Dual-Pol WES Exercises Overview

This document contains 4 jobsheets that step you though a dual-pol radar analysis in case review mode on the WES. All events are from central Oklahoma from the WSR-88D Dual-Pol KOUN. Each jobsheet in this document is specific to a particular high impact event and you don't have to work through them in any particular order. Including viewing the self-contained answer keys, these will take a total of roughly 7 hours to work through but completion times will vary from person to person. The jobsheets are:

1. **Winter Weather: ~90 min analysis time + 26 min answer keys**
2. **Heavy Rain: ~60 min analysis time + 22 min answer keys**
3. **Tornadoes and Hail: ~100 min analysis time + 60 min answer keys**
4. **Bow Echo: ~40 min analysis time + 20 min answer keys**

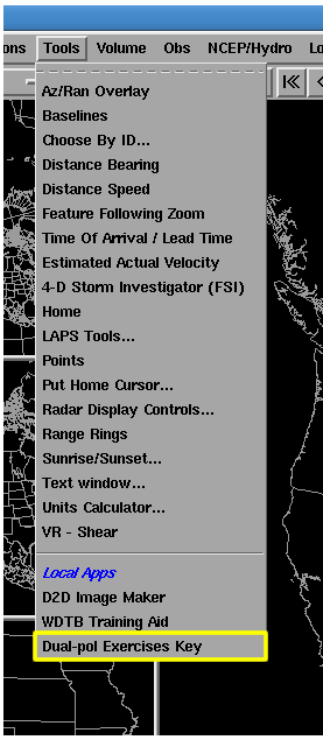
Answer Keys

Answer keys are provided on a question by question basis, and are loaded directly off the WES! They each consist of a narrated video screen capture, demonstrating how Paul Schlatter from WDTB would have answered each question on his WES. It's up to you *when* you want to view the answer key for each question, either immediately after you fill out the answer or at the end of the jobsheet. In any case, please load the answer key launch page right off the tools menu (right graphic below). A firefox window will open containing links to each of the jobsheet answer keys (left graphic below). Make sure you have a way to hear the narration associated with each video screen capture answer key.

Dual-Pol WES Exercises Answer Key

This page has the links to view camtasia presentations of the answers to each of the questions that make up the dual-pol operations coures WES exercises. Each link below will launch an external window containing the answer(s) to the jobsheet and questions listed.

Winter Weather Jobsheet (12/24/09, 2/26/10, 3/20/10)	Heavy Rain Jobsheet (June 14, 2010)	Tornado/Hail Jobsheet (May 10, 2010)	Bow Echo Jobsheet (May 19, 2010)
Question 1 Key	Question 1 Key	Question 1 Key	Question 1 Key
Question 2 Key	Question 2 Key	Question 2 Key	Question 2 Key
Question 3 Key	Question 3 Key	Question 3 Key	Questions 3-4 Key
Question 4 Key	Question 4 Key	Question 4 Key	Question 5 Key
Questions 5-6 Key	Question 5 Key	Question 5 Key	Question 6 Key
Question 7 Key	Questions 6-7 Key	Question 6 Key	Question 7 Key
Question 8 Key	Question 8 Key	Question 7 Key	Question 8 Key
Question 9 Key	Question 9 Key	Questions 8-9 Key	Question 9 Key
Question 10 Key	Question 10 Key	Question 10 Key	
Questions 11-13 Key	Question 11 Key	Question 11 Key	
Question 14 Key	Question 12 Key	Question 12 Key	
Question 15 Key		Question 13 Key	
Question 16 Key		Question 14 Key	
Questions 17-18 Key		Question 15 Key	
		Question 16 Key	
		Question 17 Key	
		Question 18 Key	
		Question 19 Key	
		Question 20 Key	
		Question 21 Key	
		Question 22 Key	
		Question 23 Key	
		Question 24 Key	



Jobsheet #1: Winter Precipitation

Objective:

- Using the knowledge gained from training modules and with the aid of all training aids, integrate an analysis of dual-pol radar products into two case studies of winter precipitation in central Oklahoma

Case Data: 24 December 2009, 26 February 2010, and 20 March 2010 in central Oklahoma.

Available Data: KOUN radar, and LAPS data for the 24 December event.

Analysis Duration: 90 min
Answer Keys Duration: 26 min

Instructions:

1. Using the WES workstation, left click on the D2D clock in the lower right part of D2D
2. Using the "Set Time" window, set the D2D clock to **2010 March 20 13:45 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
3. Set Map Scale to "WFO"
4. Click on the koun menu and load "All Tilts Base Data"
5. Set frames to 64
6. Swap panes to an empty pane
7. Set Map Scale to "WFO"
8. Click on the koun menu and load "0.5 Base Data"
9. Set frames to 30
10. Modify map backgrounds and data magnification as you see fit in both panes

11. In the 0.5 deg base data pane, loop through the 30 frames at 4 panels and/or Panel Combo/Rotate, getting a broad scale view of the base products Z, ZDR, CC, and KDP, the character and movement of the precipitation echoes, and to become familiar with controls if you are not already.

*****During this event the contractor was testing CC noise correction. As a result, there was no noise correction applied at this time. You'll see the result of this in low Signal to noise ratio (SNR), CC drops off quickly. Ignore CC in these areas, restrict your focus on CC to areas of stronger reflectivity, roughly greater than 20 dBZ.*****

12. When ready, go the 0.5 deg 4 panel layout of base data at **13:44 UTC**, and examine ZDR. You can use the 4-panel display or hit the #2 key to enter Panel Combo/Rotate (PCR) mode.

For reference, on the next page you'll find a 12 UTC sounding from near the radar, as well as a graphic with surface observations. The questions follow the graphics.

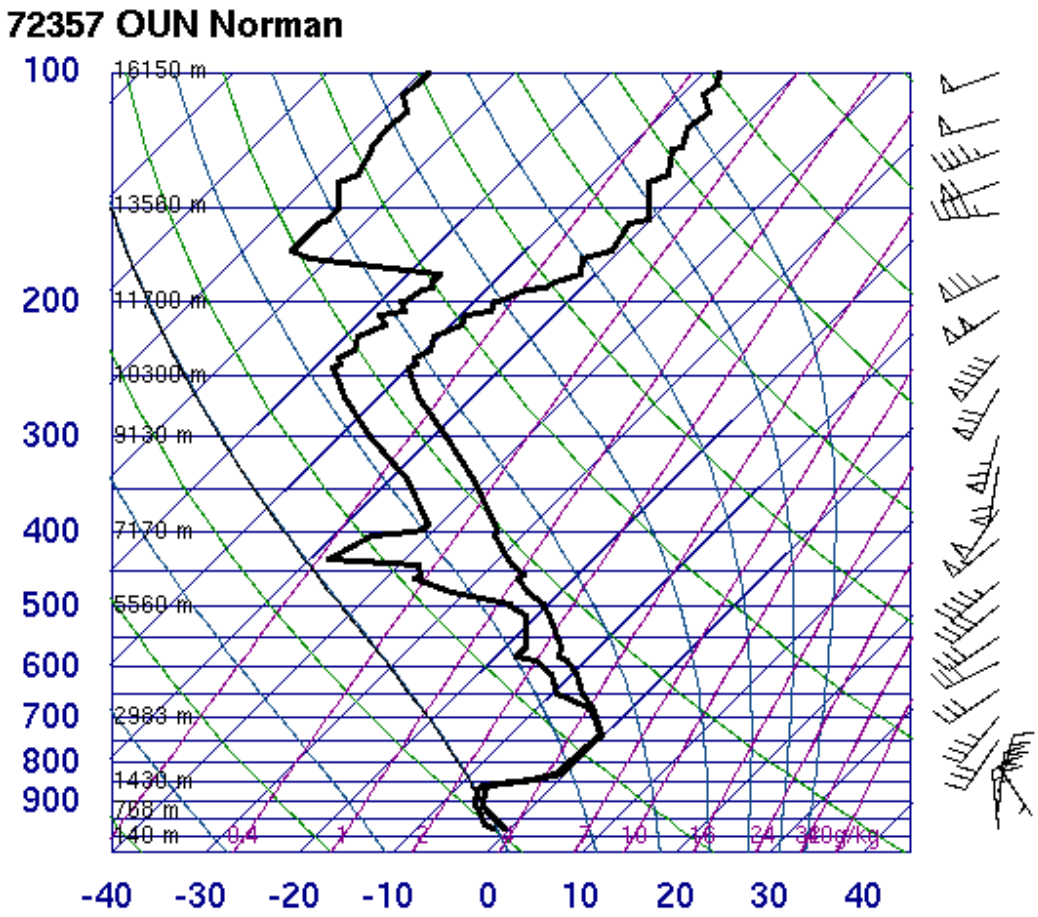


Figure 1: OUN skew-T from 20 March 2010 at 12 UTC.

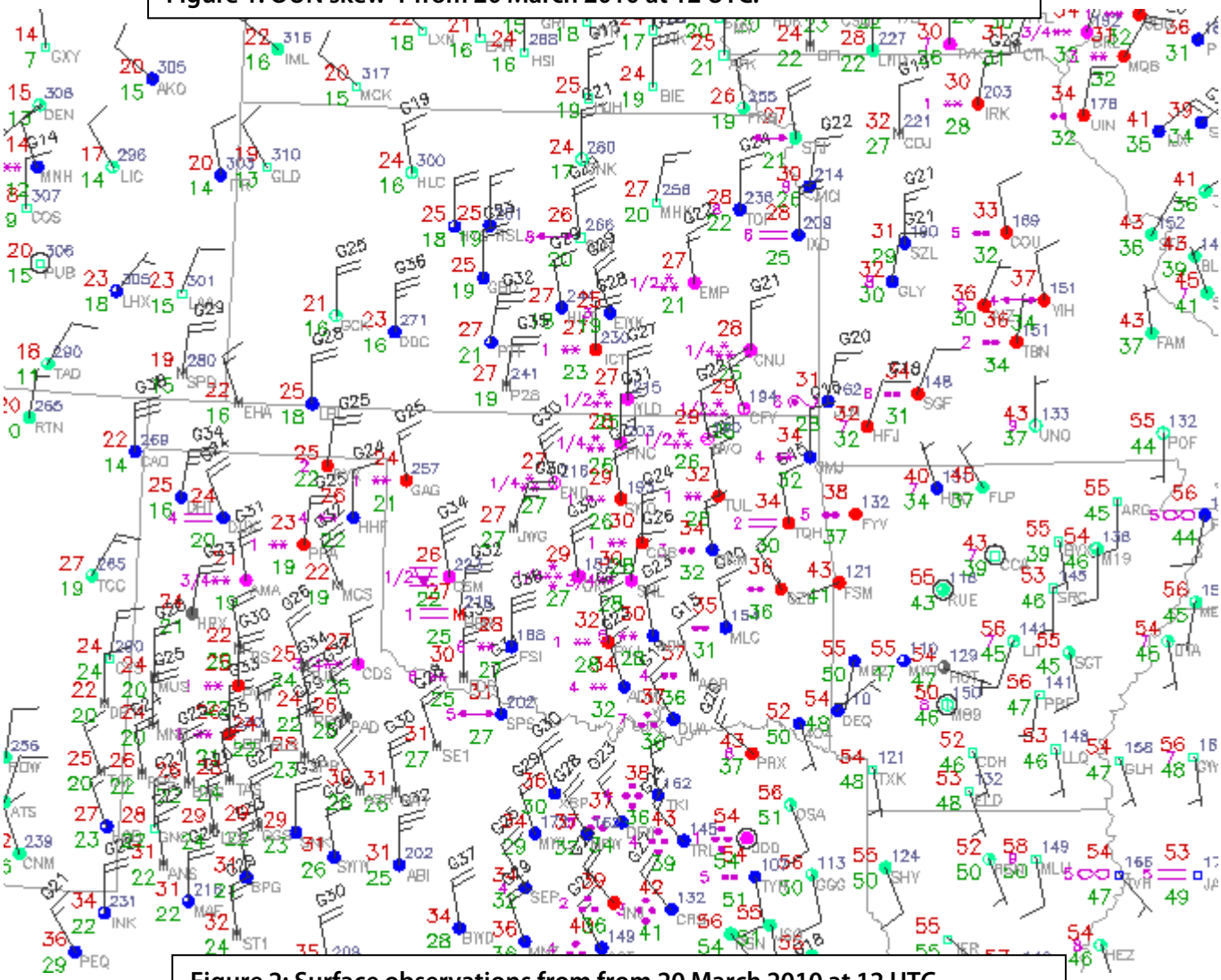


Figure 2: Surface observations from from 20 March 2010 at 12 UTC.

Question 1: Using the cursor readout sampling, what are the average ZDR values (using your eyes to average) north and east of the radar roughly between 15 and 40 nm in reflectivity greater than 20 dBZ (toggle between Z and ZDR using 1 and 2 keys)? Refer to Figure 3 below.

ZDR ~ _____ dB

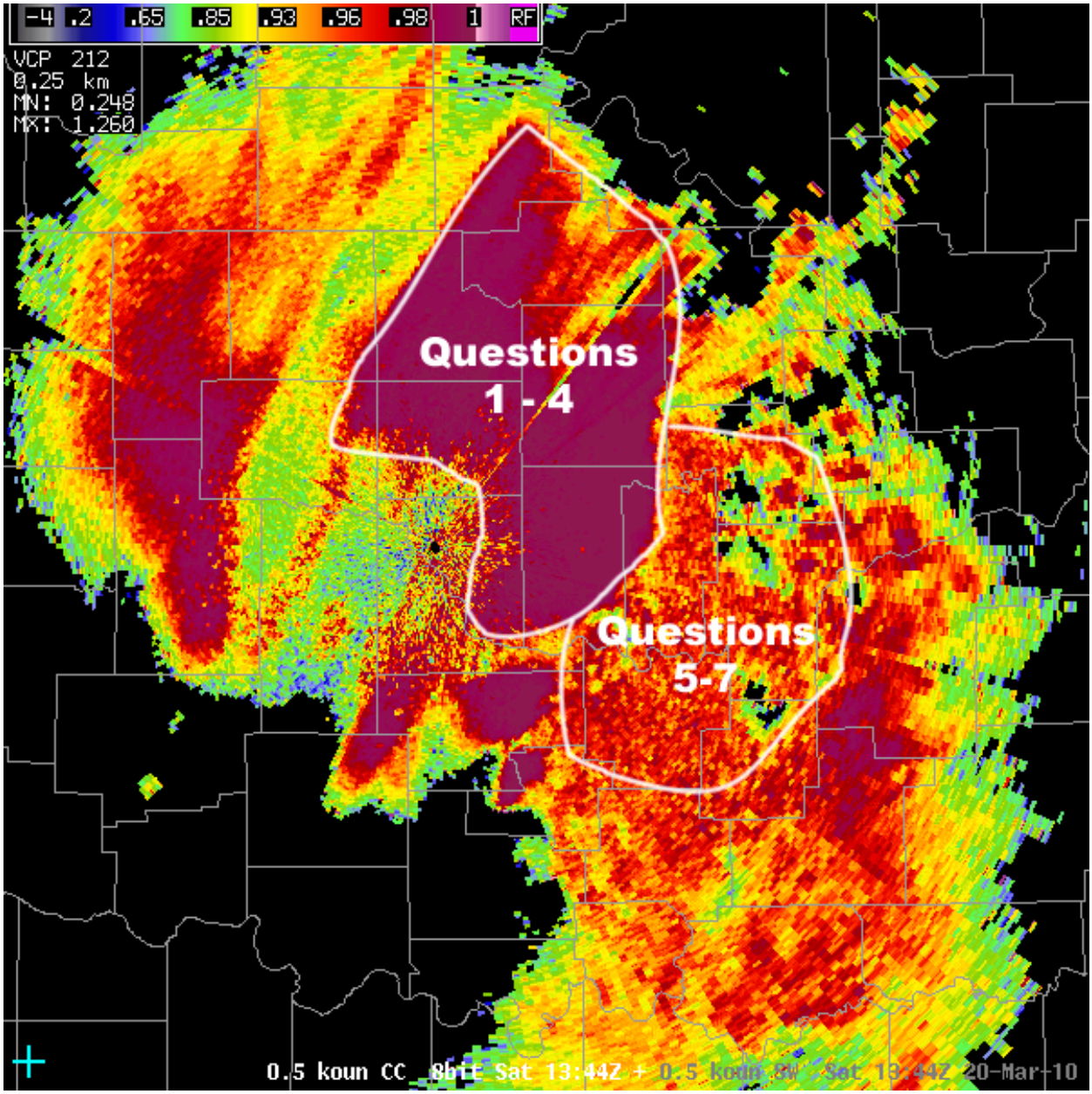


Figure 3: 0.5 deg Correlation Coefficient product from 20 March 2010 at 13:44 UTC. The region on your own workstation to analyze Z, CC, and ZDR for each set of questions is as indicated in the graphic.

Question 2: What is an "eyeball" averaged correlation coefficient (CC) values to the nearest hundredth within this same region (Use the #3 key to toggle to CC)?

CC ~ _____

Question 3: Switch to your All-Tilts Base Data display and make sure you are looking at the 1344 UTC volume scan. Zoom into CC (using #3 key) and examine all elevation angles of CC. Do you see evidence of a clear cut melting layer ring? (see next page) (Circle One Below) Stick to stronger reflectivity regions in your search (i.e. > 15 dBZ), keeping in mind that along edges of the echo CC is far too low (see Fig. 1).

Yes Clear ML / No Clear ML

Question 4: Given the ZDR and CC values from Questions 1 and 2, added with your melting layer analysis in Question 3, do you think rain, snow, or a mixture of rain and snow is the dominant precipitation type north and east of the radar from 15-40 nm? (Circle One)

Rain / Snow / Rain + Snow Mix

Question 5: Return to your 0.5 deg base data pane at 1344 UTC. Examine ZDR and CC east of the radar at ranges <u>further than ~40 nm east</u> of the radar in reflectivity greater than 20 dBZ (See Fig. 3). Use your eyes to find the average ZDR and CC values out there.

ZDR ~ _____ dB

CC ~ _____

Question 6: Are ZDR and CC values smooth or noisy in the area east of the radar at ranges beyond ~40 nm in reflectivity greater than 20 dBZ? (Circle one)

SMOOTH / NOISY

Question 7: Given the ranges of values for CC and ZDR in the previous 2 questions, and recalling the melting layer information found in Question 3, do you think rain, snow, or a mixture of rain and snow is the dominant precipitation type east of the radar roughly outside of 40 nm?

Rain / Snow / Rain + Snow Mix

Moving onto the Next Winter Event

1. Swap panes to a blank pane, you will now move onto the 2nd winter weather event.
2. Left click on the D2D clock in the lower right of D2D
3. Set the D2D clock to **2010 February 26 7:20 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
4. Set Map Scale to "WFO"
5. Click on the koun menu and load "All Tilts Base Data". NOTE: There is no KDP with this event.
6. Set frames to 64
7. Modify map backgrounds and data magnification as you see fit in both panes
8. Using All Tilts get to 0.5 deg, and loop through the 0.5 deg fames at 4 panels and/or using Panel Combo/Rotate, getting a broad scale view of the base products Z, ZDR, and CC.
9. Navigate to the **0.5 deg 0717 UTC** volume scan, and answer the following questions.

For reference, below you'll find a 12 UTC sounding from near the radar (00 UTC sounding does nothing for this event), as well as a graphic with surface observations on the next page. The questions follow the graphics.

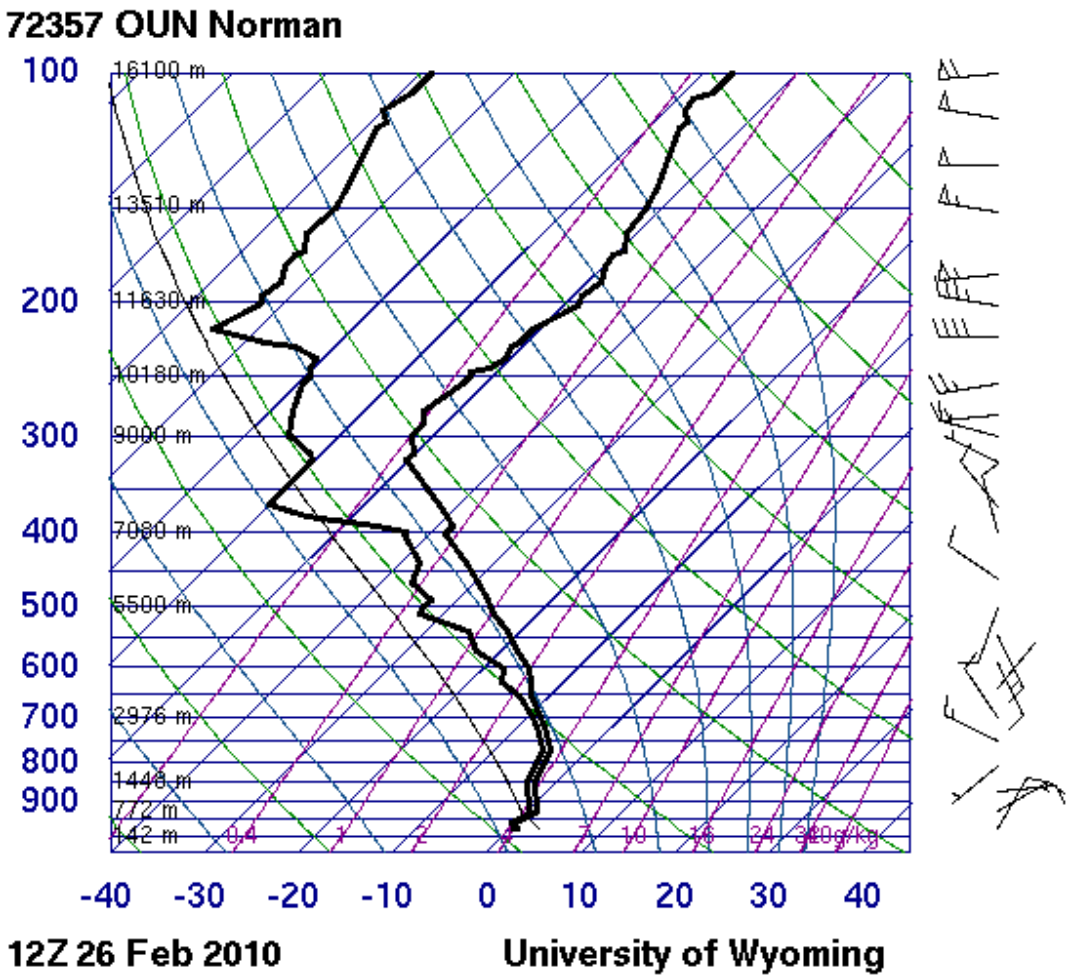


Figure 4: OUN skew-T from 26 February 2010 at 12 UTC.

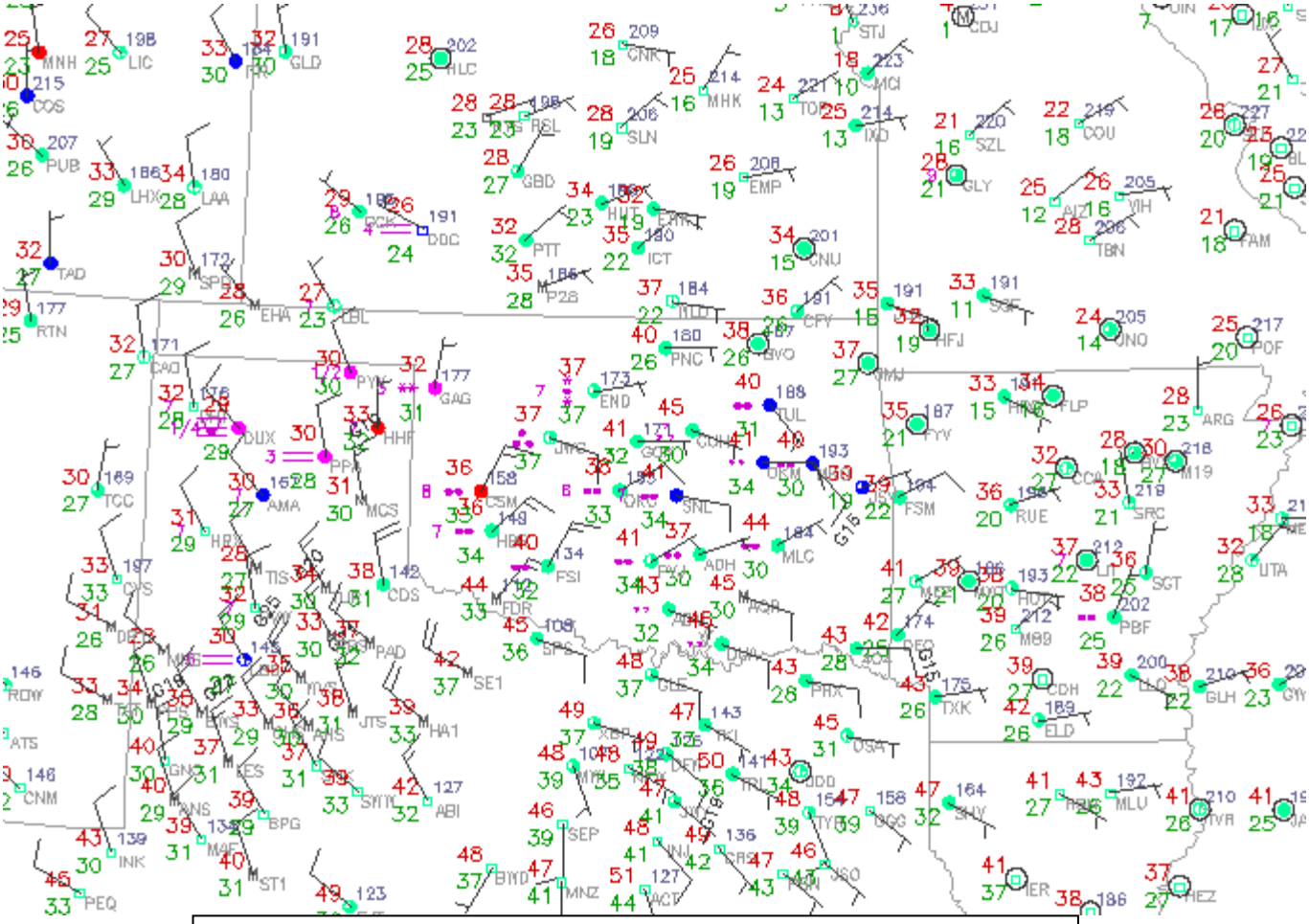


Figure 5: Surface observations from 26 February 2010 at 12 UTC.

Question 8: Toggle between Z and ZDR (buttons 1 and 2), and then add CC (button 3) to the toggle. Fill out the table below with the mean values for Z, ZDR, and CC. Scan several bins around each range and azimuth to determine the general value from each radar product listed in the table. You will use this table to answer Question 10.

	Z	ZDR	CC
20 nm @ 308°	dBZ	dB	
6 nm @ 32°	dBZ	dB	
7 nm @ 130°	dBZ	dB	
13 nm @ 281°	dBZ	dB	

Question 9: Now step up in elevation angle to 1.3 deg. Using Z, CC, and ZDR, identify areas around the radar that appear to have a melting layer signature at 1.3 deg. Only use CC and ZDR in reflectivity greater than 10 dBZ in your search. As an example, your answers only needs to be of the form: "Northwest of the radar from 10-20 nm"

Question 10: Using your melting layer information from Question 9 and your Z/ZDR/CC values from Question 8, what is your best guess at dominant precipitation type at the 0.5 deg tilt that correspond to the same points from Question 8: Choose from rain, snow, or rain/snow mix and fill out the table below?

	Pure Rain, Pure Snow, or Rain and Snow Mix?
20 nm @ 308°	
6 nm @ 32°	
7 nm @ 130°	
13 nm @ 281°	

Moving onto the Final Winter Event

1. Swap panes to a blank pane, you will now move onto the 3rd and final winter weather event.
2. Left click on the D2D clock in the lower right of D2D
3. Set the D2D clock to **2009 December 24 1907 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
4. Set Map Scale to "WFO"
5. Click on the koun menu and load "All Tilts Base Data".
6. While in the same pane as the All Tilts products, click on the Volume menu, then "Std Env Data Package", then "LAPS"
7. Set frames to 64
8. Modify map backgrounds and data magnification as you see fit in both panes
9. Using All Tilts get to 0.5 deg, and loop through the 0.5 deg fames at 4 panels and/or using Panel Combo/Rotate, getting a broad scale view of the base products Z, ZDR, and CC.

*****This event was very early in the development and testing process. As a result CC will look poor in weak reflectivity, so stick to stronger signal, roughly in regions with greater than 20 dBZ. KDP was not calibrated for this event, so it's probably best if you ignore it during your analysis.*****

For reference, below you'll find surface observations from 19 UTC. On the next page you'll find 12 UTC and 18 UTC soundings from near the radar. The questions follow the graphics.

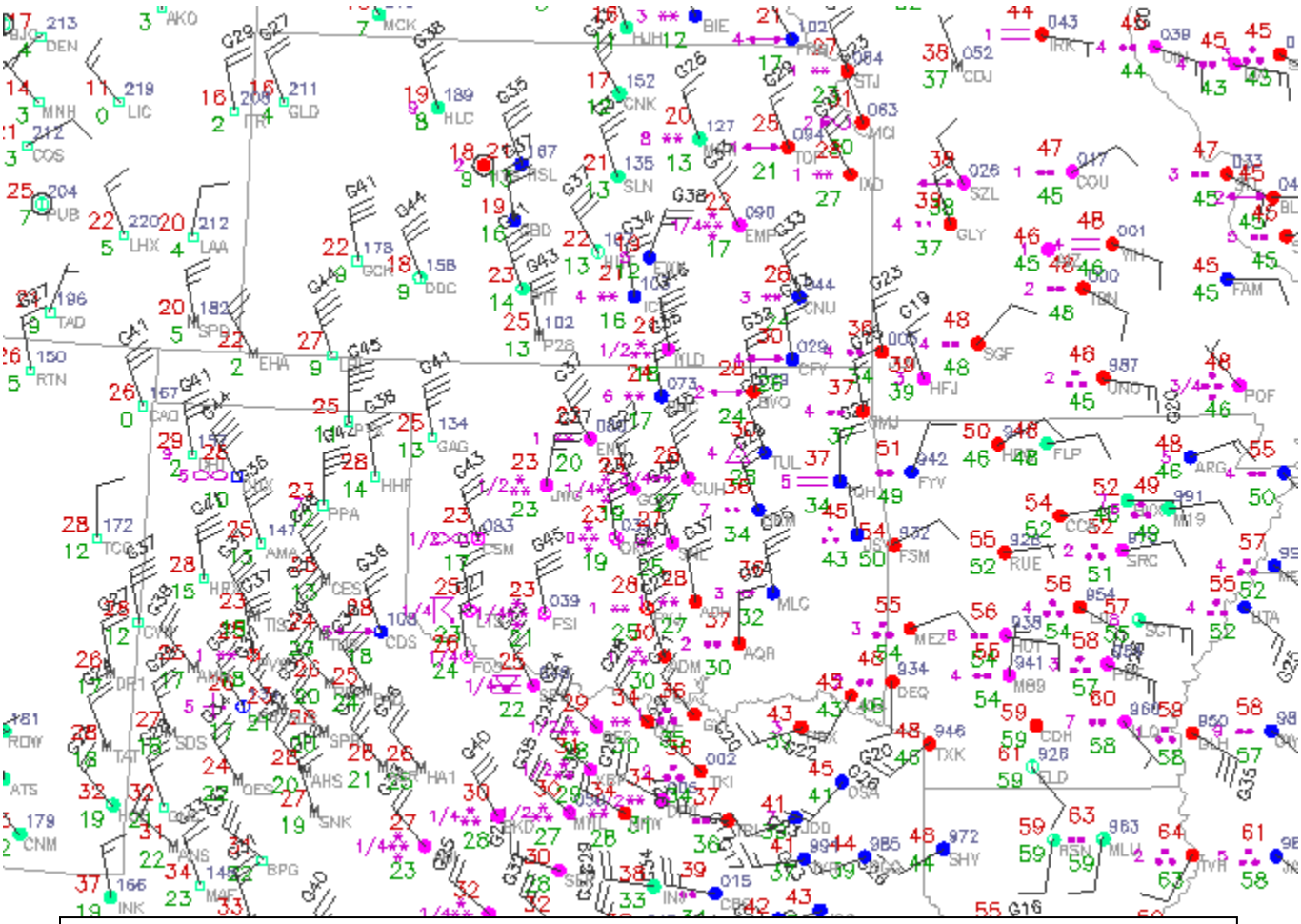


Figure 6: Surface observations 24 December 2010 at 19 UTC.

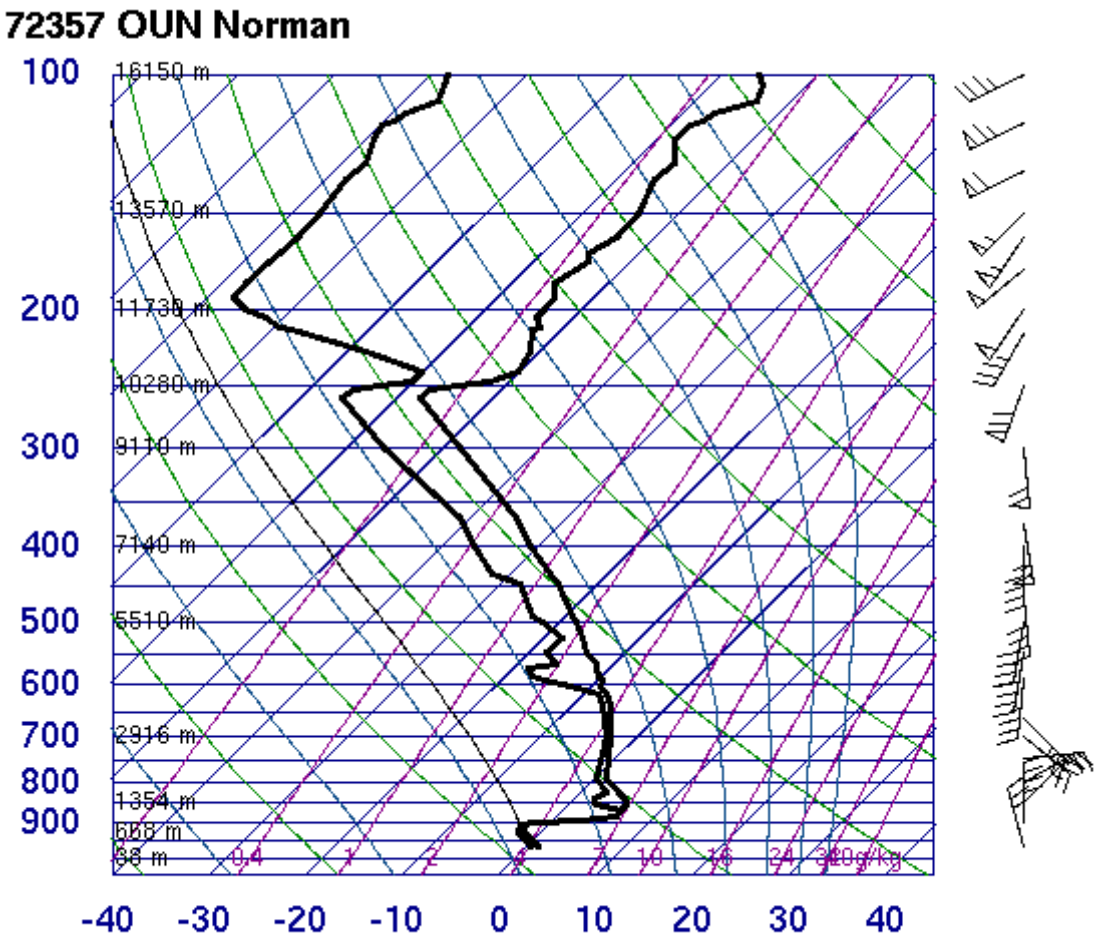


Figure 7: OUN Skew-T from 24 December 2010 at 12 UTC.

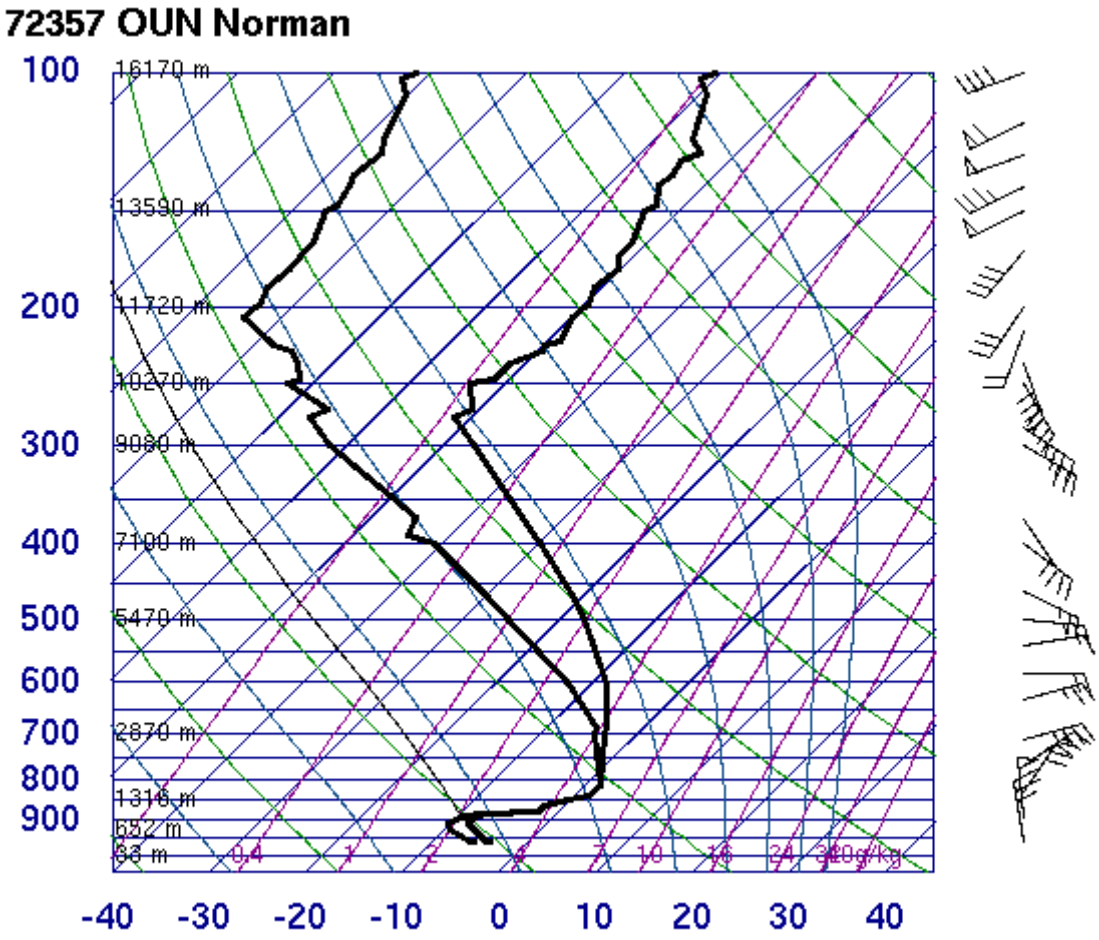


Figure 8: OUN Skew-T from 24 December 2010 at 18 UTC.

Question 11: We will apply the decision tree help determine precipitation type at the surface using the radar data that spans 1624 UTC through 1907 UTC. The first step is trying to find a melting layer. Using CC all-tilts and using trends in CC over time, are you able to identify a melting layer? (Circle one)

Yes Melting Layer / No Melting Layer

Question 12: Now look for a melting layer using LAPS temperature readout. Do the LAPS temperatures suggest any melting? (Circle one)

NO Melting / YES Melting

Question 13: Given your answers to 13 and 14, which data source do you trust in this event for the potential of a melting layer?

LAPS / Radar

Question 14: Given your answer to Question 13, where relative to the radar do you expect to find sleet or freezing rain at the surface at 1907 UTC? Where relative to the radar to you expect to see pure snow at the surface? Give your answer in a range of azimuths for each in the clockwise direction. For example, 0 deg to 90 deg means a certain type is located from north to the east of the radar. If none, enter none.

Pure Snow: _____ deg to _____ deg azimuth

IP/FZRA: _____ deg to _____ deg azimuth

Question 15: Go back to 1907 UTC, and the 0.5 deg elevation angle. Toggle between Z and ZDR (buttons 1 and 2), and then add CC (button 3) to the toggle. Fill out the table below with the mean values for Z, ZDR, and CC for the 0.5 deg elevation angle. Scan several bins around each range and azimuth to determine the general value from each radar product listed in the table, using the figure on the next page as a guide. You will use this table to answer Question 16.

Location	Z	ZDR	CC
A: 36 nm @ 205°	dBZ	dB	
B: 34 nm @ 24°	dBZ	dB	
C: 25 nm @ 187°	dBZ	dB	
D: 8 nm @ 115°	dBZ	dB	

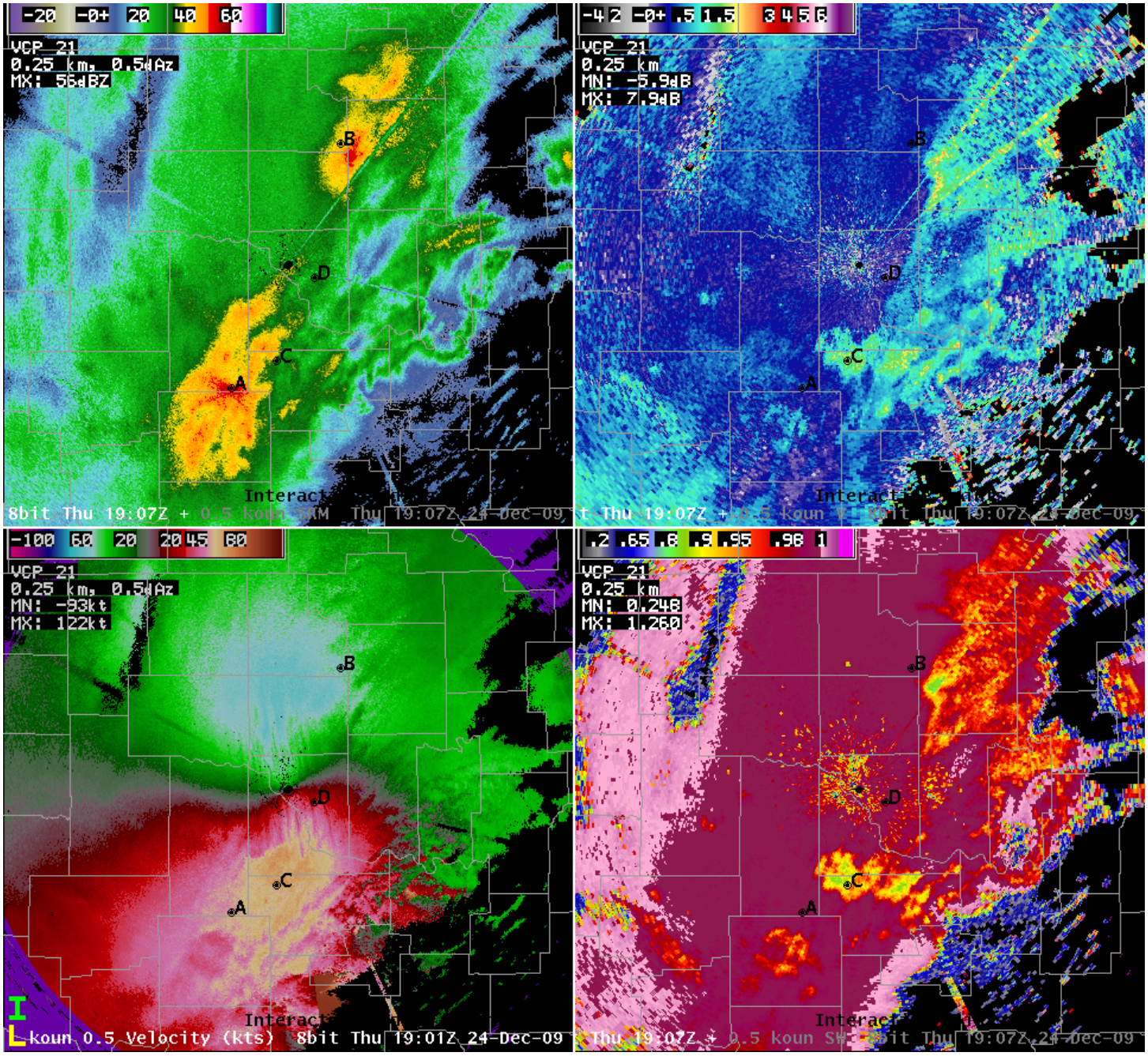


Figure 9: 0.5 deg Reflectivity (top left), Differential Reflectivity (top right), Correlation Coefficient (bottom right), and Velocity (bottom left) products from 24 December 2009 at 1907 UTC. The region on your own workstation to analyze Z, CC, and ZDR for each set of questions is as indicated in the graphic in black letters. Use these to answer questions 15 and 16.

Question 16: Using the table in question 15, the winter weather dual-pol radar decision tree, and the knowledge that any melted hydrometeors will freeze into sleet prior to reaching the surface, provide your best estimate of expected precipitation type at the height of the radar beam and at the surface for each of the 4 points.

Location	Radar Beam P-Type	Expected Surface P-Type
A: 36 nm @ 205°		
B: 34 nm @ 24°		
C: 25 nm @ 187°		
D: 8 nm @ 115°		

Question 17: Swap panes, and then load a 3.4 deg elevation angle 4-panel "base data" off the "KOUN Hi base data tilts" sub-menu option half way down the primary koun radar menu. Load 30 frames in the pane, zoom into the radar and focus on CC (Lower right pane in 4-panel, key #3 for PCR). Fill in the table below for the bottom of the melting layer in feet above ground level (MSL):

Time	Melting Layer Bottom Height (MSL)
1630 UTC	ft
1728 UTC	ft
1832 UTC	ft

Question 18: Loops all frames using the 3.4 deg CC, which should show CC data from 1624-1907 UTC. Explain in words what is physically happening to the melting layer during this time and what this means for precipitation type at the surface.

Jobsheet #2: Heavy Rain Detection

Objective:

- Using the knowledge gained from training modules and with the aid of all training aids, integrate an analysis of dual-pol radar products into a flash flood event.

Case Data: 14 June 2010 in central Oklahoma.

Available Data: KOUN radar and LAPS gridded data

Analysis Duration: 60 min
Answer Keys Duration: 22 min

Instructions:

1. Clear out all panes prior to starting this jobsheet.
2. Left click on the D2D clock in the lower right part of D2D
3. Using the "Set Time" window, set the D2D clock to **2010 June 14 12:13 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
4. Set Map Scale to "WFO"
5. Click on the koun menu and load "All Tilts Base Data"
6. While in the same pane as the All Tilts products, click on the Volume menu, then "Std Env Data Package", then "LAPS"
7. Set frames to 64
8. Swap panes to an empty pane
9. Set Map Scale to "WFO"
10. Click on the koun menu and load "0.5 Base Data"
11. While in the same pane as the 0.5 deg Base Data products, click on the Volume menu, then "Std Env Data Package", then "LAPS"
12. Set frames to 35
13. Modify map backgrounds and data magnification as you see fit

14. In the 0.5 deg base data pane, loop through the 35 fames at 4 panels and/or Panel Combo/Rotate, getting a broad scale view of the base products Z, ZDR, CC, and KDP. You may also want to get a feel for the character and movement of the precipitation echoes.

    *****With this event it's especially important to carefully examine loops of reflectivity near the radar. No ground clutter filtering was done north of the radar, so clutter contamination is a big problem in a few localized areas (see Fig. 2).*****

15. When ready, go the 0.5 deg 4 panel layout of base data at **12:13 UTC**, focusing on the band of heavy precipitation north of the radar from 10-40 nm. Be ready to utilize Panel Combo/Rotate to answer the following questions.

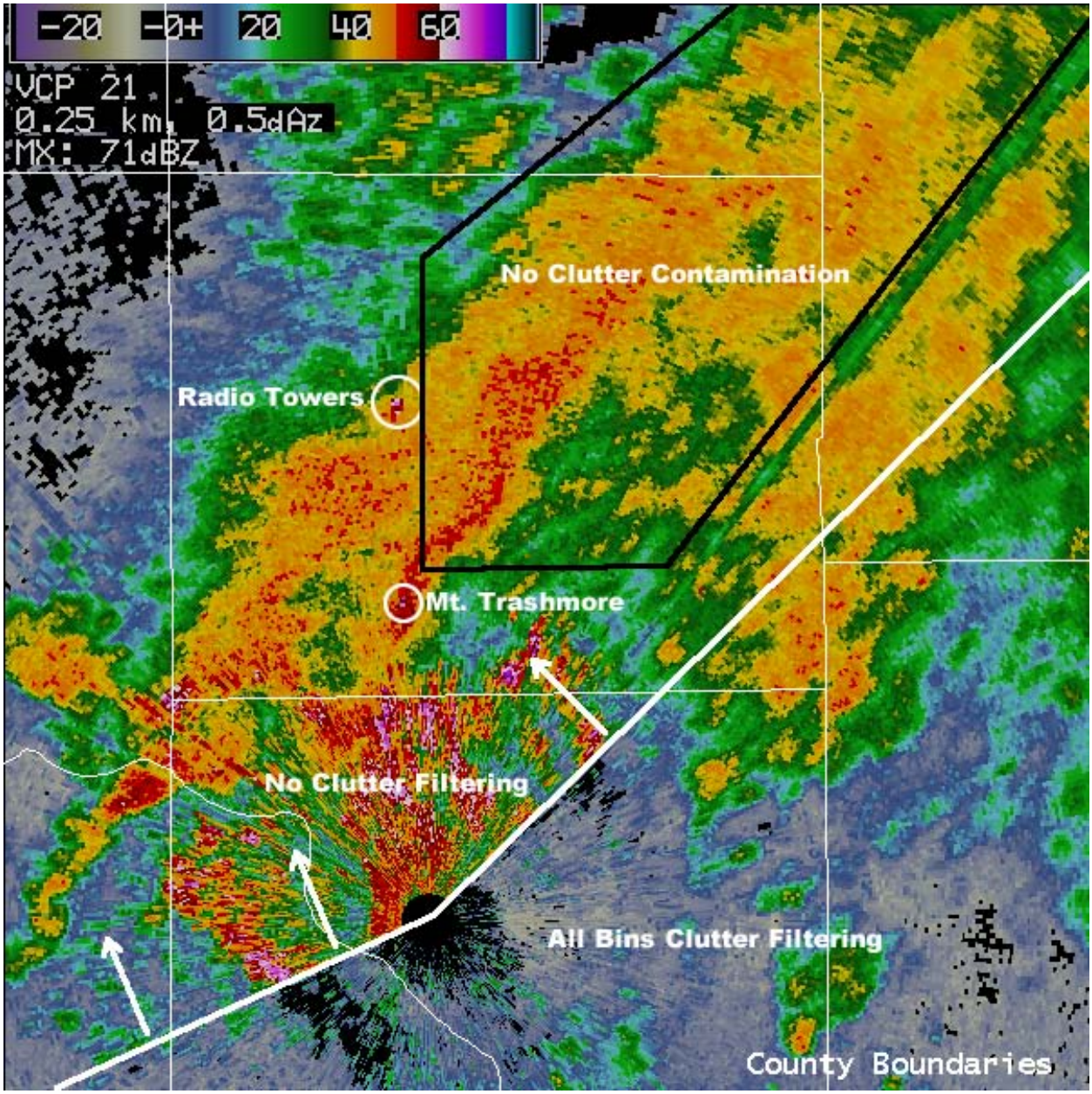


Figure 10. KOUN 0.5 deg reflectivity on 14 June 2010 at 1213 UTC. Inside the black polygon is where the radar products are NOT contaminated by clutter and should be used in this analysis. Below and to the right of the white line is where All Bins clutter filtering was enabled, above and to the left of the line no clutter filtering was done.

Question 1: Starting with a toggle between Z and CC (buttons 1 and 3), what is a mean value of CC to the nearest hundredth in reflectivity above 20 dBZ north of the radar in the band of heavy precipitation from 10-40 nm range? (Ignore the clusters of very low CC embedded in the precipitation shield which are unfiltered ground clutter)

CC ~ _____

Question 2: Use All Tilts CC and ZDR to find a melting layer, and alternately you can use cursor readout and look at the temperature values associated with the environment near the band of heavy precip. What is the height of the middle of the melting layer?

Height of the Middle of the Melting Layer: _____ ft MSL

Question 3: Using Z, ZDR, and CC, identify any regions in the band of heavy precipitation just north of the radar that might contain hail. List each potential region by range and azimuth. You'll need to see Z greater than 55 dBZ, ZDR less than +1 dB, and CC less than 0.95. Again, stay away from ground clutter (see Fig. 2). If nothing looks like hail, state "None".

Question 4: Let's shift the focus to an examination of the nature of the rain in the heavy band of precipitation north of the radar at 1213 UTC. Toggling between Z, ZDR, and KDP, scan several bins around each range and azimuth to determine the general value from each radar product listed in the table. Based on those values, also rank each rain rate and rain drop size relative to each other, such that of the 3 range and azimuths, the one with the highest rain rate is ranked #1 in rain rate. Circle 1, 2, or 3 for each one.

0.5 deg Products	Z	ZDR	KDP
22 nm @ 10°	dBZ	dB	deg/km
	Rank Drop Size: 1, 2, 3 Rank Rain Rate: 1, 2, 3		
20 nm @ 11°	dBZ	dB	deg/km
	Rank Drop Size: 1, 2, 3 Rank Rain Rate: 1, 2, 3		
20 nm @ 62°	dBZ	dB	deg/km
	Rank Drop Size: 1, 2, 3 Rank Rain Rate: 1, 2, 3		

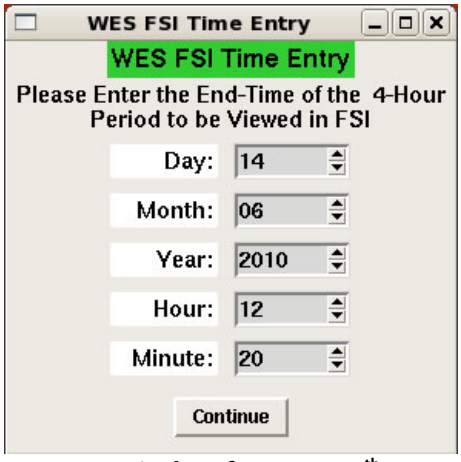


Figure 11: FSI time entry window for June 14th, 2010 event. Enter the numbers just as they are shown in the graphic.

Steps to Use FSI for this Event

1. Next, examine the 4-dimention Storm Investigator (FSI). Load this off the Tools menu onto either of your 4-panel displays.
2. In the pane with FSI loaded, right click in Oklahoma County, which is the rectangular county just north of the radar in the heaviest rain.
3. Enter the Mid-Point to match the above graphic (Fig. 11)
4. Wait about 15-30 seconds for FSI to load. Then navigate to the 1213 UTC volume scan at 0.5 deg (In FSI it will show up as 121401 UTC).
5. Orient your cross section to pass through the band of heaviest precipitation, as shown in Figure 12.

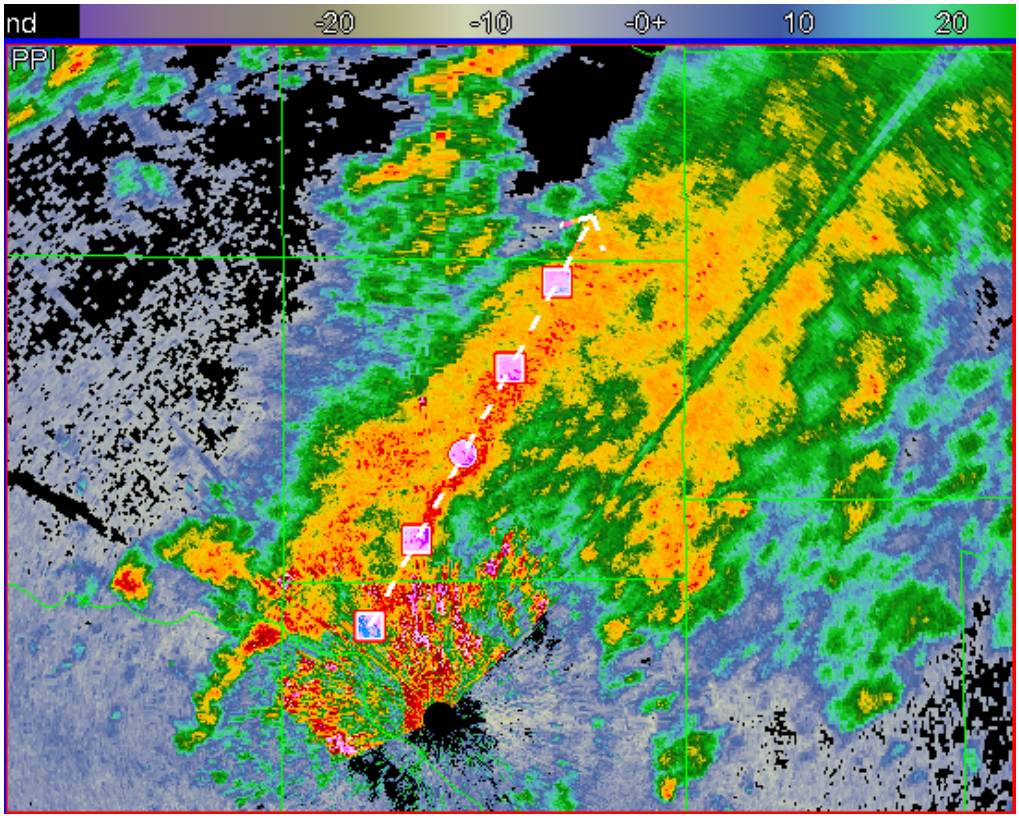


Figure 12: Top left pane of FSI, Reflectivity image at 121401 UTC 14 June 2010.

6. Examine the FSI cross section using reflectivity (Z button), ZDR (D button), CC (O button), and KDP (K button).

Question 5: <u>With only CC in the FSI cross section</u>, can you spot a well-defined melting layer? If so, what is the height?

Melting Layer via CC: _____ft MSL

Question 6: With ZDR and KDP in the FSI cross section, can you spot a well-defined melting layer? If so, what is the height?

Melting Layer via ZDR/KDP: _____ft MSL

Question 7: Toggle between KDP and Reflectivity. Where is the highest <u>KDP and Reflectivity</u> located in the vertical? (Circle one)

Above the melting layer / In the melting layer / Below the melting layer

<u>Examine Precipitation Accumulation Products</u>

1. You are done with FSI for this event. Let's examine precipitation products ending at 1600 UTC, with a disclaimer that things will likely change prior to deployment relative to what you see in this dataset. Open up procedures (control-O).
2. Double click on **DP_WESexercises**
3. Load or double click the procedure set "**DP-PPS Precip Comparison June 14**"
4. 8 products are loaded. To assist in your PCR analysis, here are the products that are loaded:

<u>Top Left Pane</u> PPS Storm Total Precip (1 key) + DP Storm Total Precip (5 key) Rain Gage totals overlaid (they precisely match the times in the storm total products)	<u>Top Right Pane</u> PPS One-Hour Precip (2 key) + DP One-Hour Precip (6 key)
<u>Bottom Left Pane</u> PPS Digitial Hybrid Reflectivity (4 key) + DP Hybrid Hydrometeor Classification (8 key)	<u>Bottom Right Pane</u> DP – PPS Storm Total Precip Difference (3 key) + DP – PPS One-Hour Precip Difference (7 key)

*****Note that PPS was running continental Z-R relationship 300R$^{1.4}$*****

Question 8: Examine the storm total precipitation products (top left pane, keys 1 and 5). Which QPE algorithm seemed to perform the best relative to the gage reports, in particular north of the radar and out to roughly 50 nm? Be careful of regions of clutter. (Circle one)

Legacy PPS (STP) / DP QPE (STA)

Question 9: In your opinion, did either dual-pol or PPS QPE do an adequate job estimating storm total precipitation north of the radar out to roughly 50 nm? Explain your answer in the space provided below.

Question 10: Examine the one-hour precipitation accumulation products (top right pane, keys 2 and 6). Which QPE (dual-pol or PPS) seems to have higher amounts on average? Again avoid regions of clutter. (Circle one)

DP QPE (OHA) / Legacy PPS (OHP)

Question 11: Examine the precipitation accumulation difference (Dual-pol QPE – Legacy PPS) products (bottom right pane, keys 3 and 7). These are "messy" because of clutter contamination. The storm total difference product (DSD) is nearly useless because of the clutter targets and the resulting dynamic scaling of the DSD. Stick to the one hour difference product (DOD) to answer this question. Do these difference products agree with how you answered Questions 8 and 10?

Agree / Do Not Agree

Question 12: Final task is to load a dual-pol instantaneous precipitation rate product (DPR) in any open pane. It's on the koun radar menu under the "koun precip" submenu. What are the largest rates across Oklahoma County (rectangular county immediately north of the radar) at the 1213 UTC volume scan time? (Avoid azimuths 353 to 358 deg and look outside of 15 nm to avoid clutter)

_____._____in/hr

Jobsheet #3: Tornado and Hail Outbreak

Objective:

- Using the knowledge gained from training modules and with the aid of all training aids, integrate an analysis of dual-pol radar products into a tornadic supercells event.

Case Data: 10 May 2010 in central Oklahoma.

Available Data: KOUN radar and LAPS gridded data

Analysis Duration: 100 min
Answer Keys Duration: 60 min

Instructions:

1. Clear out all panes prior to starting this jobsheet, if there are not already blank.
2. Left click on the D2D clock in the lower right part of D2D
3. Using the "Set Time" window, set the D2D clock to **2010 May 10 2130 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
4. Set Map Scale to "WFO"
5. Click on the koun menu and load "All Tilts Base Data"
6. While in the same pane as the All Tilts products, click on the Volume menu, then "Std Env Data Package", then "LAPS"
7. Set frames to 56
8. Modify map backgrounds and data magnification as you see fit

9. We'll start with an "early" supercell at far range from the radar. Zoom in on the supercell located at **76 nm and 001 deg** so it fills the pane.
10. Examine Z and SRM and loop through the 4 frames to get a good feel for the storm.
11. **Get to the 2126 UTC scan!**

Question 1: At <u>2126 UTC</u> and the 0.5 deg elevation angle, scan several bins around each range and azimuth to determine the general value from each radar product listed in the table fill. Using those radar product values, select from the list of potential echo types below the most likely echo type for each range and azimuth. Enter it in the row below each range and azimuth.

- **Giant Hail Mixed With Rain**
- **Hail mixed with Rain**
- **Hail Not Mixed With Rain**
- **Giant Hail Not Mixed With Rain**
- **Pure Heavy Rain**

0.5 deg Products	Z	ZDR	CC	KDP
74 nm @ 357°	dBZ	dB		deg/km
Dominant Precip Type:				
75 nm @ 000°	dBZ	dB		deg/km
Dominant Precip Type:				
74 nm @ 002°	dBZ	dB		deg/km
Dominant Precip Type:				

Question 2: Use All tilts at 2126 UTC, flipping between Z and ZDR to find enhanced regions of ZDR above the 0C level. Use cursor sampling to get an idea of the environmental 0C level and where ZDR is high significantly above it. What is the temperature at the top of the ZDR column with this storm?

Top of ZDR Column Temp: _____ degC

Question 3: Where is the ZDR column located relative to the BWER?

Time to Switch Storms

1. You can clear out the All Tilts Base Data pane. We'll move a little later when supercell fest is well underway.
2. Left click on the D2D clock in the lower right part of D2D
3. Using the "Set Time" window, set the D2D clock to **2010 May 10 2212 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
4. Set Map Scale to "WFO"
5. Click on the koun menu and load "All Tilts Base Data"
6. While in the same pane as the All Tilts products, click on the Volume menu, then "Std Env Data Package", then "LAPS"
7. Set frames to 56
8. Modify map backgrounds and data magnification as you see fit

9. In the All Tilts base data pane, loop through 0.5 deg frames at 4 panels and/or Panel Combo/Rotate, getting a broad scale view of the base products Z, ZDR, CC, and KDP. For this event, feel free to utilize velocity/SRM and spectrum width. There is a plethora of supercells!

10. When ready, go the 0.5 deg elevation angle in your 4 panel layout at **2159 UTC,** zoom far into the storms located at **14 nm and 292 degrees**, and answer the following questions.

Question 4: Use All Tilts at 2159 UTC, and toggle between Z and ZDR for the southern storm. Identify the updraft and ZDR column (Hint: the top of the ZDR column is on the 15.6 deg elevation angle). How high does the ZDR column go in feet MSL? What temperature is height at?

ZDR Column Height: _____ ft MSL

ZDR Column Temp: _____ degC

Question 5: Use All Tilts at 2159 UTC and toggle between Z (button 1) and SRM (button 5), then toggle to ZDR (button 2). Examine the vertical structure of the mesocyclone and ZDR column. At the 15.6 deg elevation angle, what is the strength of the shear signature with the mesocyclone associated with southern BWER/ZDR column? Does it have good height continuity?

∆V (|Max in| + max out): _____ kts

Good Height Continuity: Yes / No

Question 6: In your own words, briefly discuss the location of the ZDR column, mesocyclone, and BWER relative to each other and to the precip core.

Question 7: Provide a list of the signatures and attributes of the radar data that point to the strength of the updraft located at/near 15 nm and 281 deg at this time.

Instructions for FSI of this Supercell

1. Load FSI off the tools menu into your All Tilts display
2. Right click on the storm at 14 nm and 292 degrees

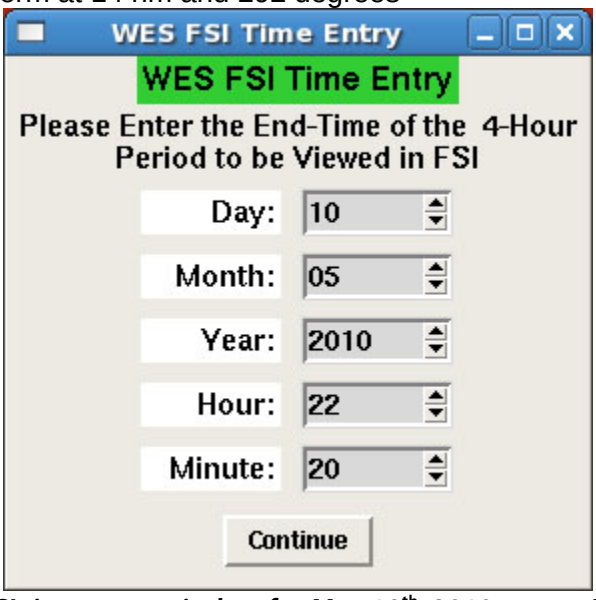


Figure 13: FSI time entry window for May 10th, 2010 event. Enter the numbers just as they are shown in the graphic.

3. Set the FSI Time Entry to match the image above (Fig. 6).
4. Get to the 14.0 deg elevation angle (which is actually 15.6 deg) at 220246 UTC
5. Cut your cross section just like the one below in Figure 7.
6. Toggle between Z (Z button) and ZDR (D button) and focus on the cross section. Pick your jaw up off the desk, then answer the following questions.

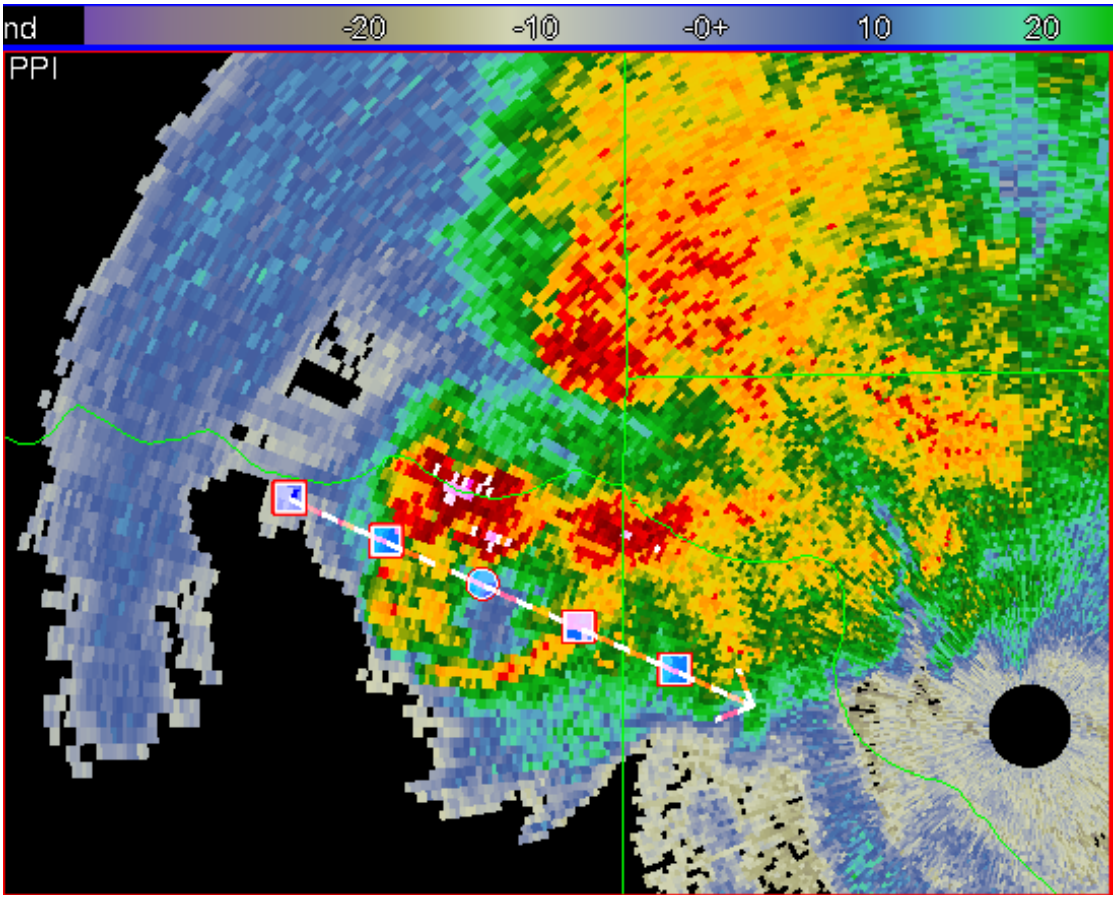


Figure 14: Top left pane of FSI, Reflectivity image at 220246 UTC 10 May 2010 and 15.6 degrees elevation angle (though in FSI it's reported at 14 deg).

Question 8: Using the FSI cross section from Figure 14, find the maximum height of the ZDR column, in feet MSL.

ZDR Column Height: _____ ft MSL

Question 9: In the cross section that matches Figure 14, toggle to ZDR and make certain the cross section passes through the 15.6 deg ZDR maximum. In the ensuing cross section, roughly how wide is the ZDR column (in Nmi)? (Hint, a ZDR column is defined as positive ZDR above the melting layer)

ZDR Column Width: _____ nm

From Updraft Stength to Hail Detection

1. You can close FSI, go back to D2D.
2. I am sure you are anxious to see what kind of hail this storm produced. For that, let's skip forward in time to the **2212 UTC** scan, which should be the latest one in your All Tilts Base Data display pane.

Question 10: Go the 0.5 deg elevation angle and zoom into the area surrounding 9 nm range, 330 deg azimuth. Toggle between Z, ZDR, CC, and KDP and scan several bins around each range and azimuth to determine the general value from each radar product listed in the table.

0.5 deg Products	Z	ZDR	CC	KDP
9 nm @ 327-336°				
15 nm @ 332°				

Question 11: Relative to storm structure and location of the updraft at 0.5 deg, where is the radar signature at 9 nm between 327 and 336 degrees located? You can use All Tilts and any of the base products (1-7 on the keys) to help determine this. Examples: In the middle of the updraft, in the precipitation core, along the reflectivity gradient adjacent to the updraft, etc.

Question 12: Relative to storm structure and location of the updraft at 0.5 deg, where is the radar signature at 15 nm @ 332 degrees located? You can use All Tilts and any of the base products (1-7 on the keys) to help determine this.

Question 13: Given the values of the radar products you found in Question 10 and the location of the signatures relative to storm structure, enter into the table from the following list of choices what you think is the most likely dominant radar echo type at those range and azimuths:

- **Giant Hail Mixed With Rain**
- **Hail mixed with Rain**
- **Hail Not Mixed With Rain**
- **Giant Hail Not Mixed With Rain**
- **Pure Heavy Rain**
- **Biological Scatterers**

0.5 deg Products	Most Likely Echo Type
9 nm @ 327-336°	
15 nm @ 332°	

Question 14: Briefly explain in the space provided below why you selected the echo types in Question 13.

Question 15: Toggle to HCA output at 0.5 deg (button 8). Fill out the table using HCA output, if multiple types exist, list them all:

0.5 deg Products	HCA Output Echo Types
9 nm @ 332°	
15 nm @ 332°	

Question 16: How did the HCA output compare to your base data analysis of echo type? Briefly explain the reason for any differences if they exist.

Tornadic Debris Signature Analysis

1. Time to go tornado hunting. Clear all panes or swap to a clear pane, and left click on the D2D clock in the lower right part of D2D
2. Using the "Set Time" window, set the D2D clock to **2010 May 11 0000 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
3. Set Map Scale to "WFO"
4. Click on the koun menu and load "0.5 Base Data"
5. While in the same pane as the 0.5 deg base products, click on the Volume menu, then "Std Env Data Package", then "LAPS"
6. Set frames to 40
7. Off the Maps menu, load "Urban Boundaries" and "Cities". Modify the map colors and data magnification as you see fit

8. We will only look at 0.5 deg products here in the interest of time, which is okay because if tornado debris is sampled by the radar, it should occur in the lowest available data.
9. You may feel a strong temptation to spend a long time perusing one of the roughly 10 simultaneously occurring supercells, please refrain from doing so and try to stay on task since time is limited. Plus, going through this in the order listed will also enable you to get an unbiased look at early tornadic signatures, in some cases well before a single-pol radar clearly indicates a damaging tornado.
10. Step backwards in time to **22:21 UTC,** zoom into the supercell located at **10 nm and 000 deg**. Answer the following questions.

Question 17: <u>At 2221 UTC</u>, and only using Z and SRM (buttons 1 and 5), find the area most likely to contain a tornado associated with the storm located at 10 nm and 000 deg. What is the range and azimuth of where you would think a tornado is most likely to be found?

In Z/SRM analysis, tornado most likely at:

_____ nm and _____deg

Question 18: Follow-up to Question 17—from Z and SRM, what is your confidence level (0-100%) that at this time there is a tornado doing damage?

_____ % confidence in damaging tornado

Question 19: Focus and zoom into 5 nm at 335 deg azimuth. Only pay attention to reflectivity values greater than 30 dBZ and very near the strong inbound velocities in SRM. What is a mean value of ZDR and CC in this area of high reflectivity and strong shear?

ZDR: _____ dB

CC: _____

Question 20: Based on your answer to Question 19, at 2221 UTC what echo type(s) are likely in the area within a few gates surrounding 5 nm and 335 azimuth and in reflectivity values above 30 dBZ? Underline ONE OR MORE of the following:

Pure Rain / Giant Hail / Tornadic debris /
Hail mixed with Rain / Biological Scatterers

Switch Storms Once Again

1. Time to examine a different storm a bit further from radar, but **DO NOT clear out** the 0.5 deg pane. We'll be using it again in a few minutes.
2. Swap Panes.
3. Set the D2D clock using the "Set Time" window to **2010 May 10 2230 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
4. Go to WFO scale
5. Load All Tilts Base Data
6. While in the same pane as the All Titls base products, click on the Volume menu, then "Std Env Data Package", then "LAPS"
7. Set frames to 56
8. Zoom in on the storm located at **35 nm @ 188 deg**.
9. Find the **2225 UTC** volume scan

Question 21: Using Z/SRM and ZDR All Tilts, list the location and the temperature at the maximum height of any ZDR columns associated with this storm at 2225 UTC. One or more may exist.

ZDR Column	Range	Azimuth	Temp at Top
1.	nm	deg	degC
2.	nm	deg	degC
3.	nm	deg	degC

Question 22: Where, in a storm relative sense, is the primary/strongest ZDR column located at 2225 for the storm examined in Question 21? Is this what you expect given the storm type? Feel free to examine SRM too.

10. **You can clear this all tilts base products pane if you'd like.**
11. Swap panes to the **0.5 deg base products display**
12. Go backwards in time to **2212 UTC**, and this time zoom all the way into the supercell located at **48 nm, 201 deg**, which is the same storm as you analyzed for Questions 21 and 22, only this time we will look for tornadic debris signatures. Feel free to update storm motion for SRM.

Question 23: Fill out the table below for each volume scan time listed and do them in chronological order, examining only this supercell.

Volume Scan Time	Tornado Debris Signature?	Range/Azimuth of TDS, if Applicable
2212 UTC	Y / N	nm @ °
2216 UTC	Y / N	nm @ °
2221 UTC	Y / N	nm @ °
2225 UTC	Y / N	nm @ °
2229 UTC	Y / N	nm @ °
2234 UTC	Y / N	nm @ °
2238 UTC	Y / N	nm @ °

Final Task: Identify all TDSs from a single scan

1. You will all be proficient at identifying tornadic debris signatures after this next task. On the 0.5 deg base data pane, move forward to **2250 UTC. Zoom into the domain shown in figure 15** (next page)**.**

Question 24: Examining ONLY the domain in Figure 15 at 2250 UTC, give the range and azimuth of all tornadic debris signatures you can find at this single volume scan time. Use any methods you see fit. There will be several.

TDS Signature	Range	Azimuth
1.	nm	deg
2.	nm	deg
3.	nm	deg
4.	nm	deg

5.	**nm**	**deg**
6.	**nm**	**deg**
7.	**nm**	**deg**

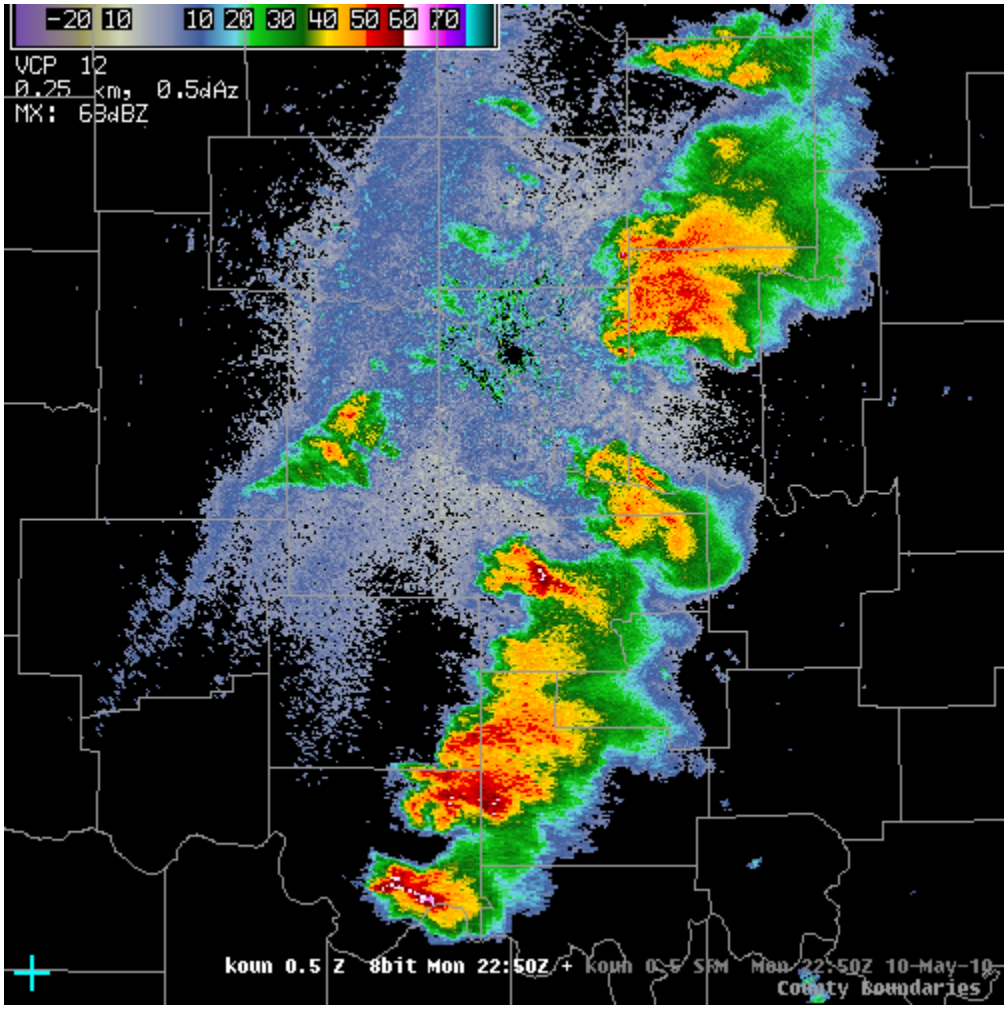


Figure 15: 10 May 2010 22:50 UTC 0.5 deg reflectivity image zoomed into the search domain for TDS signatures. Only search for TDSs on your WES workstation for the storms shown in this graphic and time.

Jobsheet #4: Bow Echo

Objective:

- Using the knowledge gained from training modules and with the aid of all training aids, integrate an analysis of dual-pol radar products into a bow echo event.

Case Data: 19 May 2010 in northern Oklahoma.

Available Data: KOUN radar and LAPS gridded data

Analysis Duration: 40 min
Answer Keys Duration: 20 min

Instructions:

1. Clear out all panes prior to starting this jobsheet, if they are not already blank.
2. Left click on the D2D clock in the lower right part of D2D.
3. Using the "Set Time" window, set the D2D clock to **2010 May 19 1045 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
4. Set Map Scale to "WFO"
5. Click on the koun menu and load "All Tilts Base Data"
6. Set frames to 64
7. Modify map backgrounds and data magnification as you see fit

8. In the All Tilts base data pane, loop through 0.5 deg frames, getting a broad scale view of the base products Z, ZDR, CC, and KDP. Pay attention to the character and movement of the precipitation echoes. For this event, feel free to also utilize velocity/SRM and spectrum width. It is a bow echo!.

   *****With this event you may notice severe data quality issues aligned along the radial. Towards the end of the case study we'll examine them and discuss why they exist in this dataset, as well any implications they may have.*****

9. When ready, go the 0.5 deg elevation angle in your 4 panel layout at **10:45 UTC.**

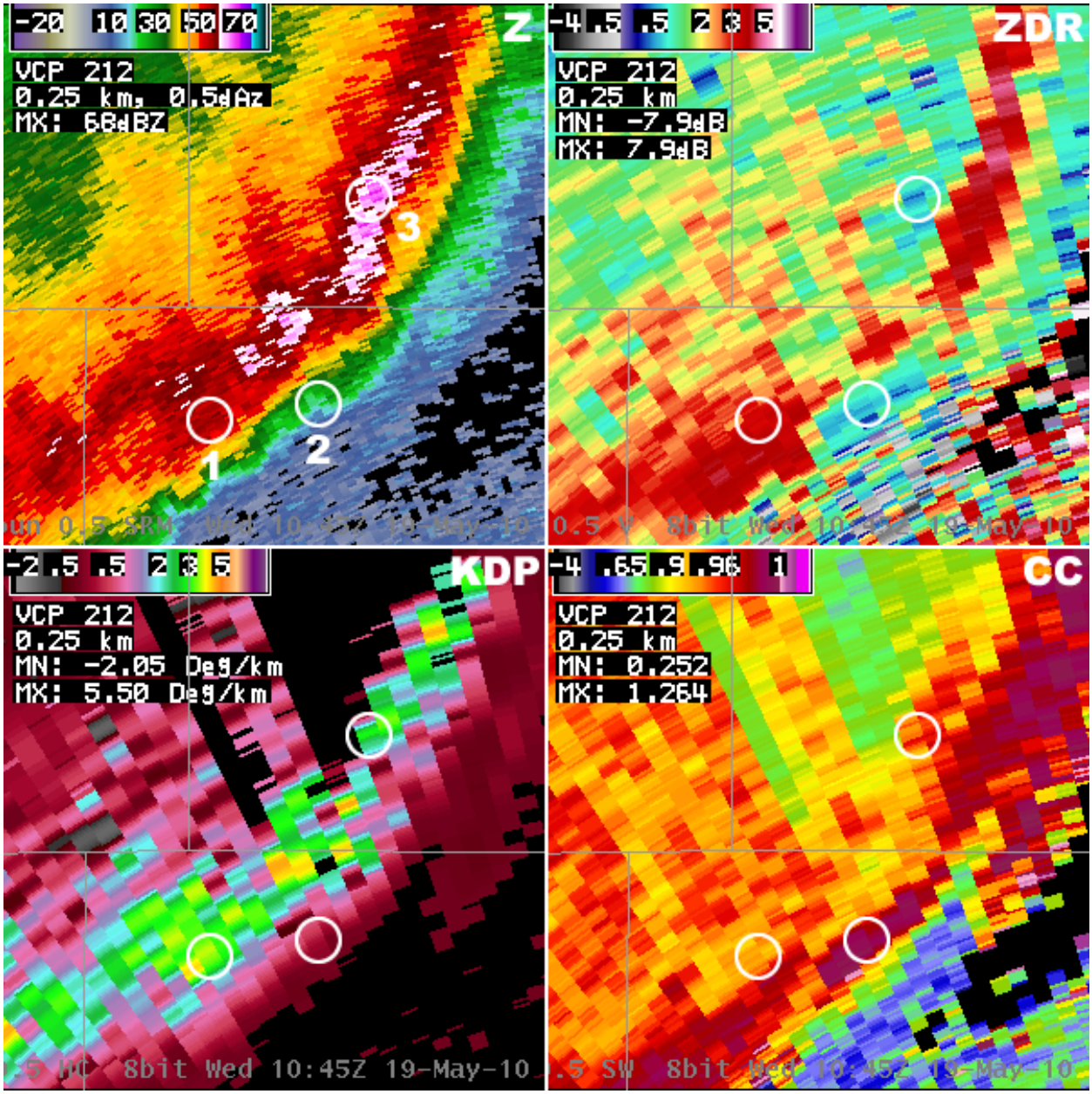


Figure 16. 4-panel 0.5 deg KOUN dual-pol product display from 19 May 2010 at 1045 UTC. The circles are areas you should examine on your own workstation to fill out the table associated with Question 1. Circles corresponding to label #1 are the area surrounding Range/Az 59 nm @ 330 deg, circles #2 are for 57 nm @ 3335 deg, and circles #3 are for 65 nm at 341.

Question 1: Toggle between Z (button 1), ZDR (button 2), CC (button 3), and KDP (button 4). Scan several bins around each range and azimuth to determine the general value from each radar product listed in the table. Use Figure 16 as a guide to help you see where you should be checking for data values. Then, in the row below each range and azimuth, fill in the row with the most likely dominant precipitation type from the list of choices on the next page:

- **Hail not mixed with much rain**
- **Rain and Hail mixture**
- **Heavy rain, small drops**
- **Heavy rain, large drops**
- **Light rain, large drops**
- **Stratiform rain (small drops, moderate rain rates)**
- **Tiny rain drops**

0.5 deg Products	Z	ZDR	CC	KDP
59 nm @ 330°	dBZ	dB		deg/km
Dominant Precip Type:				
57 nm @ 335°	dBZ	dB		deg/km
Dominant Precip Type:				
65 nm @ 341°	dBZ	dB		deg/km
Dominant Precip Type:				

10. Now use All Tilts and step up in elevation angle, through at least 2.4 degrees. Toggle between Z and ZDR (buttons 1 and 2) in between 0.5 and 2.4 degrees. Look for vertical continuity of strongest ZDR values. Note that on 1.8 and 2.4 deg elevation angles, the large blanked out areas are Range Folding (RF). A week or so after this event RF was properly coded purple, and will look that way at deployment on the dual-pol batch cuts.

Question 2: Focus on Z and ZDR at 2.4 degrees with the bow echo, and roughly between 50 and 62 nm in range. What are the mean values of the enhanced ZDR and roughly how high are they (in feet MSL)?

ZDR ~ _____dB at _____ ft MSL

Question 3: In a storm relative sense, where are these elevated values located? (Circle One):

In the Storm Core / In the Stratiform Region / Along the Leading Edge

Question 4: Given that the freezing level is 12.8 kft MSL, is this region of enhanced ZDR above the freezing level? Is this enhanced ZDR feature a ZDR column? Does this signature make sense in terms of its appearance along this bow echo? Fill out the check boxes table below:

Check Yes or No for:	YES	NO
Enhanced ZDR Above Freezing Level?		
Is it a ZDR Column?		
Enhanced ZDR where you expect to find it in terms of this bow echo?		

Question 5: At 0.5 deg and above, toggle between Z and CC (buttons 1 and 3) and focus on the azimuths 334 to 348 degrees. Where do the radially aligned, very low CC values seem to be originating from on the 0.5 deg elevation angle? This will be discussed in the answer key.)

Question 6: Toggle to HCA output (button 8). In those radials affected with poor data quality (334 to 348 degrees) at 0.5 degrees, what are some of the classifications it is coming up with? Is the HCA on the right track in this area?

Moving Ahead a Few Hours

1. Skip ahead a couple hours, to a time when the DP products are not as affected by the poor data quality. Using the WES workstation, left click on the D2D clock in the lower right part of D2D
2. Using the "Set Time" window, set the D2D clock to **2010 May 19 1246 UTC** (don't bother changing the seconds) and check the "Freeze Time at This Position" box.
3. Swap to an empty pane.
4. Set Map Scale to "WFO"
5. Click on the koun menu and load "All Tilts Base Data"
6. While in the same pane as the All Tilts products, click on the Volume menu, then "Std Env Data Package", then "LAPS"
7. Set frames to 14
8. Modify map backgrounds and data magnification as you see fit

Question 7: Using All Tilts and toggling between Z, ZDR, and CC, try to identify the melting layer. You'll probably want to use just the 0.5 deg elevation angle because of how far away from the radar the stratiform region is. What is the height of the top of the melting layer, and what is the height of the bottom of the melting layer, in feet MSL?

ML Top: _____ ft MSL

ML Bottom: _____ ft MSL

Question 8: Using cursor sampling of environmental data on the 0.5 deg tilt, what height is the 0°C level? Does it agree with your base data analysis of the melting layer? Why or why not?

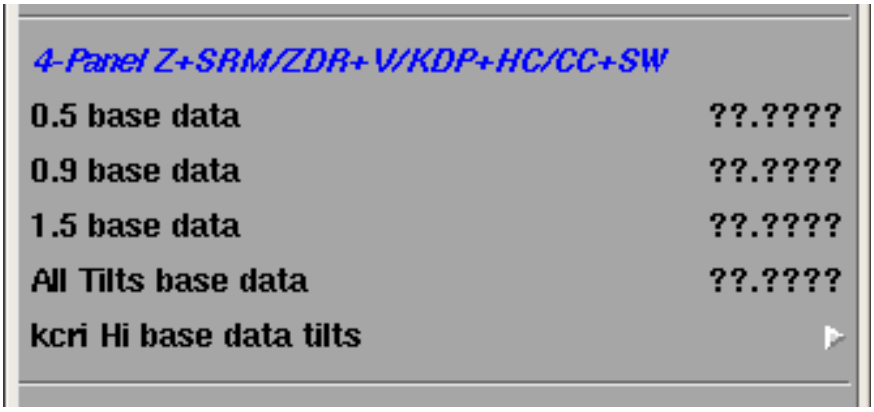
LAPS 0°C Height: _____ ft MSL

LAPS 0°C Does / Does Not Agree with radar analysis ML (Circle One, then explain why or why not)

Question 9: In the same All Tilts base data pane, go to the koun menu, click on "koun Algorithm Overlay", then "Melting Layer (ML)", and finally "Melting Layer All". This loads the melting layer overlay product on all elevation angles. Check CC: Does the melting layer algorithm place the melting layer at the same height/range that you identified in Question 7? (Hint, focus on the solid rings) Does it seem to be identifying the melting layer adequately?

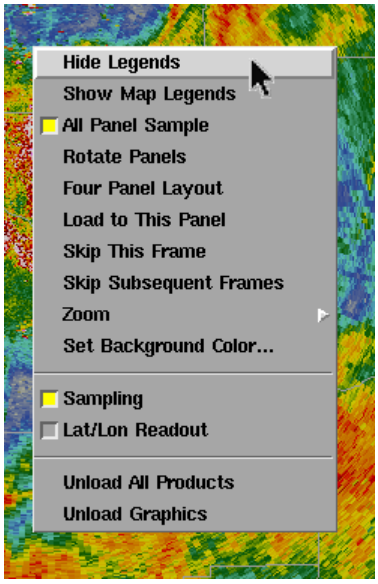
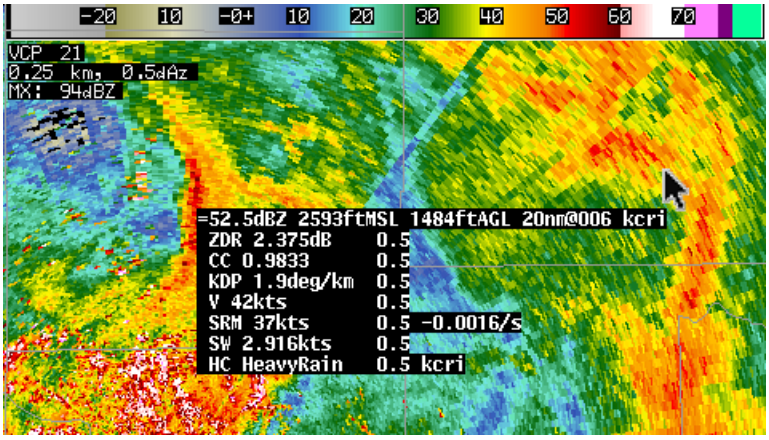
Panel Combo/Rotate (PCR) Review

1. Load a koun All Tilts Base Data display from the koun radar menu that will look similar to the one below.



2. Starting from the 4 panel layout you had from the previous set of instructions, hit the "Delete" key on the keyboard.

3. 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 the loaded with the product menu button in step #1:

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)

4. 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.