Response to Reviewer Comments (C2525) of the manuscript, **"Development of a grid-independent GEOS-chem chemical transport model as an atmospheric chemistry module for Earth System Models"** by M.S. Long et al.

Jan. 9, 2015

We thank the reviewer for their thoughtful comments and recommendations for improving the manuscript. To the extent possible, we have addressed the reviewer's concerns. Each comment (in italics) followed by our corresponding response to that comment is listed below. Unless otherwise noted, line numbers refer to those in the original, PDF version of the discussion manuscript published online.

Reviewer Comments C2525

Specific comments:
1. The authors claim that the new GEOS-Chem code can serve as an atmospheric chemistry module for Earth System Models (plural). In practice, this will be limited to those ESMs that make use of the ESMF interface. The authors should indicate which ESMs besides GEOS-5 actually use ESMF, and if there are concrete plans for integrating GEOS-Chem in other ESMs.

The inclusion of data sockets as described in the text (p. 7510, L24) places all of the data structures required to couple the system within any ESM in a few modules. This is intended to simplify coupling in any configuration. Further the use of the C-preprocessor flags "EXTERNAL_GRID" and "EXTERNAL_FORCING" automatically configure GEOS-Chem for sending and receiving data necessary for coupling. While this was not specified in the text, it was our intention from the outset to make the code as general as possible to facilitate generic coupling.

The following text has been included after p. 7512, L2:
"The redesign of GEOS-Chem's data structures was meant to simplify coupling of GEOS-Chem with any ESM regardless of its ESMF compatibility. In the absence of an ESMF interface, users would be required to engineer a specific interface for their ESM, However, GEOS-Chem's data sockets and conditional-compilation flags facilitate this task by having all input and output data structures and associated methods conveniently located in a few specific modules."

2. The splitting in a transport operator and a local or chemical operator, indicated in Equations (2) and (3) in Section 2, is inconsistent with the actual implementation, described in Section 3. According to Section 2, wet deposition is described by the chemical operator in GEOS-Chem. According to Section 3, however, cloud processing and in-cloud scavenging of chemical tracers are described as part of GEOS-5 native moist physics. Please make sure that the theoretical description given in Section 2 is consistent with the actual implementation, and adapt the equations accordingly.

The reviewer makes a good point that needs clarification. Convective scavenging fits into Eq. (2) vs. Eq. (3) since it cannot be decoupled from transport. This is now addressed in the text at p. 7509, L13:

"Wet deposition involving sub-grid convection cannot be decoupled from transport and is treated as part of convection in the transport operator".

3. According to Section 2, the transport operator describes advection, convection, and boundary layer mixing. I assume that sedimentation of large particles is also described by the transport operator. Please mention this in the text, or clarify why it is not.

The following text has been added at p. 7509, L13:
"Gravitational settling of particles is treated as part of the chemical operator."

4. Please add a statement on the mass-conserving character of the semi-lagrangian advection scheme used in GEOS-5, and explain why and for which tracers this is important.

This does not seem relevant to our work.

5. The HEMCO emission module is presented as a general tool to describe emissions in CTMs and ESMs. Please indicate how widespread its use is. Is it used in other models besides GEOS-Chem?

We deleted as indeed unnecessary "HEMCO was designed by Keller et al. (2014) as a flexible general tool for facilitating the implementation and update of emission inventories in CTMs and ESMs"

6. Page 7515, line 19: The scaling efficiency using 192 cores is close to 0.7. On a scale from 0 to 1, I wouldn't call that "close to unity".

The phrase "close to unity" has been removed from the text.

7. Page 7517, line 2: Quantitative comparison of the GEOS-5/GEOS-Chem and CTM systems does not necessarily require using the same meteorological data in both. Quantitative comparison of the climatological behavior of both systems could also be of interest, e.g. to study to role of climate biases in the GEOS-5 ESM.

The word "quantitative" has been removed, and the sentence now reads, "A more thorough evaluation of GEOS-Chem's chemistry within the GEOS-5 system would require the use of the same meteorological data as the offline CTM…"

8. Last sentence of the summary: "Although the inclusion of detailed atmospheric chemistry in an ESM is a major computational expense, it becomes relatively more efficient as the number of cores increases due to its consistent scalability." Since the chemical tracers are transported within the GEOS-5 general circulation model, the

inclusion of GEOS-Chem will affect the scaling efficiency of the dynamics. The reduced scalability of the dynamics could therefore also be related to the addition of chemical tracers, in which case the concluding sentence would not hold. Please clarify this issue.

The last sentence in the summary has been revised. It now reads,
"Although the inclusion of detailed atmospheric chemistry in an ESM is a major computational expense, chemistry operations become relatively more efficient as the number of cores increases due to its consistent scalability."

As well, the sentence, "This result also likely reflects the additional burden associated with the greater number of tracers.", was added to the text.

Technical corrections:
1. In the title, please change "GEOS-chem" to "GEOS-Chem".
The title has been corrected.

2. On page 7511, line 13, please add a space between "ESMF_" and "macro".
A space has been added.