Atmos. Chem. Phys. Discuss., 13, C4661–C4667, 2013
www.atmos-chem-phys-discuss.net/13/C4661/2013/

Atmospheric Chemistry and Physics
Discussions

Interactive comment on "A long-term satellite study of aerosol effects on convective clouds in Nordic background air" *by* M. K. Sporre et al.

Anonymous Referee #3

Received and published: 10 July 2013

General comments

Sporre et al use ground-based aerosol measurements, satellite-retrieved cloud properties, ground-based preciptation data and modelled meteorological data to investigate relationships between aerosols and convective cloud properties at two locations in Sweden and Finland. After constructing vertical profiles of cloud-top cloud droplet effective radii (r_e) for each satellite scene, they find that smaller r_e values appear to be more closely associated with higher aerosol number concentrations (N_{80}) than with various meteorological parameters. In contrast, they find that precipitation rate is more closely correlated with meteorological parameters than with N_{80}. After stratifying the data into four bins of dT, a derived surrogate for vertical cloud extent, a negative correlation between N_{80} and radar reflectivity (dbzc), one measure of precipitation rate,

is found. The authors say that they found no obvious relationships between N_{80} and cloud optical depth or dT.

Investigating interactions between aerosols and clouds is an important but difficult problem. It is very difficult to establish causal relationships between aerosol and cloud properties. Sporre et al present a careful analsysis that would be a valuable contribution to this field. I recommend publication after they have responded to the comments below.

Specific comments

1. **Profiles**. The method used for creating vertical 'profiles' has been used in other studies. However, the term has the potential to be misleading, particularly in the abstract. The authors clarify their methodology in Section 2.5. It would be good to also include some clarification in the abstract, emphasising the the r_e is cloud top r_e for different clouds in a given scene. Maybe this could be done by achieved by re-writing the sentence at 13854.7 as follows: 'From the satellite scenes, vertical profiles of cloud top cloud droplet effective radius (r_e) are created by plotting retrieved cloud top r_e against cloud top temperature for the clouds in a given satellite scene.'

I would also question the assumption that the highest cloud top temperatures really represent T_B (13862.18), and hence whether dT is really a good indicator of vertical extent for a given cloud. Another possible interpretation of dT would be that it is a measure of inhomogeneity between clouds in a given scene. It is good that the authors state their assumption about T_B at 13862.18, but they may want to provide further clarification of this when they discuss dT and ΔT_{14}.

2. **Correlation vs causation**. The authors find N_{80}–r_e and N_{80}–dbzc relationships. There can be many reasons for observed relationships between aerosols and cloud properties. (See e.g. introductions of Quaas et al, 2010, doi:10.5194/acp-10-6129-2010 and Grandey et al, 2013, doi:10.5194/acp-13-3177-2013 for a discussion of possible reasons for correlations between aerosol properties and cloud fraction. Many of

these may also apply to r_e and precipitation rate.) The authors attempt to account for many of these. For example, the use of ground-based aerosol measurements avoids the problems of cloud contamination associated with satellite-retrieved aerosol properties; and interpretation of observed relationships can be difficult if large spatial scales and many cloud types are chosen, a problem that this study avoids by focusing on two locations and one particular class of clouds. Meteorological conditions are also considered. The fact that the r_e profiles are more closed associated with N_{80} does provide evidence that the aerosols may have a significant impact on r_e. And stratification by dT is a step towards accounting for the effect of meteorology on the N_{80}–dbzc correlations. However, I am not convinced that these analsyses conclusively prove that the relationships are indeed due to aerosol effects on clouds. In particular, it is very difficult to completely account for the impact of meteorological covariation. Furthermore, satellite retrievals of r_e may be unreliable (see point 4 below), and seasonal covariability may exist (see 7f below).

At times, the authors make strong statements about the causal effects of aerosols on clouds. For example, the abstract contains statements such as 'aerosol number concentrations result in smaller r_e' and 'an increase in aerosol loadings results in a suppression of precipitation rates'. I would caution the authors against stating such strong conclusions, both in the abstract and elsewhere in the manuscript.

3. **Null results.** In the abstract and final summary, it could be good to mention the null result that no relationship between N_{80} and cloud optical thickness was found (13867.1). The lack of any observed convective invigoration (13870.16) could also be mentioned in the abstract, as could the null results for two of the precipitation datasets (13870.6).

4. **Reliability of satellite-retrieved r_e.** The possibility of errors in the r_e retrievals is acknowledged in both Section 2.2 and and Section 2.5. Indeed, the authors make an attempt to select only the more reliable data. Further discussion of possible errors would be beneficial. In particular, retrievals of r_e generally assume plane-parallel clouds, so

the retrievals are likely to be more reliable for status and stratocumulus cloud fields than they are for broken cloud fields with more complicated 3-D geometry, such as the convective cloud fields studied here (Marshak et al., 2006, doi:10.1029/2005JD006686; Vant-Hull et al., 2007, doi:10.1109/TGRS.2006.890416). It is possible that 3-D effects may be more problematic for high solar zenith angles, so there might be seasonal cycles in these errors for high latitude locations like the two sites used in this study. Other useful references include Zinner et al. (2010, doi:10.5194/acp-10-9535-2010) and Bréon and Doutriaux-Boucher (2005, doi:10.1109/TGRS.2005.852838).

5. **Vague criteria in methodology.**

(a) Only vague criteria are provided for the selection of satellite scenes at 13859.11-20. More specific details should be provided.

(b) At 13862.8, the specific cloud optical thickness and cirrus reflectance threshholds should be specified.

6. **Introduction.** A few relatively minor suggestions:

(a) The authors may want to mention the semi-direct effect, maybe at 13855.12.

(b) The review of previous studies is currently in the following order: aircraft, then models, then satellite. A more logical order might be models, then aircraft, then satellite, so the observational/satellite studies can be more closely grouped together.

(c) Modeling paragraph: the review paper by Khain (2009, doi:10.1088/1748-9326/4/1/015004) would be a useful reference.

(d) Aircraft paragraph: at the beginning of 13855.20, 'suggested' is probably preferable to 'shown'.

(e) Satellite paragraph: it could be good to emphasise that correlations between satellite-retrieved cloud and aerosol properties are not necessarily due to aerosol effects on clouds.

(f) 13856.21-23: Stevens and Feingold (2009, doi:10.1038/nature08281) and Tao et al (2012, doi:10.1029/2011RG000369) are possible references for this sentence.

7. **Miscellaneous suggestions.**

(a) 13854.18 and 13870.2: when mentioning the precipitation rates/intensities here, specify that it is radar reflectivity, a measure of precipitation rate/intensity.

(b) 13854.17-23: in the abstract the relationship between precipitation and aerosols is mentioned before a statement saying that meteorological conditions are more closely related with the precipitation. In contrast, in the concluding paragraph (13871), the relationship between precipitation and meteorology is mentioned before the relationship with aerosols. I think the order in the concluding paragraph is clearer, and a similar order could be adopted in the abstract.

(c) 13858.8-10: does the discontinuity in the upper size limit affect N_{80}? It could also be good to introduce N_{80} in Section 2.1 – when re-reading the paper, many readers (myself included) may refer back to here, rather the Results section, when looking for a definition of N_{80}.

(d) 13864.1-3: it could be good to quote the correlation coefficients of 0.94 and 0.98 from Table 2 to convince the reader that N_{80} is indeed a good proxy for CCN.

(e) 18864.12: the authors state that the 'meteorological parameters used in this study do not seem vary significantly with air mass origin (Fig. 2c to h).' This does not appear to be true. The directional patterns in Figs. 2d and 2h appear to be as strong as in Fig. 2b.

(f) As a further step to account for seasonal covariation, it could be advantageous for the authors to repeat the analysis for JJA.

Technical corrections

Throughout: where possible, 'amount' should be replaced with more accurate words.

e.g. 'number' at 13863.18, and 'number concentration' at 13863.26.

13854.3: change '2' to 'two'.

13857.20: 'has' to 'have'.

13857.23: 'measure' to 'measures'.

13857.25: 'is' to 'are'.

13858.12: 'and has' to 'have'.

13859.3: 'at a 5km' to 'at 5km'. Similar at 13859.6.

13859.23: 'conditions, affect' to 'conditions affect'.

13859.25: 'data is' to 'data are'.

13860:14: consider moving the time resolution sentence to the 13860.19 or 13860.21, so that it is next to the sentence about the timing definition of each day. Also consider deleting the 'however'.

13860.27: 'was' to 'were'.

13861.3: 'could' to 'may'.

13861.18: 'method is assumes' to 'method assumes'.

13862.3: 'contaminations' to 'contamination'.

13862.14: 'has' to 'have'.

13862.15: 'hence' to 'implying'.

13863.6: 'not available during all days' to 'not always available during days'.

13863.15: 'normalizing' to 'offsetting' (if I've understood this correctly).

13864.2: 'correlates to' to 'correlates at'.

13865.15: ‘above’ to ‘colder than’.

13869.29: ‘strongest correlated to’ to ‘more strongly correlated with’.

13870.4: ‘is’ to ‘are’.

13871.4: ‘datasets the clearly’ to ‘datasets clearly’.

13871.20: ‘is’ to ‘are’.

13871.21: ‘distributions’ to ‘distribution’.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 13853, 2013.