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A variational scheme for retrieving rainfall rate and hail intensity from polarization radar

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Polarization radar offers the promise of much more accurate rainfall rate (R) estimates than possible from radar reflectivity factor (Z) alone, not only by better characterization of the drop size distribution, but also by the more reliable correction for attenuation and the identification of hail. However, practical attempts to implement retrieval algorithms have been hampered by the difficulty in coping with the inherent noise in the polarization parameters, and the conflicting information these parameters provide in the presence of hail. A new variational retrieval scheme has been developed that overcomes these problems by employing a forward model for differential reflectivity (Z_{dr}) and differential phase shift (ϕ_{dp}), and iteratively refining the coefficient a in the relationship $Z = aR^b$ such that the difference between the forward model and the measurements is minimized in a least-squares sense. An optimal smoothing method ensures that retrieved a varies smoothly in both range and azimuth, thereby being insensitive to random measurement errors in Z_{dr} of up to $\pm$2 dB. Stable correction for attenuation is achieved simply and effectively by including its effects in the forward model. If hail is present then the forward model is unable to match the observations of Z_{dr} and ϕ_{dp} simultaneously. This enables a first pass of the retrieval to be used to identify the radar pixels containing hail, followed by a second pass in which we retrieve the fraction of the Z in those gates that is due to hail, this time being able to accurately forward-model both Z_{dr} and ϕ_{dp}. The prospects for using this rigorous approach as the basis for the variational assimmilation of polarimetric radar data into high-resolution forecast models will then be discussed.