EEC Advances Polarimetric Radar Applications for Hydrology

Dual-polarization radar technology has rapidly become the industry standard, delivering more accurate quantitative precipitation estimation (QPE) and providing for the identification of the precipitation type (HMC). Polarization diversity has also enabled more cost-effective QPE solutions using C-band and X-band radars. In the past, attenuation in precipitation at these wavelengths caused severe underestimation of rainfall if conventional radar reflectivity factor (Z) was used. Polarimetric radar provides a very efficient way to correct Z for attenuation using differential phase resulting in more accurate precipitation estimates based on corrected Z and other polarimetric variables.

In 2007, Enterprise Electronics Corporation opened a research and development office in Norman, Oklahoma, on the research campus of The University of Oklahoma. Over the past three years, EEC, in cooperation with The University of Oklahoma Atmospheric Radar Research Center (ARRC), has embarked on an aggressive campaign to develop, test, and deploy the most sophisticated adaptation of polarimetric algorithms available today. However, even the most advanced QPE algorithms cannot compensate for some of the most prevalent challenges in obtaining high quality polarimetric data such as (1) system calibration, (2) noise impact mitigation, and (3) ground clutter detection and suppression. We have addressed each of these issues with new groundbreaking solutions and demonstrated performance.

Continuous Data-Based Calibration

End-to-end, absolute calibration of power measurements in a radar system remains to this day a challenging problem. Indeed, even the U.S. NEXRAD system has recently been shown to have a 2-3 dB discrepancy between adjacent radars. Part of the problem is that the best traditional methods of calibration involve procedures that are time-consuming to perform and require the radar system to be removed from operation. A small 1 dB bias in reflectivity can result in a bias in rain total exceeding 15%. The guarantee of continuous calibration is an absolute necessity for accurate rainfall estimates.

With polarimetric radar measurements, we use rain itself to automatically calibrate the radar. Within rain, radar reflectivity Z, differential reflectivity Z_{DR}, and specific differential phase K_{DP} (which is immune to radar miscalibration) are interdependent. Hence, the Z and Z_{DR} biases are continuously monitored and eliminated by using this self-consistency and tracking the collected data. Any changes or gradual drifts in the magnitudes of these biases notify the BITE to indicate a possible system malfunction and signal an alert to the user.

EEC Multiple-Lag Processing (MLP)

Two *critical* polarimetric variables, differential reflectivity Z_{DR} and cross-correlation coefficient ρ_{hv} (utilized for HMC and QPE) become biased by receiver noise at signal-to-noise ratio (SNR) values as high as 20 dB! Traditional "zero-lag" estimators of Z_{DR} and ρ_{hv} ensure reliable and unbiased estimates of these variables for SNR > 5 – 10 dB provided that noise floors in both orthogonal channels are accurately measured (which is not always the case). In weaker radar echoes with lower SNR (e.g. in winter storms, light rain, or at longer distances from the radar), the accuracy of HMC and QPE performed with the "zero-lag" Z_{DR} and ρ_{hv} can be seriously compromised.

A novel approach, the "Multi-Lag Processing" (MLP) technique, yields reliable and unbiased estimates of Z_{DR} and ρ_{hv} for much lower values of SNR by exploiting additional correlation information contained in the received radar signal.

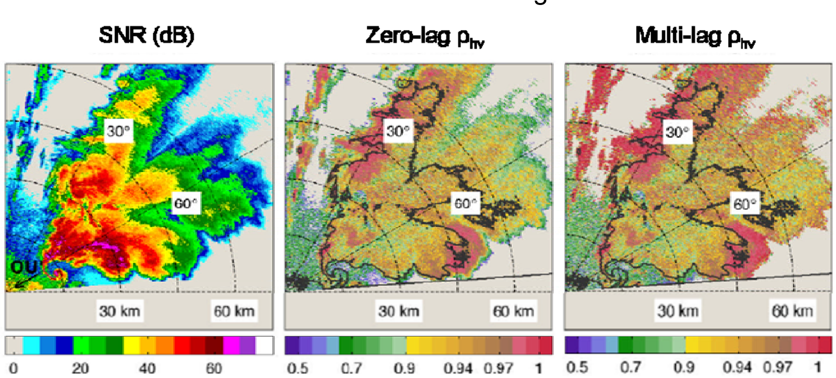

Fig. 1. The fields of signal-to-noise ratio, zero-lag ρ_{hv}, and multi-lag ρ_{hv} measured by the EEC OU PRIME C-band radar during a severe storm on May 10, 2010 (adapted from Palmer et al. 2011).

This technique extends the performance of the radar to collect accurate data from weaker signals, effectively enhancing the radar's sensitivity. MLP allows for (among other things) better classification accuracy for light snow and rain, better QPE for light rain, and better corrected data for highly attenuated signals. MLP effectively compensates for the 3 dB loss in sensitivity for simultaneous dual-polarization system measurements. The performance of MLP is illustrated in Fig. 1. There is apparent degradation of the zero-lag ρ_{hv} in the regions of low SNR, whereas the multi-lag ρ_{hv} is higher in these regions (at the periphery of the storm and in weak rain echoes), allowing proper classification of these regions as light rain and not clear-air radar returns.

Clutter Filtering

Traditional clutter filtering applied indiscriminately in the areas of near-zero measured Doppler velocity may cause the removal of weather echoes with lower Doppler velocities which results in underestimation of rain in such areas. In an urban clutter environment, this underestimation could result in missing a flash flood event. Another conventional solution is utilization of a clutter map, but this does not adapt to a changing clutter environment (seasonal variation, anomalous propagation) and requires operator intervention. Also, such filtering does not adjust dynamically to the strength of the weather—heavy rain in a weak clutter environment does not need filtering.

The EEC solution is twofold: dynamic clutter identification and adaptive clutter filtering. The dynamic clutter identification algorithm analyzes the signal for characteristics specific to clutter and identifies gates that are likely to be contaminated by clutter. Such an approach adjusts automatically to the relative contributions from weather and clutter to the resulting signal and adapts to transient clutter contamination due to anomalous propagation. Once clutter is identified, the adaptive clutter filter automatically adjusts itself to maximize the clutter suppression while minimizing the impact on the weather signal.

Validation and Verification

EEC, in a strategic partnership with the Atmospheric Radar Research Center (ARRC) at The University of Oklahoma, constructed OU-PRIME, a C-band radar system with a one million Watt transmitter and a half-degree beamwidth. This radar provides high quality dual-polarimetric data at very fine spatial resolution. In addition to serving as a cutting edge research tool, OU-PRIME provides a platform for development and testing of advancements within EEC's processing environment, streamlining the process of turning research into production solutions.

The area surrounding Norman is home to numerous resources for radar measurements and QPE ground validation.

KOUN, the dual-polarimetric NEXRAD prototype, is located 7 km north of OU-PRIME (Fig. 2) making it convenient for cross-checking S-band and C-band radar rainfall products and verification of algorithms for attenuation correction at C-band. Additionally, the Oklahoma Mesonet, nearby Oklahoma City Micronet, and several watershed areas with stream gages in central Oklahoma constitute an unmatched testbed for validation of radar QPE products at different spatial / temporal scales.

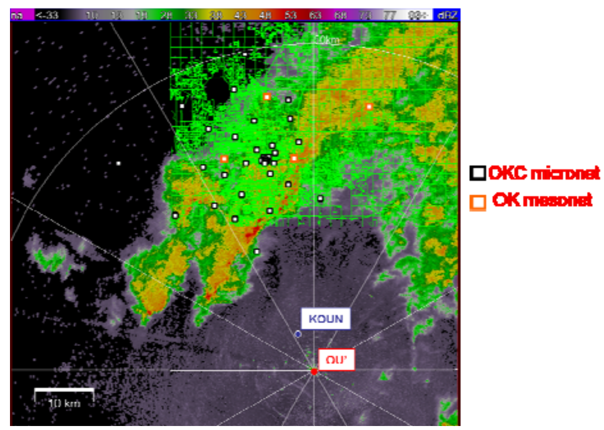

Fig. 2. Relative location of OU-PRIME, KOUN, and OKC Micronet.

A dramatic improvement in the quality of radar estimated 3-hour rain total is demonstrated in Fig. 3, using data collected on OU-PRIME for the tropical rain event of 14 June, 2010. This event caused extreme urban flash flooding in Oklahoma City.

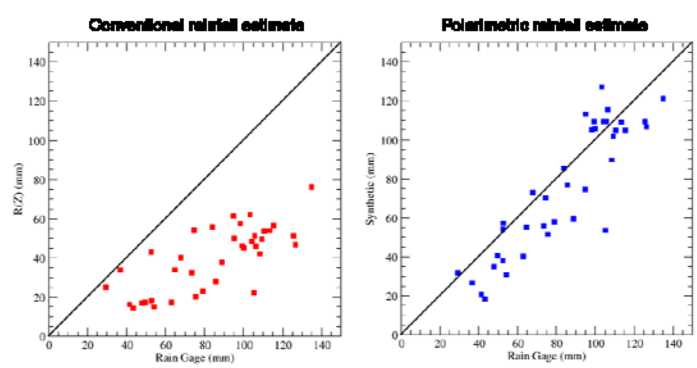

Fig. 3. Scatterplots of 3-hour rain totals measured by gages versus their OU-PRIME estimates using the conventional R(Z) relation (without correction for attenuation) and polarimetric R(K_{DP},Z) algorithm for the flash flood event in Oklahoma City on 14 June 2010.

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