Technical Advisory Committee Meeting Notes
25 March 2022 (10:30 a.m. - 3:15 p.m.)
Open Session Portion

NEXRAD TAC Agenda

Virtual Meeting

March 25, 2022 10:30 to 15:30 CDT

10:30 – 10:35 AM Roll Call & Opening remarks – John Snow, TAC Chair

10:35 – 10:45 AM SLEP Update – Dan Hoffman - Program Branch

10:45 – 11:15 AM New MLDA - John Krause, Alexander Ryzhkov, Heather Grams

11:15 – 11:45 AM Nonlinear Receivers and impact on ZDR - Valery Melnikov

11:45 – 12:15 PM Specific Attenuation Rain Rate Updates - Pengfei Zhang, Steve Cocks, Heather Grams

12:15 – 12:45 PM Dual Pol Snow QPE - Petar Bukovcic, Jian Zhang

12:45 – 1:15 PM Predicting fallout of heavy snow – Jacob Carlin

1:15 – 1:45 PM Improving fields of polarimetric variable estimates at low-to-moderate SNRs - Igor Ivic`.

1:45 – 2:15 PM Range Oversampling - Sebastian Torres.

2:15 – 2:45 PM Hazardous Weather Testbed – Brandon Smith, Thea Sandmael

2:45 – 3:15 PM Regression clutter filtering - John Hubbert

3:15 – 3:20 PM Closing Remarks and Adjourn – John Snow

SLEP Update - Dan Hoffman

Signal processor and transmitter refurbishment are fully completed. Generator SLEP is on a hiatus due to supply issues.

First three task orders are completed for the Pedestal SLEP, with 101 sites completed. Currently on fourth task order with two to go (sixth set to end in July 2024).

- Quality control issues observed during first six sites in 2018, but both teams have shown matured improvement that has been consistent in subsequent task
- OCONUS shipping costs have increased for HI and AK, so have to use ocean shipments instead of air/barging/trucking

Shelter Maintenance and Repair SLEP: 114 repaired, last shelter refurbishment in Nov 2021

Comments: Terry Clark said one of the improvements was the signal processor and transmitter. The pedestal has more digital control than it did compared to using analog before, and some of the backplane and circuit boards have been modernized.

New MLDA - John Krause, Alexander Ryzhkov, and Heather Grams

Need radar data at all elevations to overcome existing MLDA issues: only uses elevations > 4° (so only data in close proximity is used for melting-layer (ML) designation extrapolated to FOV), misses fronts at far range, and does not generate map of real heights at ML top and bottom.

New MLDA concept uses Z and CC data from all elevations (including lowest) to generate a 2-D map of ML heights; ML parameters also quantified at closer distance from radar at higher tilts. Maps of heights of ML top and bottom generated at distances up to 150 km from radar.

Initial version of the new MLDA algorithm has been implemented in C++ on ORPG Build 20 and tested on cases with varying degrees of spatial nonuniformity. Although the old MLDA performed relatively well in summer, the new MLDA generally handles winter precipitation characteristics better. Mild underestimation of ML top height is occasionally observed in the RD-QVPs, but the bottom height used with QPE for R_A and snow to rain transition is generally good.

Very minor changes were found and suggested made in coordination with the ROC after ORPG implementation. Tech Transfer (Heather) is working on adjusting the algorithm to lower its memory footprint. Wrapping and running the new MDLA on the ORPG provides a baseline for identifying performance issues when using ORPG specific radar and model data, which builds confidence in output by allowing the testing team to run cases independently of the developer.

Underlying models of ML and radial CC profiles are not valid in deep convection, so pre-classification needs to be performed in those areas, especially for embedded deep convection. Ultimate goal is to generate a map of ML height in a 150-km radius area centered on a radar with an optimal solution for merging the radar and model data in echo-free zones that works in all seasons (including deep convection). It works in ML height intervals from 0-5 km, but is best from 0-3 km.

Questions/Comments:

- Training requirements can't really be answered from the development perspective, but said the products are straightforward from ML height.
- Severe improvement is expected to HCA and its ability to identify snow. QPE reliability should increase because ML should be well delineated at top and bottom over a large area instead of having to use model data where the beam is believed to be below ML.
- Need to quantify what is meant by "mild underestimation of ML height."
- Some refractive reflectivity issues, but decent performance in strong baroclinic zones. .

Nonlinear Receivers and Impact on ZDR - Valery Melnikov

To measure ZDR with an accurate of 0.2 dB, a radar receiver should be linear to 0.1 dB> However, ZDR measurements with nonlinear receivers (like KOUN) can result in different values from similar weather objects that affects ZDR calibration and associated ZDR values from precipitation, Bragg scatter, and solar flux. An increase in ZDR with decreasing signal-to-noise ratio (SNR) is expected from analyzed weather data.

KOUN's nonlinear receiver impacts were analyzed using the SNR interval from 2-20 dB using cases with stratiform precipitation and clouds above the melting layer with antenna elevation < 30^{o} and no corrections for differential attenuation. ZDR was found to generally increase when SNR input decreases, but actual histograms differ because ZDR is not uniform in clouds.

Temperature dependence of the system ZDR offset (with examples provided) found four types of temperatures dependencies in the WSR-88D systems during February 2021 (excluding 9 sites where the temperature radome sensor was not working), including:

- 38%: Strong correlation of ZDR offset decrease with temperature drops
- 31%: Mixed correlation of ZDR offset increases and decreases with temperature drops
- 3%: Anti-correlation of ZDR offset increases with temperature drops; and
- 21% of no dependence

Vaisala/Sigmet admitted their receivers' nonlinearity in discussions with ROC engineers in February-March 2022, so future work will focus on mitigating the impacts of nonlinear ZDR responses. RDA software can and should be designed to correct for this. The temperature dependence of the system ZDR offset will be analyzed as an ongoing Tech Transfer task. The source of fast temporal variations in ZDR offsets needs to be found to reduce/eliminate them.

A fast presentation on the calibration of ZDR using dry aggregated snow above the melting layer was also given. WSR-88D cannot be bird-bathed, but this has been an advantage of other radars and can be used to help calibrate ZDR in dry aggregated snow. Seven-step process was described with an example shown that relies on four parameters from each QVP: 1) lowest CC within ML, 2) median value of Z within 1 km of ML, 3) vertical gradient of reflectivity dZ/dh in a 3-km layer above the ML, and cloud depth height above the ML top. ZDR bias exceeds 0.2 dB in about 20% of cases, which is consistent with statistics for ZDR bias across the WSR-88D fleet. Overall accuracy of ZDR bias estimation is 0.05-0.06 dB.

Questions/Comments:

- More recent research from a group in Europe (German and/or Switzerland?) suggesting the ZDR dependence on temperature may be an impedance of mismatch between antenna and receiving system. Presenters stated that by the end of the year we should be able to tell if there is any temperature dependence in ZDR or not.
- For the ZDR calibration talk, a question was asked on how this differs from what ROC uses (Bragg scattering, snow, and rain). The two main differences are that approach uses 1) QVPs and 2) dry aggregated snow, which is more sophisticated. ROC said they use dry snow from HCA to check ZDR, but presenters believe that category is too wide in the current HCA algorithm. Need dry aggregated snow/less aggregated snow.

Specific Attenuation & Rain Rate Updates - Pengfei Zhang, Steve Cocks, Heather Grams

A single, forecaster initiated Z-R relationship was applied to the entire FOV until 2012, after which ROC and MRMS Project transitioned to operational QPE algorithms that automatically assign rain rate relationships dependent upon echo classification. R(Z, ZDR) and R(KDP) used for dual pol QPE, with a multiplicative factor times R(Z) and R(Kdp) above 50 dBZ. Rain relationships that are less sensitive to precipitation microphysics and attenuation are still needed.

Specific attenuation (A) fields provide measurement of the amount of attenuation caused by rain. Key to calculating A (via R(A) = 4120*A^1.03) is the Path Integrated Attenuation Term (PIA) that is composed of the differential phase span multiplied by a parameter alpha estimated by slope of ZDR to Z. Main R(A) limitations are addressing the spatial variability in alpha (stratiform higher due to smaller ZDR and convection lower due to higher ZDR) and ice contamination. Main mitigations are to use R(KDP) where hail is likely present, using model sounding data to diagnose ML structure, and internal sanity checks of ZDR vs. Z distributions.

Wet (dry) bias in convective (tropical/stratiform) rain observed in R(A) version 1.0 related to use of net alpha over radar FOV have been improved in version 2.0 by developing an adjusted alpha derived from the best fit curve to upper 20% of alpha vs. Z distribution; this adjusted alpha is used in a ratio with a net alpha to create a correction factor. Note:

- R(A) QPE generally does well for net alpha < 0.020 (especially if rain more continental)
- Net alpha > 0.020 adjusted for 40-50 dBZ In mixed stratiform/deep convection
- Conservatively adjusted alpha for range of best fit curve from 25-35 dBZ instead of relying upon algorithm due to dry bias in stratiform rain

Several high impact cases comparing R(A) vs R(Z,ZDR) during Build 19 testing found that using R(A) (with tropical R(Z,ZDR) as backup) is less biased than using tropical R(Z,ZDR) or continental R(R,ZDR). The default in Build 18 was the Continental R(Z,ZDR), which underestimates more than the Tropical R(Z,ZDR), including for Hurricane Harvey. The operational DP QPE using R(A) showed good performance for the wet period from April 1 to June 11, 2021 (cases and overall). Range dependencies in QPE bias were found with Hurricane Ida, which were relatively low at near range (<90 nm) below ML, but higher above the ML. Future tasks will need to address DP QPE underestimation above the ML, which may be done through implementing dual pol VPR correction as shown in example.

Remaining challenges including regional addressing differences in performance (e.g., KBOX 16 April 2021), wind farms affecting R(A) estimates (e.g., KCYS 28 April 2021), and addressing how alpha may be adjusted azimuthally (current version has constant alpha for whole scan).

Proposing a new way to estimate alpha azimuthally for each radial to better reflect DSD variations in a single scan (alpha should be constant along the radial, but can get alpha at each gate and average that). KFWS 1 September 2020 test case shows a slight improvement in ZDR bias (caused by wet radome), but the spatial variation in R(A) is most important. FY22 Tech Transfer efforts examining R(A) sensitivity to severe beam blockage, with RPI/R2O pursuing further testing of azimuthally varying alpha.

Regression Clutter Filtering - John Hubbert

Using a regression filter can improve signal statistics. The regression polynomial order selection needs to be automated, which can be performed if the number of samples, spectrum width, carrier to noise ratio (CNR; or SNR of modulated signal), and Nyquist velocity are known. Gaussian fit for the ratio of velocity estimate to Nyquist velocity is used, for which 0.2-0.3 vel/Nyquist is a good threshold.

Several examples were presented, with assertion made that most areas in NEXRAD will be like the-S Pol case since there are no overlapping windows (super-res) for the batch and higher cuts $\geq 1.9^{o}$. Blackman window is used when the ground clutter filter (GCF) is applied (von Hann used for S-Pol case). Overlapping 64-point, von Hann windows which slide 32 points at a time were found to have comparable effective resolution as a 32 point rectangular window, but the 32-point resolution was found to be better.

- There was concern that windowed to un-windowed regions are being compared instead of an apples to apples comparison of one or the other. The presenter said that you get better statistics using the regression filter because you throw out the annoying windowing functions that attenuate the signal. People in the audience still felt that when comparing data before and after, we should just be looking at where the clutter and CMD is, looking at where the filter is applied.

Regression filtering with super res offers a small amount of increased resolution according to calculated effective antenna patterns and recovery statistics. Also offers reduced processing times because the regression clutter filter is applied to contiguous 64 point (Doppler scan) and 16 points (LPRT scan) with half the number of time series compared to overlapping windows.

An error during the presentation was pointed out which resulted in the presenter updating his presentation. The old presentation was removed and updated within the TAC Presentation Google folder.

Dual Pol Snow QPE - Petar Bukovcic and Jian Zhang

Numerous Z(S) relationships have been proposed in the literature, with parameters that vary over an order of magnitude and have high variability. Limited guidance exists on which relationship would be most appropriate in different situations.

Variability of size distribution, snow density, and snow habits cannot be adequately captured by reflectivity alone.

KDP can be potentially useful for snow estimation. It is closer to the first DSD moment which is preferable to reflectivity which is related to the fourth moment of the DSD. A new S(KDP,Z) relation is proposed, which is less sensitive to particle size distributions than S(Z) relations.

NSSL/CIWRO is testing both S(KDP,Z) and S(IWC) methods. Aggressive spatial averaging is needed for KDP in these techniques to mitigate noisy data in snow.

Results from a December 2020 event showed much improved correspondence between the S(KDP,Z) and S(IWC) methods to ASOS data compared to S(Z). S(Z) significantly underestimated. Similar results were also observed for a freezing rain event which suggests that the snow methods may also be useful for QPE above the melting layer even if snow is not falling at the surface.

For validation, 30 additional cases were chosen from 88D radars to evaluate the S(KDP,Z) relationship. Different levels of KDP smoothing were tested for these cases, and different methods were evaluated for areas where KDP<0.03 deg/km. The snow relationship was also evaluated using a hybrid scan approach similar to previous QPE methods where higher tilts are substituted where lower tilts are impacted by clutter near the radar. The hybrid scan was set as a range limit with thresholds of 30-50 km (interpolation of multiple tilts in between these ranges).

Showed a case study from December 2019 near Topeka, KS. The hybrid scan approach performed slightly better for the event, and the 3x3 KDP smoothing was better than unsmoothed KDP, but at 20x20 KDP smoothing the QPE showed increased underestimation compared to the 3x3 KDP.

Overall, improved performance has been observed with the S(KDP,Z) method compared to S(Z) but large amounts of smoothing on KDP can introduce a dry bias.

Improving Fields of Polarimetric Variable Estimates at Low-to-Moderate SNRs - Igor Ivic

Polarimetric variables can be noisy where SNR is less than 20 dB and where CC < 0.95. Potential methods to improve the noisiness are:

- Range Oversampling and Whitening
- Hybrid-Scan Estimators (HSE)

ORPG preprocessor using moving average smoothing on Z, V, ZDR, and CC to reduce noise in the data but degrades the range resolution.

Weighted Adaptive Range Averaging (WARA) can prevent the resolution degradation and retain information in places with high gradients/variability. Showed some case examples with a lot of noise observed in the dual pol variables at far range and demonstrated that the WARA technique did better than current ORPG preprocessor at reducing the noise.

It's possible that the WARA technique may lead to enough improvement that DP variables could be used and displayed beyond 300 km range.

Predicting Fallout of Heavy Snow - Jacob Carlin

Relatively slow terminal velocity of snowflakes may enable the ability to predict precipitation type and intensity with improved lead time. Quasi-vertical profiles (QVPs) permit convenient time-height plots of precipitation microphysics, but require azimuthal averaging. Correlating Kdp aloft with Z at the surface using VADs is promising, but correlations varied between cases.

11 cases (6 in Northeast/Mid-Atlantic region, four in Northern Plains, and 1 in lower Mississippi Valley) with high KDP aloft (>0.2 deg/km around -15^{o}C) modeled, advecting particles using HRRR u and v winds with fall velocities between 0.8-1.2 m/s. General findings include:

- Kdp trajectories are relatively accurate and can predict onset of heavy snow with 75 min lead time, but results are sensitive to fall speed assumptions and ignores PSD evolution.
- Generally can forecast a weakening of bands as well through decrease in Kdp aloft.
- In 25 Jan 2022 KGLD case, southerly component of HRRR winds might have been too strong, which in the case of a narrow band results in large displacement of model error.

Lagrangian model trajectories from IMPACTS cases (using approximate 1-D snow model Bayesian chain, or pyABC simulations) can help constrain uncertain model parameters like Z, Zdr, and Kdp by quantitatively reproducing profiles of aggregating snow that are important for evolution of PSD down to the surface and resultant sensible changes in visibility, snow fall, etc.

Also looking at sublimation for snow nowcasting as well for cases with very dry air below the snow generation layer. “Donut” closing in on radar may not so linearly depending on variable precipitation intensity and thermodynamic profile, so looking for a more robust approach. 12 cases with proflicially dry air where snow neglected to reach the ground for hours were examined using RAP model data and observed polarimetric QVPs to drive model prediction of when snow would reach the surface from collocated ASOS stations. General findings include:

- Median bias of model predicted start time relative to observed start time was 18.5 min at 6 hours lead time and 9.5 min at 1 hour lead time with IQR of 50 minutes.
- Predicted snowfall onset within 9 minutes of observed with 4 hours lead time in 8 December 2013 case at KDIX with unusually dry air in advance of unexpectedly heavy snow; downward progression of cooling and moistening layer is non-steady
- In the above case, the 1-D model using QVP did not have a dry layer which allowed snow to reach the ground whereas the RAP model did not (perhaps a bad observation?)

Additional work planning to look at 9 other high Kdp cases with coupled trajectory/microphysical model and refine microphysical retrieval equations and their sensitivities (including a Virginia case that had Kdp enhancement that did not result in enhanced snow).

Questions/Comments:

- Vertical profile of wet bulb temperature might be more useful than relative humidity (RH). Wet bulb or ice bulb temperatures is actually what is being used within the model, but RH was plotted because it was easier to visualize.
- Presenter has not tried using VAD winds that might be more representative (based on Trommel et al.) instead of the HRRR winds, but that is a likely next step for comparison.