Review of "Diurnal cycle of the semi–direct effect over marine stratocumulus in large–eddy simulations" by Ross J. Herbert, Nicolas Bellouin, Ellie J. Highwood, Adrian A. Hill.

The objective of this study is to investigate the role of an elevated aerosol layer on the evolution of a subjacent stratocumulus deck and the resulting changes in the overall radiative budget of the atmosphere integrated in the so-called the semi-direct effect (SDE). For this purpose a 3D small scale atmospheric model (LEM) was applied simulating the cloud evolution of a stratocumulus deck over a domain of 5.2x5.2 km^2 for a time period of 2 weeks, forcing the model by the diurnal cycle of SW radiation at 33°N during mid-July. After one-week period of "spin-up" a persistent aerosol layer was added above the cloud. The presence of the aerosol particles modifies the temperature conditions above the BL due to radiative heating by the absorbing aerosol during daytime. Consequently turbulent exchange processes (entrainment, detrainment) at the interface BL top / FT are altered (generally reduced) causing changes in the vertical structure of heat, turbulence and moisture over the entire BL.
The study investigates primarily the role of the depth of the aerosol layer, its distance from the cloud top and its aerosol optical depth. In this context the overall findings and conclusions are:
1) a persistent aerosol layer increases slightly SDE during daytime and
2) the strength of the SDE can vary considerably during daytime, what sheds doubt on the reliability of SDE data established from satellite observations only available during short daytime periods.
In addition also changes in the model set-up (i.e. modifications in large scale cooling, SST, FT moisture) and model processes (*no-rain* case) were imposed that confirm generally the previous results for SDE.
Only the increase of the BL depth up to 800 and 1000 m allows the suppression of a negative forcing due to the SDE.

All experiments investigate how daytime temperature perturbations just above the BL modify the BL's structure and its development. The cloud response is limited to the thermodynamic and turbulent changes in the BL and is thus only indirectly connected to the presence of an elevated aerosol layer.
General critic: the paper gives the impression that the general influence of absorbing aerosol on the cloud evolution has been investigated. However, it is only the radiative effect of the absorbing aerosol layer that enters in the discussion on the SDE, not the effect of aerosols "polluting" and thus modifying additionally the thermodynamic and hydrological cycle of the cloud and the BL. This should be highlighted in abstract and introduction, and should not only be mentioned at the end of the conclusion.
The title of the paper should already include the key parameter of this study, i.e. " a persistent absorbing aerosol layer".
It is the LES model and its turbulence closure, which primarily determine the simulation results. Also the cloud description, even in simplified way, as it is in this study, affects the finding. Using other LES and cloud models (as done by other studies) will lead to a different result for the semi direct effect. This should be also highlighted in the conclusions of this paper.

Although the study has also a couple of weaknesses (more details are below) the paper can be accepted for publication after corrections and improvements.

<u>*Detailed remarks:*</u>

123 is the radiation code applied for all 130x130 columns individually or only for one mean profiles of T, Qvap and Qliq ?

212-220 makes it almost impossible to understand the calculation of the SDE. A reference would be helpful (Hill and Dobbie, 1980?). I guess DRE uses the results of the simulations with the aerosol layer, actually not explained in the paper.

233 in caption of Fig. 3: w'w'w' is named the perturbation in mean vertical velocity. No, it is the perturbation of w to the power of 3, but it has another physical meaning. Why was it selected to illustrate the BL turbulence characteristics?

239-240 "During the daytime, … through weakened surface to atmosphere gradients". The total water profiles (which are dominated by the presence Q_vap) for t = 13h and t = 5.30h in Fig.3c illustrate the contrary. Only the surface gradient in the first 10-20 m above the sea at 5.30h is stronger than the daytime conditions.
Also for THETA_liq in Fig. 3b a weak gradient exists during daytime but none at 5.30h.
This explanation of the decoupled state of the BL during daytime is not really convincing. Fig.3d and e better indicate the daytime / nighttime differences in the BL which are controlled by the vertical turbulent transport of tke and thus by the turbulence simulated in the LES model.

241 SST is kept constant, how are surface heat and moisture fluxes calculated? Give the key parameters.

274 Terminology in the caption of Fig.4: instead of "response" a more explicit description like "differences between no-aerosol simulation and simulation with an elevated aerosol layer" would make the illustration ΔCloud, ΔLWP and ΔAlbedo and the reference to equation (1) more understandable.

298 … allows the cloud layer to maintain a higher RH. This is difficult to understand and to believe, as explained in 2.2 the cloud model excess supersaturation is converted in liquid water.

301 -302 … enhanced RH below cloud (caused by an increase in water vapour) … by the decrease in latent heat flux. This is not credible. Q_total, i.e. mainly Q_vap, continuously decreases; also LHF mainly decreases but RH increases. RH is a function of two independent state variables T and Q_vap. What happened to the temperature T during the "aerosol" simulations in the BL. The paper completely omits a discussion on changes of the T profile in the BL after section 3.1. Temperature perturbations above the BL are the key parameter for the different SDE scenario in this study but a discussion of subsequent temperature changes in the BL is completely ignored - why?

308 where can we see thicker clouds in Fig.5a in the afternoon of day 3? I can't.

335-336 "The decrease in cloud layer height allows better mixing beneath the cloud base, which enhances the evaporation of moisture from the surface between 0900 and 1500 ". This is in any case a speculation. It is not coherent with the daytime turbulence profile of Fig. 3e for the non-aerosol simulation.

346 rephrase "reduction in evaporation and associated cooling of entrained air". What do you mean with cooling of entrained air?

347 the reduced vertical motions reduce surface evaporation. Same question as above for 241.

394 Fig. caption 7: same remark as in 274

416 … quicker than the cloud base. Where or how to detect?

520 the *norain* simulation is not a model setup modification, but a change in the modeling physics.

522 the strengthening of the SDE is +1 W/m2 (or +3) from -7 to -8 W/m2 (or -9 to -12)
why not –1 W/m2 (and –3)?

527 – 535 This discussion or interpretation of the results cannot be understood with the given information on the *05cool* simulations. Thus, this part should be omitted.

537 and 547 Are the *SST* and *wetFT* simulations really with no-aerosol? This is probably a typo.

549 allowing the BL to maintain *below the cloud layer* a greater RH ?

564-565 … a redistribution of water from the cloud layer to the surface layer (Fig.9b). What do you mean with redistribution? Does it mean that rain is responsible for the significant Qvap increase in the first 300 m? This is most unlikely. Water vapor is accumulated in the lowest levels due to surface evaporation in the decoupled BL.

630 3b. The conclusion that RH increase as Q_total increase, implicates that the BL temperature remains constant or decreases. This study, however, withholds this fundamental information.

721 regional climate models as HadGEM certainly treat surface fluxes