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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Diurnal cycle of the semi–direct effect over marine stratocumulus in large–eddy simulations" *by* Ross J. Herbert et al.

Anonymous Referee #2

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General remark

The paper discusses in depth the dynamics of the stratocumulus-topped subtropical marine boundary layer and its sensitivity to an elevated absorbing aerosol layer using a sophisticated LES model. The model experiment is well designed, but could benefit from a more detailed representation of cloud microphysics including aerosol-cloud interactions, which in fact was discussed. On the other hand, more degrees in freedom would certainly complicate interpretation of model results. The sensitivity study was carried out in a well-structured fashion in order to distinguish the effects of variable aerosol-layer properties on the cloud layer. As such, the type and number of experiments seems reasonable to cover the wide range of possible scenarios. It is further

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Discussion paper

laudable the extension of the sensitivity runs to cover the influence of meteorological and model parameters to corroborate the primary results. The study highlights the complexity and variability of the semi-direct effect of aerosols on cloud decks, which are too often simplified in climate models. As such, it gives a clear and consistent picture on how the variation of the aerosol layer properties affect the sign and magnitude of the semi-direct effect. Different environmental variables dampen or enhance the cloud response. The timing of the interaction process was found to be crucial, as the boundary layer evolves diurnally and eventually adjusts to the external forcing, which potentially reverses the sign of the semi-direct effect from an initial growth of the cloud. Eventually, the authors used the benefits of a LES model to give a thorough analysis of the altered thermodynamic properties and dynamics within the boundary layer communicating the feedback mechanisms, which is an important and interesting contribution to the topic. The well-structured paper contains an appropriate number of plots to visualize the data in order to promote the readers understanding and traceability of the text content. Concluding from the above, the paper presents a valuable contribution to ACP.

Minor comments

Page 4, line 74: Plural “extend of cloud-aerosol gaps”

Page 5, Model setup: Maybe add a sentence to the lateral boundary conditions. I assume they are periodic?

Page 6 and 7, Setup of elevated-aerosol experiments: Unfortunately, the CALIOP measurements are not that reliable, which makes this paragraph less significant. For cloud measurements it is often a tradeoff between accuracy and representativeness of different datasets. Aren’t there other data available, like aircraft measurements, that could complement the used data?

Page 7, line 195: I refer to “This type of experiment is analogous to a satellite retrieval that estimates the AOD and aerosol layer top but does not detect the lower extend of the aerosol layer.” How can this be analogous, if you cannot infer the geometric thickness? Do you assume an extinction profile?

Page 7, end of line 185: “absorbing aerosol” instead of “layer”.

Page 8, Eq.1: The ordering of the flux terms in the formula is wrong. It must be:

$$SDE = F_{TOA,aerosol} - F_{TOA,no-aerosol} - DRE \tag{1}$$

Page 14, Fig. 5: Is below-cloud RH the vertical mean for the distance from ocean surface to the cloud base? Otherwise, at which height is the value taken?

Page 15, line 340: Based on Fig. 6e the total water path (TWP) (units kgm-2), and not the total water content (TWC) (kgm-3) is compared. The reduction in total water path is in-line with the reduced BL height (which also decreases by about 15

Page 17, Eq. 3: This equation is confusing. The following formulation should be equivalent:

$$\begin{aligned} Z_{lower} &= Z_{max} \cdot (1 - 0.025) \\ Z_{upper} &= Z_{max} \cdot (1 + 0.25) \end{aligned} \tag{2}$$

If not, please rewrite it in a more understandable way.

Page 17, line 374: The explanation provided is not very convincing. Isn’t the initial peak of positive SDE occurring before or around midday? Anyway, at the time it occurs, the clout top height and entrainment rate seem not to be significantly affected by the aerosol layer (look at Fig. 5 or Fig. 7 red line of the 500m-gap experiment). How much does the elevated aerosol layer affect radiative cooling of the cloud tops at night? Does the initial positive spike in SDE could be related to this?

Page 19, lines 415 - 417: See comment above.

Page 27, Fig. 10 e,k,q: Please specify “BL mean” and “BL total”. I assume the dotted line is “BL total”? If “BL total” refers to TWP and “BL mean” to TWC you can see how the moisture content of air increases within the BL, despite an overall decrease in TWP due to the shrinking of the BL.

Page 29, line 633: This can only hold true if it is reasonable to neglect emission of longwave radiation of the aerosol layer and ergo its insulating effect.

Page 29, line 638: “, the magnitude of SDE is increased . . .”, or “, SDE is amplified . . .” is less ambiguous, as the sign of SDE is negative.

Page 31, line 719: missing “explain”

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