P2.12 A METHOD TO REDUCE THE CLUTTER FILTER INDUCED BIAS BY IMPROVING THE VERTICAL APPLICATION OF WSR-88D BYPASS MAPS

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1. INTRODUCTION

The legacy Weather Surveillance Radar-1988, Doppler (WSR-88D) Radar Data Acquisition (RDA) signal processor only supported two elevation segments (each with a single bypass map): Elevation Segment 1 controlled clutter suppression application for all elevation slices less than or equal to 1.65 degrees (split-cut processing) and Elevation Segment 2 was used for all elevations above 1.65° (batch mode and contiguous Doppler elevations up to, and including, 19.5°). A single bypass map, dominated by clutter return from the lowest elevation of the particular segment (worst clutter coverage), was generated for each elevation segment. The clutter suppression control selection for an elevation segment applied to every elevation slice in that segment, regardless of how the clutter horizon changed with increasing elevation. The limitation of only two elevation segments forced the application of clutter suppression on the higher elevations, within the segment, where there was no clutter. This unnecessary application of clutter suppression frequently resulted in biased data estimates.

In contrast, the newly-deployed Open Radar Data Acquisition (ORDA) system supports the definition and application of up to five elevation segments, each with its own bypass map. Implementing five elevation segment definitions, with their respective bypass maps, tailors the application of clutter suppression to the changes in the radar's clutter horizon with increasing elevation.

This paper focuses on how increasing the number of elevation segment definitions reduces the clutter filter-induced data bias caused by applying clutter suppression in bins where there is no clutter return.

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2. BACKGROUND

As with many programs and organizations, the WSR-88D has its own unique processes, terms and acronyms. Those who work with the WSR-88D every day routinely use these phrases and words in conversation and assume everyone will associate them with the same meaning that we do. In an attempt to ensure we are all speaking the same language, the following definitions are provided as a basis for this work.

2.1 *Definition of Terms*

- **AP.** Anomalous Propagation (AP) describes the non-standard bending of the radar beam, either more or less steeply than expected. AP may result in the beam being trapped in the boundary layer for long distances, resulting in significantly more return on the product displays.

- **AP-Clutter.** AP-Clutter is the return from ground targets at longer ranges than expected. This is caused by anomalous (abnormal) propagation of the radar beam.

- **Bypass Map.** The Bypass Map is a special map generated by the RDA that identifies the geographic location of clutter targets (targets with near-zero radial velocity and a narrow spectrum width). The identified targets are those present within the radar's viewing horizon at the time the map was generated.

- **Clutter.** The broad definition of "clutter" is: Any return that interferes with the observation of desired signatures on a radar display.

  However, in our discussions with operational meteorologists, we describe "clutter" as stationary, hard (highly reflective), ground-based, non-meteorological targets. Unlike the first definition, this modified clutter definition does not include return from biological targets (insects, birds, etc.,) non-precipitable aerosols, and refractive index which may be implied in the broader definition, above. We use this more restrictive definition in our discussions to distinguish ground-based “clutter” targets from those targets that can and do provide valuable boundary layer information.

From the radar’s signal processing point of view, yet another definition needs to be introduced here. Because of the nature of the clutter filtering process, the radar considers **ALL** returns that have a near-zero **radial** velocity and a narrow spectrum width as clutter. This definition is important because, when clutter suppression is invoked, the radar performs suppression on all returns that have these characteristics (near-zero radial velocity and a narrow spectrum width).

- **Clutter (Suppression) Region.** A Clutter Suppression Region is the three-dimensional volume whose horizontal dimensions are defined by azimuth and range and whose vertical (upper and lower) boundaries are defined by the selected elevation segment (see Figure 1 for a graphical illustration). The horizontal coverage of a Clutter (Suppression) Region can encompass the entire display range of the radar.

- **Elevation Segment.** An Elevation Segment is the grouping of contiguous data collection elevation angles into subgroups. For the purpose of applying clutter suppression, each grouping (elevation segment) is treated as an individual entity.

- **GMAP.** Gaussian Model Adaptive Processing (GMAP) is the algorithm that performs clutter suppression in ORDA (Chrisman and Ray, 2005). GMAP operates in the frequency domain and uses an iterative algorithm to remove the power centered on zero (radial velocity) within a specified clutter spectrum width (Siggia and Passarelli, 2004). After suppression, if there is sufficient meteorological-like power return (return with velocity) available, GMAP will construct a Gaussian curve from that power spectrum and “rebuild” any meteorological signal power that was removed.

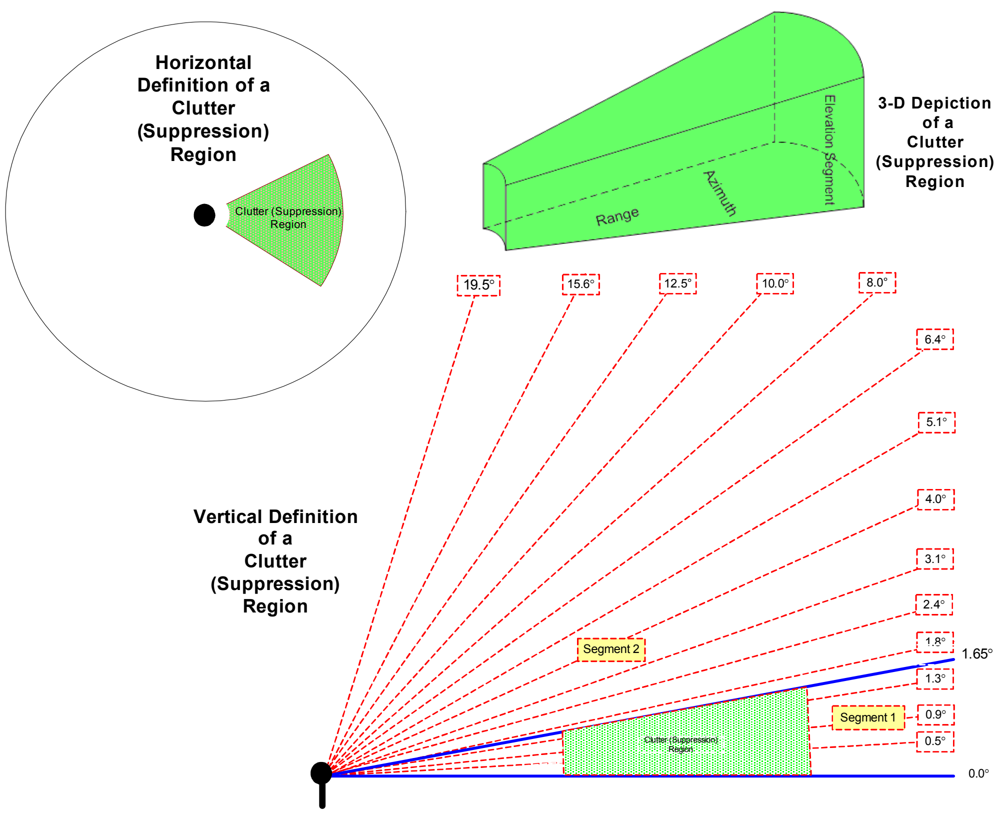

Figure 1 : Graphical Illustration of a Current Clutter (Suppression) Region Definition with VCP 12 Elevation Angles

2.2 *Review of WSR-88D Clutter Suppression Application*

The ultimate control over where to apply GMAP clutter suppression is accomplished by defining Clutter (Suppression) Regions. The geographic (horizontal) boundaries of each Clutter (Suppression) Region are defined by the WSR-88D operator via a graphical Human Computer Interface (HCI). However, the vertical boundaries (affected elevation angles) are controlled by the elevation segment definitions in ORDA adaptation data.

A graphic example of a Clutter (Suppression) Region definition is presented in Figure 1. In this example, the horizontal extent of the region is defined by the beginning azimuth, ending azimuth, starting range, and ending range. However, the horizontal coverage may be defined to encompass the entire display range of the radar. (This is commonly done to invoke the Bypass Map.) The vertical extent of each Clutter (Suppression) Region is defined by the elevation segment definition which is part of ORDA adaptation data and is selected as part of the Region definition.

Within each three-dimensional Clutter (Suppression) Region, the operator selects either "None", "Bypass Map" or "All Bins" to control the specific application of the GMAP clutter suppression algorithm.

- **None.** When None is selected, GMAP does not process the data from any range bin within the defined region.

- **Bypass Map**. Selecting the Bypass Map option means **ONLY** those range bins identified on the Bypass Map (within the defined region) will be processed by GMAP. ***Usage – the Bypass Map is used to address routine, non-transient clutter. Under normal atmospheric conditions, an operator-defined region encompassing the radar's entire display, with the Bypass Map in control, is used to mitigate routine ground clutter.***

- **All Bins**. With All Bins selected, **EVERY** range bin within the defined region will be processed by GMAP. ***Usage - operator-defined Clutter (Suppression) Regions with the All Bins selection are used to address transient clutter return caused by AP.***

GMAP only processes the signal from range bins identified on the Bypass Map or those range bins contained within a defined Clutter (Suppression) Region that has the control designation of "All Bins". Figure 2 illustrates the decision logic controlling the application of clutter suppression.

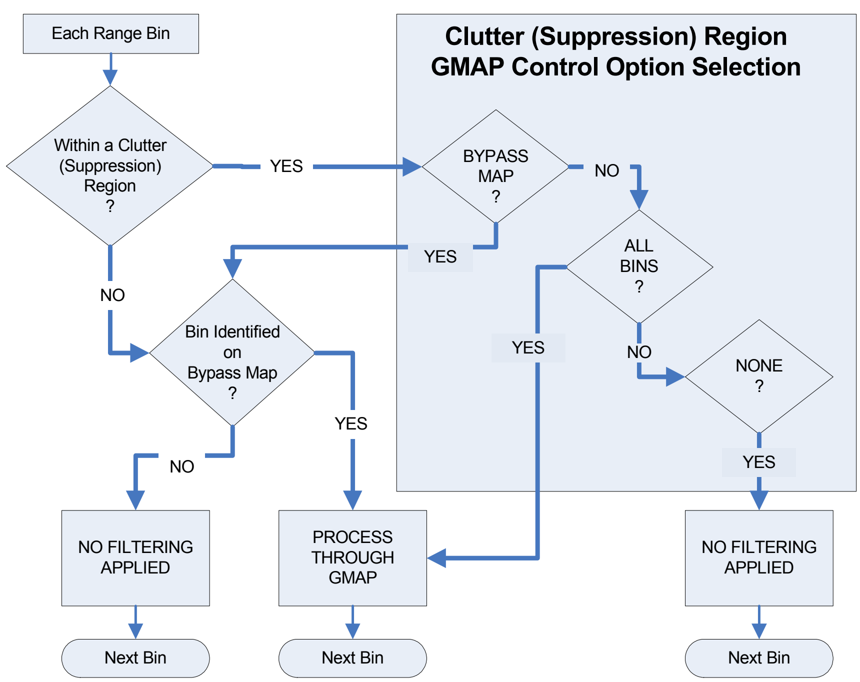

Figure 2 : Clutter Suppression Decision Logic

Multiple Clutter (Suppression) Regions may be defined for each elevation segment. Each region controls the specific application of GMAP within its boundaries according to the selected control option (refer to Figure 2).

3. CURRENT ELEVATION SEGMENT DEFINITIONS

Since the beginning of the WSR-88D program, clutter suppression has been managed using only two Elevation Segments. The delineation between these two segments segregated split cut processing from batch mode processing (see Figure 1). This segregation was desired to help reduce the clutter filter-induced data bias in Batch Mode. This bias is exacerbated in the batch mode due to the low number of samples available.

The Open Principal User Processor (OPUP) displays in both Figure 3 and Figure 4 are from the Pueblo, CO, WSR-88D (KPUX). These data were collected on a clear, dry day with clutter filtering **turned off** (Select Code - None). The resulting images provide a good example of the clutter horizon for each elevation angle.

The first image (far left) in Figure 3 shows the Elevation Segment 1 Bypass Map. The subsequent images are the unfiltered reflectivity products produced from the first three elevation scanning angles of Volume Coverage Pattern 12 (VCP 12). These three elevation scans are currently included in Elevation Segment 1 (refer to Figure 1).

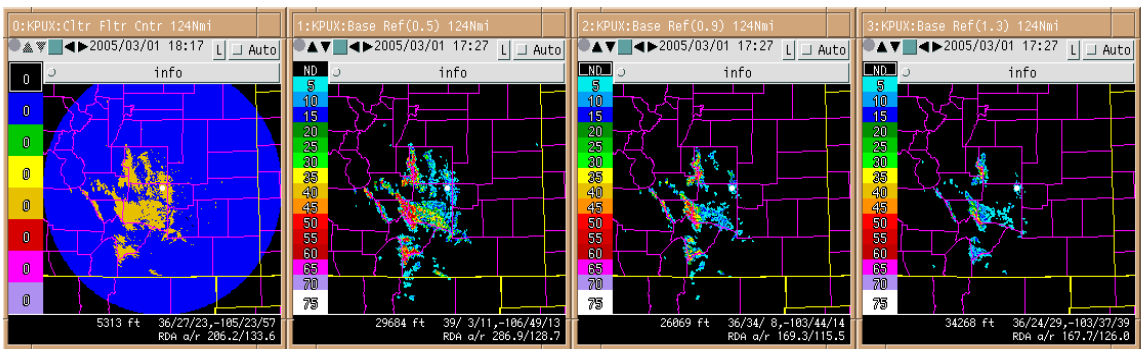

Figure 3 : Pueblo (KPUX) Segment 1 Bypass Map and Unfiltered Reflectivity Products

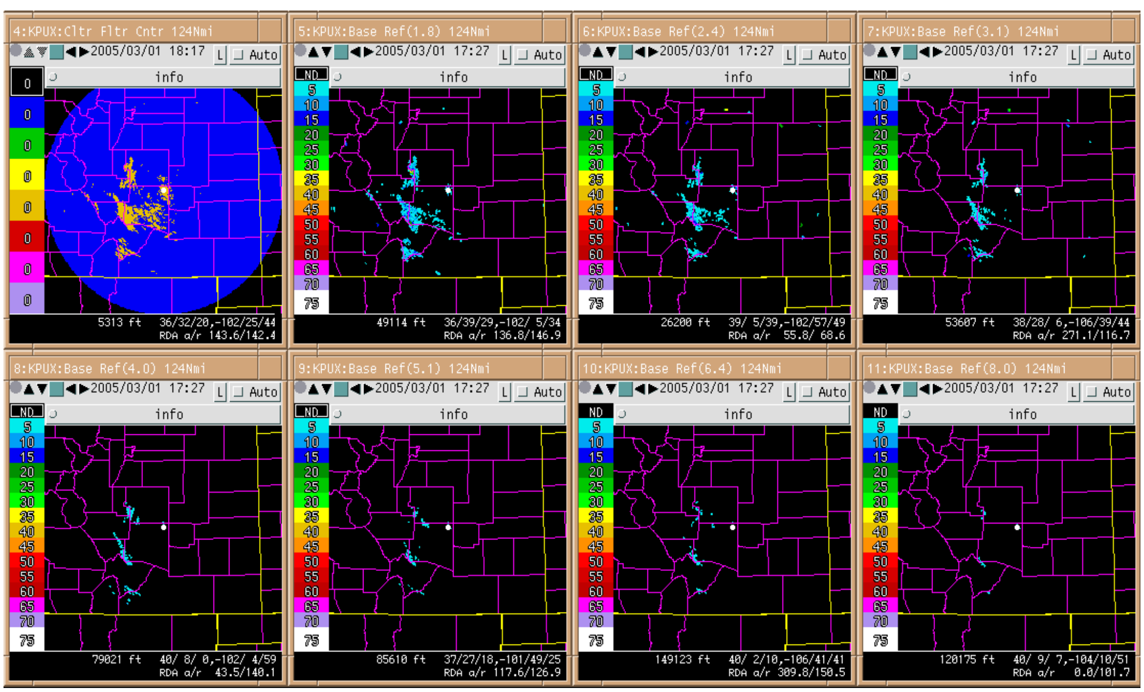

Figure 4 : Pueblo (KPUX) Segment 2 Bypass Map and Unfiltered Reflectivity Products

The first image (upper left) in Figure 4 shows the Elevation Segment 2 Bypass Map. The remaining images are the unfiltered reflectivity products from the next 7 elevation scanning angles in VCP 12, all of which are currently included in Elevation Segment 2 (refer to Figure 1).

Figures 3 and 4 provide a graphic example of the change in the amount of clutter return present as the elevation scanning angle increases. Additionally, it is quite evident each Bypass Map is dominated by the clutter present on the lowest elevation slice of the particular segment (most clutter coverage). It is important to remember that, for each elevation segment, a single bypass map is available, regardless of how the radar's clutter horizon changes with increasing elevation angle.

Another equally important point is that for each Clutter (Suppression) Region, the clutter application choice (None, All Bins, or Bypass Map) applies to every elevation slice in the particular elevation segment.

For example; if, during an AP event, transient AP-clutter targets were evident on the 1.8° slice, the operator would invoke All Bins suppression for Elevation Segment 2 (refer to Figure 1) to address this AP-clutter. However, this Clutter (Suppression) Region definition applies clutter filtering to **every** elevation slice in Elevation Segment 2 (1.8° - 19.5°), regardless of whether or not each of the slices exhibit evidence of AP-clutter contamination.

As illustrated in the example, the current elevation segment boundary definitions frequently result in clutter suppression application on several elevation angles devoid of clutter return. This unnecessary suppression introduces a bias in the base data estimates and can result in significant meteorological data loss along the zero isodop, as well as in other areas that have zero <u>radial</u> velocity (Figure 5).

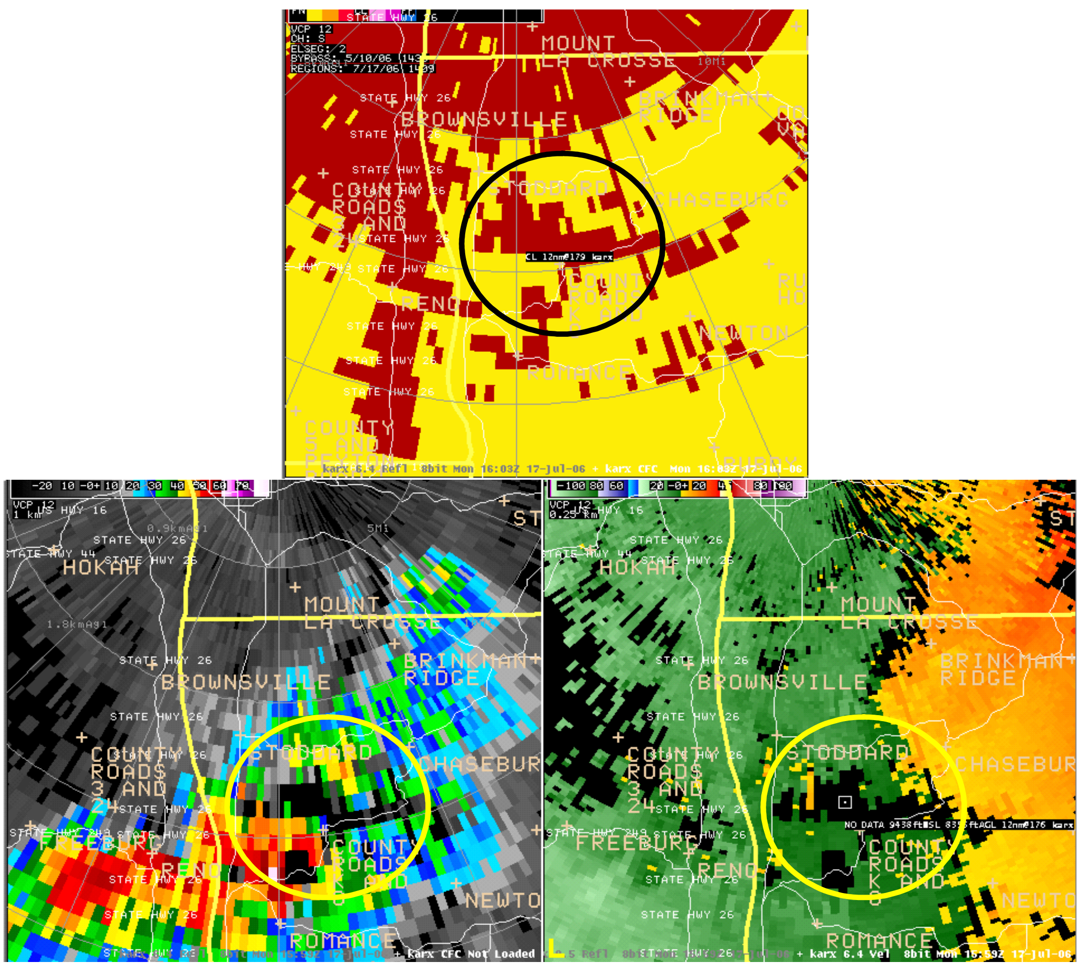

Figure 5 : La Crosse (KARX) Elevation Segment 2 Bypass Map and Products

The top image in Figure 5 is the Elevation Segment 2 Bypass Map from the La Crosse, WI, WSR-88D (KARX). Notice the identified clutter feature (red pixels) between the city of Stoddard and the cursor information (inside the black circle). This feature is only present in the lowest portion of Elevation Segment 2. The other two images are the reflectivity and velocity products from the 6.4° elevation slice. Note the "missing" reflectivity and velocity gates (black pixels inside the yellow circles) corresponding to the location of the identified clutter. Even though this clutter feature does not extend up to this elevation, the fact that these range gates are identified on the Elevation Segment 2 Bypass Map means clutter suppression is applied to the return in those gates.

In an effort to reduce this unnecessary suppression, the Radar Operations Center (ROC) is increasing the allowable number of elevation segments. The additional elevation segments will enable WSR-88D operators to better address both routine and transient clutter returns.

4. IMPROVED VERTICAL RESOLUTION OF ELEVATION SEGMENTS

For Build 9, scheduled for release in May 2007, the ORDA configuration is being modified to support the definition and application of up to 5 Elevation Segments. Each elevation segment will have a separate bypass map. Figure 6 depicts the new, default elevation segment definitions and VCP 12 elevation scanning angles.

An example of the improvement afforded by these new elevation segment definitions, and accompanying bypass maps, is presented in Figure 7. The input data used to generate these bypass maps are the same data used in Figure 3. Notice the significant reduction in the areal coverage of identified clutter above the 1.8° elevation. Using the current elevation segment definitions, the 1.8° elevation slice is the basis for the Elevation Segment 2 Bypass Map. This would result in clutter suppression being performed on all the range bins identified on this map for every elevation in Segment 2 (1.8° through 19.5°).

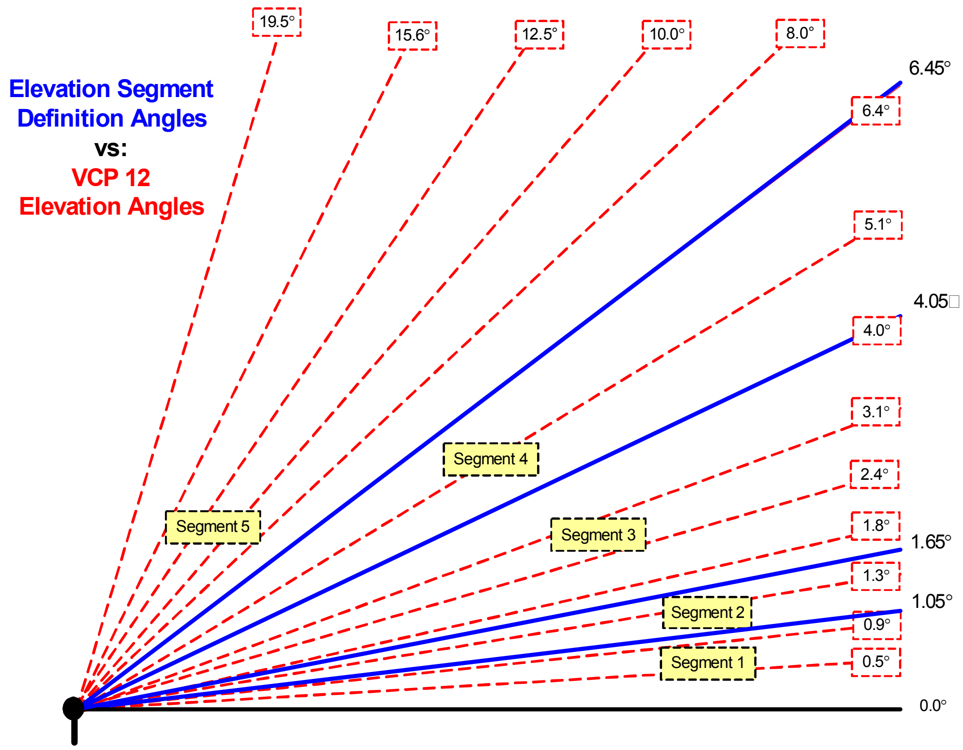

Figure 6 : New (Build 9) Default Elevation Segment Definitions with VCP 12 Elevation Angles

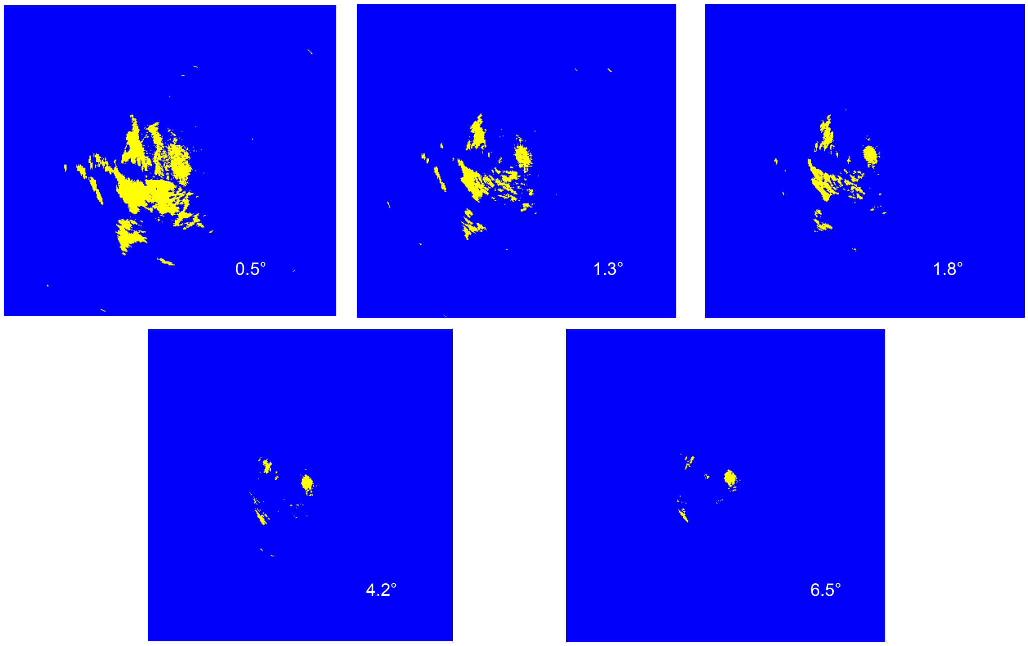

Figure 7 : Pueblo (KPUX) Bypass Maps Generated for New Default Elevation Segment Definitions

NOTE: The bypass maps in Figure 7 were created using Level I data and an off-line program designed to assist in the development of the Clutter Mitigation Decision (CMD) Algorithm.

With the new elevation segment definitions illustrated in Figure 6, the clutter suppression areal coverage, with the Bypass Map in control, is reduced as the areal coverage of identified clutter decreases with elevation.

5. OPERATIONAL APPLICATION

For Build 9, the default elevation segment definitions and bypass map generation angles were selected to provide immediate benefit to the entire WSR-88D fleet. These default selections were not meant to be the perfect solution for any particular radar. Local customization of these parameters is recommended.

For WSR-88Ds with difficult terrain, like the KPUX examples in this work, the elevation segment definitions must consider routine clutter targets that extend up through several elevation angles (refer to Figure 7). Locations with mountainous terrain can experience significant clutter contamination from the first two side lobes (approximately 2.5° and 5.0° off the main lobe) as well as from the main beam. Notice the areas of identified clutter on the 4.2° and 6.5° bypass maps in Figure 7 and on the reflectivity products in Figure 4. This clutter is attributed to side lobe return.

For sites with more benign clutter horizons, each elevation segment definition may only need to include 1 or 2 degrees to address the radar's clutter horizon. The bypass maps in Figure 8 were generated using the KCRI radar at the ROC Testbed in Norman, OK. To facilitate comparison with the KPUX Bypass Maps in Figure 7, the default elevation segment definitions and default bypass map generation angles were used in both examples.

In the KCRI example, only returns from very close to the radar (<10nm) are included in the bypass maps generated at 4.2° and 6.5°, Elevation Segments 4 and 5, respectively. These identified clutter returns are caused by the radar's side lobes illuminating the elevated terrain southwest and north of KCRI.

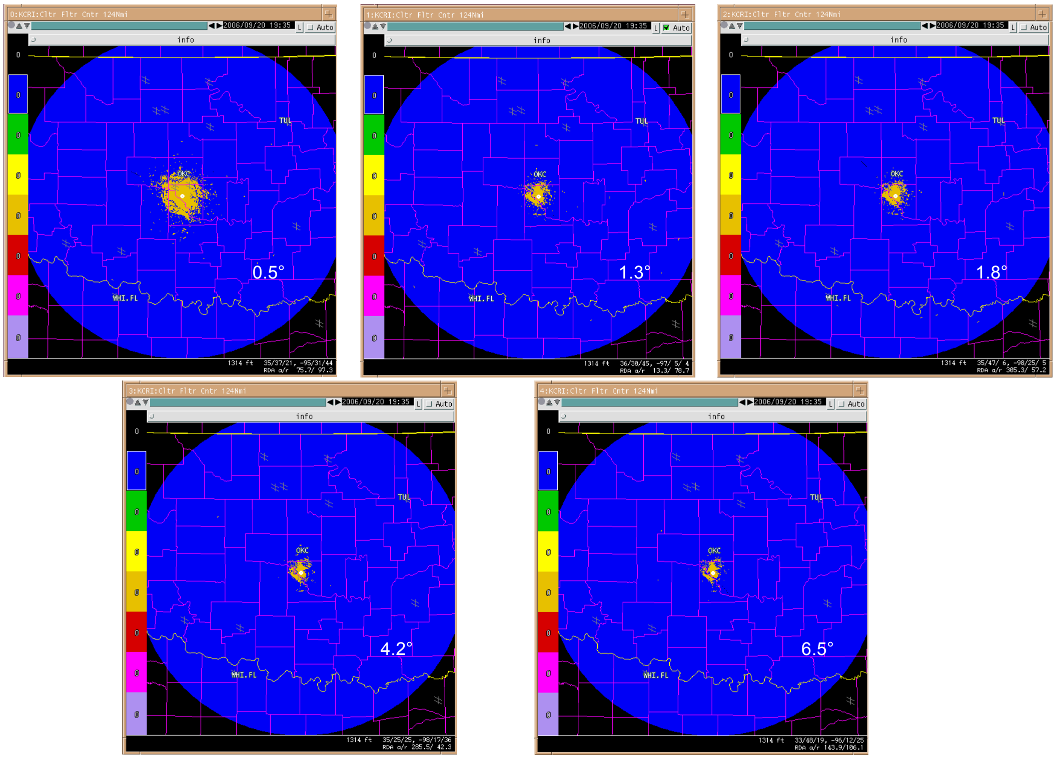

Figure 8 : ROC Testbed Radar (KCRI) Bypass Maps

To define the clutter horizon for a particular WSR-88D, the operator should examine the base reflectivity and velocity products for each elevation below 10°, with clutter suppression turned off. This information should be used to determine the individual elevation segment definition. For each elevation segment, the operator should select the closest available data collection elevation to generate a bypass map for that segment. For sites in mountainous terrain, reference to base reflectivity products is required to determine if more than one elevation should be included in the bypass map generation process because of side lobe return. This is particularly important for elevation segments whose base is above 2.5° and encompass multiple elevations.

6. CONCLUSION

The new ability to customize the Elevation Segment definitions and Bypass Map Generation angles will tailor the application of clutter suppression for the radar's routine clutter horizon. Additionally, and perhaps more importantly, when AP-clutter is present, this new functionality will enable the operator to limit the application of clutter suppression to contaminated elevation angles by ONLY invoking forced clutter suppression for the affected elevation segments. In both circumstances, the improved vertical resolution of clutter suppression application will help reduce the meteorological data bias caused by unnecessary suppression (i.e., suppression applied to meteorological return in bins that do not contain clutter), especially in batch mode processing.

7. ACKNOWLEDGEMENTS

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(Note: The views expressed are those of the authors and do not necessarily represent those of the National Weather Service.)

8. REFERENCES

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