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Atmospheric
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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.

Anonymous Referee #1

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General comments.

This paper aims at quantifying the first aerosol indirect effect (AIE) from measurements taken at the ground and analysis of satellite data.

There is however a general misunderstanding of what the first AIE is, mainly based on former publications. Following recent meetings and international assessments, the situation has now significantly evolved. I therefore recommend that the authors follow these recommendations and focus on the original part of their contribution to this subject.

Underlying the aerosol indirect effects is the fact that the droplet number concentration in warm cloud depends (among others) on the concentration of cloud condensa-

tion nuclei, which depends on the size distribution and chemical composition of the aerosol particles. This was a very active field of research in the 1950th, referred to as "aerosol/cloud interactions". The concept of AIE was introduced later when Twomey (and others) hypothesized in the 1970th, from aerosol/cloud interaction studies, that the increase of the droplet concentration should result in an increase of the cloud optical thickness (at constant LWP).

Formally the aerosol indirect effect expresses as dlnCOT/dlnNd.

Later on, and combining aerosol/cloud interactions and the Twomey hypothesis, attempts were made to connect the whole chain from aerosol to cloud optical thickness (dlnCOT/dlnα) using diverse proxy (α) for the aerosol and assuming diverse relationships between that proxy and the droplet concentration as dlnNd/dlnα. The rationale for such an approach is to develop simple parameterizations of the AIE in general circulation models where the aerosol/cloud interactions cannot be explicitly simulated, but information exists about the spatial distribution of chemical composition of the aerosol.

This paper addresses the first part of the chain (aerosol/cloud interactions), i.e. dlnNd/dlnα, discussing the best way to define α and the consequences for the simulation of the AIE in GCM. The most robust approach is to directly measure Nd, such as in Data set 2 and 3. When deriving the droplet radius from satellite measurements, the correlation generally decreases due to uncontrolled fluctuations of the LWC (Nd is proportional to the ratio of LWC to the power 3 of the droplet size).

To tackle the first indirect effect is more difficult because the COT shall be measured in clouds with the same LWP. Considering that COT is roughly proportional to LWP x Nd$^{1/3}$, its value is 3 times more sensitive to LWP fluctuations than to variations of Nd. "Fluctuation" is used here to describe the parameter that is not measured precisely (LWP), while "variation" is for the parameter from which the susceptibility is derived (Nd). This results in a reduction of the correlation in the derived ACI due to the broad range of LWP values accepted in the data base, i.e. from 100 to 200 gm^{-2}. For the contributions of LWP fluctuations (a factor of 2) to be negligible compared to Nd variations, the measured Nd values should vary by a factor of 2x3=6. The changes in the quantification of the ACI and the reduction of the correlation factor is mainly due to the added noise when trying to address the whole chain without precisely constraining LWP.

I therefore recommend to focus the paper on the most reliable part of the study, i.e. “aerosol/cloud interactions” and discuss more in depth the results shown in Fig. 1 and 2 and the consequences when trying to connect the aerosol to the cloud optical thickness to quantify the AIE.

This part is original in the sense that it characterizes a regional aerosol burden and provides important information on which part of this aerosol is likely to be activated in boundary layer clouds. The approach based on statistical variation of the ACI with the lower bound diameter of the spectrum and the sudden decrease of the correlation seems very powerful to characterize this property on a statistical basis. Interpretation of these results could also be slightly developed, especially if there are additional information on the chemical composition of the aerosol. Another issue of interest would be if, within each data base, a few aerosol types can be identified, with very different activated fractions, depending on the air mass origin for instance, that could further be used to parameterize aerosol/cloud interaction in a GCM. Finally, it would also be useful to perform a simple calculation of aerosol activation using a parcel model and vertical velocities typical of the boundary layer clouds. I assume it is probably in the range from 0 to 2 m/s with a mode at 1, or slightly less than 1 m/s, as in typical BL clouds. This would help at understanding if the droplet concentration in these cases is aerosol limited or dynamically limited.

The part of the study based on satellite retrievals does not deserves publication since it has the same weaknesses as previous analyses (unknown LWP), and a lower statistical significance compared to global studies.

Detailed comments

Page 27470, line 22: “*The first two partial derivatives must be calculated at the constant LWP or cloud liquid water content*”.

The framework of the first AIE hypothesis is constant LWP. Constant LWC is not sufficient unless its vertical integral is, i.e. the LWP.

Page 27471, line 4: *where* d_k *is the. . .*

d_k cannot be mentioned here because it does not appear in the equation. It should rather be mentioned 4 lines below where the diameter range is discussed.

Page 27472, line 7: in the range dk=50-150 nm (not 15)

Page 27473, lines 5 to 9: No, the main reason for the decrease of the correlation and lower ACI values are the fluctuations of LWP.

Fig. 1 and 2: d, on the X axis

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