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A dual-polarization Doppler radar operator for the COSMO numerical weather prediction model

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Polarimetric weather radars give relevant information about the variability and concentration of hydrometeors at a high temporal and spatial resolution. As such, they open new horizons for NWP model validation and assimilation. However, conversion from scattering properties measured by a radar to atmospheric variables simulated by a model is not straightforward.

In this work we propose a new polarimetric radar forward operator for the COSMO NWP model which is able to simulate measurements of reflectivity at horizontal and vertical polarizations, differential phase shift and copolar correlation for ground based or spaceborne (i.e. GPM) radar scans. In addition, the operator was extended with a new Doppler scheme, which allows to estimate the full Doppler spectrum. The operator was first adapted to the operational one-moment COSMO microphysical scheme with five hydrometeor types and was further extended to the non-operational two-moment scheme with hail as an additional category.

To derive polarimetric and Doppler variables, a number of additional assumptions are necessary to account for the shape and the dielectric properties of solid particles (snow, graupel and hail). The associated parameters were obtained from the litterature and from measurements performed in the Swiss Alps with a Multi-Angle Snowflake Camera (MASC).

The radar operator takes into account most physical effects affecting the propagation of the radar beam such as atmospheric refraction, electromagnetic attenuation and beam-broadening. To simulate beam-broadening, sub-beams are generated within the radar resolution volume and integrated with a quadrature scheme by using the antenna pattern as a weighting function. Comparisons with a real antenna pattern showed that the often used Gaussian antenna approximation could lead to significant underestimation of the reflectivity in the presence of a melting layer or in strong convective situations. To alleviate this issue, a new integration scheme was developped, which fits a sum of Gaussians to a real-antenna pattern and uses a combination of Gauss-Hermite quadrature (for radial integration) and Gauss-Legendre quadrature (for angular integration).

The operator was validated by performing a sensitivity analysis of its main assumptions and by a comparison of the simulated fields of radar observables with observations from the operational Swiss radar network, from a high-resolution X-band research radar and from GPM swaths.