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An efficient polarimetric radar forward operator for NWP model validation and data assimilation

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Radar observations play a crucial role in detecting and measuring precipitation (QPE, nowcasting) and are useful in various ways to improve numerical weather prediction (NWP) models. Accurate quantitative precipitation estimation remains a challenge as relationships between radar reflectivity and precipitation rate are inheritly ambiguous.Polarimetric observations have the potential to constrain hydrometeor microphysics (size, shape, orientation, etc.) better than conventional ones. Beside improving precipitation measurements, polarimetric observations can be used to evaluate, validate, and improve the representation of hydrometeors in NWP models.Calculating radar observables from prognostic NWP state variables, forward operators (FOs) are a crucial link in comparing radar measurements to NWP output. This requires that the FOs can accurately simulate corresponding observations and that they are consistent with the model(s), e.g. regarding hydrometeor microphysics. However, a wide range of parameters that affect FO output, are not constrained well by the NWP models. This includes, e.g. the melting state, the shape and microstructure, and the orientation of the hydrometeors. Characterization of the uncertainties of an FO, hence, is fundamental to allow its optimal exploitation. Here, we present the revised and polarimetry-extended version of EMVORADO (Efficient Modular VOlume RADar forward Operator) that is coupled to the ICON and COSMO NWP models and applied by DWD in operational weather forecast/data assimilation. Recent developments have focused on enabling polarimetric simulations with computational speed comparable to the Mie-based simulations so far applied in the operational data assimilation as well as to transferability of the code and intermediate calculation results (lookup tables, namely) between different computer architectures. The ability of the FO to reproduce observed polarimetric signatures is evaluated. Uncertainties resulting from weakly or unconstrained assumptions as well as effects of certain techniques and approximations to enhance efficiency are discussed, regarding their impact on analysis of observations and evaluation of NWP models.