Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2020-330-RC2, 2020

Geoscientific Model Development Discussions

Interactive comment on "Quantifying and attributing time step sensitivities in present-day climate simulations conducted with EAMv1" *by* Hui Wan et al.

Anonymous Referee #2

Received and published: 21 December 2020

Overview

In this manuscript, the authors investigate the sensitivity to model timestep of the mean climate within the EAMv1 model. They then methodically scrutinize the response to variations of the model sub-component timesteps in a series of experiments that are designed to attribute the root cause of the model sensitivity to the individual components.

Perhaps unsurprisingly to those familiar with model development, the largest deviations can be attributed to the parametrizations of clouds and moist convection. Perhaps less predictable is how and where these deviations are - in part due to the direct change

to the sub-timestepping of the microphysics scheme and in part arising from timestep sensitivities of their coupling to other components.

The investigations performed are specific to the EAMv1 atmospheric system and in particular to the specific physics parametrizations, dynamical core and transport formulations and split-explicit temporal coupling. That said, the methodology would translate to other modelling systems and formulations, potentially providing a useful framework for identifying physics or dynamics components that are not well resolved or are poorly formulated for a chosen model timestep length. The method can also help in identifying poorly performing components of the system which might otherwise be hidden or explained away with model tuning. For those without an interest in the specific behaviour of EAM, the most valuable take away message is that developing and employing an approach such as this will help to understand deficiencies and biases when developing weather and climate models.

The manuscript is very well laid out, with a clearly constructed story (with an exception noted in comment 5). I would recommend this article for publication subject to consideration of the minor comments below.

General comments

1) On L80, the authors mention the passing of tendencies between different components of the atmospheric model and provide the example of the physics tendencies being passed to the resolved dynamics. It is implied that there are other such instances. Although these aren't the subject of the investigation, it would be useful to know what the other instances are, or if these are too numerous/complex to list, then to clarify if there are cases where different physics components pass their tendencies to subsequent physics components. In particular, do those physics components (clouds, microphysics, convection) which are the focus of the sensitivity studies have such a dependency? If they do, are there any consequences to this that should be borne in mind when interpreting the conclusions about timestep choices between the dependent

schemes. If they don't, it would be useful to have that made explicit.

2) Figure 1: This is a useful schematic to quickly capture the timestepping process. I'm not sure I can see from this where/when the state is updated though. Is it at every point where State is labelled? Could this be made a bit clearer?

3) On first inspection it is quite surprising how little an impact there is in the subtropical low-cloud that can be directly attributed to the reduction of Δt_macmic. However, it is noted in the model overview (L74) that the microphysics includes dynamic substepping and so the timestep used within the microphysics itself may already be shorter than 5 minutes - particularly where numerical stability requires it. While this doesn't negate the conclusions, it might be worth re-stating this feature of the microphysics when discussing this lack of sensitivity. Do the authors have any information regarding the minimum timestep that is used or the number of hydrometeor sedimentation substeps that might add to that understanding?

4) Regarding the sensitivity of the tropical upper troposphere to the cloud macro and microphysics, there are a number of ways in which the cloud microphysics can directly and indirectly influence this region. See for example figure 1 of Hardiman, Steven C., et al. "Processes controlling tropical tropopause temperature and stratospheric water vapor in climate models." Journal of Climate 28.16 (2015): 6516-6535.

5) Section 4.3.3 - Deep convection: This section is at a slight tangent to the rest of the paper and as a result it took me several reads through to be able to absorb the conclusions. Unlike the preceding sections that look to attribute sensitivities, this section attempts to investigate the reason behind the sensitivity of the deep convection to timestep and timescale and then contrasts the findings with the arguments of Williamson (2013). This feels like a half-hearted attempt, with the authors themselves acknowledging more work is needed to fully understand this. I am tempted to suggest removal of this section, however, once I had digested it I did find it interesting and so I would suggest that this goes in an appendix. If the authors do decide to retain the

section (in its current location or elsewhere), then please could they clearly signpost at the start of this section that it is a change in direction from the previous stated aims of the paper and is looking beyond attribution?

Typos

L147: 'Working' not 'Wording'

L268: 'Tropical' not 'Topical'

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