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Interactive Comment

Interactive comment on "Comparison of a global-climate model to a cloud-system resolving model for the long-term response of thin stratocumulus clouds to preindustrial and present-day aerosol conditions" *by* S. S. Lee and J. E. Penner

Anonymous Referee #2

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Synopsis:

This study compares a GCM and a CSRM simulation of the cloudy marine boundary layer in July off the coast of Mexico under present-day and preindustrial conditions. This study is a follow-on to a recently published study (Lee et al. 2009a) in which the same GCM and CSRM are compared using present day aerosol emissions. The present study extends that study by comparing with simulations using pre-industrial aerosols. In both cases the GCM output is used for a 20-day period to force the CSRM. One of the principal conclusions of this study is that the CSRM and GCM respond very differently to changes in the aerosol concentration. Also, the stratocumulus in the preindustrial CSRM has more precipitation and thinner cloud which is attributed to a lower condensation rate.

The use of CSRM to better understand the GCM responses and to test the GCM is a promising approach, but there are serious problems with the budgets presented here which raise large doubts about the interpretation. Further, the presentation is lacking some important details. Because of these weaknesses and the fact that the complex results do not add substantially to the original Lee et al. (2009a and 2009b) studies, I cannot recommend publication in ACP.

Main points:

There appear to be some large problems with the liquid water budget for stratocumulus shown in Table 3 and discussed at length in the paper.

1. From the time-averaged conversion rate profiles of cloud liquid to rain in Figure 12b, one can estimate the cloud-base precip flux by vertically integrating. For the CSRM-PD run, for a 200m thick cloud with a mean production of 0.03 g/(mˆ3 day) that makes 6 g/(mˆ2 day) or 0.006 mm/day. This is much smaller than the mean cloud-base precip fluxes of 0.2 mm/day (before 00 17 Jul) which could be estimated from Lee et al (2009a) Fig 14.

2. There is an even larger precipitation discrepancy for CSRM-PD between Table 3 and precip rate. Autoconversion + accretion is 0.00735 mm / 16.3 days = 4.5 x 10ˆ-4 mm/day compared with 0.2 mm/day in Lee et al (2009a) Fig 14.

3. In Figure 9a, vertically integrated condensation in CSRM-PD could be estimated as 200m * 3 g/(mˆ3 day) = 600 g/(mˆ2 day) or 0.6 mm/day. Over 16.3 days that should be 10 mm, which is much larger than the 0.34 mm reported in Table 3.

4. Again for the CSRM-PD run, <dqc/dt> = 0.033 mm indicates that the LWP should be 33 g/mˆ2 bigger at 00 17 Jul than at the start of the run, while the difference in LWP between these times in figure 6 is only about 4 g/mˆ2. A similar discrepancy is present for the CSRM-PI run.

I am skeptical but intrigued by the possibility that condensation differences due to aerosol differences are driving the differences in the LWP in the clouds, as was also argued in Lee et al 2009b. However this budget analysis needs to be corrected in order to try and make that point. It appears plausible to me that drizzle fluxes and not condensation rate are causing the LWP differences. The CSRM-PD run has a diurnal mean of roughly 0.2 mm/day of cloudbase precip (Lee et al 2009a fig 14), and the clean case CSRM-E(PD)-(A(PI)) has double precipitation production (autoconversion + accretion) according to Table 3, and therefore double the cloud-base precipitation rate. The difference between the runs of 5 W/mˆ2 heating (cooling) in cloud (below cloud) is not negligible in the energy budget, and could certainly have a significant effect on LWP.

Another problem with this study is the use of a very unrealistic GCM stratocumulus simulation as the base state. The coarse GCM resolution together with the very strong thermal stratification in the chosen case results in the representation of the entire boundary layer by only one or two vertical grid points. The stratocumlus-topped boundary layer produced in the GCM is extremely and unrealistically shallow (∼350m as compared with e.g. ∼550-700m for FIRE I, July 1987, 3 degrees to the north of the study location) more akin to fog than to stratocumulus, with an unrealistically deep (>200m) capping inversion. This provides a very unrealistic initial state for the CSRM and makes the study of the GCM and CSRM sensitivity to aerosol less useful.

Other points:

How much do the temperature and moisture profiles above the boundary layer in the CSRM simulations drift from the GCM simulations over the twenty days? Lee et al

(2009a) shows that in the clear sky case the the GCM and the CSRM evolution is fairly similar in the lowest 2km of the simulations. However this may not be the case in the presence of clouds. Ideally the CSRM profiles of temperature and humidity above the inversion need to stay near to the GCM profiles to make the simulation comparisons meaningful. Temperature/moisture profiles at different stages of the runs should be shown.

It is unclear from the descriptions here or in Lee et al. (2009a) whether or not meteorological analysis is assimilated into the GCM runs other than for aerosol transport. The comparison with MODIS observed LWP in Figures 6 and 7 appears to be for a specific year. However, from the description on p. 21326 line 18, MODIS is averaged over the years 2001-2008, and is not from a specific year. If the MODIS data is not from a specific year, the MODIS time series should not be plotted, only the mean value and standard deviation for the simulation period.

The 20m vertical resolution chosen for the CSRM is also relatively coarse to be trusted to realistically study subtle changes in stratocumulus (e.g. Bretherton et al. 1999, Stevens et al. 2005) especially over a long time scale where entrainment differences could have substantial impacts.

Minor points:

One can infer from Lee et al (2009a) that the large scale vertical velocity from the GCM is imposed on the CSRM. This should be stated here, and the evolution of vertical velocity described for these cases or ideally plotted as this can substantially influence boundary layer evolution.

What was the motivation for selecting this particular location and time period for your study?

Domain averaged vertical profiles of precipitation flux would be very helpful to show in order to understand the CSRM simulations presented in this study.

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p.21326 line 17: The GCM runs don't appear to be averaged over 24 hours in Figure 6 as stated. For example the GCM-PD LWP plotted drops to zero twice at days 9.5 and 10.5, which means it couldn't possibly be non-zero at day 10.0. They should be averaged over 24 hours for a better comparison.

p.21328 line 17: The transition would be better described as a change from stratocumulus to cumulus under an elevated stratocumulus deck. The cloud fraction actually increases in the CSRM-PD run during this period compared with the stratocumulus period.

'July' should replace 'June' in many places: p.21332 line 9, p.21335 lines 13 and 18, p. 21338 line 21, p.21340 line 22, p.21342 line 27, Figure 8a top and in the figure caption, Figure 8b top of the figure, Table 2 multiple column headers

p.21321 line 15 Is the acronym CDNC defined? p.21322 line 8 'rerpresent' p.21330 line 24 should read 'Also, it needs to be pointed out' p.21331 line 2 Figure 11 is introduced here 2 pages before Figure 9 is. p.21338 line 12 It is budget 'terms' shown in Table 3 not the budget 'equation'. p.21347 line 2 should be 'changes'

Table 2: 'MODIS' and 'Simulation' should be switched relative to the diagonal line

Table 3: Text 'Domain averaged budget terms...' inside table is redundant. Units (mm) should be in the table caption.

Figure 5: An additional contour level at 0.1 g/kg or 0.2 g/kg would be helpful, as 0.4 g/kg is very large for typical stratocumulus clouds.

Figure 11. The fonts in the figure legend and at the top of the plots are too small

References:

Bretherton, C. S., M. K. MacVean, and 14 coauthors, 1999: An intercomparison of radiatively-driven entrainment and turbulence in a smoke cloud, as simulated by different numerical models. Quart. J. R. Meteor. Soc., 125, 391-423.

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Lee, S. S., J. E. Penner, and M. Wang, 2009a: Comparison of a global-climate model simulation to a cloud-system resolving model simulation for long-term thin stratocumulus clouds. ACP, 9, 6497-6520.

Lee, S. S., J. E. Penner, and Saleeby, S. M. 2009b: Aerosol effects on liquid-water path of thin stratocumulus clouds. J. Geophys. Res., 114, D07204, doi:10.1029/2008JD010513.

Stevens, B., C.H. Moeng, A.S. Ackerman, C.S. Bretherton, A. Chlond, S. de Roode, J. Edwards, J.C. Golaz, H. Jiang, M. Khairoutdinov, M.P. Kirkpatrick, D.C. Lewellen, A. Lock, F. Müller, D.E. Stevens, E. Whelan, and P. Zhu, 2005: Evaluation of Large-Eddy Simulations via Observations of Nocturnal Marine Stratocumulus. Mon. Wea. Rev., 133, 1443–1462.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 21317, 2009.