Review of
Prognostic parameterization of cloud ice with a single category in the aerosol-climate model ECHAM(v6.3.0)-HAM(v2.3)
by Dietlicher et al.

General comment:
In this study a new bulk scheme for representing stratiform cloud microphysics in large-scale models is presented. The model is based on former bulk model schemes with introducing a single prognostic ice category for representing rimed ice particles. The scheme is based on the approach by Morrison and Milbrandt (2015), also called P3 scheme. It is described and some idealized single column model tests are carried out in order to compare the new scheme with former treatment of ice in bulk model schemes for large-scale models.

Although the idea of representing ice in such a consistent way is not completely new, the design of a cloud scheme for large-scale models is an important step towards more consistent and realistic representation of ice, mixed-phase and liquid clouds in large-scale models. Thus, this study is a meaningful contribution for GMD. However, there are several issues, which must be clarified before this manuscript can be accepted for publication. Therefore I recommend major revisions for this manuscript.

In the following I will explain my concerns in details

Major points

1. Description of the new scheme
   The description of the treatment of ice particles in a single category is very short and not sufficient for a journal dedicated to model development. Referring to the original publication Morrison and Milbrandt (2015) is not sufficient. Actually, there are several inconsistencies in the text and also between descriptions and figures. For instance, in the text (page 4, lines 9-10) it is stated that depositional growth is assuming spherical shape. However, in figure 1, this is not the case. Thus, the description of the scheme must be extended and inconsistencies in the description must be avoided.

2. Treatment of sedimenting particles

   (a) The treatment of sedimenting particles of different water phases is inconsistent. While sedimenting ice particles are treated prognostically using a time splitting, rain is treated with a diagnostic scheme. Although the authors state that they want to focus on the representation of cloud ice, this is not enough because the P3 scheme actually describes the interaction of liquid and solid cloud particles. Thus, also the treatment of sedimentation should be consistent. Since former work at ETH was carried out on treatment of prognostic rain, it is not really understandable, why the authors restrict the scheme to diagnostic rain.

   (b) For the prognostic treatment of sedimentation of ice a time sub-stepping has been introduced. For the one-dimensional advection in the column an explicit Euler scheme was used. It is not really clear, why an explicit scheme is used, since this has crucial restrictions due to CFL criterion. Why not using an implicit scheme (even of higher order)? Such a scheme would be more robust and the restrictions to the sub time step would be more relaxed, since implicit schemes are commonly more stable.

3. Description of results
   Although the results seem to show an improvement in representation of ice in mixed-phase clouds, the description of the results is a bit confusing and it is hard to follow, what the authors wanted to say. Please state your major results and the improvements due to the introduction of the new scheme in a clearer and more structured way.

Minor points:

1. Sub stepping for particle generation?
   It is not clear why sub stepping was not introduced for particle generation, too. Since processes of

activation, freezing or nucleation are highly sensitive to time steps, the existing framework of sub stepping, as designed for other processes, could be used for this purpose. For instance, the resolved dynamics could be used as a criterion, whether particle generation will occur in a time step. Then, particle generation processes could be resolved in the sub stepping. Please comment on this issue.

2. Equation (9) is not consistent with thermodynamics in mixed-phase clouds
In mixed-phase clouds the water vapour is close to equilibrium with respect to liquid phase, i.,e. $RH \sim 1$ until all water has been transformed into ice; then growth of ice particles reduce relative humidity towards ice saturation. Thus, the blend of two different equilibria is not really consistent. Is this quantity only used for cloud cover or is it used for the description of cloud processes in mixed-phase clouds? Please explain this.

3. Equation (11) for growth in WBF process
Is the assumption of planar ice particles consistent with the assumptions in the P3 scheme? Please clarify.

4. Use of TKE scheme for subgrid scale vertical velocity
From a recent study it is known that the TKE based subgrid scale wind parameterisation and the releated ice nucleation significantly overestimates the ice crystal number concentration (Zhou et al., 2016). Please comment, why this parameterisation is used in the model.

5. Section 3.3.4
What is the physical basis for the melting time step of $\tau_{mlt} = 1\,\mathrm{min}$?

6. Autoconversion and accretion parameterisations
In the original article by Khairoutdinov and Kogan (2000) it is stated clearly that their scheme was derived for LES models, i.e. for a spatial resolution of tens of metres. They also stated that the scheme cannot be simply extrapolated for use in large-scale models (see page 231, left column, lines 3-16). Please justify, why this parameterisation is used in a large-scale model with a horizontal resolution of few tens of kilometres.

7. Page 11, lines 21-27:
The description of the simulation scenario, especially of initial and boundary conditions is very short. Please extend the description.

8. Description of figures 3 and 4
Although in the figure a reference simulation FL is indicated, the description of this simulation setup cannot be found in the text. The question arises if there was a series of simulations with decreasing time step leading in convergence to a reference simulation with very short time step. Was FL designed like this? Please explain. The dashed black line in figures 3 and 4 is quite hard to read, please change the line style.

9. Name 2.5 category
Actually, I was a bit confused by the names 1, 2 and 2.5 category. Since in cloud physics often single and double moment schemes are used, and we tend to believe that double moment schemes are better and schemes with more categories are also better, the names are a bit counter-intuitive. Actually, I have no better suggestion; maybe it would help to clarify the names in the very beginning in a more concise way.

References

Zhou, C., J. Penner, G. Lin, X. Liu, M. Wang, 2016: What controls the low ice number concentration in the upper troposphere? Atmos. Chem. Phys., 16, 12411-12424, doi:10.5194/acp-16-12411-2016