Interactive comment on “Microphysical processing of aerosol particles in orographic clouds” by S. Pousse-Nottelmann et al.

Anonymous Referee #1
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We thank the referee for his/her valuable comments and suggestions. The responses (blue) to the comments (black) are below each comment.

This manuscript studied how clouds regulate aerosol and how such cloud-processed aerosol impact the subsequent cloud formation using the COSMO model coupled with the M7 aerosol module and an enhanced version of Seifert and Beheng microphysics scheme. By simulating orographic clouds over two bell-shaped mountains in an idealized two-dimensional setup, the authors identified different routes of aerosol cycles in warm- and mixed-phase clouds. It is also found that the aerosol spatial distribution, mixing state and size distribution are modified by cloud processing and such processed aerosols impact the cloud formation in downwind areas. The manuscript is well written and organized. The numerical tool and model setup are appropriate for the problem. The findings of aerosol-cloud interactions in mixed-phase clouds are important and novel. I recommend accepting this manuscript for publication after my two concerns are addressed.

1. The aerosol is still treated in a bulk manner even the size distributions and mixing states are parameterized in the model. When the regenerated aerosols are released, the proportions of different components are assigned to the same values as the background aerosols, since only one set of “dry” aerosol category is used in the model.
   The present study employs a modal approach to represent the aerosol population. Upon evaporation/sublimation, regenerated aerosol mass and number are added to the background aerosol modes potentially changing the composition and size distributions of the background aerosols and the proportion between in internally mixed/soluble and insoluble background aerosols, even if the aerosol in each grid box is assigned to only one category.

   That says, the mass of soluble and insoluble aerosols are not exactly conserved (to more precisely calculate the soluble and insoluble mass of processed aerosols, more separate sets of “regenerated aerosol” should be used).
   The aerosol module distinguishes between internally mixed/soluble and insoluble aerosol particles. Insoluble particles consist of freshly formed black/organic carbon and dust without coating. Atmospheric aging like coating with sulfate is simulated as a transfer of insoluble particles into a internally mixed/soluble mode. We apply a similar approach for processed aerosol particles. Following the homogeneous mixing assumption, we consider residual aerosol particles of evaporation and sublimation to contain an internal mixture of all foreign material in the hydrometeor. Due to sulfate production in the aqueous phase, processed particles contain some sulfate mass and therefore are attributed to the unactivated internally mixed/soluble modes. This means also that initially insoluble aerosol particles will become internally mixed/soluble after aerosol processing in clouds. The information about their initial mixing state is indeed lost once incorporated into hydrometeors.
   The suggested alternative approach of separate sets of “regenerated aerosol particles” would allow to analyze the compositions and size distributions of regenerated aerosol particles in more detail. However, the employed aerosol module M7 in its current state does not account for additional aerosol modes. To

allow for coagulation, sedimentation, activation and scavenging of the processed aerosol particles altogether with the unactivated background aerosol, we summed up processed and background aerosol though loosing valuable information about their specific size distributions and compositions. We now explain that more clearly.

Therefore, the difference in Aiken mode between SCAV-ALL and AP experiments showed up in Figs, 9, 10, 15 and 16. Physically, the only difference between SCAV-ALL and AP should be the enhanced accumulation and coarse modes by regenerated aerosols. However, the Aiken mode in AP is completely missed. The authors can force the Aiken mode of AP to be the same as SCAV-ALL in an ad hoc manner. And discussions on the potential impact of such deficiency should be provided in the manuscript.
In simulation AP most of the regenerated aerosol particles are released towards the Aitken and accumulation mode. We apologize for not clearly communicating these results. Regenerated Aitken mode particles have an increased size and mass compared to the background Aitken mode particles. The average radius of the "summed up" Aitken mode is increased shifting the lognormal size distribution towards larger sizes. The Aitken mode therefore appears as a hump on the lefthand side of the accumulation mode size distribution. These findings will be described more thoroughly.

2. I found the double mountain setup and general approach of this study are similar to Xue et al., 2010 and 2012. I expect to see more comparisons and discussions of the approach and results between the current one and those two studies. For example, how the cloud-processed aerosols change the riming process in downwind orographic cloud.
   The setup and approach of this study are similar to the studies of Xue et al., 2010 and 2012. All three studies are based on the model intercomparison study of Muhlbauer et al., 2010. However, the treatment of aeorsol particles and the representation of aerosol processing and regeneration differs between the current and those two studies. Also, the analysis of present study focusses foremost on the impact of cloud microphysical processing on the aerosol population, whereas Xue et al., 2010 and 2012 concentrate on the implications of aerosol processing for subsequent cloud formation and properties. We agree that more comparisons and discussions between the findings of the different studies would be enriching and help to better understand the results. We will include such comparisons and discussions in the revised manuscript.