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Wind Farms: Coming Soon to a WSR-88D Near You

Those paying attention to the news lately know that wind power is one of the primary renewable energy sources being aggressively pursued by government and industry, as one solution to our fossil fuel dependence. In July 2008, the Department of Energy (DOE) released a feasibility study on wind energy called *20% Wind Power by 2030, Increasing Wind Energy's Contribution to U.S. Electricity Supply*, which can be found at http://www1.eere.energy.gov/windandhydro/pdfs/41869.pdf - a roadmap for reaching the report title's goal. Additionally, 25 states have now established Renewable Portfolio Standards (RPS) that mandate utilities provide a certain percentage of electric power from renewable energy sources. (RPS information is located on the web at http://www.pewclimate.org/what_s_being_done/in_the_states/rps.cfm). Soon after the release of the DOE report, oil man T. Boone Pickens announced his Pickens Plan (http://www.pickensplan.com/index.php), which aims to replace natural gas-fueled electric power plants with wind generated power and use the freed-up natural gas to fuel transportation vehicles.

The above efforts, along with increasing climate concerns and the maturing of wind power technology, are fueling the rapid growth of the wind energy industry. During Summer 2008, the U.S. wind energy industry surpassed Germany, becoming the world's leader in wind energy generation capacity with 20GW installed. However, this is still only 2% of the Nation's total electric supply. The DOE report estimates reaching the goal of 20% of the electric supply will require 300GW of wind power capacity. Today's typical wind turbine generates a max power of 1.5MW, so reaching the goal would currently require the installation of about 200,000 wind turbines across the country. As reflected in the graphic in Figure 1, installed wind power capacity is indeed accelerating.

For several reasons (e.g., adequate low-level wind resources, power

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What's Inside?

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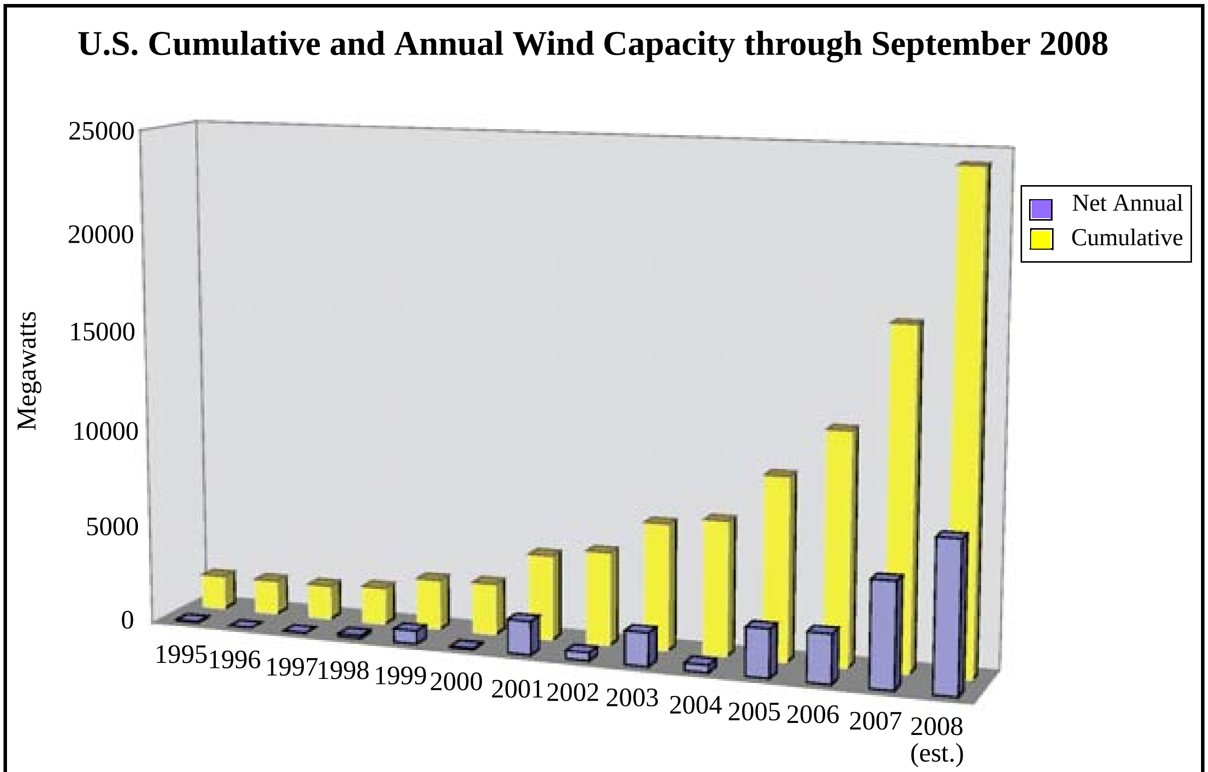

Figure 1: Annual U.S. wind power capacity (MW), net annual increase (purple bars) and cumulative capacity (yellow bars) from 1995 through 2008 (projected). (American Wind Energy Association 2008)

transmission infrastructure) the distribution of wind farms is not, and will not be, uniform across the country. As shown in Figure 2, the Southeast has the lowest wind resources, while the Great Plains states, which Pickens calls "the Saudi Arabia of wind," have the world's most abundant wind resources. (Information regarding "the Saudi Arabia of wind" can be found at http://www.heraldtribune.com/article/20080726/COLUMNIST/487392094/2312/OPINION&title=The_Saudi_Arabia_of_wind_power_.) Currently, Texas has the most installed capacity of any U.S. state and is expected to increase its lead in the next few years (Figure 3), with the Texas Public Utility Commission's approved $5 Billion plan to install 18GW of electric transmission capacity (http://www.puc.state.tx.us/nrelease/2008/071708.pdf). The growth in the number of wind farms, and the fact that optimum wind farm locations are similar to WSR-88D siting preferences - relatively high, unobstructed terrain - suggests the number of wind farms developed near WSR-88Ds is likely to increase.

So, why should anyone care about all these new wind farms? As it turns out, rotating wind turbines in the line of sight of the radar can show up very strongly on all three base products (Reflectivity (R), Velocity (V), Spectrum Width (SW)) and some derived products (e.g. precipitation estimates), even with clutter filtering applied.

Wind Turbine Interaction With the WSR-88D

Rotating wind turbines will cause clutter problems when they are in the line of sight of any coherent-type radar designed to detect moving targets, including air surveillance radars (long range and terminal) and Doppler weather radars. The numerous rotating blades of a wind farm appear similar to precipitation, which is also made up of numerous distributed moving targets. The radar clutter filter is ineffective since the filter assumes

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clutter is stationary. Wind turbine blades now commonly extend 350 ft to over 500 ft above ground level and reflect radar energy very well (greater than 70 dBz in some cases). At distances near the boundary of the radar line of sight and beyond, the wind farms may appear and disappear depending on atmospheric conditions. In the "right" atmospheric conditions, wind farms can be seen on WSR-88Ds at 50+ nm.

Studies by the University of Oklahoma have revealed that wind turbine clutter (WTC) can have negative impacts on the radar's base products (R, V, SW) and derived products such as mesocyclone detection, precipitation estimation, and Velocity Azimuth Display (VAD) Wind Profile over and near the wind energy facility. When wind farms are within ~10 statue miles, they can cause anomalous false echoes in all three radar moments. Figure 4 shows the impact of a wind farm

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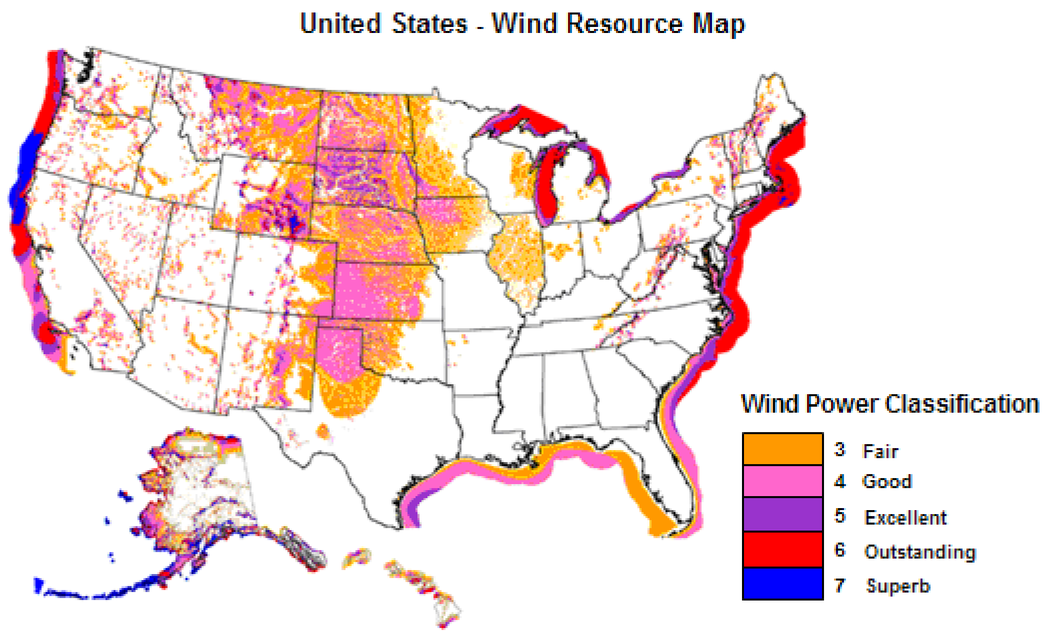

Figure 2: U.S. Department of Energy Wind Resource Map.

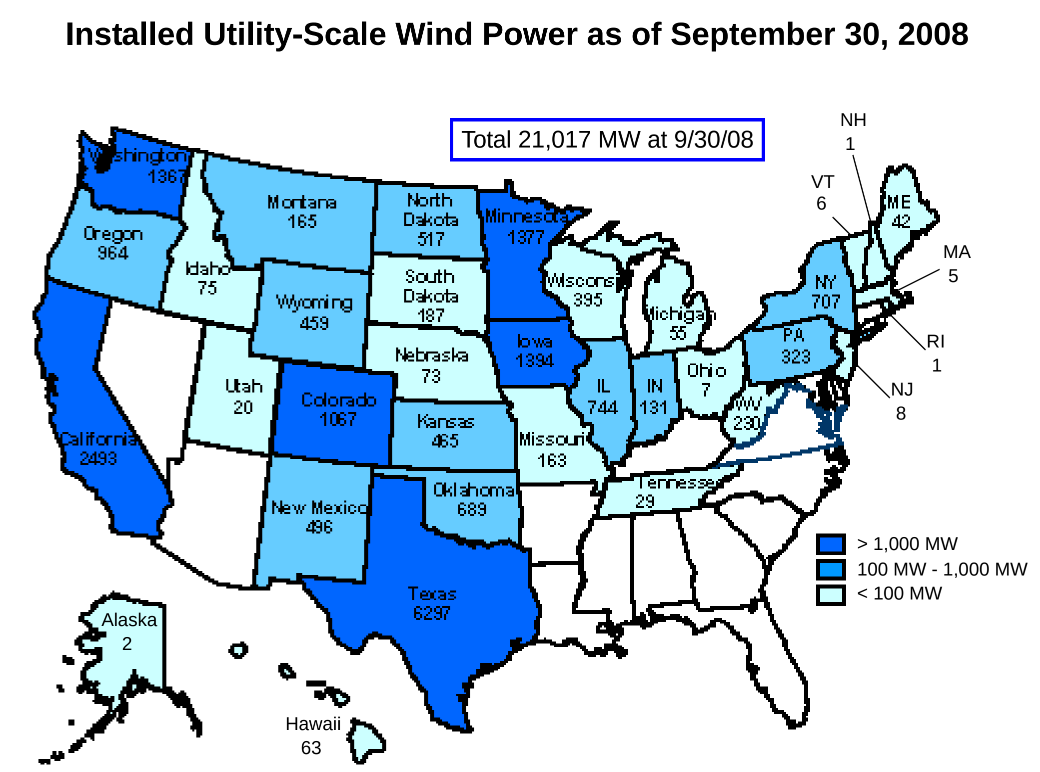

Figure 3: Installed wind power capacity (MW) for each state. (American Wind Energy Association 2008)

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close to the Ft. Drum, NY WSR-88D. Note strong echoes along the leading edge, as well as, weak return behind the turbines due to "multi-path scattering" of the radar beam. In Figure 5, the impact of two wind farms not quite as close to the Dodge City, KS WSR-88D is shown. This reduction of useable radar data can impact weather forecast operations and Federal Aviation Administration (FAA) air traffic routing operations.

Wind energy developers tend to be unaware of the impacts wind turbines can have on the WSR-88D or that the WSR-88D transmits ~750 KW of energy. At close ranges (600 ft), energy levels can exceed safety standards for personnel working at the level of the antenna center point, e.g., turbine construction or maintenance crews. At up to ~10 miles, there is a possibility the WSR-88D could impact turbine electronics without proper shielding. When wind turbines are within 1 km they can cause WSR-88D beam forming problems and partial beam blockage, and return enough radar energy to damage the WSR-88D receiver.

The ROC and Proposed Wind Farm Developments

Wind farm siting information is proprietary and closely guarded, due to a very competitive market. Sometimes the Radar Operations Center (ROC) first learns about a planned wind farm when a Weather Forecast Office (WFO) sends ROC management a newspaper article from their local area that discusses a developer's plans. Many developers, however, will follow guidance presented in the American Wind Energy Association (AWEA) Wind Energy Siting Handbook (http://www.awea.org/sitinghandbook/), which recommends that they submit their proposals for evaluation through the National Telecommunications and Information Administration (NTIA), an agency of the Department of Commerce (DOC). The NTIA forwards each proposal to several government agencies including the National Oceanic and Atmospheric Administration (NOAA). The notifications contain wind turbine dimensions, including blade length, and either location information for each wind turbine or geographic coordinates defining the polygonal area of the development.

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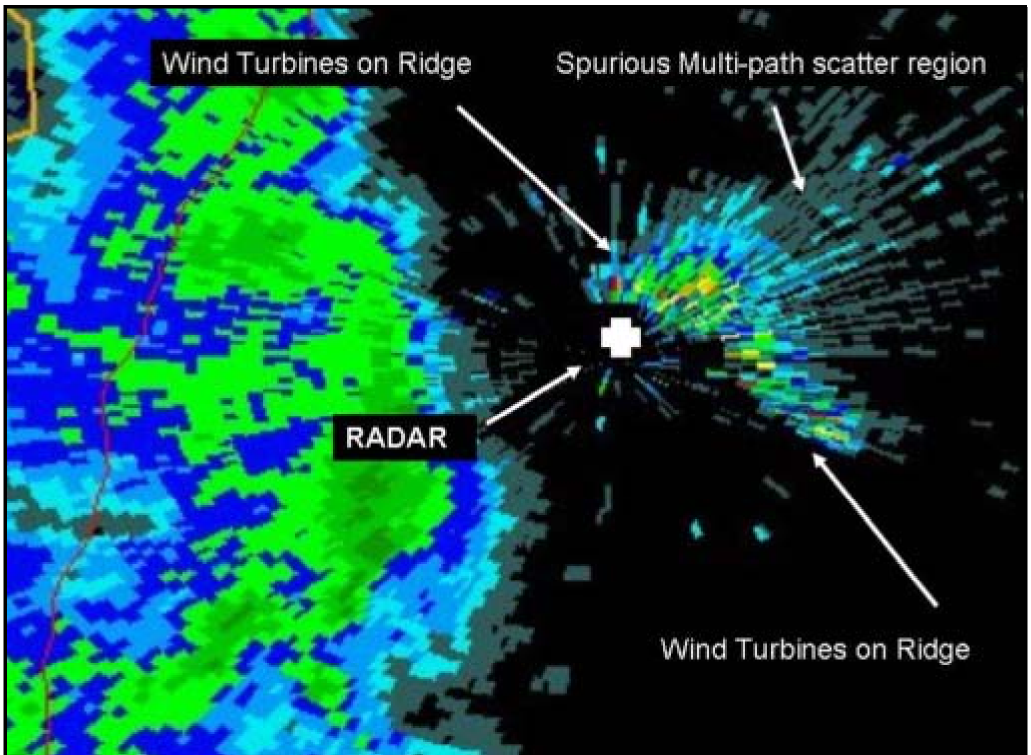

Figure 4: A 0.5 degree elevation reflectivity product from the Ft. Drum, NY WSR-88D (KTYX) on March 10, 2007 at 1234 GMT. Weather is approaching from the West. A wind farm is approximately 6-14 km north through east-southeast of the radar (see annotations).

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As the ROC receives wind farm proposals from the NTIA, a case-by-case analysis is performed of the potential wind farm impacts on the WSR-88D.
To date, the ROC has analyzed over 300 wind farm proposals (only a subset of the wind farms). The ROC's current benchmark for concern over a proposed wind farm and proactively contacting developers occurs when the wind turbine blades penetrate into the radar line of sight (RLOS), assuming beam propagation through the Standard Atmosphere.

The ROC has software that creates WSR-88D RLOS maps of the proposed project area and a database of the amount of penetration into the beam, if any. These maps and databases are based upon a data model built from the Space Shuttle Radar Topography Mission 1 arc-second digital terrain data imparting high confidence in their accuracy. The ROC understands radars will be able to see turbines below the RLOS due to side lobes and non-standard atmospheric conditions; however, the Standard Atmosphere propagation model is the benchmark used by the ROC to inform a developer of possible interference concerns, and to offer assistance in learning about mitigation techniques, e.g., terrain masking, orientation of turbines, movement of turbines to a location that will reduce the number of turbines and/or their penetration into the RLOS.

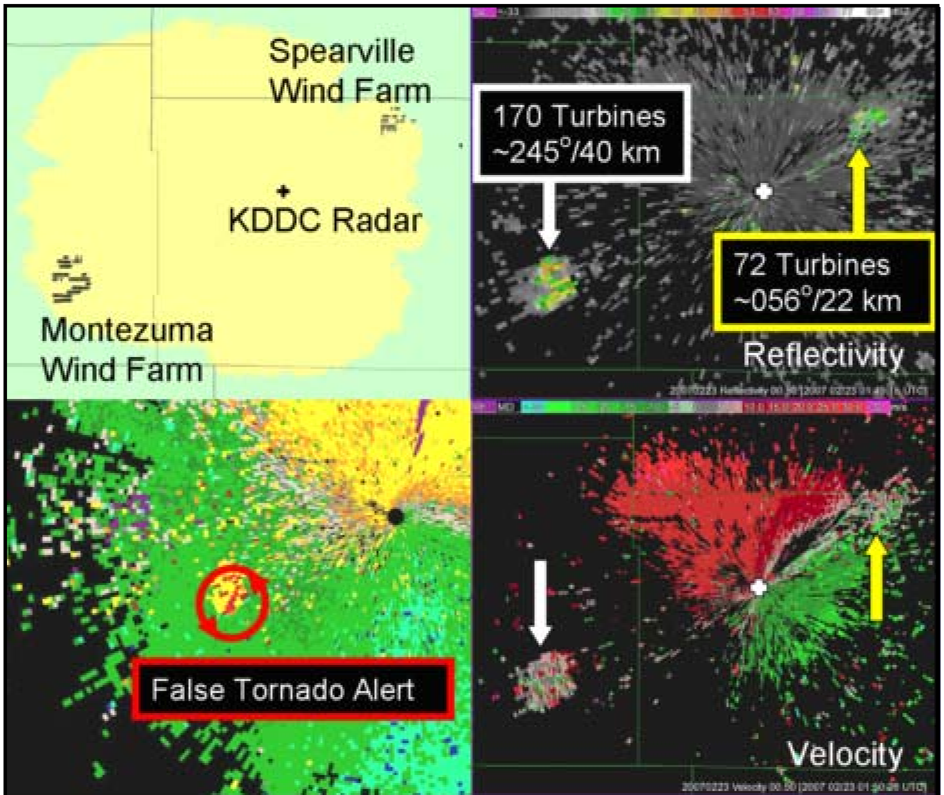

Figure 5: Dodge City, KS WSR-88D (KDDC) reflectivity (upper right) and mean radial velocity (lower right) imagery for 0150 UTC on 23 Feb 2007 showing two wind farms within the radar's line of sight. The yellow area in the upper left image depicts areas where the radar line of sight is within 130 meters of the ground. The reflectivity and velocity values are anomalous and can confuse users. The lower left panel shows the effects of the wind farm to the southwest whose influence has resulted in a false tornado alert generated by the WSR-88D algorithms.

Approximately 15% of ROC analyses show turbine blades in the RLOS, which has led some developers to contact the ROC for more information on the WSR-88D and the potential impacts of their wind farms. Some of these developers have made siting changes to reduce the impacts on the WSR-88D. During follow-up contacts with developers, the ROC invites the local WFO (or military base weather station) and regional headquarters to participate in the call.

ROC Efforts to Mitigate Wind Farm Impacts

The ROC has been working the wind turbine siting and interference issues for over two years on

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behalf of the WSR-88D tri-agencies. Since the federal government does not have statutory or regulatory authority over private land use, the ROC has been reaching out to the wind energy industry to raise their awareness of WSR-88D locations, and encouraging them to consider potential impacts on the WSR-88D before finalizing their plans. To raise developer's awareness of the WSR-88Ds earlier in the planning process, the ROC worked with the FAA to add a "NEXRAD Toolkit" to the FAA's Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) website (https://www.oeaaa.faa.gov/oeaaa/external/portal.jsp). The NEXRAD Toolkit, which was activated July 1, 2008, was patterned after the Air Force/Department of Homeland Security Long-Range Radar toolkit, which has been available to wind energy developers for over a year. The addition of the NEXRAD toolkit to the web site provides wind energy developers a single, convenient source from which to gather information to quickly and anonymously evaluate potential wind turbine sites for impacts to both WSR-88D and Long-Range radars.

ROC staff have participated in AWEA meetings to present briefings, papers and posters, and meet developers and other industry players. The ROC is also collaborating with the Department of Homeland Security/Department of Defense's Long-Range Radar Program Office to identify common issues and solutions to the WTC problem. Later this year, the ROC plans to submit proposed updates to the AWEA Wind Energy Siting Handbook that address siting issues related to the WSR-88D. A wind farm/WSR-88D interaction section has been added to the ROC web site at http://www.roc.noaa.gov/windfarm/windfarm_index.asp. The ROC is refining and updating the page, splitting it into two sections - one section for WSR-88D data users and the other for wind energy developers to provide more tailored information.

The ROC has also been supporting WTC mitigation investigations at the University of Oklahoma Atmospheric Radar Research Center. The goal is to automate wind farm detections and to invoke signal processing techniques that can filter out the effects of rotating wind turbines on WSR-88D data and products. While progress is being made in this effort, it will be several years before any software will be implemented on the WSR-88D.

Additionally, the ROC has discussed the WTC issue with the NOAA General Counsel office to determine what we and the WFOs can do and/or say when interacting with wind power developers.

How WFOs Can Mitigate Wind Farm Impacts

A WFO's first line of defense is developing an understanding of the problem. To learn more about the WTC issue, visit the ROC web site (http://www.roc.noaa.gov/windfarm/windfarm_index.asp) where several papers and briefings have been posted.

The ROC is attempting to track and evaluate all wind farm proposals within or near a WSR-88D's line of sight. Since ROC notification by developers is not required, there will be some wind farm developments of which the ROC will not be alerted through the NTIA or otherwise. Therefore, it is very important that upon hearing of a planned wind farm development, the WFO send an email to the ROC points of contact listed at the end of this article.

Also, WFOs should notify the ROC if they are currently dealing with WTC and encounter cases that impact forecasts and/or warning operations. Forecasters may want to document wind turbine clutter impacts for their particular radar, with the

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goal of developing a "climatology" of the clutter, i.e., how often, under what conditions, what products are affected, etc. To better understand the interaction between wind turbines and the WSR-88D, the ROC is interested in collecting significant impact cases (missed or delayed weather warnings) from around the country, and if warranted, make a case for action by policy makers. A clearer picture of the impacts may also help in the development of a formal policy for working with the wind energy industry, and avoiding over-reaction or under-reaction to this issue.

In the mean time, WSR-88D users can apply some simple mitigation strategies to alleviate the clutter problem. One of the most important is to apply exclusion zones over the wind farm area, to prevent false accumulations in the precipitation products. When applicable, forecasters can look at higher elevation angles or adjacent radar coverage to "see over" wind farms. Finally, speak with forecasters in other weather offices that have more experience dealing with wind turbine clutter.

The Future

Wind power will rapidly expand in the U.S over the next few decades because of its appeal as a clean, alternative energy source. As a result, the number of wind farms installed in the line of sight of WSR-88Ds will also rapidly increase. Presently there is not much the ROC can do regarding developments close to WSR-88D radars, as the federal government has no regulatory authority over wind farm developments on private land. Some WFOs and military bases, particularly those in West Texas and the Great Plains, will be more affected than others and perhaps feel as if they are being surrounded by wind farms. However, it is imperative that forecasters keep this problem in perspective - it's a clutter issue and largely confined to the lowest radar elevation tilt. Yes, the wind farms may impact the radar data and products, but the key is whether or not they affect WFO's forecasting and warning operations. Forecasters must be ready to document these operational impacts, if a successful case for action is to be made. In the mean time, WSR-88D users will have to include wind farm signatures, and possible impacts on data and products in their forecast and warning process, and work around the issue to the best of their ability.

The ROC, for its part, will continue its outreach to the wind energy industry and continue to proactively contact developers to mitigate impacts. The ROC will also work with AWEA to update its guidance with respect to the WSR-88D in their Siting Handbook, and fund investigation into mitigation techniques. Lastly, the ROC hopes to collect impact cases and/or fund case studies of wind farm impacts, with the goal of developing and fine tuning an overall NOAA policy to address the wind turbine clutter problem.

Radar Operations Center points of contact for wind farm issues are:

Tim Crum
(Tim.D.Crum@noaa.gov, 405-573-8888)

Ed Ciardi
(Edward.J.Ciardi@noaa.gov, 405-573-3439)

Major John Sandifer, USAF
(John.B.Sandifer@noaa.gov, 405-325-2095)

Tim Crum
ROC Director's Office

Ed Ciardi
Wyle Information Systems/ROC Engineering Branch

John Sandifer
USAF/ROC Applications Branch

Improving Mesocyclone Detection Algorithm in Software Build 11.0

Recent improvements have been made to the Mesocyclone Detection Algorithm (MDA), which will provide field sites an improved MDA when software Build 11.0 is fielded in 2009. To bring about these improvements, algorithm output was compared from 33 different sites, 38 cases, and more than 2,500 volume scans, using an early development version of Build 9.0 and Build 11.0 software.

The MDA was developed and tested in the mid-to-late 1990's, before Volume Coverage Pattern (VCP) 12, Radar Data Acquisition (RDA) refresh, and SZ-2 (Sachidananda/Zrnic Phase Coding Algorithm) technologies were fielded. One of MDA's original design goals was to make the algorithm more sensitive than the Legacy MESO algorithm so that lead times could be extended, and once detected, circulations would not be lost during the organizing stage. As time and technology progressed, it became clear that the MDA detected storm-associated circulations very well, but also generated many false alarms far away from storm cells.

New technology, fielded after MDA was developed, periodically generates noisy velocity values. Hence, the number of MDA false alarms has increased and a need to develop mitigation strategies arose. The following technologies periodically increase the variance of the velocity estimate: 1) VCP 12 - rotates faster than other VCP's and contains fewer radar pulses per sample volume; 2) the RDA clutter map - intelligently reduces clutter and attempts to recover weather signal which was previously unrecoverable; 3) RDA frequency domain window processing - needed for clutter filtering, requires the use of tapered data windows which slightly increase the velocity estimate variance; 4) SZ-2 processing - reduces range folding and may

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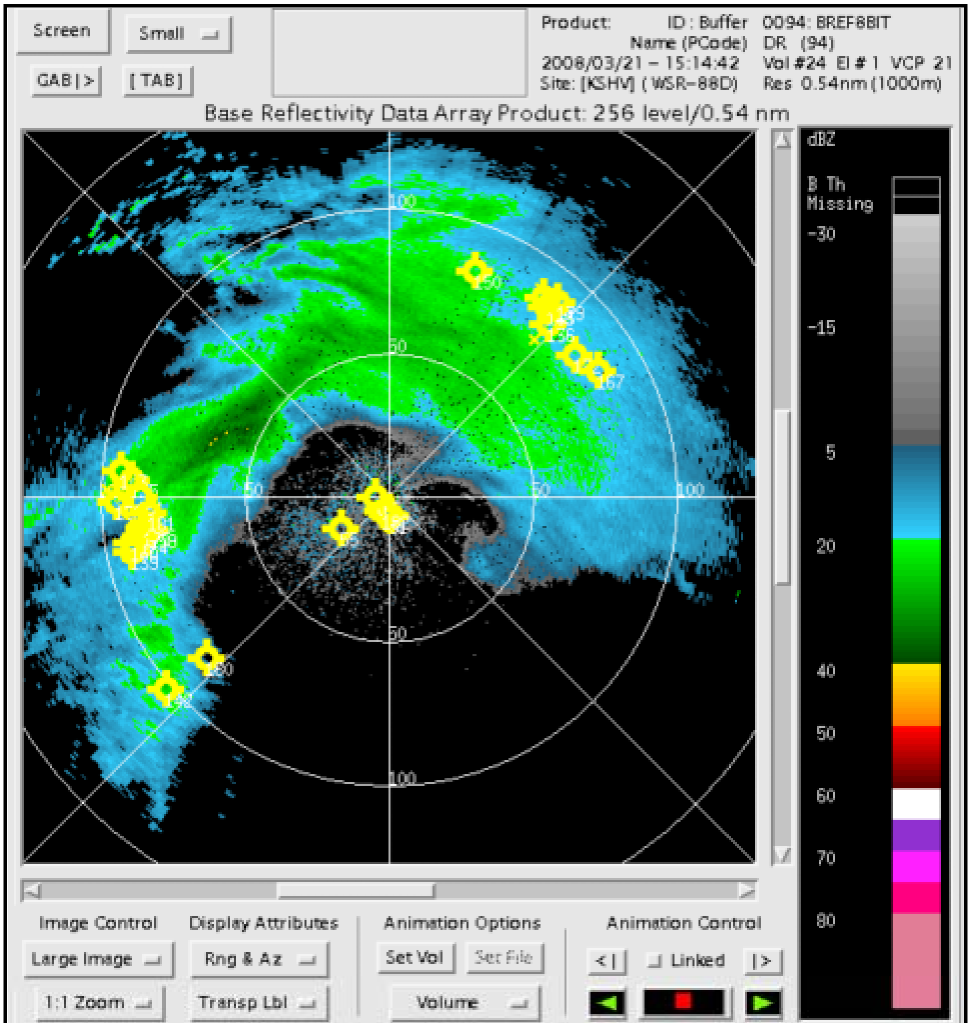

Figure 1: Mesocyclone false alarms during a stratiform precipitation event.

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not be able to obtain a meaningful measure from the weak trip signal or may have a hard time properly separating strong and weak echoes. Some radar sites have better velocity estimates than others. Weak signal return; strong velocities; biota; range overlay; internal and external interference; clutter filtering; dealiasing errors; and phase noise also contribute to noisy velocity values and MDA false alarms. Radar Operations Center (ROC) personnel are working to improve overall data quality by modifying the frequency domain window processing scheme and by perusing other techniques such as oversampling and whitening.

Beginning with an early development version of Build 9.0 software, an effort was made to take a close look at the MDA code. Investigators wanted to: 1) verify that the original design was implemented correctly; 2) include small enhancements identified during development but not originally implemented; and 3) identify opportunities to decrease false alarms. Between Build 9.0 and Build 11.0, nine Configuration Change Requests (CCRs) were submitted, approved, and implemented: one small design bug, one small coding bug, five small programming enhancements, and two false alarms mitigation changes.

The effect of the five small programming enhancements is to decrease the number of false alarms not associated with storm cells, eliminate circulations with anomalously large strength ranks, and to continue to flag important circulations for forecaster consideration. The small coding bug corrects an initialization problem which only affects MDA output during the first few volume scans after first MDA and Storm Cell Information and Tracking (SCIT) detections are first made. The design bug fix reduces the number of all MDA false alarm detections, by removing all MDA detections more than 20 km from SCIT cells.

The MDA detects two different circulation types. A low-core MDA detection is a 3D feature that is

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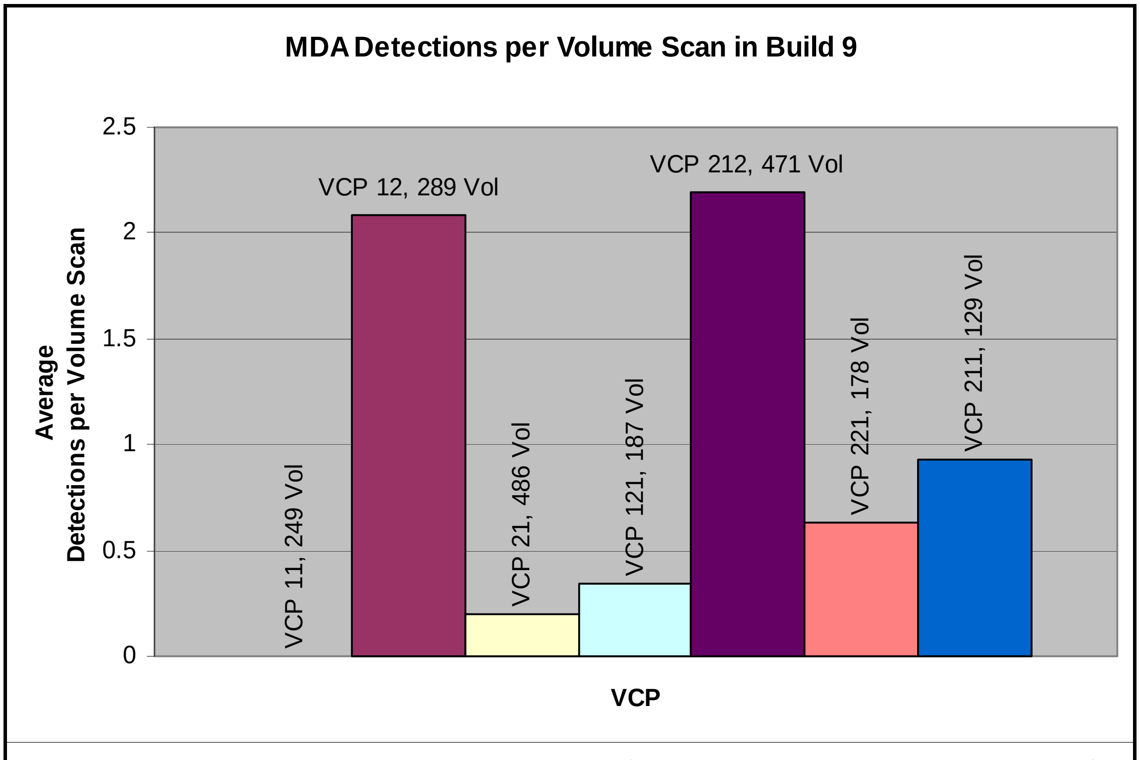

Figure 2: Average detections per volume scan for each VCP using the Build 9.0 software. The label "VOL" indicates the number of volume scans of each particular VCP in the sample.

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at least 25% of the depth of an average of the strongest 10 SCIT cells, ranked by VIL (Vertically Integrated Liquid). A regular MDA circulation is a 3D feature that is at least 3 km deep. The first false alarm mitigation technique, implemented in Build 10, removes all low-core MDA detections that are more than 20 km from a SCIT cell. The second false alarm mitigation technique, to be implemented in Build 11.0, removes all regular MDA detections that are more than 20 km from a SCIT cell. All MDA detections within 20 km of a SCIT cell are retained.

The study to improve MDA began by collecting 25 stratiform precipitation cases in which mesocyclones were not expected. Eleven additional convective cases were added to ensure the 20 km SCIT distance criteria was working properly and important circulations near SCIT cells were properly identified by the MDA.

Figure 1 shows a composite display, from Build 9.0, of 61 volume scans of MDA detections overlaid on a single reflectivity product representative of a stratiform event. Eight low-core detections and 14 regular detections were beyond 20 km of a SCIT cell. Two low-core detections were within 20 km of a SCIT cell. The Build 11.0 test, with all CCR's applied to the software, correctly generated zero MDA detections.

Figure 2 shows the average number of MDA detections per volume scan for the Build 9.0 software broken out by VCP. There were 249 volume scans of VCP 11 evaluated in which there were no MDA detections made. The MDA was well behaved; no false alarm detections were made. Note VCP 12 and VCP 212 generated many more detections due to the extra elevation angle at 0.9º. Also, in general, SZ-2 VCP's had more detections than legacy VCP's.

Figure 3 illustrates the Build 11.0 results for the same cases that were run through the Build 9.0 (Figure 2) software. There is a marked drop in the average number of MDA detections per volume scan; a large number of false alarms

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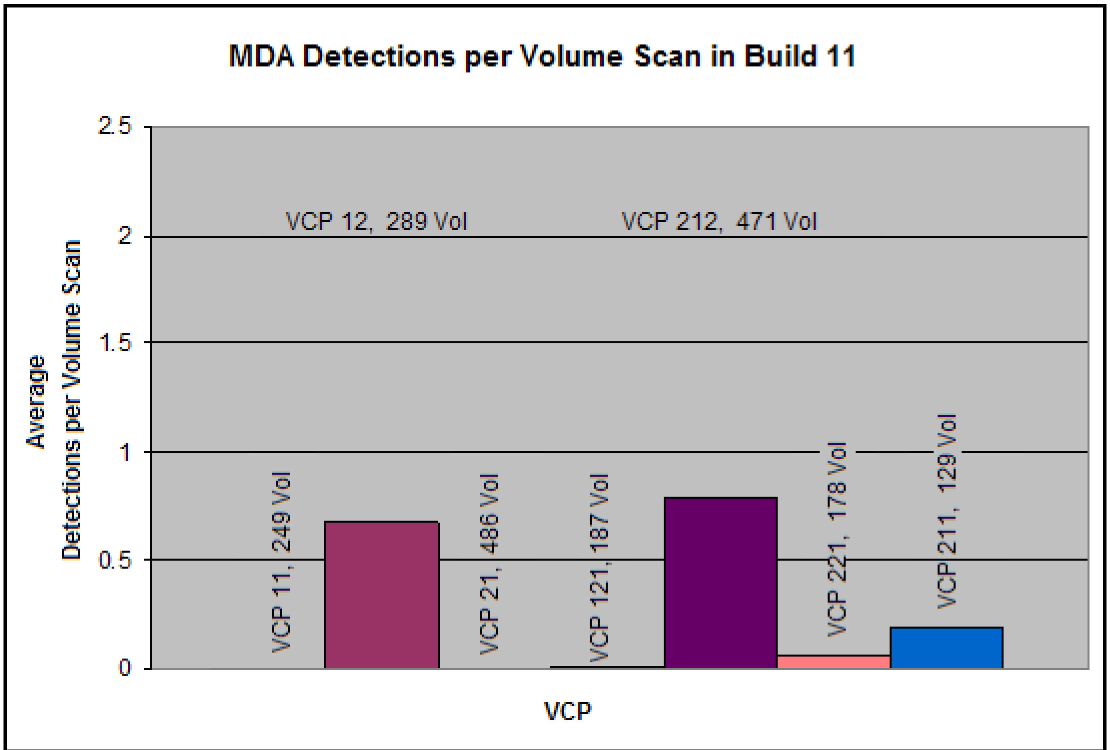

Figure 3: Average detections per volume scan for each VCP using the corrected, Build 11.0 software. The label "VOL" indicates the number of volume scans of each particular VCP in the sample.

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are removed by the program enhancements. There were no MDA detections generated from the VCP 11 and VCP 21 cases.

Figure 4 exhibits histograms of the number of low-core detections verses strength rank for Build 9.0 and Build 11.0 software. All MDA detections retained are within 20 km of a SCIT cell. Note that circulations with anomalously large strength ranks have been removed when using the Build 11.0 software, courtesy of the design bug fix.

Figure 5 shows similar histograms for the regular detections; fewer regular MDA detections, compared to low-core detections, have been removed. Therefore, low-core detections appear to have been the largest source of false alarms, which makes sense. Random, noisy velocity data is more likely to generate relatively shallow, low core detections than deep, regular detections. Once again, courtesy of the design bug fix, circulations with anomalously large strength ranks have been removed. Also note the Build 11.0 distribution of regular detections is similar to the Build 11.0 distribution of low-core detections.

Two tropical storm cases, Hurricane Humberto and Hurricane Katrina, were also evaluated. MDA detections from 769 volume scans were assessed with Build 9.0 and Build 11.0 software. Results from the tropical storm cases were consistent with the non-tropical storm cases. Build 11.0 software removed all detections more than 20 km from a SCIT cell and some very shallow, false alarm detections; approximately 8% of the total. None of the detections that were removed were associated with valid circulations.

In summary, 38 cases from 33 different sites, more than 2,500 volume scans, have been used to test MDA improvements. The MDA works well on meteorologically important circulations in the vicinity of storm cells. At times, velocity data is degraded by weak signal return, strong velocities, biota, windowing differ-

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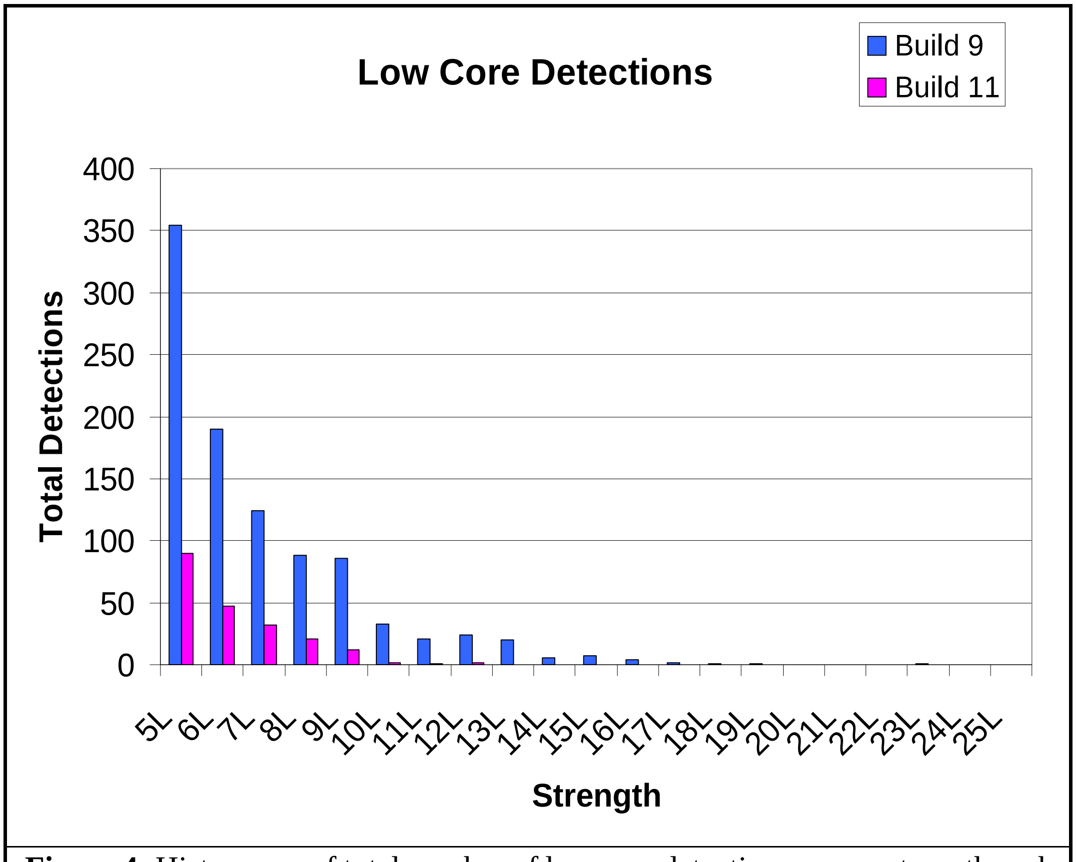

Figure 4: Histograms of total number of low core detections versus strength rank for the uncorrected (Build 9.0) and corrected (Build 11.0) software packages. The label "L" indicates low core detections.

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ences, clutter filtering, and clutter contamination. Noisy velocity data leads to MDA false alarms, the majority of which appear to be low-core detections.

All MDA detections beyond 20 km of SCIT cells are removed via the false alarm mitigation techniques. A few of the low-core detections within 20 km of a SCIT cell are removed via the design bug fix, the coding bug fix, and the five small programming enhancements. In all, 70.8% of the Build 9.0 MDA detections are not found with the Build 11.0 software. All detections that remain are within 20 km of SCIT cells.

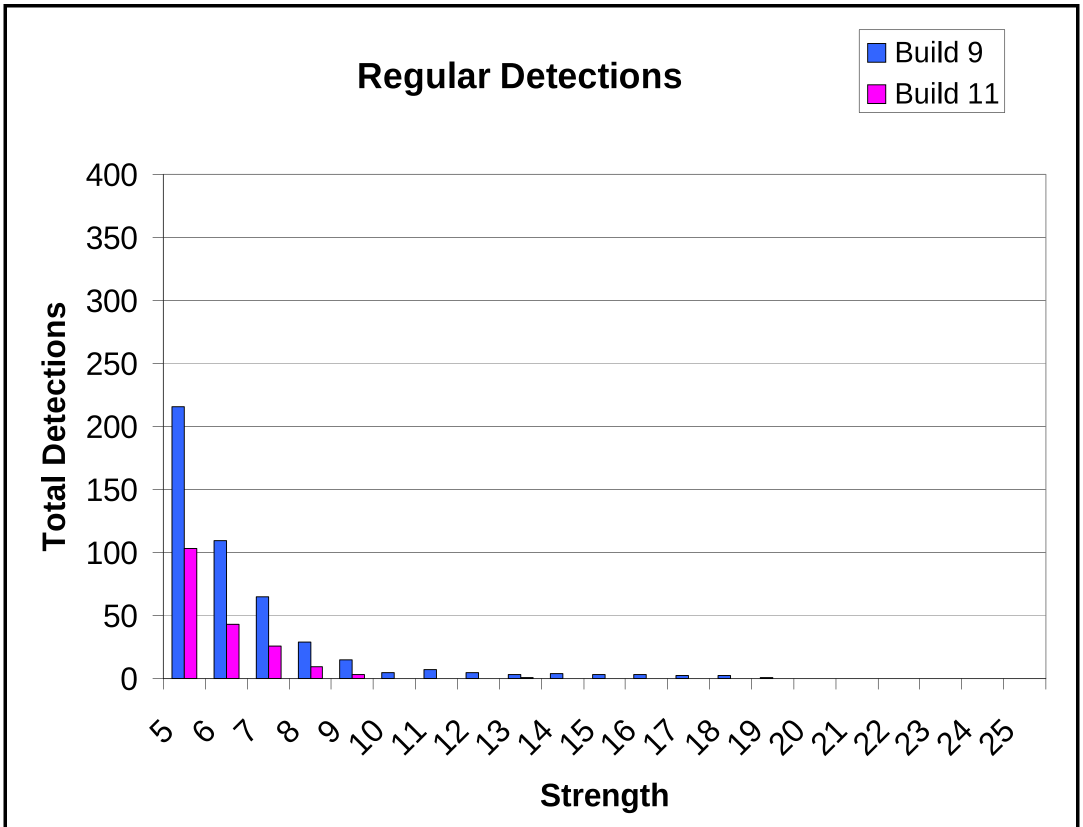

Figure 5: Histograms of total number of regular detections versus strength rank for the uncorrected (Build 9.0) and corrected (Build 11.0) software packages.

Within 20 km of SCIT cells, the number of regular detections increases by 17% as some of the low-core detections were converted to regular detections via the coding enhancements. Anomalously large strength rank values were reduced via the design bug fix. Between Build 9.0 and Build 11.0, the average strength rank of low core and regular detections decreased by approximately 10%.

Personnel at the ROC and its Memorandum of Understanding (MOU) partners are diligently working to improve the quality of all base data. Beginning with Build 11.0, forecasters will be able to use the improved MDA.

Acknowledgement: All data for this study were evaluated by OU student workers: Melissa Patchin, Luke Madaus, and Nick Langlieb.

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ROC Applications Branch

A Move Toward Automating the WSR-88D

Imagine this...50 miles west of a radar site thunderstorms are starting to build, and the radar just switched to precipitation mode. The echoes are starting to show signs of rotation, and the quick 190 second volume scans allow the operator to watch the storms evolve. As the storms increase in height and move closer, the radar automatically adds a higher elevation tilt to sample the top of the storms. One of the stronger storms collapses and a gust front moves out ahead of the storm cell. As the lowest elevation radar beam passes through the gust front, the change in refractive index causes the beam to be ducted toward the surface. This anomalous propagation (AP) of the radar beam causes AP clutter return, but one never sees any of the resultant return on the products. This is because the radar immediately detected the AP ground clutter during the volume scan in which the AP began to occur, and dynamically modified the clutter filter bypass map to address the anomalous return; only the gust front and the storm echoes remained on the operator's display.

The strongest storms pass 25 miles to the operator's north, with extensive beam ducting occurring to the northwest due to the rain cooled air. Again, this is transparent to the operator, as the radar continues to produce clean, accurate data and products. As the storms continue to move away toward the north-northeast, the radar again begins to provide faster updates, sampling the rotating mesocyclone every 3.5 minutes.

A mental review of the event highlights that the radar generated precipitation estimates that were not contaminated by AP, provided rapid (as short as 190 second) product updates for weather warning support, and provided unobscured velocity data throughout the event. And the best part is that the operator never once had to touch the radar.

Sound too good to be true? Then, read on.

From the beginning, the goal of the WSR-88D program was to automate the operation of the radar to provide accurate data, faster and more reliably than was previously possible. However, upon fielding the system, it became obvious that the capabilities of the new system could overwhelm even the most experienced forecaster, especially when severe weather warning operations were in effect.

FIRST STEPS TOWARD AUTOMATION

To assist meteorologists, it was recognized early on that some functions would need to be controlled by the computers. The end result was that several functions, with which operators are no doubt familiar, represent the first steps of automation. Some of the more important steps will be briefly mentioned here, but there's simply not enough space to discuss each in detail.

Auto Pulse Repetition Frequency (Auto-PRF)

The Auto-PRF function automatically determines the optimum PRF for the radar to use during each volume scan.

Enhanced Precipitation Preprocessing (EPRE)

Using several adaptable parameters, EPRE determines when precipitation accumulations should begin and end. Using an embedded algorithm, the Radar Echo Classifier (REC), EPRE determines which echoes are likely to be clutter and which are likely to be precipitation. "Valid" echoes are included in the hybrid scan construction, and converted from reflectivity to precipitation. The Exclusion Zone functionality is also a part of the EPRE suite, helping to ensure that residual clutter or persistent echoes, such as wind farms, aren't included in the precipitation accumulations.

Mode Selection Function (MSF)

Based on ever-changing conditions, the mode

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selection function selects the appropriate mode and default VCP.

Clutter Suppression

Clutter suppression application has long been one of the more difficult challenges faced by operational forecasters. It's vital that clutter suppression is done correctly, since EVERY downstream product is affected by its application.

Clutter Mitigation Decision (CMD) is the automation technique designed to mitigate transient clutter return, beginning in software Build 11.0. The technical concepts of CMD are discussed in an article contained in the last issue of *NEXRAD Now* (Issue 17), entitled, "The Clutter Mitigation Decision (CMD) Algorithm," which can be viewed/ downloaded from the ROC web site (http://www.roc.noaa.gov/news/NNautumn07b.pdf). Additional information will be contained in the Build 11.0 training documentation.

CMD generates a bypass clutter map for the split cuts (lowest two or three cuts depending on the VCP in use) every volume scan, and uses that real-time bypass map to filter the clutter in...well, real time. Therefore, as the clutter changes, the bypass map changes and the clutter return is addressed as it occurs without any intervention by forecasters. For all practical purposes, this makes clutter suppression, for the most part, a non-issue for forecasters. Use of "All Bins" will be a thing of the past, and it's likely operators will rarely, if ever, need to make use of the Clutter Regions Graphical User Interface (GUI).

The following images are provided to help illustrate the effectiveness of CMD. The first image shows a reflectivity product with clutter suppression turned off. The second image shows the next volume scan after application of the old "*static*" (Build 10.0) bypass map. (Maps generated by CMD will often be referred to as a "*dynamic*" bypass map.) Of particular interest in the second image, are the high levels of reflectivity on the right side of the image. These returns are caused by anomalous beam propagation; operators will no doubt recognize them as AP. In order to ensure this type of return does not make it into the precipitation accumulation and other algorithms, a forecaster generally has to begin generating clutter regions to mitigate the effects. The third image shows the next volume scan, with CMD invoked. Note, CMD has correctly identified and Gaussian Model Adaptive Processing (GMAP) has filtered every bit of the AP, entirely without forecaster intervention.

During testing, CMD has worked so well that testers have had to actually view the Clutter Filter Control (CFC) product to determine if AP was occurring. Figures 4 and 5 show the static bypass

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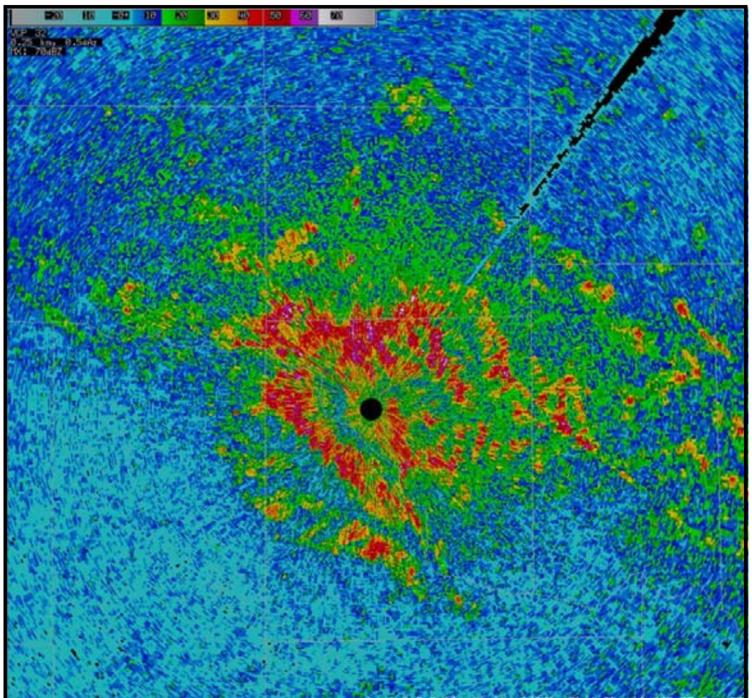

Figure 1: No clutter suppression applied.

Automating the WSR-88D

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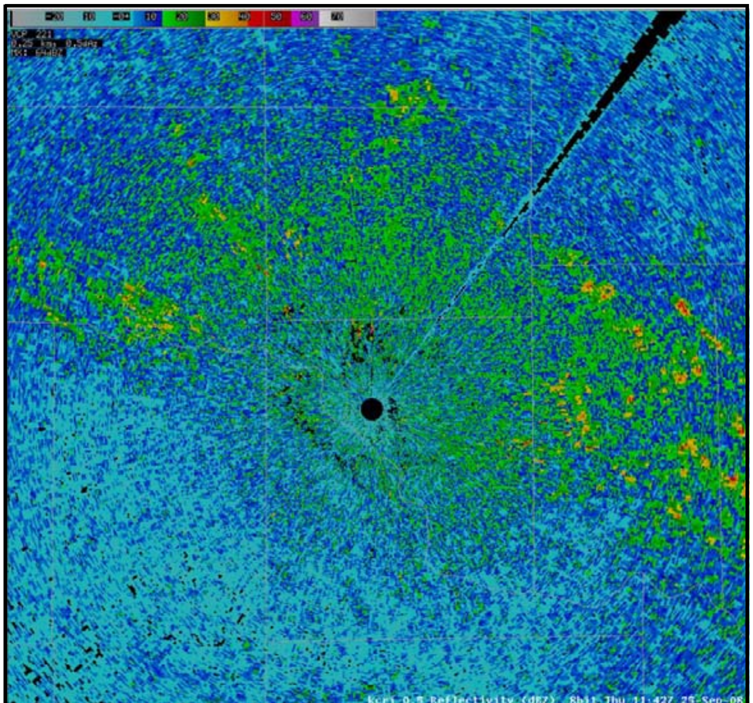

Figure 2: Suppression with Static Bypass Map applied.

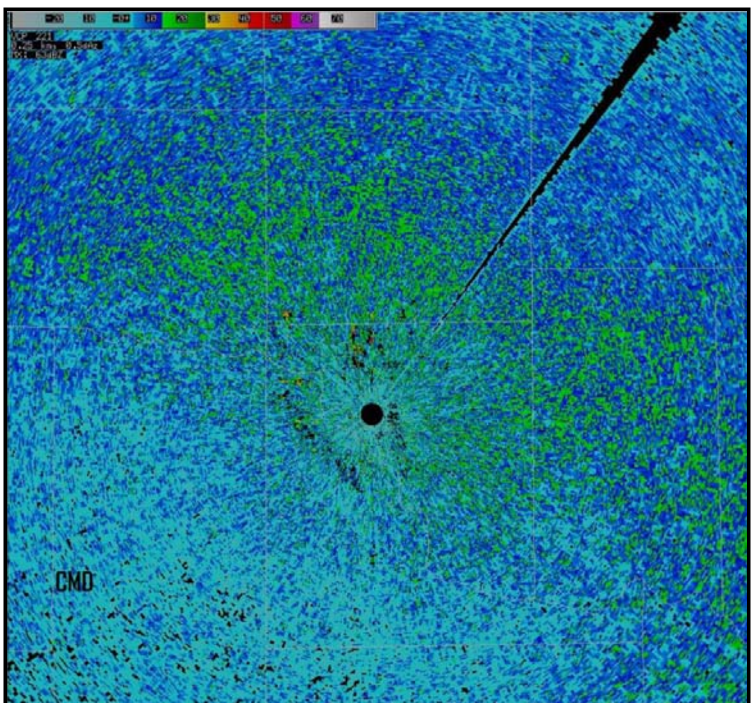

Figure 3: Suppression with CMD-generated Bypass.

map (used in filtering Figure 2) and the dynamic bypass map (used in filtering in Figure 3). The dynamic map will change each volume scan, as the refractive index changes, resulting in beam propagation changes. But, as far as operators are concerned, this is all transparent. More information is contained in this issue of *NEXRAD Now*, in the article, “Coming Attractions - The Clutter Mitigation Decision Algorithm.”

The CMD algorithm has undergone extensive testing by ROC Engineering, the Operations Test Team, and the ROC Data Quality Committee. In each case, it emerged from the testing with positive reviews. The authors have monitored CMD operating on the ROC test bed during spring and summer 2008, for weeks at a time, both day and night. Of particular interest was the performance when ducting began. The only hint that beam propagation was changing was that highways (vehicles) and wind farms not normally seen during standard propagation conditions, began to be visible. Looping the bypass maps or turning clutter suppression off, vividly revealed the quality of suppression which was occurring. Loops of the CFC product clearly show how the propagation changes from one volume scan to the next. This provides new insight into how quickly the refractive index can change, and the effect those changes have on the site’s radar beam. Those WFOs with terrain in their region will be surprised to see just how quickly the conditions will change.

Over the course of several weeks, through changing conditions, with absolutely zero intervention from operators, CMD optimized the quality of the WSR-88D data, improving all three base moments, as well as, the derived products. CMD will undoubtedly be a cornerstone of

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Automating the WSR-88D

(Continued from Page 15)

WSR-88D automation efforts.

Automated Volume Scan Evaluation and Termination (AVSET)

Now, let's look over the horizon to a future enhancement, which not only continues our march towards WSR-88D automation, but also represents a paradigm shift in WSR-88D automatic volume scanning philosophy.

Historically, every survey the ROC conducted has queried users about VCP usage and the ever changing needs of operators with respect to new VCPs. Without fail, every survey has contained comments indicating what's needed: 1) faster VCPs, and 2) VCPs which have better vertical resolution in the lower cuts. In response to those concerns, VCP 12 was born. Still, recent surveys indicate that even faster update times are required.

Operational and Engineering studies conducted by the ROC Data Quality Committee indicate that data quality will suffer if antenna rotation rates are increased beyond current VCP 12 scan rates. Since rotating faster isn't a viable option, the ROC VCP Working Group began looking for new concepts and came up with a solution that's both simple and elegant. The technique is called "Automated Volume Scan Evaluation and Termination" or AVSET.

The AVSET function, currently under test at the ROC, terminates the current volume scan after the radar has scanned all the elevations with return (echo) that exceeds predefined strength and coverage thresholds. In other words, once the data collection elevation overshoots the radar return that exceeds predefined thresholds, the volume scan is terminated (because there is no operational benefit realized by continuing the execution of the current volume scan) and a new volume scan is begun.

The series of reflectivity images in Figure 6 illustrate the AVSET concept.

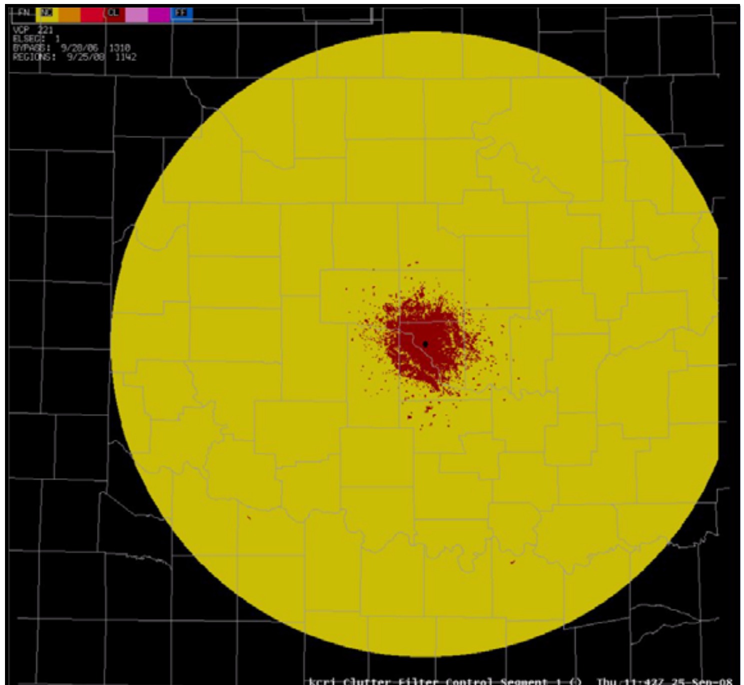

Figure 4: Static (Legacy) Bypass Map.

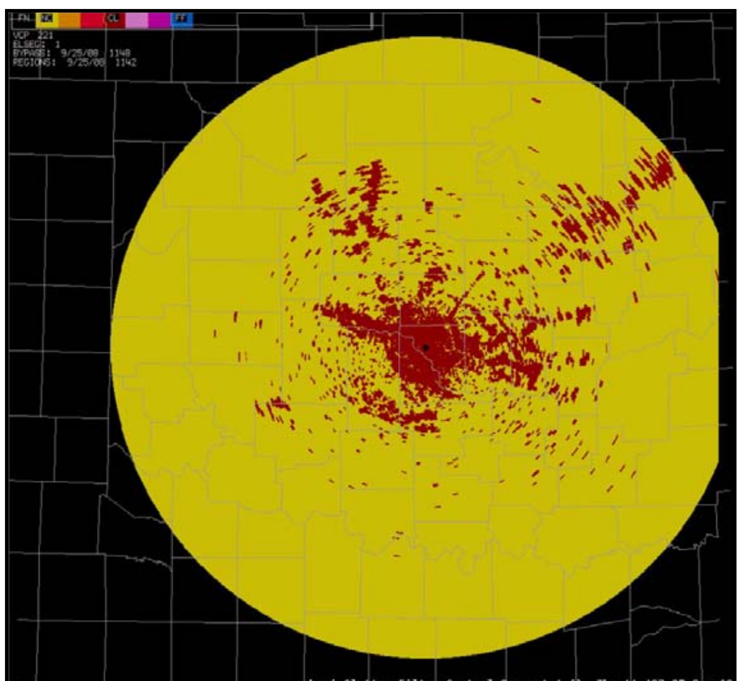

Figure 5: Dynamic (CMD) Bypass Map.

The upper left window (Window 0) of Figure 6 is the 124nm reflectivity product. The closest con-

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Automating the WSR-88D

(Continued from Page 16)

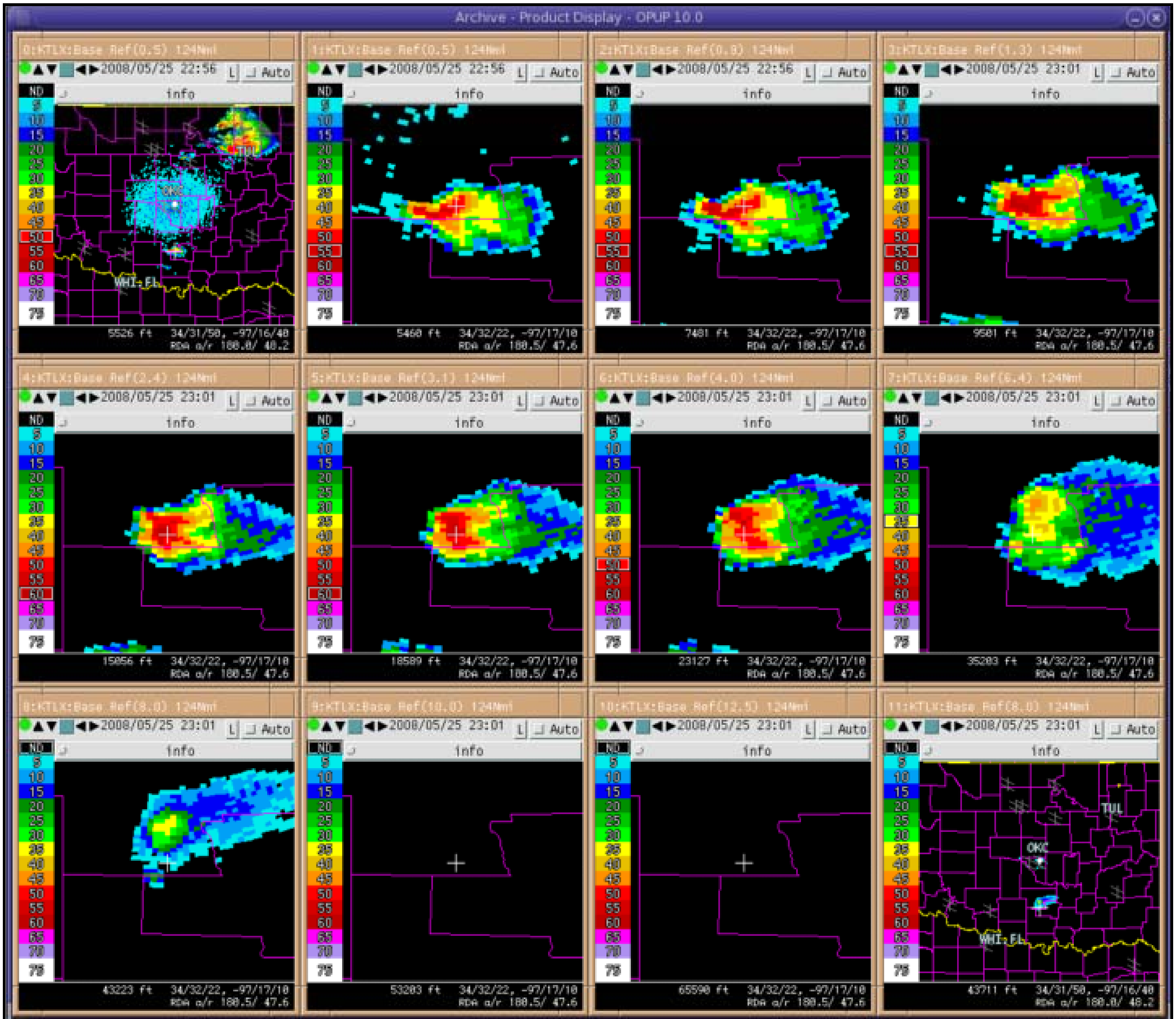

Figure 6: OPUP display of WSR-88D Reflectivity products.

vective storm is located approximately 45nm south/southeast (SSE) of the radar. Windows 1-10 present the reflectivity products from different elevation angles zoomed in on this convective storm. The storm anvil is last scanned with the 8.0º elevation slice (Window 8). The AVSET thresholds are not met on the 10.0º elevation slice (Window 9) and the volume scan is terminated <u>after</u> completion of the 12.5º elevation slice (Window 10), which results in a 220 second volume scan. Window 11 is a zoomed out depiction of the 8.0º elevation slice, which is the last elevation that sampled the storm's anvil. (For more information regarding AVSET, please refer to the article entitled "Automated Vol-

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Automating the WSR-88D

(Continued from Page 17)

ume Scan Evaluation and Termination (AVSET) A Clever Way to Achieve Faster Volume Scan Updates" in this publication.)

The net result of AVSET is a shortened elapsed time between data collection on low elevation angles (and generating volume-based products) during periods when no significant data are available on the higher elevation tilts. AVSET can reduce volume scan times by up to 100 seconds; however, the time savings achieved depends on the location and areal coverage of radar return.

AVSET has not been approved for operational fielding, yet. For now, AVSET is currently in Stage 2 of the Operations and Services Improvement Process (OSIP) and is still undergoing testing at the ROC.

PUTTING IT ALL TOGETHER

Now that we've talked about the building blocks, we can begin to put the pieces together. Since this is a narrative about how to automate the WSR-88D system, we'll not consider the situation in which operators want to automate parts of it, and manually control the others. This is just to show operators can literally make the WSR-88D a "hands-free" operation.

1. Ensure Auto-PRF is turned on. This is the default state, and very rarely should this be changed.

2. From a precipitation estimation perspective, there's little to be done. The radar is likely already optimized with appropriate values for RAINA, RAINZ, and CLUTTHRESH. These numbers will not change, regardless of whether operating manually or automated.

3. Mode Selection Function. The MSF switching for both Precipitation and Clear Air should be set to Auto/Auto. Check the adaptable parameters and also decide which VCP to use when automatically switching to Clear Air or Precipitation modes.

4. "Enable" CMD on the main Radar Product Generator (RPG) HCI (human-computer interface). This will relieve the forecasters of the most common burden associated with radar operations: chasing AP-generated clutter. If there's a single building block that's most important for optimizing data quality…without a doubt, this is the one.

5. If CMD is the subsystem most responsible for optimizing the data quality, AVSET is the tool that will ensure the radar's not boring holes into empty sky when it should be sampling the lower atmosphere. In other words, this building block keeps the radar from "wasting the government's time." Once it's available, all operators will need to do to turn it on is to "Enable" it on the main RPG HCI in the same region as the Auto-PRF button.

Having seen the building blocks, and understanding how they work together, the introductory scenario doesn't seem so much like science fiction, does it? All of the automation modules, except AVSET, are in place in the Build 11.0 software, which is scheduled for release in May 2009. AVSET, which represents a paradigm shift in WSR-88D volume scanning, is gaining acceptance and is currently making its way through OSIP. The authors' hope is it will be approved in time for field testing and inclusion in software Build 13.0 (which is the first post-Dual Polarization build).

For more information, readers are encouraged to review the ROC and WDTB web sites, and/or technical manuals, or simply contact the ROC Hotline (1-800-643-3363), or the authors of this article.

Tony Ray
ROC Operations Branch

Joe Chrisman
ROC Engineering Branch

Coming Attraction! The Clutter Mitigation Decision Algorithm

The Radar Operations Center team has been working hard on a new way to manage clutter filtering for the WSR-88D. Engineers and scientists at the ROC have completed development and testing of the Clutter Mitigation Decision (CMD) algorithm, and it is ready for deployment in software Build 11.0.

When the active CMD mode is selected by radar system operators, ground clutter is automatically identified and filtered for the split cut scans at the lower elevation angles. These are the elevations that are in Elevation Segments 1 and 2. This automatic detection and filter application process eliminates dependence on static clutter bypass maps and eases the need for operators to manually apply filtering under Anomalous Propagation (AP) conditions. The ROC provided preliminary details on the CMD algorithm and initial engineering testing in the Fall 2007 edition of *NEXRAD Now*, "The Clutter Mitigation Decision (CMD) Algorithm" (http://www.roc.noaa.gov/news/NNautumn07b.pdf).

Engineers and Scientists at the National Center for Atmospheric Research (NCAR) developed CMD in a cooperative effort with ROC engineers and scientists. CMD determines the probability of clutter contamination at each geographic location to a high degree of accuracy. It is based on three parameters that are calculated from the receiver time series (I and Q) data. These parameters are Clutter Phase Alignment (CPA), Reflectivity Texture (TDBZ), and the "spin" of the Reflectivity (SPIN).

CPA measures the coherency of the radar return at a single location. High levels of coherency indicate non-moving targets which are likely to be clutter. Moderate levels of coherency indicate weather, and very low levels of coherency indicate noise. TDBZ is a measure of the variability of Reflectivity along a radial. TDBZ is computed using 9 gates of radar data, centered on the current location for which the clutter probability is being examined. SPIN is a measure of how often the variability in Reflectivity changes from increasing to decreasing values or from decreasing to increasing values. SPIN is computed over a range of 11 gates. Both TDBZ and SPIN are used to identify regions where the Reflectivity has a "grainy" or variable appearance indicating ground clutter. Reflectivity estimates for weather are generally much smoother in appearance than those for clutter.

The CPA, TDBZ, and SPIN parameters are combined in a Fuzzy Logic algorithm to obtain the probability of clutter contamination at all locations. This clutter probability measure is then used to generate clutter flags which establish the locations to apply clutter filters in the clutter bypass map. The CMD algorithm runs in active mode during the lowest Surveillance cut of each of the two lowest elevation segments. Currently, the CMD active mode is not available for operational scans at the Batch and Contiguous Doppler cuts. However, testing has shown that the majority of AP clutter occurs in the two lower elevation segments. For cuts above the lowest 2 segments, the static bypass map is employed. However, the static maps can be generated off line with CMD as described further below.

All other operator clutter filter control functions are still available in Build 11.0. Operators can still select static bypass maps, and can apply clutter censor zones if needed. The Clutter Filter Control (CFC) products will be updated on a volume scan

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Coming Attraction

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basis when CMD is active. The off-line, static, bypass map generation function in the Radar System Test Software (RSTS) has been updated to use the CMD algorithm for generating the static bypass maps. The CMD method yields more accurate results and does not require the technician to input any performance parameters as the older method does. The ROC recommends that technicians use the CMD method for generating the static bypass maps.

CMD has undergone rigorous evaluation and testing over the past year, including engineering, integration, and system level testing. In addition, the Data Quality Team has evaluated many hours of radar data generated while clutter filters were under CMD control. Both the NEXRAD Technical Advisory Committee (TAC), and the Software Recommendation and Evaluation Committee (SREC) have recommended CMD for field operations. In short, CMD is ready for deployment.

During the meteorological data quality evaluation, the ROC team monitored the CMD clutter identification process for a large variety of conditions and weather events. By analyzing the CFC products, team members were able to observe rapidly changing radar beam propagation conditions revealed by changes in the actively generated clutter flag maps from the algorithm. This has given the team new insight into just how rapidly beam propagation conditions can change, often showing dramatically different clutter maps from one volume scan to the next. Operators should be aware that the maps at the lower scans will change significantly during AP conditions.

So, once field sites have upgraded to Build 11.0, operators will be able to use CMD to automatically manage clutter filter application at the lower elevation scans. This should greatly improve performance and radar data quality around the network.

Rich Ice
Wyle Information Systems/ROC Engineering Branch

ROC Stars

The WSR-88D program is staffed by dedicated professionals around the world. We are proud of our employees at the Radar Operations Center (ROC), many of whom have been recognized for their outstanding work and commitment to excellence. The following employees have received awards in the past several months.

- Isaac M. Cline Award
  Robert Lee, Applications Branch
  Kathe Schofield, IT&S Section
- 2007 Bronze Medal Award
  Engineering Branch members
  Lynn Allmon, Paul Krenek, and Bill Urell
- ROC Employee of the Quarter
  4th Quarter 2007 – Dave Zittel
  1st Quarter 2008 – Erin Foster
  2nd Quarter 2008 – Olen Boydstun
  3rd Quarter 2008 – Eric Ice
  4th Quarter 2008 – Danny Green
- ROC Team Member of the Quarter
  4th Quarter 2007 – Michael Prather
  1st Quarter 2008 – Darrin Cartwright
  2nd Quarter 2008 – Gary Gookin
  3rd Quarter 2008 – Michael McKissick
  4th Quarter 2008 – Kristy Owen
- NOAA Employee of the Month, August 2008
  Dave Zittel, Applications Branch
- Eastern Region Team of the Month for September 2008
  Operations Branch members
  Jimmy Roper, Mike Shattuck, Bobby Harp, Nigel Ellis, Felicia

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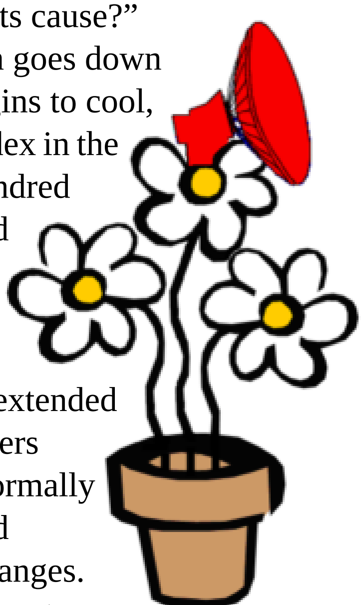
Riddle Me This...

Recently, the Radar Operations Center (ROC) Engineering Branch received the following question, "What is the type of Anomalous Propagation called "radar bloom" and its cause?"

Answer: When the sun goes down and the earth's surface begins to cool, the change in refractive index in the lowest few (to several) hundred feet of the atmosphere tend to bend the radar beam toward the surface. This bending holds the radar beam near the surface for extended distances where it encounters scatterers that would not normally be available at the standard heights expected at these ranges. These scatterers include insects, bats, aerosols, particulate matter, etc., and account for the increased radar return referred to as "radar bloom."



If the lower boundary layer cools too dramatically then an inversion strong enough to duct the beam into the surface can develop. These same low-level scatterers are still "seen" by the radar, but may be obscured in the data by the overwhelming power returned by the ground targets. With the recent implementation of the GMAP (Gaussian Model Adaptive Processing) ground clutter mitigation algorithm, more of these scatterers are preserved in the data than were when we were using the old Infinite Impulse Response (IIR) ground clutter suppression technique.

(Refer to http://www.wdtb.noaa.gov/buildTraining/ORDA/PDFs/Final_Chrisman_Ray.pdf for more information regarding GMAP.)

Joe N Chrisman
ROC Engineering Branch

ROC Stars

(Continued from Page 20)

Woolard, and Terrel "B" Ballard for their work replacing the Binghamton, NY WSR-88D bull gear in the approach of Hurricane Hanna.

- 2008 Oklahoma Federal Executive Board Employee of the Year
  Tammy Buie, Program Branch - Technical, Professional & Administrative, GS-8 and below
- 2008 Oklahoma Federal Executive Board Employee of the Year Nominees:
  Lt. Charles Parish - Technical, Professional, Admin. DOD GS-9 and above
  Dennis Roofe - Technical, Professional, Admin. Civilian GS-9 or above
  Russ Cook - Supervisory - Civilian
  Terry Clark - Supervisory - DOD
  William Urell, Paul Krenek, Marty Williams, and Jorge Mendoza - Outstanding Team Effort

Eric Ice
ROC Applications Branch

NEXRAD Now **is an informational publication of the WSR-88D Radar Operations Center (ROC).**

We encourage our readers to submit articles for publication. Please email all articles and comments to:

ruth.e.jackson@noaa.gov

All previous issues of *NEXRAD Now* can be viewed on the ROC Home Page at:

http://www.roc.noaa.gov/nnow.asp

Director.......Richard Vogt
Deputy Director.......Terry Clark
Editor.......Ruth Jackson

Testing New Modulator Switches

Modern high energy switches are being investigated by the engineering branch of the Radar Operations Center (ROC), as a successor to the present reverse biased diode thyristor (RBDT) stack in the WSR-88D transmitter Modulator 3A12. These efforts are a continuation of the development and testing done by Massachusetts Institute of Technology (MIT)-Lincoln Labs (LL) and the Federal Aviation Administration (FAA), as part of their ASR-9 transmitter modernization project. We are indebted to them for their excellent work in the area of modulator switch replacement.

The LL/FAA efforts resulted in a completely new Modulator design with much improved pulse to pulse regulation. This is achieved by closed loop regulation of the Pulse Forming Network (PFN) voltage. Better regulation equates to improved phase and amplitude jitter of the transmitted RF pulse. Excessive jitter has a negative impact on Clutter Suppression capability. Careful analysis by ROC engineering concluded that this improved regulation was not as cost effective for the National Weather Service (NWS) weather prediction mission as it was for the FAA approach control mission. Although the ROC was not interested in the complete FAA redesign, we were interested in the possibility that the improved Modulator switch could have application to the WSR-88D transmitter, especially in view of the fact that the presently used switching devices (RBDT's) are expensive and growing obsolete.

Strategic Advantages of New Switch Modules

ROC Engineering is presently evaluating switches from two vendor's, let's call them Vendor A and Vendor B. Both vendors employ fiber-optic (F/O) switch triggering; however, they use different semiconductor technologies for their switch elements. The F/O input triggering is immune to electromagnetic induced false triggering. In order to test the new switches, the ROC designed an optical transmitter printed circuit board (PCB) which converts the existing modulator discharge balanced line electrical signal available on the present transmitter backplane to a F/O signal which is connected through a F/O cable directly to the new switch. For test purposes, this PCB is mounted on an existing phenol board above the transmitter backplane at the rear of the left bay. In addition, ROC Engineering modified a legacy Modulator 3A12 to accommodate the Vendor A switch module and it's accompanying power supply and light distribution unit. Procurement of a sample switch module from Vendor B is in process.

The use of F/O triggering eliminates the requirement for the 10KV fast rising trigger presently produced by the Trigger Amplifier to turn on the present RBDT stack. It also eliminates the need for the following modulator line replaceable units (LRUs):

- RBDT stack 3A12A1 is replaced by the new switch. It has a form factor similar to the RBDT stack and is mounted in its place.
- Trigger Blocking stack 3A12A2
- Trigger Loading unit 3A12A7
- HV coupling capacitor 3A12C1
- Backswing Diode Stack 3A12A3
- HV cable 3W10 from Trigger Amplifier 3A11 to the Modulator
- All of the circuitry involved in making the 10KV pulse. This is achieved by grounding two Trig Amp control signals on the Optical Transmitter PCB. We still need the Trig Amp chassis since it is the home of two BITE circuits involved with Modulator alarms. *These circuit simplifications equate to considerable repair cost savings and improved system availability.*

(Continued on Page 23)

Modulator Switches

(Continued from Page 22)

Evaluation Results to Date

A sample of Vendor A switch module was kindly given to the ROC by the FAA. This switch had been used fault free in ASR-9 for about 3 years at Lincoln Labs. A legacy Modulator 3A12, modified to accommodate Vendor A switch module, was installed in the ROC engineering transmitter in the Pedestal Test Facility at Norman, OK and has been running fault free in the Operate mode at various Volume Coverage Patterns (VCP's) since 1 July 2008. During this time, several significant tests were conducted as follows:

- The cooling air available to cool the switch module is supplied to the Modulator through an air plenum at the rear of the Modulator. Part of the air available from the Blower Assembly 3B1 is diverted and sent to the Modulator. Therefore, the temperature of this air should be at or near the shelter ambient air in the vicinity of the left bay air input port. The bottom of the modulator consists of an air plenum which has an output opening directly below the switch module location. The air velocity was measured to be 3000 ft/min. *This is approximately 20 times the equivalent velocity required by Vendor A specification.*
- There are three switch elements in the Vendor A switch module. They are Integrated Gate

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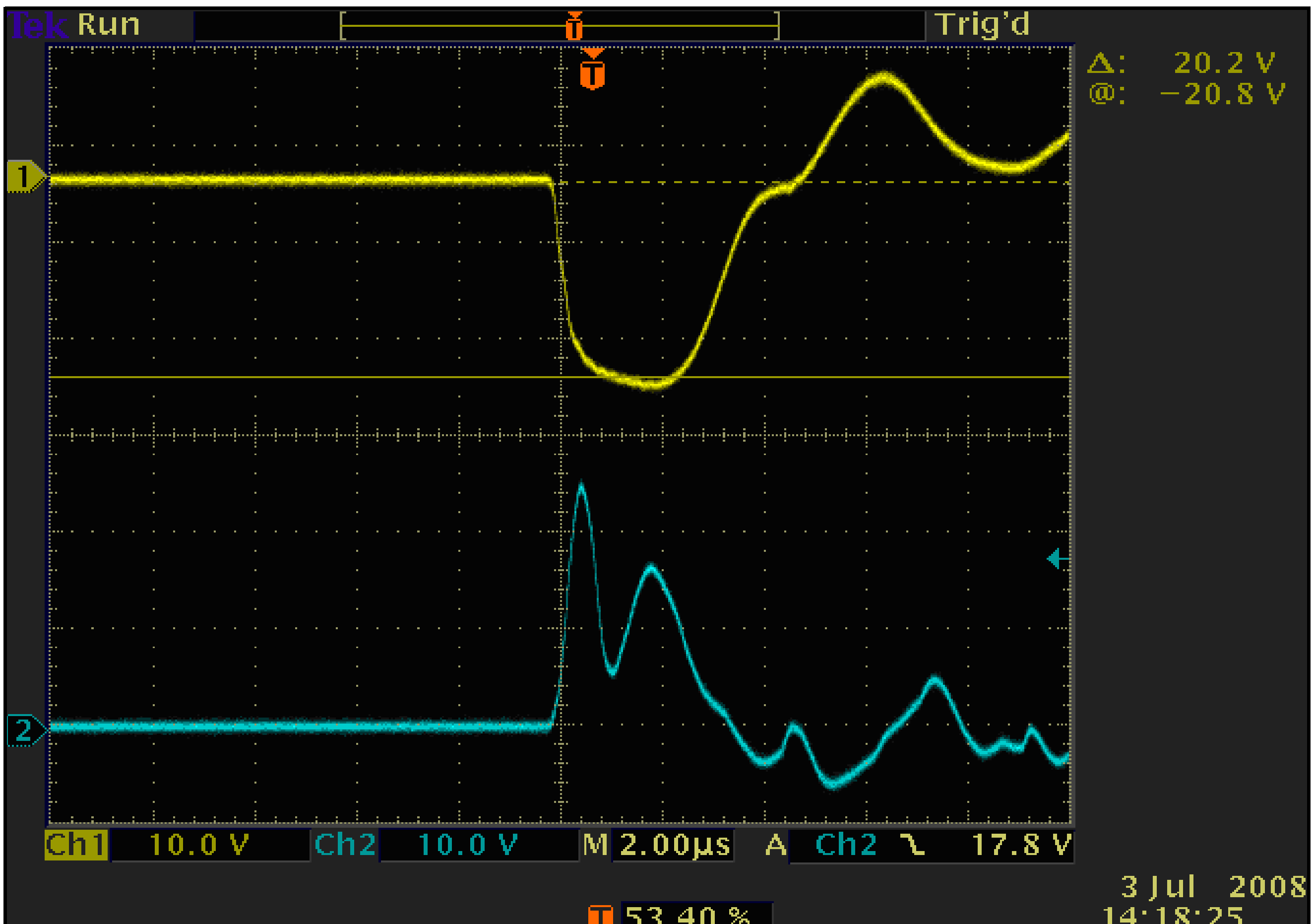

Figure 1: Channel 1 beam voltage using Vendor A's switch module. Amplitude of beam voltage is 100 X 20.2 = 2020 volts at 3A12TP2.

Modulator Switches

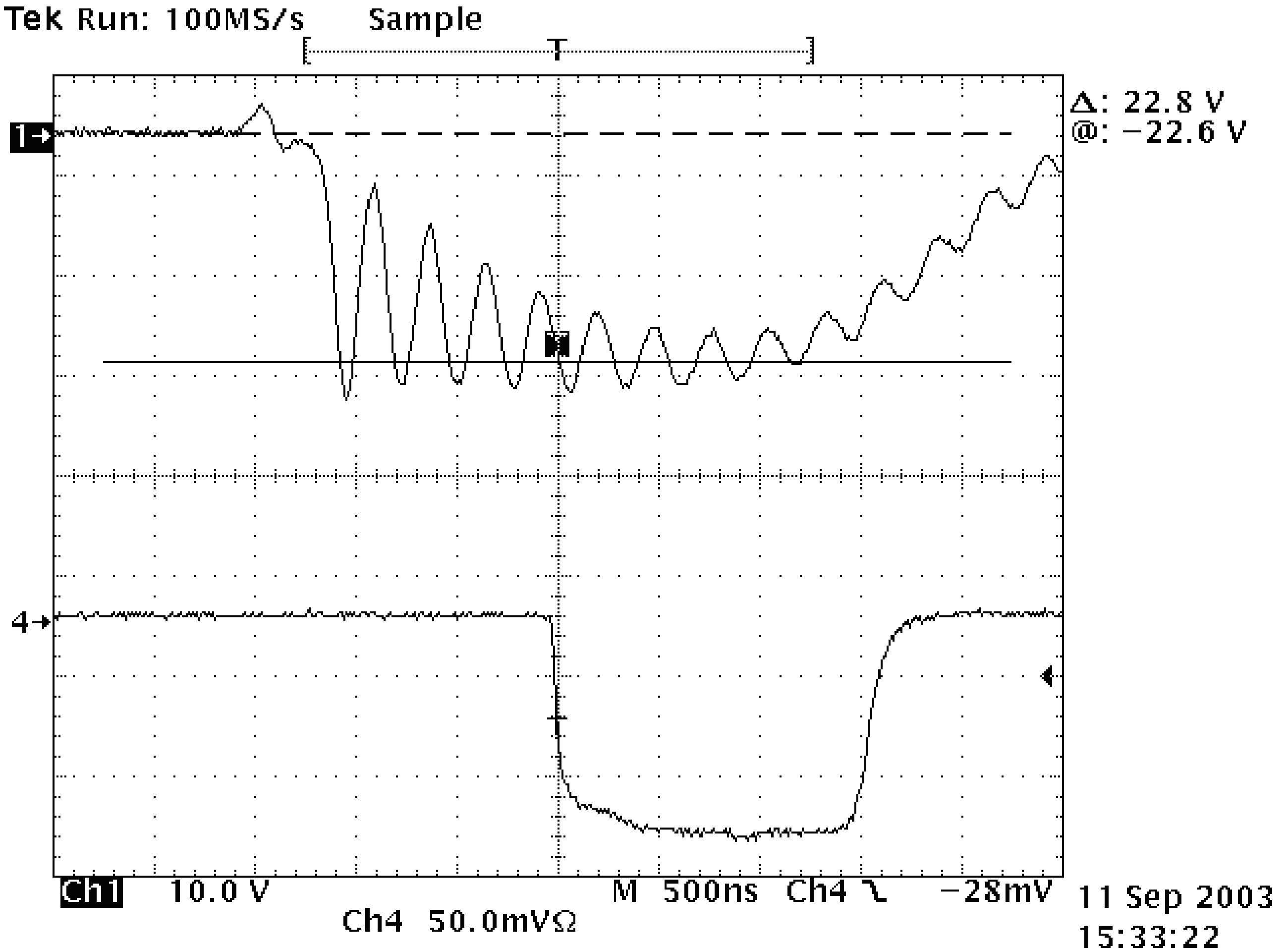

Figure 2: Channel 1 beam voltage using RBDT stack as switch (present configuration), amplitude of beam voltage is 100 X 22.8 = 2280 volts at 3A12TP2.

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Commutated Thyristors (IGCT), which feature high current, very high di/dt, reverse conducting, and optical triggering. Vendor B employs Integrated Gate Bipolar Transistor technology. *The case temperature of each of the three Vendor A IGCT's was measured with an IR Camera and found to be in the range of 109 degrees F for VCP31 (duty cycle = .001) up to 165 deg F for VCP21 (duty cycle = .003). This is entirely satisfactory and answers an important question we had as to it's application to the WSR-88D Modulator.*

- Output power stability was measured with the aid of the excellent performance logging capability of the RDA design. Initial measurements indicated a standard deviation of 46 KW from VCP to VCP. It was found that the majority of this deviation was due to a design defect in the Filament Power Supply 3PS1. We developed a hardware fix for this defect (CCR 08-00096) and when this fix was implemented at the PTF, the standard deviation reduced to about 4 KW. *This is equivalent to a standard deviation of only 0.025 dB. This*

(Continued on Page 28)

You are Entering Another Dimension: The Exclusion Zone!

Exclusion Zones were introduced in RPG Build 5.0 Software (deployed in 2004) as Enhanced Preprocessing (EPRE) adaptation parameters for the Precipitation Processing Subsystem (PPS). As stated in Guidance on Adaptable Parameters (a.k.a. the Adaptable Parameters Handbook) for the RPG in Paragraph 7.6 Hydromet Preprocessing, "Exclusion Zones are user-defined regions to account for residual clutter due to man-made objects such as buildings or wind farms, large tree growth, etc." Exclusion zones are three-dimensional volumes of reflectivity data excluded from the construction of the Hybrid Scan, to which precipitation processing applies its rainfall rate and snowfall rate relationships. The reflectivity from the first elevation angle above the top of the exclusion zone is the one used in construction of the Hybrid Scan, because reflectivity from elevations above an exclusion zone may be more representative of the precipitation in that zone than the amount actually detected.

Many sites have found exclusion zones useful to exclude reflectivity from highways and wind turbines, which, having valid velocity and spectrum width, are not identified as ground clutter by the RDA's clutter identification software. Another use is to get better rainfall estimates where beam blockages have not been identified in EPRE's blockage files. These blockages are typically trees, buildings, towers, and hills that were not part of the data from which the blockage files were generated. Near-field obstructions, i.e., ones typically within the first kilometer from the radar, are omitted from blockage files.

Keep in mind that exclusion zones only apply to precipitation accumulation products, and do not alter the base data used for the base products and other derived products. They will continue to be used once radars are retrofitted for dual polarization, because the dual polarimetric quantitative precipitation estimation (DPQPE) algorithm has no other way to eliminate highways and wind farms from the data that will be used in precipitation processing.

It is expected that the Clutter Mitigation Decision (CMD) software will greatly reduce contamination of base data by ground clutter automatically, thus reducing the need to apply manually-generated clutter suppression regions for residual ground clutter (i.e., ground clutter not already filtered at the RDA). Any ground clutter remaining in the base data should automatically be filtered from precipitation processing by the Radar Echo Classifier Anomalous Propagation Detection Algorithm (REC-APDA) in the current PPS and by the Hydrometeor Classification Algorithm (HCA) and the DPQPE algorithm in dual polarimetric systems. Exclusion zones are not intended for mitigation of ground clutter.

How to define the exclusion zones for blocked radials

1) Select a long-term widespread precipitation event either in-progress or archived.

2) Azimuths and ranges can be determined by looking for wedges of reduced precipitation in a Storm Total Precipitation (STP), Storm Total Snow Depth (SSD), or Storm Total Snow Water Equivalent (SSW) product.

The defined start azimuth and end azimuth are not part of the zone. Specify start and end azimuths 0.5 degrees wider on each end. (For example, the operator has determined a wedge to extend from 347.5 degrees to 353.5 degrees, and must define the exclusion zone as 347.0 degrees to 354.0 degrees.)

(Continued on Page 26)

Exclusion Zone

(Continued from Page 25)

The Clutter Regions graphical interface (accessed from the RPG Control/Status window) may be useful when defining the azimuths and ranges of an exclusion zone if the background selected shows these blockages, but do not save these dimensions as a clutter suppression region.

The recombined radials from Build 10.0 are centered on the half degree (0.5, 1.5, 2.5, 3.5, etc.). Exclusion zones defined during the few years prior to Build 10.0 would perform the same way as ones defined in Build 10.0 and later builds.

3) Maximum elevation angle can be determined by looking for these same wedges in base reflectivity products at low elevation angles, preferably super resolution reflectivity in VCP 12 or VCP 212. Limit the maximum elevation angle to just beneath the first elevation that no longer shows a blockage. Also, consider the atmospheric conditions for the event for which the exclusion zone will be used. Were the refraction conditions unusual? If so, the zone's maximum elevation angle may need to be adjusted to compensate for those conditions (e.g., higher during superrefraction conditions, typically during early morning hours).

Work is in progress to create a graphical user interface (GUI) to aid in the creation of exclusion zones. This new Exclusion Zone Editor (EZE) will have increased flexibility in outlining the features to be excluded (particularly highways) and will not be limited to 20 exclusion zones. In the meantime, if assistance is needed in creating an exclusion zone, contact the WSR-88D Field Support Hotline (800-643-3363).

Dan Berkowitz
ROC Applications Branch

(Graphics continued on Page 27)

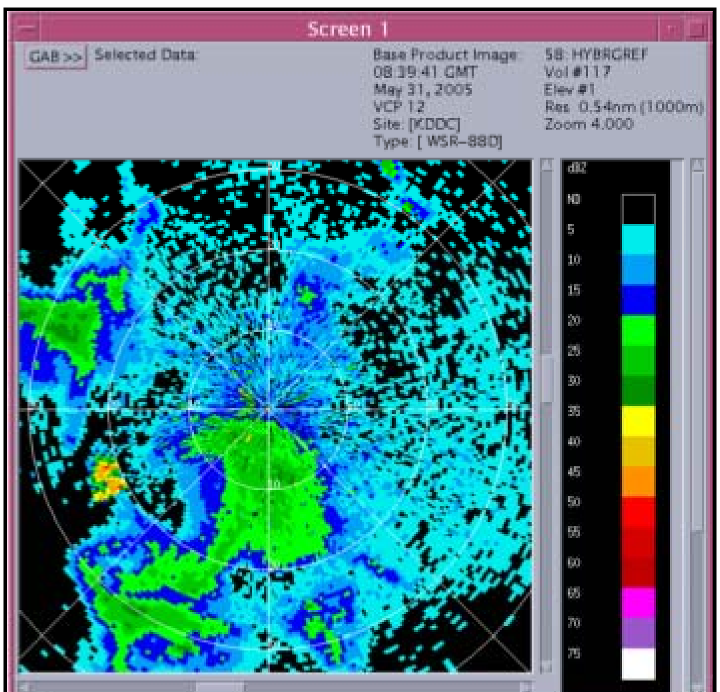

Figure 1: Hybrid Scan Reflectivity (HSR) before using an exclusion zone for the wind farm located southwest of Dodge City.

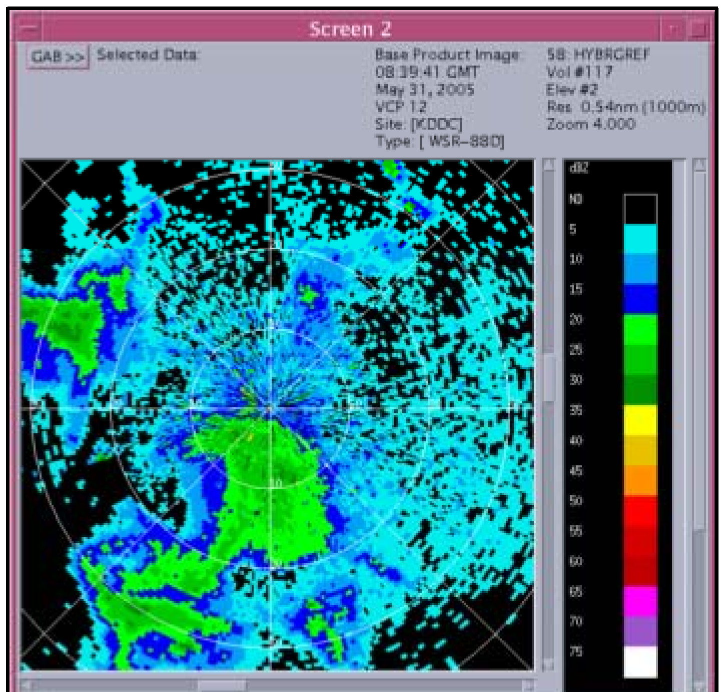

Figure 2: Hybrid Scan Reflectivity after using an exclusion zone. Note the HSR now uses two elevation angles, but does not contain the strong returns from the wind farm.

Continued from Page 26

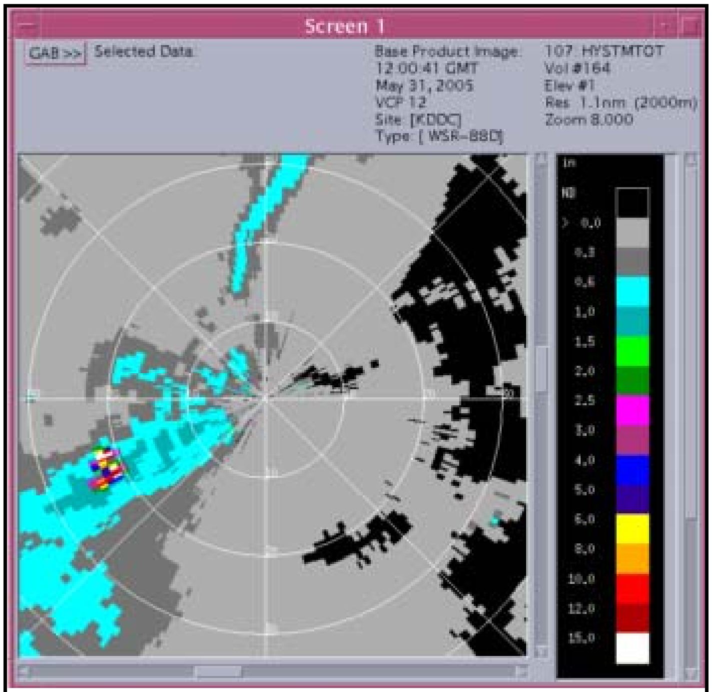

Figure 3: Storm Total Precipitation (STP) before using the exclusion zone. The "accumulation" due to the wind farm is quite high.

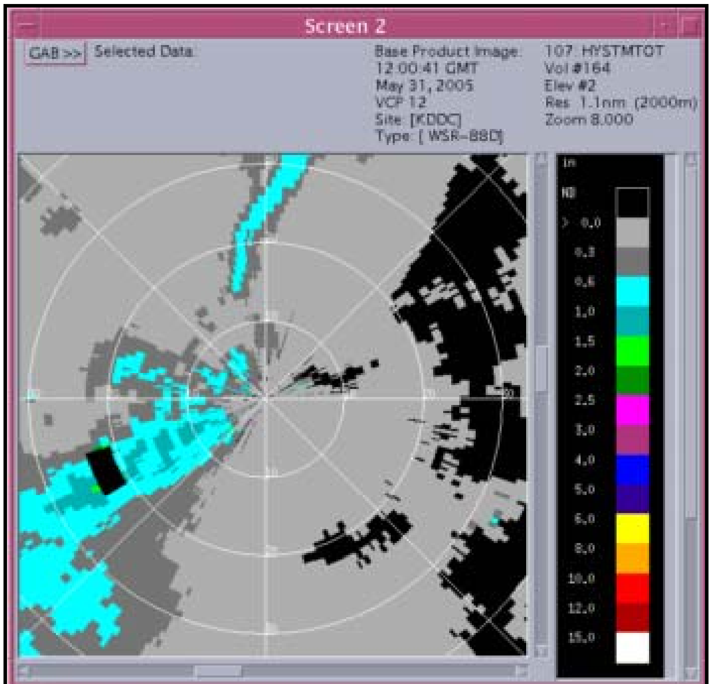

Figure 4: The STP shows no rainfall accumulation from the wind farm. (Apparently, reflectivity at the second elevation in this location was too light to fill in the box.)

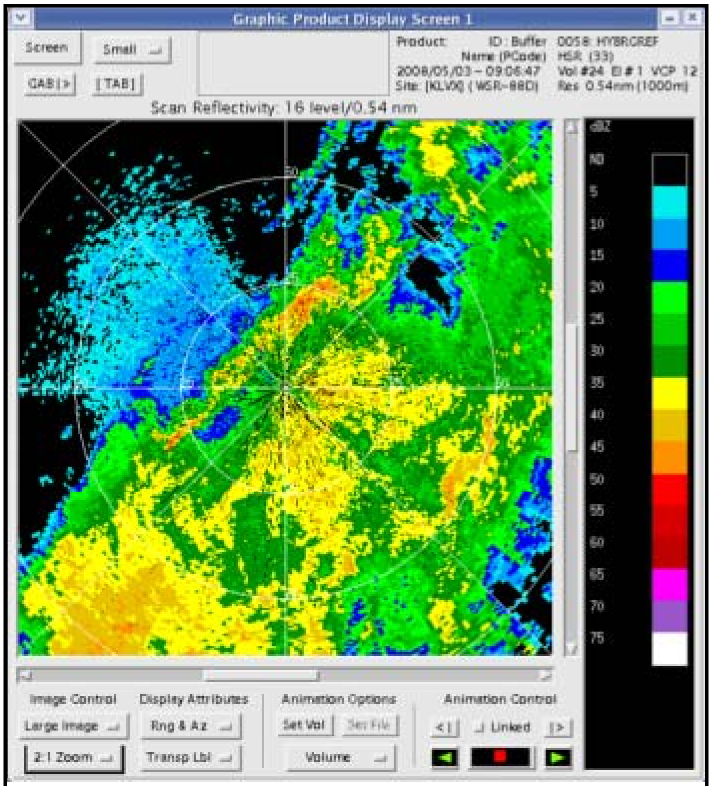

Figure 5: HSR based on lowest elevation, showing partial blockages due to trees close to the radar.

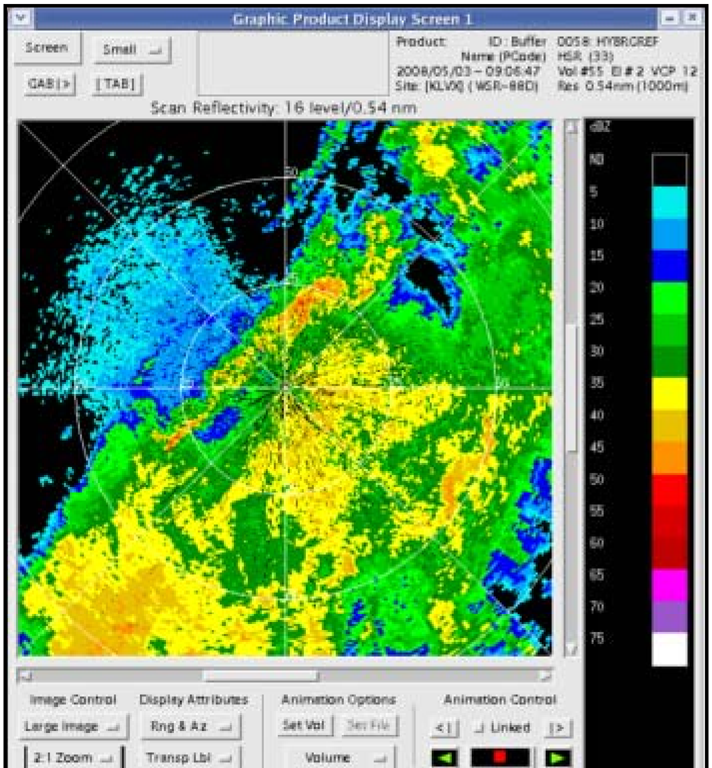

Figure 6: HSR based on two lowest elevations (0.5 and 0.9 degrees in VCP 12).

(Graphics continued on Page 28)

Exclusion Zone

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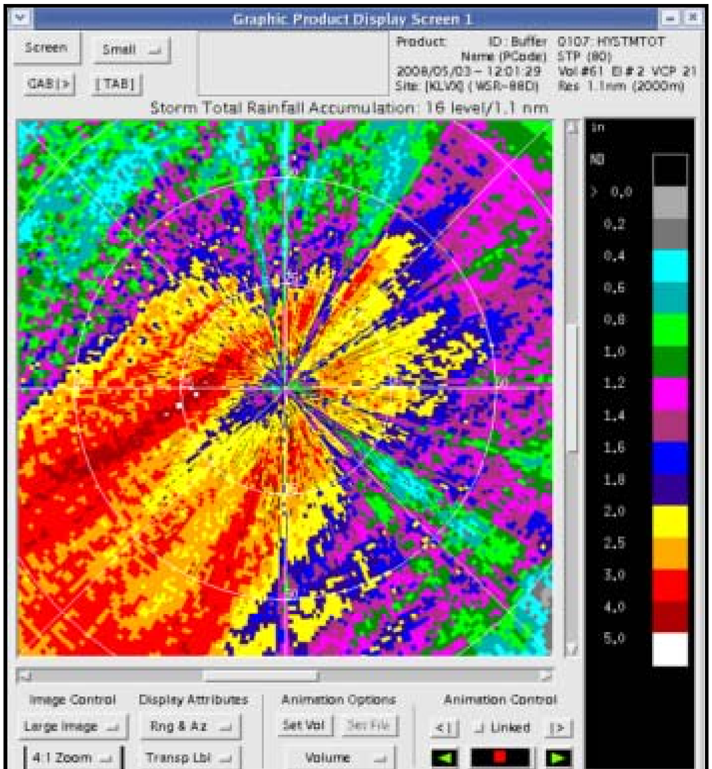

Figure 7: STP showing the effects of the blockages during a long convective rainfall event.

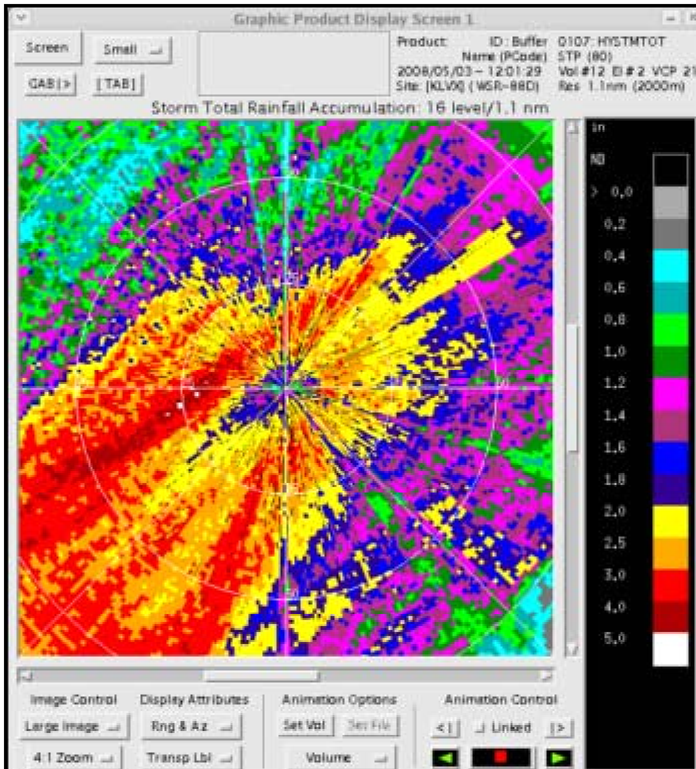

Figure 8: STP showing smother transition of accumulations across the blocked radials.

Testing New Modulator Switches

(Continued from Page 24)

excellent power stability is important since instability of the modified Modulator would directly contribute to output power instability.

- Cleaner Modulator internal waveforms. A comparison of Figures 1 and 2 illustrates this feature. We attribute this to less wiring within the Modulator especially in the critical PFN discharge path.
- No degradation in Clutter Suppression detected with modified Modulator.

Conclusions

- Based on the testing of Vendor A switch module, the inclusion of a modern switch module in the present WSR-88D Transmitter design is practical.
- Testing of Vendor B switch module is in the best interest of the WSR-88D program.
- In addition to the ROC testing done to date, CAREFUL beta testing is considered to be a requirement before any possible deployment decision can be made.

Bill Urell
ROC Engineering Branch

AVSET:
A Clever Way to Achieve Faster Volume Scan Updates

Based on a recent field survey, over 62% of respondents rate faster Volume Coverage Pattern (VCP) updates (more frequent low elevation updates) as *the most important VCP improvement* the Radar Operations Center (ROC) could provide. Constructing faster VCPs sounds easy and straight forward; however, there are only two ways to achieve faster VCPs: either spin the antenna faster, or sample fewer elevation angles. With a little thought it becomes apparent that both of these options are problematic.

If one opts to spin the antenna faster, data quality (e.g., clutter filter performance) and hardware maintenance issues soon overwhelm the discussion. For example, current VCPs like 12 and 121 are already approaching those rotational limits. On the other hand, a decision to scan fewer elevations, predefining multiple VCPs with different combinations of elevations, and the operational implementation of these new VCPs becomes a daunting task. Additionally, this option would significantly increase the number of VCPs required to fulfill the myriad of meteorological situations expected across the country.

Given the apparent incompatibility between the need for faster product (VCP) updates and the reality of VCP design, implementation and management, the ROC decided to look inside the VCP to the individual volume scan. By treating each volume scan independently, it was realized that we could dynamically control the number of scanning angles based on the sampled meteorological return. The result of this epiphany is the Automated Volume Scan Evaluation and Termination (AVSET) function.

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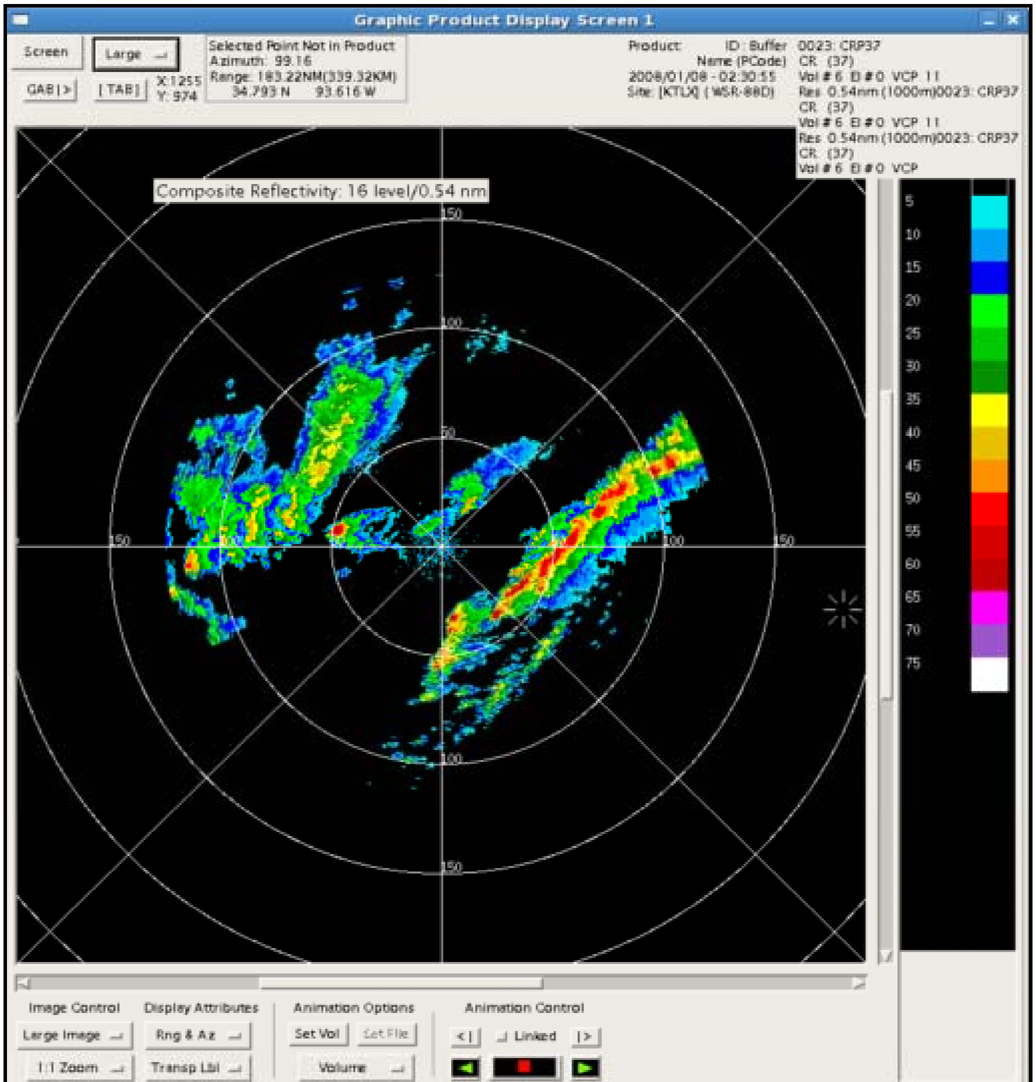

Figure 1: KTLX CR Product 02:30Z.

AVSET

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The basic premise of the AVSET function is to terminate the current volume scan after the radar has scanned all the elevations with important return. In other words, once the data collection elevation overshoots the available radar return, the volume scan is terminated, as there is no benefit realized by continuing the execution of the current volume scan, and a new volume scan is begun. The net effect of AVSET is to shorten the elapsed time between data collection on low elevation angles during periods when no significant data are available on the higher elevation tilts.

When enabled by the operator, the AVSET function evaluates the return on each elevation above 5° and calculates the areal coverage of return 18dBZ and greater and 30dBZ and greater. If the areal coverage of >18dBZ is less that 80 km^2 (total over the entire radar coverage area) AND the areal coverage of >30dBZ is less than 30 km^2 (total over the entire radar coverage area) AND the areal coverage of 18dBZ and greater has not increased by 12 km^2 or more since the last volume scan then AVSET terminates the volume scan after completion of the next higher elevation. This volume scan termination scheme causes the system to enter its normal transition (RDA antenna retrace, RPG concludes algorithm processing and product generation, etc.), to prepare for the start of a new volume scan.

Figures 1 and 2 illustrate the benefit of AVSET processing using Level II data from a severe thunderstorm event collected by the Norman, OK, Weather Forecast Office (WFO) WSR-88D (KTLX) radar. Figure 1 is the Composite Reflectivity product from KTLX at 02:30Z. Figure 2 provides the 10°, 12°, and 14° Base Reflectivity products from 02:36. Had AVSET been active during this event, this volume scan would have been terminated after completion of the 12° slice. The resulting volume scan duration would have been approximately 250 seconds which is about 45 seconds faster than the standard VCP 11 volume scan duration.

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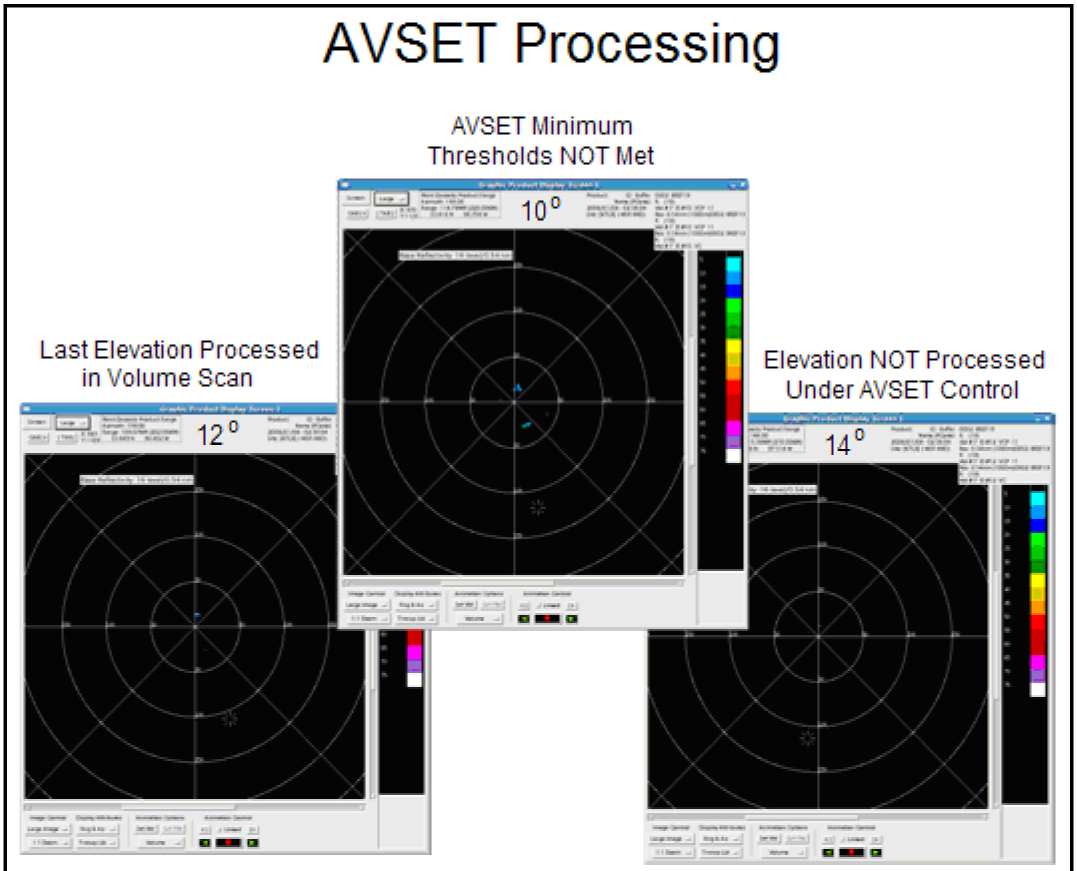

Figure 2: Example of AVSET processing.

AVSET

(Continued from Page 30)

The amount of time savings achieved by AVSET depends on the active VCP and the areal coverage of return. Given the best possible situation, AVSET will terminate the volume scan after completion of the second elevation above 5°. Table 1 provides the minimum scanning angles, elevation scan times, and shortest VCP durations for four AVSET-controlled VCPs. For reference, Table 2 provides the average update times (without AVSET) for the VCPs listed in Table 1.

To provide comparison data and images, several Level II cases have been analyzed. A representative case is the March 2, 2008, KTLX data set. During this event, severe convective weather moved through Central OK. For the 4-hour period from 02/2000Z through 03/0000Z, the Norman, OK WFO (using the KTLX radar executing VCP 11) issued three separate tornado warnings and multiple severe thunderstorm warnings. One confirmed tornado occurred at 02/2246Z, approximately 75nm northwest of KTLX.

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AVSET-Controlled Shortest VCP 11		AVSET-Controlled Shortest VCP 12		AVSET-Controlled Shortest VCP 212		AVSET-Controlled Shortest VCP 21	
Elevations	Time (sec)	Elevations	Time (sec)	Elevations	Time (sec)	Elevations	Time (sec)
0.5	19	0.5	17	0.5	17	0.5	32
0.5	19	0.5	14	0.5	21	0.5	32
1.5	18	0.9	17	0.9	17	1.5	32
1.5	19	0.9	14	0.9	21	1.5	32
2.4	22	1.3	17	1.3	17	2.4	32
3.4	20	1.3	14	1.3	21	3.4	32
4.3	20	1.8	15	1.8	15	4.3	32
5.3	21	2.4	14	2.4	14	6.0	32
6.2	21	3.1	14	3.1	14	9.9	25
		4.0	14	4.0	14		
		5.1	14	5.1	14		
		6.4	13	6.4	13		
Scan time	179		177		197		281
Ret/Trans	13		13		13		15
Total Time	**192**		**190**		**210**		**296**

Table 1: AVSET controlled VCP completion times.

NOTE: AVSET will start evaluation on the first elevation above 5°. With the current design, AVSET will always process one elevation cut above the elevation where the AVSET reflectivity thresholds are met.

	VCP 11	VCP 12	VCP 212	VCP 21
Completion Time (Seconds)	293	256	277	346

Table 2: Average VCP completion times.

AVSET

(Continued from Page 31)

The Level II data from this event was reprocessed on a ROC test bed RPG that executes special code that emulates the AVSET function. For the 4-hour time period, the AVSET-controlled volume scan times averaged 212 seconds. Focusing on the 3-hour period prior to, and including, the tornado, the AVSET-controlled VCP 11 scan times averaged 198 seconds (see Figure 3). Had it been available on KTLX, AVSET would have enabled KTLX to produce 66 volume scans during the 4-hour period; conversely, only 49 volume scans executing VCP 11 were possible.

As denoted in Figure 3, AVSET terminated the 22:40 volume scan after the completion of 7.5° (206 seconds). The left image in Figure 4 is the

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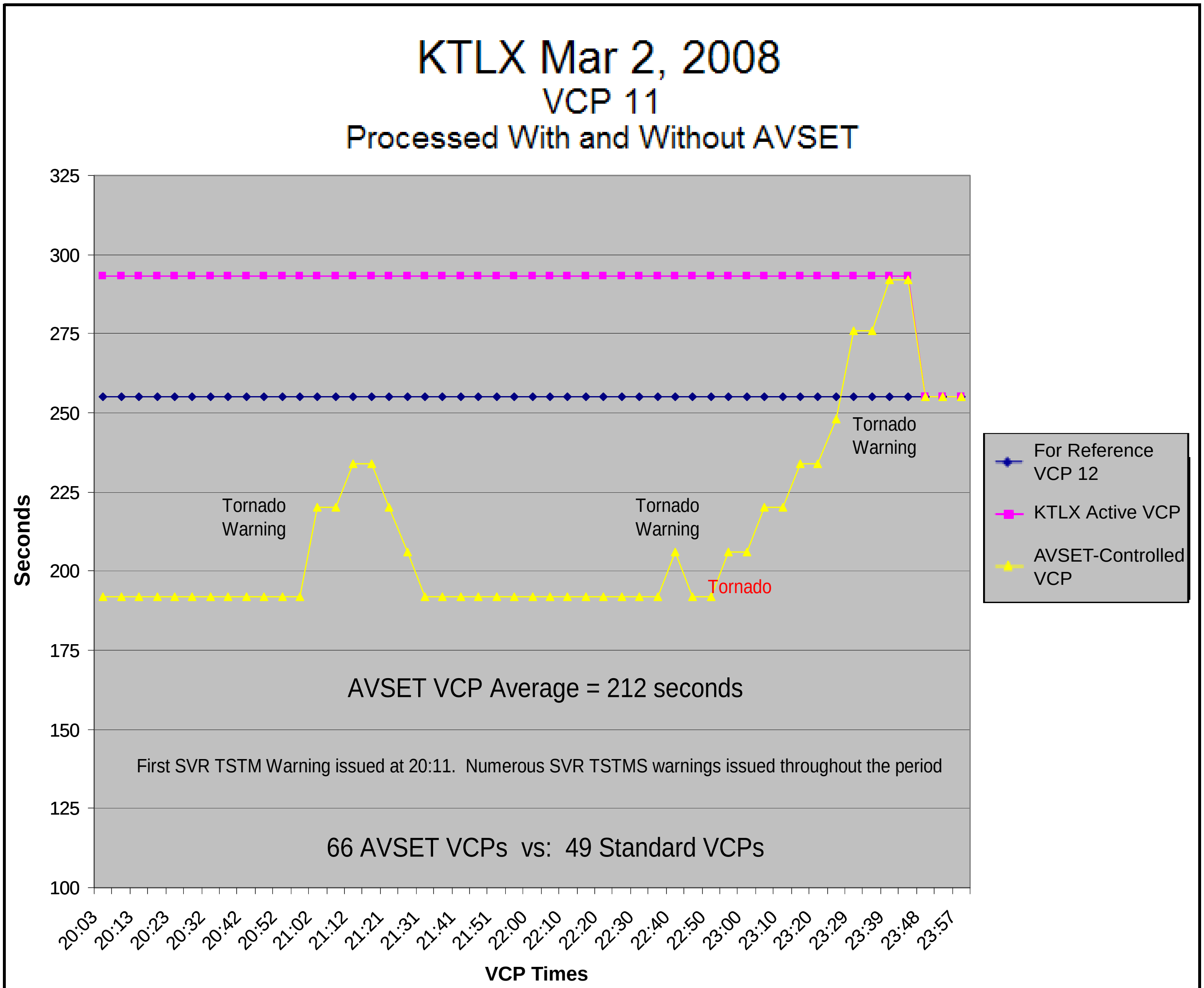

Figure 3: AVSET VCP 12 Performance versus VCPs 11 and 12.

AVSET

(Continued from Page 32)

KTLX base reflectivity product from the "last elevation cut" of this volume scan. The right image is the KTLX base reflectivity product from 8.7°, the next higher elevation cut, which would not be sampled with AVSET active.

As one can see, only a small amount of weak return was present above the elevations sampled by the AVSET-controlled VCP. In many of the test cases, the only return above the AVSET-sample elevations was attributable to side lobes.

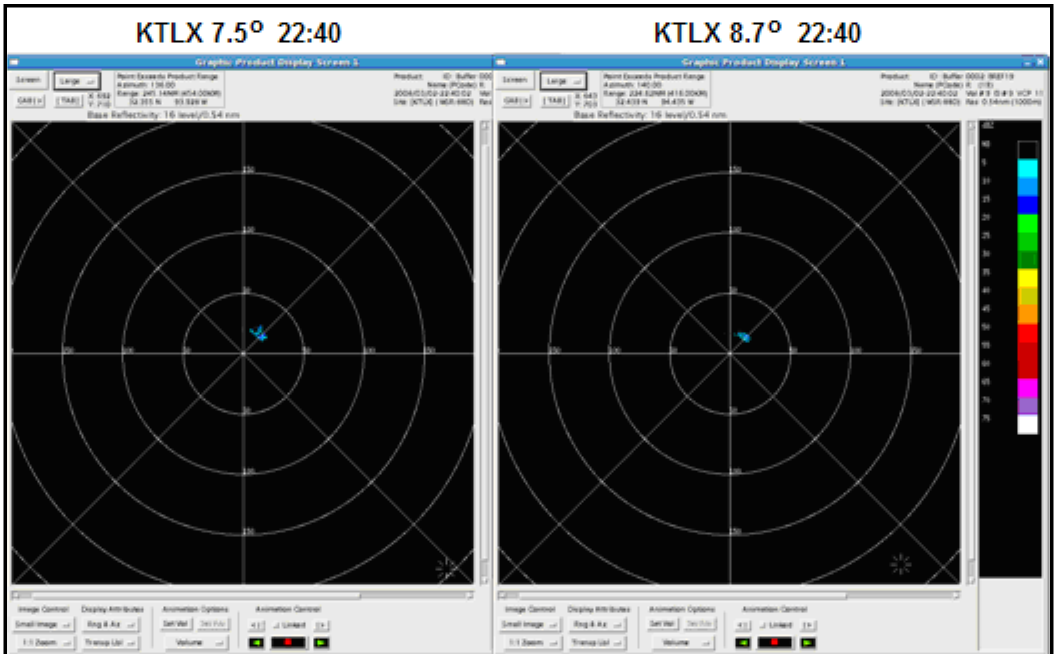

Figure 4: KTLX Reflectivity Images.

Visual inspection of the products from KTLX (standard VCP 11) and KTLX (AVSET-controlled VCP 11) showed only operationally insignificant differences (Figures 5 and 6). The observed differences did not impact the identification and interpretation of the unfolding weather events.

Note: For AVSET, the Velocity Azimuth Display (VAD) Wind Profile (VWP) task was modified to dynamically determine the elevations and slant ranges needed to achieve the required heights based on the previous volume scans available elevations. It is interesting to note that in some instances, the AVSET-induced VWP elevation/slant range combinations result in additional wind data.

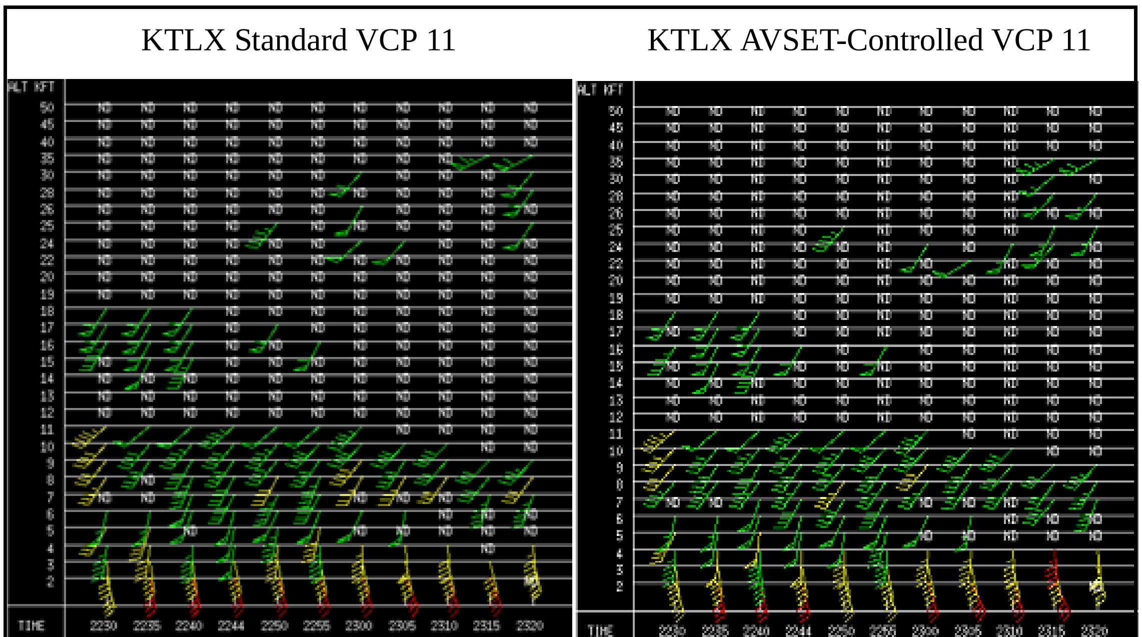

Figure 5: VWP Comparison of VCP 11 versus AVSET VCP 11.

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AVSET

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KTLX Standard VCP 11 | KTLX AVSET-Controlled VCP 11

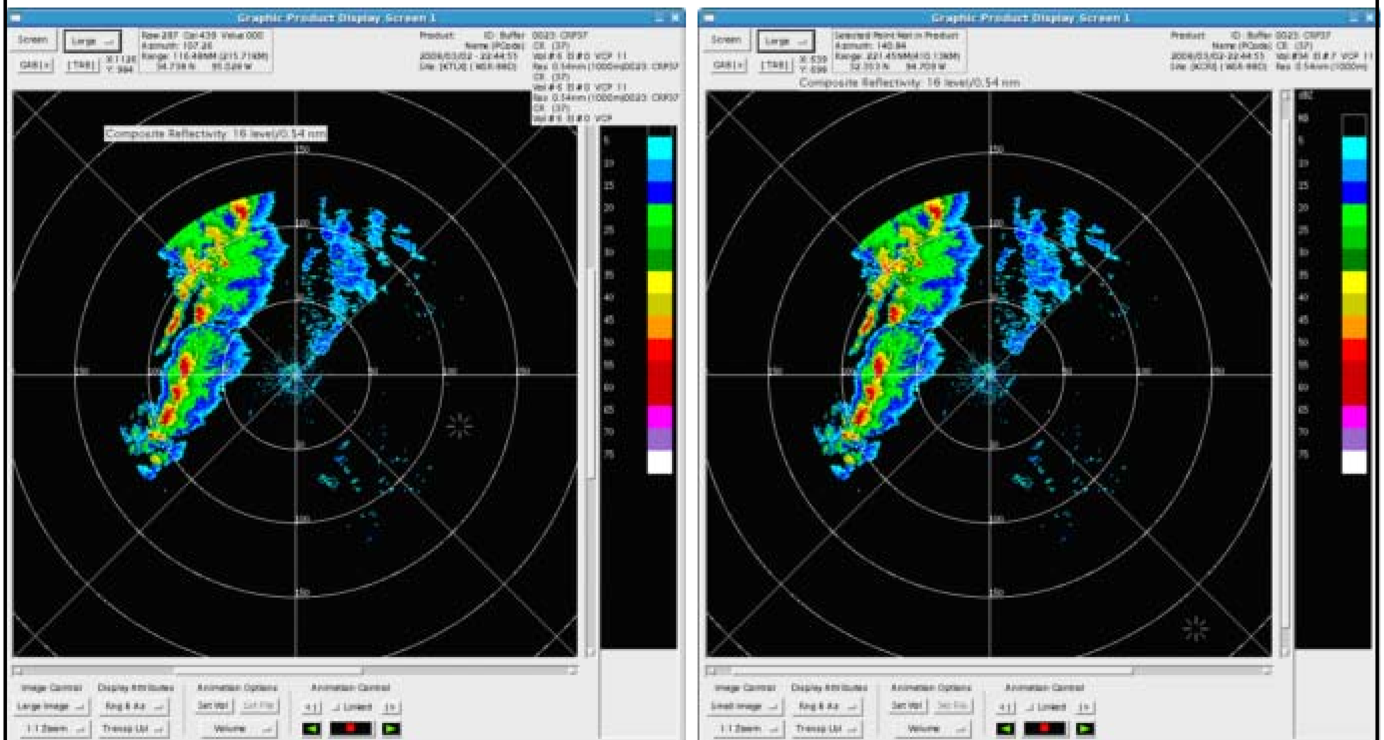


Figure 6: Composite Reflectivity Comparison of VCP 11 versus AVSET VCP 11.

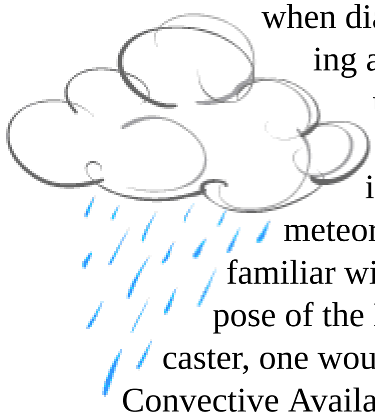
AVSET represents a paradigm shift in operational volume scanning for the WSR-88D. In the past, WSR-88D VCPs have always automatically and continuously scanned predefined elevation angles. This scheme resulted in each VCP having a particular periodic update cycle that never changed, regardless of the sampled meteorological conditions. The only way to change the update period was to invoke another VCP and accept its elevation scans and periodic update rate.

When enabled, the AVSET function evaluates the return on each elevation above 5° and terminates the current volume scan after the radar has scanned all elevations with important return. The net result of AVSET is a shortened elapse time between data collection on low elevation angles (and generating volume-based products) during periods when no significant data are available on the higher elevation tilts.

AVSET has not been approved for operational fielding, yet. For now, AVSET is currently in OSIP (Stage 2) and is still undergoing testing at the ROC.

Joe Chrisman
ROC Engineering Branch

The WSR-88D and the MPE Bias



It has become common for many to use the Multi-sensor Precipitation Estimator (MPE) Bias when diagnosing a radar as having a tendency to over- or under-estimate precipitation. Whether this is intentional or accidental, meteorologists need to be familiar with the meaning and purpose of the MPE Bias. As a forecaster, one would not simply look at Convective Available Potential Energy (CAPE) then make a forecast based solely on it. An eclectic list of parameters goes into making a forecast worthy of publishing. And, nothing short of an eclectic list should go into diagnosing a complex system such as the WSR-88D radar.

For starters, the MPE bias is an output of algorithms, and those algorithms can (and often are) changed with just a few keystrokes at the Radar Product Generator (RPG). Precipitation estimation depends on these algorithms and the associated adaptable parameters, and AWIPS uses these settings to calculate the bias. Let’s explore these parameters for a moment.

RAINZ and RAINA go hand-in-hand much like lightning and thunder; there cannot be one without the other. RAINZ defines the minimum strength of echoes included in the areal coverage calculation RAINA. Of the two of these, RAINA is a bit more difficult to define since it depends heavily on the residual clutter of the site. The default value for RAINA is 80 km^2, which is likely too low for most sites. Accepting the default or setting RAINA too low can lead to the radar over-estimating rainfall. A good rule of thumb for choosing a RAINA value is to monitor the Total Rain Area (in km^2) (from the Supplementary Precipitation Data (SPD) text product in AWIPS) during a few clear air days and then add that value to the default value of 80 km^2.

The Clutter Threshold (CLUTTHRESH) defines the maximum allowable percent likelihood of clutter. Based on its setting, a sample bin will be accepted or rejected. If a particular sample bin is rejected then a sample bin from a higher elevation will be used in the Hybrid Scan. It is these reflectivity estimates contained within the Hybrid Scan that are converted to rainfall. Using a higher elevation than necessary may result in erroneous rainfall estimates, and the errors may be over- or under-estimates depending on the nature of the weather. The radar beam may sample the bright band which would cause an overestimate, or the radar beam may overshoot the weather echo which would cause an underestimate. The possibilities of erroneous precipitation estimates due to a poorly chosen CLUTTHRESH setting are virtually endless when working with Mother Nature.

In addition to the previously mentioned parameters, there can be precipitation estimation errors due to insufficient clutter suppression. The Radar Operations Center (ROC) recommends using the default Bypass Map (BPM) unless Anomalous Propagation (AP) is present. Under these conditions, defining clutter suppression regions of Forced Filtering (All Bins) may be needed to address the transient clutter. However, using All Bins during any weather event, other than AP, is not recommended and can lead to an underestimation of rainfall. Remember, clutter suppression reduces the power of signals which have a mean radial velocity at or near zero, and this reduction in power decreases the clutter’s power contribution. The BPM most effectively filters clutter (other than AP) and has the potential to provide the best

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MPE Bias

(Continued from Page 35)

precipitation estimates. It should be updated seasonally so it represents the average conditions for the upcoming season. Doing so will optimize the BPM and, thus, clutter filtering.

Oftentimes, intermittent clutter targets, such as wind farms or water towers may pop up over night as radar beam propagation changes. These targets can contaminate precipitation estimates. Unfortunately, areas such as these may not be identified in the previously generated BPM for several reasons. Wind farms and vehicular traffic will likely have valid velocity signatures and will not usually be identified when the BPM is generated. Water towers often appear during AP conditions and may show up as areas of bright, stationary echoes or wedges in data where there normally are none. Using a clutter censor zone over the water tower will remove the strong reflectivity; however, the wedge due to the AP induced blockage will remain until the beam is propagating normally. More accurate precipitation estimates may be realized by defining an Exclusion Zone (EZ). EZs are defined by choosing begin and end azimuths, begin and end ranges, and a maximum elevation angle. An EZ can prevent areas of known clutter, which can't be removed by the clutter filter, from contaminating the Hybrid Scan.

Coming up in software Build 11.0, bypass maps will be generated in real time, every volume scan in an automation technique called Clutter Mitigation Decision (CMD). This new algorithm will identify and filter AP clutter on the fly. For additional CMD information, see "Coming Attraction! The Clutter Mitigation Decision (CMD) Algorithm," as well as, "A Move Toward Automating the WSR-88D" in this issue of *NEXRAD Now.*

Each RPG also requires the input of a valid Z-R (reflectivity to rainfall rate) relationship. The optimum Z-R relationship is a function of numerous environmental variables, including the season, the geographic location, and expected weather type. The ROC recommends sites use one of five relationships, based on geographic location and precipitation type. All of these parameters are further explained in the Guidance on Adaptable Parameters, which has been updated for Build 10.0 and is available on the ROC web site at https://www.roc.noaa.gov/security/files/manuals/Operations_TMS/B8/APH_B8_FINAL.pdf.

With all of these possibilities, there are simply too many things that a meteorologist can do to make a perfectly good radar *look* bad. For example, let's assume the meteorologist likes a "hot" radar, because it shows clear air phenomena very well. Unfortunately, a radar which is a bit warm overestimates precipitation. One can decrease RAINA, decrease RAINZ, or increase CLUTTHRESH (or some combination of the three), all of which will service to increase precipitation estimates. And, it is just as easy to make a perfectly calibrated radar *look* "cold" (tend to under-estimate rainfall).

Now, a perfectly calibrated radar *should* have a precipitation (MPE) bias around 1. A radar whose calibration has drifted would have a low bias if the radar is "hot" and a high bias if the radar is "cold."

The above is completely true in a perfect world with perfect, homogeneous weather events. But, how often is that the case? Given the radar is perfectly calibrated and given that all of the adaptable parameters are set to the optimum values, there are often times that the MPE bias is not around 1. What may be causing this to happen? The first variable to consider is the weather. No weather event is completely homogeneous, so having the ability to apply just one Z-R relationship induces the possibility for precipitation estimation errors.

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MPE Bias

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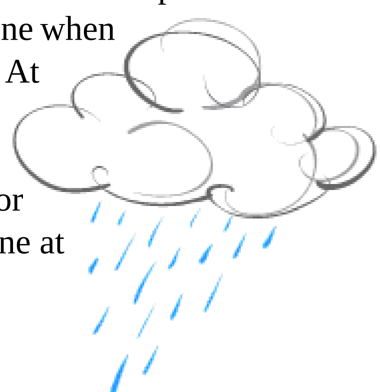
Also, there are below beam effects, i.e. strong winds displacing the rainfall causing the possibility of both over- and under-estimates; and, evaporation and/or coalescence may induce a bias. The character and duration of the weather event can also have a major impact on the calculated bias.

While discussing the subject of radar precipitation estimates being sensitive to the weather, it should be mentioned that the MPE bias itself is sensitive to the weather. For example, given the same radar and same calibration, a long-lived winter storm will likely have a different bias than a thunderstorm event. Other factors affecting the bias in addition to the radar and the weather include: functionality of the rain gauges, their locations, the limited sampling area of the rain gauges (which is magnitudes smaller than a radar sampling bin), and software, which are all independent of radar issues.

So how can a radar be diagnosed as "hot" or "cold" with the huge number of uncertainties that comes from using the bias? Stick to the basics. Look at the base reflectivity and the calibration. Comparing the base reflectivity of one radar with its neighboring radars is the best way to determine if one of the radars in question is "hot" or "cold." The base data have not been manipulated by algorithms and adaptable parameters like the MPE bias. Remember, the radar doesn't measure precipitation; it measures the reflectivity of targets and then calculates precipitation. The MPE bias is simply a tool available to correct for a non-representative Z-R relationship. It says NOTHING about the radar calibration. Radar calibration does not change based on whether or not the bias is applied. That being said, if the bias stays consistently high or low, or continually rises or falls, then there may be a radar issue or there may be an operator-induced issue. Correcting the problem may be as simple as changing one of the adaptable parameters discussed above. And, that is the best place to start when diagnosing suspected radar precipitation estimate problems.

The moral of the story is: NEVER troubleshoot a radar based on precipitation estimates. If the problem is caused by a radar calibration issue, then the MPE bias should track with the other information gained from troubleshooting. In other words, if the calibration is "cold," then the reflectivity estimates should be weaker and the rainfall estimates should be low (underestimated) and this should result in a high bias. The opposite is true for a "hot" radar. If the information does not track, such as would be the case if the radar was found to be cold and the bias was low (indicating a "hot" radar), then it is almost certain that a significant change was made to the adaptable parameters at the RPG, in an attempt to adjust for the cold radar. This is really hard for the technicians to troubleshoot.

The best solution to these issues is to have the technicians do their best to tune-up the radar then have the radar focal point baseline the adaptable parameters on the RPG end. Precipitation estimates will then fall in line when the radar is calibrated. At any time, if there are questions or concerns, please contact the author on the NEXRAD Hotline at 1-800-643-3363.



Amy Maddox
ROC Operations Branch

Scenic RDA Photo Contest

Photo Courtesy La Crosse, WI WFO

Photo Courtesy Medford, OR WFO

Photo Courtesy
Radar Operations Center

Scenic pictures of WSR-88D RDA tower sites are now being accepted for the Scenic RDA Photo Contest. Field site personnel throughout the WSR-88D network are invited to apply their photographic creativity and skill in taking scenic shots of their respective RDAs which uniquely incorporate factors like lighting, weather, sky cover, and setting. Unenhanced digital photos should be sent to the WSR-88D Hotline at nexrad.hotline@noaa.gov with email title, "SCENIC RDA PHOTO CONTEST" no later than December 31, 2008. Entries will be judged by a panel of judges from all three NEXRAD agencies. Winners and finalists will be announced in *NEXRAD Now*. Winning photos will be shared in *NEXRAD Now* and the ROC web site, so all can enjoy them. Please direct contest questions to Daryl Covey at 405-573-8866.

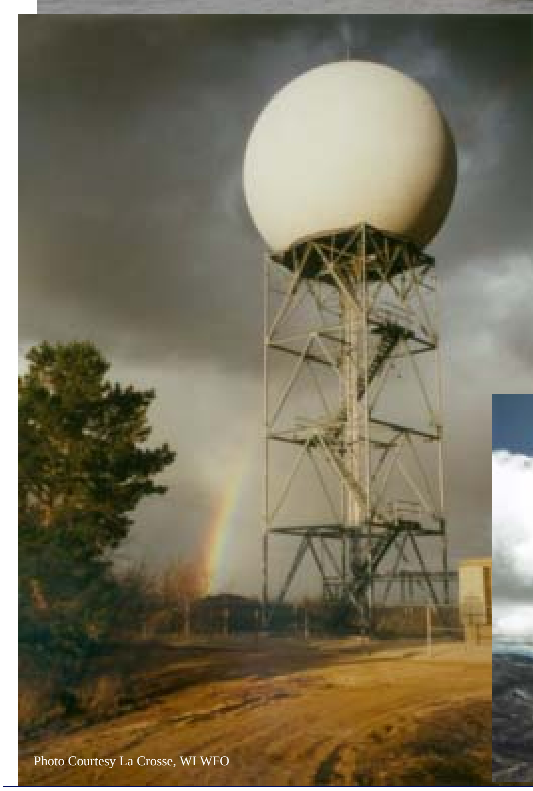


Photo Courtesy La Crosse, WI WFO

Photo Courtesy
Radar Operations Center

Daryl Covey
ROC Operations Branch