Atmos. Chem. Phys. Discuss., 10, C14818–C14821, 2011
www.atmos-chem-phys-discuss.net/10/C14818/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "The two faces of cirrus clouds" *by* D. Barahona and A. Nenes

D. Barahona and A. Nenes

nenes@eas.gatech.edu

Received and published: 4 April 2011

We thank Dr. Krämer for her thoughtful review and comments.

1) The simulations shown in Fig. 4 f are initialized with T = 195K, p = 100 hPa and S = 0. This corresponds to a water vapor mixing ratio of 7.55141 ppmv, which is quite unlikely to find at this temperatures. In Fig.4 of Krämer et al. (2009) frequencies of clear sky RHi are shown as a function of temperature. The most frequent RHi at 195K is around 30-60%, corresponding to 1.5-3 ppmv. How would your model results be influenced when using the observed lower water vapor mixing ratios as initial values? The freezing temperature will be lower, so maybe more and smaller ice crystals would appear?

The temperature would be lower for the initial freezing pulse; however the system would eventually follow a similar trajectory as in Figure 4. During the simulations presented in

Figures 6 and 7 (and the new Figure 8), several homogeneous freezing pulses occur, the last one occurring at about 180 K. Also over the first 10-20 h of simulation the layer is dehydrated to values of q in agreement with observations. There is however some sensitivity of the model trajectory to the initial conditions and we have added a new Figure 8 showing their effect on the results.

(By the way, the modelled ice crystal sizes in the dynamical equilibrium are significantly larger than 20 micron, which is the observed mean mass diameter at low temperatures, see Fig.9, Krämer et al., 2009). Would the Nc observations still be matched by the simulations?

Yes, N_c would still be in agreement with observations; we present this in a new Figure 8. D_c is larger than observations at the beginning of the runs, however when equilibrium is reached D_c shows good agreement with *Krämer et al., 2009* data. This is product of the sensitivity of the system trajectory to initial conditions. We have included new runs in Figure 5 to show evolution of D_c under a different set of initial conditions.

2) Model studies shown in Fig. 1 and Fig. 4f: a) The initial temperature in Fig. 1 is T = 185 K, but in Fig. 4f T = 195 K. I suggest that both temperatures should be the same.

The result of Figure 1 are obtained at T = 185 K which is assumed to be the temperature at the point of freezing. The simulations of Figure 4 span over 20 K due to large scale vertical motion. In Figure 4, the last freezing event occurs at around 180 K. Therefore T=185 K was selected in Figure 1 as the appropriate T for comparison.

Then it could already be seen in Fig. 1 that at 195 K homogeneous freezing can produce ice crystal numbers falling into the range of observations if the vertical velocity is small, because the lower the temperature the higher the ice crystal numbers.

This would be true only if u $<$ 1 cm s^{-1}. Figure 4 was generated using a vertical velocity spectrum with fluctuations up to 100 cm s^{-1}. The lower N_c in the new approach does not result from starting at a warmer T but from the proper consideration of internal S

variations within the cloud. The new Figure 8 with initial S=-0.4 emphasizes this as the initial freezing pulse occurs at around T=187K.

b) How would the results shown in Fig. 4ff would look like at T = 185/190 K? Would the simulated Nc in the 'dynamical range' in Fig. 8 still match the observations?

They would look the same. As mentioned above, the temperature decreases to 180 K in the simulations of Figure 4. We have selected the initial conditions in Figure 4 (and also in all the simulations at cold T in our study) so that during the period of the simulation T would not decrease below 175-180K which is the typical temperature of the cold point tropopause.

3) Page 30862: I agree with the points 9) and 10) made by Ben Murray.

Please see our response to Dr. Murray's comments.

4) I missed some discussions of other studies: a) Page 30859-30860: 'These mechanisms however only act under specific conditions and cannot explain the low Nc and high S coexisting in low temperature cirrus clouds (Peter et al., 2006).' In Krämer et al. (2009) it is shown that the coexistence of low Nc and high S is not a surprise, since classical microphysics explains that in case of low Nc the supersaturation is persistently high because the few ice crystals cannot efficiently deplete the water vapor. Only the low Nc are still under discussion.

This is a good point. We have rephrased the statement clarifying that these mechanisms cannot explain the low N_c in low T cirrus.

b) Page 30860, line 7: Gensch et al. (2008) performed a combined model-observation case study (superposing small temperature fluctuations to the large scale updraft) showing that heterogeneous freezing may be a candidate to explain the features of cirrus clouds at low temperature.

Thank you for pointing out this reference. We have included a new paragraph in section 1 where we make a more comprehensive review of previous studies on the subject.

c) Jensen et al. (2010) suggested ammonium sulfate particles as a potential IN candidate for TTL cirrus that may explain the low Nc.

We discussed heterogeneous freezing of ammonium sulfate in section 2. A discussion on the specific results of Jensen et al. (2010) in relation to our study has been added to section 1.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 30857, 2010.