Geosci. Model Dev. Discuss.,
doi:10.5194/gmd-2016-199-AC2, 2016

Geoscientific Model Development Discussions
Open Access
EGU

Interactive comment on "Review of the global models used within the Chemistry-Climate Model Initiative (CCMI)" *by* Olaf Morgenstern et al.

Olaf Morgenstern et al.

olaf.morgenstern@niwa.co.nz

Received and published: 16 December 2016

We thank the review for his/her very constructive and useful comments.

This paper presents a technical overview of the models and simulations that contribute to the Chemistry-Climate Model Initiative (CCMI). In particular, the authors highlight changes and improvements to the models since CCMVal-2. This paper contains a vast array of useful information that I anticipate will be widely used as a point of reference by many in the chemistry-climate modelling community. I recommend publication after my comments below have been addressed.

General comments

1. *Firstly, I suggest some structural changes - mainly in Section 3 and related Tables*

Printer-friendly version

Discussion paper

– to enhance readability. A few points:

(a) *Why is Section 2 standalone? Why not use this as an introduction in Section 3, (since both sections describe model details)? Then, the paper would be neatly partitioned into sections describing model details (Sect. 2), simulations (Sect. 3) and forcings (Sect. 4).*

We have merged sections 2 and 3, to improve readability.

(b) *I do not find the ordering sensible of Sect. 3 sensible. It is currently difficult for a reader to quickly obtain information about any particular aspect of the models. How about ordering such that similar subsections appear close together, especially since there are so many of them. For example, consider the ordering below (but feel free to make changes around this general idea):*

- *Grid and numerical methods: general model makeup, model resolution, advection, time-stepping and calendars, horizontal diffusion*
- *Dynamical and physical processes: QBO, gravity wave drag, physical parameterizations, cloud microphysics*
- *Chemistry, aerosols, radiation: trop chemistry, strat chemistry, heterogeneous chemistry, PSCs, trop aerosols, volcanic effects, photolysis, SW, LW, solar forcing*
- *Coupling / other boundary conditions: ocean surface / ocean coupling, land surface*

We have reordered the subsections following the reviewer's suggestions.

(c) *The tables in the Supplement should more or less follow the above order. Consider also adding an explicit sentence at the beginning of each subsection that references the appropriate supplemental table e.g. 'Table Sx shows . . . '.*

We have revised the ordering of the tables and have improved the referencing. Generally, though, we find that the references linking the subsections to the supplementary tables are clear enough.

(d) *Similarly, in Section 4, I would re-order such that the simulations in which one set of boundary conditions is kept fixed (fGHG, fODS, fEMIS, fCH4, fN2O) appear together, as do the simulations in which time-varying perturbations are applied (C1-Emis, C2-RCP, C2-GeoMIP, C1-SSI, C2-SolarTrend).*

We follow the reviewer's suggestion.

2. *My second general point is to include more detail throughout the paper. This includes, but is not limited to, my questions in the Specific comments below. This also applies to Table captions (including expansion of abbreviations); the reader cannot be expected to reference the CCMVal-2 report. Finally, this applies to Appendix A e.g. no details on the chemical species or mechanisms is not provided for most models; I understand that this is might be a tough task given the large number of different modeling groups involved. On that note, I do commend the authors on well documenting the changes in each model since CCMVal-2.*

   Indeed, we consider it impractical to document here full details of the chemical mechanisms used as these tend to be big, and there are a lot of models listed here. We feel this should be the subject of a separate paper. We have revised text in various places to provide more detail and improve clarity.

Specific comments:

I organize the following points primarily by section, and page/line number where necessary:

(3.1) General model make-up:

- *I'm not entirely sure about the point of this subsection. Much of it could be neatly partitioned elsewhere. Perhaps just include some general comments on the components/coupling in the models and retain the text on familial relationships.*

We have reorganized this into two newly titled subsections on family relationships and on the grids in use by the CCMI-1 models. The sentence on coupling to ocean models duplicates another sentence in the corresponding ocean coupling subsection.

- *First few lines are repeated in Section 3.12 (Ocean Forcing). Could remove details here and reference that section.*

  We have removed the duplication.

- *P3 L20: 'the impact of ozone depletion on surface climate is represented consistently': a bit unclear. Consider making a broader statement (first): 'surface climate is able to respond to changes in atmospheric composition, some of which may be considered climate feedbacks', or simply make the point that climate feedbacks are self-consistently incorporated.*

  We have rephrased this sentence.

- *P3 L28: would make sense to include grid details with model resolution (Sect. 3.2).*

  We have merged these two paragraphs into one subsection ('Atmosphere grids and resolution').

- *(3.2) Model resolution:*

- *P4 L9: from Table 3, it looks like CNRM-CM5-3 and TOMCAT also do not completely cover the stratosphere (I'm defining a stratopause at 50km, 1hPa).*

  These two models extend into the mesosphere (with tops at 7/8 Pa and 10 Pa respectively). We now consistently use units of Pa here, to avoid this confusion.

- *(3.3) QBO:*

- *P4 L15: '...which means the QBO may not require explicit forcing to occur in the models, or it may be absent': I don't understand this sentence. Please clarify.*

  In these models, the QBO is not externally imposed. This means it's either spontaneously occurring (with a degree of realism not assessed here) or it is absent. We have rephrased the sentence.

- *Mention which models do not have a QBO at all and which (few!) internally generate a QBO either in the text or tables.*

  We stated at the start of the paper that model evaluations (such as of the occurrence and realism of the QBO) would be out-of-scope for this paper. An assessment of which models spontaneously produce a QBO would then lead to a discussion of the quality of this simulation; we prefer to leave this to other CCMI papers to explore.

- *(3.4) Volcanic effects:*

- *Clean up slightly: highlight, in turn, which (or how many) models include (a) online volcanic aerosols, (b) impose offline aerosols (heating rates) and (c) do not have any representation of radiative effects from volcanic aerosols. This will correspond much better with Table S4.*

  We have revised this section.

- *(3.5) Advection:*

- *Expand on the 'different settings for hydrological and chemical tracers' in the MetUM models or add reference.*

  We have removed this sentence. Moisture and chemical tracers are advected consistently in these models. These models are based on a semi-Lagrangian dynamical core, and physical tracers (momentum, heat) are transported using different settings from the chemical and hydrological tracers. But this is not the

topic of this paragraph, and in other models these physical quantities would likely also be advected using schemes that differ from the tracer advection scheme.

- *(3.8) Tropospheric aerosols:*
- *Combine this section with Sect. 3.21.*

  Done.
- *Would it be worth mentioning the main tropospheric aerosol species / heterogeneous reactions included in the models?*

  We have added a sentence summarizing what's listed in table S18.
- *(3.9) Stratospheric chemistry*
- *P5 L28: 'to lump all': is it really all, or most?*

  We have cut out the word "all". The lumping makes sure that realistic amounts of chlorine and bromine enter the stratosphere.
- *Reference for how Cl source gases are lumped?*

  This is detailed in Morgenstern et al. (2009). Reference added.
- *Are Br source gases also lumped in some cases?*

  Yes they are. We have added a sentence to this effect.
- *P5 L30: reference for the recommendation for Br species?*

  We have added a reference for this (Eyring et al., 2013).
- *Besides halogen chemistry, can you briefly describe the differences/commonalities in stratospheric chemistry between the models? E.g. how is CH4 is oxidized to stratospheric water vapor in the models?*

The models generally employ a detailed methane oxidation scheme that represents intermediates of methane oxidation such as methyl hydroperoxide and formaldehyde. A sentence is added to this effect.

- *How is stratospheric chemistry represented for the models that do not cover the full vertical extent of the stratosphere?*

  With the exception of the upper-atmosphere chemistry of WACCM, there is no characteristic of the chemistry schemes discussed here that could be attributed to the lower top in the low-top models.

- *(3.11) Strat/trop heterogeneous chemistry*

- *Provide more details of SO2 → SO3 oxidation (e.g. is it with interactive or offline oxidant fields?).*

  We have added a few sentence on this process. In all cases where we now give details on this process, oxidants are calculated interactively.

- *(3.15) Cloud microphysics*

- *P8 L10: Add reference(s) to first sentence.*

  Reference added (IPCC 2013).

- *(3.15) and (3.16)*

- *Little detail provided on cloud and land surface schemes – elaborate if practical.*

  We feel that a discussion of the details of these (that would be of use to specialists in these areas) would need to be the subject of a separate paper. Both are highly complex science areas in their own right, and their treatments in the models are highly diverse.

- *(3.17) PSCs*

- *For the non-expert, elaborate on what is calculated assuming 'thermodynamic equilibrium'. Can mention formation of NAT/ice PSCs, and how these differ between models.*

  We have added a sentence explaining "thermodynamic equilibrium", and a further sentence on the PSCs.

- *It would make sense for this section to be near Sect. 3.11 (heterogeneous chemistry)*

  We have re-ordered the subsections.

- *(3.22) Ocean coupling*

- *This section should be combined with Sect. 3.12 (ocean surface forcing) or appear close to it.*

  We have combined the two subsections.

- *Mention also the sea ice modules / boundary conditions here.*

  We have added a sentence on sea ice.

- *(3.23) Solar forcing*

- *In cases where SW radiation and photolysis are not handled consistently, what are the radiation schemes for photolysis? For these photolysis schemes, can we assume the effects of the 11-yr solar cycle are not included?*

  A diversity of photolysis schemes are used, as is detailed in table S22. Some of them consider the solar cycle, others don't. We have rephrased this for clarity. The fact that shortwave radiation and photolysis have not been made consistent in several models does not imply there are significant inconsistencies in these models. It only means the schemes were developed independently. In response

to this question, several models have been re-classified as treating shortwave radiation and photolysis consistently.

- *(4) CCMI simulations*
- *P10 L15: 'Forcings are discussed briefly...' → 'The specific forcings imposed are discussed briefly...'.*

  Done.

- *P10 L18-20: This sentence is very unclear and should probably be separated into at least 3 sentences. Do you mean that ODS concentrations (or EESC), rather than emissions, peak around yr 2000? Which 'industrial emissions' do you mean? Separate the discussion of GHGs from ODSs and the other 'emissions' that are referred to. Should this sentence be in the Forcings section?*

  We agree that this sentence is displaced and "loose". We have cut it out. A more exhaustive discussion of emissions is in the "Forcings" section.

- *P10 L22: clarify that SD stands for "specified dynamics".*

  Done.

- *P10 L22: differences in dynamics between nudged and free-running models are not necessarily due to inherent dynamical biases in the model; they could also be due to the greater presence of internal variability in the free-running case.*

  Indeed. The opposite (reduced variability) can also be the case. We have rephrased this sentence.

- *P11 L3: which emissions?*

  We have clarified the statement.

- *P11 L5: I'm confused as to the exact forcings imposed here: GHGs? SSTs and sea ice for models not coupled to an ocean? ODSs (including those that are not GHGs)? NOx? NMHCs?*

  In this set of simulations, all assumptions about future climate forcings are changed from RCP 6.0/WMO (2011) to a different RCP (keeping WMO (2011) for ODSs). This includes changing ocean conditions accordingly, for those models that require that. We have added two sentences to this subsection.

- *P11 L9: 'sea surface' → 'sea surface and sea ice'.*

  Done.

- *P11 L11: only surface emissions, or also 3D emissions (e.g. aircraft NOx)?*

  Both. We have changed the sentence accordingly. This does not include lightning NOx emissions which are usually handled interactively though.

- *P11 L15: clarify that SSI stands for Spectral Solar Irradiance.*

  We have expanded the acronym.

- *(5) Forcings*

- *P12 L1-2: clarify that N2O and CH4 boundary conditions refer to surface mass mixing ratios.*

  Done. Actually the plots show volume mixing ratios.

- *P13 L9: add reference.*

  Done (WMO, 2015).

- *P13 L14: 'cause NOx emissions to peak and then decline' - clarify that this is only an assumption for the future.*

  We have rephrased this sentence to make this clear.

- *P13 L26: reference for MEGAN model*

  We have added a web link for MEGAN.

- *P13 L19-30: which dataset(s) is/are used for historic emissions in which biogenic emissions are not interactively computed?*

  The recommendation was to use biogenic emissions datasets of the modellers' choice, which was "preferably consistent with the model's meteorology". In reality, a range of different emissions was used.

- *P14 L10: reference appropriate table*

  Done.

- *P15 L1-15: much of this information is provided in Sect. 3.21. Instead of repetition, talk here about the time series of aerosol precursor emissions (e.g. the projected reduction in future aerosol emissions over certain regions as with ozone precursors).*

  We now include a mention of this effect. We now have a plot showing emissions of NOx and SO2, at different times throughout the REF-C2 period.

- *Tables*

- *Table 2: Is it possible to list (alongside the model names) the versions used for CCMVal-2, and, where relevant, the name of the ESM? Right now, there is little consistency.*

  In as far as Morgenstern et al. (2010) have given versions, we now state these versions in the table.

- *Table 4: caption: state that the numbers in the table stand for (I'm guessing) the number of ensemble members.*

  Done.

- *Table 5 and 6: why are some numbers in bold and in brackets? What does L39 stands for?*

  Numbers in brackets mean that these simulations are in progress (i.e. unavailable at the time of writing). "L39" stands for the 39-level version of the LMDz model. We have clarified these issues in the caption. The boldface will disappear for the final version.

- *Table S2 caption: clarify that the numbers represent number of grid boxes.*

  Done.

- *Table S5 caption: expand on abbreviations used in the table e.g. SL = semi-Lagrangian etc.*

  Done.

- *Table S5: for CESM models, CAM4 describes the atmospheric component but not the transport scheme (is it SL? please check.)*

  It's finite-volume (Neale et al., 2013). The entries have been changed accordingly.

- *Table S26: would make sense to keep this next to Table S5.*

  We have re-ordered the table in line with the reviewer's earlier comment.

- *All tables: please try to find more references for each model (e.g. for the aerosol schemes in Table S4).*

  We have added more references in several tables.

- *Appendices*

- *P22 L22-24: The two first sentences are already mentioned in the previous paragraph.*

  We have shortened this paragraph to remove the duplication.

- *P23 L15: citation for Wesely scheme.*

  Added. This scheme is also used by UMUKCA-UCAM and HadGEM3-ES; citations have been added.

- *P25 L29: why are two of the simulations in bold?*

  We have changed this to regular font.

- *P26 L24: elaborate.*

  We now state a reference (Jöckel et al., 2016) which has the details on this. Diagnostic tracers are the subject of a separate publication; we have therefore avoided discussing them here.

- *Technical comments*

- *P4 L12: misspelled 'oscillation'*

  Corrected.

- *P5 L18: 'included' → 'include'*

  That sentence has been rephrased.

- *P5 L27: 'Unified Model' → 'MetUM' for consistency*

  We have applied this name throughout the paper.

- *P9 L2: Remove comma after 'table S17'*

  Done.

- *P10 L8: 'increasing' → increasingly'*

  Done.

- *P19 L13: "Earth'" → "Earth's"*
  Done.
- *P24 L18: 'CTM be' → 'CTM can be'*
  Done.
- *Table S3 caption: 'CCM name' → 'model name'*
  Done.

Interactive comment on Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-199, 2016.

Printer-friendly version

Discussion paper