Replies to reviewer #1

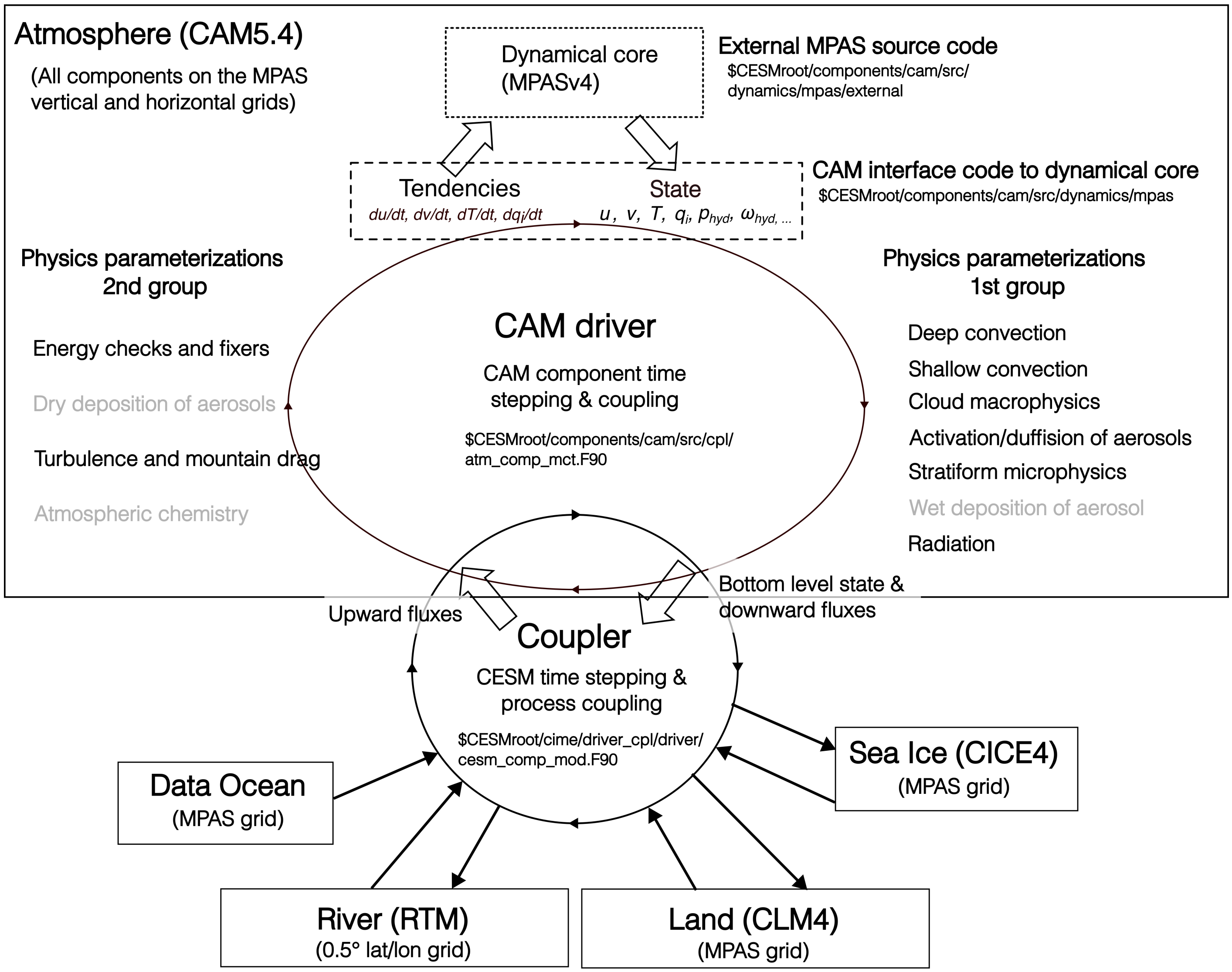
We thank reviewer 1 for going through all the materials including the appendices and providing us helpful suggestions. Please see below for our responses to your comments. The comments from the reviewer are shown in italics, and our responses are written in the regular font.

Main remarks:

CAM-MAPS coupling:

Lines 170-181: It is not easy to follow how exchanges take place along the vertical grid(s). Is there an interpolation/extrapolation along the vertical? If possible, a kind of schematic view of the way it is done could help to better understand. Figure 2 is the only figure that explains the MPAS-CAM coupling and I think it could be improved to better support the text

Thank you for the suggestions. We have revised Figure 2 (shown below) and corresponding text to make clearer the coupling between CAM and MPAS in the context of the overall process coupling within CESM1.5 (in the AMIP configuration).



Revised Figure 2

• *Adding a box could help to identify CAM;*

Done.

• *What is the role of subroutines p_d_coupling/d_p_coupling? vertical interpolation? Timestep management?*

Those two subroutines do not perform the tasks you mentioned. Realizing that more than the two subroutines were involved in all the functions necessary for the coupling, We have replaced the two subroutine names by "CAM interface code to dynamical core" in the revised figure. The role of the interface layer has been added to the main text (section 2.3 CAM-MPAS coupling), which has been reorganized with additional texts to answer your questions:

"The CESM coupler is responsible for time-step management and sequential coupling of component models. When CAM is called by the coupler, the CAM driver cycles the dynamics, physics parameterizatons, and communication with the coupler. When the dynamics is called by the CAM driver, the MPAS dynamical core receives tendencies of horizontal momentum, temperature, and mixing ratios that are predicted by physics parameterizations and the other CESM component models, and summed by the CAM driver prior to the communication with MPAS."

"... After MPAS completes its (sub) time steps, the updated atmospheric and tracer states are passed to CAM through the interface, including hydrostatic pressure, pressure thickness of each grid box, and geopotential height. The last three variables are required by the CAM physics that operates on a vertical column under hydrostatic balance, without the need to know that the vertical column is discretized in a height-based or hybrid pressure-based coordinate. No vertical interpolation or extrapolation are performed in coupling CAM and MPAS. The CAM-MPAS interface layer also calculates hydrostatic pressure velocity and performs other required conversions (e.g., convert the prognostic winds normal to cell edges to conventional u and v winds at cell centers, and mixing ratios defined with dry air in MPAS to those with moist air in CAM)."

- *Are surface parameters tendencies provided to MPAS or are they only used inside CAM physics?*

They are only used inside the CAM driver, and this point has been made clearer in the revised figure. We have mentioned the surface and other process coupling in the main text as well:

"...the MPAS dynamical core receives tendencies of horizontal momentum, temperature, and mixing ratios that are predicted by physics parameterizations and the other CESM component models, and summed by the CAM driver prior to the communication with MPAS."

Section 3.1:

I think this section, and in particular the two first paragraphs could be reorganised for more clarity... maybe speaking first about the different resolutions used, then describing the time- stepping and the physics schemes in CAM. Finally explanations of the different runs with the "eval" and "rcp8.5" simulations could be given (and only at that final point, the specific treatment of the sea surface/sea-ice could be given, and also the explanations about the differences with downscaling experiments done with limited area models, i.e. direct downscaling from GCMs or "pseudo- warming" downscaling with addition of climate-change signals).

Thank you very much for the suggestion. We have revised section 3 to address your comments, which we believe substantially improved the readability and clarity of the section.

Specifically, we have re-ordered the materials, made several minor edits throughout the section, added one more subsection, and changed the subsection titles as follows:

3.1. Model grid and parameters

Resolutions and model parameters (e.g., time step) used for the experiment

3.2. Model configurations

Overall CESM configurations (land, sea ice, etc.) used for the experiment

3.3. Model experiments and input data

Description of the eval and rcp8.5 simulations, input data and their preparation, and differences from limited-area modes in some aspects of the CAM-MPAS downscaling experiments.

Other comments:

1. Introduction

line 74: The reference here should be to Figure 3 I think.

Thanks, we have added a reference to Figure 3.

Caption of Figure 1 and line 88: Maybe, it's not necessary here to speak about the use of ERA- interim SST and sea-ice cover, as this piece of information suits more to the experiments description in the section 3.

Agreed and have removed sentences referring to ERA-Interim SST.

2. Model description

line 128: "... the default physics option for this version of CESM...". Two versions are cited in this sentence. If possible, rephrase to better relate "default physics" with "version 6".

We have revised the sentences as follows

"The atmospheric component model CAM has multiple versions of physics parameterization package. We use the CAM version 5.4, which is an interim version toward CAM version 6 (Bogenschutz et al., 2018). The CAM5.4 physics is the default option for CAM in CESM1.5."

line 169: "... the updated atmospheric and tracer states are passed to the CAM physics.". Please see my remarks about Figure 2. As there are two groups of parametrizations, a better identification of CAM "contours" would be useful.

Yes, a contour grouping the CAM components has been added to the figure.

3. Downscaling experiments

line 222: "...but still covers the most of the NA CORDEX domain.". Not precise.

We have revised it as "... but still covers the most of North America."

Line 274: "climatological"

The typo has been Fixed.

line 297: "...the so-called NAM grid...". Please refer also here to Table 2 which contains information about NAM grid resolutions.

Thanks, we have added a reference to Table 2.

5. Simulations

line 390: I think it's Table 5 (and not 2).

Thank you, we have revised the reference.

line 478: "CONUS"

Thank you, the typo has been fixed.

line 544: "...in SAT..." in TAS?

Yes, it is. We have fixed the typo.

Annexe C

Tables C3 and C4: I am just wondering what are the meaning of having daily max/min temperatures in 6-hourly and 3-hourly outputs. Is it to identify the timing of these minimum and maximum in the day?

That is right, these were mistakes. We realized that most of the variables listed in Table C3 and Table C4 were either wrong or missing; we apologize for these mistakes and have completed those two tables with correct information.

We also have corrected the units in the tables using the exponential format following the GMD guideline.

We appreciate reviewer #1 for going through the tables and letting us know the mistakes.

Replies to reviewer #2

We thank reviewer 2 for going through our manuscript, in particular for evaluating our manuscript from the potential data user's point of view. We have incorporated your suggestions in our revision to make readers aware of additional aspects of our experimental protocol that need to be resolved in future studies. Please see below for our responses to your comments. The comments from the reviewer are shown in italics, and our responses are written in the regular font.

Main remarks:

Reading with an eye to how one might use these simulations, I feel there are several issues with the experimental protocol that are not adequately addressed. These issues may be better explored in subsequent research, but I feel they need to be raised here. Primarily, there are many elements being varied among the simulations compared so it is difficult to assess which is responsible for the results. A couple examples:

1. *The global precipitation increases with model resolution is not intuitive and is made more complex do to tuning of the convective scheme.*

That is probably the case, but our intention here is to explore viable options to mitigate known resolution sensitivity of the CAM hydrological cycle, and to share the result (both success and failure) with the community. To adhere more closely to this goal, we have revised the following sentences describing the sensitivity of global-mean precipitation in section 5.2.1 "Present-day climate":

"... This unexpected resolution sensitivity is not necessarily an improvement for the model hydrological cycle, and attributed to the changes we made in the convective time scale of the ZM convection scheme (Sect. 2.2) based on our previous study (Gross et al., 2018). It would be more preferable that the total precipitation and fractions of convective (associated with unresolved updraft) and large-scale (associated with resolved upward motion) components remain unchanged for grid resolution coarser than the so-called "gray-zone" (e.g., Fowler et al., 2016). However, our result does illustrate a potential (and cursory) use of the convective time scale for tuning CAM-MPAS VR simulations. For example, smaller changes than we made in the time scale (Table 3) may result in more preferable partitioning of precipitation components. Readers are referred to section 8b of Gross et al. (2018) for in-depth discussion about tuning mass-flux based convection parameterizations for VR models. "

2. *The delta SST is taken from MPI and may not be consistent with the circulation shift seen in the free-running CAM model.*

Thank you for pointing this out. We have added the following to section 3.3 "Model experiments and input data":

"... Also of note is that the SST or near-surface air temperature (TAS) biases and their changes in the MPI simulations differ from those of fully coupled CESM simulations with CAM5 or CAM6 (Meehl et al., 2012, 2013; Danabasoglu et al., 2020). Specifically, our CAM-MPAS downscaling data describe the response of the atmosphere to the ocean conditions derived from the external data (as with the case for regional model simulations in NA-CORDEX), which may be very different from the climate evolution simulated by CAM-MPAS being coupled to an active ocean model. Because CAM-MPAS and other VR atmosphere models are typically a part of global coupled climate models, it is possible (but beyond our scope) to use ocean boundary conditions derived from fully coupled simulations of the host model, or to run a fully coupled VR simulation, which provide climate-change signals that have co-evolved with the same atmosphere model."

Reply to the editorial office's recommendation

We thank the editor and editorial team for handling our manuscript and review process. Considering the recommendation about the color schemes (avoid using red and green colors together), we have changed colormaps for Figures 4, 8, 10, 11, 12, and D1, for which we think the color scheme is important to identify the features discussed in the text.

Best regards,

Koichi Sakaguchi