted by the blue line here. Notice that this front is losing definition with time. Only to the southwest of the RDA is there a leading edge of inbound velocities. Otherwise, use the subtle leading edge of the enhanced outbounds as the frontal interface.

Summary

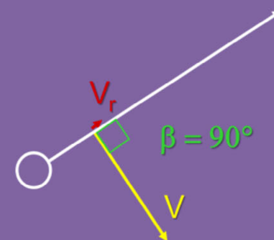
When looking at a display, you are looking into a cone with north at the top of the display.



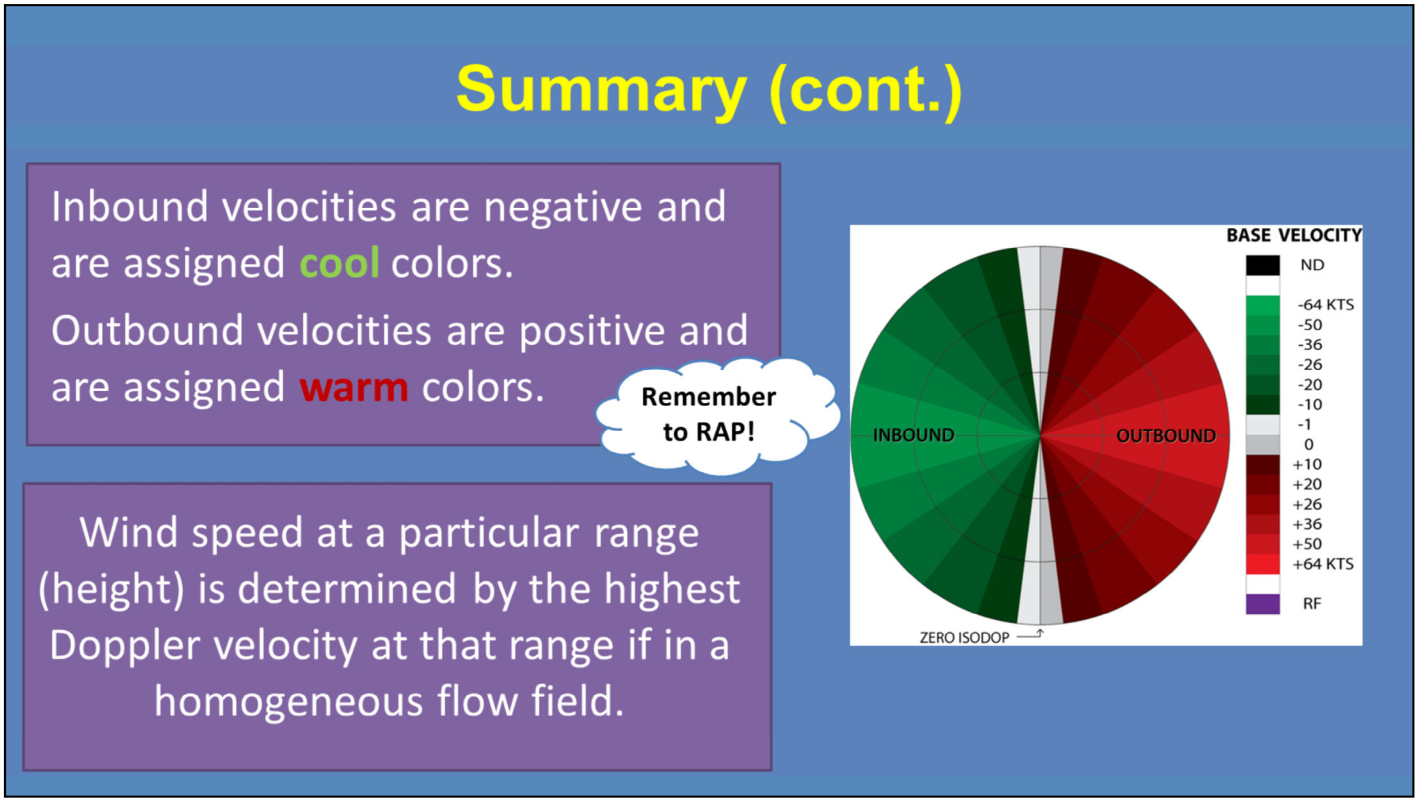


The full component of the wind will be measured only when it is **parallel** to the radial.

When the wind is **perpendicular** to the radial, none of the wind is measured.



Alright, let’s summarize the heavy hitters. First, when you are looking at a velocity display, you are looking into a cone with north at the top of the display. Next, the full component of the wind will be measured only when it is parallel to the radial. When the wind is perpendicular to the radial, none of the wind is measured.



Inbound velocities are negative and are assigned cool colors. Outbound velocities are positive and are assigned warm colors.

And, wind speed at a particular range (height) is determined by the highest Doppler velocity at that range if in a homogeneous flow field.

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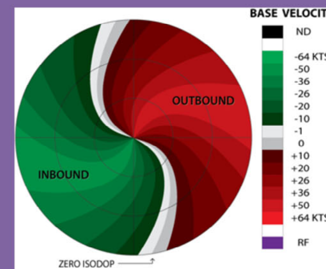
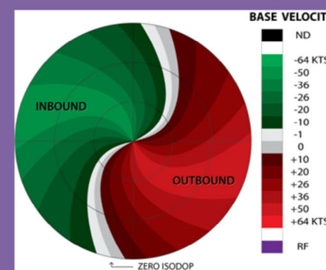
Summary (cont.)

A normal “S” shape zero isodop produces a <u>clockwise</u> turning vertical wind profile (**veering**).



A backward “S” shape zero isodop produces a <u>counterclockwise</u> turning vertical wind profile (**backing**).



Continuing on, a normal “S” shape zero isodop produces a clockwise turning vertical wind profile (veering), while a backward “S” shape zero isodop produces a counterclockwise turning vertical wind profile (backing).

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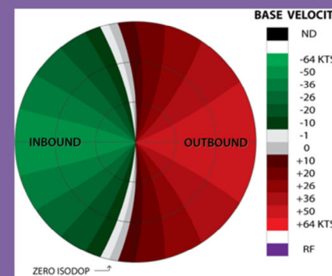
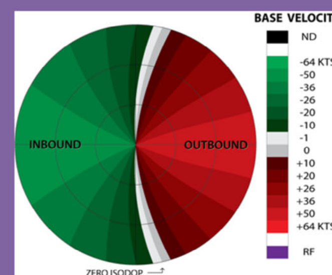
Summary (cont.)

A bow-shaped zero isodop with **inbound** velocities inside the curve represents diffluence.

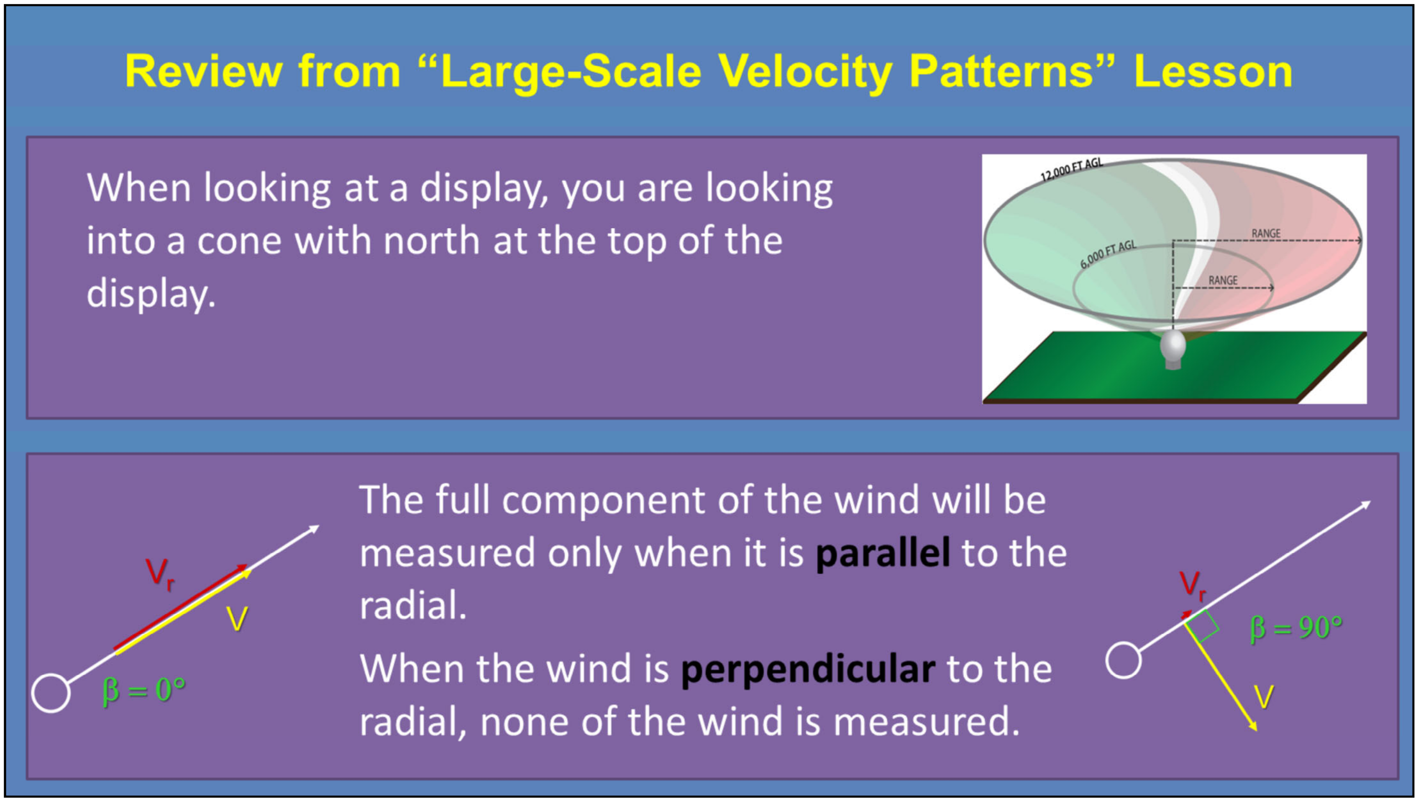


A bow-shaped zero isodop with **outbound** velocities inside the curve represents confluence.

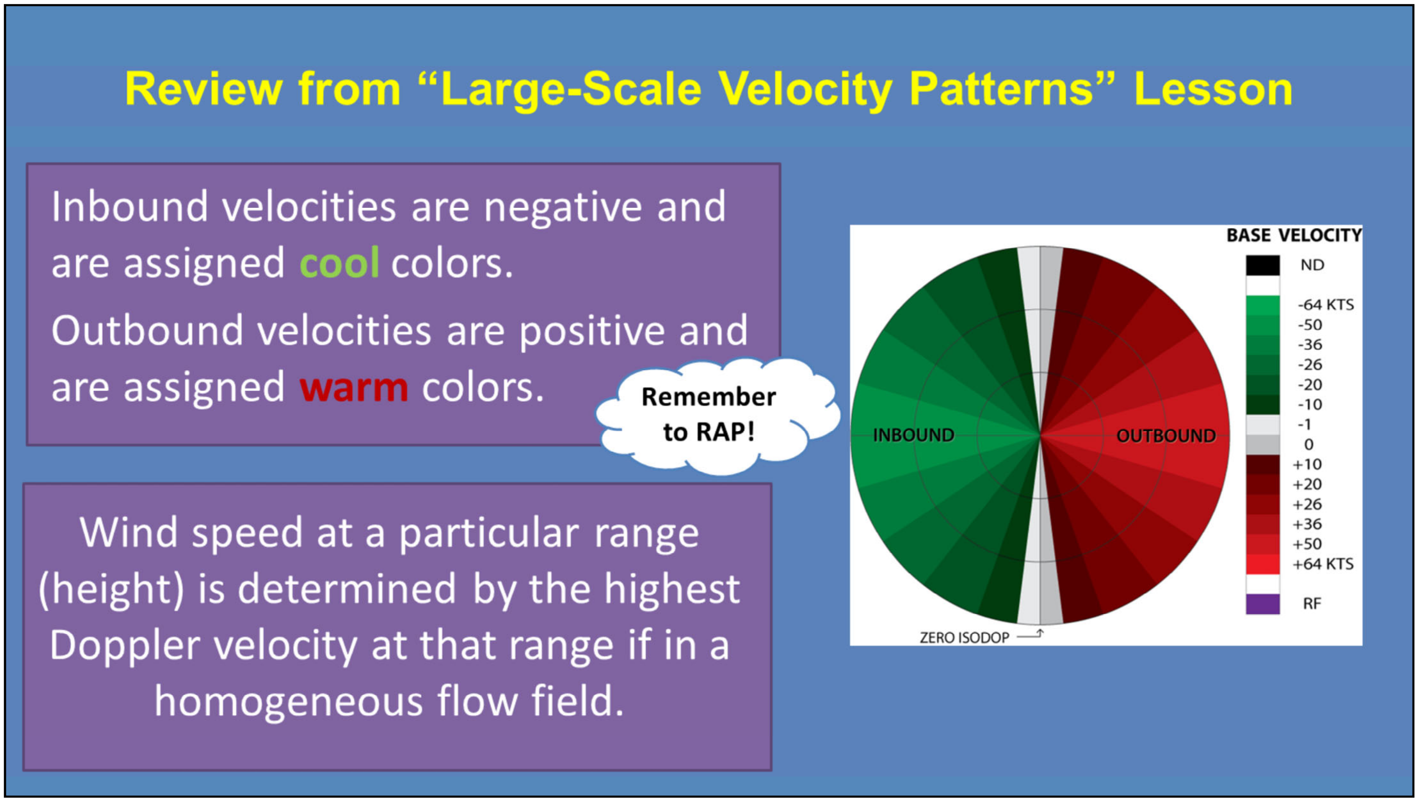


Finally, a "bowed" shape zero isodop with inbound velocities inside the curve represents diffluence, while a "bowed" shape zero isodop with outbound velocities inside the curve represents confluence.

Hi again! It’s Jill Hardy and welcome to this lesson on storm-scale Doppler velocity patterns.



Recall from the previous lesson that when you are looking at a velocity display, you are actually looking into a cone where the farther from the RDA you get, the greater the height above the ground the data is being measured. The full component of the wind will be measured only when it is parallel to the radial. When the wind is perpendicular to the radial, none of the wind is measured. You saw this through the Radial Velocity Equation.



Inbound velocities are negative and are assigned cool colors. Outbound velocities are positive and are assigned warm colors. And a helpful way to remember this is to RAP: red, away, positive.

And, wind speed at a particular range (height) is determined by the highest Doppler velocity at that range if in a homogeneous flow field. Of course, you saw how complex this became when the wind field became horizontally non-homogeneous.

Learning Objectives

1. How to identify convergence and divergence storm-scale signatures

2. How to identify cyclonic and anticyclonic storm-scale signatures

There are two learning objectives for this lesson. You should be able to understand how to identify storm-scale convergence and divergence signatures, and understand how to identify cyclonic and anticyclonic storm-scale signatures.

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Performance Objectives

1. Interpret Doppler velocity patterns under uniform, non-uniform, ambiguous, and meteorologically complex conditions identifying:
   - Convergence & Divergence
   - Cyclonic & Anticyclonic rotation
   - Any combination of the above

2. Assess the mesoscale meteorological conditions and threats associated with the identified velocity patterns

There are also two performance objectives with this lesson. The first objective is to be able to interpret Doppler velocity patterns under uniform, non-uniform, ambiguous, and meteorologically complex conditions. You will be identifying convergence and divergence, cyclonic and anticyclonic rotation, and any combination of the above.

The second objective is to assess the mesoscale meteorological conditions and threats associated with the identified velocity patterns.

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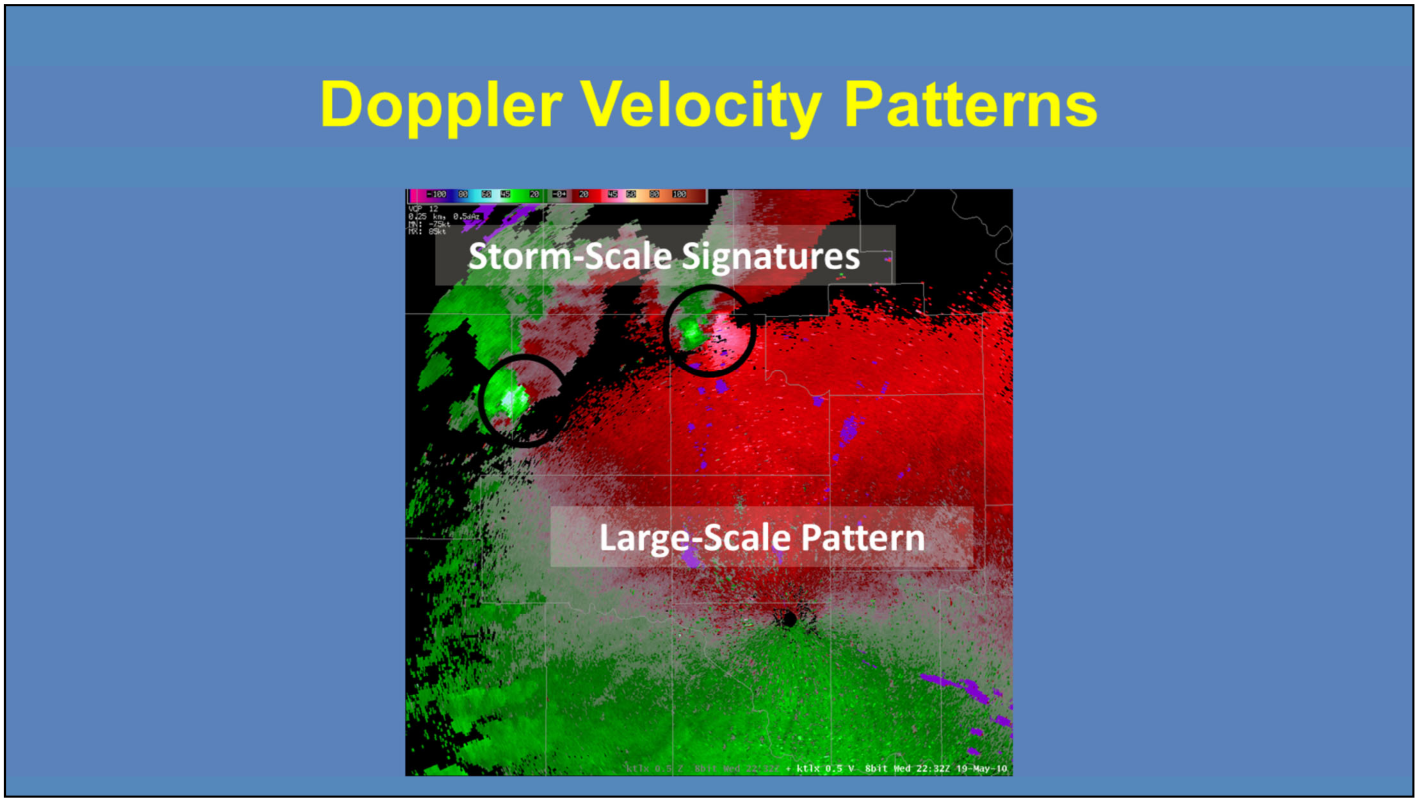

In the first lesson, you saw a variety of factors and examples that influence the large-scale velocity field and its display in the AWIPS environment. Now, we will go ahead and focus on the small-scale phenomena, which cover only a few range gates, and therefore, have a relatively small change in elevation.

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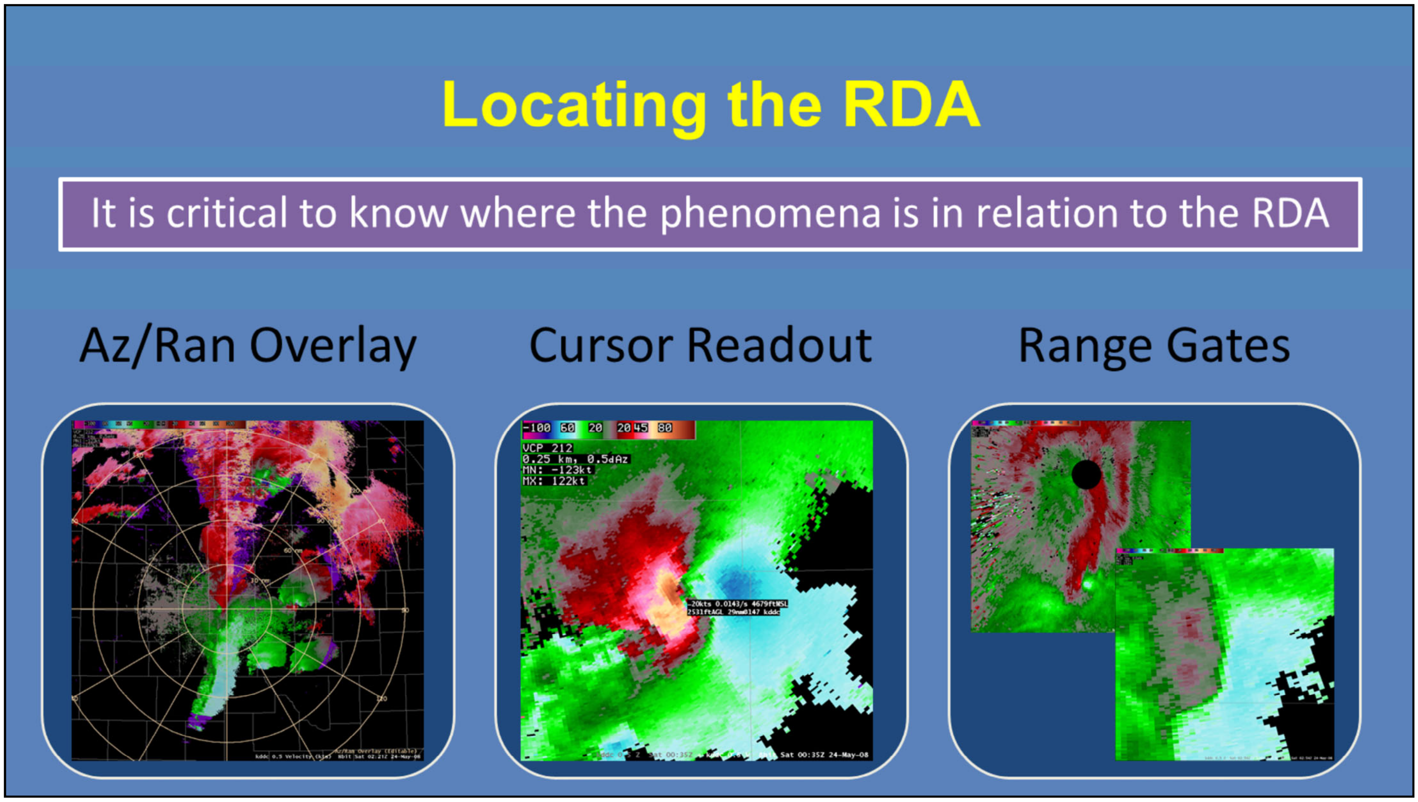

When examining data on this scale, you will be zooming in AWIPS in order to see small scale rotation and/or convergence and divergence. It is critical to know where the phenomena is in relation to the RDA. Here, you can no longer assume that the RDA is in the center of the display, or on the display at all. The following three actions, either used separately or in combination, will help in locating the RDA.

--You can select the Azimuth and Range (or Az/Ran) Overlay from the Tools menu to help determine the location of the RDA by overlaying a polar grid centered on the RDA.

--Or you can place your cursor at the point of interest and hold down the left mouse button. The cursor readout will give the azimuth and range (in statute miles) from the RDA. To see this readout all the time, you can right-click and turn on Sampling, as well.

--Or you can visually analyze the range gates in your velocity display. Range gates increase in width along each radial as they increase in distance from the RDA. This is one advantage to an unsmoothed radar display.

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Small Scale Pattern – Convergence and Divergence

For pure convergence or divergence patterns, the velocity maxima lie along the same radial

- **Convergent** signatures - velocity maxima aligned on the same radial with the **outbound maxima** closest to the RDA
- **Divergent** signatures - velocity maxima aligned on the same radial with the **inbound maxima** closest to the RDA

When interpreting pure convergence or divergence patterns, the velocity maxima lie along the same radial. Whether the pattern is convergent or divergent is dependent upon which maximum is closest to the RDA.

With a convergent signature, the outbound maxima is closest to the RDA.

With a divergent signature, the inbound maxima is closest to the RDA.

Note that in the following examples, the RDA is located to the south of the velocity signature.

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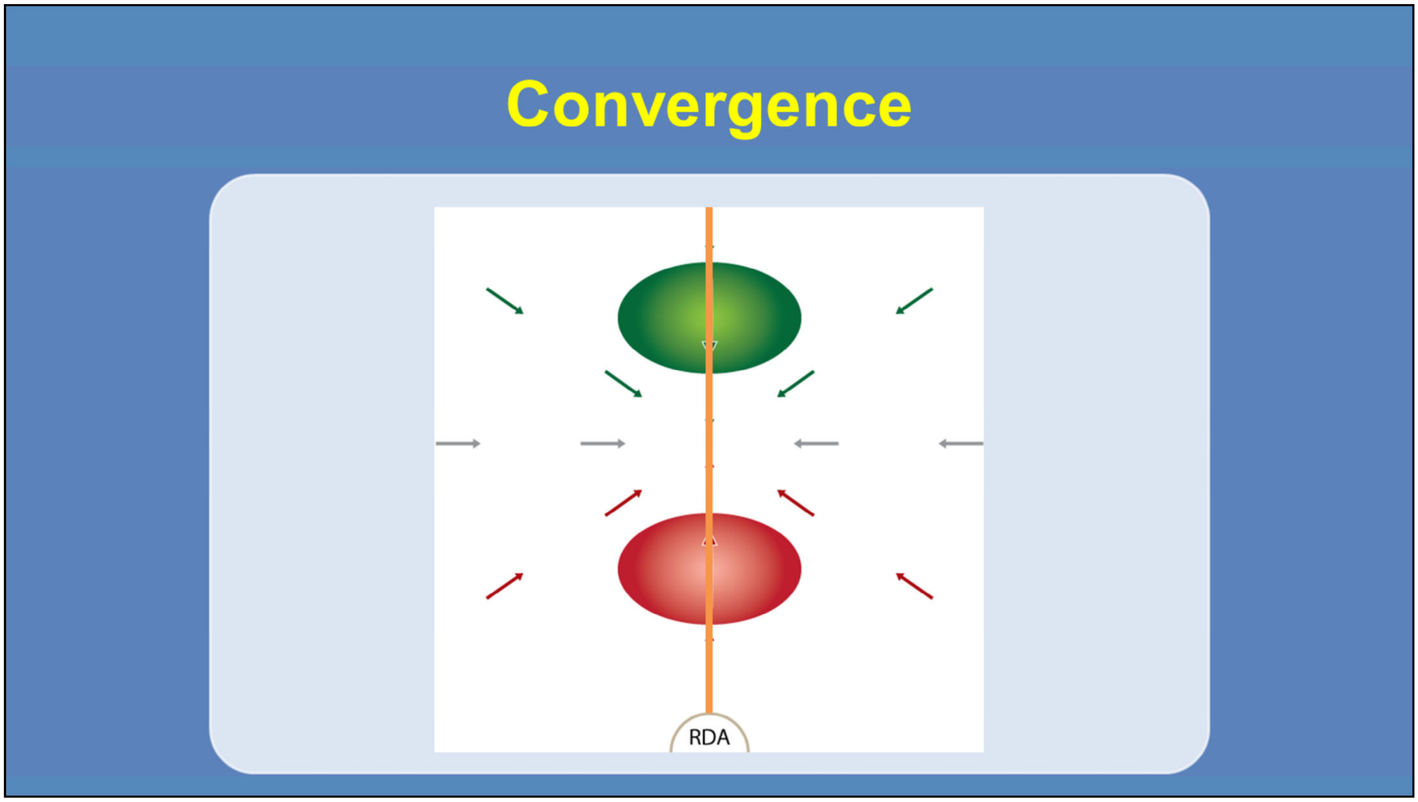
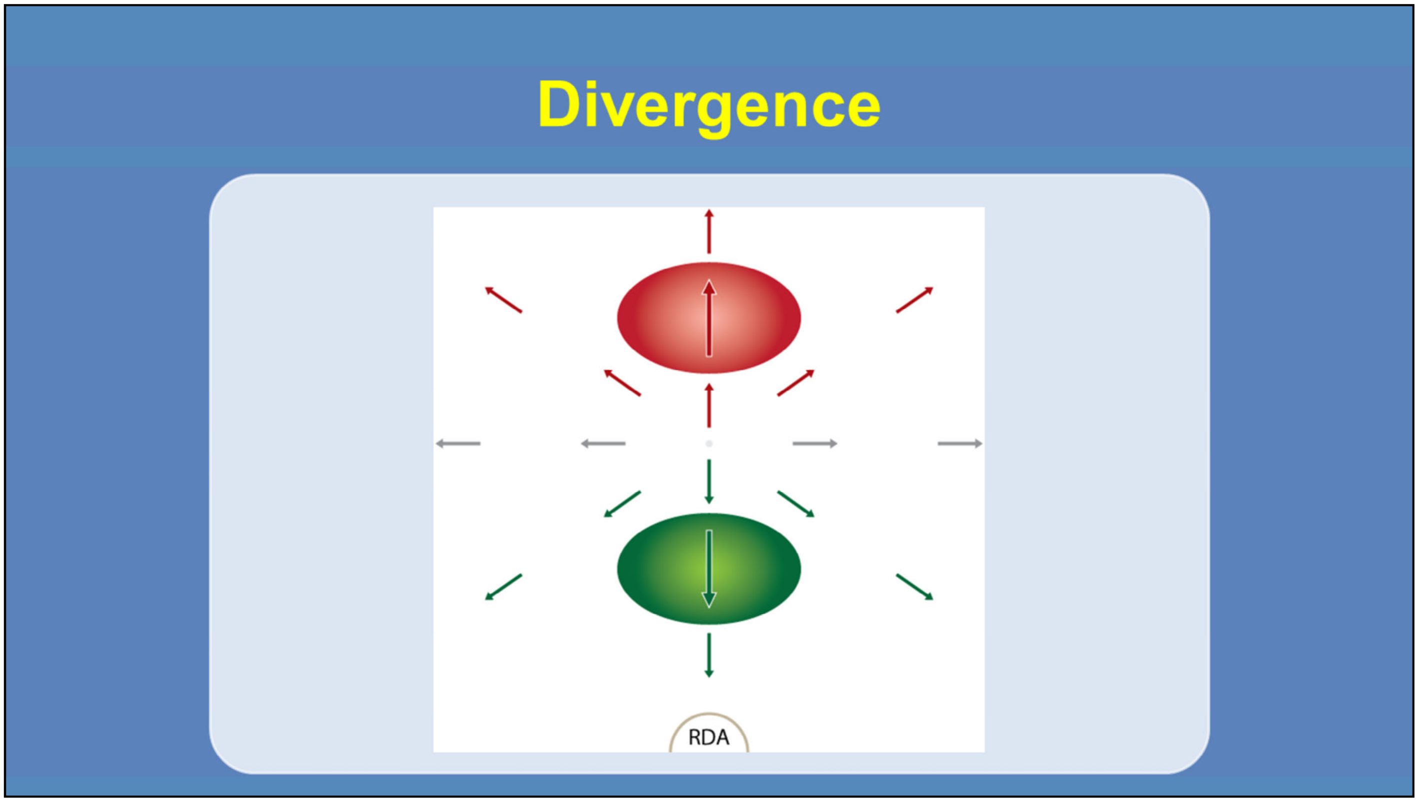


Here is a basic diagram of a convergent velocity signature. As you can see here, both the maxima lie along the same radial with the outbound velocity maximum closest to the RDA.



Same thing here for the divergent velocity signature, except that the inbound velocity maximum is now closest to the RDA.

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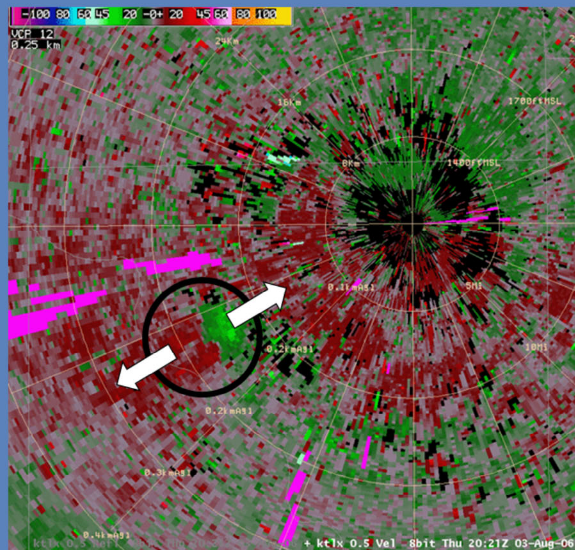
Divergent Velocity Example



In this real-world example, there is a divergence signature located to the west-southwest of the RDA. This occurred just after a downburst from a thunderstorm. Note that the maximum inbound velocity is closer to the RDA than the maximum outbound velocity.

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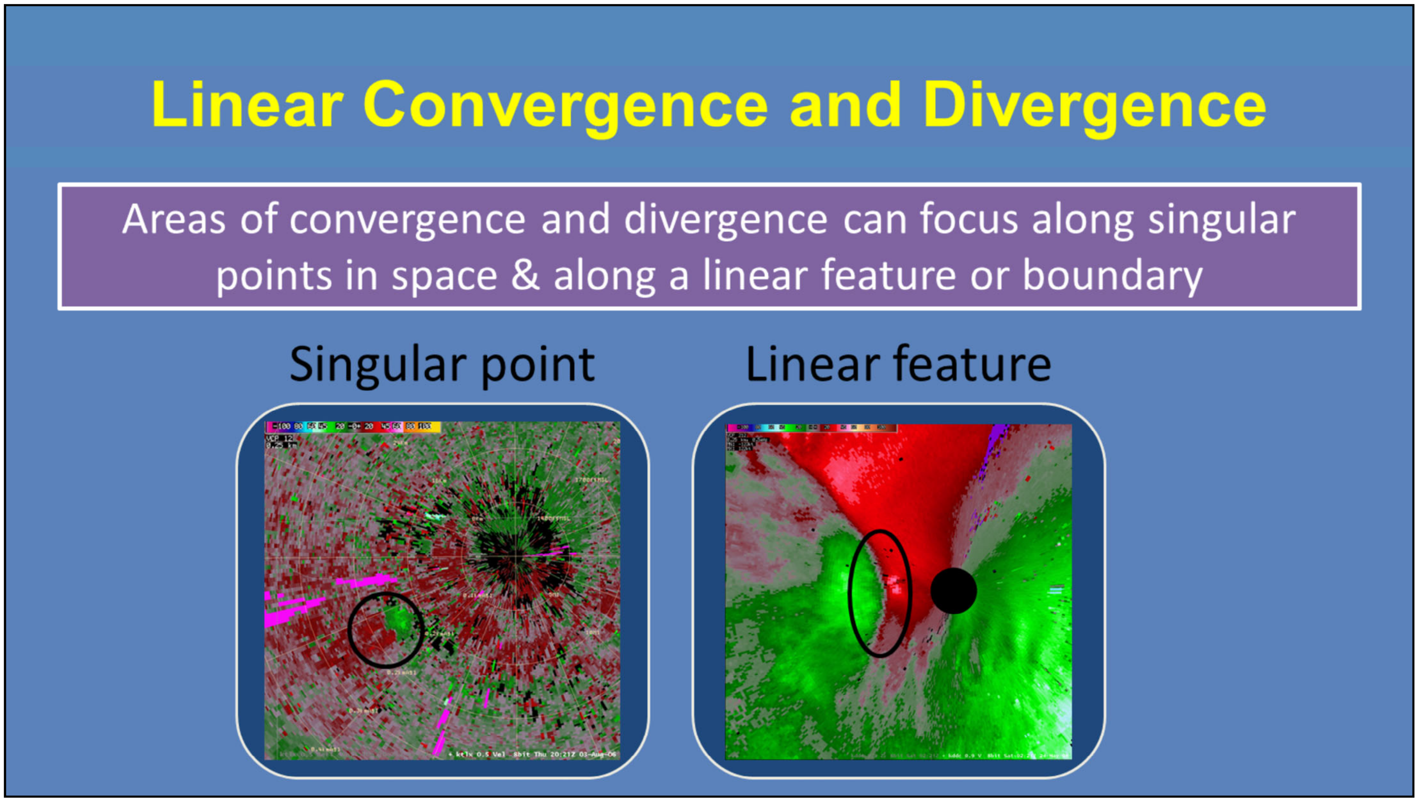
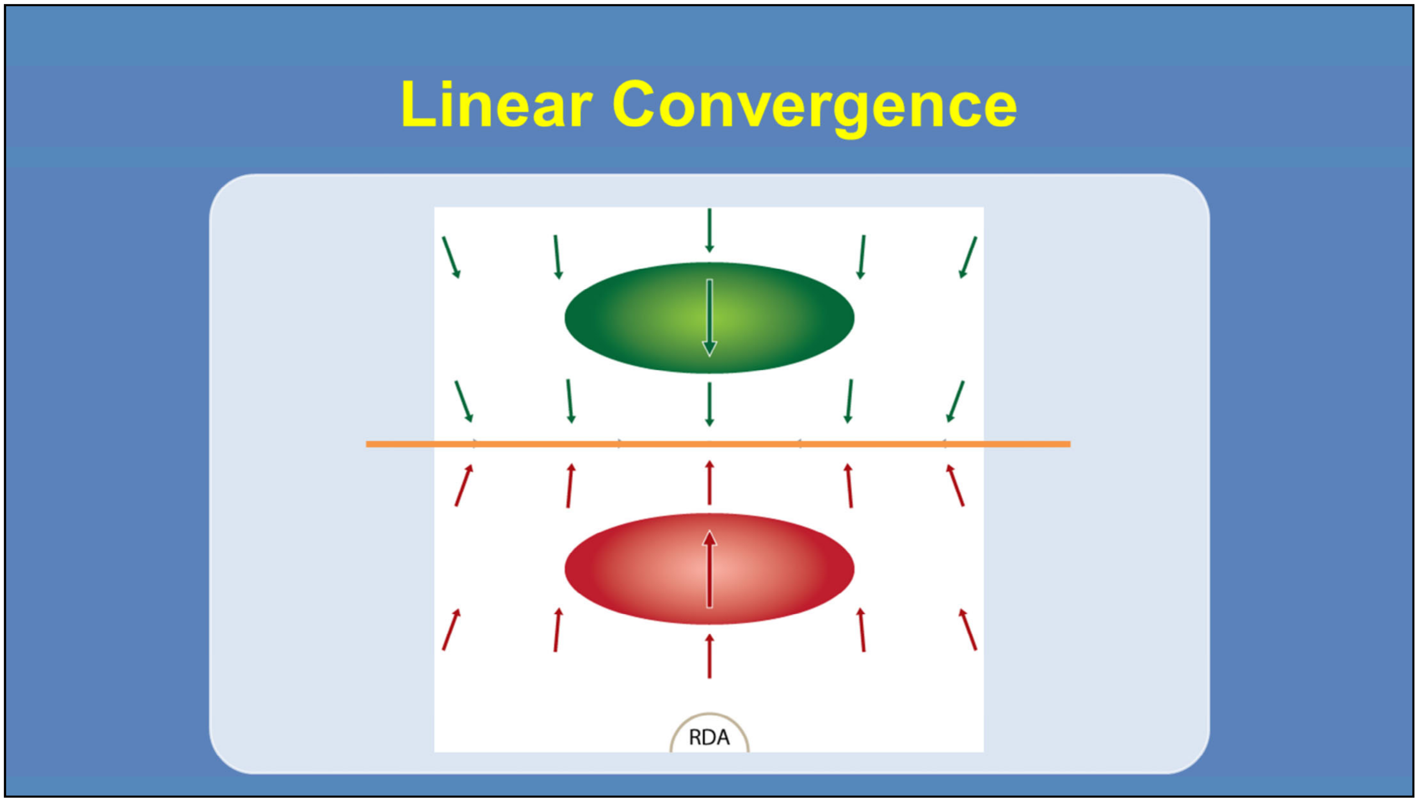
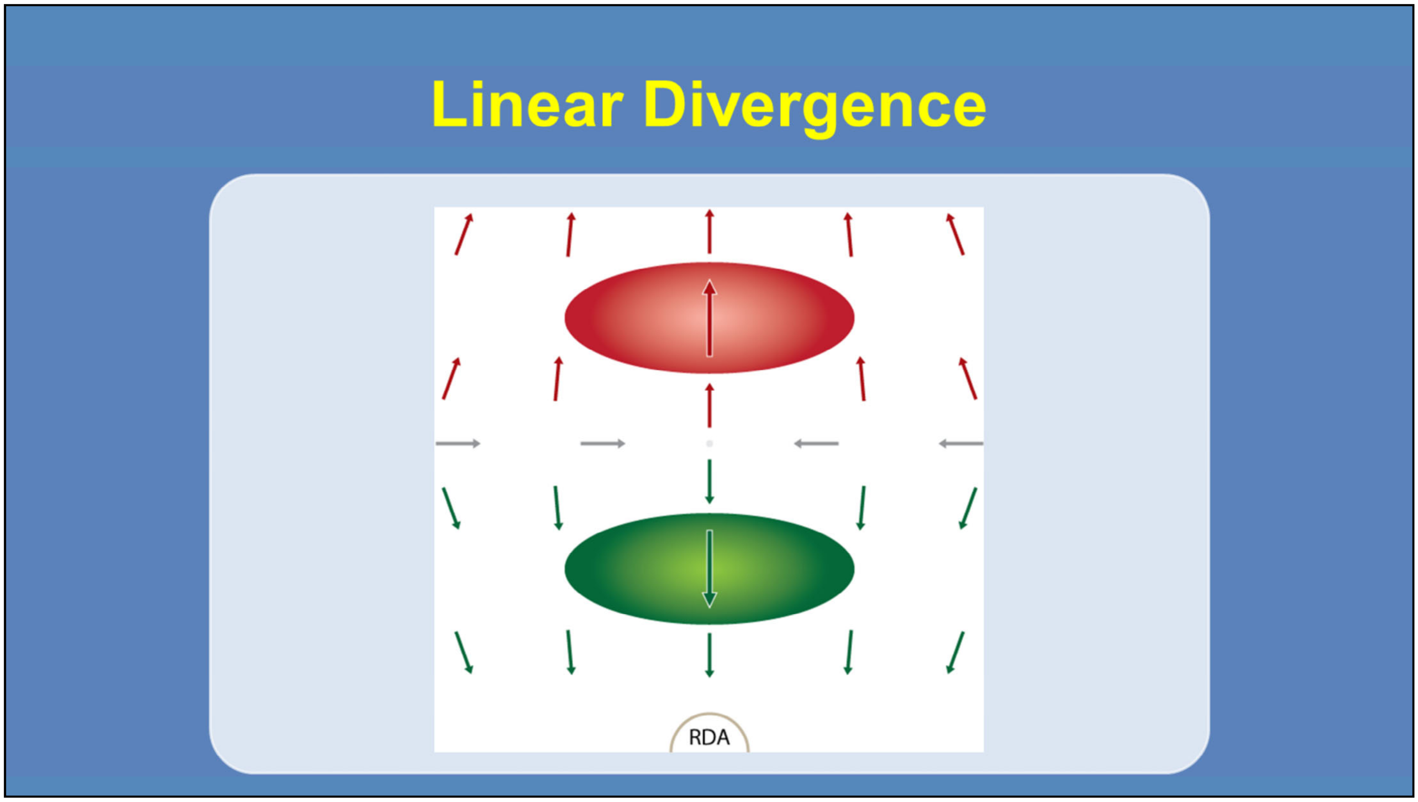


The examples shown in the last few slides were of pure convergence and divergence on a single point in space. However, areas of convergence and divergence can also focus along a linear feature.



Here is a basic diagram of a convergent velocity signature focused along a linear feature. As you can see here, both the maxima still lie along the same radial with the outbound velocity maximum closest to the RDA. The exception is that these maxima are elongated across a number of radials at about the same range from the RDA.



Same thing here for the divergent velocity signature. Again, both maxima are elongated across a number of radials, but now the inbound maximum is closest to the RDA.

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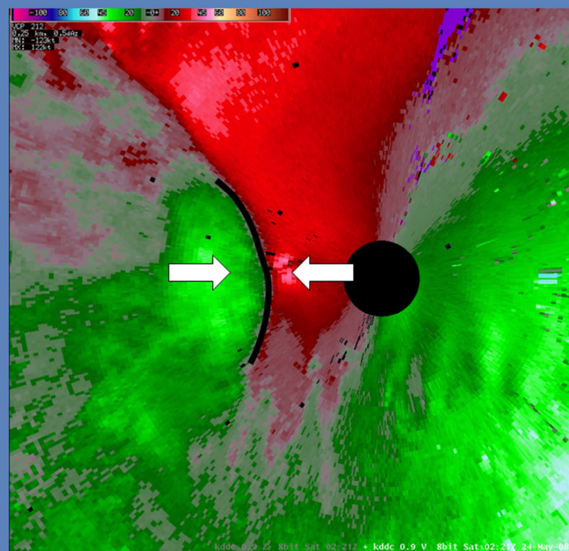
Linear Convergence Example



Here is a real-world example of a linear storm-scale convergence signature. In this case, a QLCS is approaching the RDA from the west, and a segment of the line is bowing out at this point, creating an enhanced convergence signature. Areas of enhanced convergence along a line segment could lead to mesovortex formation, which can enhance the wind threat and increase the probabilities of a tornado in areas of vorticity that are generated.

Small Scale Pattern - Rotation

For pure rotational patterns, the velocity maxima are equidistant from the radar

- **Cyclonic Rotation** – velocity maxima are equidistant from the radar with the inbound maxima on the **left**, as seen from the RDA
- **Anticyclonic Rotation** – velocity maxima are equidistant from the radar with the inbound maxima on the **right**, as seen from the RDA

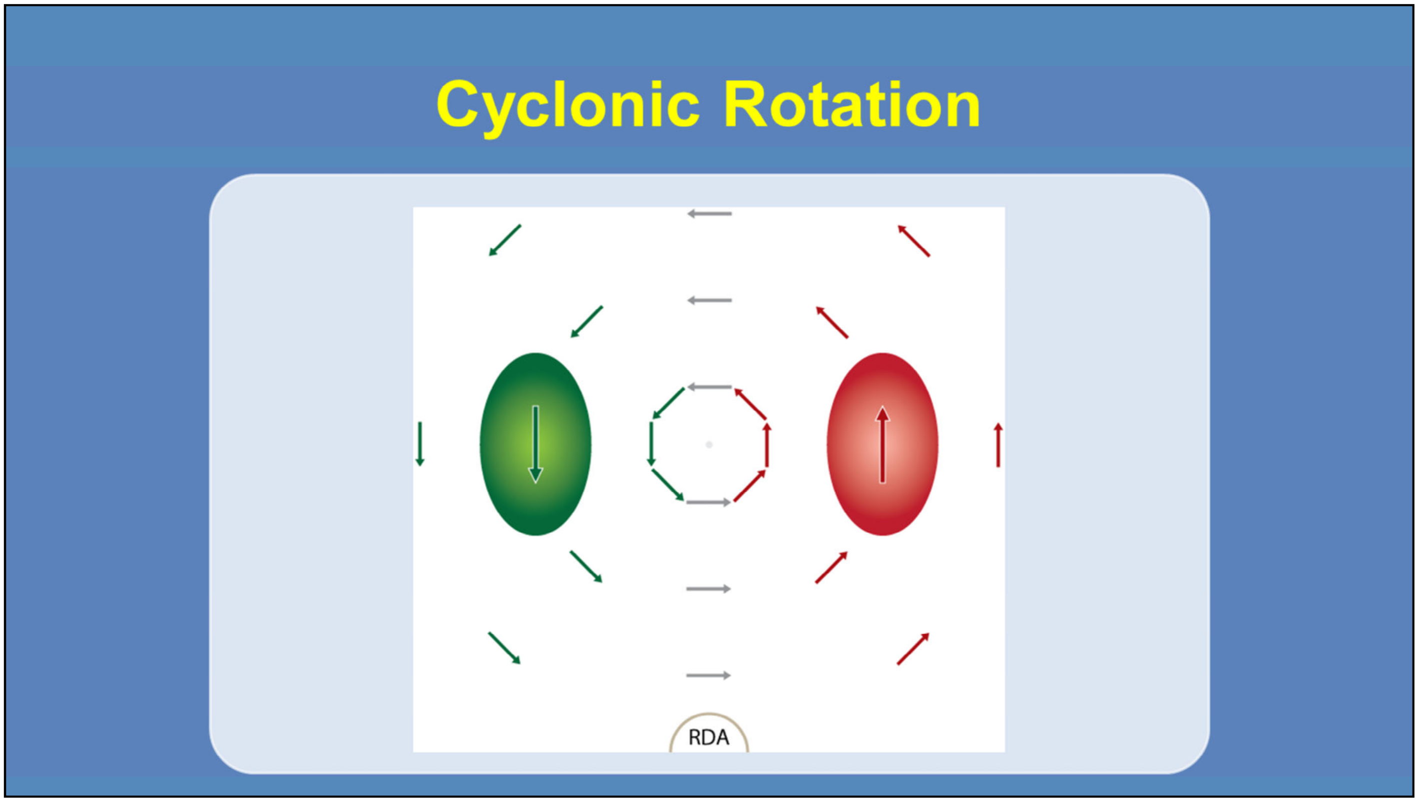
If the velocity maxima are not equidistant from the radar, then some degree of convergence/divergence exists with the rotation

So now let's consider times when there's a rotational component.

When examining pure rotational patterns, the velocity maxima are equidistant from the radar. Whether the pattern is cyclonic or anticyclonic is dependent upon whether the inbound maximum is on the left side or the right side of the signature, as seen by the RDA.

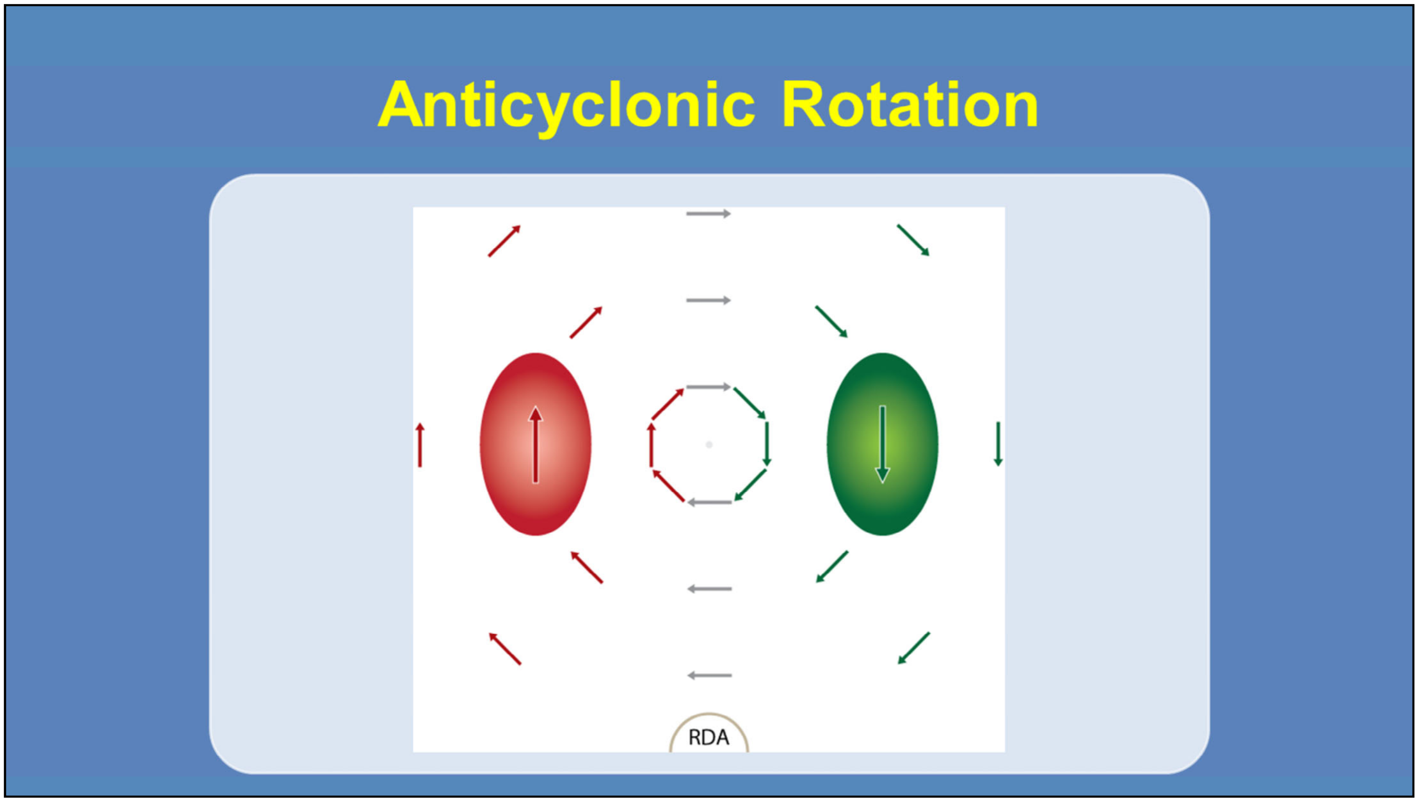
--With cyclonic rotation, the inbound maximum is on the left hand side, while the inbound maximum is on the right hand side with anticyclonic rotation.

--Velocity maxima oriented any other way means some combination of rotation and convergence or divergence is occurring. We'll talk more about that later in the lesson.



Again, for the following examples, the RDA is located to the south of the velocity signature.

Here is a basic example of pure cyclonic rotation. As you can see here, both of the velocity maxima are equidistant from the RDA with the maximum inbound velocities on the left side of the signature.



Now with pure anticyclonic rotation, both velocity maxima are again equidistant from the radar with the inbound velocity maximum on the right side of the signature.

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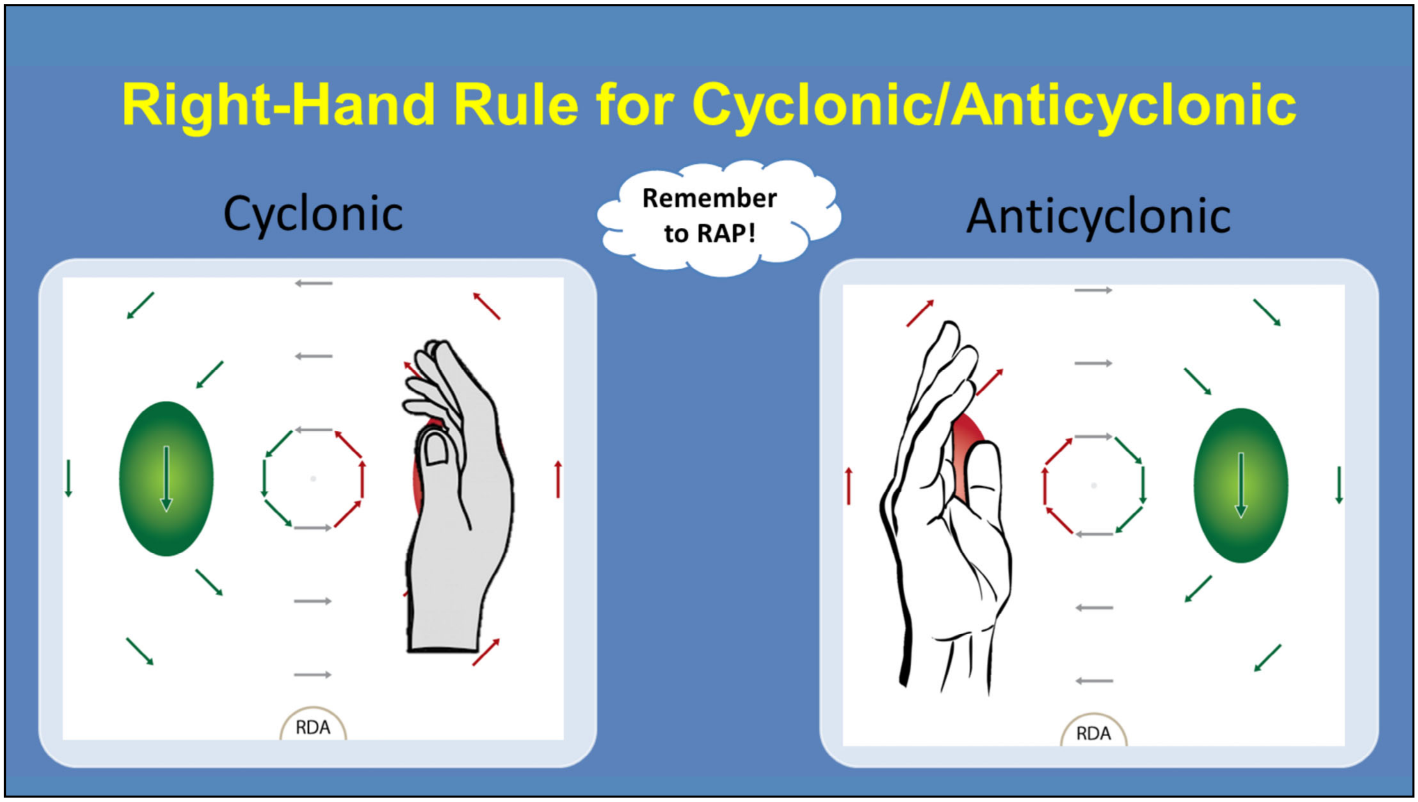
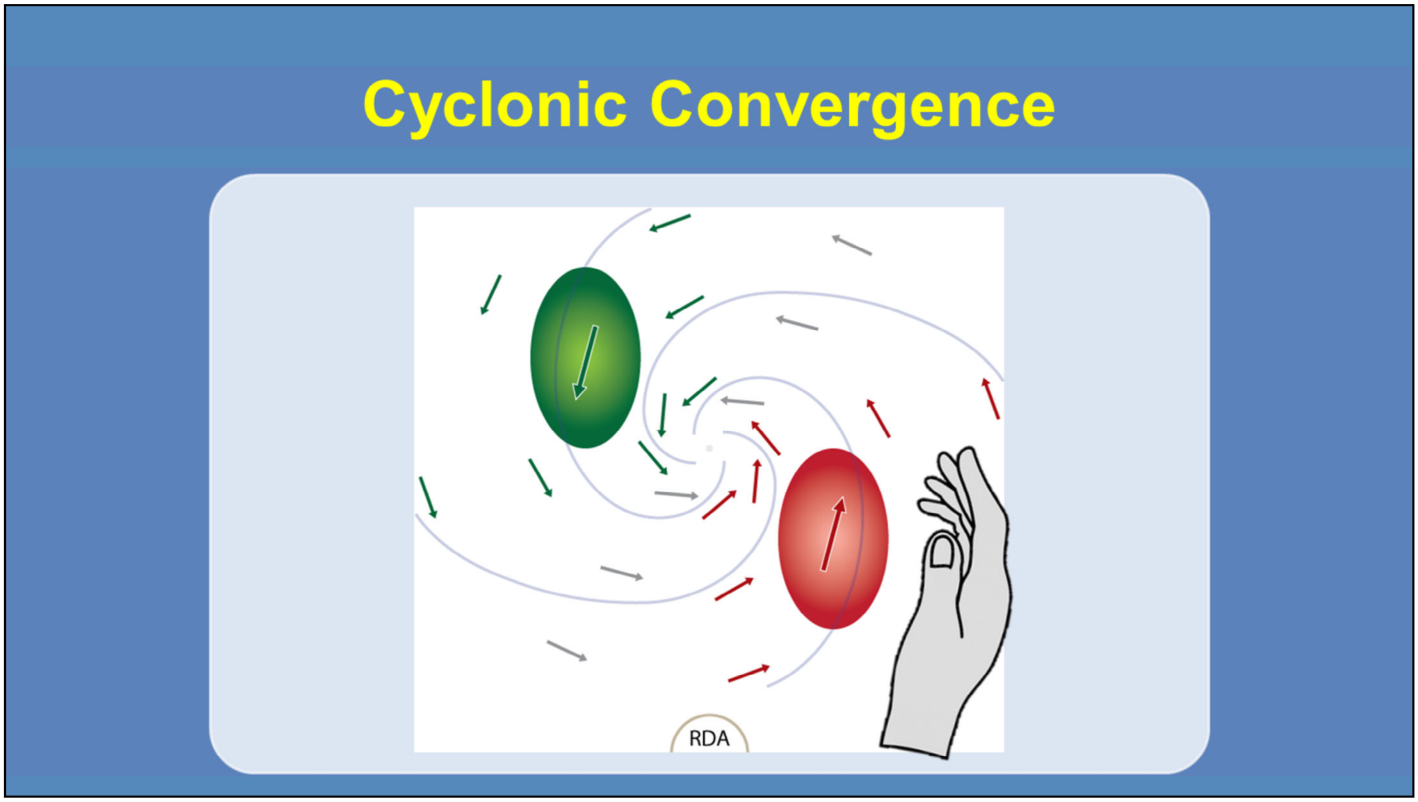
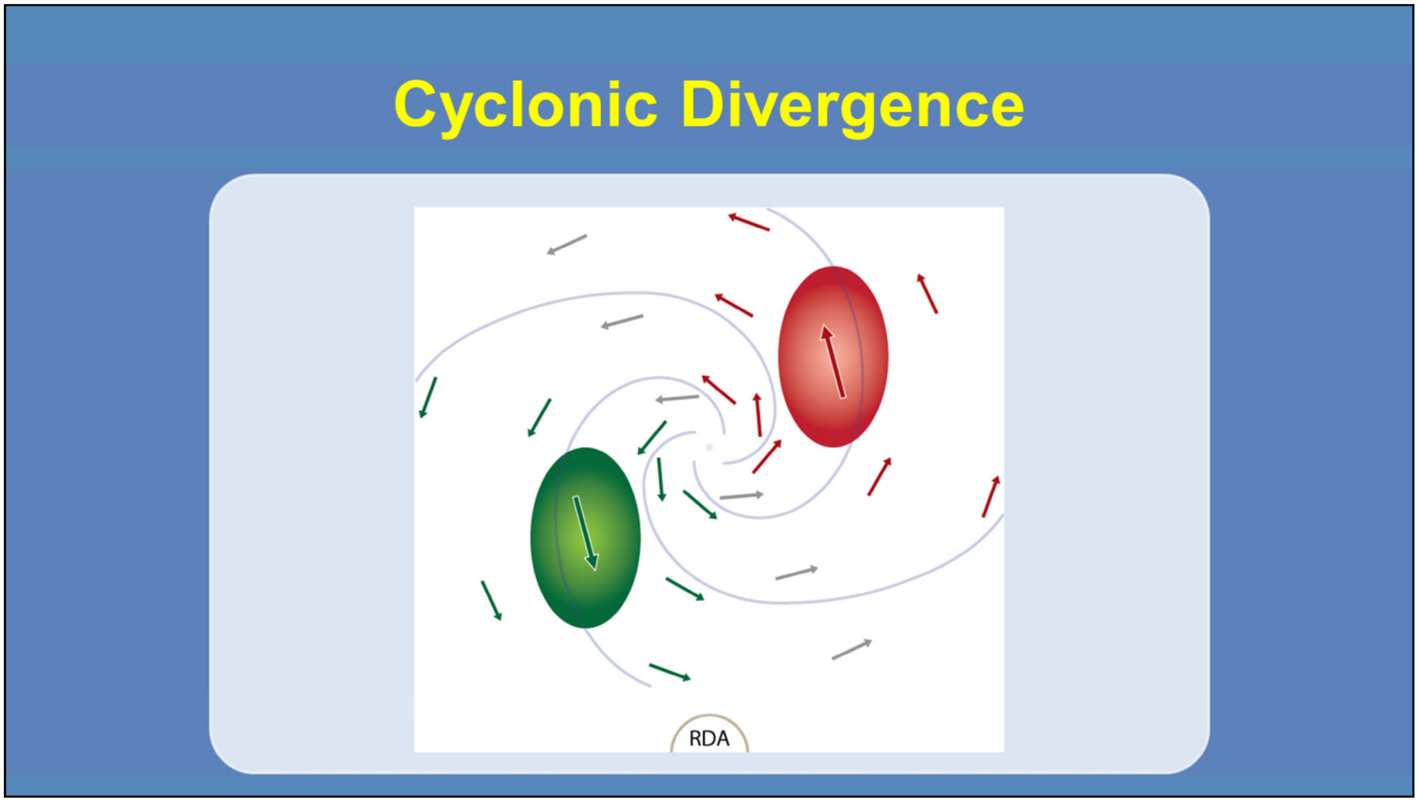


Another way to remember cyclonic and anticyclonic (that's much easier for me) is to use the right-hand rule. First, I RAP to find the outbounds (red, away, positive). Then I align my right hand in that direction, with the base of my hand closest to the RDA and my fingertips pointing outbound. Then I curl my fingers in the direction of the inbounds (or green). When my thumb faces towards me, it's cyclonic. When it faces away from me (or into the screen), it's anticyclonic.

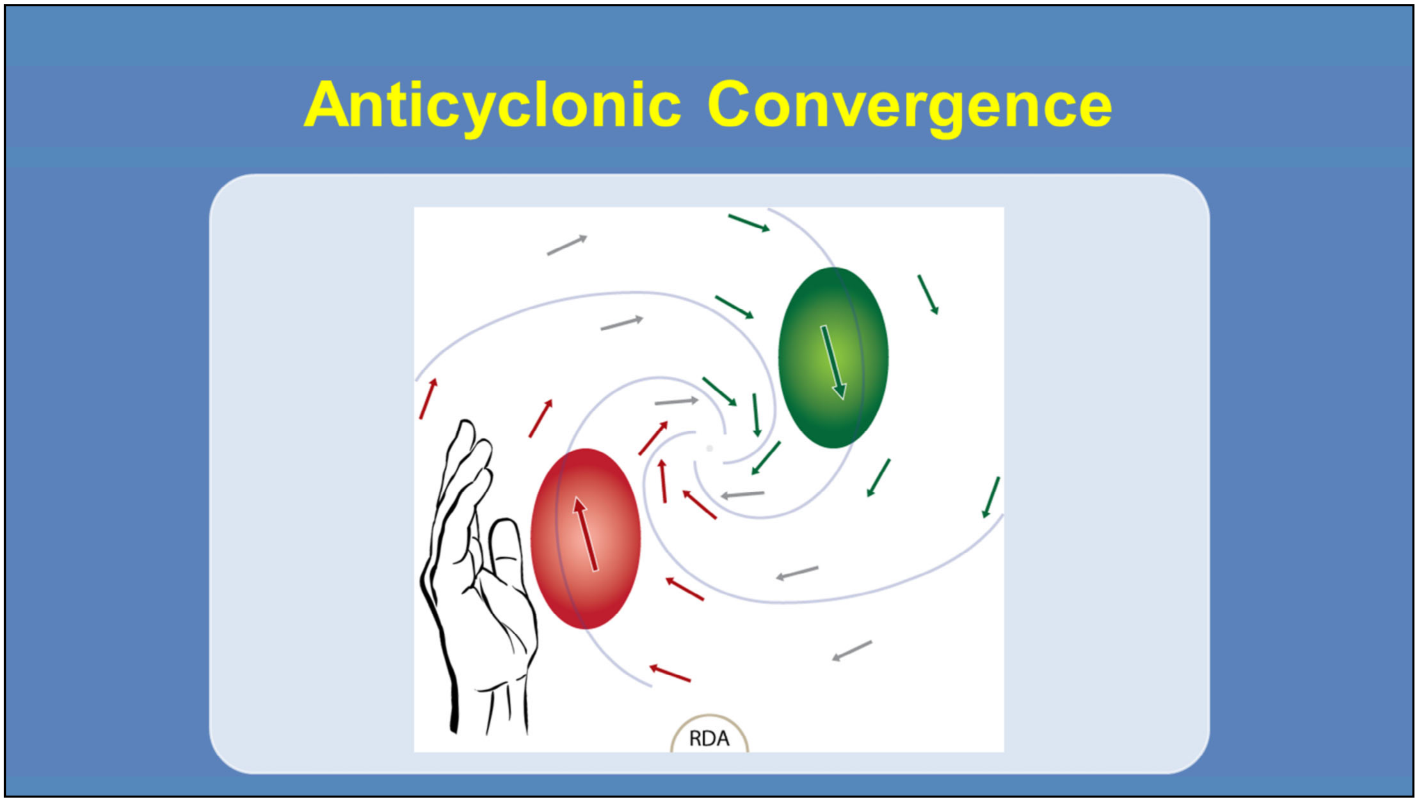


So let's put it all together and show combinations of both rotation and convergence or divergence. This is an example of cyclonic convergence. First note that both the maxima are not on the same radial and not equidistant from the radar. So it can't be pure rotation.

Here, the outbound maximum is closest to the RDA, signifying convergence, and the inbound maximum is to the left, signifying cyclonic rotation. Similarly, the right hand rule would have your hand oriented like this, curling towards the inbounds, and giving you a thumbs up, also signifying cyclonic rotation.



Here is an example of cyclonic divergence. The inbound maximum is closest to the RDA, signifying divergence, and the inbound maximum is still to the left, signifying cyclonic rotation.



Here is an example of anticyclonic convergence. The outbound maximum is closest to the RDA, signifying convergence, and the inbound maximum is to the right, signifying anticyclonic rotation.

Once again, the right hand rule would have your hand oriented like this, curling towards the inbounds, and giving you a thumbs down into the screen, signifying anticyclonic rotation.

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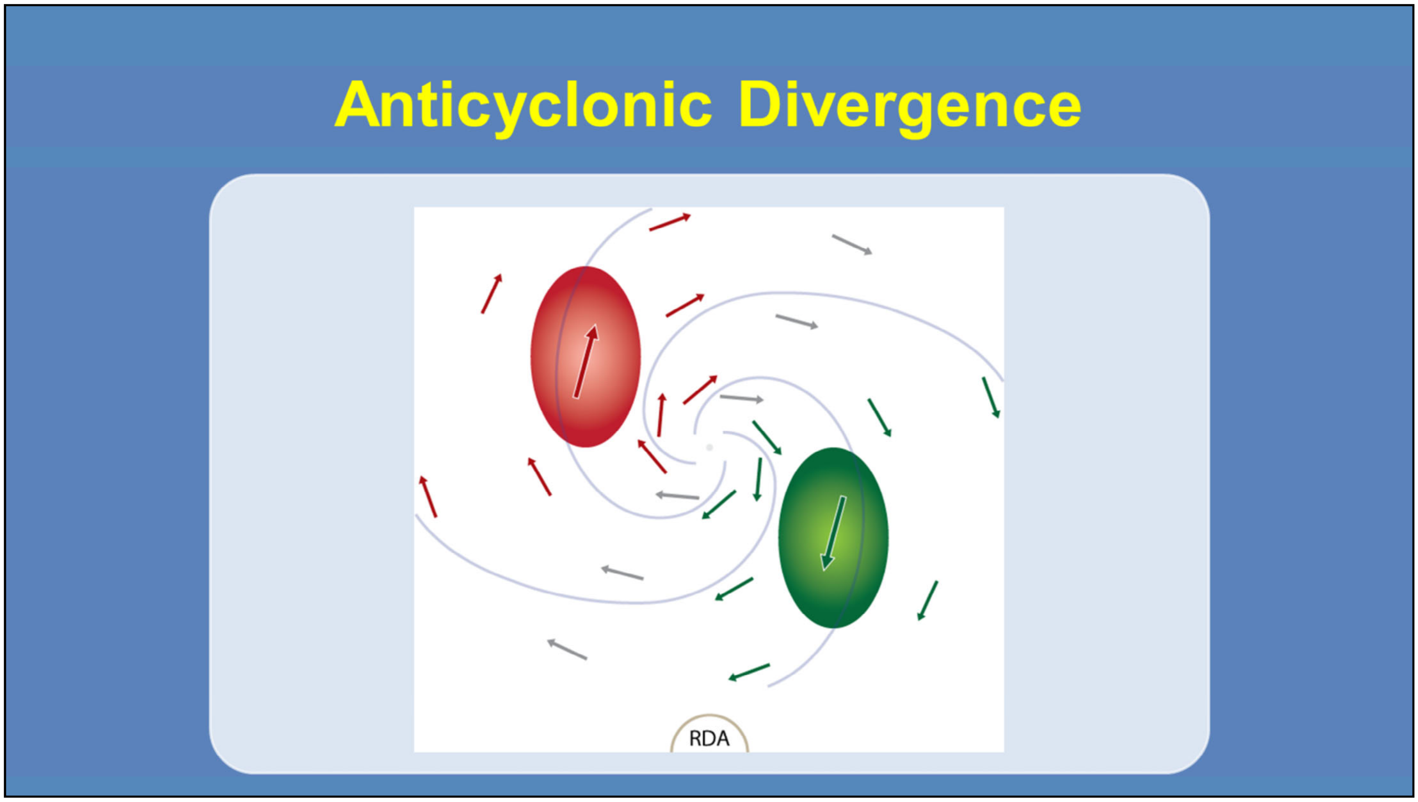
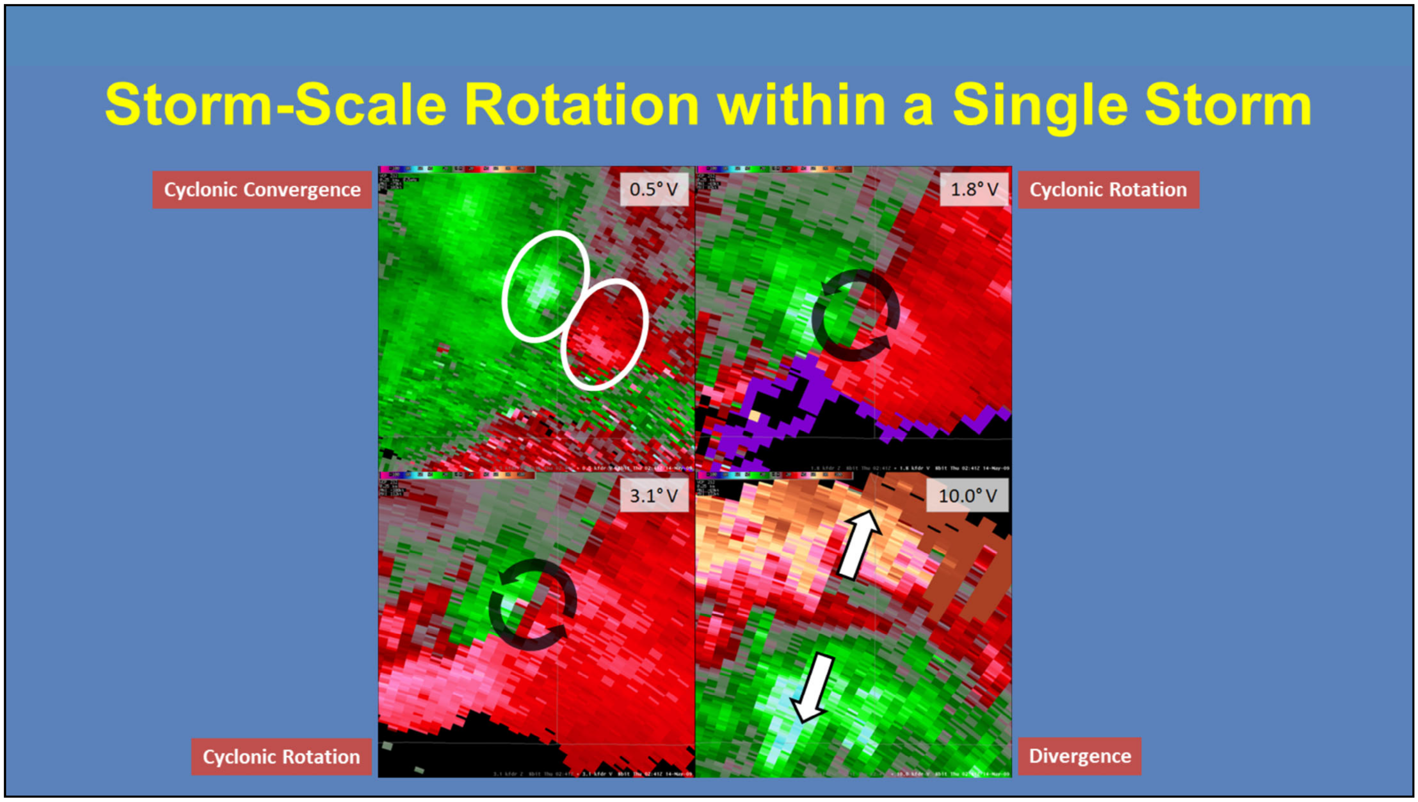


Finally, here is an example of anticyclonic divergence. The inbound maximum is closest to the RDA, signifying divergence, and the inbound maximum is to the right, signifying anticyclonic rotation.



Here is a real-world example of storm-scale signatures through various tilts of what would become a tornadic supercell. Using the range gate method, we can note that the RDA is located to the south-southwest of the storm.

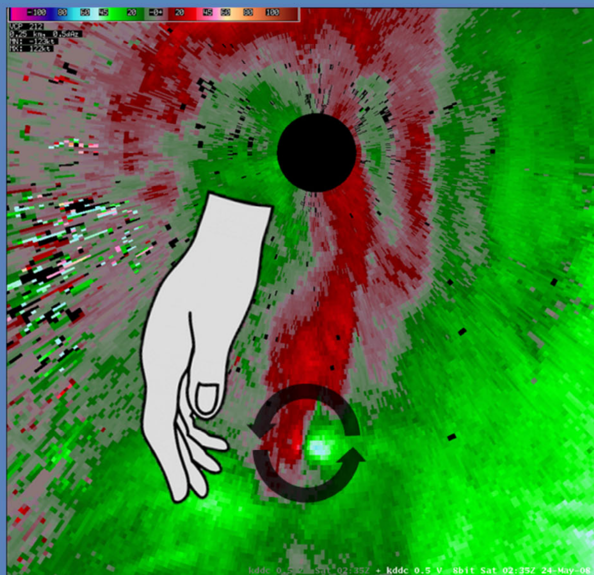
--In the upper-left panel (0.5° tilt), you see a cyclonic convergence signature with the storm. The red outbound maximum is slightly closer to the RDA, signifying convergence, and the inbound maximum is to the left, signifying cyclonic rotation.

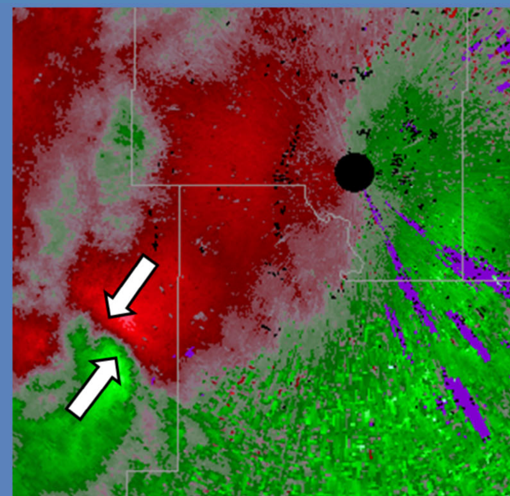
--The next two elevation scans up (1.8° tilt in the upper-right panel and 3.1° tilt in the lower-left panel) are close to “pure” cyclonic rotation, since the maxima are equidistant from the radar.

--Finally, the highest tilt (in the lower-right panel) is an example of storm-top divergence, with the maxima oriented along the same radial.

Move onto the next slide when you are ready.

Remember RDA location!





One final note…Don’t forget to keep in mind where the RDA is located when identifying storm-scale signatures. Til now, we’ve only shown examples where the RDA is to the south. But in this example, the RDA is north of the storm-scale feature.

This is why I like the right-hand rule, because you don’t have to remember left and right. Simply find the outbound maximum, orient your right hand such that your wrist is closest to the radar, and curl your fingers towards the inbound maximum. In this example, the thumb is pointing towards you, so it’s cyclonic rotation. Since the maxima are equidistant from the radar, there’s no convergent or divergent signatures.

But this example on the right shows cyclonic convergence because the outbound maximum is closer to the RDA.

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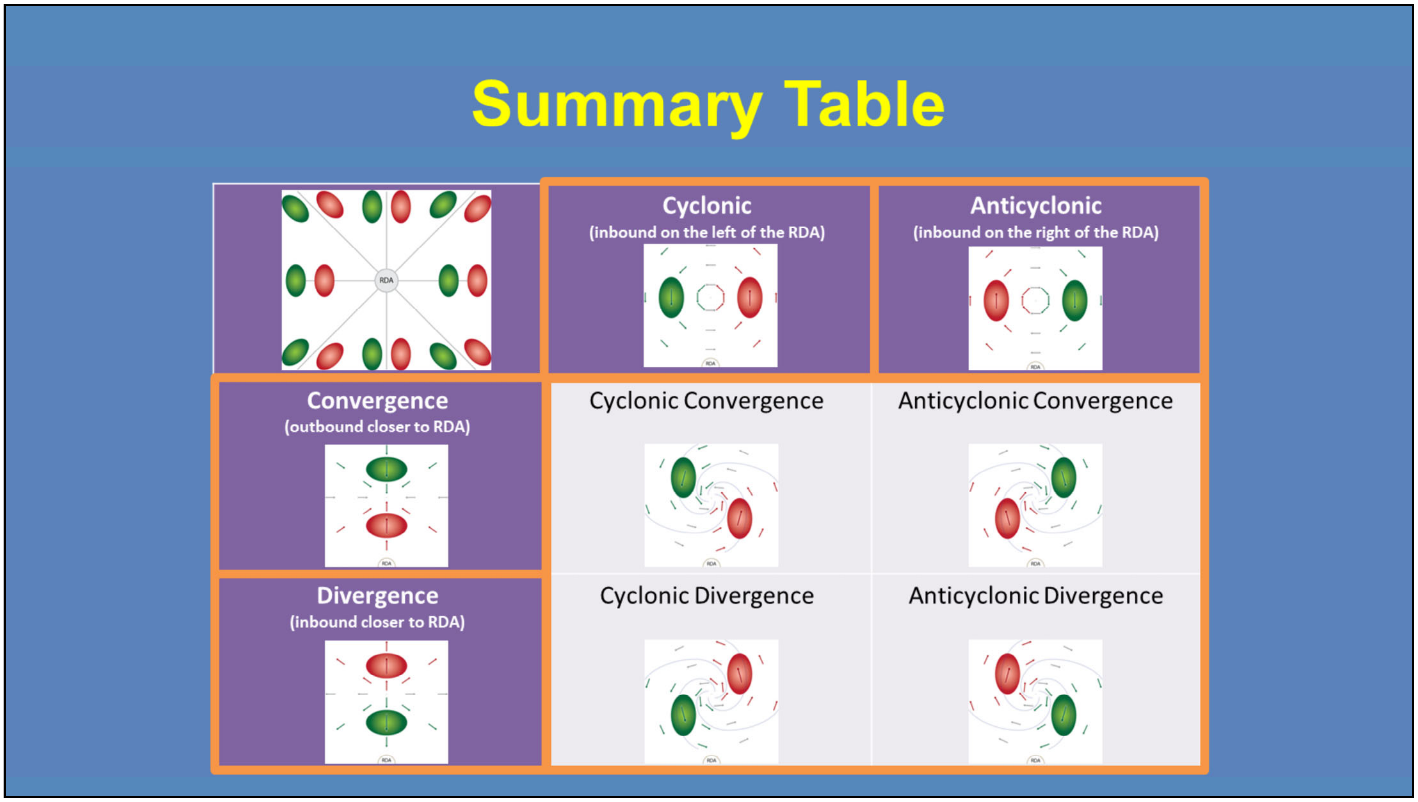

Let’s go ahead and summarize storm-scale velocity signatures. Convergence signatures have the velocity maxima lie along the same radial with the outbound maximum closest to the radar. Divergence signatures have the velocity maxima lie along the same radial with the inbound maximum closest to the radar.

Cyclonic rotation signatures have the velocity maxima equidistant from the radar with the inbound maximum to the left, as seen from the radar. Anticyclonic rotation signatures have the velocity maxima equidistant from the radar with the inbound maximum to the right, as seen from the radar.

Velocity maxima oriented any other way means some combination of rotation and convergence or divergence is occurring.

Move onto the next slide when you are ready.

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Velocity Contamination Artifacts

Introduction

Notes:

Welcome to this lesson on Velocity Contamination Artifacts. Let’s get started.

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Learning Objectives

Learning Objectives

1. Identify the common sources of velocity contamination artifacts
2. Identify both the common and alternate signatures associated with velocity artifacts
3. Identify the reason why velocity and spectrum width data might have their respective data appearance
4. Identify the steps for identifying velocity couplet imposters

Notes:

Here are the learning objectives for this lesson. Please take a moment to read through them and advance to the next slide when you are ready.

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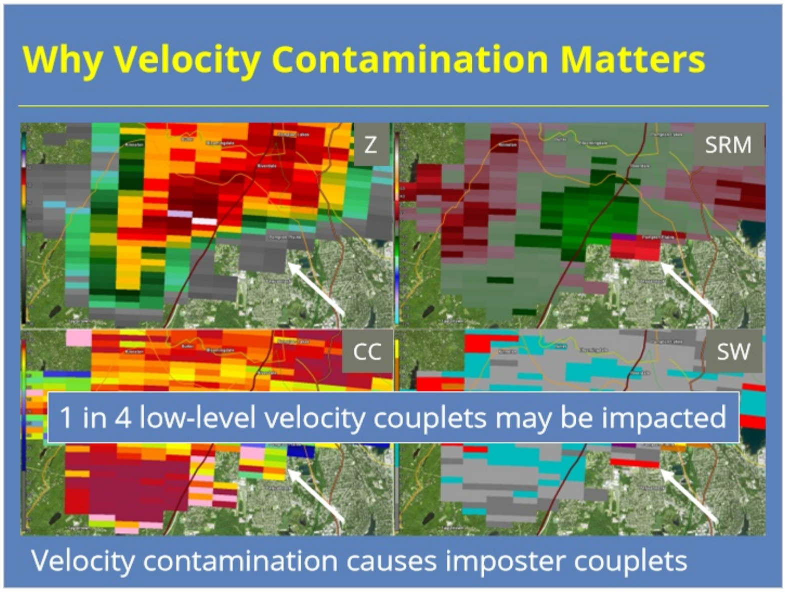
Why Velocity Contamination Matters



Notes:

RAC has a lesson dedicated to data quality issues, and velocity contamination sounds like a data quality issue. So, why does Velocity Contamination have it's own lesson? Well, this topic has grown in visibility over the last several years. Since this issue disproportionately impacts Tornado Warning decisions, we see it as a higher profile problem. Researchers recently focused attention on the subject in three papers as well. Nai et al. (2020) coined the term elevation sidelobe contamination to describe what we have commonly called vertical sidelobe contamination. They identified some parameters that best show when this contamination occurs, which was more fully defined in Boettcher and Bentley (2022). This lesson will borrow from their work to provide a basic methodology for identifying when velocity contamination occurs due to either elevation sidelobe contamination or three-body scatter spikes. In Bentley et al. (2021), they found about one in four low-level velocity couplets over a three year period were potentially impacted by this artifact. Armed with this information, hopefully you see it as a higher profile problem that matters, too.

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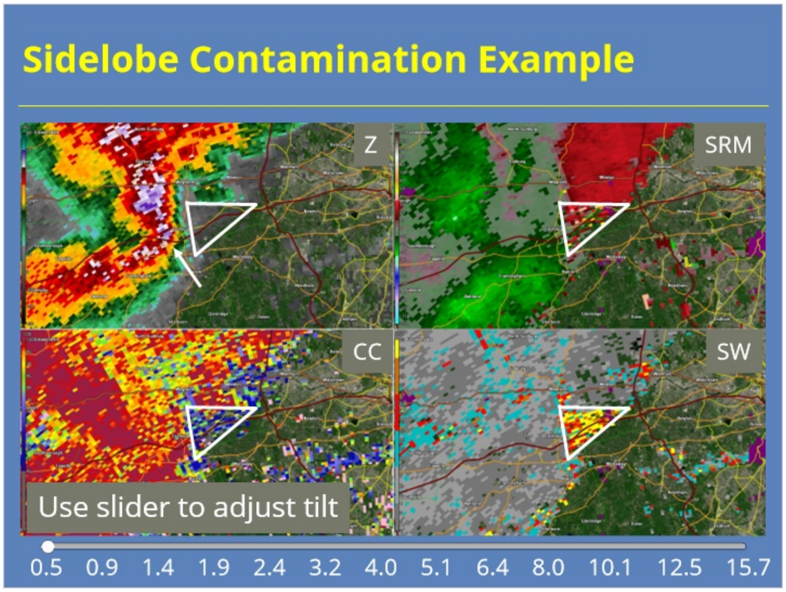
Sidelobe Contamination Example



Notes:

Elevation sidelobe contamination is the more common source of velocity contamination of the two we mention in this lesson. We show an example mentioned by Boettcher and Bentley (2022) of elevation sidelobe contamination on the 0.5 tilt indicated by the white triangle in each product. We show a 0.5 SAILS tilt collected between the 3.2 and 4.0 scans, and you can use the slider bar on the bottom of the slide to view each tilt. Forecasters commonly make a mistake when diagnosing elevated sidelobes by only focusing on the tilts a specific range of tilts away from 0.5 (usually about 3 degrees) and directly above the affected area. That’s one reason we will refer to the phenonmena as elevated or elevation, and not vertical, sidelobes in this lesson. In this particular example, we likely see a more cumulative sidelobe contamination not only from directly above on the 6-10 degree tilts, but also from the strong reflectivity returns just to the west (and at the same range) of the highlighted area on all of the tilts between 0.5 and 10 degrees (as indicated by the white arrows).

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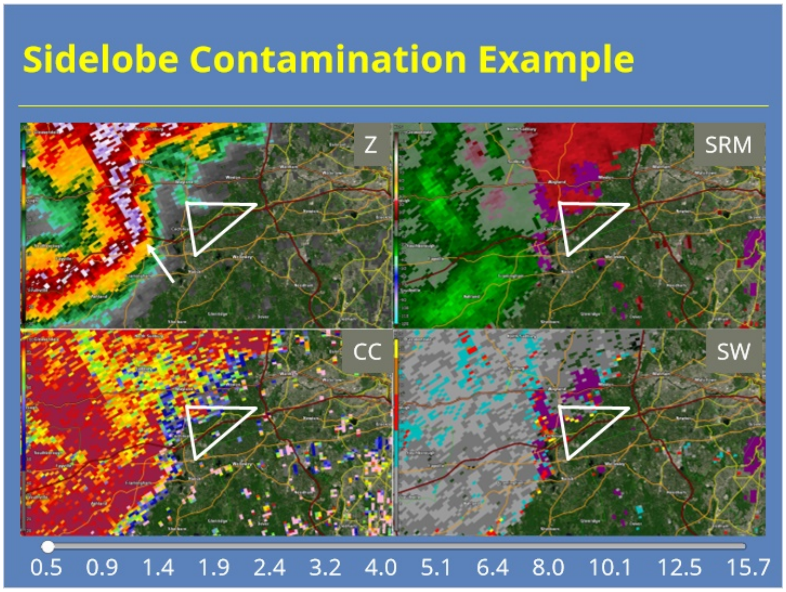
0.9 (Slide Layer)



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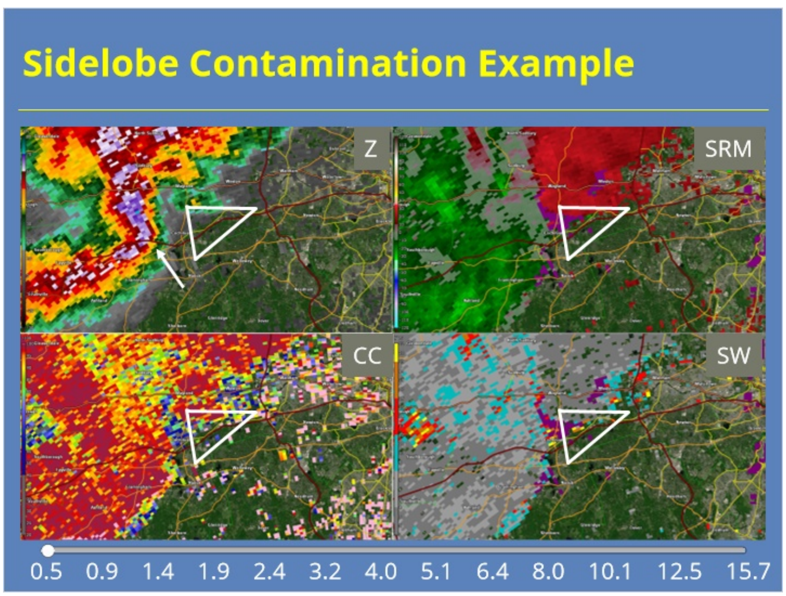

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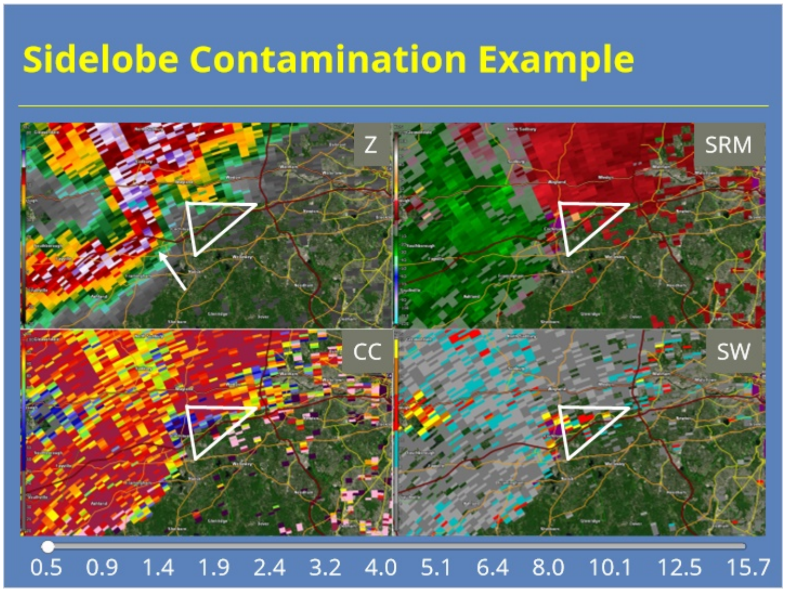

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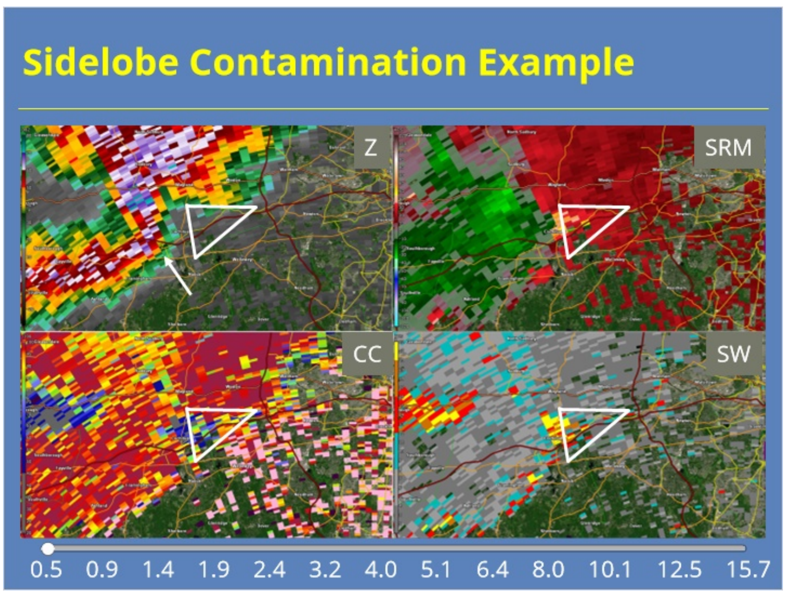

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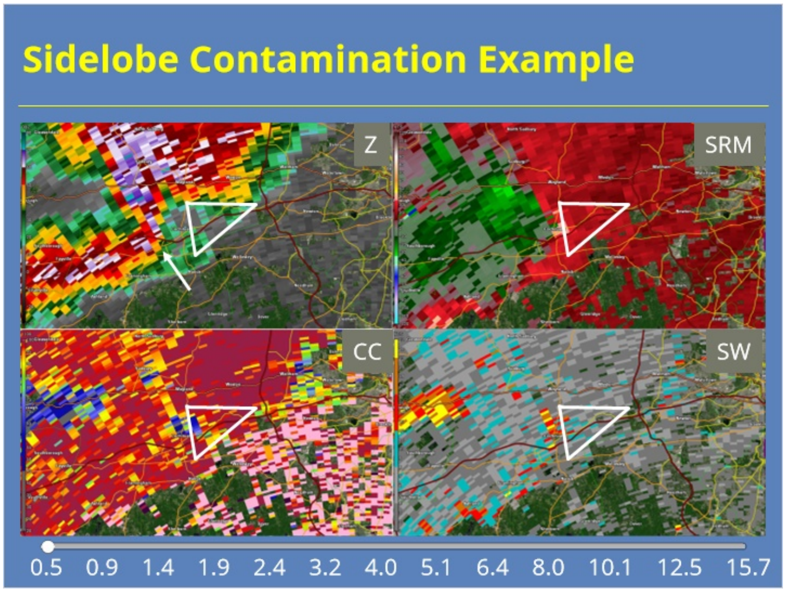
3.2 (Slide Layer)



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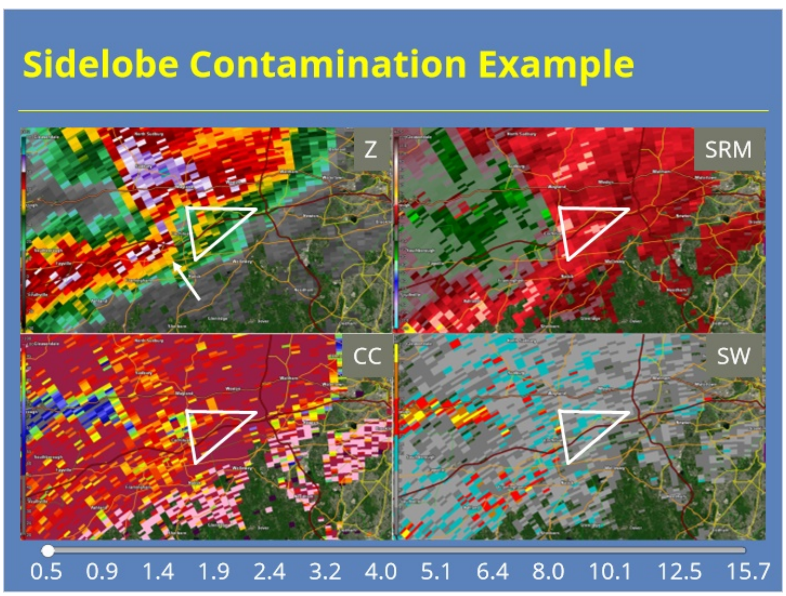

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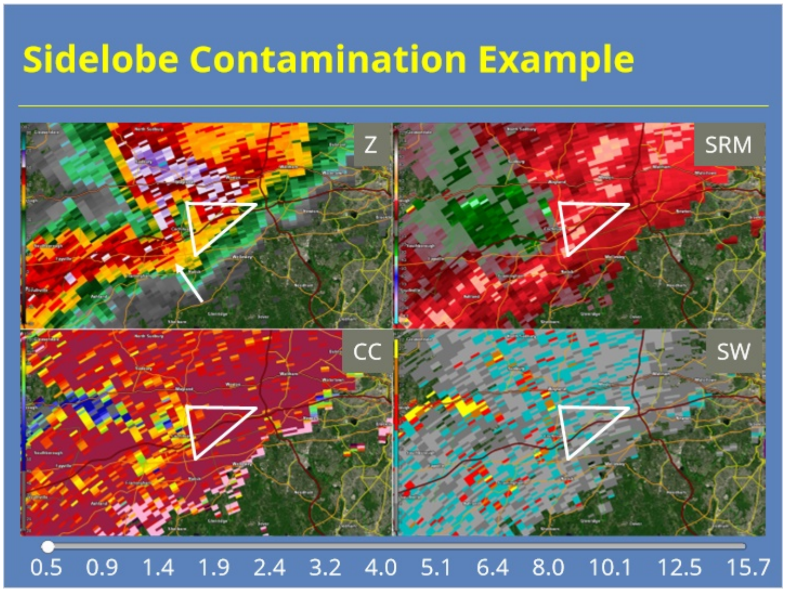
5.1 (Slide Layer)



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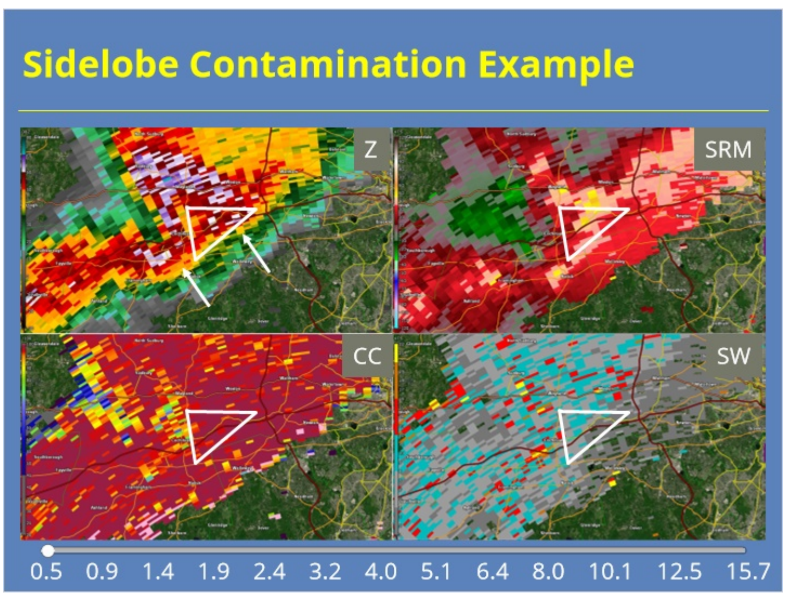

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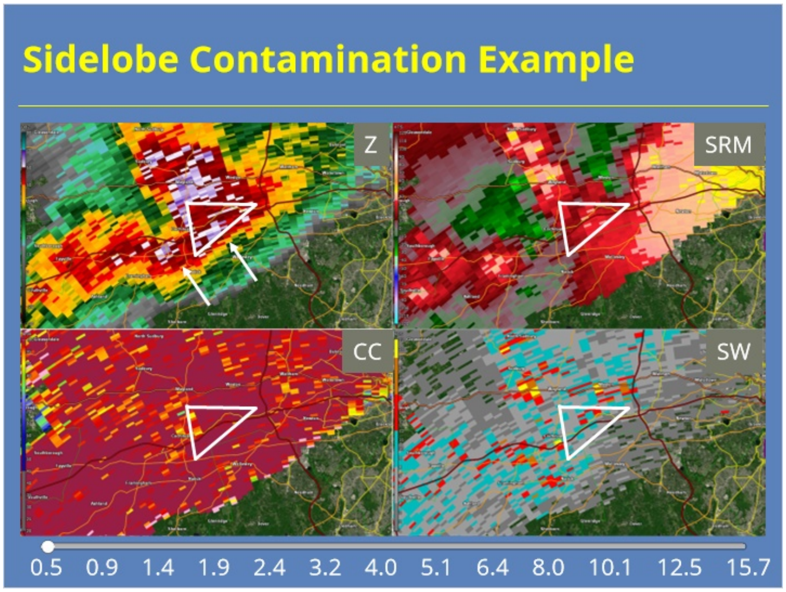
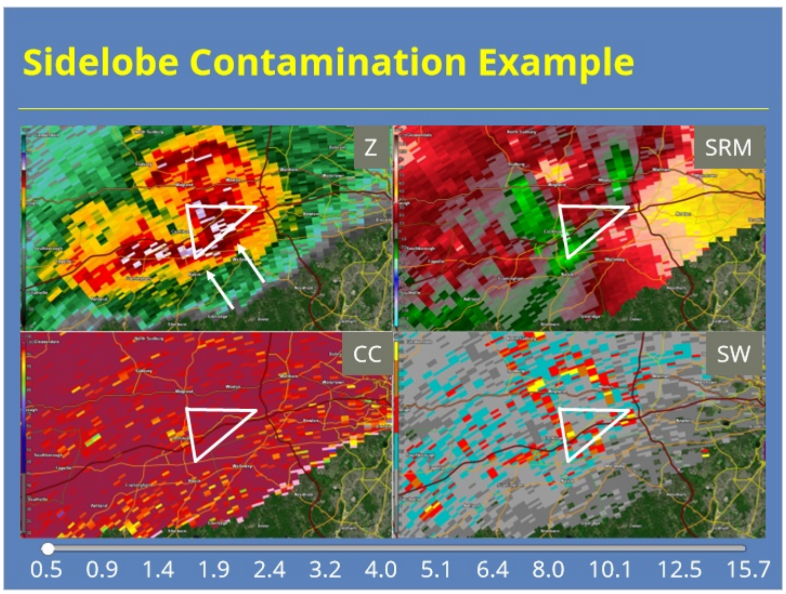
8.0 (Slide Layer)



10.1 (Slide Layer)



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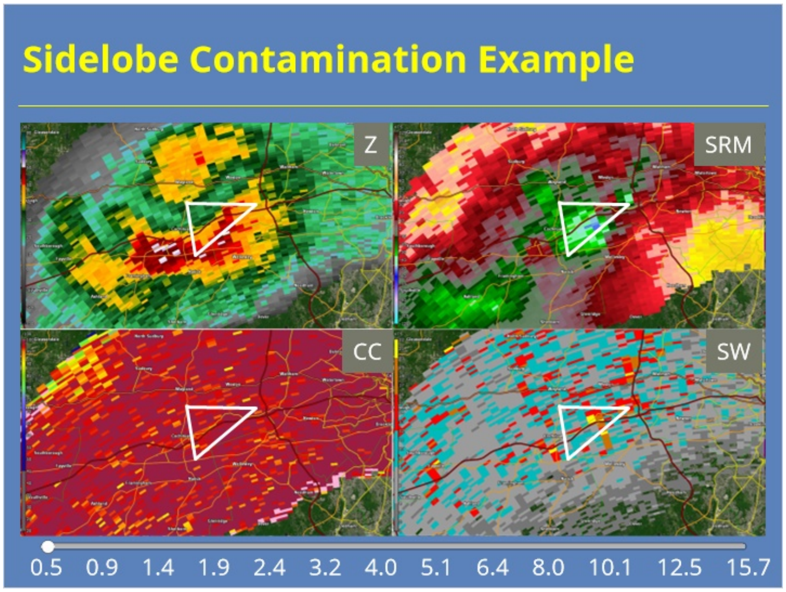
12.5 (Slide Layer)



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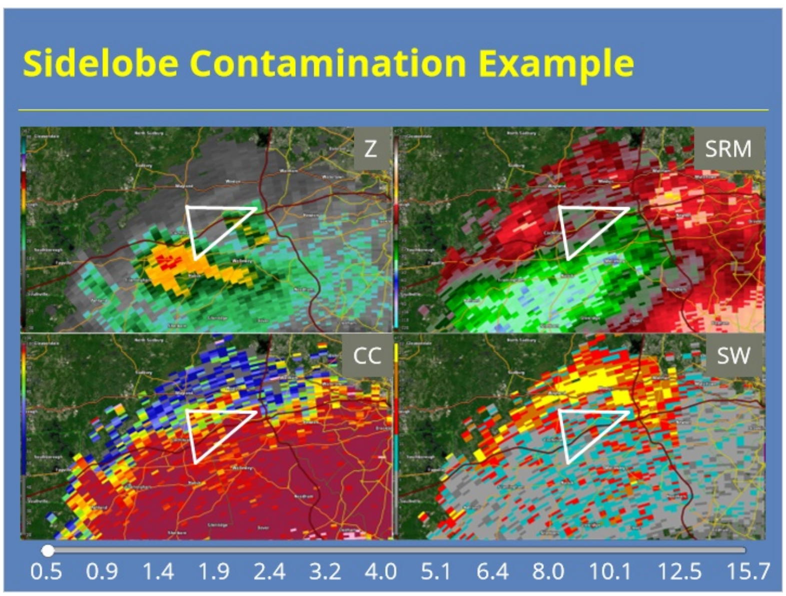

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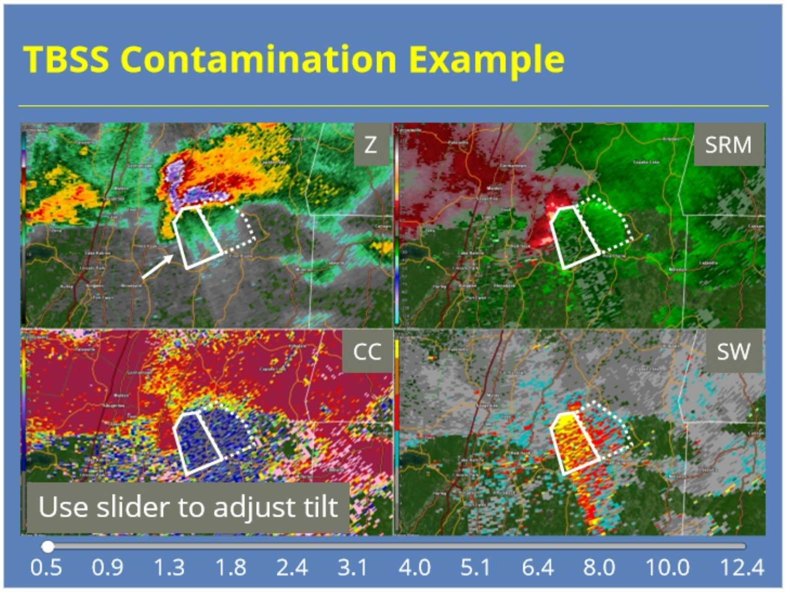
TBSS Contamination Example



Notes:

Three body scatter spike (or TBSS) contamination occurs when you observe a TBSS in the vicinity of a storm's inflow region. In most cases, these situations occur when storms are located south of the radar and the storm has a significant hail core. Boettcher and Bentley (2022) presented this example, and it has multiple interesting features. A prominent TBSS eminates from the back side of the storm in the supercell's inflow region forward flank. The reflectivity values in this region approach 30 dBZ, but the storm-relative velocity, correlation coefficient, and spectrum width all show clear contamination. Additionally, this case shows signs of both TBSS and elevation sidelobe contamination. Notice how the SRM and SW data appear different in the western and eastern sides of the prominent spike in Reflectivity? In the area where SW is higher to the west (highlighted by the solid white line), we likely see both forms of contamination. Evidence of the TBSS remains prominent through the 6.4 tilt. The area highlighted by the dashed line likely has less TBSS influence and appears dominated more by the elevation sidelobe contamination from the core visible aloft from 3.1 to 8.0 degrees. Even though this elevated core isn't directly over the TBSS, it still falls in the sidelobes contributing to the returned signal.

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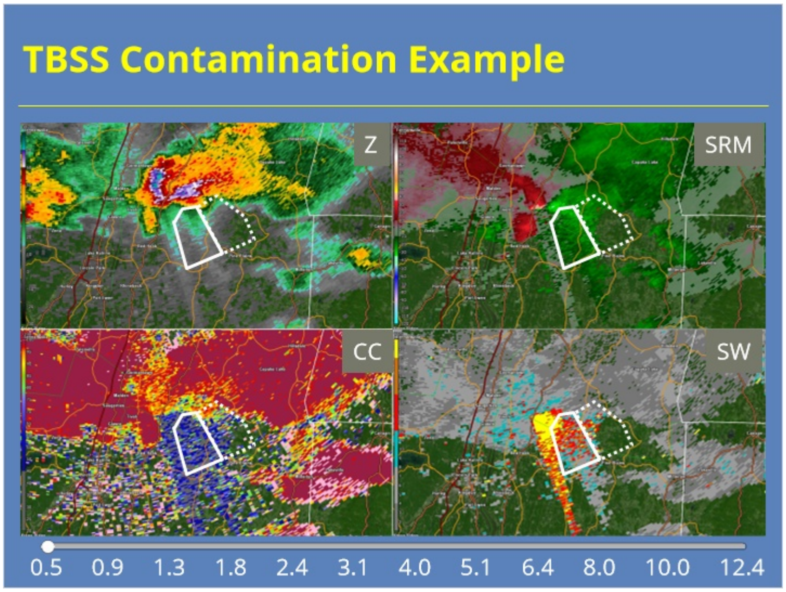
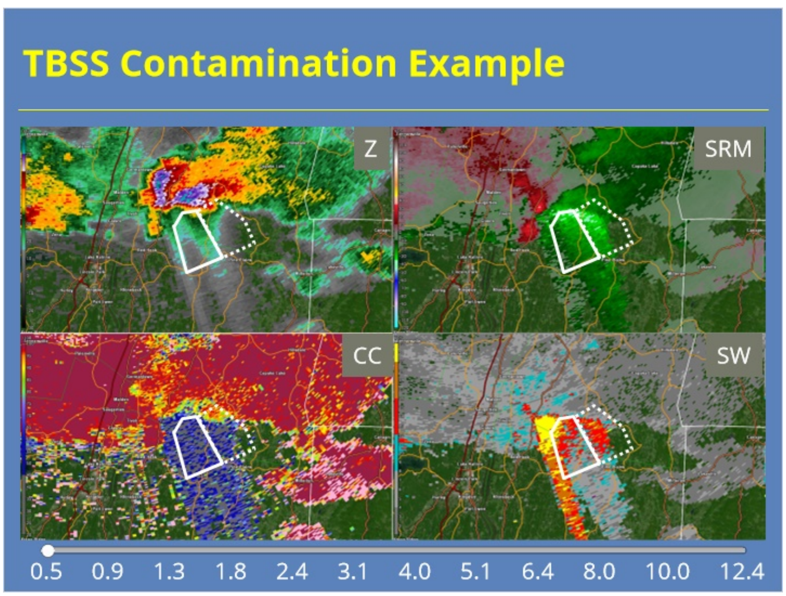
0.9 (Slide Layer)



1.3 (Slide Layer)



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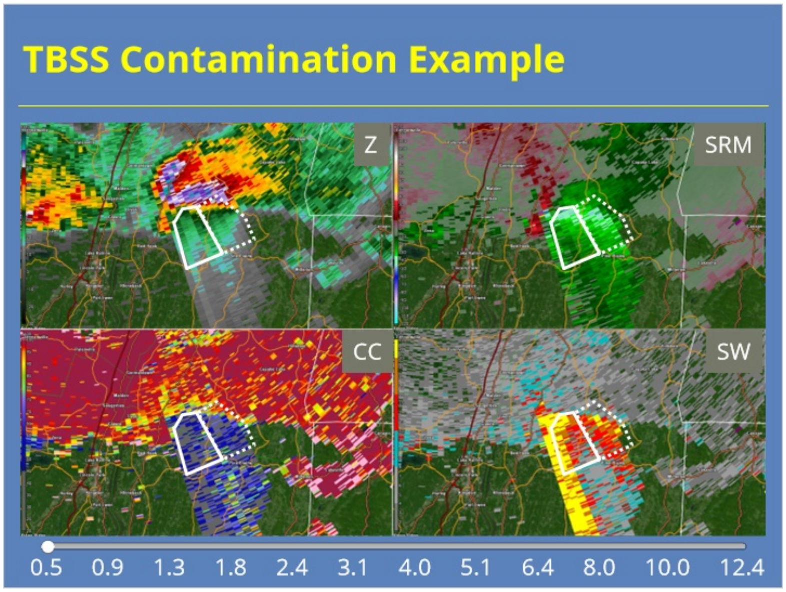
1.8 (Slide Layer)



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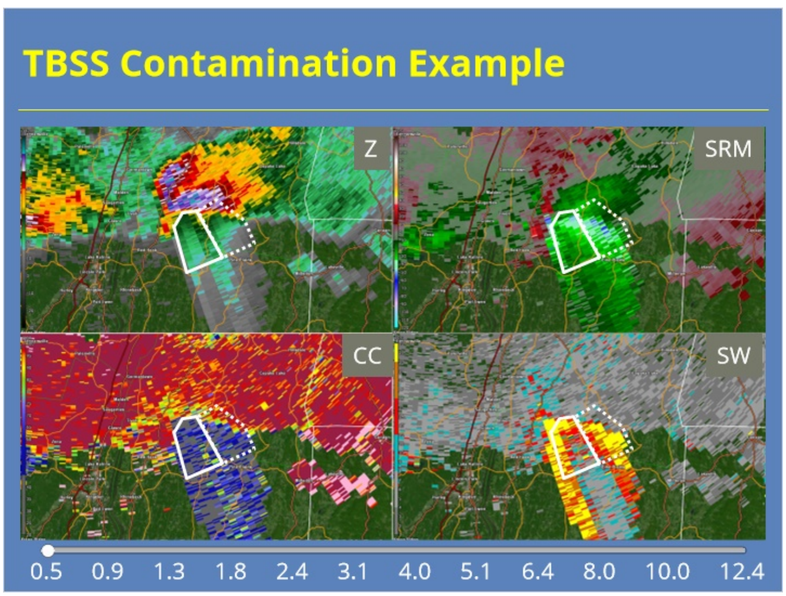

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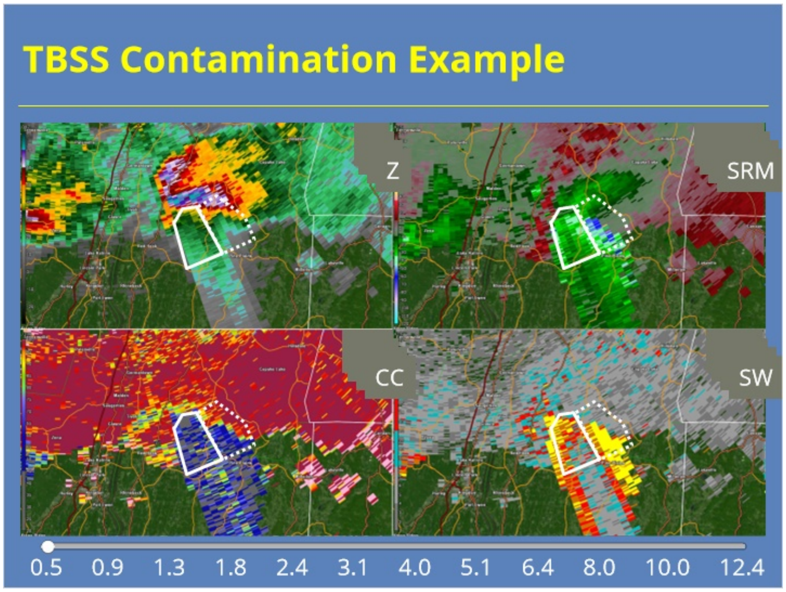
3.1 (Slide Layer)



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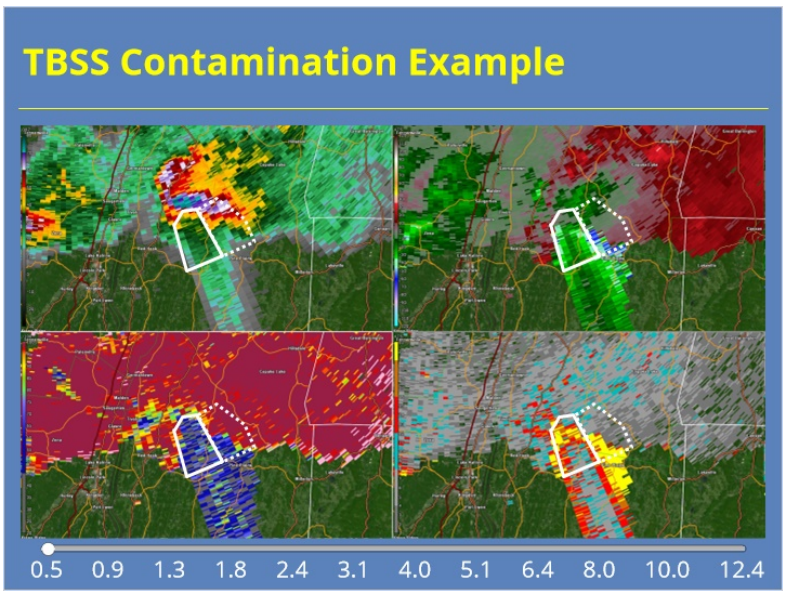

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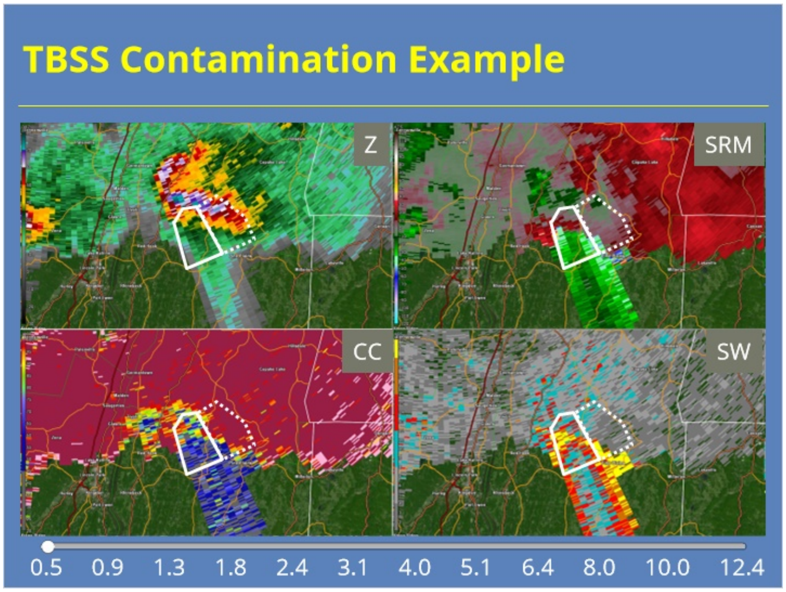
5.1 (Slide Layer)



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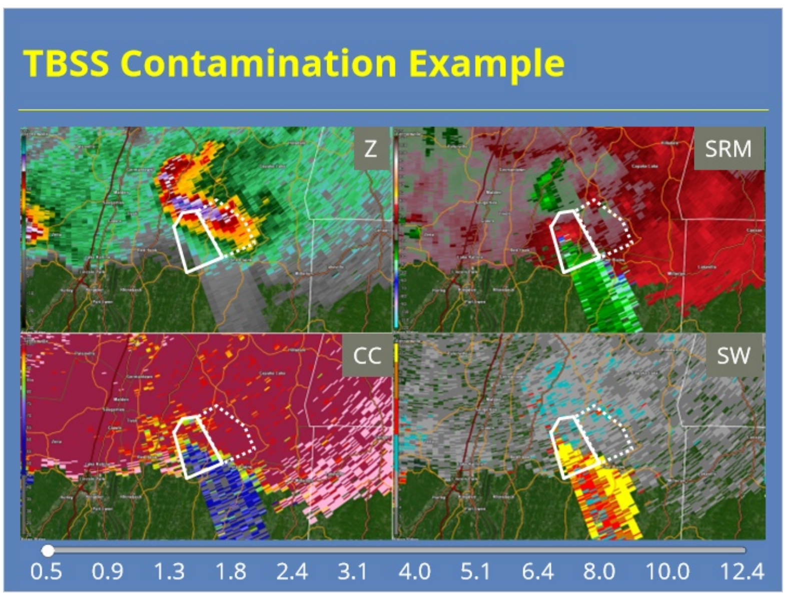

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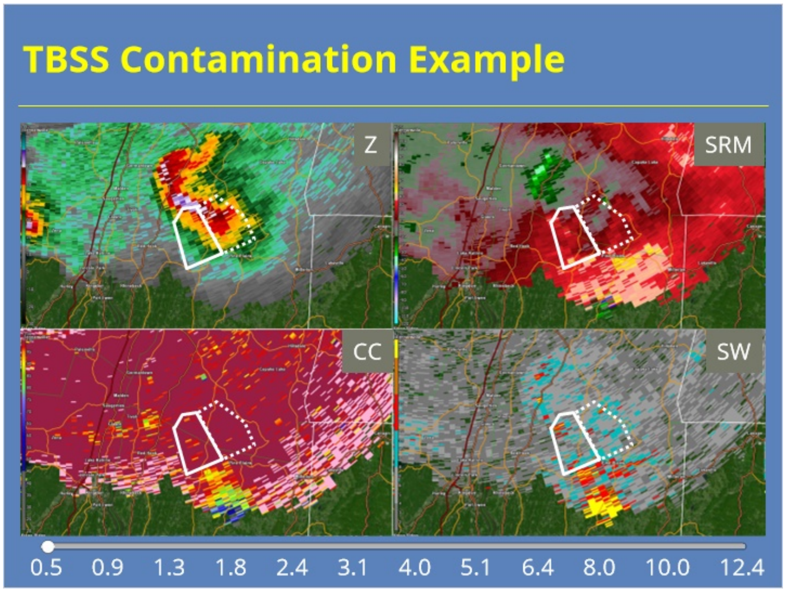
8.0 (Slide Layer)



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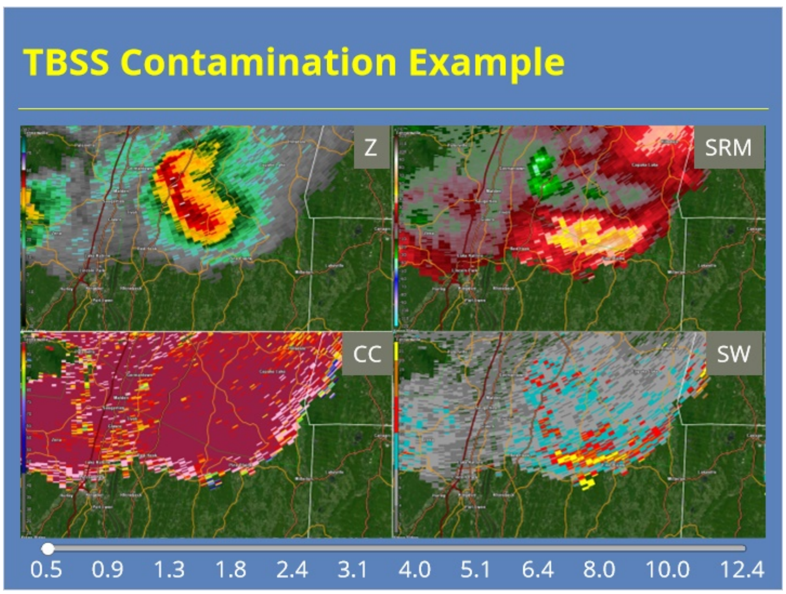

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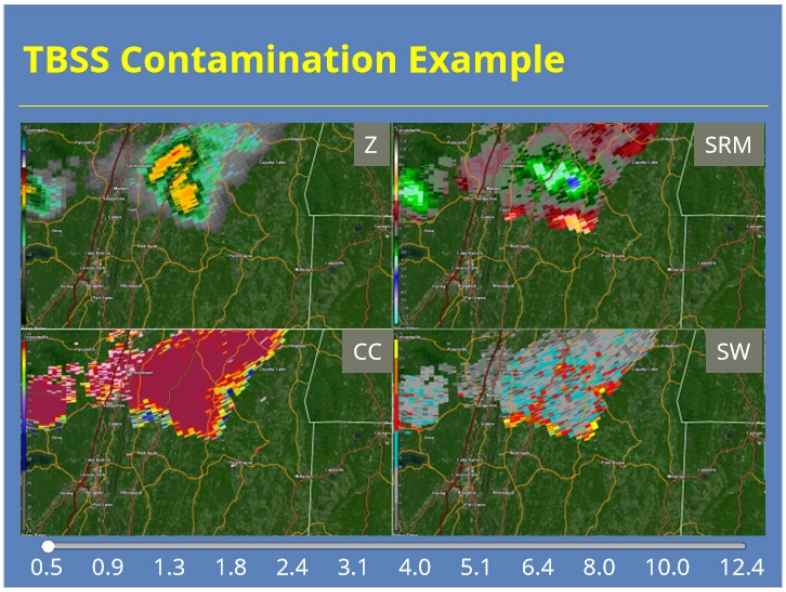
12.4 (Slide Layer)



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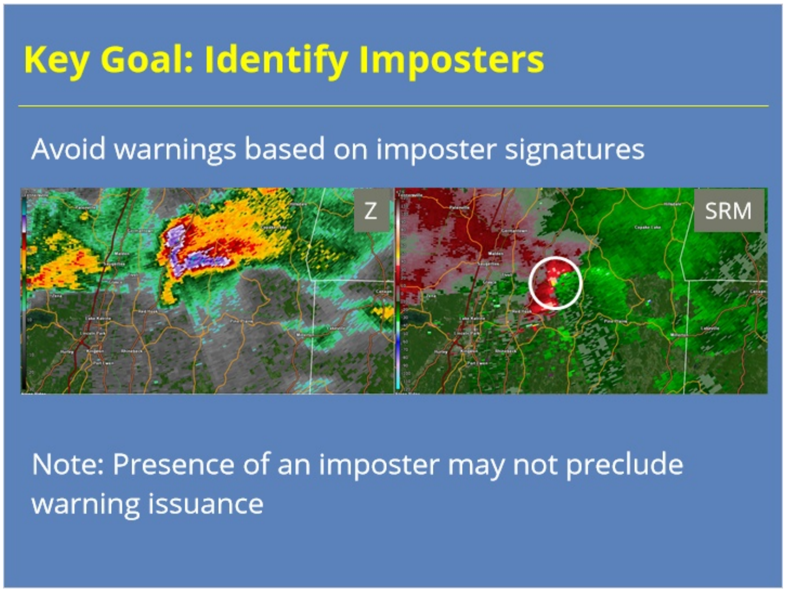
Key Goal: Identify Imposters



Notes:

Now that you have seen some examples, you should have a better understanding about what we mean about velocity contamination. We highlight this issue in order to achieve an important goal: Identifying velocity contamination that may result in imposter velocity couplets. Identifying imposter circulations has critical importance to reducing Tornado Warning issuance on storms that would otherwise not warrant it. From here on out, this lesson focuses on identifying velocity artifacts due to elevation sidelobes as those situations are more challenging (and occur more frequently) than TBSS contamination. Before we discuss specifics on how to identify these imposters in the remainder of this lesson, I need to point out an important point. Just because a storm contains an imposter circulation, that shouldn't prevent you from issuing a warning if the remaining evidence indicates a tornado is likely present or imminent. You still need to follow the preponderance of the evidence and make the best scientifically defensible decision you can.

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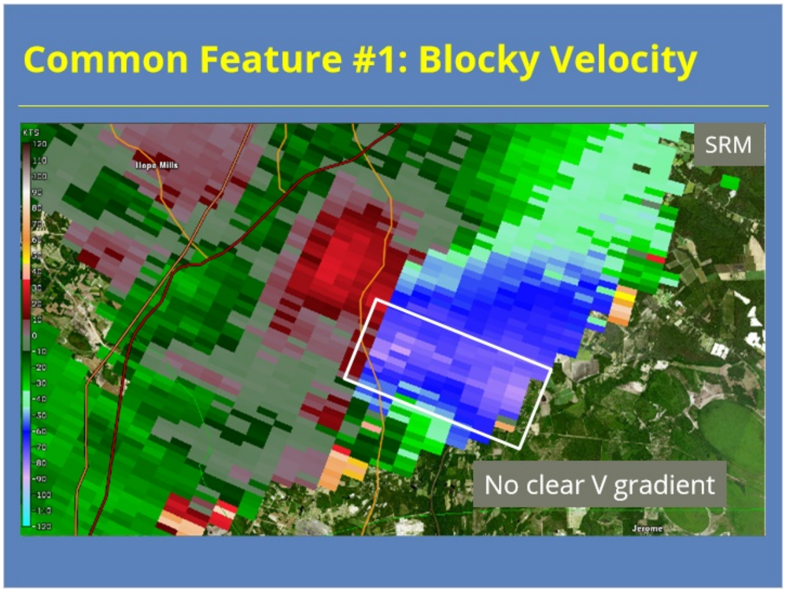
Common Feature #1: Blocky Velocity



Notes:

For the first few features, we will focus on the velocity data. In this example, we see an apparent velocity couplet in SRM. However, a quick look suggests a problem at the inbound velocities on the right side of couplet. See how the velocities look blocky with no distinguishable velocity gradient or maximum near the center of the circulation. Typically, velocity data in a mesocyclone appears as a Rankine vortex. We will discuss what that is in more detail later in RAC, but a Rankine vortex doesn't look like this.

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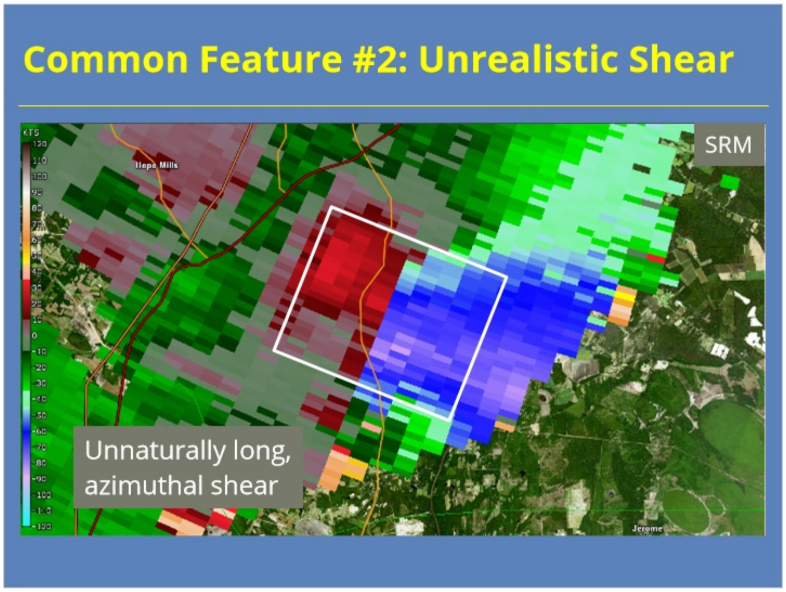
Common Feature #2: Unrealistic Shear



Notes:

Another questionable aspect of this potential circulation is the unrealistic region of azimuthal shear. The shear region in this box extends to approximately 3 nautical miles in length. Legitimate mesocyclonic shear rarely gets that large. That fact combined with the blocky velocity mentioned previously makes this circulation appear more suspicious.

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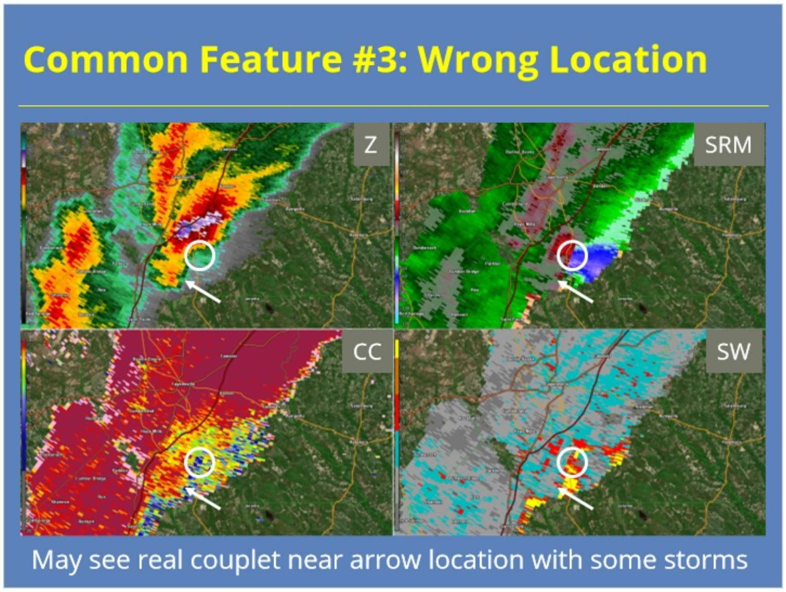
Common Feature #3: Wrong Location



Notes:

Another quirk with this possible circulation is it's location. The circle marks the approximately the center of the apparent circulation in the velocity data. This location puts the circulation more along the storms forward flank than near the hook like appendage in Reflectivity indicated by the arrow further to the south. While this may seem a subtle difference, it's an important one. In some storms with a potential imposter like this one, you will notice a second circulation in the area where you would expect it. Being able to spot the difference helps you gauge the true rotational velocity for the storm and not get sucked in by the imposter.

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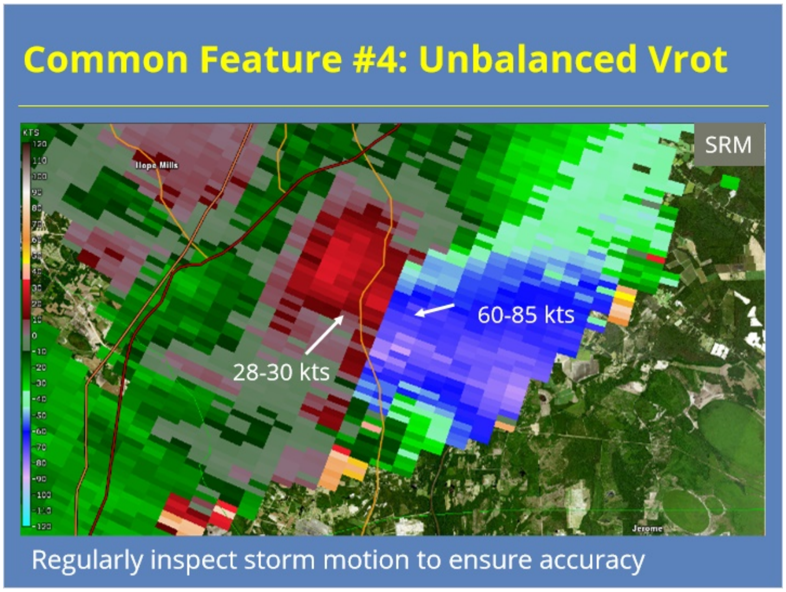
Common Feature #4: Unbalanced Vrot



Notes:

Let's go back to the SRM data for the next feature common with imposter circulations. Assuming you have a good storm motion, most low-level mesocyclones in SRM will have relatively balanced velocity couplet maxima. I'm not saying they will be the same, but the difference might be 15-20 kts. In this circulation, the maxima are more like 40-50 kts different. This feature depends on the radar operator using a good storm motion, so regularly inspect your SRM storm motion when investigating this one.

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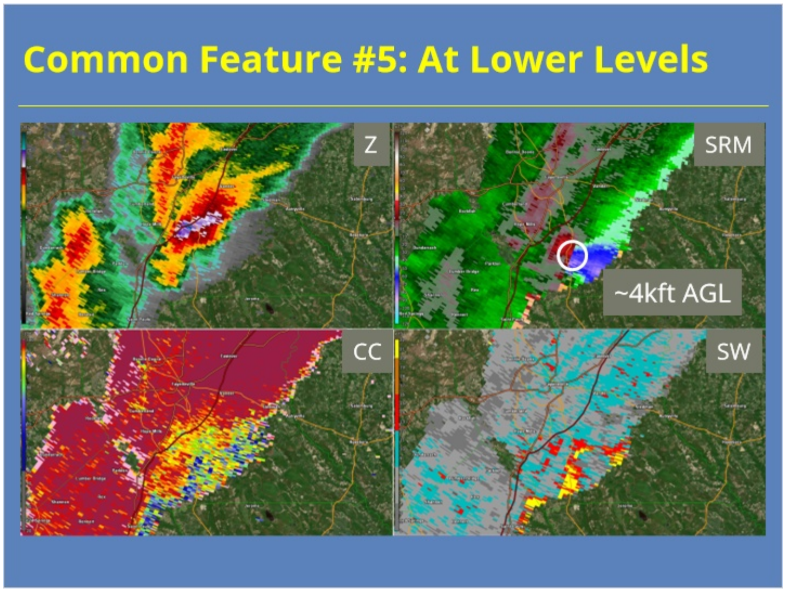
Common Feature #5: At Lower Levels



Notes:

Velocity couplet imposters tend to be seen in the lower parts of the storm in the weak echo region underneath the midlevel reflectivity overhang. For classic supercells, you will usually see them in the lowest 6 km AGL of a storm. For mini-supercells, that height would be even lower. In other, more intense, deeper storms, you might see velocity contamination even higher in the storm. In other words, typical heights don't mean a hard and fast rule.

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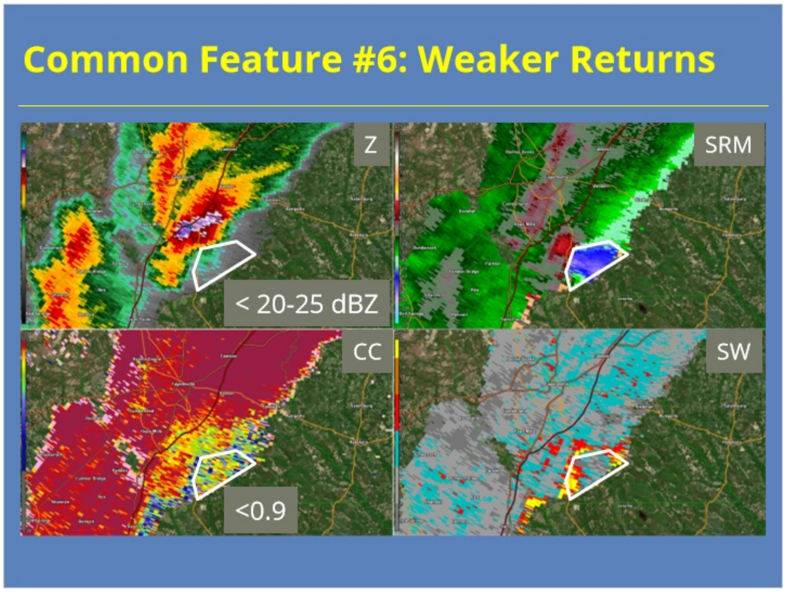
Common Feature #6: Weaker Returns



Notes:

The last common feature is that the contaminated velocity values tend to be found in areas with weaker reflectivity returns. Expect most Reflectivity values to be 20-25 dBZ or less with corresponding CC values below 0.9 (suggesting non-meteorological echoes). In this particular example, the CC values are a little higher than what you may typically see in comparable situations. In this case, the elevation sidelobe returns likely dominate the signal in parts of the highlighted area, resulting in CC values more comparable to Mie scattering from larger hail than from typical non-meteorological returns.

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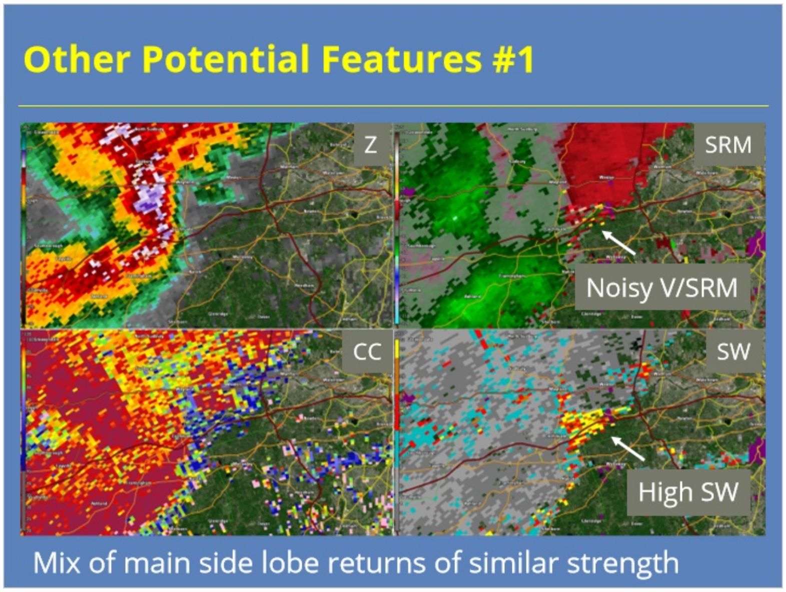
Other Potential Features #1



Notes:

You may see some other potential features with velocity contamination depending on how the main and side lobes contribute to the returned signal. In one scenario, you might see noisy velocity data associated with high Spectrum Width values. When this happens, the returned power likely contains a fairly even mix of power return from the main and side lobes. The same scenario might occur if the sidelobes sample different parts of the storm with significantly different velocity values (or if you get a mix of TBSS and sidelobe velocity contamination).

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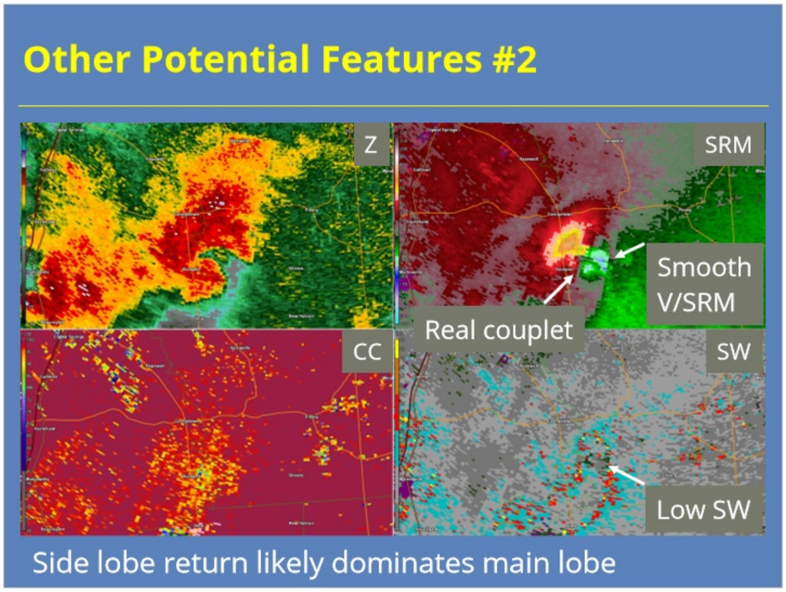
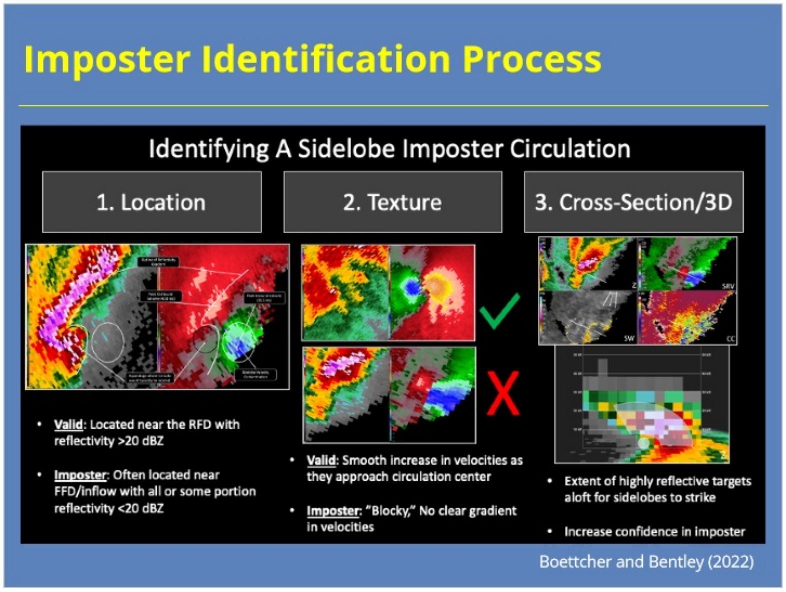
Other Potential Features #2



Notes:

You could also observe fairly smooth velocity data associated with low Spectrum Width values in an imposter circulation like the inbound velocities highlighted here. These situations occur when the side lobe return likely dominates the signal from the main lobe and the sampled velocity is fairly uniform. Before I move on, I need to point out one more thing in this particular example. While the area I highlighted shows a clear imposter, another area to the southwest appears to be part of a legitimate couplet. Even though a clear imposter circulation exists, this storm still warrants a Tornado Warning due to the remaining features visible in this storm.

Imposter Identification Process



Notes:

At this point, we have explained many details on velocity contamination. Before we wrap things up, I want to walk through the methodology that Boettcher and Bentley (2022) proposed in their study and shown on this slide. When forecasters interrogate a storm with a circulation that might be an imposter, they should focus on three steps to confirm that the circulation likely is an imposter.

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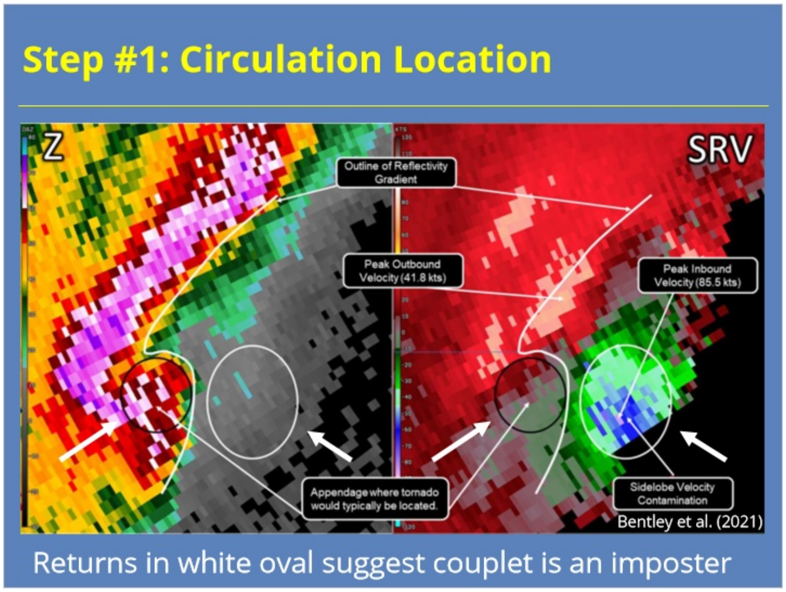
Step #1: Circulation Location



Notes:

First, look at the potential circulation's location to identify if it is an imposter. Specifically, is the circulation located near the RFD and/or hook echo like the black circle in the image? Or is it located more in the forward flank and with a significant amount in weak echo returns like the area in the white oval in the image? The latter location would suggest the circulation is an imposter.

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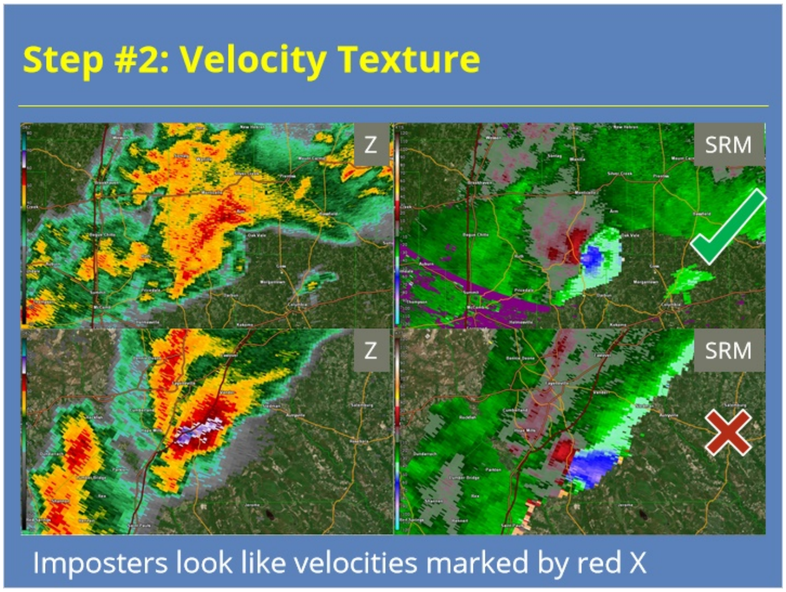
Step #2: Velocity Texture



Notes:

The second step involves looking at the velocity texture in the potential imposter. Real circulations (like the example marked by the green check mark) generally have a Rankine vortex appearance with a smooth increase in velocities to well-defined velocity maxima. Imposter circulations (like the one marked by the red X) have a blockier appearance, with no clear gradient in velocities visible.

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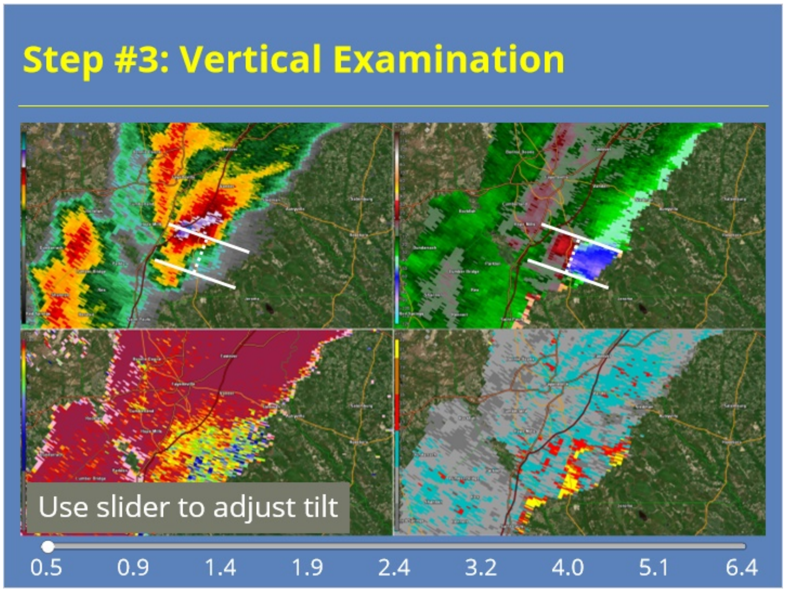
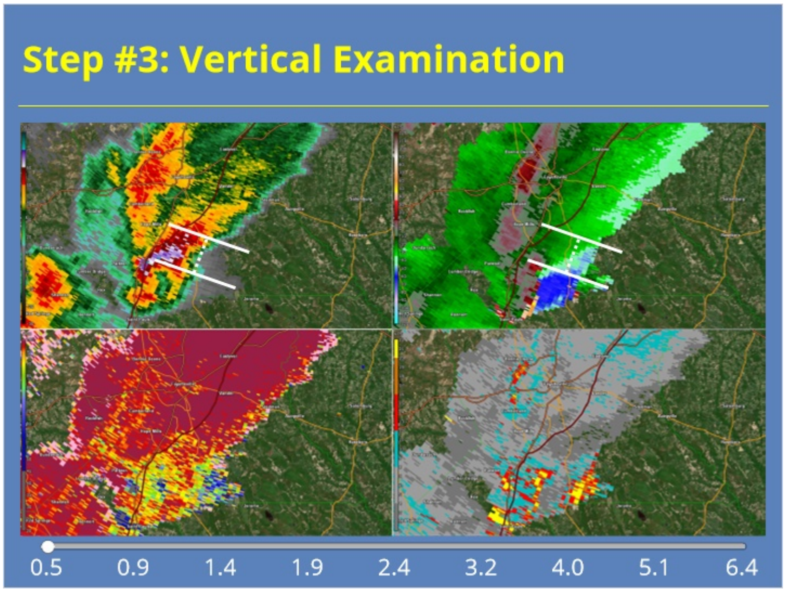
Step #3: Vertical Examination



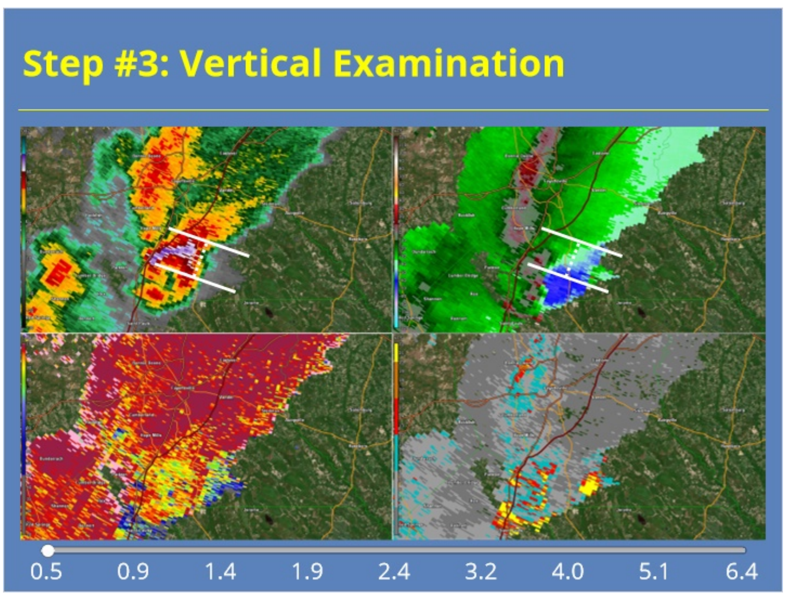
Notes:

In the last step, you want to look at the vertical structure of the storm to identify highly reflective targets that could be struck by sidelobes. Remember that those sidelobe targets need to be located at the same range as the main lobe, so it's more of an arc than a true line normal to the beam. Ideally, you would use a vertical cross-section oriented perpendicular to the radar beam to perform this task. However, radar cross-section tools in NWS operations have some significant limitations at the moment. As a result, the better option is to analyze the radar data in an all-tilts display to look for strongly reflective cores. I have added some annotations on the slide to help on the pertinent tilts. It's the blue, inbound radial velocities on the 0.5 tilt that appear to be corrupted. Looking aloft, you can see several tilts have strong reflectivity values perpendicular to the beam just to the west of the impacted area.

0.9 (Slide Layer)



1.4 (Slide Layer)



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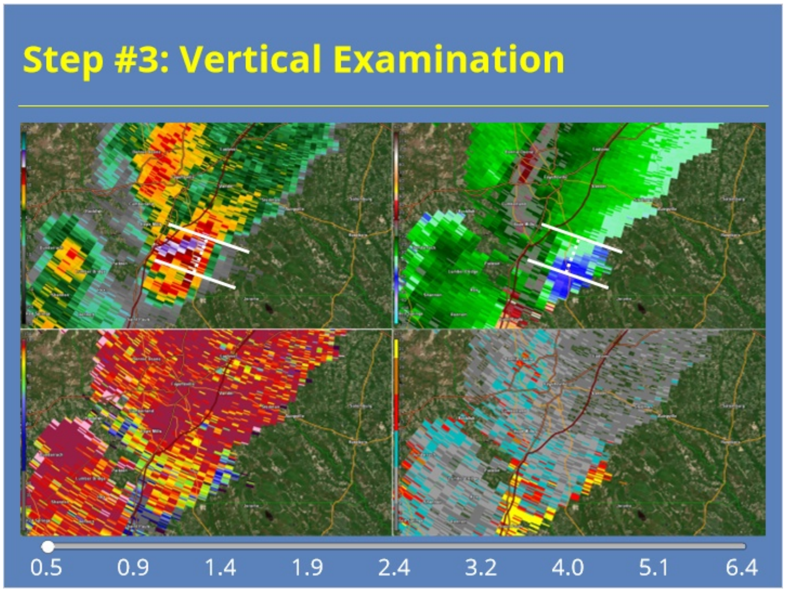

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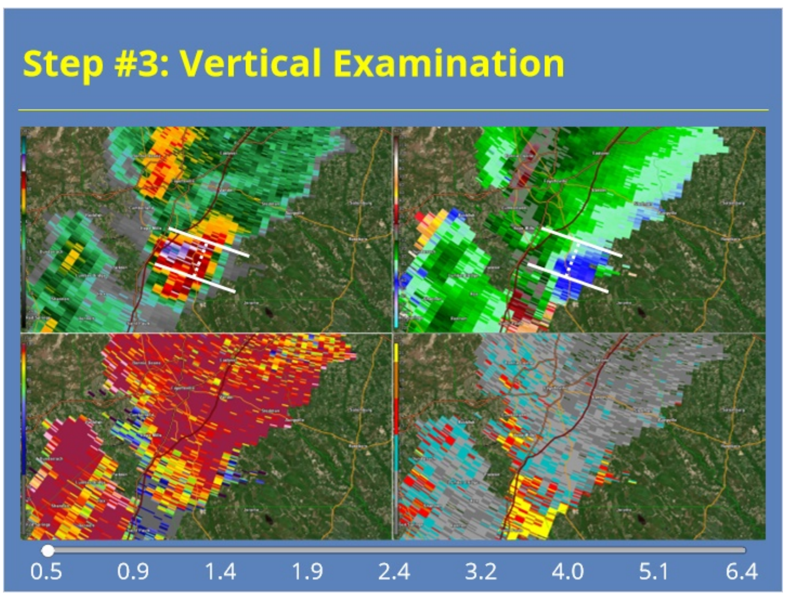

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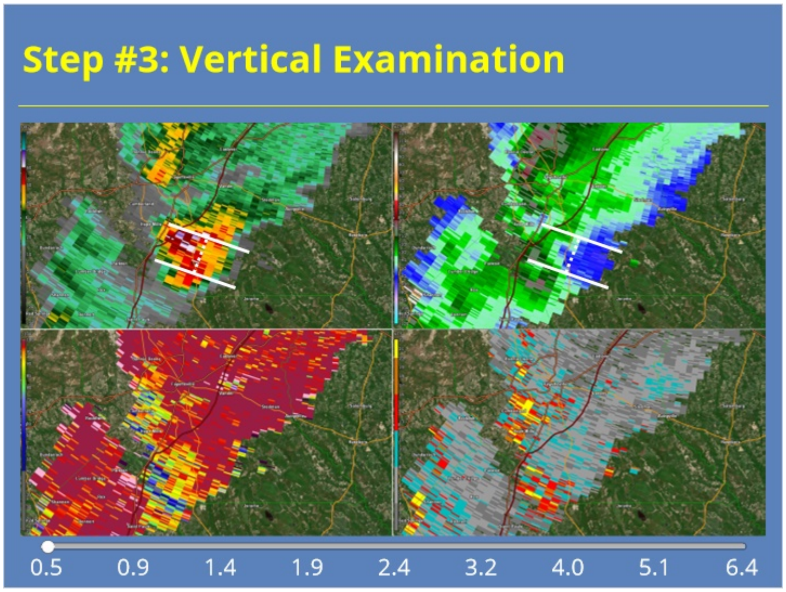
3.2 (Slide Layer)



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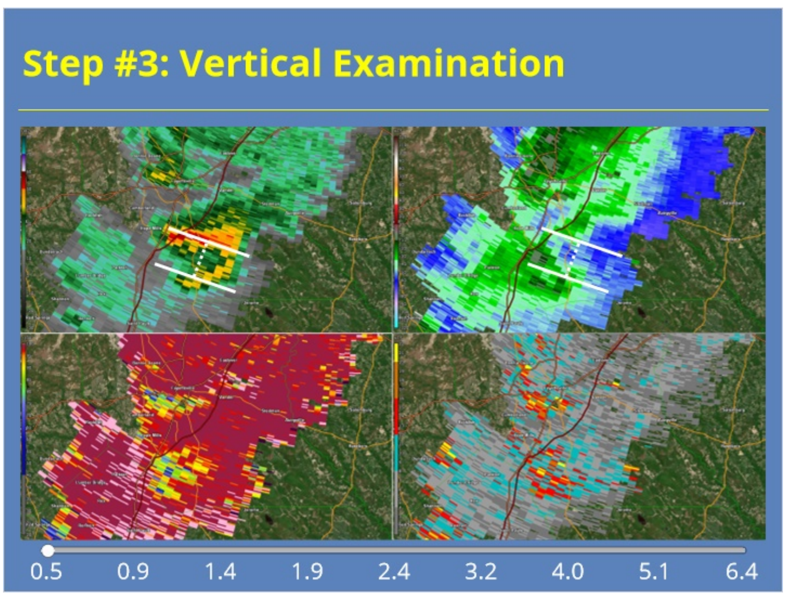

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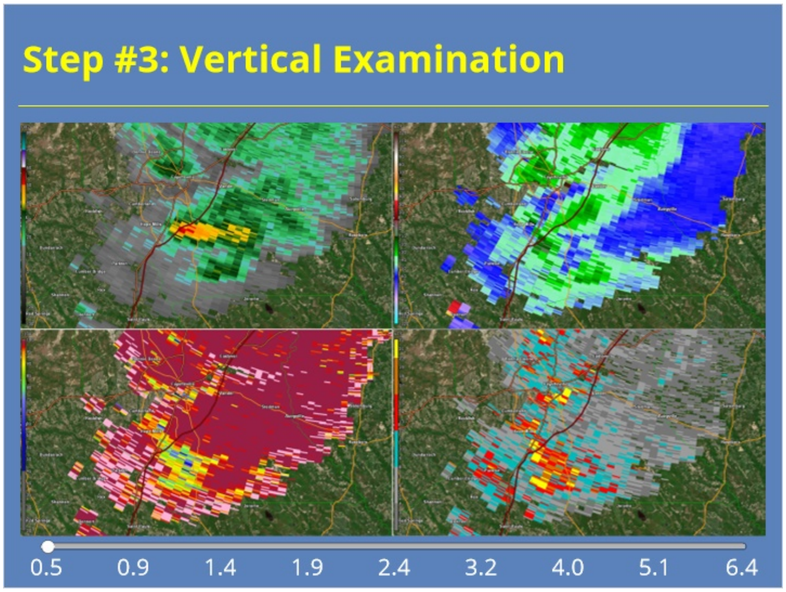
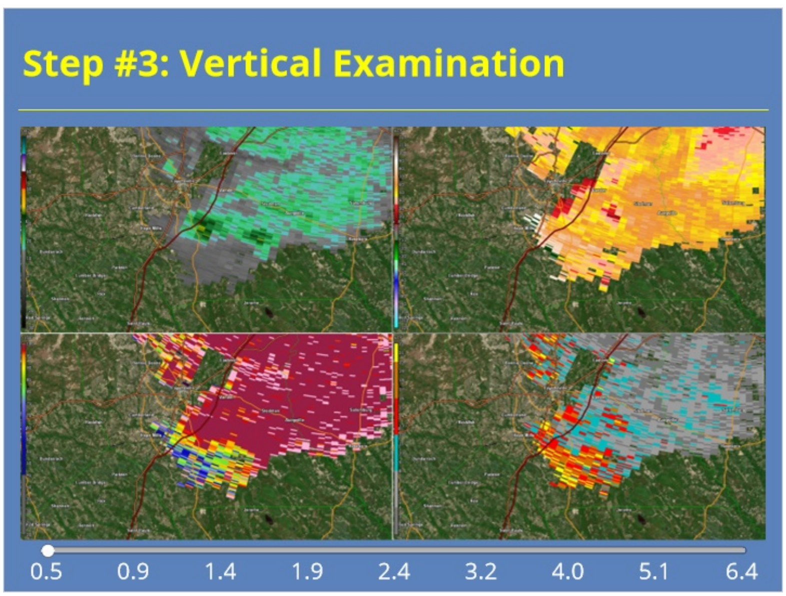
5.1 (Slide Layer)



6.4 (Slide Layer)



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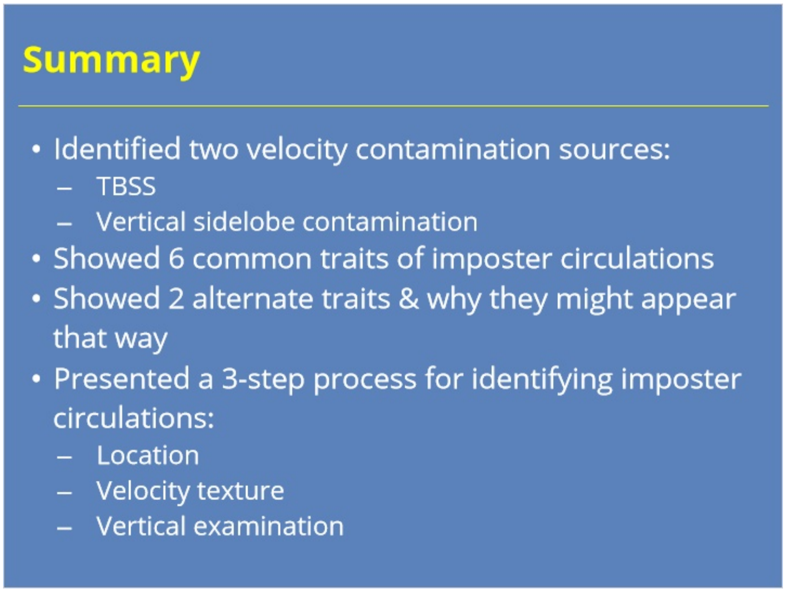
Summary



Notes:

In summary, we discussed various aspects of the causes of and ways to identify velocity contamination artifacts. The two most significant causes of these artifacts were three-body scatter spikes and elevation sidelobe contamination. When these artifacts result in a potential imposter circulation, we discussed 6 common traits they might have. These traits include blocky velocities, unrealistic shear, wrong location, unbalanced velocity maxima, seen at lower levels, and in weak returns. In some cases, velocity data may be noisy with high spectrum width values if the mainlobe and sidelobe returns are similar. In other cases, the velocity data may be smooth with lower spectrum width values if the sidelobe contamination dominates the signal. Forecasters can follow a simple three step process to identify potential imposter circulations. First, make sure the circulation is located in the correct location. Second, examine the velocity texture to make sure it appears realistic. Third, examine the vertical storm structure to see if there's highly reflective sidelobe returns near and above the low-level storm inflow.

When you are ready, please proceed to the next slide to start the quiz.

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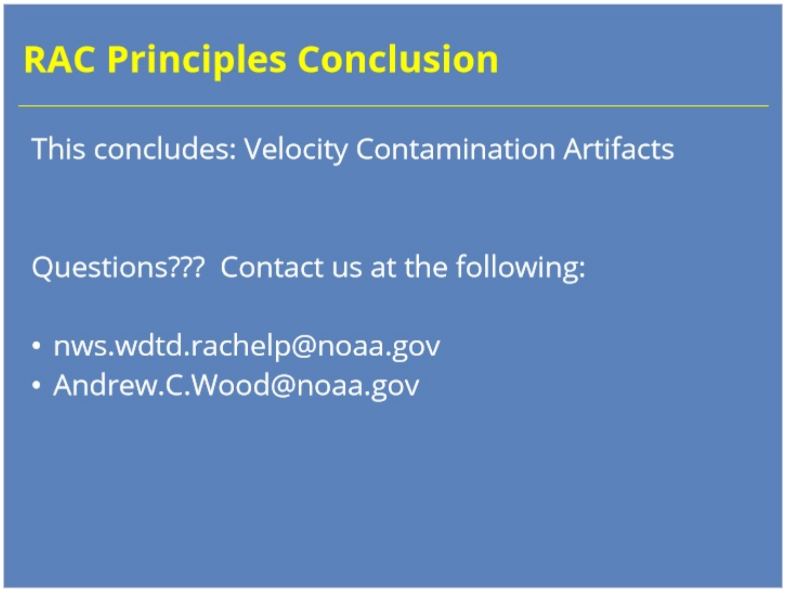
RAC Principles Conclusion



Notes:

You have successfully completed this course. You are now ready to advance to the next lesson in this topic. Choose the Exit button to close the window and record your completion.