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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Diurnal variation of heavy rainfall over the Beijing-Tianjin-Hebei region: Role of aerosol cloud effect and its sensitivity to moisture" *by* Siyuan Zhou et al.

Anonymous Referee #1

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Major:

The authors attempt to empirically link rainfall and other cloud properties to AOD with the implied underlying mechanism that AOD∼CCN at cloud base. The use of AOD as a proxy for CCN is not robust and has been discussed at length in the literature for many years (see Shinozuka et al. (2015) and references therein). This particular calculation is mainly problematic because AOD is increased by humidity (Twohy et al., 2009), which is also important to rainfall and the various cloud properties the authors are attempting to link to AOD. The authors show that RH covaries with AOD (Fig. 4a), but this is cast in the light of sources of moisture and pollution covarying, which

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may be partially true, but ignores the leading order problem with their analysis. The authors are guaranteed a correlation between AOD and CF, rain rate, and so on, just by aerosol swelling and increasing scattering. It has been shown that when these effects are taken into account the correlation between AOD and cloud properties becomes much much weaker(Christensen et al., 2017). For the paper to be acceptable to be published the authors must use a different proxy for CCN that doesn't build in the result. One possibility would be for the authors to use something like cloud droplet number concentration (CDNC) instead of AOD. This is also a problematic technique as CDNC may potentially be affected by cloud structure/heterogeneity, which will be different between precipitating and non-precipitating clouds. The authors do use CER in their analysis, but this implicitly builds in variations in liquid water content. For example, in a cloud with a fixed CCN and thus a fixed CDNC the LWC can decrease and decrease the CER. The authors do use MACC reanalysis aerosol data as well. They could instead try and rely on the aerosol mass from this product, which has been shown to have skill in predicting variations in CDNC in previous studies(McCoy et al., 2018;Boucher and Lohmann, 1995;Lowenthal et al., 2004). However, in doing this they need to deal with whether variations in precipitation are driving aerosol.

Overall- the built-in correlation between RH and AOD via swelling and the inability to show causality makes this paper unpublishable in ACP.

The authors treat MERRA2 cloud properties like they are observations. They are not. MERRA2 does NOT ingest cloud properties (McCarty et al., 2016). MERRA2 creates clouds just like any other GCM (Molod et al., 2015) and the cloud fraction is not reflective of the observations (see Fig. 9 of Molod et al. (2015). For example- on L223 P7 the authors refer to the 3D cloud properties. I believe this is just the MERRA2 cloud properties based on the discussion on L147 P5.

The authors may want to consider consulting a copy editor as some of the statements are hard to parse as written. Because the paper must remove the AOD as a proxy of CCN and remove MERRA2 cloud properties I have not bothered to note all the places

that the English needs to be clarified.

The abstract is on the short side. This makes it hard to tell what they are actually doing in the paper. The description is very vague. Things like aerosol and humidity are discussed, but it is unclear precisely what they mean. Is it AOD, aerosol number in the PBL? Is it RH or specific humidity? Is it in the PBL or the free troposphere.

Specific comments

L65 P2: Complicacy is a word, but I am not sure it's fair to say that the complexity of the clouds alone leads to complexity in the indirect effects. Aerosol processes are also important.

L70 P3: The author refers to the Albrecht/lifetime/adjustments and the Twomey effect/first indirect effect as the Twomey effect.

L74 P3: What is the different condition of moisture? I think what the authors mean is that if the air near cloud is moist or not the cloud droplet size can increase or decrease. This sentence needs a bit of clarification. The Twomey effect is not related to cloud droplet radius. It is the relation between CCN and Nd.

L82 P3: In one day of what? Do the authors mean that convective rainfall usually starts and stops within a day?

L111 P4: I assume this means above sea level. Also, wouldn't the orographic effect be the lifting by the orography, so the slope and the advection, not just the height? Limiting to sub-100m is probably ok, but there needs to be a better discussion of this.

L114 P4: AOD is not a proxy for particle number. It is the brightness of aerosol in the column of atmosphere, which in turn is a function of the scattering of the particles, the number of particles, and the mass of particles. The authors want to relate this quantity to CCN, which is a very outdated idea. CCN is more directly related to AI, but even then this is a highly imperfect metric because it is sensitive to aerosol swelling by moisture and the vertical structure. See, for example, Shinozuka et al. (2015). The

use of AOD as a proxy for CCN in this paper is a critical error and makes it hard to draw any meaningful conclusions from their analysis because AOD is enhanced by RH (Christensen et al., 2017;Twohy et al., 2009).

L134 P4: The spatial resolution is not 1x1° in MACC. The authors presumably mean the data is regridded to 1x1°.

L141 P4: Provide a citation for the evaluation of MODIS CTH with CALIPSO.

L147 P5: The authors appear to be using cloud properties from MERRA2 as if they were observations. This is a model product and is not nudged to agree with observations in any way. This is another critical flaw in the paper.

L159 P5: The ECMWF-Interim resolution is not 1x1°- again I assume this is the gridded resolution used in the study, but is confused by saying MERRA2 is 0.624x0.5° (L152).

L184 P6: How was the t-test applied? Was it difference in means or difference in the means within a bin. Throughout the paper it is stated that results are significant at 95% confidence, but it is unclear what this actually means.

L223 P7: MERRA2 is NOT equivalent to observations of cloud properties. This is just an analysis of the modeled cloud properties in MERRA2.

L239 P8: Different moisture conditions (which I guess just means RH at a fixed pressure level) also affect clouds.

L240 P8: Fixing the wind direction is not enough to orthogonalize RH, AOD, and clouds.

L300 P9: The authors do try and use BC and SO4 mass concentrations, which sort of gets around the issues with AOD and RH. The model level that the concentration is taken at is not specified. However, the authors still partition by AOD, and just use BC and SO4 to partition the high and low AOD cases. The results shown in Fig. 8 are not terribly convincing. It is stated that the results are significant at 95% confidence. What does this mean? Are the means different and 95% confidence or are the values of the

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PDF in each bin different at 95% confidence? From just looking at the PDFs it seems like only the BC peak time and SO4 duration are all that are different. The CF PDFs in Fig. 9 look different for SO4, but the jump in the PDF of CF at 90% does not look terribly robust. This may change if more bins are used in the PDF.

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