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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol-cloud interaction determined by both in situ and satellite data over a northern high-latitude site" *by* H. Lihavainen et al.

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Lihavainen et al. investigate the influence of aerosol concentrations on cloud microphysical properties. Since by these processes, anthropogenic aerosols may indirectly affect the Earth's energy balance, careful analysis and process understanding is essential for climate science. It is particularly valuable to assess aerosol-cloud interactions from observations, thus also providing evaluation metrics for climate model parameterisations.
The study follows propositions in the literature to define a metric of the impact of aerosols on cloud microphysics formally as the partial derivative of the microphysical quantity with respect to the logarithm of aerosol concentration. The observation of both aerosol concentration is taken in this study from different kinds of observations

at or in the region of one particular site in Finland. Specifically, the metric as derived from satellite remote sensing data is compared to in-situ data and a combination of the two data sources.
The study thus addresses an important subject which is pertinent to the field covered by Atmos. Chem. Phys.. The applied methods are adequate and interesting. The English language is very good.

There are a number of points on which in my opinion the study could be improved considerably.

Literature review
I would suggest the authors discuss in their paper the article by Andreae (Atmos. Chem. Phys., 9, 543-556, 2009) which shows that cloud-base cloud condensation nuclei concentrations are very well correlated with AOD.
There is of course already a large body of in-situ results for the aerosol-cloud interaction metric, which is not discussed in the paper. An example is the study by Boucher and Lohmann (Tellus, 1995) who summarized aircraft results available at that time. Their results have been implemented as a parameterisation in many general circulation models. Their formula "D", e.g., yields ACI = 0.41 / 3. At least some review of the plenty of aircraft studies should be given.
Important studies of the scale-dependency of the metrics for aerosol-cloud interactions have been described by Sekiguchi et al. (J. Geophys. Res. 2003) and the paper by McComiskey et al. (J. Geophys. Res. 2009) already cited. More discussion of their results would be useful.

Main comments
The study addresses only the first aerosol indirect effect (Twomey effect). A crucial element in defining this is that cloud liquid water path (LWP) is held constant. In

this study, this is condition not always really satisfied. For the remote sensing data, LWP is only a confined to a very broad range (100 – 200 g m^{-2}), which, in addition, pre-selects a particular cloud type. One possibility to better address this issue would be to stronger constrain LWP. Another one would be to rely on the satellite-derived cloud droplet number concentration as, e.g., Quaas et al. (Atmos. Chem. Phys., 9, 8697-8717, 2009). It would be useful to directly compare the individual quantities (cloud droplet effective radius and aerosol concentration) of remote sensing vs. in-situ observations rather than only the regressions between the two.

Specific comments
p27466
l23: not meteorological conditions, but just updraft velocity probability distribution (c.f. Köhler theory)
l26: this is not quite true. If effective radius or cloud optical depth are used, it is a metric for the first aerosol indirect effect only when cloud liquid water path is held constant.

p27467
l16: Do I understand it correctly that at the site, aerosols are measured continuously, but cloud properties only during specific measurement campaigns? Please specify. Are clouds in all cases liquid water clouds?

p27469
l11: Is this limitation on cloud top assuring that only entirely liquid-water clouds are looked at?
l16: This choice for LWP range would need to be justified. Does the aerosol-cloud interaction metric quantification depend on this choice? How large would the parameter be if the range was reduced, what if clouds with less LWP would be investigated? Is the LWP the one retrieved by MODIS? It would be very useful if a histogram of LWP

would be shown. What is the LWP distribution for the in-situ cases?
l21: Should this read ”doy”?
l23: It would be very useful to add a comparison (joint histogram) of effective radius and aerosol concentration in-situ vs. remote sensing.
l25: What is actually used: Collection 4 (Remer et al.) or collection 5 (Levy et al.)?

p27470
l5: It would be useful to add another study in between 2.1.2 and 2.1.3, in which the same cloud microphysical data are used as in 2.1.2, but the AOD as in 2.1.3, in the 1°x1° grid-box around the cloud retrieval. This would allow to assess to which extent the spatial averaging of the cloud properties is responsible for the decrease in the aerosol-cloud interaction metric.
l9: Please specify that this definition is only true for constant liquid water path.
l17: (eq. 1) It is formally a partial derivative.

P27471
l3: Some words on how this equation is evaluated numerically are needed. Is it the slope of a linear regression?
l9: I had difficulties in understanding this definition. A potentially clearer re-formulation would be: ”...we calculate different ACI(d_k) for varying cut-off aerosol diameter d_k by...”
l18: Could you report here some information about aerosol chemical composition and characteristics of the updraft probability distribution?
l21: ACI=0.3 means $\frac{\partial \ln N_d}{\partial \ln \alpha} = 0.9$, right?

p47472
l4: Is most interesting that this seems to be true even for the lowest size bin.
l6: It would be sufficient if the CCN concentration scaled with the aerosol number concentration.
l7: Which d_k range is actually meant? To me, it looks more like 20 – 300 nm.

l9: drop ”3”

p27473
l10: A reason for this could be variations in liquid water content. LWC scales with cloud droplet effective radii scale to the third power, while it scales only linearly with optical depth.
l21: To be more clear on this, you mean, the local aerosol concentration is not necessarily representative for the entire 5°x5° region, right?

p27481
Fig.1: Please label in nm rather than m (10nm – 100nm – 1μm). Maybe reformulate ”as a function of cut-off size. (c)”

p27483
Fig. 3: What is the meaning of the error bars? Could you show a histogram of AOD?

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 27465, 2009.