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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Links between satellite retrieved aerosol and precipitation" *by* E. Gryspeerdt et al.

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The authors investigate the relations between aerosols and precipitation properties of clouds. They address important questions that until now hampered the attribution of changes in precipitation to an aerosol effect, in an attempt to disentangle the effects of aerosols and meteorology. They did so by classifying the scenes into cloud types, and by applying lag correlations between the time of aerosols and precipitation properties. They also addressed the possible role of ice processes in the precipitation invigoration by classifying the scenes to warm and cold cloud tops, where warm clouds are defined as having top temperatures higher than 0 degrees C. I recommend accepting this study for publication in ACP after a revision that will address the comments here.

We thank the reviewer for their comments and address them in detail below.

Major comments:

The actual rain rate is not necessarily increased, although the indicated rain rate is higher. An outcome of the aerosol effect is to increase the drop and ice precipitation particle size for the same rain intensity (Rosenfeld and Ulbrich, 2003, Kuba et al., 2014). This is interpreted by radar and passive microwave measurements as more intense rainfall, and affects also clouds without ice. Furthermore, the added aerosols can cause expanded anvils for the same rainfall amount (Fan et al., 2013), which is again interpreted by 3B42 as a greater rainfall amount. This does not exclude the possibility of aerosol-induced cloud invigoration, as aerosols are inherently part of the physical process leading to it, as proposed by Rosenfeld et al. (2008). However, this means that the invigoration does not necessarily result in enhanced rainfall amounts. All the discussions and conclusions have to be revised to reflect these physical considerations.

We agree that there is considerable uncertainty in the retrieval of precipitation, generating significant possible systematic biases when investigating aerosol-precipitation interactions. Changes in the droplet size distribution, with an increased number of larger particles may result in an increased radar reflectiviy and retrieved precipitation without an increase in surface precipitation. This is a difficult problem to properly resolve and impacts both radar and passive microwave measurements. Whilst we are unable to completely exclude this as a factor in our results, it would be expected that this would also influence the retrievals at times before T+0 (as the temporal autocorrelation of AOD suggests that the pixels that have a high AOD at time T+0 also have a high AOD at times before T+0). The observation of a relationship consistent with wet scavenging rather than an increased precipitation rate at high AI before T+0 lends support to the idea that the observed increase in precipitation is not entirely due to retrieval errors.

Although it is also possible that our results are influenced by increases in the occurrence and size of anvil cirrus, this is also unlikely to be important for our study. Previous work (Tompkins and Adebiyi, 2012) suggests that the influence of anvils on the precipitation retrievals in the 3B42 product is smaller than in other precipitation retrievals due to the inclusion of retrievals from the TRMM precipitation radar. In the supplementary information, we also show plots where our analysis is repeated using the vertically resolved radar reflectivity from the TRMM PR. This also shows an increase in radar reflectivity after T+0, consistent with an increase in precipitation, rather than an increase in cloud anvil area. An increase in cloud anvils would not result in an increase in radar reflectivity at lower altitudes unless it was also coupled by a change in the precipitation properties (either the total precipitation rate or the droplet size distribution). The wet scavenging-like effect observed before T+0 also suggests that we are actually looking at changes in precipitation, as only changes in precipitation properties would be able to generate this effect; a change in cloud properties (such as an increased anvil area) would not impact aerosol and so could not generate this wet scavenging relationship.

We have expanded on this in the section covering the limitations of the precipitation retrievals (4.1) and modified some of the conclusions to reflect this.

Specific comments:

Page 6829 line 15: Please clarify what is meant by "mean daily minimum rain rate".

This has been replaced by "daily minimum rain rate", as the minimum rainrate observed in the composite precipitation diurnal cycle for each regime.

Page 6830 line 9: I can't see much effect in either Fig. 3m or 3n.

This section is intended to point out that there is little observed increase in precipitation with increasing AI in certain regimes at certain times. This is due to the diurnal cycle of

the regimes, such that deep convective regimes over land at 1030LST are a relatively rare occurrence. As such, they do not show a peak in precipitation in the afternoon and so compositing is less successful.

Page 6839 lines 10-11: Lower passive microwave brightness temperature at 85 GHz is interpreted as a higher rain rate.

Amended

Page 6839 lines 14-16: Please elaborate here on the way aerosols can affect rain drop size distributions and the indicated rainfall rates, and the implications to this study.

This has been covered above. We have amended the text to improve the clarity of our argument

Page 6839 lines 20-24: How is the possibility that the results are due to aerosols increasing radar reflectivity and decreasing passive microwave brightness temperature eliminated here? Please explain or change the conclusion.

We have amended this section to better explain the arguments behind this being a physical increase in precipitation. We have noted that this is not conclusive evidence and modified the conclusions accordingly.

Page 6843 lines 10-13: The suppression at high aerosols due to both microphysical and radiative considerations was proposed by Rosenfeld et al. (2008). Koren et al. (2008) ascribed the decrease only to radiative effects.

We have inserted this reference at the appropriate place in the text.

References:

Fan J., L. R. Leung, D. Rosenfeld, Q. Chen, Z. Li, J. Zhang, H. Yan, 2013: Microphysical effects determine macrophysical response for aerosol impacts on deep convective clouds. Proceedings of the National Academy of Sciences, 110(48), E4581-E4590.

Kuba, Naomi, et al. “Relationships between layer mean radar reflectivity and columnar effective radius of warm cloud: Numerical study using a cloud microphysical bin model.” Journal of Geophysical Research: Atmospheres (2014).

Rosenfeld D. and C. W. Ulbrich, 2003: Cloud microphysical properties, processes, and rainfall estimation opportunities. Chapter 10 of “ Radar and Atmospheric Science: A Collection of Essays in Honor of David Atlas”. Edited by Roger M. Wakimoto and Ramesh Srivastava. Meteorological Monographs 52, 237-258, AMS.

Tompkins, A. M. and Adebiyi, A. A.: Using CloudSat Cloud Retrievals to Differentiate Satellite-Derived Rainfall Products over West Africa, J. Hydrometeorology, 13, 1810–1816, doi:10.1175/JHM-D-12-039.1, 2012.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 6821, 2014.