1. Introduction to Dual Polarization Base Products
Jobsheet 1.1: Preparing the WES data and Loading Products in AWIPS

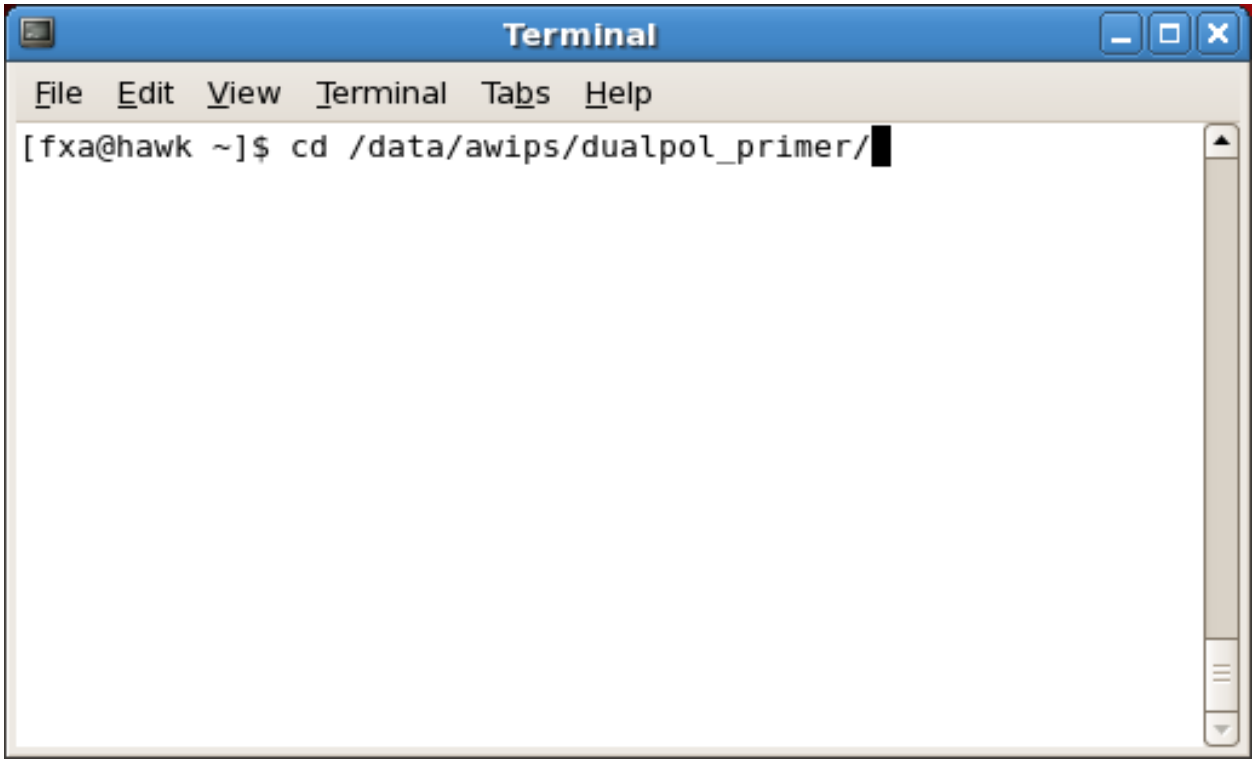
Objectives:

- Gain familiarity with AWIPS applications for visualizing dual-pol data and the new radar menus

Introduction: This is the first of 15 jobsheets. They can and should be broken up into parts and taken a little bit at a time. We ask that you go through this one first as it prepares you for the rest of them. Most of the jobsheets utilize procedures to view and analyze the dual-pol data, but it's still important to know where and how to load dual-pol products, and that is the primary motivation behind this first jobsheet.

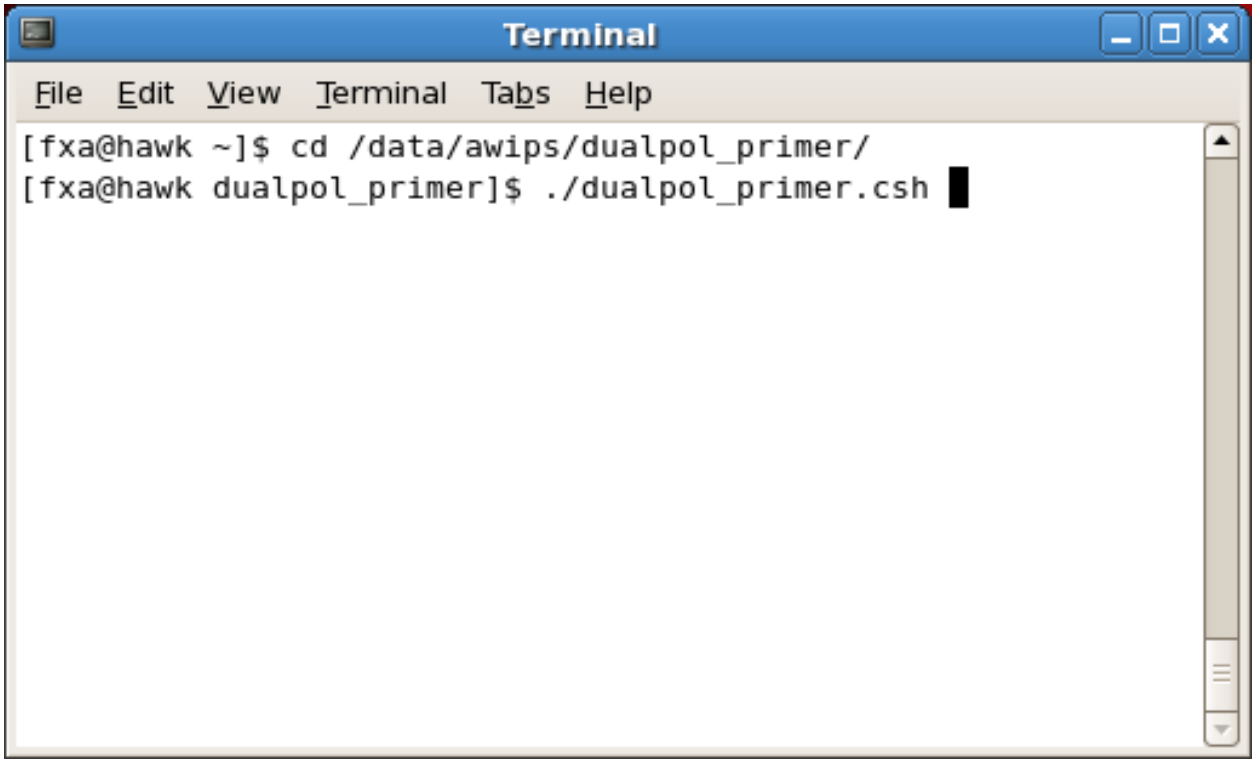
Loading D2D and Dual-Pol Radar Data on the WES for the Jobsheets

1. We have a nice script that prepares the data for each jobsheet and also launches D2D. You must run this script prior to going through most of these jobsheets. From any terminal window, change directory to the location of the dual-pol primer case data, i.e. **cd /data/awips/dualpol_primer** (See below graphic)

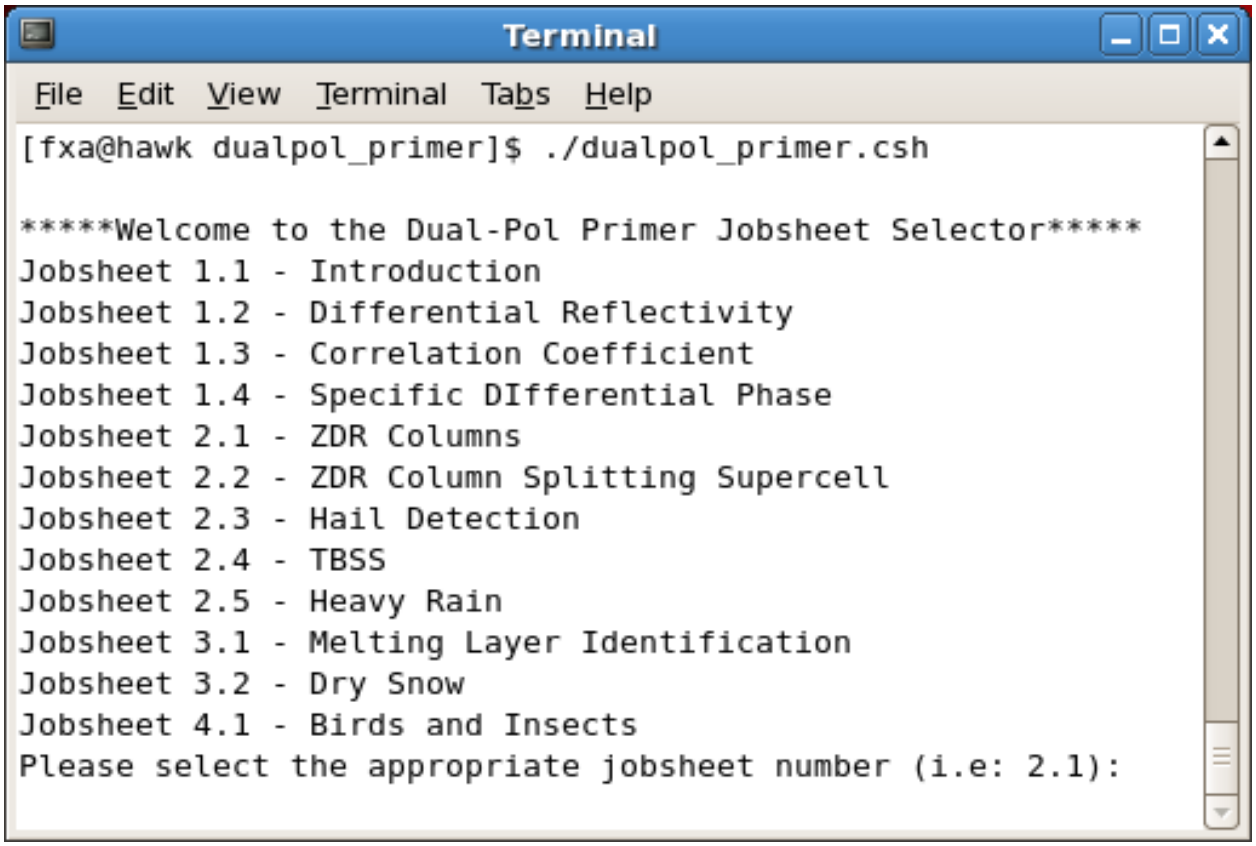


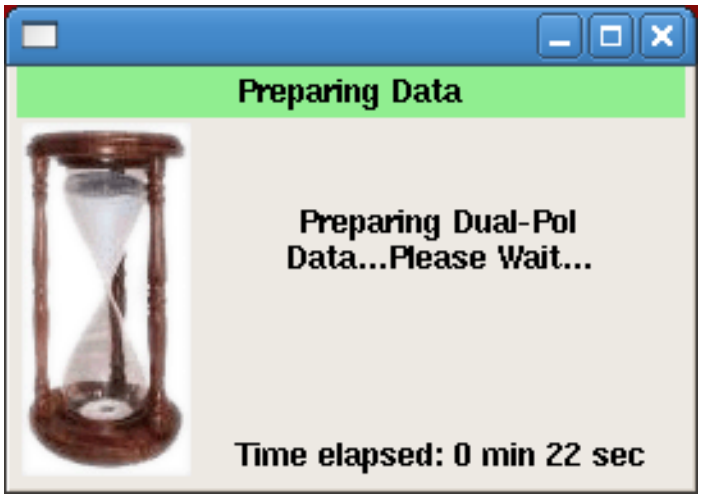
2. Run the Dual-pol Primer launcher script from the dualpol_primer case directory, i.e. **./dualpol_primer.csh** (See graphic on next page)

    a. You might see the script ask you to ensure that no start_simulator processes are running. When you are sure no start_simulator process are running, continue on.

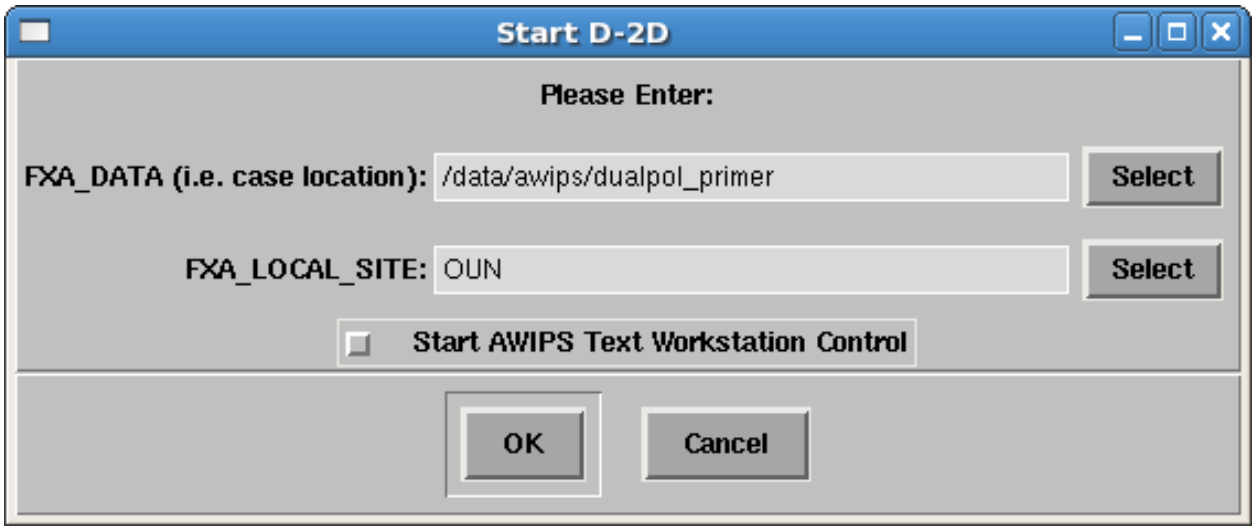


3. You'll see a screen like the below graphic. Type in the #.# value for the jobsheet you want to run and hit the "enter" key. In this case, type in **1.1**.





4. The script will launch several new windows. The one to watch is the "Preparing Data" window (shown above). Once the "Time elapsed" reaches anywhere from 45-90 seconds (depending on machine computational speed), you'll notice the new windows will close, and be replaced by the window shown below:



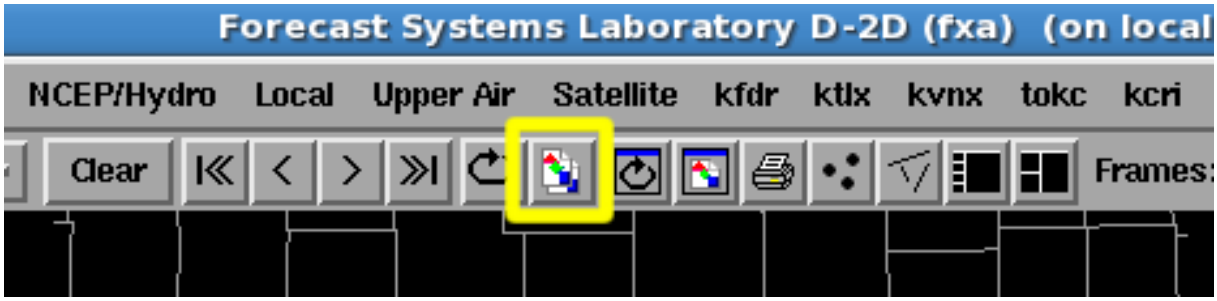
5. The window should look like the following. Click "OK" in this window and "Start" in the next one that pops up.

6. Once D2D loads, ensure the D2D clock is set to the current time by going to "Options", then "Set Time…". Next, Switch to WFO scale and click on the "kcri" menu. At this point search around the kcri menu a bit, as this is the new default radar menu once dual-pol is implemented. Feel free to load products at will. When you've seen enough of the menu, go onto step 7 where we'll build a 4 panel 0.5 degree dual-pol data display with the end goal of using PCR (Panel Combo/Rotate).

7. Clear out a pane and set it to WFO scale. Hold down right click in the main pane and select "Four Panel Layout".

8. With your mouse over the TOP LEFT panel, hold down right click again and select "Load to this Panel".

9. Click the button for “Toggle Image Combination”, shown below:



10. Load kcri 0.5 deg. Reflectivity (Z)

11. Load kcri 0.5 deg. Storm Relative Mean Radial Velocity (SRM). You should now have Z/SRM combo in the top left panel.

12. Move mouse over to the TOP RIGHT panel, hold down right click and select “Load to this Panel”

13. Load kcri 0.5 deg. Differential Reflectivity (ZDR).

14. Load kcri 0.5 deg. Velocity (V). You should now have ZDR/V combo in the top right panel.

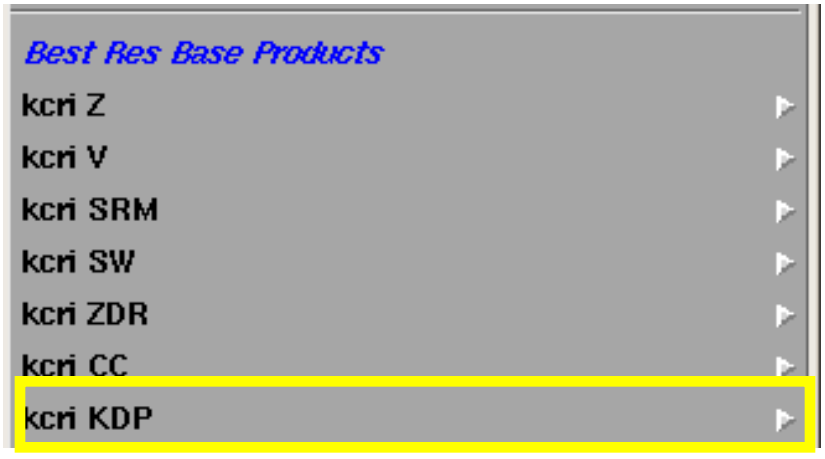
15. Move mouse over to the BOTTOM RIGHT panel, hold down right click and select “Load to this Panel”

16. Load kcri 0.5 deg. Correlation Coefficient (CC).

17. Load kcri 0.5 deg. Spectrum Width (SW). You should now have a CC/SW combo in the bottom right panel.

18. Move mouse over to the BOTTOM LEFT panel, hold down right click and select “Load to this Panel”

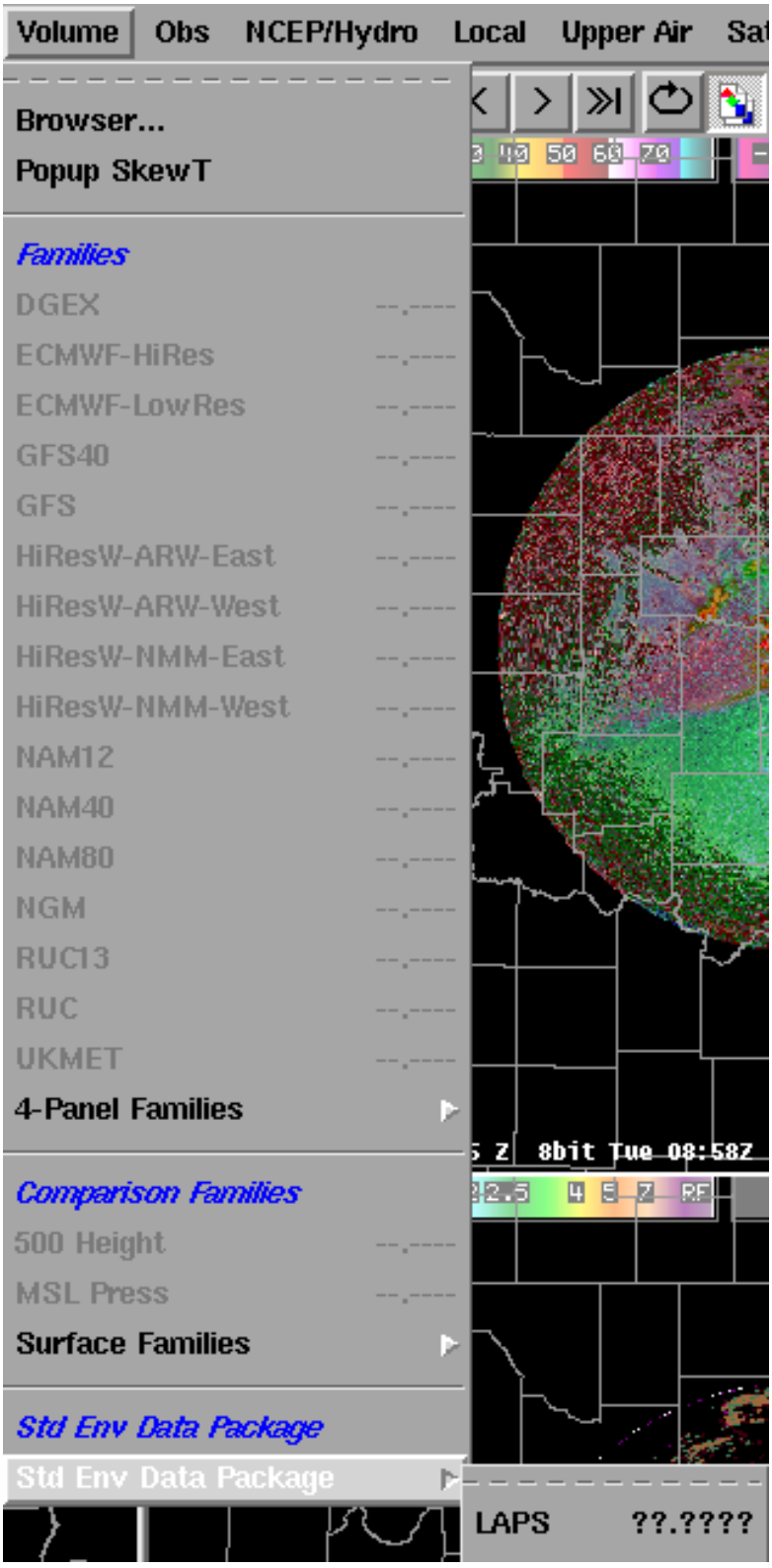
19. Load kcri 0.5 deg. Specific Differential Phase (KDP).



20. Load kcri 0.5 deg. Hydrometeor Classification (HC). You can find HC by clicking first on the menu for "Derived Products". HC will be at the very top of this menu under "Reflectivity Based". You should now have a KDP/HC combo in the bottom left panel.

21. Hold down right click in any panel and select "Load to All Panels".

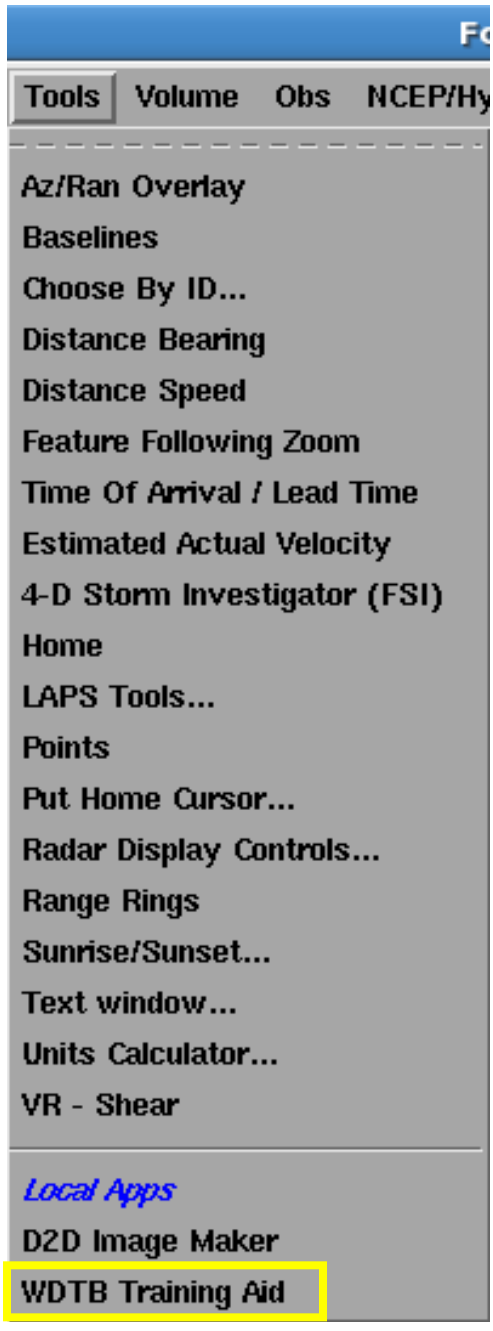
22. Go to the “Volume” menu from the main D2D bar at the top, and select “Std Env Data Package”, and click on the option for “LAPS”, shown below. This allows for the capability of sampling environmental parameters on the radar data, on all 4 panels.



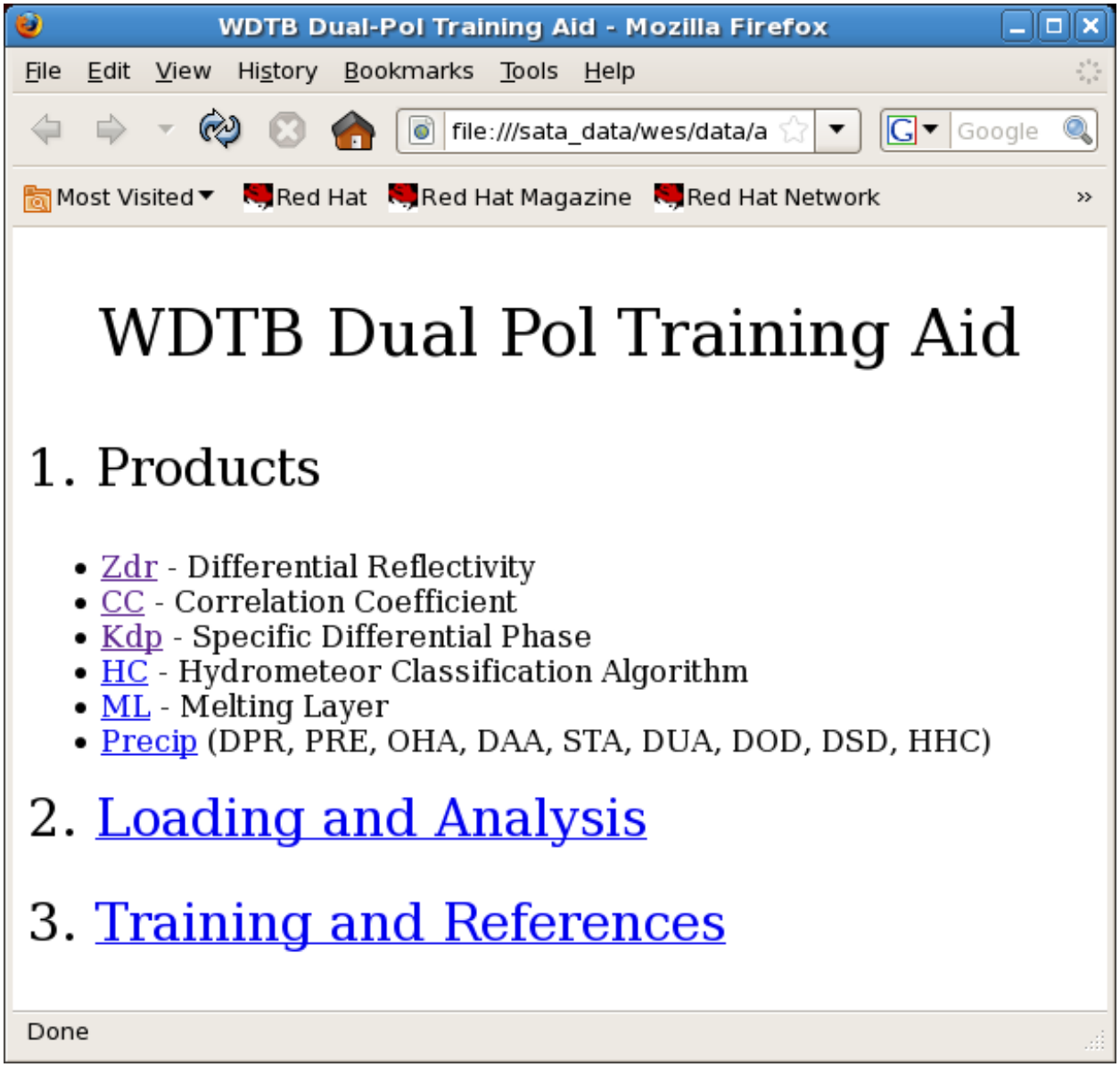
23. Countless other customizations could be performed at this point, but are not necessary. Going through this part of the jobsheet hopefully allowed you to gain some familiarity with the new radar menu structure. Your next task is to load and become familiar with the new "WDTB Training Aid" on the WES.

Instructions for Loading the WDTB Training Aid

1. Many times throughout these jobsheets you might be asked about typical values for one of the dual-pol products. To help job your memory, or since you are likely brand new to dual-pol, you'd want a way to find these answers quickly. We created the WDTB Training Aid to help meet that need. It can be loaded right from this case in D-2D. Go to the "Tools" menu at the top of D-2D, and click on "WDTB Training Aid", highlighted in the graphic below.



2. Up pops firefox with an html page like the one below.



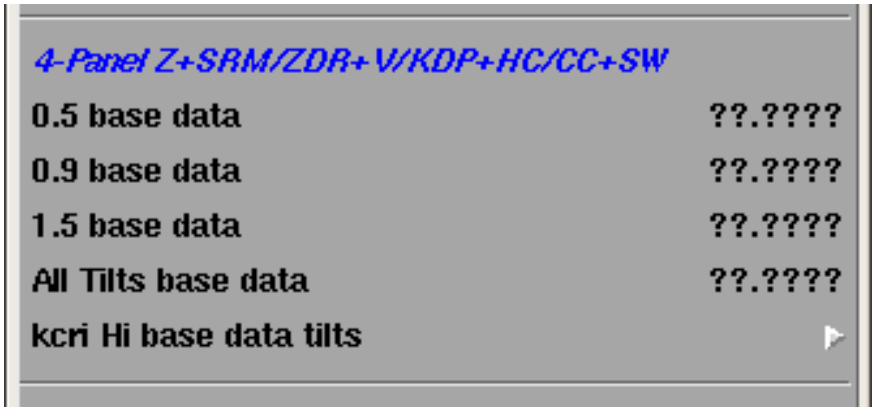
3. Navigate your way around these pages to get a feel for what is in them. The primary tools from the training aid that you'll want to utilize throughout the jobsheets are the 6 engage tools loaded from links under the "1. Products" header.

4. A final "optional" task is for you to become comfortable using Panel Combo/Rotate (PCR). If you already know how to use PCR well, you can skip the next steps and move onto Jobsheet 1.2. If you are not very comfortable with PCR, it's strongly encouraged that you work through the next set of steps.

Instructions for Panel Combo/Rotate (PCR)

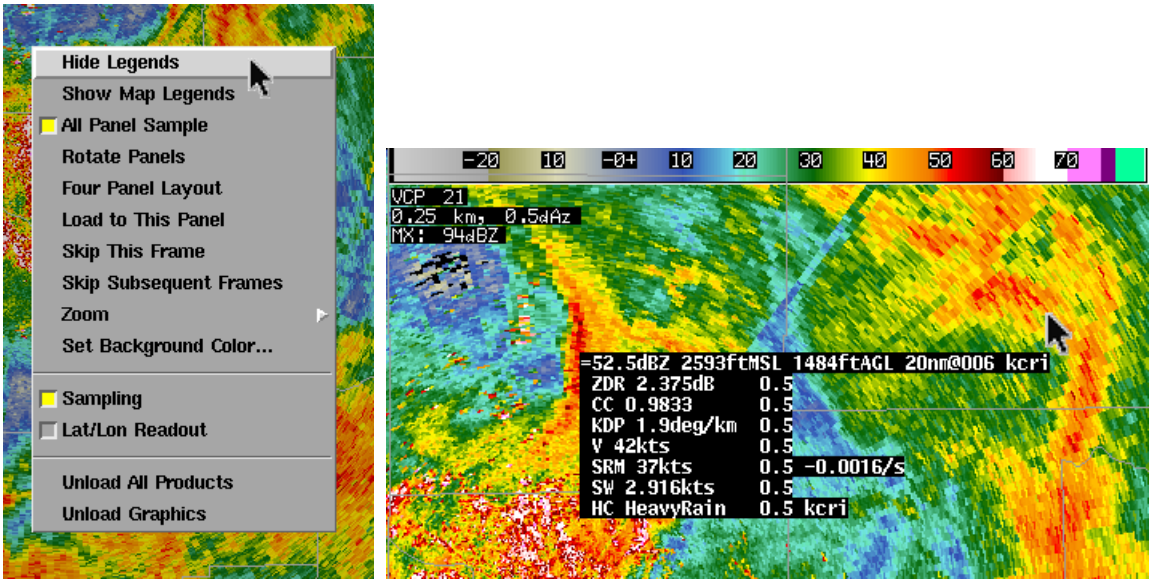
1. Starting from the 4 panel layout you had from the previous set of instructions, hit the “Delete” key on the keyboard.

2. You’ll notice that the display shifts to single panel, focused on what was the top left panel. Use the number keys shown above in the yellow rectangle to toggle from product to product, though you can still toggle between 2 products with the keypad ./Del key if you like. At the bottom of this page are the numbers associated with the products you loaded in the previous set of steps, and they are also associated with the product bundle loaded from the main kcri menu shown here:



1. Reflectivity (Z)
2. Differential Reflectivity (ZDR)
3. Correlation Coefficient (CC)
4. Specific Differential Phase (KDP)
5. Storm Relative Mean Radial Velocity (SRM)
6. Velocity (V)
7. Spectrum Width (SW)
8. Hydrometeor Classification (HC)

3. One final addition you may not be familiar with is the all panel sample. While in PCR mode, enable cursor sampling. Then hold down right click and enable “All Panel Sample”. To access it, hold down right click in any pane while in Panel Combo Rotate mode. Select the button to turn on “**All Panel Sample**”, and the box to the left of the menu entry should be yellow (See graphic on next page). Clicking the “**Sampling**” button as well will allow the All Panel Sample to be on as you roam the cursor around, otherwise you’ll have to hold down left click to view the full All Panel Sample cursor readout (right image on next page). You can toggle All Panel Sampling on and off using the space bar, changes take effect when you move the mouse. Play around with this for a bit.



4. You are now “ready” to move on to the next jobsheets!

1. Introduction to Dual Polarization Base Products
Jobsheet 1.2: Differential Reflectivity (ZDR)

Objectives:

- Gain a basic understanding of ZDR and how to properly visualize it in conjunction with reflectivity

Case Data: 8 April 2008 nocturnal elevated supercell event in central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **1.2** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 1". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. 0.5 degree reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
    2. 0.5 degree differential reflectivity (ZDR) paired with base mean radial velocity (V)
    3. 0.5 degree specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
    4. 0.5 degree correlation coefficient (CC) with velocity spectrum width (SW)

3. Navigate to the 0434 UTC volume scan, and turn on cursor sampling.

4. Zoom into the storm located at about 10 degrees and 23 nm, in northern Oklahoma County

5. Examine the ZDR product in the upper right hand quadrant either in 4-panel mode or hit the #2 key to enter Panel Combo/Rotate (PCR) mode and zoom into ZDR. Try both to see what you like better, then answer the following questions.

Question 1: Using the cursor readout sample and panel-combo rotate functions, what are the values of ZDR in the forward flank core of this supercell, roughly between ranges 22-26 nm and azimuths 012-024 degrees?

Question 2: What are the reflectivity (Z) values within this same sample volume?

Question 3: Given these values of Z and ZDR, what can be said about the hydrometeor distribution in this sample volume? Refer to the job aid for ZDR if needed by starting up the job aid from the bottom of the Tools menu.

Question 4: Given this signature along the forward flank of this supercell, can you tell if there is hail mixed with the liquid hydrometeors in this sample volume?

Question 5: Using cursor sampling, what are the values of ZDR in the main precip core of this supercell, roughly between ranges 24-29 nm and azimuths 004-010 degrees and embedded in the highest reflectivity?

Question 6: What are the reflectivity (Z) values within this same sample volume?

Question 7: Given these values of Z and ZDR, what can be said about the hydrometeor distribution in this sample volume?

1. Introduction Dual Polarization Base Products Jobsheet 1.3: Correlation Coefficient (CC)

Objectives:

- Gain a basic understanding of CC and how to properly visualize it in conjunction with reflectivity

Case Data: 8 April 2008 nocturnal elevated supercell event in central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **1.3** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 1". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. 0.5 degree reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
    2. 0.5 degree differential reflectivity (ZDR) paired with base mean radial velocity (V)
    3. 0.5 degree specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
    4. 0.5 degree correlation coefficient (CC) with velocity spectrum width (SW)

3. Navigate to the 0434 UTC volume scan, and turn on cursor sampling.

4. Zoom into the storm located at about 10 degrees and 23 nm, in northern Oklahoma County. This is the same storm that we looked at in jobsheet 1.2.

5. Examine the CC product in the lower right hand quadrant either in 4-panel mode or hit the #3 key to enter Panel Combo/Rotate (PCR) mode and zoom into CC. Try both to see what you like better. Using the cursor sampling (and all-panel sampling) and panel-combo rotate functions, examine the CC values in the forward flank core of this supercell, roughly between ranges 22-26 nm and azimuths 012-024 degrees.

Question 1: What are the correlation coefficient (CC) values within this sample volume?

Question 2: Considering *only* CC values, what can you say about the hydrometeors within this sample volume? Feel free to refer to the CC job aid.

Question 3: Now consider the CC values in combination with the values of Z and ZDR in this sample volume. What do you think the most likely hydrometeor type is within this sample volume? Feel free to refer to the CC job aid.

Now shift your focus to the CC values in the main core of this supercell, roughly between ranges 24-29 nm and azimuths 003-010 degrees. This is the same sample volume where Z values are generally between 56-67 dBZ, and ZDR values are generally between +0.5 and +1.5 dBZ, as we saw in the job sheet exercise 1.1.

Question 4: What are the correlation coefficient (CC) values within this sample volume?

Question 5: Considering *only* CC values, what can you say about the hydrometeors within this sample volume?

Question 6: Now consider the CC values in combination with the values of Z and ZDR in this sample volume. What do you think the most likely hydrometeor type is within this sample volume? Feel free to use the job aids for ZDR and CC.

1. Introduction to Dual Dual-Pol Base Products
Jobsheet 1.4: Specific Differential Phase (KDP)

Objectives:

- Gain a basic understanding of KDP and how to properly visualize it in conjunction with reflectivity, ZDR, and CC

Case Data: 8 April 2008 nocturnal elevated supercell event in central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:

a. Open a terminal window on your WES
b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
c. Start the launcher script, i.e. **./dualpol_primer.csh**
d. Type in **1.4** from the list of options
e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
f. Ensure that D2D clock is set to current real time.

2. Click ok in the "Start D-2D" window and the subsequent window that pops up.

3. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 1". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

1. 0.5 degree reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
2. 0.5 degree differential reflectivity (ZDR) paired with base mean radial velocity (V)
3. 0.5 degree specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
4. 0.5 degree correlation coefficient (CC) with velocity spectrum width (SW)

3. Navigate to the 0434 UTC volume scan, and turn on cursor sampling.

4. Zoom into the storm located at about 10 degrees and 23 nm, in northern Oklahoma County. This is the same storm that we looked at in jobsheets 1.2 and 1.3.

5. Examine the KDP product in the lower left corner of the 4 panel display. Using Panel Combo/Rotate or the 4-panel display, and cursor sampling (and/or all-panel sampling), focus on the forward flank core of this supercell, roughly between ranges 22-26 nm and azimuths 012-024 degrees. This is the same sample volume where Z values are generally between 48-55 dBZ, ZDR values are generally between +4.5 and +6 dB, and CC values are generally between 0.95 and 0.99, as we saw in the job sheet exercises 1.1 and 1.2.

Question 1: What are the specific differential phase (KDP) values within this sample volume?

Question 2: Considering *only* KDP values, what can you say about the hydrometeors within this sample volume? Feel free to use the KDP job aid.

Question 3: Do these values of KDP support the idea given in job sheet exercise 1.1 and 1.2 that rain is the most likely hydrometeor type within this sample volume?

Using the cursor sampling and panel combo/rotate or 4-panels, examine the KDP values in the forward flank core of this supercell, roughly between ranges 24-29 nm and azimuths 003-010 degrees. This is the same sample volume where Z values are generally between 56-67 dBZ, ZDR values are generally between +0.5 and +1.5 dBZ, and CC values are generally between 0.85 and 0.95, as we saw in the jobsheet exercises 1.2 and 1.3.

Question 4: What are the specific differential phase (KDP) values within this sample volume?

Question 5: Considering *only* KDP values, what can you say about the hydrometeors within this sample volume and specifically about rain rates?

Question 6: Do these values of KDP support the idea given in job sheet exercises 1.2 and 1.3 that heavy rain is present in addition to hail within this sample volume?

Bonus Question 7: Review the 0.5 deg Z, ZDR, CC and KDP base data at 0434 UTC in the elongated hook echo portion of this supercell, roughly 20-22 nm range between azimuths 003-004 degrees. Using what you have learned, what is your best estimate of hydrometeor type within this sample volume? (Refer to Training Aids for assistance)

Now use either the image toggle in 4 panel or Panel Combo/Rotate mode (hit the 8 key), to view the Hydrometeor Classification Algorithm (HCA) output for this storm at 0434 UTC. Compare the HCA output to the hydrometeor types we determined from our analysis of the dual-pol base data.

Question 8: Does the HCA output agree with the most likely hydrometeor types deduced from the base data analysis? Feel free to refer to the HCA training aid.

Wait!

Before moving onto subsequent jobsheets, please go to the NWS E-learning Center and take a short quiz covering the basics of the base products jobsheets, 1.2-1.4.

https://doc.learn.com/noaa/nws

Search for “Dual-pol Primer” and take the short quiz

2. Warm Season Dual-Pol Radar Signatures
Jobsheet 2.1: ZDR Columns

Introduction:

Objectives:

- Identify a "ZDR column" signature in dual-pol radar base data, and understand its significance in determining the updraft core location and relative updraft strength
- Gain experience in integrating all dual-pol base products with each other, reflectivity, and in terms of location relative to temperature levels.

Case Data: 8 April 2008 nocturnal elevated supercell event in central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **2.1** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 2.1". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. All-Tilts reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
    2. All-Tilts differential reflectivity (ZDR) paired with base mean radial velocity (V)
    3. All-Tilts specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
    4. All-Tilts correlation coefficient (CC) with velocity spectrum width (SW)

3. Navigate to the 0.5 degree elevation slice of the 0513 UTC volume scan.

4. Find your way to the storm in central Kingfisher County, which is located at AZ/RAN 332/49 nm.

5. Using the up and down arrows in all tilts, move up and down through the elevation slices between 0.5 and 8.0 degrees to gain a general feel for the 3D reflectivity structure of this storm.

Focus on the ZDR product in the upper right panel, and navigate to the 1.8 degree elevation slice. Using cursor sampling, examine the ZDR values in the strong reflectivity core (greater than 50 dBZ), using the 4 panel layout or entering Panel Combo/Rotate (PCR) mode and toggling between #1 and 2.

Question 1: In a general sense, what are the ZDR values within the 50+ dBZ reflectivity core on the 1.8 deg tilt? What are the maximum values in this area?

Question 2: What do you note about the KDP values at the same location as the higher values of ZDR at the 1.8 deg tilt? (Hint, in PCR mode it's the #4 key)

Question 3: What is your assessment of the hydrometeor type in the sample volume along the southwest edge of the 50+ dBZ Z core, where ZDR is maximized?

Now step upward to the 2.4 degree elevation slice, and again examine the ZDR and KDP values co-located with the 50+ dBZ Z core.

Question 4: What are the ZDR and KDP values co-located with the 50+ dBZ Z core at 2.4 degrees?

Question 5: Using the cursor readout, what is the approximate beam centerline height (in MSL) at the 2.4 degree elevation slice at this location?

Now step upward to the 3.1 degree elevation slice, and examine the ZDR and KDP values co-located with the 50+ dBZ Z core.

Question 6: What are the max values of ZDR and KDP, co-located with the 50+ dBZ Z core at 3.1 degrees? What is the height (MSL) of this signature?

Finally, step upward one more time to the 4.0 degree elevation slice and examine the Z, ZDR and KDP values near AZ/RAN 330/50.

Question 7: What is your assessment of the hydrometeor type at AZ/RAN 330/50 on the 4.0 degree elevation slice?

Optional Exercise using FSI: Using FSI to infer Bounded Weak Echo regions prior to dual-pol was a very useful tool. FSI is also very useful for ZDR column analysis. Load FSI in your display, choose KCRI as the radar, and then click set the centerpoint of the data window to 0320 UTC. Find your way to the 0513 and move the baseline so it passes through the ZDR maximum. It seems as though orienting the baseline along the radial with maximum ZDR aloft produces a nice cross section. Play around with FSI in this storm, toggling between Z, ZDR, KDP, and CC for the ZDR column, getting a feel for FSI and the characteristics of the ZDR column.

2. Warm Season Dual-Pol Radar Signatures
Jobsheet 2.2: ZDR Columns and Splitting Supercells

Objectives:

- Identify ZDR columns associated with a storm in the process of splitting
- Gain experience in integrating all dual-pol base products with each other, reflectivity, and in terms of location relative to temperature levels.

Case Data: 8 April 2008 nocturnal elevated supercell event in central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:

a. Open a terminal window on your WES
b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
c. Start the launcher script, i.e. **./dualpol_primer.csh**
d. Type in **2.2** from the list of options
e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 2.2". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

1. All-Tilts reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
2. All-Tilts differential reflectivity (ZDR) paired with base mean radial velocity (V)
3. All-Tilts specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
4. All-Tilts correlation coefficient (CC) with velocity spectrum width (SW)

3. Navigate to the 0.5 degree elevation slice of the 0434 UTC volume scan.

4. Find your way to the storm in extreme southwest Kingfisher County, which is located at AZ/RAN 315/50 nm.

5. Using the up and down arrows in all tilts, move up and down through the elevation slices between 0.5 and 8.0 degrees and backwards/forwards in time to gain a general feel for the 3D reflectivity structure of this storm.

Focus on the ZDR product in the upper right panel (or #2 key in Panel Combo/Rotate (PCR) mode), and navigate to the 2.4 degree elevation slice. Using cursor sampling, examine the areas of enhanced ZDR (+1.5 dB and higher).

Question 1: Check/toggle ZDR with reflectivity at 2.4 degrees on the 0434 UTC scan. Identify the AZ/RAN of the regions of enhanced ZDR that have sufficient reflectivity returns such that data quality is probably not in question (Hint: Avoid edges of storms and Z less than ~15 dBZ)?

Question 2: Examine the time and height continuity of the features you identified in question 1. Check for continuity from 0.5 degrees and up until a tilt where you can no longer see the feature. List the relative location (relative to the core of reflectivity, i.e. "North of the main core of reflectivity") of the ZDR feature, and how high each one extends (MSL) at 0434 UTC. Optional: Feel free to use FSI to check out these features as well. FSI is an ideal tool for this kind of analysis!

Question 3: Now examine KDP at 2.4 degrees (Key #4 in PCR mode). What are the characteristics of KDP in the vicinity of the ZDR columns you identified in question 2?

Question 4: Now examine CC at 2.4 degrees (Key #3 in PCR mode). What are the characteristics of CC in the vicinity of the ZDR columns you identified in question 3.

2. Warm Season Dual-Pol Radar Signatures
Jobsheet 2.3: Hail Detection

Objectives:

- Identify dual-pol radar signatures associated with hail
- Gain experience in integrating all dual-pol base products with each other, reflectivity, and in terms of location relative to temperature levels.

Case Data: 8 April 2008 nocturnal elevated supercell event in central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **2.3** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 2.3". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. All-Tilts reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
    2. All-Tilts differential reflectivity (ZDR) paired with base mean radial velocity (V)
    3. All-Tilts specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
    4. All-Tilts correlation coefficient (CC) with velocity spectrum width (SW)

3. Navigate to the 0.5 degree elevation slice of the 0518 UTC volume scan.

4. Find your way to the storm in western Lincoln County, which is located at AZ/RAN 039/32 nm.

5. Using the up and down arrows in all tilts, move up and down through the elevation slices between 0.5 and 8.0 degrees and backwards/forwards in time to gain a general feel for the 3D reflectivity structure of this storm.

6. For this jobsheet…IGNORE the data along the 036 degree azimuth. Blockage prevents usable/reliable dual-pol data.

Question 1: In the reflectivity core of greater than 60 dBZ on the 0518 UTC scan, what are the values of ZDR on the following tilts?

0.5 deg (3.7 kft):

1.8 deg (8 kft):

4.0 deg (15 kft):

6.4 deg (24.4 kft):

Question 2: Given the ZDR values recorded in Question 1, what does that say about the median shapes/orientations of the hydrometeors in the high reflectivity core? (Feel free to use the training aids)

Question 3: In the reflectivity core of greater than 60 dBZ on the 0518 UTC scan, what are the values of CC on the following tilts?

0.5 deg (3.7 kft):

1.8 deg (8 kft):

4.0 deg (15 kft):

6.4 deg (24.4 kft):

Question 4: Given the CC values recorded in Question 3, what does that say about the probable bulk hydrometeor properties of this high reflectivity core? (Feel free to use the training aids)

Question 5: In the reflectivity core of greater than 60 dBZ on the 0518 UTC scan, what are the values of KDP on the following tilts?

0.5 deg (3.7 kft):

1.8 deg (8 kft):

4.0 deg (15 kft):

6.4 deg (24.4 kft):

Question 6: Given the KDP values recorded in Question 5, what does that say about the presence of rain in this high reflectivity core? (Feel free to use the training aids)

2. Warm Season Dual-Pol Radar Signatures
Jobsheet 2.4: Three-Body Scatter Spike

Objective: To gain a greater understanding of three-body scatter spike signatures in dual-pol radar base data.

Case Data: 8 April 2008 nocturnal elevated supercell event in central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **2.4** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 2.4". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. All-Tilts reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
    2. All-Tilts differential reflectivity (ZDR) paired with base mean radial velocity (V)
    3. All-Tilts specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
    4. All-Tilts correlation coefficient (CC) with velocity spectrum width (SW)

3. Navigate to the 0.5 degree elevation slice of the 0513 UTC volume scan.

4. Find your way to the storm in Kingfisher County, which is located at AZ/RAN 332/50 nm.

5. Using the up and down arrows in all tilts, move up and down through the elevation slices between 0.5 and 8.0 degrees and backwards/forwards in time to gain a general feel for the 3D reflectivity structure of this storm.

Prior to answering the following questions, first ensure you are focused on the 0513 UTC volume scan.

Question 1: Looking at *only* All-Tilts reflectivity data at 0513 UTC, is a three-body scatter spike evident? If so, at which elevation angle(s)?

Now scan up and down through the elevation slices again, but this time look at both reflectivity and correlation coefficient base products, either using 4-panel or Panel Combo/Rotate (PCR).

Question 2: In the 1.8 and 2.4 degree elevation angles, what are the CC values in the three-body scatter spike?

Question 3: What do these values of CC tell us? Feel free to use the training aids.

Now use the up and down arrows in all-tilts to scan up and down through all elevation angles of this storm between 0.5 and 8.0 degrees. Examine the CC values down-radial from the strong Z core > 60 dBZ in the area where you would expect three-body scattering to occur.

Question 4: At elevation slices at and below 4.0 degrees, what is evident in the CC data?

Question 5: How does the CC data help you in determining the presence or absence of three-body scattering at the elevation slices where Z data alone does not provide high confidence?

2. Warm Season Dual-Pol Radar Signatures
IC2.5: Intense Rainfall Rates

Objectives: Identify the dual-pol base data signature for intense and/or tropical rainfall rates.

Case Data: 19 August 2007 Tropical Storm Erin re-intensification in central Oklahoma

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **2.5** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 2.5". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. 0.5 deg reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
    2. 0.5 deg differential reflectivity (ZDR) paired with base mean radial velocity (V)
    3. 0.5 deg specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
    4. 0.5 deg correlation coefficient (CC) with **Instantaneous Dual-Pol Precip Rate (DPR)**

3. Navigate to the 1004 UTC volume scan.

4. Zoom in as far as you can, centering on Kingfisher County, northwest of the KOUN radar at the approximate AZ/RAN 332/47 nm.

Question 1: First, examine the Z data in central Kingfisher County. What Z values are apparent in the area near AZ/RAN 332/47?

Question 2: What are ZDR values at this same location?

Question 3: What are CC values at this same location?

Question 4: What are KDP values at this same location?

Question 5: Based on the base data values sampled in the previous four questions, what is your assessment of the hydrometeor phase and distribution within this sample volume? Feel free to use the training aids.

Toggle to the Instantaneous Precipitation Rate Product that you loaded into the lower right panel, or select Key #7 if in Panel Combo/Rotate mode.

Question 6: What are the radar-estimated instantaneous precipitation rates at this location in central Kingfisher County?

For the next series of questions we will examine the base data in southwest Kingfisher County, near AZ/RANs 320-322/48.

Question 7: What are the base moment values in southwest Kingfisher County neat AZ/RANs 320-322/48?

Question 8: Based on the values of the base products, what is your assessment of precipitation and hydrometeor type at this location?

Question 9: What does the DPR (key #7 in PCR mode) product estimate for instantaneous precipitation rate at this location using the dual-pol data?

Question 10: Through analysis of the base data, we have concluded that heavy rain is likely the precipitation type in both central and southwestern Kingfisher County. Toggle to the Hydrometeor Classification (HCA) output (Key #8 in PCR mode) and examine HCA output in both of these locations. What does HCA say?

3. Cold Season Dual-Pol Radar Signatures
IC3.1: Melting Layer Identification

Objectives: To gain understanding of dual-pol base moment signatures of wet snow and the melting layer, and to explicitly determine the location of the melting layer from dual-pol base data.

Case Data: 27 January 2009 winter storm case from central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **3.1** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 3.1". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. All-Tilts reflectivity (Z)
    2. All-Tilts differential reflectivity (ZDR)
    3. All-Tilts specific differential phase shift (KDP) paired with hydrometeor classification (HC) and overlaid with the Melting Layer (ML) output
    4. All-Tilts correlation coefficient (CC)

3. Using All-Tilts 4-panel and/or Panel Combo/Rotate (PCR), navigate back and forth in time and up and down in elevation angle. Examine the base products Z, ZDR, CC, and KDP primarily (Keys 1, 2, 3, and 5 in PCR, respectively).

4. Note that CC/ZDR/KDP data will be unusable for some elevation angles. When you see ZDR turn red all of a sudden or if CC goes all dark purple, you know the data are worthless and should be skipped over. This is an issue with the research data and will not occur with the WSR-88D.

Question 1: Focusing on just reflectivity for now, is a bright band in reflectivity data evident from 2154 UTC? If so, what elevation angles do you see it on?

Question 2: Navigate to the 2.4 and 3.4 degree elevation angles at 2154 UTC. What do you see in the correlation coefficient (CC) data in the 2.4, 3.4, elevation angles at 2154 UTC?

Question 3: What do you observe in the differential reflectivity (ZDR) data in the 2.4 and 3.4 degree elevation agle at 2154 UTC?

Question 4: Is there a signal in the specific differential phase shift (KDP) field at the 2.4 and 3.4 degree elevation angles at 2154 UTC?

Question 5: Hit the #4 key in PCR mode, or just focus on the HC/ML products in the lower right pane. Toggle between 4 and 3 (CC). Does the melting layer output correspond well with the level of the melting layer as determined by interrogation of the base data?

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3. Cold Season Dual-Pol Radar Signatures
Jobsheet 3.2: Precipitation Type in Similar Reflectivity Cores: Dry Snow

Introduction: Unfortunately, good snow storms in central Oklahoma are rare enough that we don't presently have KOUN data processed into AWIPS for winter precip that involves just snow. Thus, many of the cold season precipitation job sheets will ask you to look at images on the jobsheet rather than the WES. For this first cold season jobsheet, the event we have is a freezing rain event so there won't be any dry snow signatures near the surface. However, there is normally dry snow at some altitude for most cold season precipitation events, so we'll be looking above the warm nose you identified in 3.1 to find it.

Objectives: Identify dual-pol base data signatures of dry snow in the cold season.

Case Data: 27 January 2009 winter storm case from central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **3.2** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 3.2". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. All-Tilts reflectivity (Z) paired with storm-relative mean radial velocity (SRM)
    2. All-Tilts differential reflectivity (ZDR) paired with base mean radial velocity (V)
    3. All-Tilts specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
    4. All-Tilts correlation coefficient (CC) with velocity spectrum width (SW)

3. Focus on the 1722 UTC All-Tilts. The area of interest is northwest of the radar, beyond the melting layer characterized by a ring of CC values less than 0.95 surrounding the radar.

4. Note that CC/ZDR/KDP data will be unusable for some elevation angles. When you see ZDR turn red all of a sudden or if CC goes all dark purple, you know the data are worthless and should be skipped over. This is an issue with the research data and will not occur with the WSR-88D.

Question 1: **Ensure cursor sampling is turned on so you can see what the 12 UTC raob temperatures are. Northwest of KOUN roughly between 295-315 azimuth on the 2.4 deg tilts, use CC to determine the height (AGL) of the top and bottom of the melting layer. Use your skills obtained from Jobsheet 3.1 to identify the melting layer.**

Question 2: Where the radar identifies the melting layer between 295-315 azimuth on the 2.4 deg tilts, what is the 12 Z raob temperature at the top and bottom of it?

Question 3: Now that you have identified the melting layer, you are able to say that precipitation is liquid inside the ring of reduced CC, and frozen outside the ring of CC. Examine the dual-pol data between 295 and 315 deg on the 2.4 deg elevation angle, in particular the Z, ZDR, and CC data, which in PCR mode are 1, 2, and 3 respectively. Fill out the table below, paying attention to the "general" values and not individual maxes/mins:

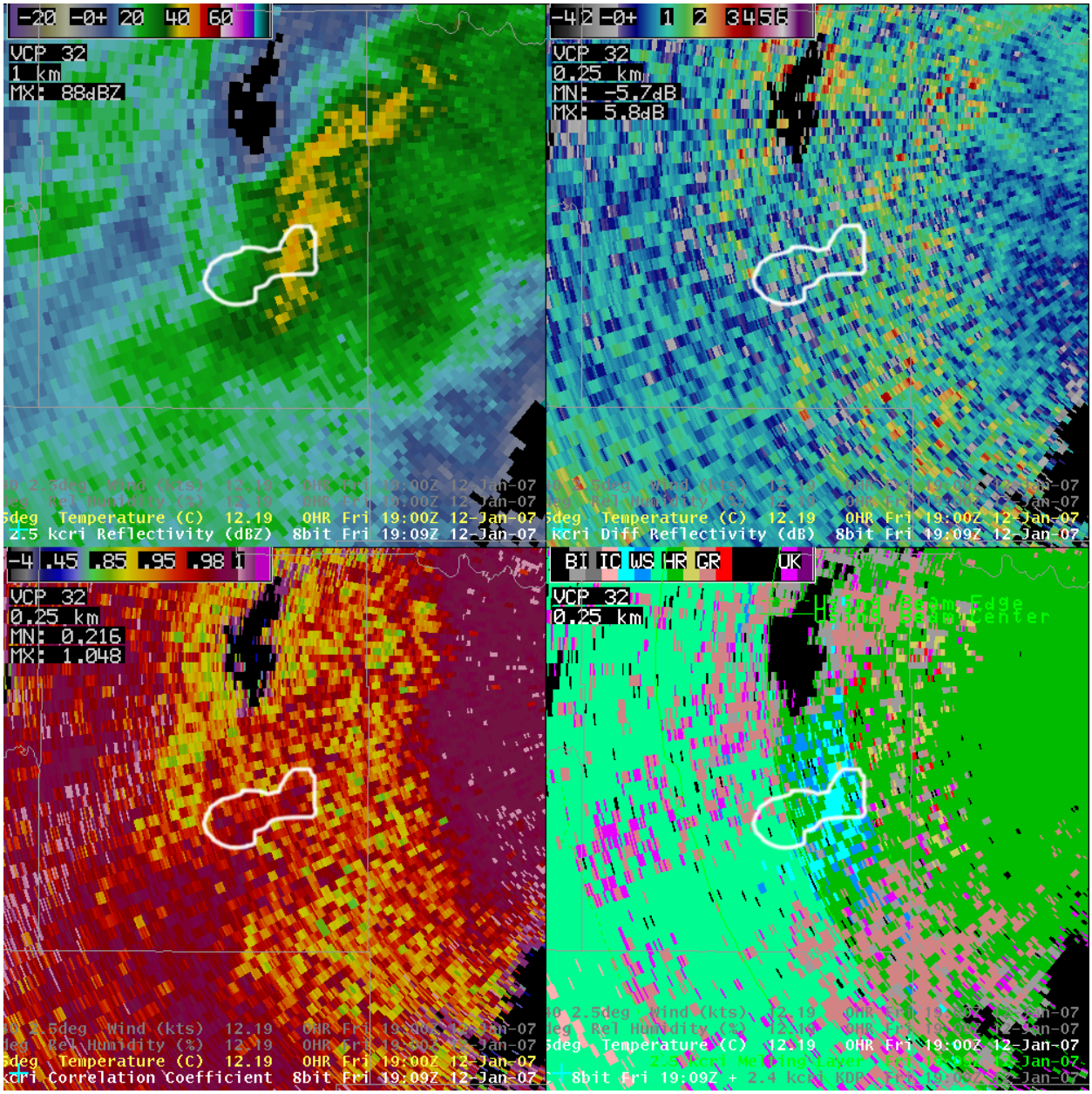
AZ/Ran	Reflectivity (Z)	Diff. Reflectivity (ZDR)	Correlation Coeff. (CC)
295-315 deg azimuth, 30-45 nm range			
295-315 deg azimuth, 45-55 nm range			

Question 4: Using the values you input into the table above, and the training aids for these base products, and correctly assuming completely frozen particles, what is the most likely hydrometeor in the two regions?

Question 5: Given what we identified as the most likely hydrometeor type above the melting layer northwest of the radar, let's examine how the algorithm handled it. Look at HC output at 2.4 deg (you can hit the #8 key in PCR mode). How does it classify the 2 regions identified in previous questions?

Question 6: What about HCA output appears to be clearly in error at the 1722 UTC volume scan?

Question 7: Using cursor readout to get a feel for temperature near the surface, and given what the radar is saying about hydrometeors aloft, what is the most likely precipitation type at the surface in C. Oklahoma?



2.4 deg elevation angle: Z (top left), ZDR (top right), HCA (bottom right), and CC (bottom left).

Question 8: Examine the above graphic, focusing on the region inside the white polygon. What are the characteristics of this region and what do you think is the most likely precipitation type? Explain your reasoning, and feel free to use the training aids. Hint, HCA is incorrect in parts of this polygon, so trust your base data analysis!

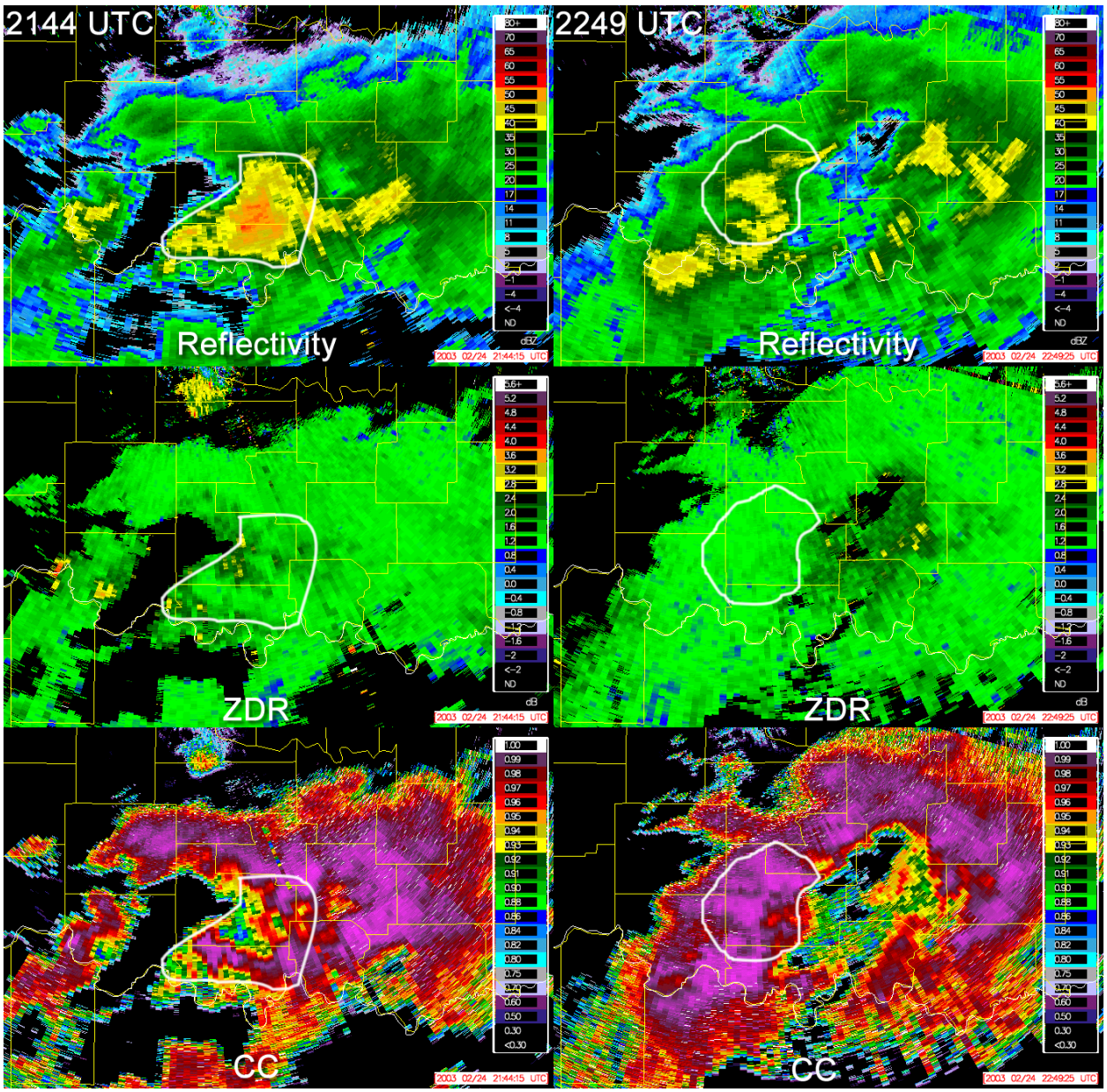
3. Cold Season Dual-Pol Radar Signatures
IC3.3: Precipitation Type in Similar Reflectivity Cores: Snow and Mixed Hydrometeor Type

Objectives: To gain knowledge in dual-pol base data characteristics during snow, mixed hydrometeors, and hydrometeor/precipitation type changes.

Case Data: 24 February 2003 winter storm in southern Oklahoma. There is no WES data for this case. Job sheet images are below.

Instructions: On the next page is an image of reflectivity (top), differential reflectivity (middle), and correlation coefficient (bottom), from the KOUN radar at 2144 UTC, 24 February 2003 (left) and 2249 UTC, 24 February 2003 (right).

Examine the base Z (top), ZDR (middle), and CC (bottom) data inside the white polygon on the images on the next page, and compare the character of these three base moments between the 2144 UTC time (left) and roughly one hour later at 2249 UTC (right). Answer the questions that follow the graphic on the following pages.



Question 1: Comparing the reflectivity images (top) between 2144 UTC (left) and 2249 UTC (right), what differences and similarities do you see regarding both the character of the reflectivity echoes and the values?

Question 2: Now, compare the differential reflectivity images (middle) between 2144 UTC (left) and 2249 UTC (right), what differences and similarities do you see regarding both the character of the ZDR echoes and the values?

Question 3: Finally, compare the correlation coefficient images (bottom) between 2144 UTC (left) and 2249 UTC (right). What differences and similarities do you see regarding both the character of the reflectivity echoes and the values?

4. Non-Meteorological Echo Dual-Pol Radar Signatures
IC4.1: Birds and Insects

Introduction:

Objective: To gain a basic understanding of dual-pol radar signatures of non-meteorological bird and insect returns

Case Data: 8 April 2008 in central Oklahoma.

Instructions:

1. Follow the steps 1-4 in Jobsheet 1.1 for loading D2D for the dual-pol primer jobsheets. Here are the steps, in brief:
    a. Open a terminal window on your WES
    b. Change directory to the dual_pol primer case, i.e. **cd /data/awips/dualpol_primer**
    c. Start the launcher script, i.e. **./dualpol_primer.csh**
    d. Type in **4.1** from the list of options
    e. After ~1 minute, the new windows will close to be replaced by a "Start D-2D" window.
    f. Click ok in the "Start D-2D" window and the subsequent window that pops up.
    g. Ensure that D2D clock is set to current real time.

2. Open the procedure "Dual-pol Primer" and select the bundle "Jobsheet 4.1". This will give you these products loaded into the following 4-panel layout, as well as the ability to do environmental sampling:

    1. All-Tilts reflectivity (Z) paired with storm-relative mean radial velocity (SRV)
    2. All-Tilts differential reflectivity (ZDR) paired with base mean radial velocity (V)
    3. All-Tilts specific differential phase shift (KDP) paired with hydrometeor classification (HCA)
    4. All-Tilts correlation coefficient (CC) with velocity spectrum width (SW)

3. Navigate to the 0434 UTC volume scan.

4. In this exercise we will interrogate the expansive area of roughly 10 to 20 dBZ echoes covering approximately the southern half of the radar sampling domain.

5. Toggle to base velocity (key #6 if using PCR), you will note that the radar is sampling a near 60 knot southerly low level jet feeding into the storms to the north of the radar. The maximum wind speeds are within the 1,500 to 2,500 foot agl layer directly to the south of the radar site, suggesting wind direction is roughly from 180-190 degrees.

Question 1: Interrogate reflectivity and dual-pol base data over the southern half of the radar sampling domain. What is the general character of the reflectivity data?

Navigate up to the 1.8 degree elevation slice and interrogate the Z data.

Question 2: What is the general character of the Z data at the 1.8 degree elevation slice?

Question 3: Navigate back down to the 0.5 degree reflectivity slice and examine the ZDR data (key #2 in PCR mode). What is the character of the ZDR data?

Question 4: Switch to CC (key #3 in PCR mode). What is the character of the CC data?

Question 5: Switch to HCA output (key #8 in PCR mode). What is the output from the HCA over the southern half of the radar sampling domain?

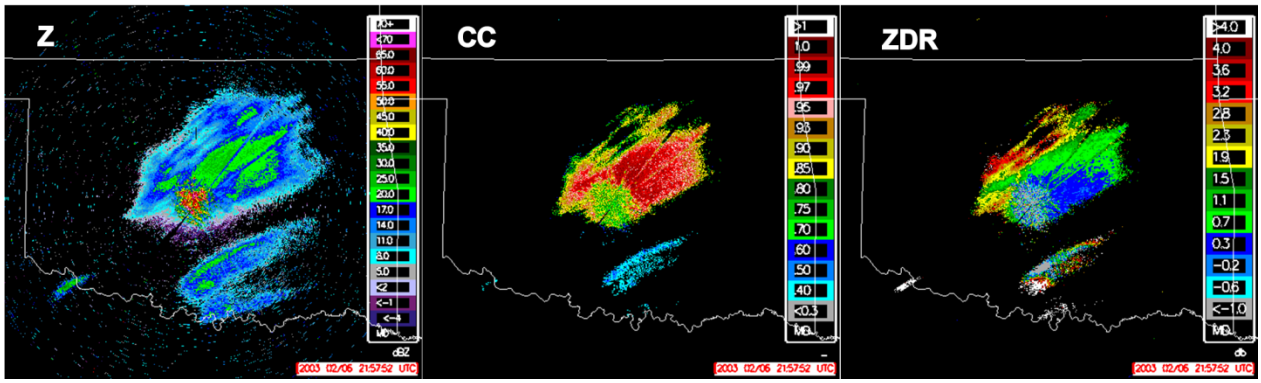
4. Non-Meteorological Echo Dual-Pol Radar Signatures
IC4.2: Chaff

Introduction:

Objectives: To gain a basic understanding of dual-pol radar signatures of non-meteorological chaff returns.

Case Data: 6 February 2003 light snow event in central Oklahoma. There is no WES data for this case, but an example of chaff echoes is displayed below.

Instructions: Below is an image of reflectivity (left), correlation coefficient (center), and differential reflectivity (right), from the KOUN radar at 2157 UTC 6 February 2003:



Examine the base reflectivity, correlation coefficient, and differential reflectivity data in the image above, and compare the character of these three base products between the returns in central and northern Oklahoma (north of the radar site), and the returns in southern and southwest Oklahoma (south and southwest of the radar site).

Question 1: How do the Z values compare between the echoes in central/northern Oklahoma, and the echoes in southern Oklahoma, and southwest Oklahoma/northwest Texas?

Question 2: How do the CC values compare between the echoes in central/northern Oklahoma, and the echoes in southern Oklahoma, and southwest Oklahoma/northwest Texas?

Question 3: How do the ZDR values compare between the echoes in central/northern Oklahoma, and the echoes in southern Oklahoma, and southwest Oklahoma/northwest Texas?

4. Non-Meteorological Echo Dual-Pol Radar Signatures
IC4.3: Anomalous Propagation

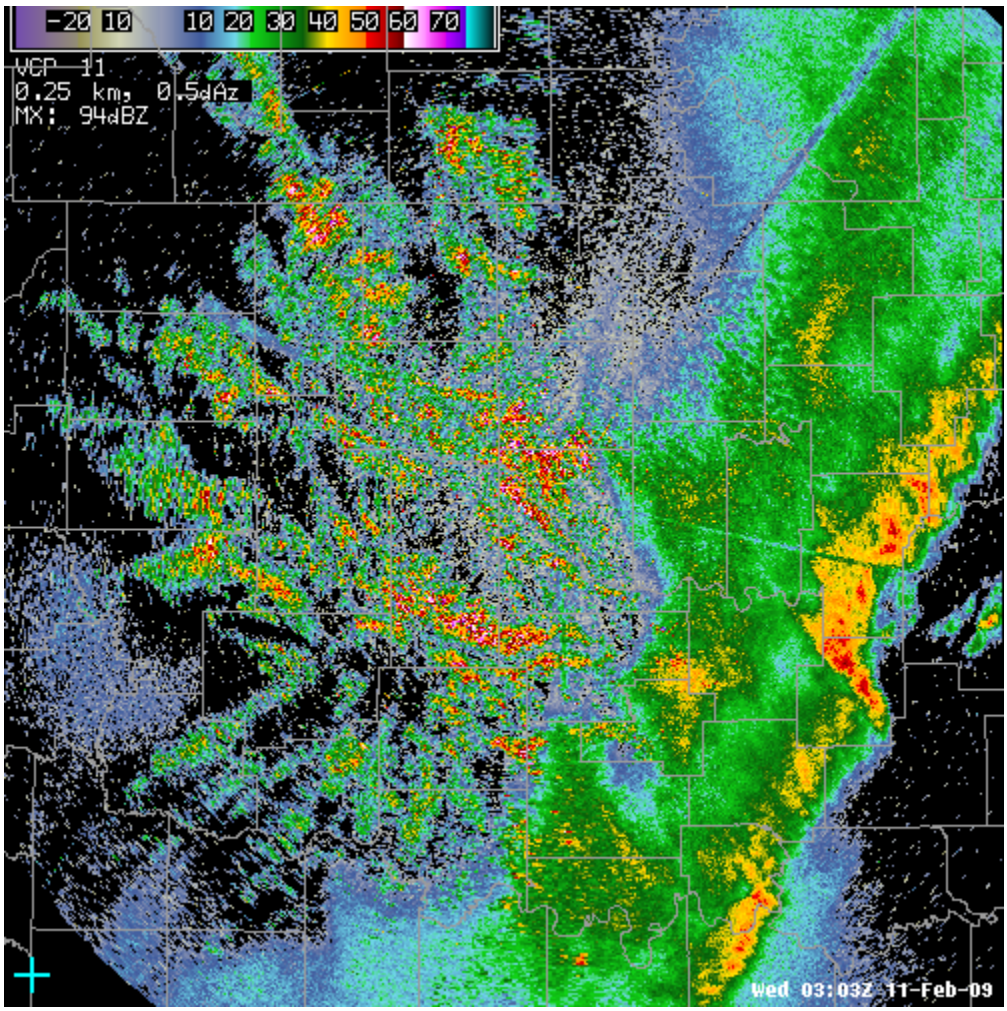
Introduction:

Objectives: To gain a basic understanding of dual-pol radar signatures of non-meteorological AP returns.

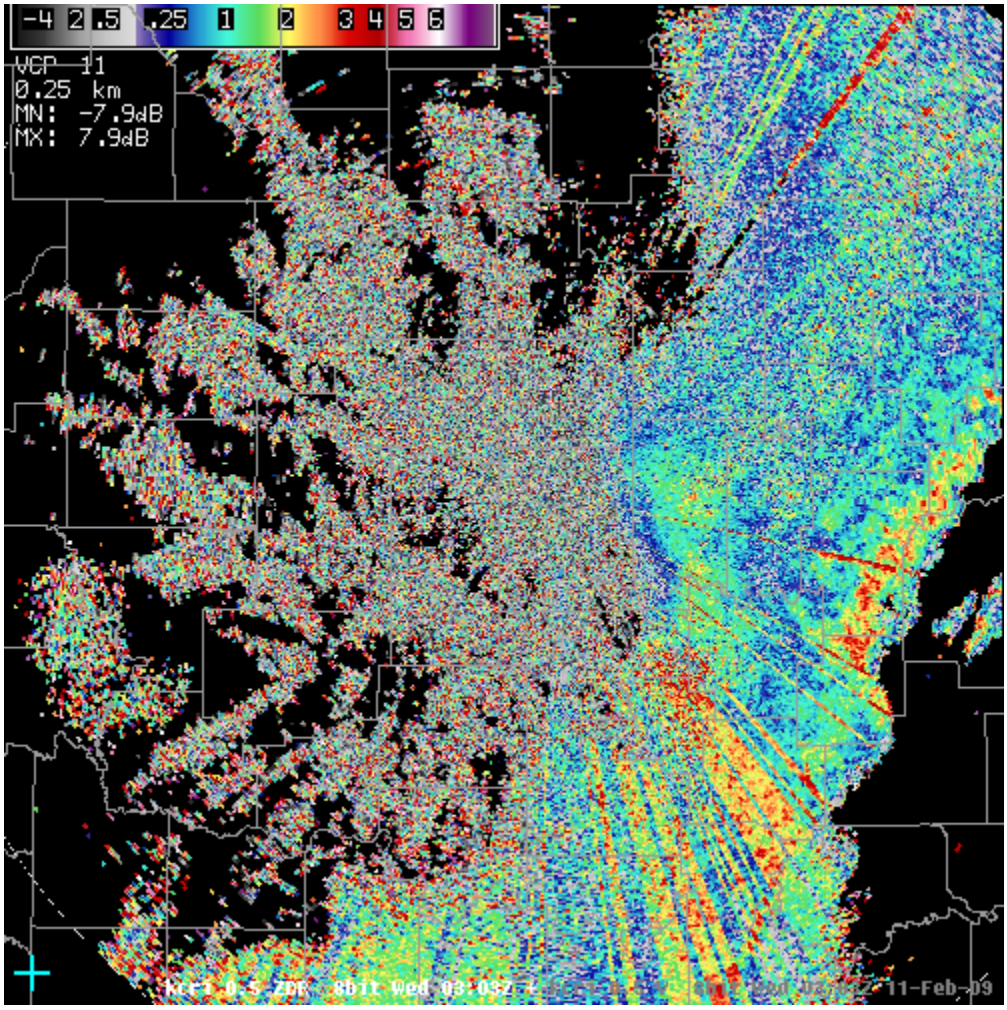
Case Data: 11 February 2009 post-squall line in central Oklahoma. There is no WES data in your primer, but below is an excellent example of AP.

Instructions: Note that absolutely no clutter filtering has been applied, so the sheer amount of AP is staggering. WSR-88D data after the upgrade should filter AP as much as and likely more than before.

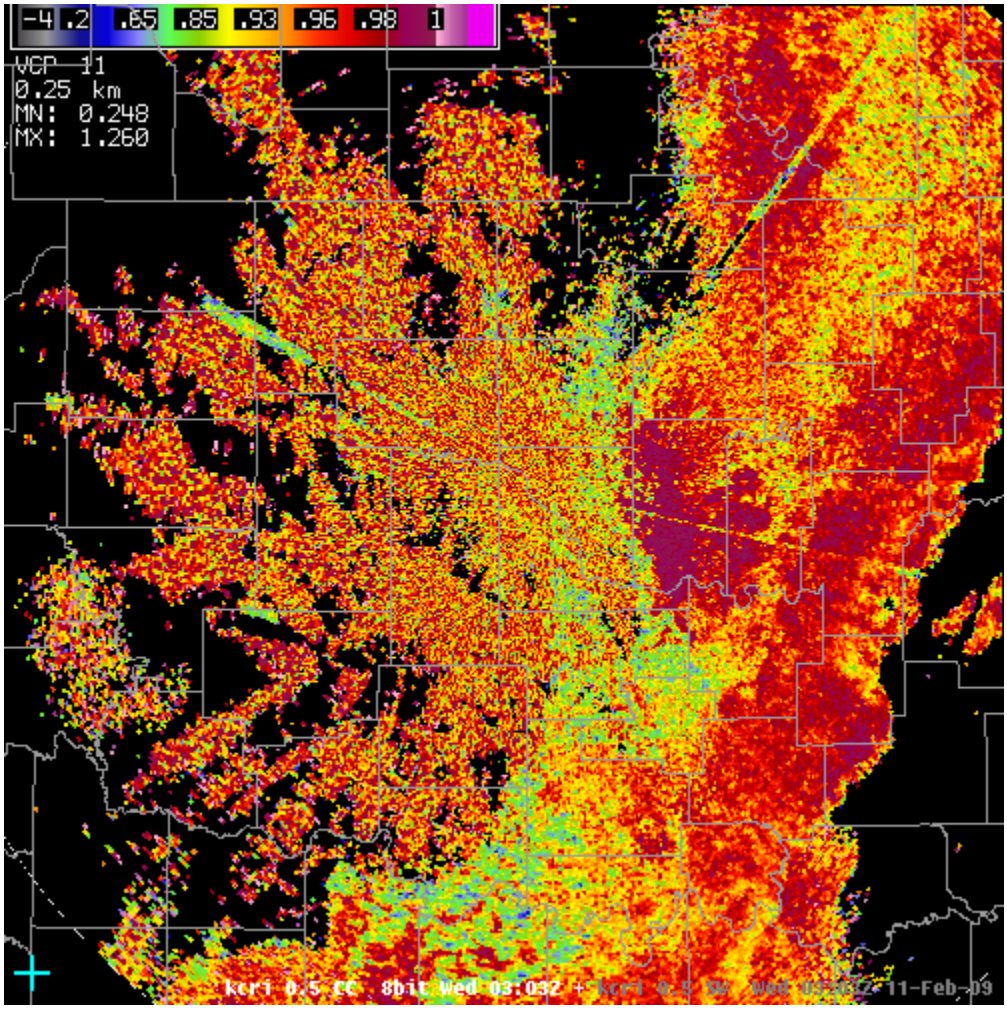
Question 1: **Below is an image of reflectivity after a strong squall line passes to the southeast of KOUN. Use it as a reference as you examine the dual-pol products. What is characteristic of the AP echoes west, northwest, and north of the radar?**



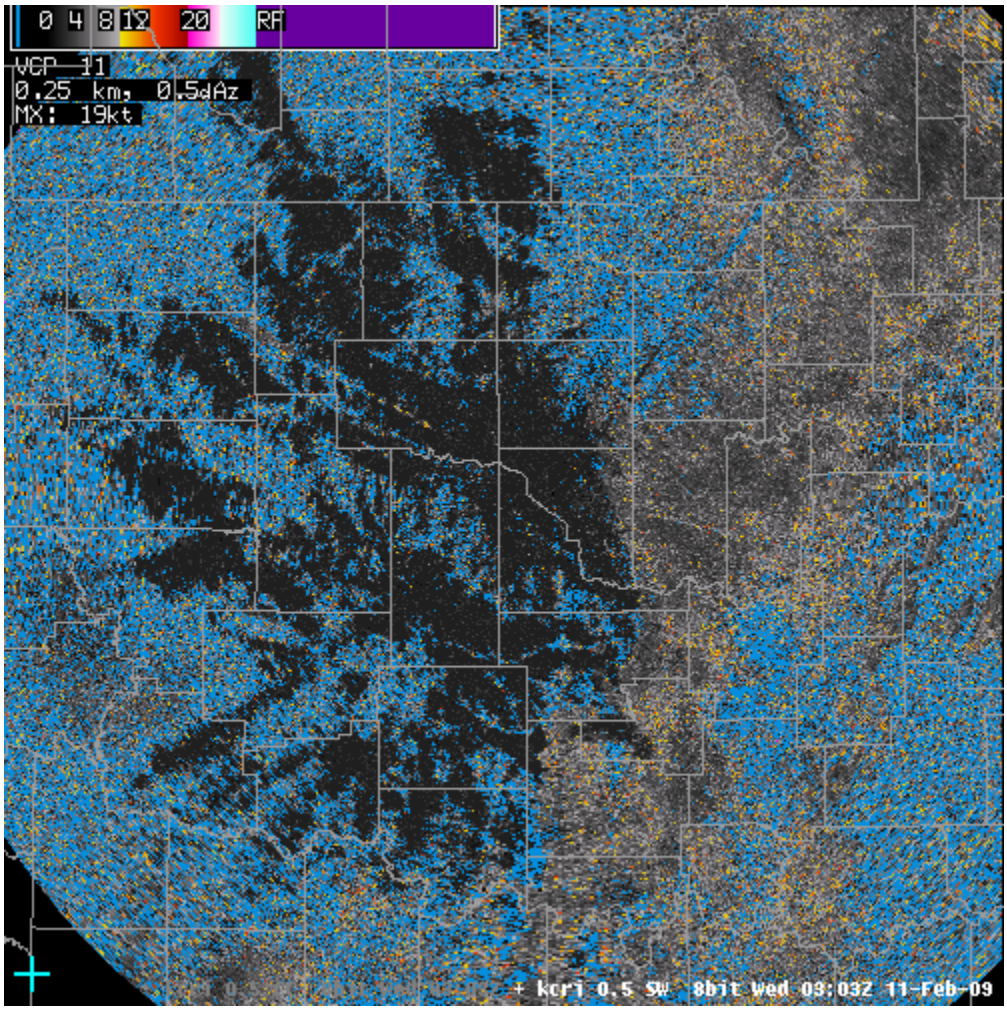
Question 2: Below is ZDR. What are the characteristics of ZDR in AP?



Question 3: Below is CC. What are the characteristics of CC in regions of AP?



Question 4: We chose not to show velocity because it is so noisy and error stricken it's essentially not worth showing. However, below is SW. What are the characteristics of SW in regions of AP?



Question 5: Given the characteristics of the base products from questions 1-4, how do you think the Hydrometeor Classification Algorithm would perform in this case at tagging areas of AP as "GC" (Ground Clutter/AP)?