The Importance of Proper Clutter Filtering

For the past few months, CMD (Clutter Mitigation Decision) has been available to field sites with the recent software upgrade of Builds 11.0 and 11.1. We at the ROC have seen vast improvement across the field of day-to-day clutter filtering, especially during Anomalous Propagation (AP) events.

A rather impressive event occurred over most of the central US, including Oklahoma, in late June 2009 with an unusually steep inversion. Figure 1 shows a Clutter Filter Control (CFC) product while CMD was enabled (the dynamic Bypass Map) with the corresponding reflectivity and velocity images shown to its right. The CMD algorithm detected a large amount of clutter – almost the entire radar coverage area was flagged as having clutter. Now that's a lot of AP!

After CMD flagged these bins, GMAP (Gaussian Model Adaptive Processing) removed the clutter and rebuilt the weather signal, which is seen in the base moments below. The resulting reflectivity and velocity products show clear air return from moving scatterers.

Don't believe it? We turned off CMD and ran the legacy static Bypass Map. The results of which are shown in Figure 2.

Operators should request a

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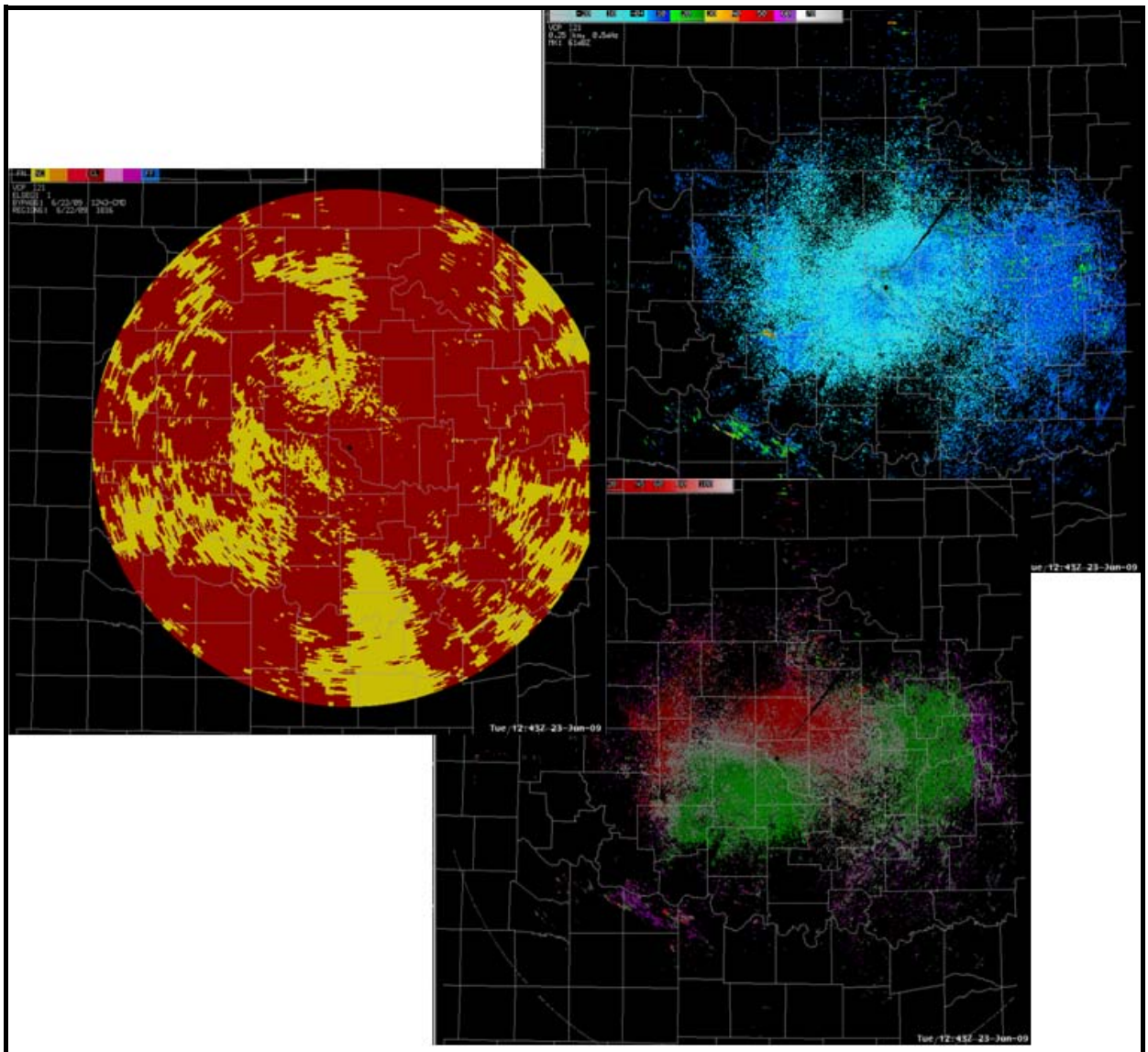

Figure 1: A Clutter Filter Control product while CMD was enabled at 1243Z with the corresponding reflectivity and velocity images shown at right.

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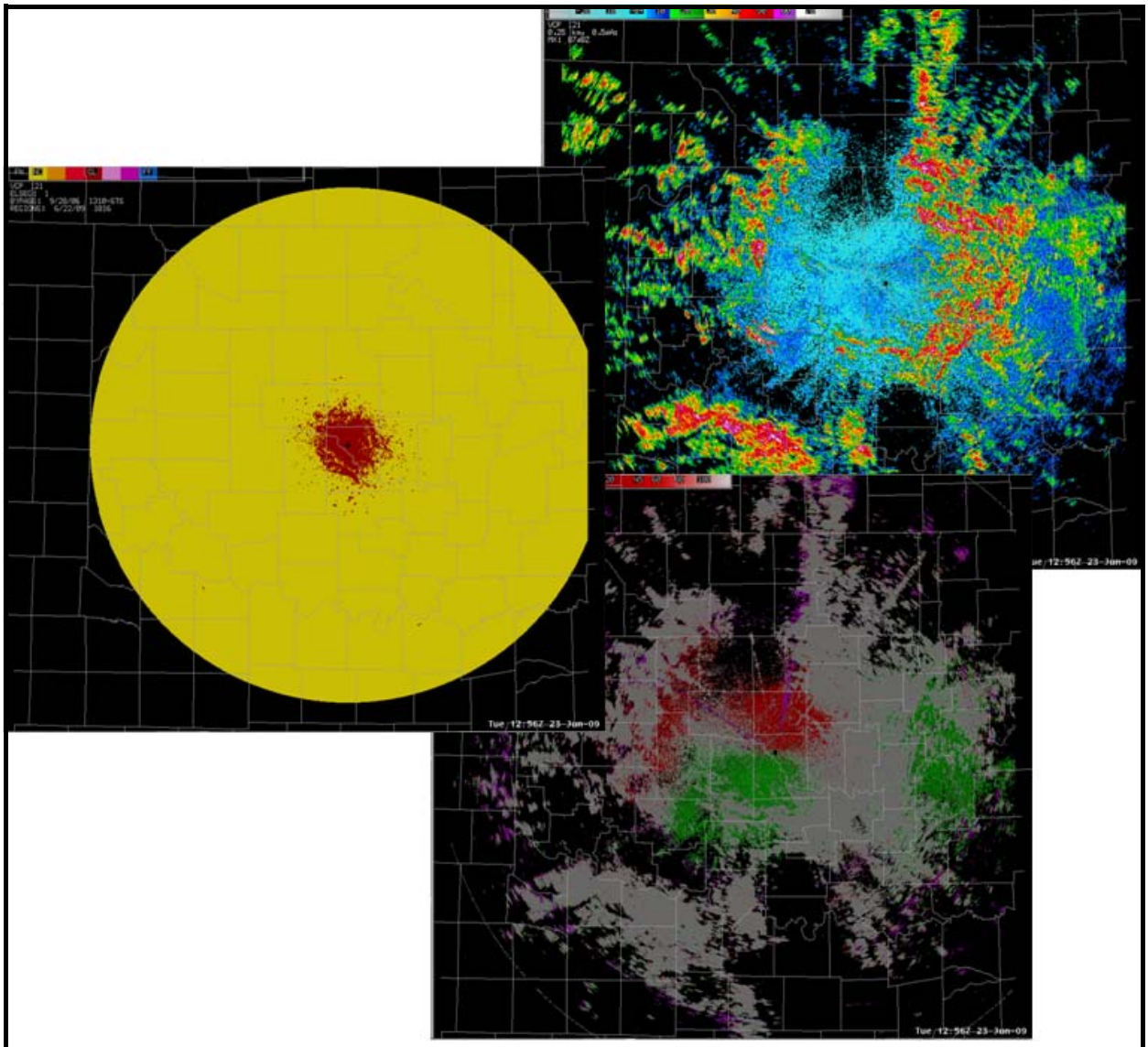

Figure 2: As in Figure, 1 but for 1256Z when CMD was disabled.

CFC product via an Advanced Weather Interactive Processing System (AWIPS) Radar Multiple Request (RMR) and watch the loop of the product during an AP event. It's amazing how fast the atmospheric properties change from volume scan to volume scan!

There was an unexpected issue in the Build 11.0 version of CMD. Beta sites with rugged mountainous terrain saw small isolated areas of missed detections by CMD. ROC engineers quickly found the source for the error and applied a "fix" to CMD which was included in the Build 11.1 version of CMD. The first ten sites experiencing missed clutter detections were sent the new version of CMD in Build 11.1, which received numerous favorable comments.

With the Build 11.1 version, unusual box-shaped areas became noticeable along the zero isodop during not only slow-moving stratiform events, but also faster-moving convective events. The data in these boxes have weaker reflectivity values than surrounding bins, and velocities biased away from zero. This is the result of the bias when clutter filtering is applied. In Figure 3 below, the three base moments are shown, each illustrating these biased areas.

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What causes the box-shaped biased areas? CMD now operates with a processing resolution of 1 degree by 1 km, meaning there are 8 Super Resolution (SR) bins in each of the bins CMD identifies for filtering. The boxes in the data are a result of this map-building process. There may be 1 or 2 SR bins which are flagged, but the entire 1 degree by 1 km bin is flagged for filtering, even if the rest of the SR bins do not have clutter. And, if the data falls beneath the thresholds used by GMAP, then the bins are filtered, which may result in biased data: weaker reflectivity values and velocities biased away from zero. If one is looking at the SR data, one can see that these patches are in multiples of 4 SR bins down radial and 2 SR bins in azimuth. In addition, the weaker areas of reflectivity that result seem to be more evident in the faster VCPs because of the fewer pulses used to sample the data, leaving the possibility for noisy calculations. Folks at the ROC continue to analyze data to refine the CMD algorithm; though, there is always a trade off. The Build 11.0 version of CMD used SR bins for the processing, and there were missed detections of clutter by CMD in rugged mountain terrain. The Build 11.1 version is performing better than the Build 11.0 version for many sites, but the filtering is more aggressive than the former version.

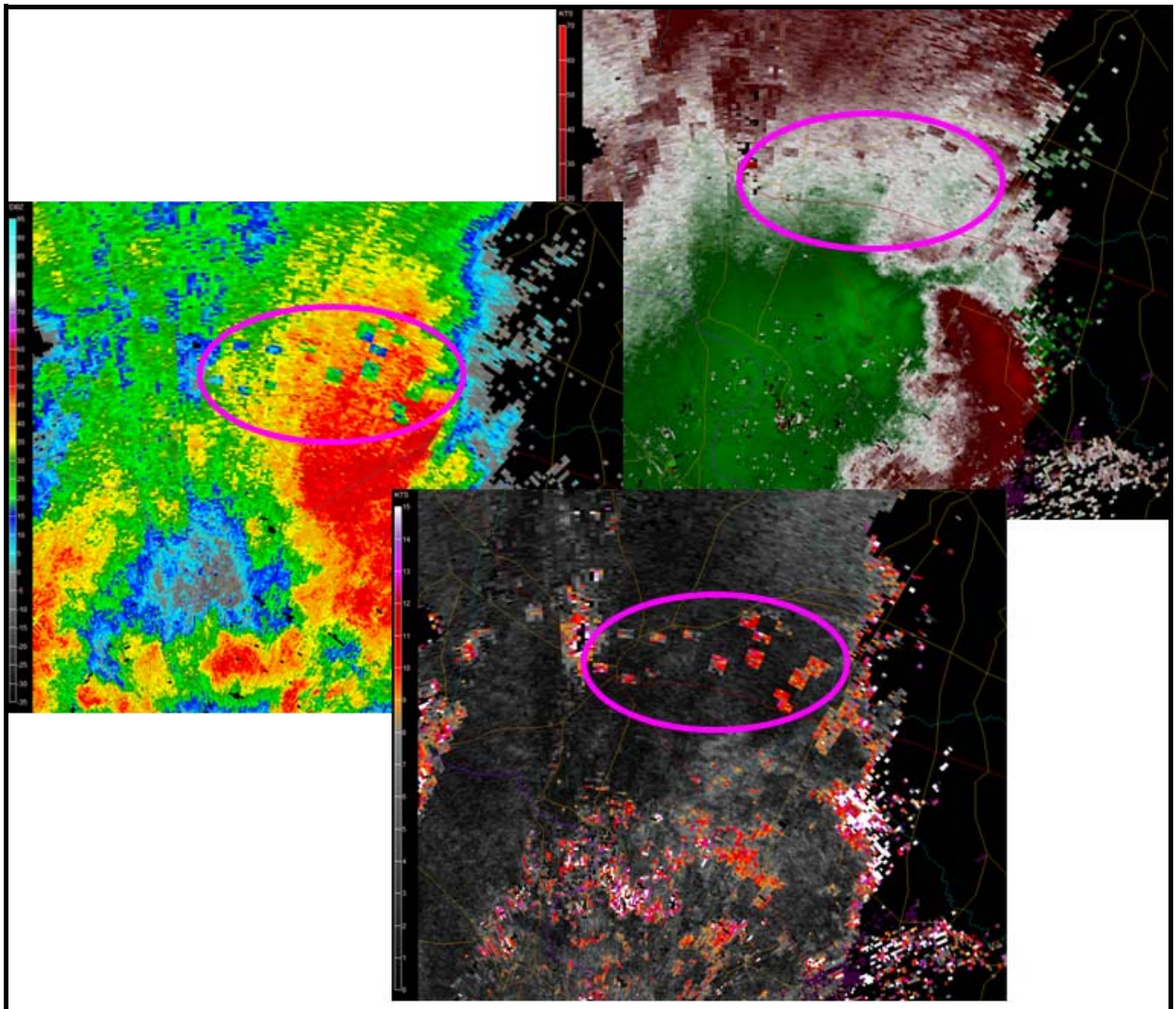

Figure 3: The three base moments illustrating the biased areas along the zero isodop.

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While these biased areas seem new, the data loss due to too much clutter filtering has always been a possibility. In fact, the downstream effect due to over-suppression degrades the data far more if applying forced filtering everywhere, aka All Bins. The box-shaped areas that are occasionally possible along the zero isodop with CMD tend to move around from one volume scan to the next so the 'loss' in terms of precipitation accumulation is negligible. So far, we have not yet seen a case where the 'losses' due to CMD negatively impact precipitation products. We have often, however, seen negative impacts on precipitation accumulation when All Bins is left as the clutter filter for a period of time. Figure 4 shows a vertical cross-section of reflectivity on the left with the usual Plan Position Indicator (PPI) view of base reflectivity from tilt 2 on the right. The dashed line on the plan-view image indicates the cross-section location. It can be easily seen that the second tilt shows reduced power, even holes, in reflectivity, which correspond to holes, or losses, of data seen in the cross-section. This can result in significant underestimations of precipitation.

But, what was the cause for the holes seen in Figure 4? That's right - filtering. Forced filtering was used on Segment 2 as opposed to the Bypass Map (pre-Build 11.1). In this case, only one elevation was affected. But, if forced filtering had been invoked on Segment 1, and say, VCP 12 was running, then the lowest *two* elevations (0.5 and 0.9 degrees) would have seen data losses. Over-suppression results in a reduction of power. How? GMAP. Remember that if a bin is flagged to be filtered (and every bin is flagged when using All Bins), then GMAP removes power from signals with zero to near zero velocities then rebuilds some of the weather signal ... But, not the entire signal. In the event shown in the figures, slow-moving stratiform rain remained over the radar site for more than 40 hours! Weather events with these

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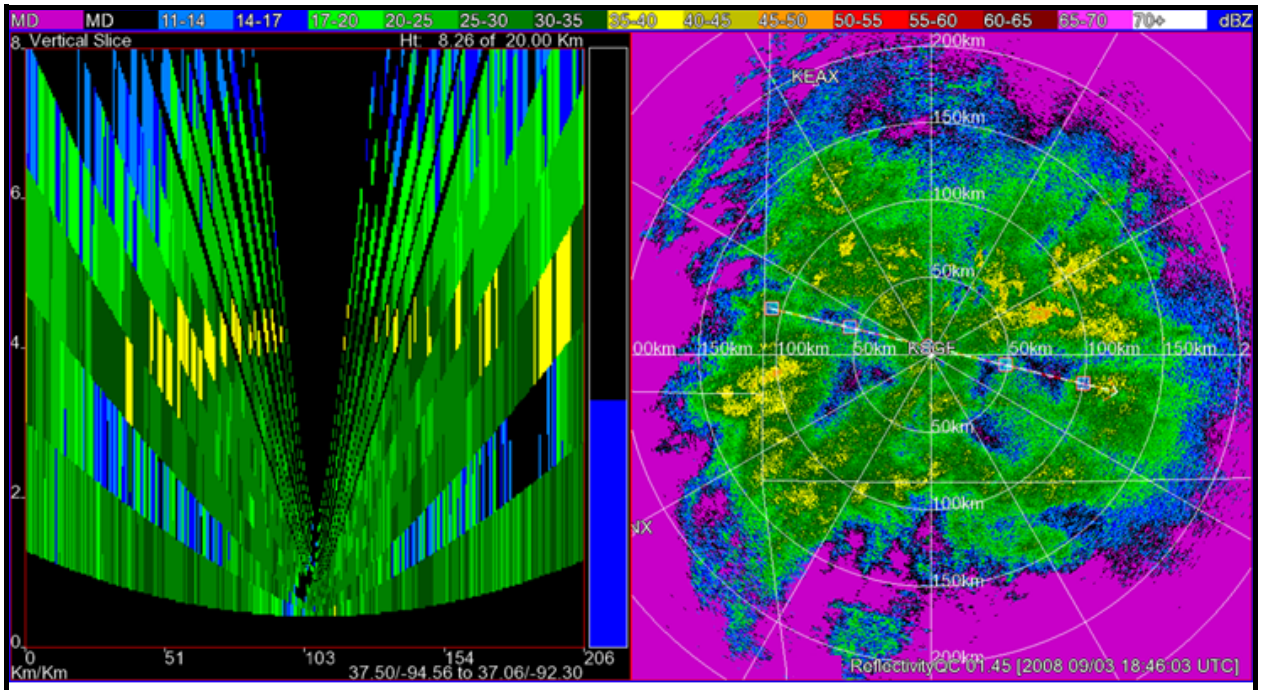

Figure 4: Vertical cross-section of reflectivity (left) and base reflectivity of the second tilt (right) at 1846Z. The dashed line shows the location of the cross-section.

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characteristics commonly result in lost power return, and lower precipitation estimates, when clutter filtering is overdone, aka All Bins.

Prior to the image in Figure 4, the site had been running with the Bypass Map defined on all five segments. In Figure 5, we see that the reflectivity is filled-in on both images. This would have been the likely case as well if the data had been processed with the CMD algorithm.

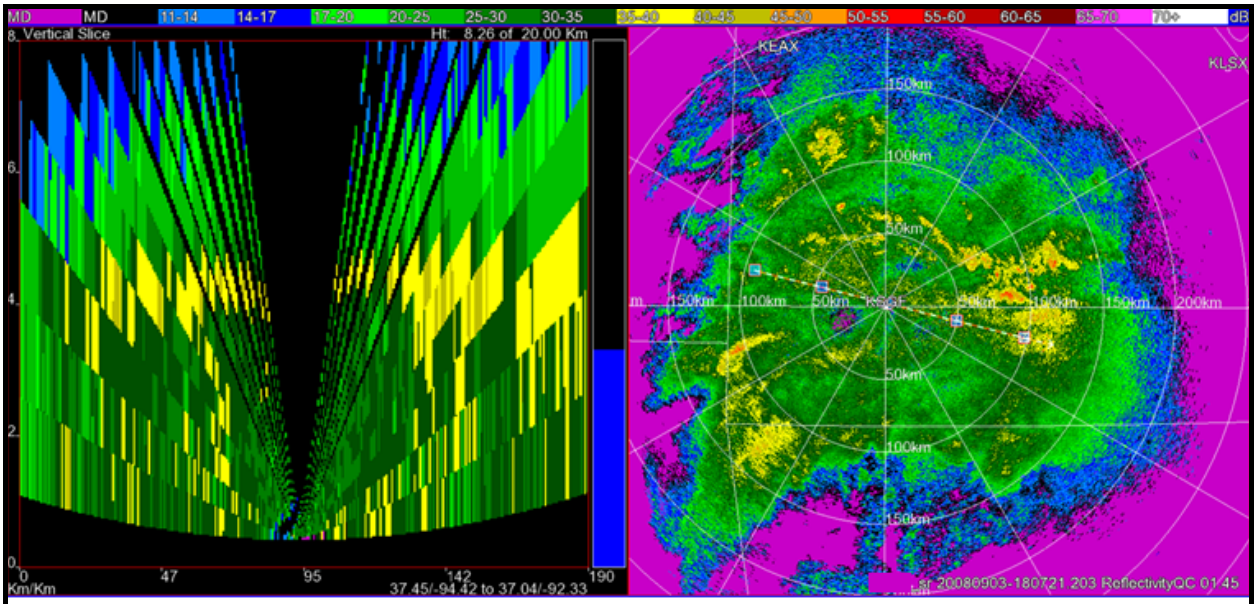

Figure 5: Same as in Figure 4, but with the Bypass Map applied to all five segments at 1807Z.

As the Dual-Polarization (DP) installation draws nearer, we want to remind sites of the importance of proper clutter filtering. The first fielded build version of DP will not include CMD; although, CMD will be included in the first build upgrade after DP installation (Build 13). Some sites will have a short interruption to the use of CMD, whereas other sites will experience longer interruptions depending on the deployment schedule for DP. During this time without CMD, sites will need to resume using the legacy static Bypass Map.

When DP is installed, it is essential that operators revert to tried-and-true filtering: generating a new Bypass Map, as well as, seasonal Bypass Maps with an electronics technician and employing the map on all five segments. At most field sites, it is unnecessary to use All Bins filtering higher than Segment 2, and is typically only necessary during AP events. If time permits, it is more beneficial to use clutter regions on the Bypass Map during AP events than to employ All Bins filtering over the entire range of the radar. There are mountainous sites, however, which may have to create small clutter regions over peaks and ridges, somewhat like the sites did when Build 11.0 was first deployed. For further review of generating Bypass Maps and optimizing clutter filtering, the Build 9 training (when Bypass Maps were first introduced with five segments) is still available at (http://www.wdtb.noaa.gov/buildTraining/Build9/index.html).

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