Atmos. Chem. Phys. Discuss., 9, C3612–C3619, 2009
www.atmos-chem-phys-discuss.net/9/C3612/2009/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Comparison of a global-climate model simulation to a cloud-system resolving model simulation for long-term thin stratocumulus clouds" *by* S. S. Lee et al.

S. S. Lee et al.

seoungl@umich.edu

Received and published: 6 August 2009

First of all, we would like appreciate the reviewer's comments and suggestions. In response to the reviewer comments, we have made relevant revisions in the manuscript. Listed below are our answers and the changes made to the manuscript according to the questions and suggestions given by the reviewers. Each comment of the reviewer is listed and followed by our responses.

Anonymous Referee #2 Received and published: 20 July 2009 The manuscript presents numerical simulations of a marine atmospheric situation characterized by formation of stratus clouds that evolve further into cumulus. Numerical simulations are

carried out with a relatively detailed cloud resolving model, that accounts in some way for aerosol, aerosol activation and cloud microphysics, and a global climate model in which aerosol and cloud processes are parameterized in a relatively simple way. The CRM reproduces the cloudy episode relatively consistent with measurements, whereas the GCM fails to represent the intricate boundary layer dynamics that lead to the formation of cumulus from the stratus.

The cloudy episode is presented in detail, with attention for heat and radiation fluxes, LWC and LWP, and aerosol concentrations. The dynamics and microphysics are described in a clear and convincing manner. The comparison with the GCM is also very clearly presented. Of course it is no surprise that the more detailed model performs better than a GCM, with relatively coarse resolution and highly parameterized microphysics, but it is highly illustrative to compare the performances of both models with detailed attention for all relevant parameters. The figures are clear and of good quality. The manuscript is certainly suitable for publication in ACPD and ACP. I have a few minor comments that need to be considered.

Specific comments

Section 2. CSRM contains a sophisticated aerosol activation scheme, but the representation of aerosol in the model is not clearly explained.

The representation of aerosols (e.g., aerosol species and parameters of aerosol size distribution) is described in more detail in Liu et al. (2005) and Wang et al. (2009).

The aerosol mass profiles produced by the CAM-UMICH are used to obtain aerosol size distribution of each species. Here, the distribution is assumed to obey the log-normal distribution. Using the assumed mode radius, standard deviation, and partitioning of aerosol number among modes described in Chuang et al. (1997) for sulfate aerosols and Liu et al. (2005) for non-sulfate aerosols, we can obtain the distribution of aerosols of all species (e.g., sulfate, fossil fuel BC/OM, biomass BC/OM, sea salt, and dust) considered here using the predicted aerosol mass. The more detailed procedure

to construct the size distribution is as follows:

1. Based on the assumed mode radius and standard deviation, partitioning of unit aerosol number among modes described in Chuang et al. (1997) for sulfate aerosols and Liu et al. (2005) for non-sulfate aerosols, we can calculate aerosol mass in each size bin in each mode with assumed aerosol number like Ni in Table 3 in Liu et al. (2005) and Table 2 in Chuang et al. (1997) for each mode; in this case the sum of aerosol number over the modes is only 1 for each species and we used assumed aerosol particle density for each species.

2. Then, increase or decrease mass in each size bin in each mode for each species until the sum of aerosol mass over the modes becomes equal to the predicted aerosol mass from the CAM-UMICH.

3. Finally, with the determined aerosol mass in each size bin in procedure 2 and assumed aerosol particle density for each species, we can calculate aerosol number concentration in each size bin in each mode for each species, which is fed into the nucleation scheme.

To give more information of the aerosol representation to readers, the following is added:

(LL348-354 in p12-13)

Aerosol number concentration is calculated from the mass profiles using parameters (mode radius, standard deviation, and partitioning of aerosol number among modes) described in Chuang et al. (1997) for sulfate aerosols and Liu et al. (2005) for non-sulfate aerosols (e.g., fossil fuel BC/OM, biomass BC/OM, sea salt, and dust) as in the GCM runs. Here, bi- or tri-modal log-normal size distribution is assumed for aerosols and the number of aerosols in each size bin of the distribution is determined using these parameters and assumed aerosol particle density for each species.

page 12307. The last sentence before 6.5: “condensation provides liquid water as a

source ....” can be formulated more clearly.

Cloud liquid formed by condensation eventually disappears via evaporation and very small portion of cloud liquid converts to rain via autoconversion and accretion before its disappearance in this study. This indicates that condensation controls evaporation by determining the amount of source (i.e., cloud liquid) of evaporation; the role of autoconversion, accretion, and sedimentation in the determination of the source is negligible. Larger (smaller) condensation induces larger (smaller) cloud liquid. Larger (smaller) cloud liquid eventually disappears and this disappearance should involve larger (smaller) evaporation for larger (smaller) cloud liquid (produced by larger (smaller) condensation).

The following replaces the sentence pointed out here:

(LL664-669 in p23)

Cloud liquid formed by condensation eventually disappears via evaporation. Since very small portion of cloud liquid (produced by condensation) converts to rain via autoconversion and accretion before its disappearance, condensation controls most of cloud liquid as a source of evaporation. Hence, condensation induces much larger evaporation than autoconversion, accretion, and sedimentation (Eq. 7).

Fig. 8a/b: How do you explain the large LWP variability in the GCM compared to MODIS and the CSRM? And how do the approximate accuracies/uncertainties associated with the retrieval of the MODIS LWP and droplet size compare with the model observation discrepancies?

As stated in the text, the saturation adjustment scheme in the GCM used here tends to produce ~ 4 times larger condensation as compared to the condensation scheme in the CSRM. It is found that, as clouds deepens, the difference in condensation between the GCM and the CSRM becomes larger. In other words, the difference in condensation and thus LWP becomes larger, as diurnal decoupling weakens during the nighttime

when clouds in both the CSRM and the GCM have maximum LWP on daily basis. This indicates that the sensitivity of the scheme associated with condensation in the GCM is more sensitive to the variation of the water-vapor transportation from the surface to the cloud layer, which is controlled by the magnitude of decoupling. We think one of the causes of this different sensitivity is because the scheme in the CSRM tends to smooth out supersaturation through interactions between supersaturation and CDNC whereas the scheme in the GCM does not have these interactions allowing the occurrence of very high ratio of water-vapor mixing ratio to saturation water-vapor mixing ratio.

The following is added to state about the possible cause of the larger fluctuations in LWP in the GCM than in the CSRM.

(LL877-886 in p30)

The diurnal variation of LWP in the GCM run is much larger than that in the CSRM run. This leads to much larger temporal fluctuation in LWP in the GCM run than in the CSRM run as shown in Figure 8a. It indicates that the saturation adjustment scheme in the GCM is much more sensitive to diurnal decoupling and thus the diurnal variation of the transportation of water vapor from the surface to the upper layers than the scheme predicting supersaturation in the CSRM. This demonstrates that the presence of interactions between CDNC and supersaturation acts to damp down the variation in supersaturation with varying decoupling, whereas the absence of these interactions allows comparatively high supersaturation to occur. Further study to gain the understanding of the role of these interactions in supersaturation and sensitivity of clouds to diurnal decoupling is needed.

The following is added to discuss about the uncertainty associated with the retrieval of the MODIS LWP and droplet size:

(LL461-465 in p16)

It should be noted that there is an uncertainty associated with the retrieval of the

MODIS LWP and droplet size. Generally, the retrieval errors are $\sim$ 10 % for LWP and droplet size according to Juárez et al. (2009). Hence, the qualitative nature of the differences in LWP and droplet size among the CSRM run, the GCM run, and the MODIS observation shown here is not likely to depend on the uncertainty.

Section 3.I missed information on the vertical resolution of the GCM in the relevant atmospheric domain.

The following is added in Section 3:

(LL240-243 in p9)

The coupled system is run with 26 vertical levels and a 2° x 2.5° horizontal resolution. In the MBL, the vertical grid length is $\sim$ 300 - 600 m. This system is run in MPMD (Multiple Processors Multiple Data) mode to exchange aerosol fields and meteorological fields at each advection time step of the IMPACT model.

According to Fig. 18, the condensate in CSRM*2 is about 10% different from CSRM. On page 12308 it is mentioned that the average cloud drop sizes in both simulations are 10 and 16 micron, respectively. Are these numbers really correct? Firstly, for an average size of 16 micron, larger than the precipitation threshold of 14 micron, significant precipitation might be expected. Secondly, to achieve more or less the same liquid water content for these sizes, the amount of activated particles in CSRM*2 must be about fourfold the amount activated in CSRM. However, for a doubling of initial aerosol I expect something in the order of 20-80% more (as is shown in Fig. 19a), dependent on the circumstances, but not fourfold. Precipitation formation can not explain this, since it is demonstrated that precipitation formation is rather unimportant throughout most of the CSRM simulation.

The bulk microphysics of Saleeby and Cotton adopted here divide droplets into small and large cloud droplets. Small and large cloud droplets range 2-40 micron and 40-80 micron in diameter as described in section 2 (the more detailed description can

be found in section 3 in Saleeby and Cotton (2004)). This division is to simulate two droplet modes frequently observed in clouds as described in Saleeby and Cotton (2004). When droplets grow above 80 micron in diameter, they are classified as rain. Hence, the precipitation threshold is 80 micron in diameter, since the terminal velocity of small and large cloud droplets is very small as compared to that of rain. So, no surface precipitation in both the simulations is not that unreasonable result.

The effective size presented here is averaged over all grid points in cloud, not conditionally averaged over gird points with the condensation rate > 0; to explain the difference in cumulative condensation in Figure 18, obtaining the effective size over grid points where condensation occurs is more convincing, excluding grid points with zero condensation. When conditionally averaged over gird points with the condensation rate > 0, the effective sizes are 14 and 12 micron for the CSRM and CSRMx2 runs, respectively. The difference in this conditionally averaged is 3 times smaller than that between 10 and 16 micron, explaining difference in cumulative condensation fairly well.

Summary and conclusions, p. 12315 “The role of autoconversion .... is negligible when spectral information ... is considered”. The study uses an idealized gamma-distribution, which may or may not be consistent with an actual droplet size distribution. What is the impact of this particular choice?

We tested the sensitivity of results to the choice of distribution. Two types of distributions are used for the test: exponential and log-normal distributions which are generally accepted as representative droplet distributions. It is found that results in this study do not vary qualitatively with the choice of one of these distributions.

The following is added to indicate the impact of the choice of a gamma-distribution:

(LL930-937 in 32)

This study assumed the gamma-size distribution for droplets. Although many observational studies have showed that droplets obey the gamma distribution, autoconversion

and accretion may vary with the choice of the distribution. Additional tests using exponential and log-normal distributions showed that results here did not depend on the choice of the type of representative distributions of droplets generally used in modeling studies. However, evolution of drop-size distribution in this study was not simulated as explicitly as in bin-model studies. The effect of explicit simulation of droplets in each size bin with no assumed size distribution (as in bin-model studies) on the results here needs further investigation.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 12283, 2009.