Review GMD-2021-188

Title: Evaluation of the COSMO model (v5.1) in polarimetric radar space – Impact of uncertainties in model microphysics, retrievals, and forward operator

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Recommendation: Accept with minor revisions

General comments:

This paper presents an evaluation of the COSMO model for a stratiform precipitation event over Germany. The evaluation is performed using a polarimetric radar network and rain gauges. On the one hand, the evaluation is done using a model-to-observations approach, retrieving synthetic polarimetric signatures from the model with the Bonn Polarimetric Radar Forward Operator. This is complemented by an observations-to-model approach, retrieving synthetic model fields from the observations using several Hydrometeor Classification Algorithms.

The paper discusses a number of fairly simple, but relevant sensitivity tests, including two conversion thresholds within the model microphysics parameterization, and aspect ratio and canting angle assumptions within the forward operator.

Using the model-to-observations approach in combination with an observations-to-model approach, the authors demonstrate nicely which aspects of the evaluation point to real issues with the model assumptions (e.g. overprediction and too slow melting of graupel particles in the default model near and below the melting level, as well as an overprediction of large snow aggregates aloft). Issues with the forward operator are also highlighted as the too large cross-correlation coefficient in all experiments suggest a lack of variability in shapes of the ice hydrometeors.

While the experiments are fairly simple, I think the paper is well-written and structured and presents a very nice example of state-of-the-art techniques in model evaluation with relevant recommendations to the scientific community. Hence, I only have a few minor comments that should probably be addressed before I would recommend acceptance for publication in *Geoscientific Model Development*.

Minor comments:

- L25: Maybe it is worth mentioning the P3 scheme here (Morrison and Milbrandt, 2015), as an example of a microphysics scheme that no longer requires a hard separation in hydrometeor categories.
- L115: Since the authors are discussing *size* distributions here, shouldn't this be the *third* and *zeroth* moment, rather than the *zeroth* and *first* moments respectively?
- L125: small typo: …, it**s** mu depends on….
- L230: Do the authors mean a 340 km by 340 km domain, rathe rather than a domain of 340 km^2? If the latter, that would be a very small domain…
- Figure 3: It is worth indicating explicitly in the caption that panel a refers to cloud ice, panel b to snow etc..
- L312: It is worth referring to Figure 3 here for comparison against the model.

- Table 3: One possibly larger comment is about the microphysics experiment design. How did the authors pick the different values for the snow auto-conversion threshold and the graupel temperature threshold? More specifically, I am not sure I understand the rationale for the differences between EXP2 and EXP3. Wouldn't it be cleaner to only vary the $T_{graupel}$ in EXP2 and use values of D_{ice} = 50 µm and $T_{graupel}$ = 270.2 K? At the very least, it is not clear to me why the $T_{graupel}$ is different between EXP2 and EXP3? Since EXP2 is hardly mentioned, I feel that it might even be worth just removing the experiment from the table and all discussions altogether.
- L340: Not sure I agree that the qr between CTRL and EXP1 are similar. There appear to be much larger peak values of qr in EXP1 than in the CTRL.
- Figure 4: Could the authors add the panels for EXP1 as well here? That would show more clearly the impact of only the D_{ice} change.
- L400: Compare against? Do the authors mean compare Figure 11 against Figure 5?
- L430: Could the authors speculate as to why the AR_{low} + σ_{low} could lead to a reduction in ρ_{HV}? I would think that a low aspect ratio and low canting angle would lead to more uniform behaviour and hence a larger ρ_{HV}.

References:

Morrison, H., J.A Milbrandt, 2015: Parameterization of Cloud Microphysics Based on the Prediction of Bulk Ice Particle Properties. Part I: Scheme Description and Idealized Tests, Journal of the Atmospheric Sciences, 72, 287-311.