DIFFERENTIAL REFLECTIVITY (Z_{DR}) CALIBRATION FOR CASA RADAR NETWORK USING PROPERTIES OF THE OBSERVED MEDIUM

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Abstract

The use of X-band radars for weather surveillance and research, either as standalone or in collaborative and adaptive networks, has advanced significantly during the past years. With advantages that include lower cost, smaller infrastructure and easier deployment, and the capability to provide the required resolution and coverage when sampling the atmosphere at the mid to long range low altitudes [1], X- band radar networks have gained special attention in the radar meteorology community, especially to alleviate long range radars limitations.

The Center for Collaborative and Adaptive Sensing of the Atmosphere (CASA) has deployed a Distributive, Adaptive and Collaborative Sensing (DCAS) network of four radars in central Oklahoma working as a closed-loop system since 2006. The radars operate at the X-band frequency and are capable of polarimetric and Doppler measurements. The system was developed with the goal of improving weather detection and prediction in the lower troposphere with special attention to weather hazards that affect people (e.g. tornadoes, convective cells, supercell detection) while advancing radar technology [1].

X-band radars capable of dual-polarization measurements have demonstrated an improvement in rainfall estimation when compared to single polarization measurements [2]. On the other hand, X-band measurements are affected by attenuation and differential attenuation, but advances in path attenuation correction techniques based on polarimetric measurements [3, 4, 5] aim to mitigate this problem. By means of dual-polarization, weather radars have demonstrated the capability to improve weather detection and prediction, in particular, Quantitative Precipitation Estimation (QPE). Dual-polarized measurements based on propagation phase can perform better than power-based measurements in the presence of poorly calibrated radars, beam blockage, rainfall attenuation and hail contamination [6]. Rainfall algorithms based on the combination of radar observables (e.g. $R(Z\text{-}Z_{DR})$ or $R(K_{DP}, Z_{DR})$) can produce an additional improvement. In addition, radar networks can provide the capability for attenuation correction and reflectivity retrieval based on multi-radar measurements [7].

Before any QPE attempt, the reflectivity and differential reflectivity radar observables require evaluation for system bias errors. Bias in the radar observables is mostly caused by the difficulty of precisely calibrating the radar hardware. Recent studies [8] have demonstrated a required accuracy of 1 dB and 0.2 dB for reflectivity (Z_H) and differential reflectivity (Z_{DR}), respectively, for the discrimination of light rain and aggregated dry snow. Storm identification of rain from mixed-phase states is essential for properly addressing the QPE problem. Furthermore, Z_{DR} bias correction is important for the absolute calibration of the radar using the self-consistency method.

Different methods have been proposed in the literature for the absolute calibration of Z_{DR}. Gorgucci et al. [9] proposed the vertical looking (90° elevation angle) of light rain to take advantage of the nearly circular shape of the raindrops seen from below. Since the CASA radars' antenna mechanism does not go that high, this method cannot be applied and an alternative technique needs to be adopted. Ryzhkov et al. [8] used the observing elevation angle dependency of Z_{DR} as an alternative technique and concluded that the high variability of Z_{DR} in rainfall is not suitable to achieve the required absolute calibration of 0.2 dB. Furthermore, Ryzhkov et al. [8] proposed a method that utilizes the structure characteristics of the melting layer in stratiform clouds and used the dry aggregated snow present above the melting layer. Dry aggregated snow Z_{DR} measurements above the melting layer resulted in a mean value of 0.2 dB at S-band and an accuracy of 0.1 to 0.2 dB. Due to the low variability of dry aggregated snowflakes between S- and X-band, the estimated value of 0.2 dB can be used for the absolute calibration of Z_{DR} at X-band.

This paper will apply the method that uses the ice present above the melting layer to estimate the absolute Z_{DR} calibration constant for each of the four CASA IP1 X-band radars. Vertical scans (RHI) of single azimuth angles are performed to identify the melting layer in the stratiform clouds. After the melting layer is identified, polarimetric observables are used for the discrimination of dry aggregated snow from wet snow or ice crystals in the first kilometer above. This procedure is performed for each RHI azimuth angle from two different storms (May 07, 2008 and May 25, 2008) and scatter plots are generated to obtain the storm Z_{DR} statistics from which the absolute Z_{DR} calibration constant is estimated. Results show a calibration accuracy of 0.1 to 0.2 dB for both storms with the low mean reflectivity stratiform storm of May 25th showing the best accuracy of 0.1 to 0.15 dB. In addition, Z_{DR} bias is estimated at low elevation angles using Z-Z_{DR} scatter plots in light rain. At low elevation angles (2° elevation angle for the purpose of this study) water drops less than 0.5 mm have a nearly spherical shape (raindrop axis ratio ≈ 1) and the average value of Z_{DR} is expected to be 0 dB plus/minus the estimated bias. Results form both methods were compared. As future work, the bias-corrected Z_{DR} will be used in the self-consistency principle to compute the absolute calibration of the radars, and the QPE using the CASA IP1 radar network will be evaluated.

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