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Geoscientific Model Development Discussions

Interactive comment on "HIRM v1.0: A hybrid impulse response model for climate modeling and uncertainty analyses" *by* Kalyn Dorheim et al.

Anonymous Referee #3

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The authors present a model that couples radiative forcing (potentially from any source, but here solely from the Hector simple climate model) to an impulse response function to calculate global mean surface temperature anomaly, with the possibility to choose different impulse response functions for different forcings (e.g. black carbon).

It is difficult to see what kind of advance this model is. HIRM relies very heavily on Hector, the details of which are documented extensively elsewhere. Using different IRFs for different forcings is not a new concept either (e.g. Richardson et al 2019 for CO2, CH4, BC, SO2 and solar forcing, Larson and Portmann 2016 for volcanic as a special case).

This could be a nice module to include in Hector as an alternative way to calculate temperature in that model. The comparison to the default Hector temperature response

function is shown in Figure 2 and seen to be almost identical, so this simplification (is it a simplification?) may be worthwhile. But, due to its nearly total dependence on Hector and the fact that species-dependent efficiacy response functions have been done previously, it doesn't qualify as a brand new model for me. Rather it is a submodule of Hector. It is possible that there is more to this paper than meets the eye, but if there is it should stand out more, and if the authors believe this does warrant a standalone model, expend some effort in decoupling it from Hector and explain what is improved or new over e.g. Richardson et al. 2019.

Specific comments:

Line 18: Examining the effect of aerosol forcing on global temperature: a worthwhile cause. There is not actually done in this paper however. To me this would involve varying the present-day forcing of aerosols, climate sensitivity, and carbon cycle feedbacks, and investigating how this would cause temperature to evolve in a probabilistic fashion. The projections shown in figure 3 are far too constrained as explained in a later comment.

Around line 25, there is a missing link between ESMs and SCMs: Earth System Models of Intermediate Complexity (EMICs). In fact, you could say that in decreasing order of complexity we have ESMs > GCMs > EMICs > SCMs.

In the paragraph starting on line 32, the authors discuss the differences between process-based and idealized simple climate models, presumably as a preface for introducing their own model that couples the two components. It is not clear to me that these two concepts are necessarily separate, and if they are, this model may not be as novel as the authors claim. The later versions of FAIR (Smith et al., 2018, GRL) include an impulse response function for CO2 emissions to concentrations and for converting forcing to temperature, and "processed-based" representations of concentrations of greenhouse gases, radiative forcing of GHGs and short-lived climate forcers, and feedbacks from temperature on the carbon cycle and radiative forcing. Leach et al. (2020)

in the Generalised Impulse Response model extends the impulse-response framework of the carbon cycle to other greenhouse gases and short-lived climate forcers. In both of these models, the radiative forcing is internally calculated (process-based, in the language of the authors?) and not supplied externally/provided by a different model (as discussed in lines 82-83 for HIRM). For my benefit if not others, could you cite maybe one example of a "process-based" SCM on line 32 if these concepts are separate? MAGICC perhaps?

line 37: "top of troposphere" - this is an old and incomplete definition of radiative forcing, and effective radiative forcing is now preferred - the Smith et al (2018, JGR) reference which is in the bibliography (but not in the text, oddly) goes into some detail on this. I should say this discussion is of limited importance for SCMs.

line 54: "in addition, the physical interpretation of their behaviour is not always straightforward". Please explain why not.

Line 90: This is a confusing paragraph. On first reading it seems like HIRM doesn't allow for species-dependent efficacy. Then I later read the discussion on BC, and see that the different IRF for BC can be included, which *is* a different efficacy (and time-dependent too). Then on second reading I see that the authors are talking about Hector not having species-dependent efficacy which is more evidence that this model is a component of Hector and not standalone. In general, in section 2.2 it is difficult to follow what the authors did. A flow diagram could help.

Lines 97-102: It is not correct to exclude carbon cycle feedbacks. It is no good if HIRM can emulate Hector with feedbacks switched off if the latter is not representative of the real world. If the forcing comes from Hector in the first place, feedbacks need not be excluded in the Hector configuration, because HIRM doesn't calculate forcing. The analogy here would be concentration-driven GCM runs, where the concentrations are calculated by MAGICC (which includes carbon cycle feedbacks) but the GCMs themselves do not, going from concentrations > forcing > temperature.

line 120-121: people have underlying assumptions, but software doesn't

line 124: Hector's IRF - this is the function in figure 1 isn't it, because Hector is not impulse-response based. Could just refer to confirm.

lines 131-132: it goes without saying that 4xCO2 tests the climate model's response to CO2. The importance of the 4xCO2 experiment is that it can be used to (imperfectly) estimate climate sensitivity, climate feedback and CO2 radiative forcing in GCMs (Gregory et al 2004) by using a forcing with a high enough signal-to-noise ratio to get a clear signal but still small enough to avoid substantial non-linearities and tipping points. Hence it can be used as a line of evidence for climate sensitivity, which itself is an input parameter to many simple climate models. Also, putting the Schwarber reference in line 132 reads like they invented this experiment.

line 145: The difference ... and the following sentence, can be dropped. It's apparent from the naked eye that the differences are imperceptible, I don't think this needs to be rigorous. Similar sentence in following paragraph.

line 157: Which SCM? Hector?

lines 161-162: needs a reference

line 174: 29000 is a bit of a random number, is there a motivation for this?

lines 176-177: wrong values (-1.9 to -0.1 is AR5 "very likely" i.e. 5-95% estimate), and also wrong citation (Myhre et al., 2013).

Figure 3: why does uncertainty reduce over time? 2100 temperature is very tightly constrained, but this is the timeframe over which uncertainties in radiative forcing, climate sensitivity and carbon cycle feedbacks multiply. I know these are not sampled, but this should very clearly be stated and the fact that this is not a true future uncertainty quantification of warming. I'd also check the constraints - is 1.6C of warming in 2010, which passes the constraint, realistic?

lines 189-190: Important point, long known. Compare/cite some relevant studies e.g. Forest (2018). Figure 4 would be more naturally expressed in terms of a W/m2 aerosol forcing posterior for e.g year 2010, perhaps add a subpanel e. This would back up the claim that strong aerosol forcing values do not pass the constraints.

Line 214: Mention the perturbation size from line 220 here. Richardson et al. (2019) included a multi-model response for BC and would be more appropriate to use than the single-model study here.

line 230: maybe a better wording would be "... the global temperature was 0.2C lower using the specific BC IRF from Sand et al. (2015)." Avoid using "decreased" in this sentence.

minor:

line 9: Earth (rather than earth)

line 29-30: would probably get picked up in proofing but check citation spellings (Meehl, Meinshausen)

line 40: Myhre et al.

line 91: forging

line 200: also Richardson et al. 2019

line 226: units, should be C/(W/m2)? i.e. the m2 is in the numerator

line 253: HRIM (and in several other places)

line 244: "a" not required

line 245: "dynamics" - not really dynamics is it - just a different IRF.

line 438: 29000 times

References:

Richardson et al. 2019: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019JD0305

Larson and Portmann 2016: https://journals.ametsoc.org/jcli/article/29/4/1497/35504/A-Temporal-Kernel-Method-to-Compute-Effective

Smith et al. 2018, GRL: https://gmd.copernicus.org/articles/11/2273/2018/

Leach et al. 2020: https://gmd.copernicus.org/preprints/gmd-2019-379/

Forster et al. 2016: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016JD025320

Smith et al. 2018, JGR: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GL0798

Gregory et al. 2004: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2003GL018747

Forest 2018: https://link.springer.com/article/10.1007/s40641-018-0085-2

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