9/21/2011

An Operational Assessment of Pre-Deployment Dual Polarization WSR-88D Radar Data

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Assessment Goals and Resources:
In June 2009, the National Severe Storms Laboratory (NSSL) baseline WSR-88D, KOUN, was upgraded to Dual Polarization (DP) capabilities. As part of a series of internal reviews of the DP data from KOUN, a group of meteorological and radar experts recommended that field forecasters assess DP data prior to its deployment to the field. In response, the Radar Operations Center (ROC) Applications Branch and the Warning Decision Training Branch (WDTB) jointly planned and conducted an operational assessment of Pre-Deployment Dual Polarization data from the KOUN WSR-88D. The assessment took place in the WDTB Training Laboratory located in the National Weather Center, Norman, OK. The primary objective of the operational assessment was to have field forecasters assess the utility of applying DP data to forecasting and warning operations. Additionally, the assessment had some key secondary objectives: 1) *train and expose forecasters to the use of DP data, 2) document forecaster feedback on DP data and their expectations of integrating the new data into their office's forecast and warning operations*

A team, composed of ROC, WDTB and NSSL personnel, was assembled to plan the assessment. The team decided early-on to use WDTB's 24-workstation Advanced Weather Interactive Processing System (AWIPS) laboratory to hold the majority of the assessment. The classroom's facilities were perfect to have participating forecasters test DP concepts and applications by reviewing DP case studies. Classroom training was also held in a conference room within National Weather Center. Team members coordinated with the National Weather Service (NWS) Regional Science Directors to select forecaster participants from across the country. Center Weather Service Units (CWSU) and United States Air Force (USAF) forecasters were also invited. Although the CWSU invitees had to bow out due to commitments, two USAF forecasters did participate. A total of twenty forecasters participated in the assessment, the majority coming from the NWS.

Test Methodology:
In order to meet the goals of the assessment we organized it into four phases:

PHASE I: Train and expose forecasters to DP fundamentals, DP base variable and derived products and DP forecasting and warning applications

PHASE II: Forecasters review and assess DP data

PHASE III: Train forecasters on key DP performance characteristics

PHASE IV: Forecasters write assessment summaries: this included their opinion about 1) what are the top DP key benefits, 2) the top challenges to integrate DP data into operations, and 3) what are most important research areas to improve DP products and algorithms

Funding for this event was limited so we restricted the assessment to three days. PHASE I, the training phase, was conducted via pre-assessment training and on the 1st day of the assessment. PHASE II, the assessment phase, occurred on the 2nd and part of the 3rd day of the assessment, followed by PHASE III and PHASE IV, also on the 3rd day. To assist with the execution of the operational assessment, a team of experts was assembled to provide insight into the use and interpretation of DP data as well as answer forecaster questions. We looked for key individuals within the WDTB, the ROC and NSSL who were Subject Matter Experts (SMEs) in weather radar, operational testing, meteorological training, DP data interpretation and applications. This group of individuals, the Operational Assessment Team (OAT), finalized the assessment plan, conducted the assessment and analyzed and summarized the results.

During PHASE IV, forecasters reviewed data via a "case study review" format. This consisted of forecasters reviewing radar data for a given weather event while completing tasks listed in a job sheet. Job sheets were written such that forecasters were required to use DP data in conjunction with legacy WSR-88D products while reviewing the given case study. For each case study the OAT provided forecasters a synoptic weather overview, a case-study analysis period where radar data was reviewed and a post-case study review. OAT members were available to answer forecaster questions during the case study analysis period and the post-case study review. The post-case study review consisted of a review of storm reports and tasks listed in the job sheets. The weather events the OAT chose for DP case study reviews were related to mission-critical forecasting and warning operation areas: winter weather, flash floods, tornadoes and severe convection (severe wind and hail alone). Obviously, there are other important weather event operations such as those associated with fire and marine weather events. However, the KOUN DP prototype is located in Central Oklahoma, far from the coast, and there weren't any notable scrub fires in 2010. The four case studies chosen for the assessment are summarized in Table 1.

Table 1: Case studies used during the case study review phase.

CASE STUDY	REVIEW TIME ALLOTTED
I. Two DP Winter Weather Events over Northern and Central Oklahoma, 26 February and 20 March, 2010	2 hrs 10 minutes
II. 14 June 2010 Flash Flood Event in Oklahoma City, OK	2 hrs 10 minutes
III. Central Oklahoma Tornado Outbreak and Examples of Very Large Hail, 10 May 2010	3 hrs 20 minutes
IV. Bow Echo over Northern Oklahoma, 19 May 2010	1 hr 45 minutes

Data Collection and Preparation

For the purpose of creating DP data cases for the assessment, Level II WSR-88D data from the KOUN DP prototype were collected, played-back and ingested into AWIPS. For use during the synoptic overviews upper air and surface maps were downloaded from a host of Internet web-sites. We also downloaded storm reports from the Storm Prediction Center, Norman WFO and the CoCoRahs web-sites to provide ground truth information for each DP data case during the case study post briefings. Finally, Level II WSR-88D data were collected from a number of sites across the U.S. to be used as part of a DP vs. Legacy sensitivity demonstration during the assessment.

Assessment Training

Critical to meeting the primary goal of the assessment was training forecasters, some of whom had little experience with DP data, to a level sufficient to consider DP data's utility in forecasting and warning operations. To mitigate this, we required forecaster participants to take part in DP training prior to the assessment. For NWS personnel, this consisted of an eight hour training course, the "Dual Pol Primer on the Weather Event Simulator (WES)" produced by the WDTB. As the Air Force forecasters do not have access to a WES, a proxy of this training was provided via existing WDTB DP education modules available on the WDTB web-site. This way, all the forecasters arrived at the assessment with an introduction to the fundamental concepts of DP.

Table 2: A listing of the training course provided prior to and during the 1st day of the operational assessment.

COURSE WORK	TIME ALLOTTED
Dual Pol Primer on the WES ***(Pre-assessment only)***	8 hours
Dual Pol on-line Training Modules ***(Pre-assessment only for AF)***	2 hours
Basic Principles of Dual Polarization	15 minutes
Correlation Coefficient	30 minutes
Differential Reflectivity	45 minutes
Specific Differential Phase	45 minutes
Hydrometeor Classification and Melting Layer Detection Algorithms	40 minutes
DP Quantitative Precipitation Estimate Products	30 minutes
DP Forecasting Applications for Snow, Rain, Melting Layer and Heavy Rain	40 minutes
DP Forecasting Applications for Hail, Strong Updraft, and Tornado Debris Signatures	1 hour
Putting it all together: AWIPS DP Demo with 16 May OKC hailstorm, 19 May Central Oklahoma Supercells & 04 July Heavy Rain event	1 hour 15 minutes

The training provided on the 1st day of the operational assessment was designed to reinforce, as well as, build upon the training they completed prior to their arrival. Presented were the fundamental DP concepts, the key DP base variable data and derived products, and how to practically apply the information during forecast operations. A section was provided that taught forecasters how to pull together the various DP products in order to make forecasting decisions.

We emphasize that the training provided was not sufficient to develop forecaster expertise. Instead, it provided familiarization with the DP data and knowledge of how to apply it during forecasting and warning operations. Therefore, when forecasters began the assessment phase, e.g. PHASE II, they would have enough knowledge to consider the utility of using DP data. A complete listing of the training provided can be seen in Table 2.

Sensitivity Demo

A portion of the last day of the assessment was used to discuss key DP performance characteristics. One of the items addressed was the 3.5 to 4 dB sensitivity loss expected when a WSR-88D is upgraded to DP capabilities. The sensitivity loss is due to the splitting of the power into horizontal and vertical channels (3 dB) and the additional power loss associated with the installed DP hardware (0.5 to 1 dB). The maximum sensitivity loss for each WSR-88D radar is expected to be no more than 4 dB as deduced by a ROC engineering analysis (ROC Technical Report III, 2010). For the assessment, we took radar data from locations across the country exhibiting a wide variety of weather radar signatures. We showed forecasters these signatures at legacy and at DP sensitivity. For the DP sensitivity, we simulated a 4 dB sensitivity loss via a methodology very similar to that used by Scharfenburg, et al. (2005). Specifically, we adjusted the signal-to-noise ratio (SNR) thresholds to remove the data with the lowest 4 dB of power return. Some examples of what was shown to forecasters are seen in figures 1-3. In general, the images show that weather radar signatures are still clearly visible in DP data with a reduced sensitivity. This demo was used to help alleviate any concerns forecasters may have about losing forecasting and warning capability due to the DP associated sensitivity reduction.

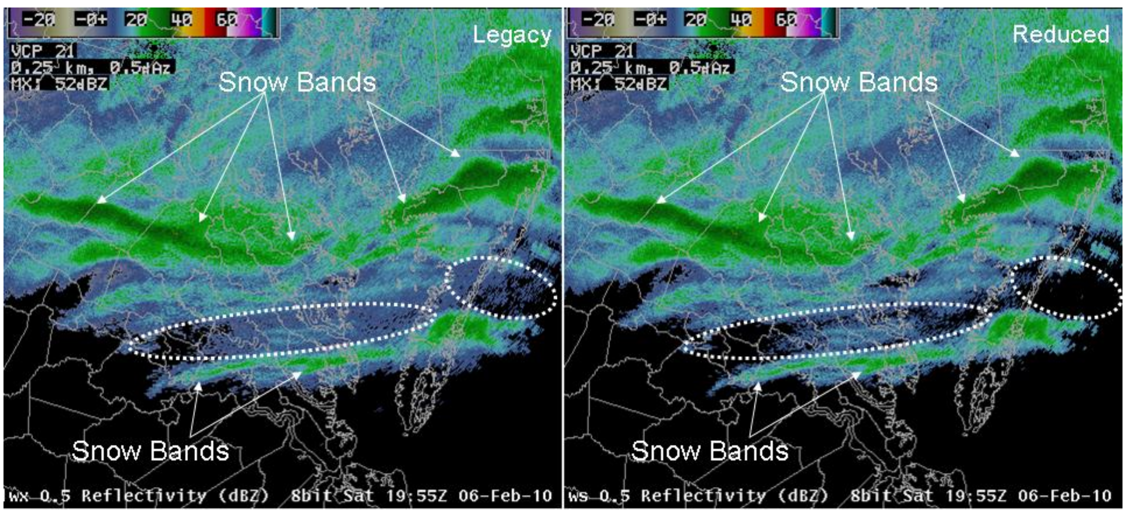

Figure 1: Sensitivity Demo example: 1/2 degree base reflectivity at legacy, left, and 4 dB reduced sensitivity, right, 1955Z for snow bands southeast of the Sterling, VA radar on 06 February 2010. Only the weakest signal, located on the fringes of the echoes (dashed ovals), are lost in the reduced sensitivity image. The structure and the peak dBZ values within the snow bands are preserved.

Assessment Surveys

As mentioned previously, the primary objective of the operational assessment was to have field forecasters assess the utility of applying DP data to forecasting and warning operations. The OAT used a combination of on-line surveys and assessment summaries to document forecaster

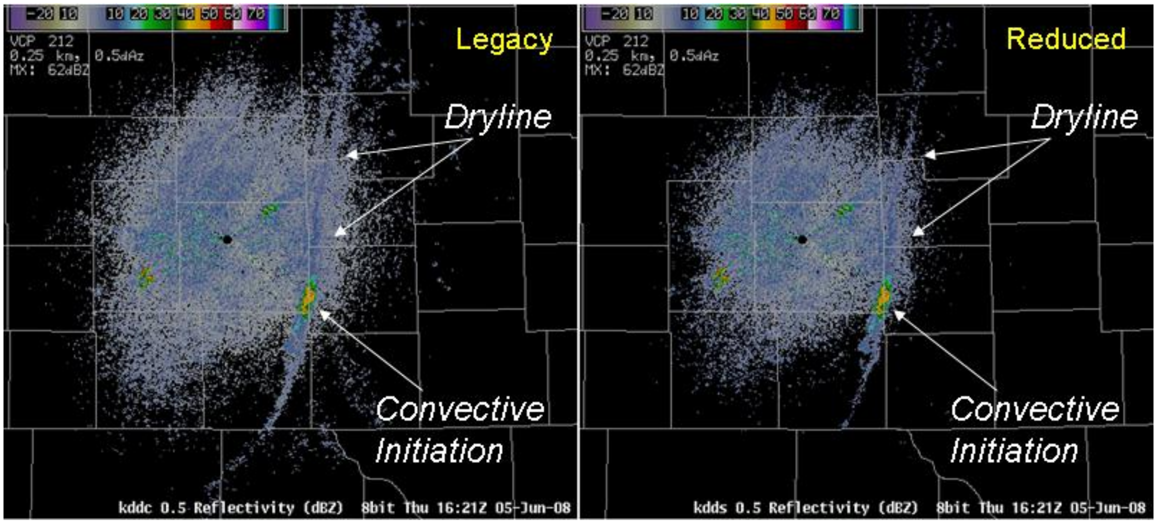

Figure 2: Sensitivity Demo example: 1/2 degree base reflectivity at legacy (Left Top, Left Middle, Left Bottom) and 4 dB reduced sensitivity (Right Top, Right Middle, Right Bottom) at 1609 and 1621Z for a dryline passing through Dodge City, KS.

feedback about the utility of using DP data in operations. The on-line surveys were used to gain a measure of whether forecasters believed DP data would increase the effectiveness of the WSR-88D. To do this, participating forecasters completed a pre-assessment survey rating the effectiveness of the legacy WSR-88D in their winter weather, flash flood, severe convection and tornado forecasting and warning operations. Immediately after the operational assessment, the forecasters took ta survey nearly identical to the one taken prior to the assessment. The key differences were forecasters were asked to rate the effectiveness of the DP WSR-88D for operations based on what they learned during the operational assessment and to provide feedback on the utility of the DP data. The changes in the pre and post-assessment effectiveness ratings measured whether they could foresee an increase or decrease in the WSR-88D's effectiveness due to the DP upgrade. We also examined the forecaster comments about DP data for recurring themes to gain an understanding of why the forecasters gave the DP WSR-88D a particular rating. We classified the post-assessment survey comments as positive, negative and neutral. A ***positive*** comment clearly indicated forecasters thought DP data could improve their capabilities. A ***negative*** comment indicated a forecaster believed DP data could detract from their capabilities. A **neutral** comment clearly indicated forecasters believed that the addition of DP data neither improved nor detracted from their capabilities. An example of a neutral comment would be the following: *"The use of dual-pol variables did not significantly increase my ability to detect tornadoes."* Finally, the OAT asked forecasters to write what they believe are the top DP benefits, the top challenges they believe they will face when the DP upgrade comes to them and what DP areas they consider needed the most research and development.

Operational Assessment Survey Results

The pre and post assessment rating averages for each of the key forecasting and warning operations are shown in figure 4. The largest difference in what the forecasters foresee as an improvement in the effectiveness of the WSR-88D that the DP upgrade will bring is with respect to Winter Weather events. Pre-assessment ratings were quite varied but after the assessment ratings shifted and clustered toward higher values (figure 5). Out of 29 comments, nearly 76%

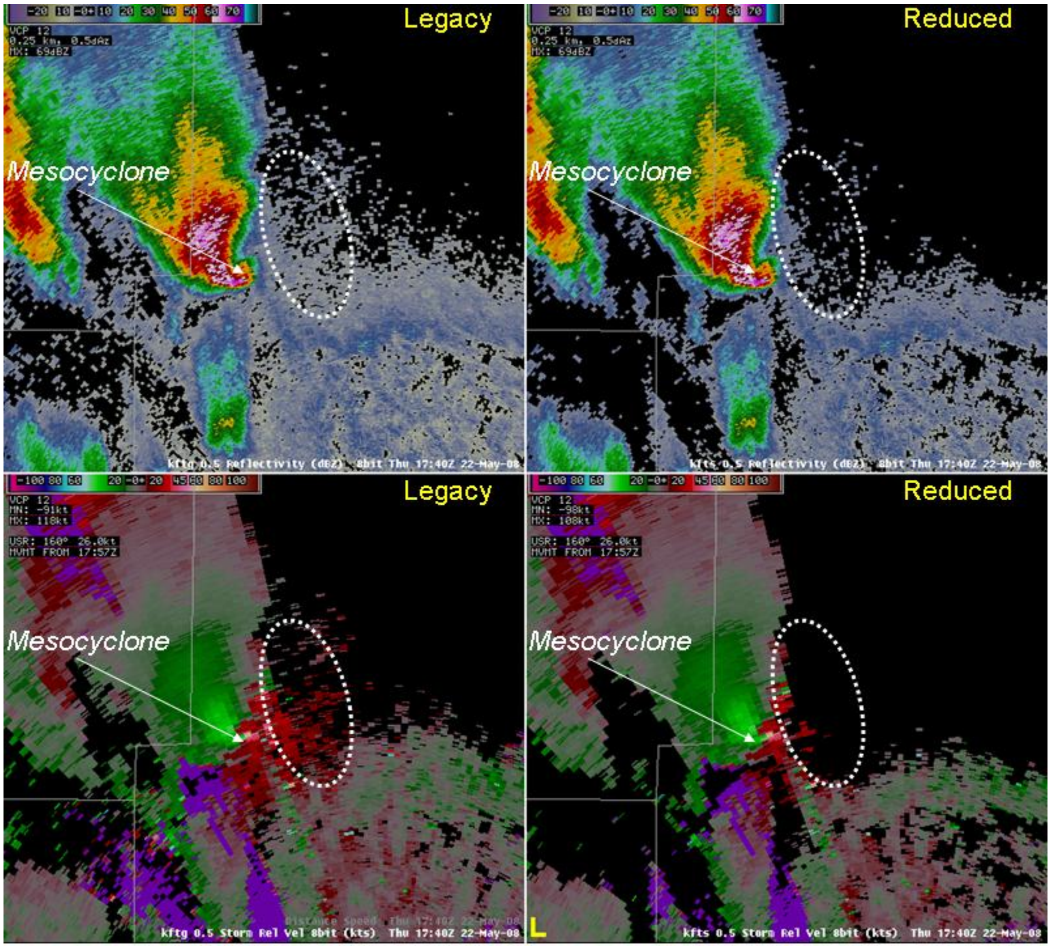

Figure 3: Sensitivity Demo example: 1/2 degree base reflectivity and storm-relative velocity images at legacy (Top Left, Bottom Left) and 4 dB reduced sensitivity (Top Right, Bottom Right) for the Windsor, CO supercell, 1740Z on 22 May 2008. Note the loss of low signal-to-noise ratio data in reflectivity and velocity data (white dashed ovals); nonetheless, the mesocyclone is clearly visible.

were positive, 21% were considered neutral and one was negative. Positive comments focused on the use of DP data 1) to explicitly determine the location of the melting layer, 2) to determine the precipitation type during winter and delineate where rain/snow transition lines likely exist, particularly in areas where spotters or surface observations are sparse, and 3) to potentially bring a higher degree of confidence in short term forecasting during winter events. Some key comments include:

".....This, along with hydro(-meteorology), is where DP should pay for itself. In its current configuration, the WSR- 88D is more of a background tool during winter precipitation events since the vast majority of our events in the interior Southeast involve mixed precipitation type. It is often the case that precipitation type remains largely a mystery to our forecasters until spotter reports of precipitation type are received. DP will infuse the now-casting and near-term forecasting of winter weather events with a boost of confidence"

"Dual Pol radar will be most effective at winter weather analysis and precipitation type determination………"

Forecasters also foresee DP increasing the WSR-88D's effectiveness during Flash Flood forecasting and warning operations with nearly 80% of the comments positive. As seen with the ratings distribution for winter weather, pre-assessment ratings for WSR-88D effectiveness in

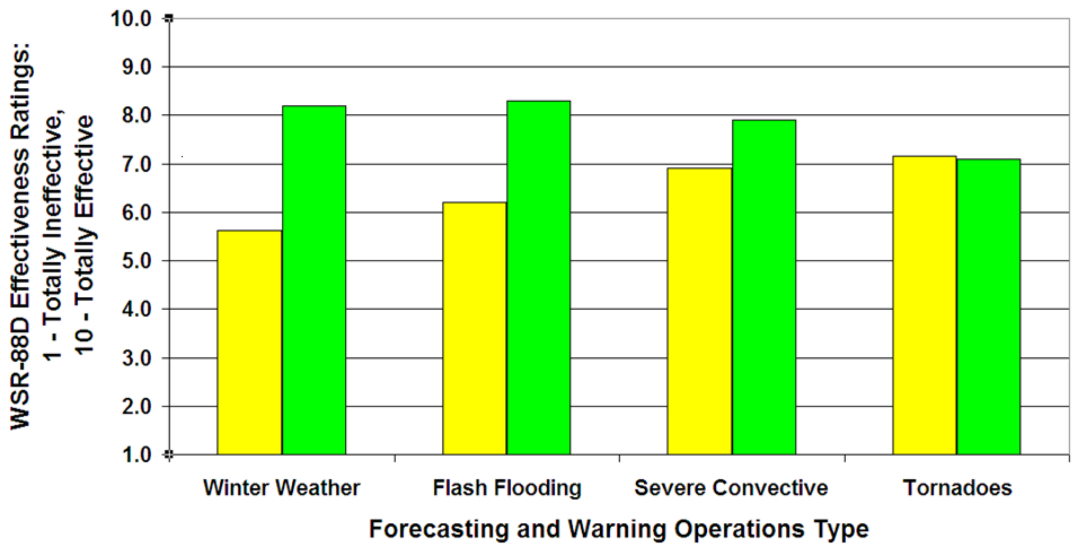

Figure 4: Average forecaster ratings for the effectiveness of the current (yellow) and the coming DP (green) WSR-88D for key forecasting and warning operations events.

flash flood operations were varied but had shifted to higher values after the assessment (see figure 6). Nearly half of the positive comments specifically mentioned the utility of the DP base variable products to target areas with the heaviest rain rates. Three (out of 25) comments were negative and focused on some of the DP Quantitative Precipitation Estimation (QPE) limitations discussed during the assessment. Some key comments include:

"Better able to identify areas of heavy precipitation over the standard radar, especially (using the DP product) Specific Differential Phase (data)"

"…….The use of specific differential phase (DP product) to help ascertain precipitation loading/rain rate and differential reflectivity (another DP product) for drop size was a great help in building my conceptual model of the ongoing processes in the cloud. Elevated specific differential phase would definitely point me to potential areas for flash flooding, especially embedded within a broad area of heavy rain. I'm sure it will also help our other forecasters."

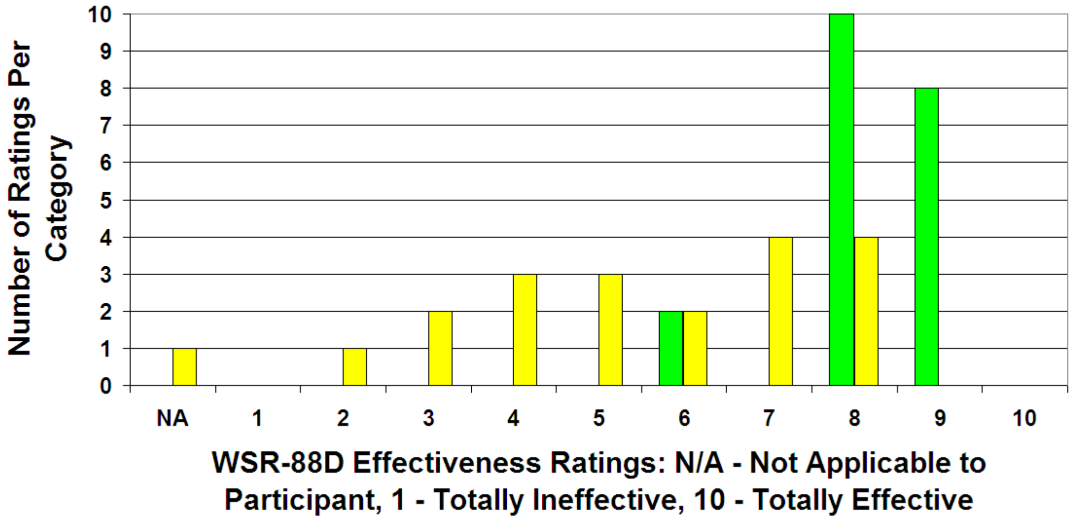

Figure 5: Distribution of the Pre (yellow) & Post (green) Assessment forecaster ratings for the effectiveness of the WSR-88D during winter weather events. Note the large spread in ratings in the pre-assessment changing to a tighter cluster in the post.

Forecasters also foresee DP increasing the WSR-88D's effectiveness during Severe Convection (not shown) but not to the magnitude of what they expect for Winter Weather and Flash Flood operations (figures 5 & 6 respectively). An examination of the comments reveals why. Forecasters noted the need to discern between non-severe and severe hail size: 1" or greater for NWS, greater than ½ inch for the Army and greater than ¾ inch for the Air Force. Currently, there is no algorithm using DP data that is sophisticated enough to provide this information. Additionally, forecasters did not see DP data adding value to the prediction or detection of damaging winds. Nonetheless, forecasters noted that DP data 1) increased their awareness of where hail was located within storms, 2) helped them distinguish whether or not hail is of extreme size (> 2 inches) and 3) helped them target storms with strengthening updrafts, hence needing closer monitoring. Of the 23 comments, 65% were positive and 35% were neutral. Some key comments include:

"……..I would rate this higher if we had the capability to distinguish severe hail (one inch) vs "giant" (two inch+) hail…….. most of our storms are pulse with 1-2 supercells per year so it is this "marginal" realm that would provide the biggest operation improvement for us."

"I think that dual pol variables will be used in our office quite a lot in determining the location of hail….. as well as the location of the heaviest rain shafts…… I think the (DP) variables give good insight in being able to assess not only the threat but also helps to fill in the gaps in the conceptual picture of (an) individual storm's structure."

Forecasters did not believe DP would appreciably change the WSR-88D's effectiveness in tornado warning operations, at least in terms of increasing tornado lead time. Again, an analysis of the comments provides an explanation. Forecasters noted that DP would not add any value over what is currently available in the legacy WSR-88D base products for issuing a tornado warning. However, forecasters did note the potential for DP data confirming the presence of a damaging tornado for storms within 60 nm of the radar, a great asset at night or in spotter-sparse regions. Forecasters noted this would 1) enhance their situational awareness, 2) provide a way to communicate the tornado threat more effectively via follow-up severe weather statements and 3) help in tornado track analysis for damage surveys. Of the 29 comments provided, 59% were positive, 38% were neutral and one was negative. The one negative comment was a concern about the potential loss of velocity data due to the inherent sensitivity loss associated with the DP hardware upgrade. Some key comments include:

"…….using the correlation coefficient and differential reflectivity (DP products) to determine the potential for debris will likely aid in increased threat wording in the (communication of) severe weather statements as well as aid in where to focus a post storm survey team."

***"**Using Dual-Pol data to identify debris can definitely add value to tornado warnings by identifying that a damaging tornado has been confirmed, and, when Dual-Pol rolls out, I see this as a signature that we will all be closely looking for when dealing with potentially tornadic convection."*

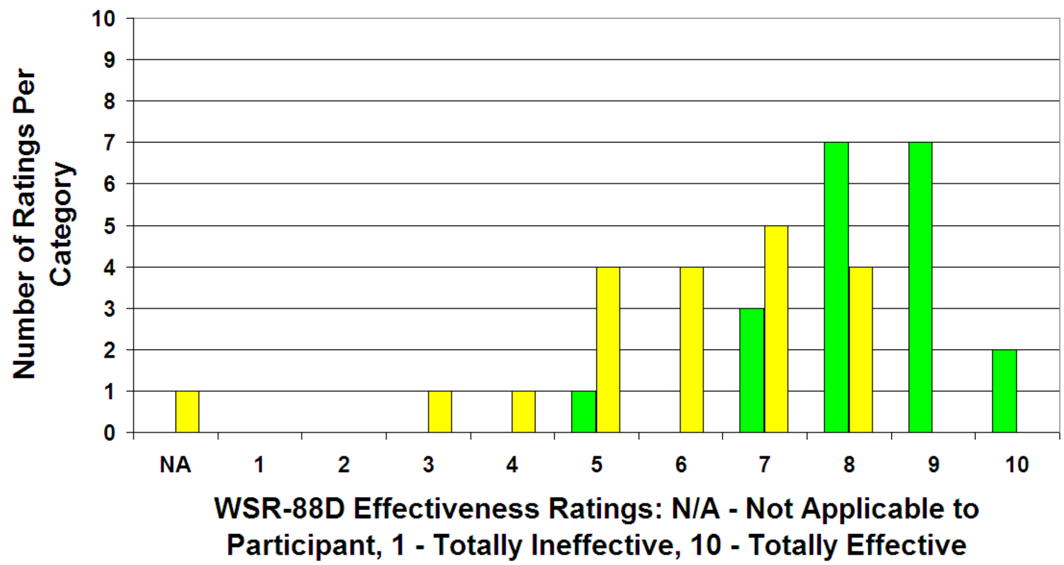

Figure 6: Distribution of the Pre (yellow) & Post (green) Assessment forecaster ratings for the effectiveness of the WSR-88D during flash flood events. Note the spread in ratings in the pre-assessment changing to a tighter cluster in the post assessment ratings.

At the end of the assessment, each forecaster wrote a summary that addressed what they believed were the top DP benefits, the top challenges of implementing DP into their office operations and what they believed are the top research areas needed to improve DP data. By far, the top DP benefits noted were 1) the improved ability to pinpoint heavy rain along with the potential for receiving better rain estimates through DP QPE, 2) the improved ability to interrogate severe convection, e.g., discerning hail, updraft strength and tornado debris locations, and 3) an improved capability to discern precipitation type during winter weather events. The top challenges mentioned in forecaster summaries were the 1) need for DP training, 2) developing expertise within the office and 3) the perceived workload increase with the addition of the new DP data. Finally, summaries showed forecasters believed the most important DP areas needing additional development and/or improvement were 1) work in refining the DP QPE algorithm and 2) developing a method for DP to explicitly discern hail size.

Conclusions

The OAT team was able to draw some conclusions based upon the analysis of the Operational Assessment survey results, comments and forecaster summaries. First, forecasters foresee DP increasing the WSR-88D's effectiveness during Winter Weather, Flash Flood, and Severe Convection forecasting and warning operations. Forecasters don't anticipate DP data will improve their ability to issue tornado warnings with increased lead-times. However, forecasters do see potential for DP to confirm the presence of damaging tornadoes, which in turn will improve their situational awareness and the ability to convey to the public the threat in follow-up severe weather statements.

Second, forecasters believe the top challenges of implementing DP into office operations will be the development of a robust training program, developing forecaster expertise and a method for mitigating the increased workload perceived with the new DP data. In response to this feedback, WDTB prepared four different Dual-Polarization radar courses, two of which are intended for NWS users, one designed for non-NWS meteorologists, and finally, training for non-meteorologists. The most extensive training is the DP Radar Operations Course for NWS users. It is presented in a series of modules on the new DP products and their applications, followed by hands-on exercises. This course requires 8-10 hours for completion. The WDTB has also made available numerous training aids, and printed documents of course materials. All of the above can be accessed from

http://www.wdtb.noaa.gov/courses/dualpol/index.html

Third, forecasters believe the top research areas to improve DP data should be to continue improvement of the DP QPE algorithm and to develop the ability to distinguish hail size. The Office of Science and Technology and the ROC has supported funding in these areas for fiscal year 2012. A copy of the final report for the Operational Assessment can be found at the following ROC URL site:

http://www.roc.noaa.gov/WSR88D/Applications/AppsPapers.aspx

References:

Scharfenburg, K. A., K. L. Elmore, E. Forren and V. Melnikov, 2005: Estimating the Impact of a 3-dB Sensitivity Loss on WSR-88D Data. 32nd Conf on Radar Meteorology, Albuquerque, NM, Amer. Meteor. Soc.

Technical Report, 2010: Sensitivity Analysis: Comparing the WSR-88D Baseline and L3 Baron Dual Polarization Modification, Report from the Radar Operations Center, 25 pp [Available from NOAA/ROC, 1200 Westheimer Drive, Bldg 375, Norman, OK 73069]