Atmos. Chem. Phys. Discuss., 9, C10962–C10967, 2010
www.atmos-chem-phys-discuss.net/9/C10962/2010/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Comprehensively accounting for the effect of giant CCN in cloud droplet activation parameterizations" *by* D. Barahona et al.

D. Barahona et al.

nenes@eas.gatech.edu

Received and published: 18 February 2010

Response to Reviewer #2

We thank the referee for his/her comments. Our responses to specific comments follow.

1. The abstract states: "Cloud droplet activation parameterizations used in aerosol indirect effect assessments often assume that droplet growth after activation is much greater than their equilibrium size close to cloud base." What does it matter if it occurs "after activation", unless LWC is unconstrained?

The statement states an assumption often taken in development of parameterizations; it arises from the need to represent the size of activated droplets at the point of maximum supersaturation, which depends strongly on the size variation they experience between cloud base and the point of s_{max}. We have rewritten the abstract to avoid any confusion.

2. Also in the abstract, you state: "If a large fraction of the aerosol is composed of such particles (such as regions with large fractions of dust particles and seasalt), neglecting such kinetic limitations in cloud droplet activation parameterizations leads to an underestimation of droplet surface area during cloud formation, hence overestimation of maximum supersaturation and cloud droplet number." And accordingly, in the introduction you state: "Incorrectly accounting for this surface area can underestimate the condensation rate of water vapor, which leads to overestimation in maximum supersaturation, Smax, and droplet number." I understand the logic of this conclusion as being that larger droplets are oversized by existing parameterisations (models) and therefore smaller droplets with more of the surface area are undersized. Your inherent assumption (?) is that the smaller droplets have more surface area, and of course we assume that the models adequately conserve LWC. But if this assumption is not always true, then the model will overestimate the surface area associated with these kinetically limited particles/droplets, not underestimate it. To me, this point is not so obvious and requires a better explanation.

This point is well taken. Given the length required for its explanation, it has been removed from the abstract and discussed in the introduction.

For example, Phinney et al (Limitations of using an equilibrium approximation in a cloud droplet activation parameterization, J. Geophys. Res., 108, 4371-4380, 2003.) compared the effect of treating this phenomenon in the ARG aerosol-cloud droplet parameterization with a parcel model and appears to have found *the opposite to your statements (see their Figure 4).*

The results of this work and those of Phinney et al. (2003) are complementary. They showed that assuming that all particles attain their equilibrium size leads to an overestimation of the surface area of kinetically limited particles and therefore to an underestimation in s_{max} and CDNC. Nenes and Seinfeld (2003) developed a method to account for kinetic limitations to droplet growth in cloud formation parameterizations based on the "population splitting" concept, which tends to underestimate the droplet population surface area when a significant fraction of large CCN is present, leading to overestimation in CNDC. The method developed here addresses both issues. This has been clarified in the text.

3. The introductory statement "For a single-mode aerosol, an overestimation of Smax may not lead to substantial errors in droplet number given that most CCN would activate." Does this mean for all modal sizes and spreads, for all updraft speeds as well as for all compositions? This statement can only be true in a very limited number of situations.

Indeed, the statement was referring to a situation were particles in the mode are very large (Giant CCN) and activate at very low supersaturation. The statement has been removed in the revised version of the paper.

4. There can be subtleties associated with applying a parcel model to this issue of kinetic limitation. When you initiate your parcel model, how do you define the sizes of the kinetically limited particles and at what position w.r.t cloud base? Does it make a difference?

Initially, all aerosol particles are assumed to be in equilibrium with its environment at RH=80%. Within the range RH=60-90% the model results are rather insensitive to this assumption. Phinney et al. (2003) used RH=99 %; using this

would result in lower CDNC (although mostly within 10%) for low V (< 0.1 m s^{-1}). This discussion has been included in the revised version of the paper.

5. Section 2, equation 1 etc – There is no plausible physical reasoning behind the parameterisation of entrainment in an adiabatic parcel model to study cloud base activation.

Equation (1) expresses the supersaturation balance for an ascending parcel with homogeneous entrainment. As shown in Barahona and Nenes (2007) Eq. (1) is equivalent to the supersaturation balance for an entraining parcel (e.g., Pruppacher and Klett, 1997; Seinfeld and Pandis, 1998)

It is misleading because its application says that there are no adiabatic parcels in cloud. How then did the cloud form?

There is a plethora of literature showing that there are very few "truly adiabatic" parcels in a cloud (e.g., Guibert et al., 2003; Conant et al., 2004; Meskhidze et al., 2005; Peng et al., 2005; Fountoukis et al., 2007; Lu et al., 2008). This is however not an issue as complete adiabaticity is not a requirement for the generation of supersaturation.

6. The authors need to explain their results in relation to those of Phinney et al. (2003)and any other appropriate study.

We apologize for this oversight. The suggested discussion has been included (see response to point 2 above).

7. The colour coding of updraft speed appears to be incorrectly labelled in Figure 1.

The color coding refers to the modal size of the coarse mode in the aerosol population. This is now made clear in the figure caption.

References

Barahona, D., and Nenes, A.: Parameterization of cloud droplet formation in large scale models: including effects of entrainment, J. Geophys. Res., 112, D16026; doi: 16010.11029/16207JD008473, 2007.

Conant, W. C., VanReken, T. M., Rissman, T. A., Varutbangkul, V., Jonsson, H. H., Nenes, A., Jimenez, J. L., Delia, A. E., Bahreini, R., Roberts, G. C., Flagan, R. C., and Seinfeld, J. H.: Aerosol-cloud drop concentration closure in warm clouds, J. Geophys. Res., 109, D13204, doi:13210.11029/ 12003JD004324, 2004.

Fountoukis, C., Nenes, A., Meskhidze, N., Bahreini, R., Conant, W. C., Jonsson, H. H., Murphy, S., Sorooshian, A., Varutbangkul, V., Brechtel, F., Flagan, R. C., and Seinfeld, J. H.: Aerosol-cloud drop concentration closure for clouds sampled during the International Consortium for Atmospheric Reseach on Transport and Transformation 2004 campaign, J. Geophys. Res., 112, D10S30, doi:10.129/2006JD007272, 2007.

Guibert, S., Snider, J. R., and Brenguier, J. L.: Aerosol activation in marine stratocumulus clouds: 1. Measurement validation for a closure study. , J. Geophys. Res., 108, 8628; doi: 8610.1029/2002JD002678, 2003.

Lu, M., Feingold, G., Jonsson, H. H., Chuang, P. Y., Gates, H., Flagan, R. C., and Seinfeld, J. H.: Aerosol-cloud relationships in continental shallow cumulus, J. Geophys. Res., 113, doi:10.1029/2007JD009354, 2008.

Meskhidze, N., Nenes, A., Conant, W. C., and Seinfeld, J. H.: Evaluation of a new cloud droplet activation parameterization with in situ data from CRYSTAL-FACE and CSTRIPE, J. Geophys. Res., 110, D16202, doi:16210.11029/12004JD005703, 2005.

Peng, Y., Lohmann, U., and Leaitch, W. R.: Importance of vertical velocity variations in the cloud droplet nucleation process of marine stratocumulus, J.

Geophys. Res., 110, D21213, doi:21210.21029/22004JD004922, 2005.

Phinney, L. A., Lohmann, U., and Leaitch, W. R.: Limitations of using an equilibrium approximation in an aerosol activation parameterization, J. Geophys. Res., 108, 4371, doi:4310.1029/2002JD002391, 2003.

Pruppacher, H. R., and Klett, J. D.: Microphysics of clouds and precipitation 2nd ed., Kluwer Academic Publishers, Boston, MA 954 pp., 1997.

Seinfeld, J. H., and Pandis, S. N.: Atmospheric Chemistry and Physics, John Wiley and Sons, New York, NY, USA, 1998.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 24717, 2009.