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Geoscientific
Model Development
Discussions

Interactive comment on "Evaluation of the University of Victoria Earth System Climate Model version 2.10 (UVic ESCM 2.10)" *by* Nadine Mengis et al.

Anonymous Referee #2

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General comments

This paper provides an overview of the latest update to the long-used UVic Earth System Model of Intermediate Complexity (version 2.10). The UVic model represents an impressive effort on behalf of many scientists in the Canadian climate modelling community and beyond. The previous version 2.9 has been used for many years in carbon budget assessments and modelling long-term climate change, applications for which full-complexity Earth system models are too computationally expensive. Particularly welcome is the inclusion of a permafrost module.

This update provides a valuable addition and extension to the UVic model, and it should be used extensively in the forthcoming IPCC assessments. Moreover, with a global focus on carbon budgets and net zero emissions, ESMs and EMICs that represent carbon cycle processes are even more valuable than previously. It should be published following the detailed minor revisions.

Specific comments

More should be done to convince the reader that in the era of increasing computing power, UVic is still a valuable model. Some indication of model runtime and the benefits of running UVic 2.10 versus a full-complexity ESM would be useful. What experiments can be done with UVic that ESMs would struggle with? Can you run perturbed parameter or perturbed physics ensembles (also leads into my next point)? On the other side of the coin, much emphasis is now being placed on simple climate models like MAGICC and FAIR, over which UVic has the advantage of fully representative physics, at least for the ocean and land surface.

The paper, to an extent, describes the tuning process for CMIP6. It is unclear which components of the model are hardwired and which are able to be changed according to the user's wishes. For example, can the aerosol forcing efficiency of sulphate optical depth to forcing be altered by the user? By default, the 1850-2018 aerosol ERF is around -1.43 W m^{-2} in UVic 2.10. This is in fact stronger than all 12 CMIP6 ESMs and GCMs which have evaluated their aerosol forcing under CMIP6 emissions (Smith et al., 2020). Previous versions of UVic showed that metrics such as committed warming and climate sensitivity depend very strongly on the present-day aerosol forcing (Matthews and Zickfeld, 2012).

Related to this, on page 5, line 12: "All data used in the creation of this dataset can be accessed from Input4Mip on the Earth System Grid Federation (ESGF) unless otherwise specified." This slightly implies that we are constrained to use the CMIP6 tuning and/or forcing timeseries. Is this the case, or is this just for the tuning setup described in this paper?

Subheadings (i), (ii), (iii) in section 2.1 could be third level headings? (2.1.1, 2.1.2, 2.1.3)

Page 6, line 17: The AR5 aerosol effective radiative forcing range is -1.9 to -0.1 W m^{-2}. The appropriate references are Boucher et al., 2013 and Myhre et al., 2013, not the cited Ciais and Sabine.

Page 8, line 8: "might still be problematic": in what way? Could this affect long-term projections of near-surface air temperature?

Page 8, line 14: Temperature performance is evaluated with respect to the Global Warming Index (GWI), which seeks to isolate the anthropogenic component of historical warming from the natural component/total observed warming. But isn't natural forcing included in UVic? Section 2.1 suggests it is, and we can see the signatures of Krakatoa, Agung and Pinatubo in the temperature timeseries of figure 1a. On closer inspection, the curve marked as GWI seems to have a lot of internal variability, when it should be smooth like the yellow curve at http://globalwarmingindex.org/. Is this definitely GWI?

More pressingly, GWI is a mean of four datasets which are near-surface air temperature over land blended with sea-surface temperatures, of which three of the four have coverage bias by excluding regions where there are no observations such as the rapidly warming Arctic. If you are comparing UVic global near-surface air temperature over land and sea with no coverage masking (as is typically done when analysing temperature change in climate models) against GWI or any observational dataset without adjustment, you are likely underpredicting the present-day warming. See Richardson et al. (2016).

Page 8, line 26: It could be worth remarking on the interesting non-linearity between 2$\times$ and 4$\times CO_2$ ECS and possible mechanisms. Are these true long-term equilibrium values — presumably the model can be run long enough to determine this — or from a 150-year abrupt forcing (Gregory) regression?

Figure 2: Would it be better to plot summer minus winter and compare both hemispheres on one scale? A third plot showing the differences between UVic and obs would be nice too.

Supplementary figure S5: I'm not completely sure it's appropriate to copy the diagram from Wild et al., 2013 in fig. S5 unless you have permission from the publisher, but maybe you have obtained this.

Technical corrections

- line 9: "reproducing well changes" reads a little awkwardly, how about "reproducing changes in historical temperature and carbon fluxes well,"?
- page 3, line 3: Special Report on Global Warming of 1.5°C
- page 3, line 13: merge → merging
- page 3, line 25: period after (Weaver et al., 2001) rather than comma would improve flow in my opinion
- page 5, line 15: calculated → calculates
- page 5, line 16: Etminan reference as author (year)
- page 5, line 28: β is better described as a forcing efficiency. NO_x (NO and NO_2) are nitrogen oxides which are emitted in the gas rather than aerosol phase. As

you correctly allude, NO_x are implicated in the formation of nitrate aerosols, as well as being an ozone precursor.

- page 6, line 2: Input4Mip → input4MIPs (also a few other places)
- page 6, eq. 4: $Ci \rightarrow C_i$
- page 6, line 7: E^{-5} and E^{-3} would be better written e.g. $\times 10^{-5}$.
- page 7, line 2: the IMAGE model
- page 7, line 8: close bracket has no corresponding open bracket
- page 8, line 20: CO2 → CO_2 (also a few other places)
- page 8, line 21: remove “with”
- page 9, lines 1-2: written a little awkwardly. Generally, it would be good to be consistent with units throughout the paper: use either K or °C consistently.
- page 11, line 8: than in → compared to
- page 12, table 3: solar down range should be 340 not 240?
- page 12, line 7: remove “with”
- page 12, line 18: at → is at
- page 12, line 20: simulates → simulated
- page 12, line 24: consistency with citing IPCC chapters
- page 18, figure 9 caption: Taylor 2001 is not in the list of references.

- page 22, line 15: Capitalise Coupled Model Intercomparison Project, although will UVic actually be used in CMIP6? I would assume ZECMIP and C4MIP? If so I would also suggest highlighting this in the abstract too.
- page 23, line 10: “are slightly off”: can this be written more scienficially?

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