A comparison of K_{DP} retrieval algorithms in an idealized known-truth environment

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Specific differential phase (K_{DP}) is a popular choice for polarimetric radar rainfall estimation and attenuation correction. Unfortunately, K_{DP} is not straightforward to retrieve because polarimetric radars do not directly measure K_{DP}. Instead, radars measure the total differential phase shift (Ψ_{DP}), which comprises the accumulated differential phase shift owing to propagation (Φ_{DP}) and the backscatter differential phase shift (δ). To accurately estimate K_{DP}, one must remove δ from the Ψ_{DP} profile to isolate Φ_{DP}, and then take half the range derivative of Φ_{DP}. Φ_{DP} is inherently noisy owing to measurement errors, which can lead to uncertain K_{DP} estimates; therefore, Φ_{DP} must be smoothed before taking its derivative. There are numerous published methods tackling this smoothing problem, each with varying complexity. For example, some simply fit a line to the Φ_{DP} profile; others use more advanced methods (e.g., a Kalman filter) to smooth Φ_{DP}. A few algorithms even use other radar variables, such as $Z_{H,}$ to determine where sharp gradients in K_{DP} might be expected. Each proposed algorithm successfully smooths Φ_{DP} and retrieves K_{DP}, but it is unclear which algorithms are most accurate and what the resulting K_{DP} estimate uncertainty is. To address this problem, we analyze and compare seven K_{DP} estimation algorithms using an idealized framework. We create a synthetic ("true") K_{DP} profile, and then integrate over it to obtain the "smoothed" Φ_{DP}. We then add noise typical of weather radar measurements and apply each algorithm to our noisy Φ_{DP} profile. The algorithm-estimated K_{DP} profiles are compared to our known truth profile, and the errors and uncertainty are quantified. The synthetic K_{DP} profiles are Gaussian in shape, allowing us to vary their magnitude and width to determine how each algorithm performs in smooth, slowly changing K_{DP} profiles, as well as steep and peaked profiles. We show that the algorithm errors vary over the range of different Gaussian widths and peak values. The overall patterns of these errors also change between algorithms, suggesting that the performance of each algorithm is dependent on the type of Φ_{DP} profile it receives. This result is further supported by an error analysis of each algorithm for a set of more complicated synthetic K_{DP} profiles.

Keywords: specific differential phase, KDP, retrieval, uncertainty