Geoscientific Model Development Discussions

Geosci. Model Dev. Discuss., referee comment RC1
https://doi.org/10.5194/gmd-2021-79-RC1, 2021

Comment on gmd-2021-79

Anonymous Referee #1

Referee comment on "Minimal CMIP Emulator (MCE v1.2): a new simplified method for probabilistic climate projections" by Junichi Tsutsui, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-79-RC1, 2021

Review of Minimal CMIP Emulator (MCE v1.2): A new simplified method for probabilistic climate projections by Tsutsui.

This study describes the Minimal CMIP emulator (MCE) model for projections of global mean surface air temperature and presents probabilistic ensembles generated using a Monte Carlo approach.

In the study, a set of 600 simulations is generated to construct a prior ensemble, with model parameters varied according to estimates of the relevant properties in the literature. A constrained ensemble is then also generated using observational constraints to train an additional 600-member ensemble.

This approach has been well justified within the manuscript, and links well to existing current literature (such as the RCMIP of other computationally fast climate models).

I find the study well written, and I am confident that both the model and Bayesian approach to ensemble generation will be a useful addition to the literature. I find the current version of the manuscript is close to recommendation for publication. I do have some comments and concerns that I would like to see addressed in a revised version and/or explained in a response, before recommending publication of the manuscript. I outline these comments and concerns below.

Comments/concerns:

(1) Schematic of the MCE

The description of the model (Section 2) is well written, and I came away understanding how the model was constructed mathematically. There is enough information there for someone to code their own version of this model if required.

However, there were instances where I think a schematic of the MCE, or some other representation that would show how the equations are applied, would be very helpful to the reader.

For example, a schematic showing exactly what is meant by the ‘composite atmosphere-ocean mixed layer’ in equations (3) to (6) would be helpful to more quickly understand how carbon in the atmosphere and surface ocean mixed layer are being treated.

One reason I find that a schematic would help the reader tremendously is that I couldn't work out whether the MCE uses different representations for heat and for carbon, or the same representations. For example, Lines 299 to 302 indicate that temperature is effectively treated as a three layer heat-exchange model:

"The IRM for temperature change is transformed into a three-layer heat exchange model in physical space. When diagnosing the CO2 forcing and response parameters, the top layer temperature was treated as global mean surface air temperature (GSAT). As in HadCRUT GMST was defined as a surface air ocean blended temperature change; here, a factor of 1.04 was used to convert observed GMST change into the MCE's GSAT change."

A schematic would help the reader work out whether the top layer in this heat exchange is the same thing as the composite-atmosphere-ocean mixed layer' for carbon. At present I am unsure, and so I cannot see whether observational records of Global Surface Air Temperature, Global Surface Temperature or Global Sea Surface Temperature would be the best type of record to compare this top layer with (e.g. if the top thermal layer is meant to represent the heat uptake by the composite surface mixed layer and atmosphere {as in the carbon-component of the model}, then an SST record is the best one to compare it to since the surface mixed layer is the majority of the heat uptake. However, if the top layer is meant to represent the temperature response of the atmosphere only, then Global mean Surface Air Temperature records are best, as currently used).

(2) Development of 'Constrained' ensemble.

I would like to see the tests used for the derivation of the 'constrained' ensemble more explicitly stated. At present the manuscript reads (starting line 292):

"The 'Constrained' uncertain parameters were sampled from those of 'Prior' through a sequence of the MH sampler with a subset of RCMIP constraints, as follows: (1) CO2 ERF in 2014 relative to 1750 evaluated in Smith et al. (2020), (2) TCR estimated in Tokarska et al. (2020, Table S3, both constrained), and (3) GMST in the period 1961–1990 relative to the period 2000–2019 from the HadCRUT.4.6.0.0 dataset (Morice et al., 2012) and ocean heat content (OHC) in 2018 relative to 1971 from the dataset of von Schuckmann et al. (2020). In this case, in addition to 1pctCO2 runs, historical scenario runs with a set of proposed parameters were conducted to obtain data fed into the sampler."

It would help the reader reproduce an equivalent constrained ensemble, perhaps with different simple climate model, if these 3 tests were explicitly stated. Possibly a table could be used, or else mathematical functions for the tests given, in an Appendix or supplementary material?

(3) Relevant literature for context.

The placing of the manuscript within existing literature is a general strength of the study. For example, the comparison to the 600-member ensembles produced by the MAGICC emulator is presented well, as is the comparison to the FaIR model, allowing the reader to understand the key similarities and differences between the approaches of the MCE model used here and these previous models and approaches. Also, the placing of the MCE within the RCMIP provides the reader with necessary context.

However, the manuscript could be improved further by placing the work within context of at least one recent climate model study that has also adopted a similar Bayesian approach to ensemble generation, for example the recent studies by Goodwin and Cael (2021) and Goodwin (2021).

The methods used here and in Goodwin and Cael (2021) and Goodwin (2021) adopt a Bayesian approach to ensemble generation, with both the similarities and differences between them. For example:

(i) Goodwin and Cael (2021) use a much larger prior ensemble with an observational filter used to either accept or reject each simulation to form the posterior, whereas this study uses a sampling algorithm to keep the prior sample size smaller.

(ii) Goodwin and Cael (2021) vary a set of ~25 model parameters independently (including model parameters for radiative forcing) in the prior ensemble, and then allow any relationships between variables to emerge within the posterior ensemble. These relationships are then explored with a principle component analysis of the parameters within the posterior ensemble. In contrast, this study varies the model parameters using pre-defined relationships between varied parameters in the prior, using principle components to evaluate what those pre-defined relationships should be.

(iii) Both studies use observational records of surface warming and heat uptake to constrain the ensembles, but with a different approach.

Placing this study's method in context with previous Bayesian approaches to climate model ensemble generation within the literature would be helpful to the reader. Perhaps some of the findings from the Principle Component and other analyses in Goodwin and Cael are consistent with some of the findings of this study?

(2) Line 135: Temperature IRM split into three time-constants:

"*The IRM of the temperature change defines three components with typical time constants of approximately 1, 10, and > 100 years. Although the temperature response is usually well represented by two separated time constants of approximately 4 and > 100 years (e.g., Held et al., 2010, Geoffroy et al., 2013), …*"

There is an additional reason why having the three time-constants may be important, and be of benefit to the MCE model: The sea surface warming pattern effect. The climate feedback and warming responses of complex CMIP-class models to radiative forcing are found to be affected on a (multi-)decadal timescale by the changing pattern of surface warming (e.g. see Andrews et al., 2015). It seems to me that to emulate the impact of this pattern effect on surface warming in a CMIP-class model using MCE it is a benefit to have three timescales, and that this should be highlighted in the study.

Minor points:

Abstract, line 17:

"… CMIP- and observation-consistent ensembles …"

At present, the hyphen is critical to the meaning of this sentence: if the hyphen were not there then you would be comparing the CMIP simulations to the observation-consistent simulations – which is how I originally read it. Actually, the author is comparing the CMIP-consistent simulations to the observation-consistent simulations.

To avoid confusion, here I suggest changing this to "… CMIP-consistent and observation-consistent ensembles …".

Line 315:

"Other details of experimental specifications are provided in the MCE's code repository."

It would be helpful to put the reference or doi of the code repository here.

References:

Andrews, T., Gregory, J.M., and Webb, M.J. (2015) The dependence of radiative forcing and feedback on evolving patterns of surface temperature change in climate models. J Clim 28, 1630–1648. https://doi.org/10.1175/JCLI-D-14-00545.1 .

Goodwin, P. and Cael, B.B. (2021) Bayesian estimation of Earth's climate sensitivity and transient climate response from observational warming and heat content datasets, *Earth System Dynamics*, 12, 709–723, 2021, https://doi.org/10.5194/esd-12-709-2021

Goodwin, P. (2021) Probabilistic projections of future warming and climate sensitivity trajectories, Oxford Open Climate Change, kgab007, https://doi.org/10.1093/oxfclm/kgab007