Atmos. Chem. Phys. Discuss., 13, C3706–C3714, 2013
www.atmos-chem-phys-discuss.net/13/C3706/2013/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Cloud-Aerosol-Radiation (CAR) ensemble modeling system" *by* X.-Z. Liang and F. Zhang

X.-Z. Liang and F. Zhang

xliang@umd.edu

Received and published: 14 June 2013

We wish to express our great appreciation for your careful review and detailed instructive comments. In the revised manuscript, we have incorporated all your comments to the extent possible. In the response below, we address each of these comments. Your comments are in quotation marks and our responses immediately follow.

"General comments: It's virtually impossible to argue against publication of this paper because the effort needed to build the tool used (CAR) and to run all the experiments described herein is of heroic proportions. I can't start to imagine how much hard work has been put to make column versions of various GCM-class radiation codes work with such a wide range of input and parameterizations. The authors should be re-

ally commended for their achievement, and a paper that introduces CAR to the world deïňĄnitely deserves to be published. However, this particular paper packs so much stuff, so many numbers, so many experiments, that makes it hard to follow, digest, and ultimately obtain something of lasting value from (I have at times regretted having accepted to review the paper as I was going through what seemed like an endless parade of results and scenarios). After all is said and done, the conclusion is what we already suspected: many cloud and aerosol treatments combined with many RT schemes give a wide range of answers. The full range cannot be given because the number of possible combinations is astronomical, and the individual ranges provided here are just a small, and hard to characterize as representable, sample. It's almost as if the authors made their tool so ambitious, expansive and all-inclusive that in the end it is impractical to use for picking the optimal sets for a particular application. Nevertheless, I recommend publication of the paper to reward the authors for their noble intention to help the GCM community, and their courage for pursuing and completing this line of work."

Answer: We thank you very much for recognizing the value of our work, and your time and effort in reviewing this manuscript with instructive comments.

"Specific comments: – The title of the paper should be "THE CAR Ensemble Modeling System""

Answer: We agree and change the title accordingly.

"– The introduction is long, quite verbose, disorganized and feels often repetitive. It'd beneïňĄt from trimming and becoming more focused."

Answer: We partially agree with you. We have now deleted entirely the 2nd paragraph of the introduction, including 13 references. We believe that the remaining content is important to clearly explain the motivations and challenges in developing the CAR system, and specifically define the scope of this study for the system evaluation. In particular, the discussion at length on model errors versus uncertainties has been demanded by several reviewers of the earlier versions of the manuscript. We feel that

ACPD
13, C3706–C3714, 2013

further reduction may introduce questions by other readers, including Reviewer #1.

"– What is the plan for maintaining, updating, and keeping CAR relevant? For example, if a new version of RRTMG is released will it be incorporated in CAR in a timely manner? If a code/scheme is on its way of becoming obsolete (not used by anyone any longer, – a couple of the RT schemes included in CAR seem to fall in that category, as do some cloud parameterizations) will it be removed from CAR?"

Answer: We plan to update the CAR system on a regular basis by our own team and the user community after its public release (see below). Any bug fixes and significant updates will be incorporated upon the availability. We however will not delete the schemes as they become obsolete. We feel that being all-inclusive is useful in certain circumstances, for example, helping students better understand cloud-aerosol-radiation modeling from relatively simple to advanced theory bases. Including them in the system does not affect its usage or CPU performance, as all schemes are fully plug-and-play selective. On the other hand, we will provide a subset of the system based on the dimension reduction study that is in progress. That subset will certainly exclude the obsolete schemes, and will also be revised along with the update.

"– It seems to me that CAR is the type of tool that should be freely and openly available to the intended user community. Yet, I don't see any info in the paper on how to obtain the system. I visited the website as well and couldn't ïňĄnd any relevant information (although the "forum" page appears to be constructed to serve potential users). So, will CAR be available for distribution? If yes, how can one obtain it, by contacting the authors at this stage?"

Answer: We plan to provide the CAR system for a wide community use, including as a research tool for experts in the cloud-aerosol-radiation field and for developers of climate models, as well as an education fool for students to explore numerical representations and structured uncertainties. The full system will be released after the publication of this manuscript and another two papers on dimension reduction and cli-

ACPD
13, C3706–C3714, 2013

mate sensitivity that are fundamental for the CAR general application. The release will include a subset of the system based on the dimension reduction study. In addition, we will follow our approach in releasing CWRF to provide a control version of the CAR that is cost-effective for simulating the present climate. The schedule for these efforts, however, will largely depend on the availability of supercomputing resources and funding supports. When released, an online registration will be required (just like CWRF) to track its usage and promote collaboration on maintaining and further developing the system.

– I ïňĄnd it hard to conceive how CAR would be implemented in a GCM. All the options for cloud parameterizations (cover, water path, indirect effects, etc) would certainly need to be turned off. And then, would the radiation calculations be purely diagnostic? If they were interactive (with feedbacks) would it be possible to ever interpret the results? Also, the data volume would be tremendous. Even if the tool was publicly available, I'd think that it'd take an enormous investment of time to make the whole system run within (in parallel?) a GCM.

Answer: We ascertain that implementation of CAR into any specific climate model is a technical challenge, requiring in-depth knowledge of all relevant physical processes, their numerical representations, and computer codes. We have successfully coupled the full CAR system with CWRF and NCAR CESM. The CWRF coupled with CAR is currently available for a partial release version through online registration (http://cwrf.umd.edu). The CESM coupled with CAR is now being tested in the NCSA Blue Water supercomputer facility. In both coupling efforts, we have replaced the entire radiation package of the original model (CWRF or CESM) with the CAR system. This involves labor-intensive software engineering, debugging, testing, and performance evaluation. As a general and desirable practice, we incorporate all existing schemes (cloud, aerosol, radiation) originally built in the intended climate model (such as CWRF or CESM) into the CAR system. This enables us to test the revised CAR system with the options for the exact combinations of the schemes in parallel with the original pack-

ACPD
13, C3706–C3714, 2013

age in the host model.

"– p. 10201, lines 20-22: This sentence is exactly the same as in p. 10196. Delete."

Answer: Done.

"– p. 10202, lines 26-28: “As discussed earlier, not all of these variations can be practically applied due to the fact that signiïňĄcant system tuning must be made to ensure. . .”. No, it’s not a tuning issue, the practical matter is that it’s impossible to run all these variations and store/analyze the output!"

Answer: We agree with your view and revise the statement as follows: “As discussed earlier, not all of these variations can be applied because significant system tuning must be made to ensure the total radiative balance in the coupled GCM closely matching observations and thus dramatically constrain the acceptable combinations of the component schemes. It is also impractical to run all variations and analyze their output of astronomical scale, calling for the necessity of dimension reduction of the system (see discussion in Section 5).”

"– I disagree with the way the term “cloud geometry” is used in this paper. For me the term geometry should be reserved for situations when clouds are three-dimensional (e.g., with shapes, sides, etc)."

Answer: We believe it is appropriate to use “geometry” to describe the configuration of clouds with subgrid variability. As discussed in Liang and Wang (1997) cited in this manuscript, for GCM parameterization the subgrid variability related to cloud-radiation interaction includes not only the cloud geometric association (vertical overlap or more general macrogrouping) and inhomogeneity (within-cloud optical property variance) that have already been built in CAR, but also broken-cloud effects (interaction between finite clouds, i.e., mutual shielding and reflection) to be developed in the future. We add this as a footnote in 3rd paragraph of Section 2.

"– p. 10197, line 10: “The radiation transfer modeling. . .” I’m not sure I agree with

ACPD
13, C3706–C3714, 2013

this statement. Approximate models sacriïňĄce spectral resolution and this results in errors. The statement is more true for LBL calculations."

Answer: We agree with you and now add a specification to read “The radiation transfer modeling with detailed spectral resolution. . .”

"– p. 10203, lines 8-12: If ICA is used, there is no reason for clouds to be horizontally homogeneous. GCM runs with horizontally inhomogeneous clouds are shown by Oreopoulos et al. (2012), ACP."

Answer: We agree that multiple ICA calculations can incorporate cloud inhomogeneity effect. This is implemented in the McICA approach discussed in the subsequent paragraph of the manuscript. For clarity, we have revised the sentence to read “As such, clouds are conventionally considered to be horizontally homogeneous within a model grid and to follow various vertical overlap assumptions for a single radiation transfer calculation using an Independent Column Approximation (ICA).”

" – p. 10204, lines 11-12: “whereas McICA assumes all cloud types to follow the same statistical relationship as α-weighted maximum-random overlap.” Simply not true. McICA is not tied to any particular overlap scheme. It can operate on subcolumns generated with any arbitrary overlap assumption. The same misconception persists in line 8 of page 10211. There is NO vertical overlap scheme inherent in McICA!"

Answer: We agree that McICA does not explicitly assume vertical overlap. We have now revised the statement to read “whereas McICA typically employs some stochastic cloud generators that assume all cloud types to follow the same statistical relationship such as α-weighted maximum-random overlap.”

"– p. 10204, lines 24-25. Do MODIS and MISR provide aerosol mass loadings? I thought they provide aerosol optical depths."

Answer: We have now revised the statement more specifically to read “The CAR has the ability to incorporate either modeled (CMIP, AEROCOM, CMAQ, WRF-Chem,

ACPD
13, C3706–C3714, 2013

CAM-Chem, GEOS-Chem) 3D aerosol mass loadings and optical properties or observed (MISR, MODIS) 2D aerosol optical depth distributions."

"– p. 10206, lines 9-13: How is surface albedo spectral variability handled? Each model has its own band scheme and whatever spectral albedo is available from MODIS should be averaged somehow."

Answer: We have now added "The parameterization determines albedos separately for direct and diffuse radiation at the visible (0.4-0.7 um) and near-infrared (0.7-5.0 um) bands. These values are interpolated with insolation-weighted spectral integration to the specific bands of each radiation scheme."

"– p. 10213, line 15: "2125"??"

Answer: This is a typo from document conversion. It should be 21-25 Wm-2, representing a range.

"– p. 10216, line 15: "based on satellite estimates". Are there really aerosol direct effect estimates from satellites (please provide references) that do not involve radiative transfer calculations, using possibly one of the schemes included in CAR?"

Answer: This is a direct citation from Yu et al. (2006) and IPCC (2007). We believe that all satellite retrievals must also involve certain radiative transfer model calculations. The difference between satellite estimates and model simulations result mainly from the input aerosol loadings. We do not know exactly which radiative schemes were used in these studies.

"– p. 10217, line 15: Again, some of the "observational" estimates of TOA ïňĆux (ISCCP, SRB) involve running a RT code with whatever error this state of affairs introduces. Given this, the authors may also want to rethink their conclusion in lines 16-19 of p. 10219."

Answer: We have now added a cautionary note "It is not clear whether the discrepancies among the satellite estimates result from the differences in their retrieval algo-

ACPD

13, C3706–C3714, 2013

rithms that involve certain radiative transfer modeling."

"– p. 10229, lines 17-19: There are other uncertainties in GCMs besides clouds-aerosols-radiation that play a role in the range of climate sensitivities, so I don't think this statement is true."

Answer: We have now added a specification "that are associated with cloud-aerosol-radiation interactions and feedbacks,"

"– The paper needs considerable attention to ïňĄx grammar, syntax and spelling errors. It'll be too burdensome to provide a full list, but here are some examples, just from the introduction section (I had already run out of steam by that time): – p. 10194, line 7: "the world's leading"; line 15 "demonstration purposes""

Answer: Corrected.

"– p. 10195, line 2: "different parameterization" "

Answer: Corrected.

"– p. 10196, line 3: "built the innovative Cloud-Aerosol-Radiation"; "collection of alternate"; line 8 "the intercomparison of the numerical" "

Answer: Corrected.

"– p. 10197, line 24: "in reality to achieve a radiation" "

Answer: Corrected.

"– p. 10198, line 2: "They are largely alternate"; line 5: "considers"; line 15: "cannot reveal the true uncertainty but rather the errors"; line 19: "and thus hamper the GCM"; line 22 "lack thereof"; line 25-26 badly structured sentence; line 29: "designed to represent". "

Answer: Corrected.

"– p. 10199, line 2: "collection of parameterization"; line 10: "the best available"; line

ACPD
13, C3706–C3714, 2013

11 “alternate scenarios”; line 19 “deïňĄned differently” "

Answer: Corrected.

"– p. 10200, line 10 “of the integrated”; line 11 “host GCM”; line 15 “when interpreting” (this sentence is problematic as a whole, by the way); line 19, “highlight some key features”; line 25, missing period; line 26 “alternate schemes”."

Answer: Corrected.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 10193, 2013.