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Earth System Dynamics
Discussions

Interactive comment on "Comparison of CMIP6 Historical Climate Simulations and Future Projected Warming to an Empirical Model of Global Climate" *by* Laura A. McBride et al.

Anonymous Referee #1

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McBride etal presents a physics informed statistical model of temperature change induced by anthropogenic and natural forcing. They use a comprehensive set of observational datasets to inform the nine parameters of their model. They conclude that the observed attributable anthropogenic warming rate, and climate sensitivity, is not only significantly lower than the model mean of CMIP6, but also, for climate sensitivity, significantly lower than our recent assessment of multiple lines of evidence on climate sensitivity.

I believe the stark contrast between the current study and the recent assessment by Sherwood et al. (2020) is partially an artefact of data choices, most significantly the

choice of the HadCRUT dataset for global temperature, which has poor coverage of quickly rising Artic temperatures. The inclusion of older estimates of ocean heat uptake have a secondary effect. I think that the paper will be a useful contribution to debate around climate sensitivity after major revisions.

Major comments:

1) The HadCRUT dataset is known to underestimate recent warming. The model mean is computed without compensating for the fact that Artic temperatures are underrepresented, leading to an underestimate of warming (Cowtan and Way, 2014, Cowtan, 2017). Even with corrected sea surface temperature, this still leads to under-reported warming compared to a record with global coverage (Cowtan, 2017). The HadCRUT data should be replaced by the Cowtan record.

2) According to the IPCC's SROCC report, older estimates of ocean heat uptake have biases that may lead to an underestimate of ocean heat uptake (Bindoff, 2019, p.457). Carton et al (2018), whose record was derived with data assimilation, indicated that previous estimates with data assimilation (possibly like Balmaseda's record), may have contained errors that have prevented them from being sufficiently. Similarly, Cheng et al (2017) and Ishii et al (2017) can be considered superior to the old standard of Levitus (2012).

3) Armour (2017) showed that climate sensitivity estimates from energy budgets can be reconciled with climate models by treating models as observations: if you estimate climate sensitivity of models using only data up to the present, your climate model sensitivity will be underestimated. The reason is that most models show increased sensitivity over time. The climate feedback parameter in McBride et al is assumed to be time-constant without justification. On timescales longer than the 150 years of the Gregory method, positive feedbacks are set to increase even further (Rugenstein, 2020).

4) Considering the previous comment, I would like to be convinced the simple method

can be used to estimate climate sensitivity when applied to climate models. Is this method able to give accurate predictions of climate sensitivity of climate models in contrast to previous energy balance methods?

5) I could not quite understand the computations behind the TCRE: how are uncertainties in the carbon cycle taken into account? This is important for the 66% and 95% likelihood estimates.

6) The paper is quite long and I think that it will become more convincing after a good look at the prose. My minor comments will give further suggestions.

Citations:

Armour, K. Energy budget constraints on climate sensitivity in light of inconstant climate feedbacks. Nature Clim Change 7, 331–335 (2017). https://doi.org/10.1038/nclimate3278

Cowtan, K. and Way, R.G. (2014), Coverage bias in the HadCRUT4 temperature series and its impact on recent temperature trends. Q.J.R. Meteorol. Soc., 140: 1935-1944. doi:10.1002/qj.2297

Coverage bias in the HadCRUT4 temperature series and its impact on recent temperature trends UPDATE (2017) https://www-users.york.ac.uk/∼kdc3/papers/coverage2013/update.171107.pdf

Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M.S. Karim, L. Levin, S. O'Donoghue, S.R. Purca Cuicapusa, B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson, 2019: Changing Ocean, Marine Ecosystems, and Dependent Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press

Rugenstein, M., BlochâĂŘJohnson, J., Gregory, J., Andrews, T., Mauritsen,

T., Li, C., et al. (2020). Equilibrium climate sensitivity estimated by equilibrating climate models. Geophysical Research Letters, 47, e2019GL083898. https://doi.org/10.1029/2019GL083898

Minor comments: 76. Remove the word "active", as that implies a dynamic ocean, which is not what the model has

82. The paper uses many capitalised abbreviations, which is inevitable. However, words like months and obs can be written in lowercase to make reading more pleasant.

101. Maybe repeat what delta TMDL means

132. I'm not sure whether your definition of lambda can also be called a climate feedback parameter. It would be confusing to have two different parameters with the same name

136. This sentence can be removed, as it's not providing any information relevant to the study.

188. Normally the reduced chi-squared parameter is denoted $\chi\nu 2$ to differentiate from normal chi-squared.

Figure 1: The AAWR in panel b is different from the lead, which one is correct?

239-243. In this study, the datasets are referred to by the name of the institutions responsible for them, but they have specific names. Could you replace CRU with HadCRUT, GISS with GISTEMP and so forth.

242: Typo. Berkley=Berkeley

247. Transformation usually means adjusting the mean and variance, where you're only adjusting the mean

257. The baseline is defined as no mitigation, so this sentence would be corrected if you remove that word

263-269. Description of the tiers is unnecessary for this study, consider dropping it.

272. Add “the” (“in the supplement”)

279-281. Which equation comes from which source?

289. Remove brackets around Myhre

295. Upon -> on?

320. Are you sure it’s not perfectly identical?

323. Remove “described above”, it’s unnecessary

363-369. If I understand it correctly, three different time series are appended. Would it not be easier to derive the entire time series yourself? That would also be more easy to describe.

415-416. Normalization involves both the mean and standard deviation, offsets are always additive. Maybe rewrite as “the five datasets are all set to zero in 1986 by applying an offset”

433. I didn’t understand which standard deviation of the mean was taken

463. Replace “based upon” by “using”, remove “shown below”?

477-480. I didn’t understand why AAWR is not affected at all, as regression variables, such as lambda, are surely influenced by the inclusion of AMOC.

519. if I understand it correctly, these equations assume there is no uncertainty at all in the radiative forcing at the doubling of CO2, which is inconsistent with definitions of radiative forcing and with CMIP6 models.

550-552. I did not understand what an asymmetric Gaussian was, could you explain?

649. Remove “as indicated”

675. The value of 1.85 contradicts the value in the next paragraph of 2.01. Which one

is correct?

Figure 8: This figure only uses studies with low climate sensitivity and compares them to assessments of climate sensitivity (Sherwood/IPCC). Either explain the selection criteria, or add some studies to make this figure more balanced (the carbon brief provides an excellent overview: https://www.carbonbrief.org/explainer-how-scientists-estimate-climate-sensitivity)

689. The word “yet” implies a contradiction. However, with the very wide uncertainty specified by the IPCC, these probably overheating models are still within range.

698. rm the word “actual”?

704-705. Consider deleting “ninety-five. . .multi-model ensemble” as I think it is an unnecessary detail. Presenter 713. Remove “then”?

739. Remove information between brackets, repetition of information within paragraph.

782. Bifurcation has a specific meaning within mathematics, consider replacing by bimodality. If more models are added, check whether it’s still true.

Figure 10: Use different colour scheme. The rainbow colour scheme has false perceptual thresholds or hides real ones: https://www.nature.com/articles/519291d.

811. Replace “will” with “is set”, we don’t know the future.

931. Replace “since” with “after”.

669. Insert dioxide after carbon

1002. Unnecessary to show all these percentiles, remove 25 and 75.

1009. 2017 was not an El Niño-year and non-El Ninõ-years 2018 and 2019 were comparable in temperature.

1012. Similar, summarise, so do not show all percentiles

1056. Similar, summarise.

1061. Replace “will” with “will not”

1071. Repetition of the information in 1061

1073. What is a literal interpretation? The model democracy interpretation?

1074. Modeling is not the only source of information on warming of 1.5 degrees, many studies extrapolate current trends.

Figure S1: Replace the rainbow colour scheme.

Figure S7: Caption should indicate that it’s the unweighted one.

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