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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Impacts of solar-absorbing aerosol layers on the transition of stratocumulus to trade cumulus clouds" *by* Xiaoli Zhou et al.

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This manuscript examines the behavior of a stratocumulus to cumulus transition (SCT) in the presence of sunlight-absorbing aerosols distributed both inside and above the boundary layer, using the well-respected DHARMA model. The transition is based on the template of a northeast Pacific transition. Different impacts have been postulated to occur over the past 30 years in this complex regime. These are capable of either strengthening or diminishing the overall radiative impact of the low clouds on climate; this study adds to a nascent literature attempting to unravel the significance of the different effects. In this study, the increase in cloud droplet number concentra-

tion (Nc) reigns dominant in both hastening the SCT, by increasing entrainment, and in the overall radiative impact, through the Twomey effect. The study is valuable for encouraging continuing thought and discussion on the various effects and is generally well-presented.

Recommendation: Acceptance with minor revisions

Main comment:

The aerosol representation does not allow for new sources or sinks so that the total particle number concentration (Na) is conserved. From what I can tell, once the initially-specified aerosol concentrations are activated, the cloud drops also don't leave the boundary layer, in both lightly-drizzling and heavily-drizzling conditions. This would be consistent with the conservation of Na. Thus in both the sulfate and soot aerosols, the Nc approach a value of 1000/cc after 1-2 days with basically no decrease thereafter. Is this interpretation correct? There is not much discussion of the actual precipitation rates: the authors characterize light/heavy drizzle as a sulfate Na of 150 or 25/mg respectively, with no discussion of the actual precipitation rates, including of the amount reaching the surface. It would be nice to see the model precipitation rates, and to see some discussion of this feature. If it is true that Nd can't leave the boundary layer, then the conclusion that the microphysical interaction is the dominant effect is to some extent built into the model setup, it seems to me. With the power of hindsight it is easy for me to say that the post-activation Nd amount of 1000/cc is at the high end of what measured in the southeast Atlantic. The attached plot shows the number of CCN at Ascension Island, where soot is often present near the surface. At 0.4% supersaturation, an unrealistically high supersaturation, CCN only reach 1000/cc occasionally. This just meant to provide context for the modeling results.

Specific comments:

abstract, line 4: include "to cumulus" line 85: the Feingold et al 2005 study pertains to smoke-laden clouds over the Amazon. Decreases in cloudiness were explained by reductions in surface fluxes because of attenuation by the smoke layers aloft. The current study does not examine how changes in surface fluxes related to the absorbing aerosol aloft (if surface fluxes do change) affect cloudiness, and during the SCT I suspect surface fluxes most likely change because of changes in SST. It would be useful to at least provide the SST range the clouds experience during the simulations (I don't see it anywhere). But what might be more relevant to the study's focus and introduction is to mention the observational results of Wilcox et al. (2010), who found increased cloud LWP when smoke was present overhead, and Loeb and Schuster (2008) and A15, who document increased cloud cover and TOA albedo when absorbing aerosols are present aloft. These observational results seem to suggest support for a negative (cooling) semi-direct effect (though in truth given how much the thermodynamic profiles in the aerosol composites shown in A15 fig. 14 differ from those depicted in the study in review, one has to wonder if perhaps associated changes in the large-scale circulation end up dominating the cloud response). in line 116 and in other places (line 202, the authors connect humidity increases with outflow from a deep continental boundary layer. It's also worth mentioning the role of the large-scale circulation, as for much of the year the smoke flows westward rather than eastward. Strong easterly winds aloft are needed to advect both the aerosol and moisture offshore, with some portion caught up in an anticyclonic circulation induced by a heat low over southern Africa, that further disperses both aerosol and humidity offshore. This characterization is the focus of Adebiyi and Zuidema, 2016. lines 197-206: a table of the different experiments would be useful, including within it a column listing the figures in which their results are shown. line 204: should 'impact' be preceded by 'microphysical'? line 238: worth mentioning that higher-level clouds are not considered. line 243 or elsewhere: it would be useful to see the precipitation rates and vertical structure associated with both the lightly and heavily drizzling cases…and the SST values imposed on the simulation. Figs 1, 2 and elsewhere: It would also be useful to mark the daylight (e.g. 6am-6pm LT) portions on the figures, and include mention of the starting time of the simulation in the caption of at least fig. 1. I also don't see discussion anywhere of how the large-scale subsidence

is prescribed. It is not connected to the radiative warming I'm pretty sure, which would also be good to mention. section 3.3: it looks to me from fig. 5 that the microphysical effect is still included from the absorbing aerosol experiments intended to focus on the semi-direct effect, is that correct? section 4.1, line 384: I don't think the simulations allow the radiative heating to translate into anomalous ascent. ERA-I reanalysis (A15, fig. 15 and the simulations of Sakeada et al 2011 do suggest the larger-scale subsidence is weaker when absorbing aerosols are present). It's worth mentioning. line 383: 'owning' should be 'owing'

Figures: see comment 7 above Tables: I had difficulty interpreting Table 4, perhaps it was just my printout. The physical processes sometimes span two lines, other times not. Why does increased evaporation not get a '+' in the SW column and '-' in the LW column? Why are other SW/LW columns left blank?

Tables 7 and 8: I think this is the first time I see an ensemble of the same simulations mentioned. would be useful to mention in section 2 somewhere if ensembles were indeed done.

References:

Adebiyi, A.and P. Zuidema, 2016: The role of the southern African easterly jet in modifying the southeast Atlantic aerosol and cloud environments. Q. J. R. Meteorol. Soc., 142, p. 1574-1589 doi: [10.1002/qj.2765] Loeb, N. G., and G. L. Schuster, 2008: An observational study of the relationship between cloud, aerosol and meteorology in broken low-level cloud conditions. J. Geophys. Res., 113, D14214, doi:10.1029/2007JD009763. Wilcox, E., 2010: Stratocumulus cloud thickening beneath layers of absorbing smoke aerosol. Atmos. Chem. Phys., 10, 11 769– 11 777, doi:10.5194/acp-10-11769-2010.

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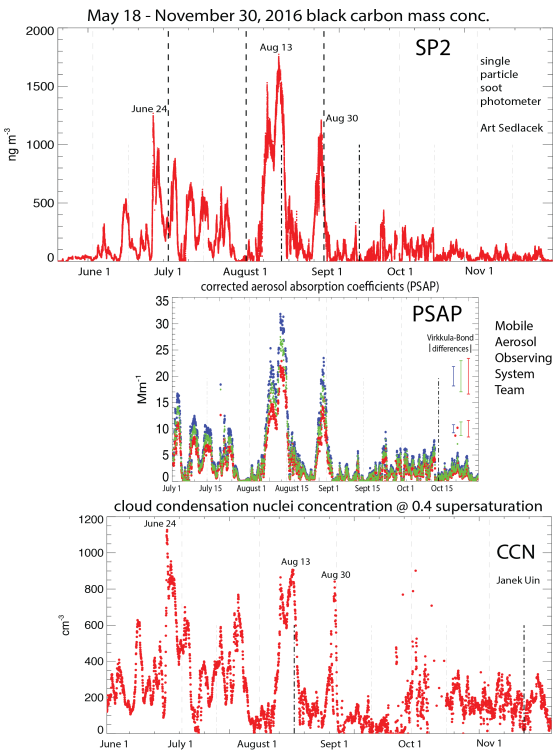

Fig. 1. data from Ascension Island, located at the end of the SCT. note the bottom panel in particular)