

# **An Introduction to WSR-88D Clutter Suppression, and Some Tips for Effective Suppression Utilization**

Stephen M. Goss  
NEXRAD Weather Service Office, Nashville, TN

Joe N. Chrisman  
WSR-88D Operational Support Facility  
Operations Training Branch, Norman, OK

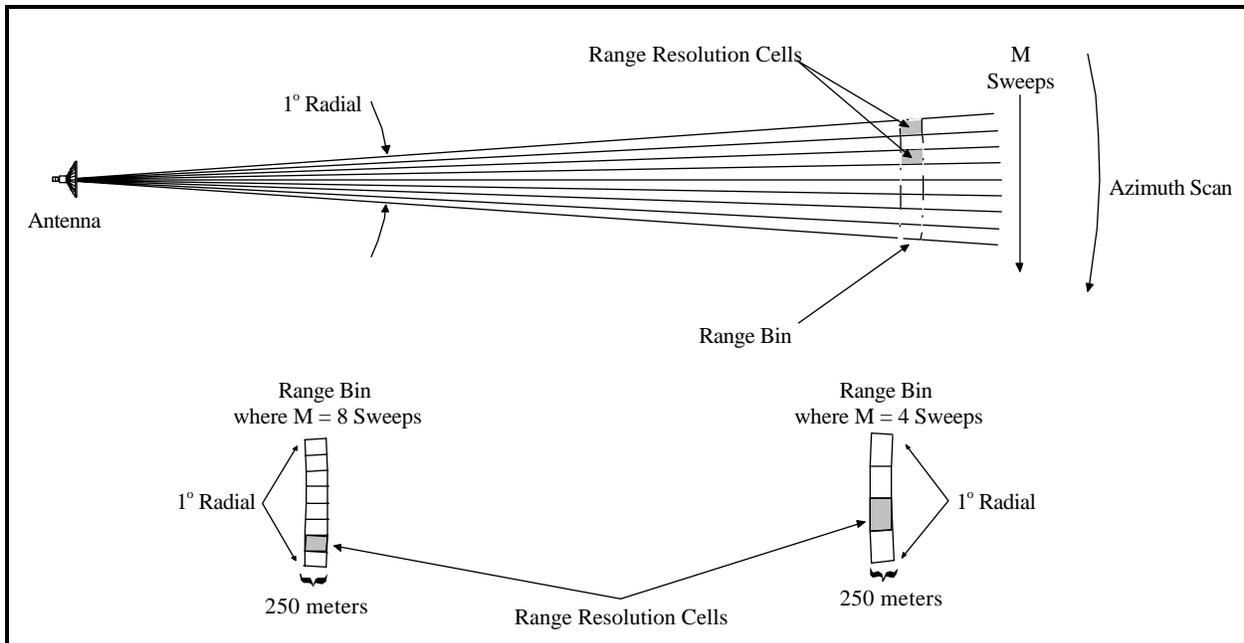
## **1. Introduction**

In radar meteorology, ground clutter is generally defined as radar return from ground-based targets. Normally, ground clutter is limited to within about 30 miles of the radar antenna. Furthermore, ground clutter is usually evident in the lowest elevation slices only. Because the terrain surrounding each radar site is different, each radar exhibits a unique, persistent ground clutter pattern.

However, under certain meteorological conditions (usually atmospheric temperature inversions), the radar beam is *ducted*, or superrefracted toward the ground. When superrefraction occurs, return from ground-based targets may be significantly increased beyond the typical, persistent ground clutter pattern. This expanded area of ground clutter is known as *anomalous propagation*, or AP.

Energy return from ground-based targets can cause significant bias in the base data estimates. Not only will return from ground-based targets contaminate the WSR-88D base data (radial velocity, reflectivity, and spectrum width), but this return will also cause a significant degradation in the quality of all WSR-88D products, since all WSR-88D products are derived by algorithms using the base data. To understand *how* this contamination occurs, one must understand how the WSR-88D calculates radial velocity, reflectivity, and spectrum width data.

To produce a base data estimate, the WSR-88D calculates data values for numerous small areas called *range bins*. Like tiles which cover a floor, range bins are small portions of the WSR-88D's area of coverage. Each range bin is comprised of still smaller areas which are called *range resolution cells*. The range resolution cell is the smallest area from which the WSR-88D collects data. The return from each range resolution cell, which is the return from an individual pulse within a range bin, is averaged to give a base data estimate for that particular range bin. (See Figure 1.) It is important to note that clutter suppression is performed on these individual range resolution cells.

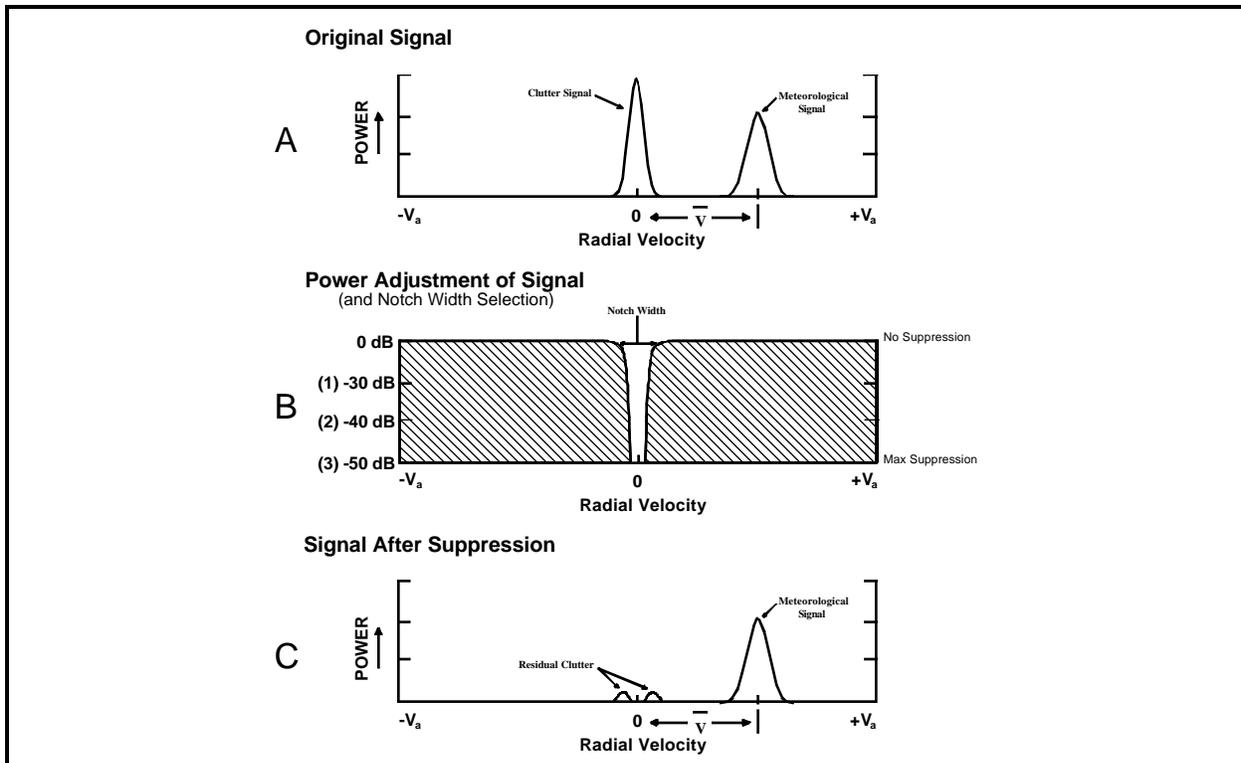


**Figure 1**

**Note:** Figure 1 shows four and eight sweeps per radial for illustrative purposes only. In reality, the number of sweeps per radial ranges from approximately 40 to 200.

## 2. Clutter Suppression

Clutter suppression filters are designed to reduce signal power for each range resolution cell whose mean radial velocity is at or near zero knots. To do this, clutter suppression filters reduce signal power within a small velocity interval, or *notch width*, centered about the zero mean radial velocity value. This reduction in signal power for the contaminated range resolution cell(s) effectively decreases the clutter's power contribution in the given range bin. To maintain meteorological return integrity, only the signal power whose instantaneous radial motion falls within the notch width is reduced (Figure 2.)



**Figure 2**

- A.** A depiction of the input power for a given range bin. The clutter signal has a radial velocity centered around zero and the meteorological signal is offset from zero due to its radial velocity.
- B.** Represents the clutter filter with a notch width centered on zero radial velocity. The scale represents the **amount of power reduction**, from 0 dB (no power reduction) to -50 dB (maximum power reduction), applied within the notch width.
- C.** A diagram of the resulting power after the algebraic addition of the signal from A and the power reduction factor from B ( $A+B=C$ ).

Remember, the goal of clutter suppression is to reduce the power return contributed by clutter targets from the range bin prior to the calculation of the base data estimates. Therefore, for each range bin in areas where clutter suppression is in effect, the portion of the power return with near zero radial velocity will be reduced (filtered), as represented in Figure 2C.

For additional information about clutter suppression in the WSR-88D system refer to [WSR-88D Clutter Suppression and Its Impact on Meteorological Data Interpretation](#), J. N. Chrisman, et al, 1995.

### 3. Steps for Effective Operational Utilization of Clutter Suppression.

Given this brief review of clutter suppression, some suggestions are offered for clutter suppression management at a Weather Service Office utilizing the WSR-88D.

1. Generate a Bypass Map as soon as practical after WSR-88D acceptance. This should

be done when the meteorological conditions allow "normal" radar beam propagation for your site for the particular season. These conditions should result in your normal ground clutter pattern for the time of year. A new Bypass Map should also be regenerated whenever the "normal" ground clutter pattern changes (e. g., a high-rise building is erected). In addition, it is recommended that a new Bypass Map be generated on a seasonal basis.

The NEXRAD focal point may wish to make a hard copy of the 0.5° base reflectivity and velocity products with and without the Bypass Map clutter suppression in effect. These hard copies will give the forecasters a sense of the effectiveness of the clutter filter in suppressing the normal ground clutter return.

2. Choose Clutter Suppression Region File 11 to set aside as the "baseline file." Define two clutter suppression regions, one for each elevation segment number (see Figure 3, below). These regions should encompass the entire radar coverage area, specify the Bypass Map in control (Operator Select Code 1), and use a notch width selection of 2 (medium) for the Surveillance channel and a selection of 3 (high) for the Doppler channel. Notice that this file is now set have the Bypass Map in control of identifying where to apply suppression. This file allows an operator to return to baseline clutter filtering (the Bypass Map in control) when the need for forced clutter suppression (Operator Select Code 2) has abated.

CLUTTER SUPPRESSION REGIONS							PAGE 1 OF 2	
COMMAND: AD, WXMAN1, CL, C, 11							RPG ALARM	
FEEDBACK: COMMAND EXECUTED - AD, ****, CL, C, 11, DO							OPER A/L 21	
(M)odify, {LINE #}		(DE)lete, {LINE #}		(DO)wnload				
(E)nd		(C)ancel						
	Start	Stop	Start	Stop	Elev Seg	Operator	Channel Width	
Region	Range	Range	Azimuth	Azimuth	Number	Sel Code	D	S
-----								
1	2	510	0	360	1	1	3	2
2	2	510	0	360	2	1	3	2
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0

**Figure 3**

3. At the beginning of each shift, download the baseline clutter suppression region file (11). This

baseline clutter suppression region file will negate any forced clutter suppression, thereby revealing any AP which may be present. This procedure will ensure that the forecasters know what clutter suppression file is in effect and will enable them to make an informed decision as to whether or not any forced clutter filtering is required. If forced clutter filtering is required, download the clutter suppression region file which has been set up for that particular situation (or define one to handle the situation; see the step-by-step procedure in the UCP Operator Handbook). If forced clutter suppression is not required (no AP present), leave the baseline clutter suppression region file (11) in control.

4. Predefine each of the four Clutter Suppression Region files to include, as a minimum, regions (lines) 1 and 2 to invoke the Bypass Map (see figure 3). Additional regions (lines) may be defined to address particular clutter regimes as necessary.
5. Implement an office policy for documenting any changes to operator-defined clutter suppression regions, and a procedure for recording the date, time, and file number each time a clutter suppression region file is downloaded to the RDA. This procedure will ensure that everyone responsible for data interpretation can determine the active clutter suppression region file.

#### **4. Examples of Creating Clutter Suppression Region Files for Particular Meteorological Situations.**

In this section, a couple of example situations which a meteorologist might face will be discussed. The situations will be described, and suggestions for how the situations could be handled will be presented. For step-by-step instructions for building a clutter suppression region file at the UCP, or for downloading a particular file, please refer to Appendix 1.

**Situation 1.** You are the UCP operator and have just arrived on the midnight shift. As suggested in section 3 above, you download Clutter Suppression Region File 11, which has been set up as the baseline ground clutter suppression file (with the bypass map in control). You wait for one volume scan to allow file 11 to take over, and you then check the PUP display. No echoes are apparent on the base reflectivity product, so you leave file 11 in effect. You note, however, that with clear skies and light winds, a nocturnal inversion is likely to develop, and therefore you feel that AP formation is likely during the next several hours.

Sure enough, at about 2 AM, you notice that a few weak echoes are apparent to the south on the base reflectivity 0.5° elevation scan. You check a few higher scans, and although no AP is present above 0.5°, you do expect additional development of AP, both at other locations and higher elevations. Because precipitation is not expected to develop in your radar's area of coverage through the night, you decide to download clutter suppression region file 21, which has been predefined by the NEXRAD focal point. This file has proven effective at removing AP for your radar coverage area. This particular file forces

suppression over all range bins (operator select code 2) within your entire area of coverage and for all elevation slices. It applies medium suppression (notch width 2) to both the surveillance and Doppler channels. After one volume scan, this file takes over, and you note that the AP echoes have been effectively suppressed. Periodically during the remainder of your shift, you check the base reflectivity product at the PUP, and no AP is apparent. At 8 AM, you notify the day shift UCP operator that you are currently using suppression region file 21, and that he will probably want to return to baseline clutter suppression (file 11) within a couple of hours, as the nocturnal inversion erodes.

**Situation 2.** You arrive on shift at 8 AM, and the midnight shift UCP operator informs you that widespread AP had developed overnight. Therefore, he has Clutter Suppression Region File 21 in use. This file is the one used by your office during situations involving widespread AP echo coverage. Because the sun has risen, and the nocturnal inversion should be eroding, you download file 11 (your office's baseline clutter suppression file), and after one volume scan, you notice a few high-reflectivity echoes to your south, between  $165^\circ$  and  $190^\circ$  azimuth, and between the ranges of 125 km and 150 km. You check a few higher elevation scans, and you note that the AP is present only in the  $0.5^\circ$  and  $1.5^\circ$  scans. You are not expecting any additional AP to develop, and in fact expect the AP to cease within an hour or two. You therefore decide to create a Clutter Suppression Region File (you choose file 31) which will apply suppression only for the region in which the AP is present. At the UCP, you go to the clutter suppression regions menu, and set your start range for region 3 (line 3) at 125 km and your stop range at 150 km. You set the start azimuth at  $165^\circ$ , and the stop azimuth at  $190^\circ$ . You choose elevation segment number 1 (which includes the  $0.5^\circ$  and  $1.5^\circ$  elevation slices), you set the operator select code at 2 (forced suppression to all range bins within the suppression region), and you set the channel width (notch width) at 3 (high) for both the Doppler and surveillance channels. Now that you have created suppression region file 31, you save it, and then download it to the RDA. After one volume scan, you notice that the base reflectivity products reveal no echoes, so the suppression region file you created has effectively suppressed the AP. At 11 AM, you feel that the inversion has been eroded, as atmospheric mixing has taken place, evidenced by the fact that your surface winds have kicked up to 15 mph. You therefore download clutter suppression region file 11 at the UCP, to return to baseline clutter suppression, and you notice after one volume scan that no echoes are present within your radar area of coverage.

**Situation 3.** You are working the 4 PM to midnight shift, and at 8:00 PM, you notice a few thunderstorms developing about 120 miles to the west of your radar site. These storms remain well to the west for a couple of hours, and about 10:30 PM you notice widespread echo development beginning over much of your radar coverage area. A quick glance at the newest satellite image shows that the only clouds in your area are those thunderstorms well to the west of your radar site. You decide that the other echoes are AP, and you are now faced with the decision as to whether or not to invoke clutter suppression. Although you realize that clutter suppression can occasionally have minor negative impacts on precipitation echoes (e.g., reduction in power with zero radial

velocity, data smearing, etc.), you realize that your current radar data is useless, as the thunderstorms are embedded within widespread AP. To improve the overall quality of your radar data, you decide to invoke Clutter Suppression Region File 31. This file is the one used by your office to handle situations involving widespread AP. You expect that downloading this clutter file will minimize the AP echoes around your radar, while leaving the precipitation echoes basically unaffected. After downloading file 31, you notice that the AP has been effectively suppressed, while the thunderstorms to your west are once again apparent. Figures 4A and 4B show a situation where widespread AP was occurring with embedded thunderstorms. Figure 4A shows a base reflectivity product with no operator-defined clutter suppression regions being used. Figure 4B shows a base reflectivity product from the very next volume scan, after downloading a clutter suppression file to remove the AP.

*Note: although using clutter suppression in areas where precipitation is occurring should be avoided in most instances, the benefits attained by using clutter suppression during widespread AP / embedded precipitation situations will often outweigh any possible negative impacts on the precipitation echoes.*

Obviously, there are many different types of situations which could occur involving AP, but hopefully these 3 examples have helped to show the reasoning process as well as some actions which could be taken to effectively manage clutter suppression.

## **5. An Example of Proper Operational Use of Clutter Suppression**

Sacramento, California is a somewhat unique radar site, for two reasons. Sacramento sits in a valley in northern California, a valley between two basically north-south oriented mountain ranges - the Sierra Nevada to the east, and the Coastal Ranges to the west. Because of its valley location, Sacramento is particularly susceptible to nocturnal inversions, and thus, AP; and furthermore, the proximity of mountains to the Sacramento radar site produces a quite extensive ground clutter pattern. For these reasons, Sacramento is a good location for exploring the use of clutter suppression. On April 24, 1995, a nocturnal inversion developed in the Sacramento Valley, with widespread AP manifestation. Figures 5A and 5B show the reflectivity and velocity products at 7:49 AM LST, with no clutter suppression invoked. This was accomplished by designing an operator-defined clutter suppression region which consisted of the entire radar coverage area, and then choosing operator select code 0, which turns off all clutter suppression, including the bypass map and default notch width map. Notice the large area of  $\geq 28$  dBz echoes. South and southeast of the RDA site, and directly north of the RDA site, much of the high reflectivity echoes are a result of AP along the Sacramento Valley. Most of the echoes west through northwest of the RDA site, as well as northeast through east, are the result of mountains. Note the large area of zero radial velocity surrounding the radar as a result of non-meteorological echo contamination of the base velocity product.

Figures 6A and 6B show the reflectivity and velocity products from the same morning as Figures 5A and 5B, and the same clutter suppression region (the entire radar coverage area) was chosen.

However, in these two figures, operator select code 1 was chosen. Remember that operator select code 1 is the default clutter suppression choice, in which the bypass map is in control. Remember also that this default clutter suppression option is used to suppress return from a particular radar's unique, persistent ground clutter pattern. Much of Sacramento's ground clutter is a result of the aforementioned mountains, and note in the reflectivity product (Figure 6A) how much of the high-reflectivity echoes have been eliminated. Note also how much less contamination (zero radial velocity) is evident in the radial velocity product (Figure 6B). Most of the remaining high reflectivity echoes in Figure 6A are in a north-south oriented line through the KDAX (Sacramento) RDA site. These echoes are AP echoes within the Sacramento Valley.

Since AP is occurring in the valley, the operator of the Sacramento radar downloaded a predefined clutter suppression region file that invokes the bypass in control (operator select code 1) for the mountainous areas and forces suppression (operator select code 2) for the Sacramento Valley to eliminate the AP echoes. Figures 7A and 7B show this option. Notice how nearly all of the high reflectivity echoes have been eliminated in Figure 7A, and notice also how much valid velocity data is apparent in Figure 7B. There are still a few pixels of high reflectivity apparent in Figure 7A, especially east and south of the RDA, and this is due to the unusually high reflectivity of a couple of the mountains very close to the RDA. Even with maximum clutter suppression (notch width 3, approximately 55 dBz), some of the high reflectivity echoes from mountains will remain as residual clutter. Keep in mind, however, that Sacramento is an extreme case. The ground clutter return for most radar sites is much less severe than at Sacramento. This case is an excellent example how proper use of clutter suppression leads to maximum reliability of WSR-88D products.

## 6. Summary

**The impact that a clutter-dominated power return has on the base data estimates can be substantial. Additionally, the clutter-induced bias in the base data affects the performance of ALL WSR-88D algorithms and products.** The intelligent application of clutter suppression will significantly improve the accuracy of all WSR-88D data.

*Acknowledgements:* The authors would like to thank Steve Rinard, NWS Southern Region NEXRAD Meteorologist, for his assistance and suggestions. Thanks also to Glenn Austin, Southern Region Headquarters, Hydrologic Services Division, for his review of the manuscript. Finally, thanks to Mike Foster, SOO, NWSFO Fort Worth, TX, and Suzanne Sims, Meteorologist, NWSFO Sacramento, CA for supplying the WSR-88D hard copies contained herein. Support for printing costs associated with this document were provided by the NWS Headquarters Office of Meteorology. Stephen Goss completed much of this study while on temporary assignment to the NWS Southern Region Headquarters in Fort Worth, TX, as part of the region's Southern Region Training and Achievement Residency (STAR) program.

## References

Chrisman, J. N., D. M. Rinderknecht, and R. S. Hamilton, 1995: WSR-88D Clutter Suppression and Its Impact On Meteorological Data Interpretation. Postprints, *The First WSR-88D User's Conference*, Norman, OK, 9-20.

**APPENDIX I. UCP Commands for Building and Downloading Clutter Suppression Region Files (from the WSR-88D Handbook UCP -1, UCP Job Sheet 1-4, *Modifying Clutter Suppression Regions*)**

**NOTE: These procedures were developed for Build 8.0 and MAY NOT be valid for other WSR-88D software builds.**

**CAUTION:** There are two basic rules to follow when invoking clutter suppression regions.

- 1) **DO NOT cross over Zero degrees (0°) azimuth when defining clutter suppression regions.**
- 2) **NEVER download a clutter suppression file that contains only zeros (0s).**

Both of these circumstances will cause an error in the clutter filtering logic and the message "RDA Alarm: Notch Map Generation Error" will be recorded in the System Status (ST,S) log. When this error occurs, the RDA **WILL NOT** use your region definitions to suppress clutter.

1. Press the **F1** key to get the RPG Main Menu.
2. Type **AD,{PASSWORD 1}** and press **RETURN**.
  - The Adaptation Data Menu appears.
3. Type **CL** and press **RETURN**.
  - The Clutter Maps Menu appears.
4. Type **C, {VCP}** and press **RETURN**.

***\*NOTE: Enter ANY currently valid VCP number (11, 21, 31, or 32). The "VCP" in this case is actually a clutter suppression region file number. It has nothing to do with an actual volume coverage pattern. ANY clutter suppression region file may be used with ANY volume coverage pattern.***

- The Clutter Suppression Regions Edit Screen appears.
- The currently defined clutter suppression regions for the file name (specified in step 4) are displayed by line (region) number on this and the subsequent page.

5. Select the line (region) number to modify, type **M,{LINE #}** and press **RETURN**.
  - This command initiates the editing session
  - The selected line (region) number with its currently defined parameters is copied into the edit window. The cursor is positioned on the first editable character.
  - A new additional region may be defined by selecting a line (region) number with zeros as entries in all fields.

6. Enter the Start Range in **KILOMETERS** (Start Range).  
-Any number from 2 to 510 km is allowed.
7. Enter the End Range in **KILOMETERS** (End Range).  
-Any number from 2 to 510 km is allowed.
8. Enter the Start Azimuth in **DEGREES** (Start Azimuth).  
-Any number from 0 to 360 is allowed.
9. Enter the Stop Azimuth in **DEGREES** (Stop Azimuth).  
-Any number from 0 to 360 is allowed.
10. Enter the appropriate Elevation Segment Number (Elev Seg Number).  
1 = all elevations  $\leq 1.5^\circ$   
2 = all elevations  $> 1.5^\circ$
11. Enter the appropriate Operator Select Code (Operator Sel Code).  
0 = No filtering  
1 = Bypass map in control  
2 = Clutter Suppression region is in control for the selected start/stop range and start/stop azimuth.
12. Enter the Notch Width for the Doppler and Surveillance channels.  
1 = Low. Creates a notch width of  $\approx 4$  kts (or approximately 30 dB).  
2 = Medium. Creates a notch width of  $\approx 5$  kts (or approximately 40 dB).  
3 = High. Creates a notch width of  $\approx 7$  kts (or approximately 55 dB).
13. After all parameters have been modified to define this region, press **RETURN**.  
-The modifications are temporarily stored in memory and the cursor returns to the command line.
14. To modify or create additional regions, repeat steps 4-13.
15. To save the changes, type **E** and press **RETURN**.  
-This ends the edit session and saves the edits to the adaptation file.

**NOTE:** If you do not wish to save the modifications, type **C** and press **RETURN** (or press **F3**).

-This cancels all modifications made during this edit session and exits the edit mode.

**NOTE:** If you want the system to use this modified Clutter Suppression Region(s), you **MUST** “download” the modifications to the RDA after saving the changes. To accomplish this, do the following:

16. To download the Clutter Suppression Region file, type **DO** and press **RETURN**.

**NOTE:** The full command on the command line is **AD,{PASSWORD1},CL,C,{VCP},DO.**

-This command transmits the newly created Clutter Suppression R0.egion file to the RDA.

-The RDA will update its clutter suppression map to incorporate the modified regions.

-The new clutter suppression map will take effect at the start of the next volume scan.

-This command may be used anytime you want to download a Clutter Suppression Region file, whether it is a previously stored file, or one you have just created.

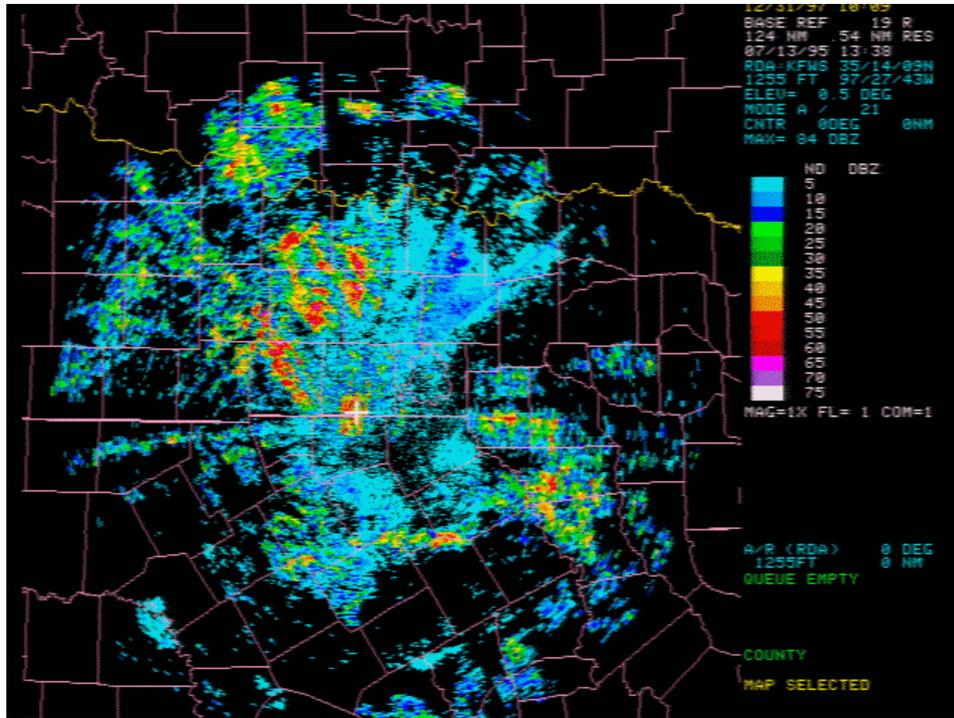


Figure 4A. KFWS Base Reflectivity, 0.5 degree elevation, no clutter suppression.

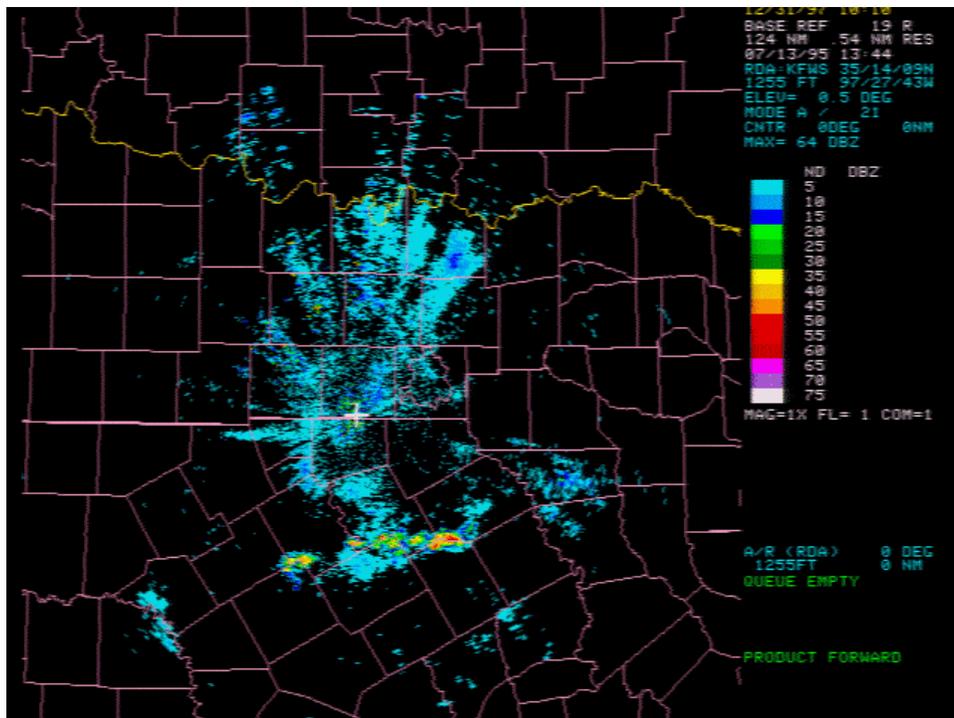


Figure 4B. KFWS Base Reflectivity, 0.5 degrees elevation, operator-defined clutter suppression.

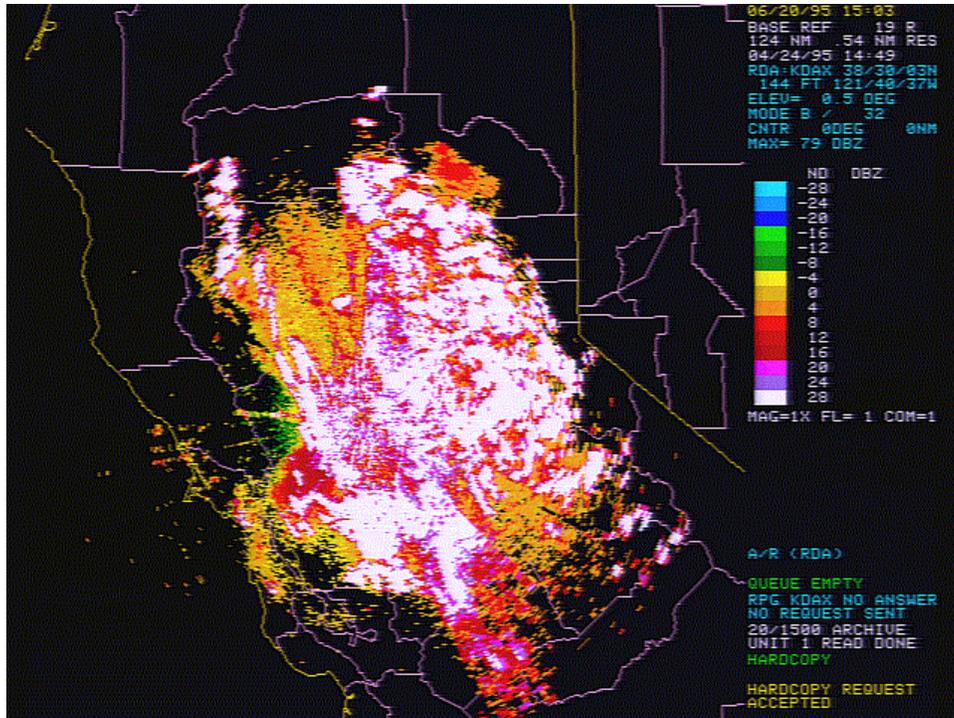


Figure 5A. KDAY Base Reflectivity, 0.5 degrees elevation, no clutter suppression.

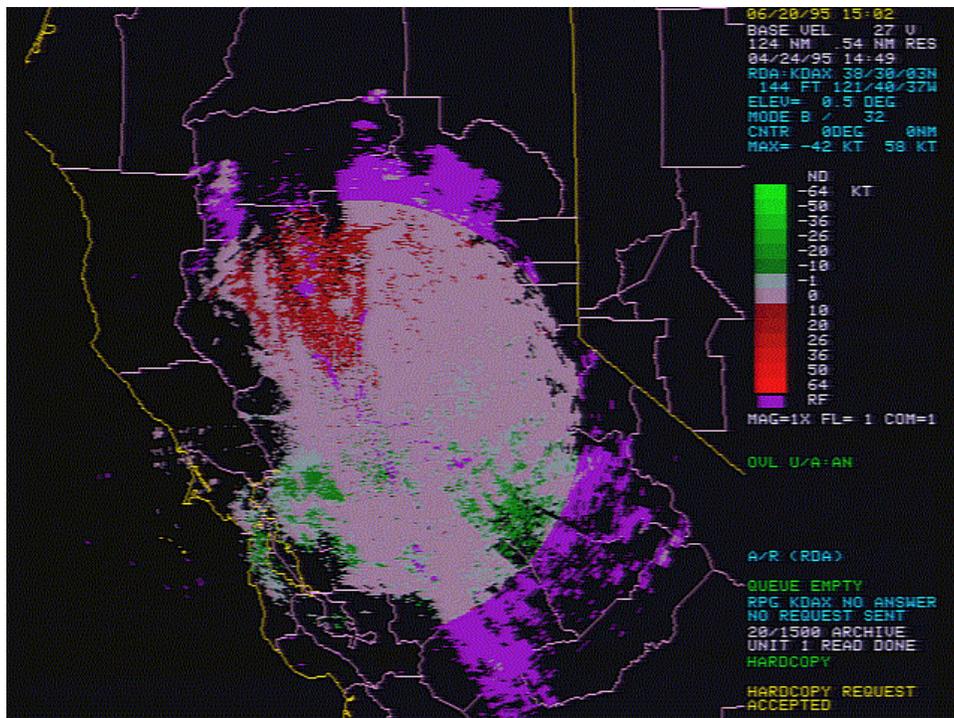


Figure 5B. KDAY Base Velocity, 0.5 degrees elevation, no clutter suppression.

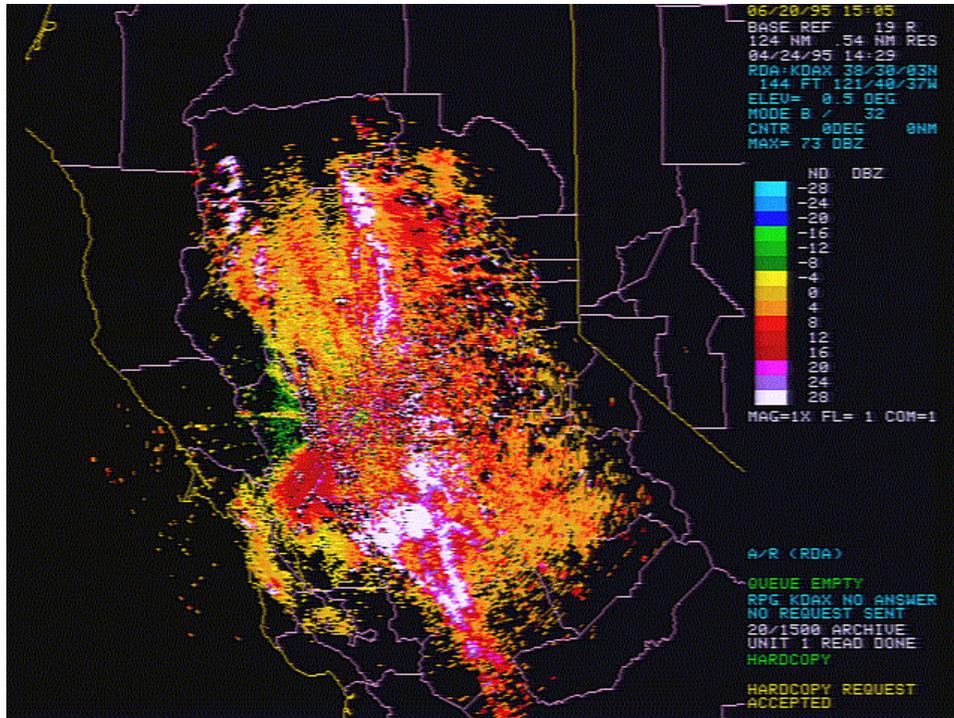


Figure 6A. KDAY Base Reflectivity, 0.5 degrees elevation, bypass map in control.

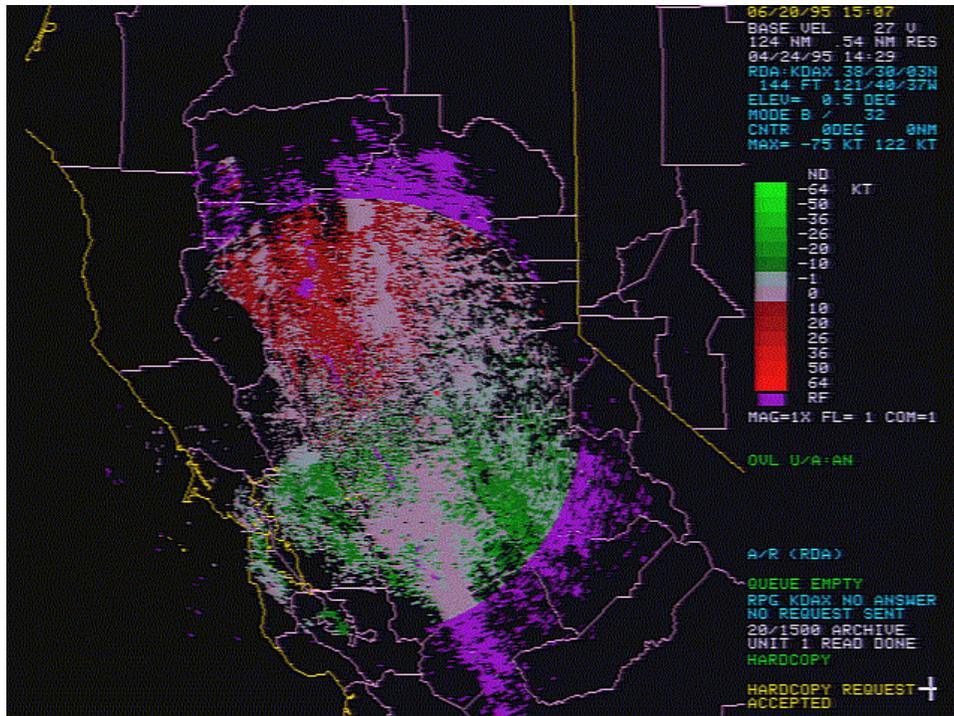


Figure 6B. KDAY Base Velocity, 0.5 degrees elevation, bypass map in control.

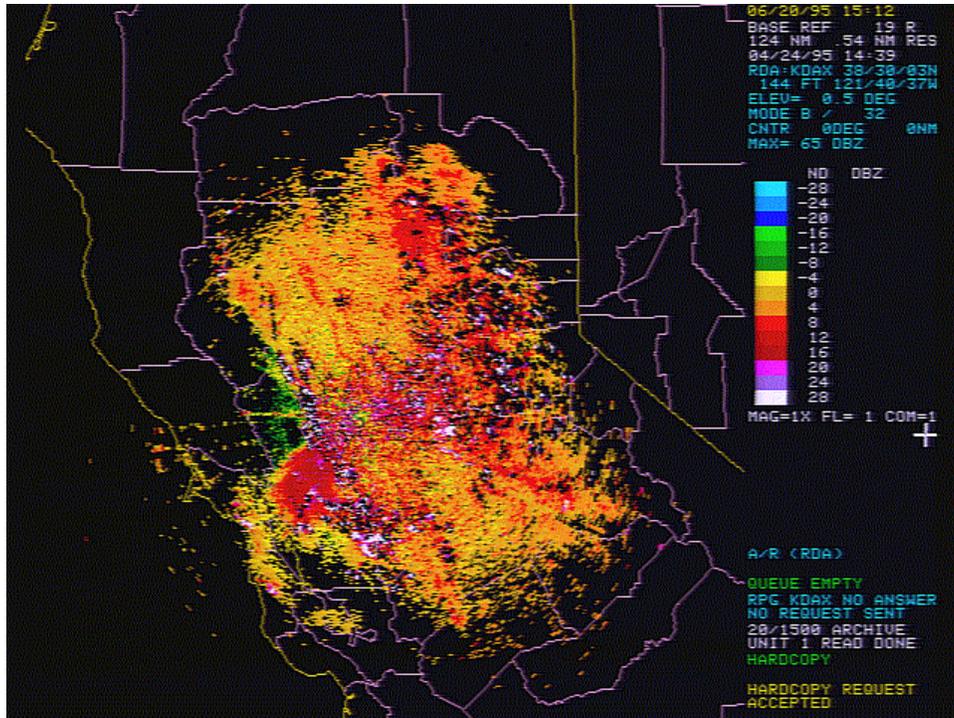


Figure 7A. KDAY Base Reflectivity, 0.5 degrees elevation, operator-defined clutter suppression invoked.

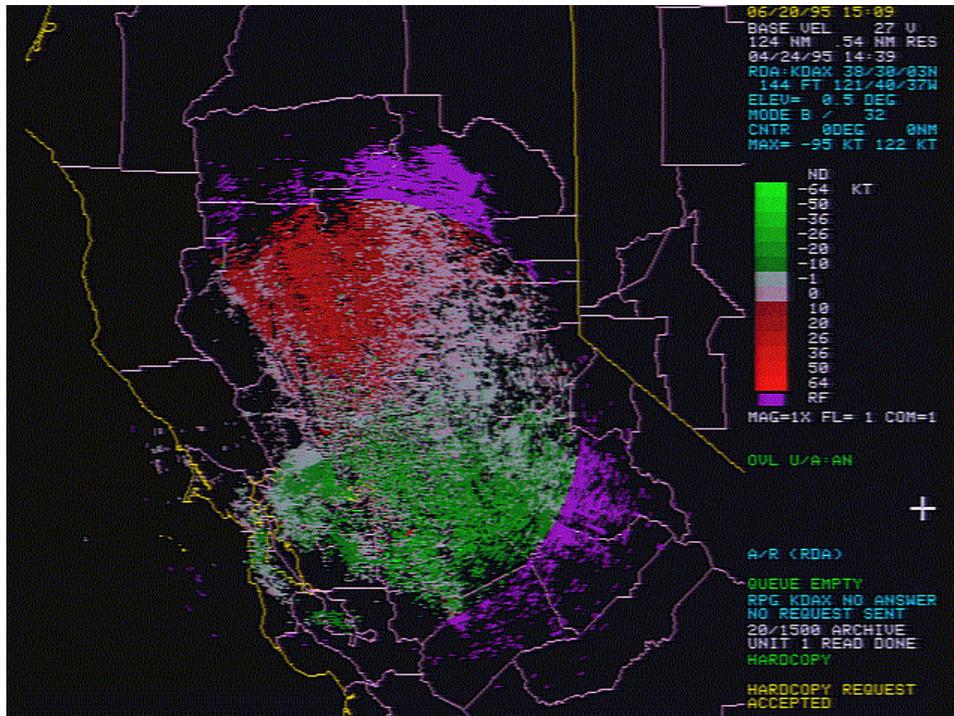


Figure 7B. KDAY Base Velocity, 0.5 degrees elevation, operator-defined clutter suppression invoked.