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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Potential impact of aerosols on convective clouds revealed by Himawari-8 observations over different terrain types in eastern China" *by* Tianmeng Chen et al.

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In this paper, the authors seek to explore correlations between aerosol and convective clouds over Eastern China, with a focus on how these correlations depend on meteorological factors and the diurnal cycle. They develop a new method for identifying convective clouds in geostationary satellite data that compares well with existing methods. Using surface measurements of PM2.5 as their CCN proxy, they show that the occurrence of convective cloud is correlated to the aerosol environment across a range of meteorological environments. This relationship varies depending on the time of day and the terrain altitude, which they suggest may indicate variations in the response of convective clouds to aerosol.

This paper makes a useful contribution, investigating and enumerating aerosol-cloud relationships in a variety of conditions. There are some things I would suggest modifying in the presentation and interpretation of the results, following which this paper may be suitable for publication in ACP.

1 General points

Correlation vs causation. This is mentioned at the end of the paper, but should probably be more clearly addressed throughout. In particular, it is implicitly assumed that the aerosol is independent of the meteorology (at least when presenting the aerosol-CCF results), but it is then clearly shown that PM2.5 is correlated with almost every meteorological variable studied (Fig. 13). The results in Fig. 13 are then used to interpret results as a changing sensitivity of CCF to aerosol, rather than the perhaps simpler conclusion that the observed relationships are driven by meteorology. The changes here do not have to be large, but the authors should make it clear when interpreting their results that they have shown a correlation between aerosol and cloud properties, rather than the aerosols are a cause of these relationships (and definitely not the main cause - L642).

I might also suggest changing "probable" to "potential" when discussing the TH relationship to aerosol-cloud correlations, as it has a slightly different meaning when considering the likelihood of such a relationship being due to aerosol.

Terrain height vs. gradient. The use of terrain height to try and identify some information about the in-cloud updraft is a very interesting route. I might suggest that the authors consider the gradient of the terrain, rather than the altitude. Global model parameterisations (e.g. Joos et al, JGR, 2008) typically rely on information about the terrain variability, rather than the absolute height, to infer updrafts. These parameterisations are intended for cirrus, but seem to provide some information on convective

cloud updrafts too (e.g. Gryspeerdt et al, ACP, 2018). Similarly, the proposed mechanism (Li and Weng, 1987, 1988, 1989) seems to point more towards terrain variability, rather than absolute magnitude - perhaps for study in future work.

References. I am sure that it is a simple oversight given the large number of references, but quite a high proportion of the references are written by one of the coauthors. The authors are experts in this area and have written many important papers, so this is to be expected. I wouldn't suggest removing anything at this stage (and these references are not inappropriate), but including papers on aerosol impacts on Arctic stratus while leaving out seminal papers on aerosol-cloud relationships in convective clouds (Koren et al, GRL, 2005 and Williams et al, JGR, 2002 being particularly notable) might suggest the references could use a bit of attention.

Connected to this, there is a large amount of work specifically around accounting for meteorological effects in aerosol-cloud relationships (following on from Koren et al., ACP, 2010; Quaas and Boucher, Nat. Geosci, 2012), which would be highly relevant for the interpretations of aerosol-cloud correlations in this work.

2 Specific points

L118 - they cannot track cloud development individually, there are a number of papers that use multiple polar-orbiting satellites to observe cloud development (e.g. Matsui et al., JGR, 2006; Meskhidze et al., ACP, 2009)

L189 - Is PM2.5 suitable for use as a CCN proxy? Presumably there has been some work done on this before, but I imagine the suitability as a proxy depends on aerosol type. Is that constant across this region, particularly between the lowlands and highlands?

L206 - A number of meteorological variables are quoted here, but different ones are

then described below. How do they relate to each other?

L215 - LTS has shown some skill at predicting stratiform cloud cover over the ocean (Klein and Hartmann, J. Clim, 1993). Is it really suitable for investigating convective clouds? It also has a dependence on the surface altitude, as the lapse rate is not usually the dry adiabatic lapse rate (e.g. Wood and Bretherton, J. Clim, 2006). Is it suitable for a study where the terrain height changes?

L230 - Wang et al (2018) are also using other meteorological variables that include humidity information (such as CAPE). CAPE is not used here (but might be suitable for looking at convective clouds?)

L243 - Lee et al (2019) is looking at surface heterogeneity in a high resolution model for a 28km domain. Is it a suitable reference relating the large scale average vertical velocity to cloud-scale updrafts?

L257 - This texture method looks like an interesting way to identify convective clouds, but I was not clear on what exactly is being done. Equations 3-6 are introduced, but apparently not then used or referred to. It is stated that the contrast at d=1 is used. Is this then the central-difference second derivative at each point? It would be good to have some way to visualize it for those not familiar with the GLCM.

L300 - Which wavelength is used to calculate the contrast?

L302 - It was stated earlier that the texture method could reduce the need for thresholds, but some are still included. How much extra does the texture filter add beyond these filters? L326 suggests that the majority of the difference from MOD35 comes from the cirrus filtering, as the TCT-CID method selects the convective cores.

L311 - "Numerically smaller " is a bit ambiguous. Do you mean "less than"?

L343 - Does this mean that the TCT-CID method has an error that depends on solar zenith angle? That might be an issue for looking at the diurnal cycle. Does it have a large impact?

L366 - Yang and Slingo, M. Weather Rev. (2001) might also be a useful reference, although it only covers the southern part of China

L371 - You probably only need to cite one edition of "Cloud Dynamics"

L373 - The gray lines were a bit difficult to see on my screen. Perhaps you could make them black and remove the provinces from the map?

L388 - The LTS has an in-built dependence on the above-inversion lapse rate and hence the altitude of the 700hPa level. This could explain part of the dependence on the altitude.

L396 - The split of RH and updraft levels for the high and low populations might generate an artificial difference between them. Might it be more appropriate to use an updraft and RH at a specific height above the surface instead?

L399 - Related to L396 - the difference may be that different variables are being compared? This make the following interpretation difficult.

L427 - Is there a regional bias in the clean/polluted pixels? Does this end up comparing N. China to S. China (for example)?

L451 - It is interesting that the change is first observed in smaller clouds and this is a useful result. I am not clear how aerosol-radiation interactions are responsible though.

L467 - An extra explanation step would be useful to help the reader. How does a decrease in surface temperature lead to a suppression of the vertical moisture flux?

L500 - This would be good to check.

L510 - I am not sure what the semicolon means here (rather than a comma)

L514 - This is a little bit ambiguous, is the daytime 0800-1700, or is it defined using solar zenith angle?

L526 - How are the values in Fig. 9 calculated? My reading of Eq. 8 would make it

constant. In Fig. 9, the values presented are averaged over the whole region, so

$$N\bar{C}CF \propto \Sigma_i \Sigma_j NCCF = \frac{\Sigma_i \Sigma_j N_{C(P)}(i,j,h,t)}{\Sigma_i \Sigma_j N_{C(P)}(i,j,h,t)} = \text{const.}$$

Clearly I am missing something here, as this would lead to the NCCF being constant in time and altitude.

L564 - How are clean conditions defined here? They were previously defined at a gridbox level, but this is apparently an average over the whole regions?

L568 - This is a good example of the correlation vs causation issue. While the reduced above cloud RH in polluted conditions could lead to a "restraint of convective cloud development due to the inhibition of (the) aerosol microphysical effect", a simpler explanation is that the reduced above cloud RH itself limits convection, which doesn't require an aerosol impact on cloud. It is not clear which explanation is correct (probably a little of both), but it is not clear to me that aerosols are responsible for the aerosol-CCF relationship.

L609 - "may prove", "are probably". I am not sure that the evidence is there to make this strong a claim. There is still a considerable correlation between the aerosol and meteorological environment (Fig. 13)

L619 - Updraft is also related to the activation - if this is an aerosol effect, an increased updraft can lead to a larger sensitivity to aerosol (moving to an aerosol-limited environment).

L642 - "testing whether the results are mainly due to aerosol effects" is the same things as establishing causality (as I read it). I would perhaps consider - "However, establishing a correlation between aerosol and cloud properties is only a first step;"

L690 - Perhaps the pattern is "...consistent with the combined action..."? Given the correlations between aerosol and meteorology (Fig. 13), it is not clear that these correlations imply causality. This follows in later parts of the conclusions. Correlations have

been shown (and these are very interesting!), but it is not yet clear these are the result of an aerosol impact on clouds.

3 Additional references

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