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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Lidar observation and model simulation of a volcanic-ash-induced cirrus cloud during the Eyjafjallajökull eruption" *by* C. Rolf et al.

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We thank Referee 2 for reviewing the paper and for your fruitful comments which were helpful to improve the paper. All changes are highlighted with blue and red colors. Point by point answers to your comments are reported below.

Major points

1. *Humidity as derived from ECMWF and radiosonde*
The results of the study are of cause very sensitive to the water vapor concentra-

tion. The radiosonde data in this paper were not corrected for any bias in relative humidity. We now correct the relative humidity data with the algorithm provided by Miloshevich et al. 2009. Figure 3 includes the new corrected relative humidity radiosonde profile showing a better agreement to the ECMWF data. The corrected values are up to 10 % higher in cirrus altitude. However, no high supersaturation is visible. So the non existence of homogeneous freezing is more justified. The correction is now mentioned in the text (see page 6, lines 451-456 and page 7, figure 3).

2. *Sedimentation of ice crystals*

    - *a) Size and shape of simulated ice crystals*
    The ice crystals are assumed to be spherical in MAID. For sedimentation the terminal velocity relation is derived as a function of crystal mass assuming hexagonal columns as described in Spichtinger and Gierens 2009. Columnar behavior of ice crystals is the most probable as described in Bailey and Hallet 2004. However, the exact shape of ice crystals in this case is unknown and of course a wrong falling behavior cannot completely excluded.
    - *b) Sedimentation in the model and build of 2D structure*
    You understand the description correctly, the single boxes are not coupled and each model box is ran along his own trajectory. A better representation of sedimentation would bring better results concerning fall strikes. The upper and lower cloud borders would be then probably in a better accordance to the measurements. However, a coupling between single boxes or column approach cannot be done with the model MAID. But, in this study we don't want to reproduce the structure of the volcanic ash induced cirrus cloud exactly. We want to show the general effect of volcanic ash particle on cirrus formation. With the sedimentation module implemented in MAID (described by Spichtinger and Gierens 2009) the general effect of falling ice crystals in

the center part of the cloud could be appropriately simulated. More information about the sedimentation are included in Section 2.2. (see page 3, lines 211-214) and Section 4.2 (see Page 12, lines 773-775).

Minor points

1. *Adiabatic change of temperature*
The temperature and pressure values are used directly from the trajectory model. We know this issue about assumption of adiabatic changes and the correction is planed to be included in future. We checked the trajectories used in this study for strength of diabatic source terms and found an overall deviation of around 0.25 to 0.35 K compared to the adiabatic assumption. This deviation is smaller than the typical amplitude of temperature fluctuations (0.3 - 0.5 K). The uncertainties by using the temperature and pressure values of the trajectory model directly are therefore covered by the different representations of temperature fluctuations of each trajectory.

2. *Resolution of ECMWF Data*
The resolution of ECMWF data is 1°x 1°, but the trajectory coordinates can have much finer resolution due to interpolation of the coarse ECMWF wind field. Therefore it is appropriate to display the trajectories in a PDF with a grid resolution of 0.2° x 0.2°.

3. *Setup of small-scale variations*
The fluctuations are caused by small scale gravity waves with wavelength of 10 - 20 km roughly producing frequencies of 1*10-3 to 2*10-3 s-1 or periods of 16 - 8 min (see Hoyle et al. 2005 Fig.1). These waves are clearly smaller than the resolution of ECMWF data and therefore not included in the data and producing fluctuation amplitudes of around 0.5 K, which are used in this study.

4. *Statistical error from different realizations*
You are right, the number of different realization is pretty small. But, the different realizations produce very similar ice crystal concentrations. We plot the standard deviation of number concentration for the 5 trajectory realizations for each box in the 2D picture of the ash induced cirrus cloud (see bottom left panel of the attached figure). It can be seen that only at the cloud borders the statistical spread is partially around 0.04 cm-3. Within the cloud the spread is 0.003 cm-3 and smaller. Therefore, it seems that two realizations are enough for the case study. This is now mentioned in the text (see page 12, lines 810-813).

5. *Mixing timescale*
Mixing implies all kinds of atmospheric mixing from turbulence (small scale) to large scale mixing (e.g. wind shears). In Lagrangian models like CLaMS two air parcels are mixed when they are come very close together. Under normal conditions without strong vertical winds this mixing typically happens after few days (see e.g. McKenna et al. 2002). Often used trajectory length are 5 days and longer assuming the non existence of mixing. Therefore, a cut after two days is rather conservative and the water vapor concentration should be rather constant along these trajectories.

6. Missing idealized runs with pure homogeneous nucleation
We decided to skip the pure homogeneous freezing because this study is focused on the impact of volcanic ash on heterogeneous ice nucleation. It is mentioned that the results of IN impact is quite similar to the mentioned studies (see page 10, lines 714-717)

7. *Vertical velocity estimation*
The large scale vertical updrafts were rather small with values around 1cm/s and a standard deviation of around 0.5 cm/s. This value is estimated by taken the slope of each hourly trajectory temperature point and assuming dry adiabatic

conditions to get the updraft velocity. The large scale cooling rate is now mentioned in text to show the range of updrafts of the trajectories of the ash induced cirrus (see page 11, lines 748-751).

Technical corrections

- *Page 15686, line 15: 'few' instead of 'view'*
  Is changed, of course (see page 6, line 460).
- *Dots in Figure 6*
  The points in the figure are now enlarged (see page 11).