Review of Bulatovic et al.

This paper uses Large Eddy Simulation (LES) modelling to investigate the effects of aerosol and ice concentrations on a 2-layer Arctic stratocumulus cloud case study. The control case produces a cloud that seems to match the observations very well (although a more detailed comparison to observations could be performed; see below). The effects of changing the aerosol concentration is investigated with the model and shows an increase in LWP with increasing aerosols. At low aerosol concentration the upper cloud layer dissipates with large shortwave and longwave surface radiative impacts (a change from an overall net SW+LW warming of the surface in the control case to a near-zero net radiative surface flux; this will likely affect surface melting). The effects of ice concentrations and divergence are also investigated but they only have small impacts. Increasing the wind speed causes the lower cloud layer to dissipate while the upper one remains (but gets thinner). The removal of the lower layer causes an increase in the longwave surface cooling and reduces the net surface LW+SW flux by around 50%.

Overall, the study is well designed and the paper is well written with some interesting results. The model seems to produce realistic results for the control case, although the available observations could be used to test the model more thoroughly (e.g., a comparison of radar reflectivity). And there are some questions about how realistic the treatment of entrainment is (particularly its variation with aerosol concentrations). I also think that the paper could do a better job of describing some of the shortwave vs longwave effects of the upper cloud layer vs that of the lower cloud layer. Please see the comments below for more details on all of these issues.

I recommend the publication of this paper once the points below are addressed.

Main issues

Section 2.2 – the model details give no information about whether the model includes droplet sedimentation. It would be good to provide this information and to comment on what that implies for entrainment changes as a function of aerosol changes. More discussion on the literature of entrainment effects would also be good.

Fig. 2 – is it possible to make versions of this from the modelled data for comparison to the observations? E.g., a comparison of the radar reflectivity would help to test whether the model precipitation rates and snow/graupel amounts are accurate since this is likely to be an important process that determines the sensitivity to aerosols. Or if not, it could be mentioned as something that could be done in the future.

L432 – could the smaller IWP in the run with the larger LWP be due to the fact that there was lots of graupel in that run (Fig. 8i) so that graupel water path would actually be quite large (maybe around 5 g/m2). So if you combined the ice, snow and graupel to give a total ice water path it may be larger than the other runs? Does the IWP from the observations also include snow and graupel?

L444 – It would be worth mentioning the SW+LW effect – i.e. that very low aerosol can prevent the net surface energy input to the surface (that could cause melting).

L576 – “This means that the lower layer became partially transparent to radiation so that the longwave radiative effect dominated instead of the shortwave effect, i.e., a lower aerosol concentration resulted in a cooling of the surface.” – this is a little bit imprecise and unclear. How

about :- “This meant that the both cloud layers were partially transparent to shortwave radiation, which increased the shortwave heating of the surface. However, both cloud layers also became too thin to emit significant longwave radiation which increased the longwave cooling of the surface. The longwave radiative cooling effect dominated over the shortwave warming effect so that the lower aerosol concentration resulted in a cooling of the surface.”

- Although it’s not clear from the rest of the paper whether you determined whether it was the disappearance of the top cloud layer in aero_id_low that led to the increase in net surface shortwave, or whether it was the thinning of the lower layer. And similarly for the longwave effects – the lower cloud layer still looks to be there in aero_id_low. Fig. 14 suggests that the removal of just the lower cloud layer in the wind_8.5 experiment leads to an increase in the LW surface cooling from -4 to -12 W/m2 by the end of the simulation (a difference of -8 W/m2), whereas Fig. 10 shows a reduction from -4 to -40 W/m2 due to the removal of the upper cloud layer (with the lower cloud layer still present, although thinned out somewhat – Fig. 9). This suggests that it is the removal of the upper cloud layer in aero_id_low that is having the bigger impact on the longwave and shortwave fluxes?
- This should also be addressed in the abstract. Currently you write :-
    - “The investigated cloud structure is persistent unless there are low aerosol number concentrations (≤ 5 cm-3), which cause the upper cloud layer to dissipate, or high large-scale wind speeds (~ 8.5 m s-1), which erode the lower inversion and the related cloud layer. These types of changes in cloud structure lead to a substantial reduction of the net longwave radiation at the surface due to a lower emissivity or higher altitude of the remaining cloud layer.”
- However, you should also mention the importance of the increased surface warming from the shortwave and increased LW cooling when the upper layer is eroded. It would also be good to talk about the net SW+LW effect in the abstract since this will help determine surface melting. I.e., the very low aerosol case leads to a near-zero net radiative heating at the surface, which may reduce or prevent surface melting. Although the wind effect on the surface net warming (lower layer only) is smaller.

L584 – It would be good to document what happens to the total ice water path here as well (ice+snow+graupel). Also, it is interesting that IWP increases towards the end of the simulation in the lower ice concentration cases, so that it matches the higher ice concentration cases – can you say something on why this is?

L593 – “A noticeable effect on the longwave radiation was only obtained in the experiments where the lower cloud layer became optically thin or completely dissipated (i.e., the simulations with the lowest aerosol number concentrations and the highest wind speed, respectively).”

- I’m not sure that I agree with this since the removal of the upper cloud seemed to have an even larger large longwave effect – see above.

Figures

Fig. 2 – It would be good to have some titles and colorbar labels on this figure.

Fig. 5 – It's not quite clear what dN refers to and why the x-axis is the modal diameter. Is this instead showing dN/dlogDp with Dp being just the aerosol diameter? I.e., does the integral under the curves give the total number?

Fig. 6 – the colours for 12 and 18h are not very colorblind friendly – I'm finding it hard to distinguish them.

Typos etc.

L23 – "capped by a lower temperature inversion" – do you mean a smaller magnitude inversion or a lower-altitude one?

L24 – "The investigated cloud structure" – better as "The simulated cloud structure" to show that this was the result of modelling rather than from observations.

L27 – "net longwave radiation at the surface" – would be good to say that this is the "net downwelling longwave radiation" for clarity.

L85 – "difficulty to simulate" -> "difficulty simulating".

L150 – "minimize the risk of sampling pollution from the ship, I/B Oden was turned approximately upwind" – it would be good to mention that the ship exhausts are (presumably) at the rear of the ship relative to the instruments.

L359 – "likely due to that large-scale advection is not explicitly considered in the LES" -> "likely due to the fact that large-scale advection is not explicitly considered in the LES"

L419 – "less (more) aerosols" -> "fewer (more) aerosols"

L568 – "solar part of the spectrum" should be "shortwave part of the spectrum" since the solar spectrum covers the whole range (although peaking in SW of course).

L570 – "for 4W/m2" -> "by 4 W/m2".

L572 – "When Aitken and accumulation mode aerosol number concentrations in. being representative of the whole ice drift period" -> "When Aitken and accumulation mode aerosol number concentrations that were representative of the whole ice drift period"

L573 – "then the total LWP decreased substantially (up to 150 g m-2)" -> "then the total LWP decreased substantially (by up to 150 g m-2)"

L575 – "representative of the lowest observed percentile (=5 cm-3)," -> "representative of the 25th percentile of the ice drift observations (=5 cm-3),"