RESPONSE TO ANONYMOUS REVIEW 2

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We thank the anonymous reviewer for his/her thoughtful comments. Our responses to the major points are below. The points correspond, in order, to those in the review.

(1) It is understood that using a 2-D LES or a kinematic framework for testing the continuous spectral microphysics scheme is computationally less expensive. However, the purpose of the present study is to demonstrate the model's capability at predicting the continuous evolution of a 2-D aerosol-droplet spectrum in 3-D. Moreover, demonstrating the model's use in a 2-D or 1-D framework would require some turbulence closure scheme that is not 3-D and/or prescribed boundary forcings. These assumptions could potentially inadvertently alter the simulated results. By performing 3-D simulations, we can relax the assumptions regarding boundary forcing and turbulence such that the inter-model inconsistencies arise the representation of the microphysical processes within each scheme, and the inherent dynamical feedbacks that occur (i.e., entrainment, detrainment, turbulence, etc.).

Moreover, the simulated domain is comparable to that used in previous studies (i.e., *Chen et al.*, 2011) and the resolution is understandably not high, but required in order for the simulations to be computationally possible at this time. Moreover, the duration of the simulations is restricted so as not to rely on idealized large-scale forcing parameterizations that will ultimately affect the modeled results. The goal of the present study is to isolate the aerosol effects using the different microphysics schemes and not to simulate the diurnal evolution of marine stratocumulus and/or specific case studies.

(2) We have clarified the manuscript so that the uses of "overpredict" and "underpredict" are clear and specifically relate relative changes to that of the new continuous spectral microphysics scheme.

(3) The first bin does correspond to $i = 1$ and $k = 1$. The equations have been corrected as follows:

$$x_{i+1} = 2x_i$$

$$x_{k+1} = 2x_k$$

(4) In the case that the aerosol particle is "dry", the total particle size is equivalent to that of the aerosol's dry size. As a result, it will lie in the first bin of the "droplet" distribution (even though it is technically not a droplet). The fact that it contains no water *is* accounted for in all calculations. In the present study, the ambient relative humidity is high enough throughout most of the domain such that particles ought not to exist in the first "droplet" bin, but, the model requires such a bin for situations in which the ambient relative humidity is low enough for particles to lie below their deliquescence point. This has been clarified in the manuscript.

(5) We have included descriptions for all variables in the revised manuscript. Equation (10) has been corrected.

(6) It is true that the sedimentation is critical to droplet evaporation. We have included a more extensive description in the revised manuscript: "The terminal fall speeds required to compute sedimentation are calculated following *Beard* (1976) in which the particles are categorized into different regimes based upon their Reynolds number. The change in mass and number within a grid box due to sedimentation is computed then by predicting the mass and number that fall into the box from above and subtracting the mass and number that fall out of the box and into the box below. At the lowest level, the loss of mass through the bottom boundary is considered precipitation. This algorithm is analogous to that which is used in the 1-D bin and bulk models. Therefore, the only difference between the representation of sedimentation amongst the models is in the calculation of the terminal fall speeds (the bulk model has the least complex and fastest calculation while the new continuous spectral scheme is more accurate and computationally expensive)."

(7) The statement has been clarified by noting that "the aerosol is *included* in the droplet size"

(8) The statements following Equations (14) and (15) have been clarified to state: "$\Delta N_{(i,k)-(j,l)}^{(n,m)}|_{\text{gain}}$ represents the gain of particles in bin n, m due to collisions between droplets in bins i, k and j, l. The subscripts n and m correspond to the droplet and aerosol bins, respectively, that contain the particles formed by collisions between particles in bins i, k and j, l. " Moreover, it is noted in the manuscript that the collection kernel is symmetric and thus the collection of small droplets by large drops is numerically the same as the collection of large drops by small droplets.

(9) "Size" has been replaced with "mass" so that the new statement now reads "x' is the mass of a droplet formed by collisions...".

(10) In regard to the large-scale forcing, see the first comment above. The Monin-Obukhov Similarity Scheme is used for the surface layer. This has been added to the revised manuscript.

(11) The discussion surround the LES_bulk_NoReg case is included to demonstrate, in the simplest microphysical representation, the significance of simply adding an explicit treatment of aerosol activation. We agree that it is customary for bulk models to fix the droplet number concentration. However, we feel that it is important for the current study to represent activation in a more physically consistent manner among the suite of models used.

(12) We have revised the manuscript so that q_{tot} refers to the total water mixing ratio and q_t refers to the total condensed water mixing ratio. Thus, $q_{tot} = q_t + q_v$.

(13) The rapid decrease in N_d occurs in all simulations. In fact, the largest decrease is found for the bulk simulations in which the collection process is parameterized following *Khairoutdinov and Kogan* (2000). The reason for this quick decrease is that the cloud itself is quite moist, hence, within the first few minutes of the simulation, the droplets grow quite rapidly and reach sizes at which collision-coalescence is efficient. In the presence of large droplets, collection of smaller droplets can occur quite rapidly. The cases shown are both relatively low aerosol concentrations in comparison to that which one might find in polluted continental regions. Thus, if the aerosol number concentration were to be increased to several thousand particles per cubic centimeter, this rapid drop in N_d would likely not occur. Moreover, in the case of the 1-D bin scheme, initially all of the particles

activate within the cloud layer, but, within the first half hour, as the supersaturation adjusts to growth and latent heat release, the smaller droplets evaporate, thus reducing the number concentration as well. We have included a similar discussion in the revised manuscript surrounding the description of Fig. (4).

(14) This comment is unclear. No response made.

(15) The statement was removed and replaced with a reference to Sect. 1 where the different regeneration parameterizations are described in detail.

(16) The reviewer brings up a good point here in regard to the chosen number of bins in the microphysics scheme. In any Eulerian bin microphysics scheme, the number of bins is always determined by the user. However, for specific cases, the number of bins should be extended toward larger sizes or can be reduced to only include smaller sizes. For example, to simulate Arctic stratus, *Harrington et al.* (2000) employed 25 bins while for simulations of deep convective clouds, *Khain and Lynn* (2009) and *Lebo and Seinfeld* (2011) used 33 and 36 bins, respectively, to capture large droplets and graupel. In determining the number of bins necessary for the study at hand, one must consider the differences in such things as terminal fall speed, activation, collection efficiency, etc., of the added or removed bins. In the case of the number of aerosol bins, we restricted the calculations to 15 bins. Simulations (not shown) with 20 bins were performed. There was no qualitative difference between the simulations using 15 and 20 bins. In fact this should be expected since the actual size of the aerosol upon regeneration and subsequent re-activation ought to only be important when the critical supersaturation of the newly formed particle is approximately that of the ambient supersaturation attained in the cloud during the simulation. Since the critical supersaturation of aerosol particles is not a linear function of size, adding bins with smaller sizes will act to increase the computational expense, with little to no change in the cloud properties since these particles are likely to not activate during the simulation. On the other hand, adding bins with larger sizes will also have little to no effect on the cloud properties since these particles have a very low critical supersaturation and thus will likely re-activate in the presence of *any* supersaturation. Thus, the chosen aerosol binning is dependent upon the ambient supersaturation within the cloud. For future studies of other cloud types, e.g., shallow convection, deep convection, etc., the aerosol size distribution will have to be extended to encompass

particles with higher critical supersaturations since the ambient supersaturation in these cloud types is often higher than in marine stratocumulus. This discussion has been added to the revised manuscript.

Minor Edits:

(1) A comma was added between q_v and t.

(2) We removed 'is'.

(3) We replaced 'are' with 'is'.

(4) 'No' was changed to 'not.

(5) The color has been changed from 'yellow' to 'red' to accurately correspond to Fig. (9).

(6) We changed 'once' to 'one'.

(7) The caption has been revised to be more clear.

(8) Figs. (5), (6), and (7) have been changed to match the alignment of Fig. (4). The caption for figure (4) has been changed for clarity.

References

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