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Atmospheric Chemistry and Physics Discussions

ACPD

12, C9570–C9574, 2012

Interactive Comment

Interactive comment on "Cloud-resolving modeling of aerosol indirect effects in idealized radiative-convective equilibrium with interactive and fixed sea surface temperature" *by* M. F. Khairoutdinov and C.-E. Yang

Anonymous Referee #1

Received and published: 20 November 2012

Paper: Cloud-resolving modeling of aerosol indirect effects in idealized radiative-convective equilibrium with interactive and fixed sea surface temperature, Authors: Khairoutdinov and Yang, Manuscript #: acp-2012-796

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Summary:

Several simulations of radiative convective equilibrium have been performed with varying concentrations of cloud condensation nuclei (CCN) with both fixed and interactive

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sea surface temperatures (SSTs). Increased CCN concentrations lead to stronger cloud albedos and a weakening of the cloud greenhouse effect. In runs with an interactive SST, this leads to cooling of the ocean surface with increasing CCN. Increasing CCN by 10 times offsets most warming experienced with a doubling of carbon dioxide (CO2) concentrations. While cloud changes are broadly similar in the fixed and interactive SST runs, the precipitation changes are quite different in both amount (decreasing precip with increasing CCN in interactive runs, little change with fixed SST) and in vertical structure (fixed SST runs have vertically coherent changes in precip amount, while interactive runs have opposite sign changes around the melting level from those aloft and near the surface).

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Recommendation:

Publish subject to minor revisions after taking account of the comments offered here.

The paper is mostly descriptive, but is interesting in that it describes a set of novel experiments in a clean framework. While I have some minor quibbles with the setup (e.g., I would have preferred more realistic tropical insolation with a prescribed sink of energy at the base of the ocean mixed layer), this paper makes a nice contribution to the literature on aerosol indirect effects in deep convection. I especially like the notion of performing more cloud-resolving model simulations over a dynamic ocean, so that the surface energy budget is closed. This will gradually force improvements in the representation of cloud radiative effects because of their feedbacks on surface temperature in this framework. The paper could perhaps make a greater effort to distinguish between the roles of the first and second indirect effects in the cloud response, if possible. Additional insight into the differing vertical structure of precipitation changes with increasing CCN between the fixed and interactive SST runs would also be useful, if this can be cleanly illustrated.

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Major comments (all page numbers are prefixed with 29):

104/5 (p. 22104, line 5): Why does the TOA imbalance need to be zero? The study is motivated by the exploration of tropical deep convection, but the tropics have a net influx of energy at TOA, which is balanced by heat export to the subtropics and extra-tropics through both the atmosphere and ocean. I would have preferred that the simulations be performed with realistic insolation at TOA and that this energy export be modeled by an energy sink in the ocean (probably 50-80 W/m2) that allows the column to equilibrate. I'm not sure that this would change the results of this study, and it's probably not realistic to expect a repeat of the considerable computational effort expended on this study. Still, in future work, it would be desirable to use a more tropics-like insolation, as this would affect the SW heating due to absorption by clouds and water vapor in the tropics and possibly change the precipitation in the base case. Last, as noted in Hartmann's Global Physical Climatology (chapter one), it is desirable to use the zenith angle whose cosine is the equal to the insolation-weighted coszrs over the diurnal cycle.

106/sec 3.2: I would be curious to see how the PDFs of SWCF and LWCF changed with increasing CCN. This could be computed either over single grid cells or over chunks of the domain. Could you use such an analysis to distinguish between the Twomey effect and cloud fraction/cloud lifetime changes? Similarly, could you add a line to figure 3a that estimates the changes in SWCF due to the Twomey effect alone? This might take work to do it faithfully, but even an estimate would be valuable in thinking about the relative roles of the first and second indirect effects here.

109/8-15: Could profiles of cloud fraction and in-cloud liquid (or in-cloud condensate) concentrations help illuminate the issue of what role the second indirect effect is playing here? Do the number concentrations of cloud ice change much with CCN, or do the fixed ice nuclei concentrations constrain this? It might be nice to have figure 6 be a three column figure with the left column showing the profiles of QC, etc. from the FA100, IA100 and 2CO2 runs and the other two columns as before.

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110/1-18: The early part of the paper does a good job talking about how the atmosphere-integrated radiative cooling constrains precipitation. Some of that discussion should enter into this analysis as well. Second, the differing vertical structure of the precipitation changes here (fSST vs. iSST) is interesting, I think, and could be explored more. Are these driven by changes in stability, decreasing tropopause height, changes in RH profiles, changes in convective mass flux profiles? If there is some coherent explanation of these different vertical structures, it might add to the paper.

Last the changes in the vertical profiles of radiative heating aren't shown in the paper. Is there any information in these profiles that informs the response seen in these simulations? They don't need to be included unless they illuminate some issue, but they could hold an explanation for some of the behavior seen here.

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Minor recommendations (all page numbers are prefixed with 29):

100/14 (p. 22100, line 14), suggested rewording: "... agree on the tendency _of increased aerosol concentrations_ to make the shortwave ..."

101/2: "... _Earth's_ radiative budget."

102/3: "In RCE, ..." – remove the.

102/9: ?? "... using _forcings_ prescribed from observations ..."

103: It should be noted that no change is made to ice nuclei concentration. Others (e.g., the new ACPD discussion paper of Seigel et al, 2012, doi:10.5194/acpd-12-29607-2012) consider the effects of changes to ice nuclei concentrations.

104/20: Since SST is itself an acronym, why not use lowercase "f" and "i" to modify it, as in "iSST", "fSST"?

105/20: Is susceptibility always defined relative to log10? I would suggest using a subscript "10" to make clear that increases by a factor of 10 are your reference.

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105/27: "_associated_ with the doubling of CO_2."

107/7-14: In the discussion of the interactive SST runs, a citation to Romps (2011, JAS, http://journals.ametsoc.org/doi/pdf/10.1175/2010JAS3542.1) would be in order. He looked at precipitation changes in small-domain CRM runs with increasing CO_2 over an interactive SST. He "accelerated" convergence of the SST to equilibrium by making occaisional abrupt changes to the SST to move it towards an equilibrium value. See the appendix A to his paper. His paper may also have broader relevance to this study, as it looked at precipitation responses to changing CO_2.

108/11: I believe that Grabowski and Morrison (2011, JClim, http://dx.doi.org/10.1175/2010JCLI3647.1) talk a bit about the contrast between single-cloud and ensemble thinking about aerosol indirect effects, that is similar to the short timescale-longer timescale contrast here.

110/4-5: "The _conversion_ rates for the moments in _the_ two-moment bulk microphysics..."

110/17: "iSSP" –> "iSST"

121/fig 1: I would suggest varying either line thickness or line type to make it easier to decode this plot, e.g., solid for 100,500,2CO2 and dashed for 50,200,1000. Alternately, one group could have double the line thickness of the other.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 29099, 2012.

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