Geosci. Model Dev. Discuss., 7, C1719–C1728, 2014
www.geosci-model-dev-discuss.net/7/C1719/2014/

Geoscientific Model Development Discussions
Open Access

Interactive comment on "Pan-spectral observing system simulation experiments of shortwave reflectance and longwave radiance for climate model evaluation" *by* D. R. Feldman and W. D. Collins

D. R. Feldman and W. D. Collins

drfeldman@lbl.gov

Received and published: 11 September 2014

We have summarized and expanded on our short comments in response to the findings of the four referees for this manuscript. We appreciate all of their comments and hope that this manuscript can be revised in such a way as to be acceptable for publication in GMD. Below are our responses:

Response to Referee #1:

As partially mentioned in SC C1229, we are pleased that the referee finds the paper

interesting and well-written. With regards to the statement concerning the amount of new science in the paper, we respectfully submit that this paper presents several novel findings in relationship to previously published work:

1. The paper formally presents the pan-spectral OSSE, which has not been covered in other manuscripts. The Feldman et al, 2011 presentation of the SW OSSE discussed the formulation of the SW OSSE in detail and the Feldman et al 2013 paper only briefly discussed the LW calculations, but the pan-spectral capability was not central to that latter paper, and the details of its construction were not presented. We submit that it is critical that the details of a pan-spectral OSSE are described in a way that is satisfactory for peer-review, so as to enable robust measurement-model intercomparisons in the future.

2. The paper presents a discussion of radiometric validation of the OSSE for the infrared calculations and how such validation is straightforward for clear-sky conditions but challenging for all-sky conditions due to whether the radiative transfer is formulated with layers or levels.

3. The paper broaches the complementarity of the SW and LW signals in describing the processes that may change the top-of-atmosphere spectrum of the planet. The numerous signals in the SW and LW spectra provide a potentially large number of constraints for model performance beyond OLR and albedo.

4. The paper discusses prospect for, and provides initial results of, OSSE calculations based on the fields from the Climate Model Output Rewriter (CMOR) for two models spanning the range of climate model sensitivities in the CMIP5 archive. This presents a path towards developing hyperspectral diagnostics for models based on their climate sensitivities and ultimately confronting those models with decadal-length satellite records. There are numerous opportunities for measurement-model confrontation with existing hyperspectral datasets (such as AIRS, IASI, CrIS, and SCIAMACHY) as the protocols for CMIP6 are developed, and with this new capability, we hope to

constrain sensitivities and/or tuning. Also, this tool enables the consideration of how absolutely-calibrated instruments shortwave AND longwave data, such as those from the proposed CLARREO mission, could assist in model constraints.

We would welcome further comments from this referee on these topics and how to clarify them better so as to improve the manuscript in a revision.

Response to Referee #2:

As partially mentioned in SC C1236, below are responses to the referee's comments:

1. The issue that the referee raises of simulations based on monthly mean values is extremely well-taken, because the integration of the equation of radiative transfer is generally non-linear. There are several challenges here, however: (1) the fields necessary in the CMIP5 archive to perform competent radiative transfer are archived at monthly resolution and (2) As the referee rightly notes, it is extremely computationally expensive to calculate. Currently, the OSSE radiometric validation performed with CCSM3 was based on offline calculations to the CAM radiation code and to MODTRAN. Validation against online radiation calculations has not been performed. In order to address the referee's comment, limited numbers of CFMIP calculations may be necessary to ensure that the radiometric validation against online results are not biased. This may satisfy the referees' suggestion to perform instantaneous radiation calculation comparisons. We look forward to evaluating whether the use of monthly profiles obscures, enhances, or has no affect on climate change signals in a revised manuscript, per the referee's suggestion.

2. The simulation configuration is generally flexible, allowing for different, and even arbitrary, cloud-overlap approximations based on a subroutine that performs sub-column generation and uses multiple calls to MODTRAN based on the results of this generator to great a grid-box averaged spectrum. With respect to cloud optics, it is straightforward to implement different cloud optics and the gray approximation can easily be relaxed, though the exercise in model excavation necessary to determine the cloud op-

tics parameterizations for each model may be non-trivial. The referee's point regarding benchmark computation times can certainly be included in a revised manuscript.

3. The presence and meaning of dipole features in the SW+LW response would resolve broadband signal degeneracy and would be very scientifically interesting to explore in a revised manuscript. We will emphasize spectral compensation in a revised manuscript.

Response to Referee #3:

As partially mentioned in SC C1244, below are responses to the referee's comments:

We thank the referee for the numerous detailed comments on this manuscript and look forward to implementing all of these suggestions in a revision. We are particularly grateful for the comment regarding communication with the climate modeling community. The utilization within the modeling community of OSSE techniques such as those described here will only take place if papers can convince them of the value of spectral measurements as model constraints. We plan to add language to the revised manuscript to achieve that goal.

Response to Specific Comments:

Abstract

1. The suggested change will be made in the revised manuscript.

2. We plan to modify the phrase ‘long-duration’ to ‘multi-decadal’ and refer to several studies of concatenated satellite instrument datasets to support this statement.

3. We plan to substitute the word “described” with the word “calculated” in the revised manuscript.

4. We shall ensure that units are consistent, but will also point out that the shortwave hyperspectral community tends to work in wavelength units while the longwave hyperspectral community tends to work in wavenumber units.

5. The language will be changed to read: "how climate change impacts Earth's reflected solar and emitted infrared spectral mean and variability" in the revised manuscript.

Introduction:

1. The suggested change will be made in the revised manuscript.

2. The suggested citation will be included in the revised manuscript and we apologize for the oversight in citing that important paper.

3. The suggested change will be made in the revised manuscript.

4. Language distinguishing process and climate studies will be made in the revised manuscript.

5. The suggested change will be made in the revised manuscript.

6. The suggested change will be made in the revised manuscript.

7. The suggested change will be made in the revised manuscript.

8. The suggested change will be made in the revised manuscript.

Methodology:

1. The suggested change will be made in the revised manuscript.

2. The suggested change will be made in the revised manuscript.

3. The suggested change will be made in the revised manuscript. Having language that is accessible to the broadest possible audience is critical.

4. The suggested citation is much more appropriate in this context and will be included in the revised manuscript.

5. A formal estimate of the time-savings with novel radiative transfer algorithms, such as PCRTM (Liu et al, Applied Optics, 2006), will be included. Currently, we are able

to achieve 25x speed up with PCRTM relative to MODTRAN, but need to determine if such an advantage is maintained under parallel programming conditions where overhead, thread-safety, etc. must be considered.

Results:

1. The suggested change will be made in the revised manuscript.

2. The suggested change will be made to the text in the revised manuscript.

3. The purpose of Figure (1) was to convince the reader that the radiometric biases were generally small compared to climate change signals, though this point should be made more explicitly in the revised manuscript.

4. The point of this statement is to assure the reader of the OSSE's radiometric accuracy across a range of zenith angles, up to 5 degrees from the terminator at which point the plane-parallel assumption begins to break down. This point will be rephrased in the revised manuscript.

5. The suggested change will be made in the revised manuscript.

6. The suggested change will be made in the revised manuscript.

7. The suggested changes will be made in the revised manuscript.

8. The suggested change will be made to the figure in the revised manuscript.

9. The suggested change will be made in the revised manuscript.

10. The suggested change will be made in the revised manuscript.

11. The suggested changes will be made in the revised manuscript.

12. The suggested change will be made in the revised manuscript.

13. The suggested change will be made in the revised manuscript.

14. Language to clarify and quantify the qualitative term "striping" will be included in

the revised manuscript.

15. "Changes" refers to increases in cloud cover, which leads to a higher, and thus colder emission height and radiance. This point should be clarified in the revised manuscript.

16. That is a type-o and should read "decadally-averaged."

17. Language describing CRE will be added to the revised manuscript and accompanying discussion.

18. The language was unclear and should just read "trends in albedo and OLR."

19. Similarly to the previous comment, the word "difference" will be removed and should clarify this point.

20. The language in this paragraph, particularly at the start will be clarified, because both shortwave and longwave hyperspectral trends need to be considered in the climate-change context.

21. The suggested change will be made in the revised manuscript.

22. This will be clarified in the revised manuscript.

23. The suggested change will be made in the revised manuscript.

24. We appreciate this comment.

Discussion:

1. To reiterate the response to Specific Comment 5 of the Abstract, we will include language regarding reflected solar and emitted infrared means and variability in the revised manuscript.

2. The language will be clarified to note that there are distinct instruments being proposed for CLARREO. However, we will also include language regarding another proposed instrument concept out of JPL that is a single, pan-

spectral Fourier Transform Spectrometer with the Tier 2 GEO-CAPE mission (see http://dx.doi.org/10.1364/FTS.2011.FMB1 for details), noting that a monolithic hyperspectral instrument is achievable.

Figures:

1. The choice of January 2099 was for demonstration purposes only, and the caption in the revised manuscript will indicate this. Also, the language in the caption will be changed to note that it is a histogram and not a scatterplot. We apologize for the oversight. The original figure was a scatterplot, but the caption was not updated properly when we substituted a histogram. Furthermore, the labels will be adjusted in the revised manuscript to be larger and more legible.

2. We calculated trends based on annual averages and will indicate this in the revised manuscript.

Technical Corrections:

1. The word "are" will be changed to the word "of" in the revised manuscript.

2. The word "covering" will be removed in the revised manuscript.

3. The phrasing will be "from a model" in the revised manuscript.

Response to Referee #4:

As partially mentioned in SC C1239, below are responses to the referee's comments:

We appreciate the referee's noting of the previously-published results and hope that the centralized presentation of the OSSE method in GMD could focus the modeling community on the potential benefits of hyperspectral simulations. Regarding the paper's goals, we look forward to clarifying them for the readers and reviewers in a revised manuscript. Briefly, however, with the effort, we seek to build a bridge between previous OSSE work and a comprehensive analysis of multi-model archives in order to understand if spectral signatures provide unique ways to differentiate models according to their climate sensitivity and ultimately how if existing hyperspectral measurements can provide that constraint. This would then help the modeling community to understand the value of spectrally-resolved measurements, and how they can be used for future model intercomparison and assessment activities (e.g., CMIP6).

With respect to the appropriateness of this paper for this journal, we respectfully submit that the enabling of model comparisons between both longwave and shortwave datasets is straightforward in principle, but the implementation, validation, and managing of the extreme computational expense are highly non-trivial exercises. Furthermore, there is not currently a clear pathway towards inline hyperspectral simulator calculations due to computational infeasibility, even though there is a wealth of hyperspectral data (e.g., AIRS, IASI, CrIS, SCIAMACHY) with which potentially to confront models. Nevertheless, it is necessary to do so if the existing and future information in hyperspectral datasets is to be brought to bear to constrain climate models.

As we noted in a response to Referee 2, the issue that the reviewer raises of simulations based on monthly mean values is extremely well-taken, because the integration of the equation of radiative transfer is generally non-linear. There are several challenges here, however: (1) the fields necessary in the CMIP5 archive to perform competent radiative transfer are archived at monthly resolution and (2) Currently, the OSSE radiometric validation performed with CCSM3 was based on offline calculations to the CAM radiation code and to MODTRAN. Validation against online radiation calculations has not been performed. In order to address the reviewer's comment, limited numbers of CFMIP calculations may be necessary to ensure that the radiometric validation against online results are not biased. This may satisfy the reviewer's suggestion to perform instantaneous radiation calculation comparisons.

The use of CCSM3 was for demonstration purposes. This model of course is considerably less complex than CESM1 (CAM5), but the utilization of CMOR-ized variables to compare reported results MIROC5 and HADGEM2-ES also enables the comparison to CESM1.

Interactive comment on Geosci. Model Dev. Discuss., 7, 3647, 2014.