Geoscientific
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Discussions

Interactive comment on "A simple object-oriented and open source model for scientific and policy analyses of the global carbon cycle – Hector v0.1" *by* C. A. Hartin et al.

Anonymous Referee #2

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General comments

The manuscript *A simple object-oriented and open source model for scientific and policy analyses of the global carbon cycle – Hector v0.1* by Hartin et al. describes a new modeling framework of a simple climate carbon-cycle model for use in platforms that require computational efficient representations of the climate system. To my knowledge, the open source structural design of this modeling framework is novel and has not yet been developed for simple climate models. This framework has many potential applications within the Integrated Assessment Modeling community, especially for users who want to substitute individual components of the climate system.

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I have two major concerns with the manuscript: 1) experiments to validate Hector are not well described, and 2) Hector appear to have issues at longer timescales that are not well described or acknowledged. I recommend the authors include additional material on the performed experiments and fidelity of Hector at different timescales. The manuscript also need significant cleanup of typos and grammatical errors, and could benefit from improvement of figures.

The effort is important and useful to the community and so even if there remain some issues I believe that is worthwhile publishing as a progress report. I recommend acceptance pending major revisions from the authors. Specific comments on aspects of the paper follow below, in order.

Specific comments

Title: The title of the paper does not appropriately describe the contents of this manuscript. The title suggests that this manuscript describes a global carbon cycle model, but Hector is a full climate model and the paper describes all the components of Hector. A better title might be something like, *A simple object-oriented and open source model for scientific and policy analyses of the global climate system – Hector v0.1*. I recommend that the authors revise the title to better reflect the overall contents of the paper.

Introduction: The introduction is lacking a description of previous work in the field and needs to add citations and discuss the novelty of Hector. The authors properly describe the purpose of simple climate models, their general structure and implementation. But, the authors should cite previous simple climate models and explicitly explain why the design of Hector is novel. Relevant citations include but are not limited to Meinshausen et al. (2011), Joos et al. (2013), Glotter et al. (2014), and models described in van Vuuren et al. (2009) and Hof et al. (2011).

Results: The experimental design for the tests performed in this manuscript are not well described. There remain several ambiguities in Section 5 that must be clarified so results can be properly assessed. In general, figure captions should be expanded to explain the experimental design used to make that display. The authors may find it beneficial to add a table that describes all experiments performed, including Hector's configuration for each experiment, input data used to drive Hector, and the model output (or data) that Hector is compared to. Specific examples of ambiguities related to experimental design include:

- For most figures, it remains unclear precisely when Hector is driven by an emissions scenario and when atmospheric carbon is prescribed. For example, is Figure 8 made using fixed exogenous CO_2 concentrations or with emissions scenarios that reproduce RCPs? The authors should clarify when RCPs are used and when esmRCPs are used. An experimental design table (as described above) would help clarify here.

- The paragraph on page 7081 (lines 4-16) that describes how atmospheric concentrations are prescribed needs to be re-written. If the model simply inverts concentrations to find emissions, it is not clear why the assumption in lines 14-15 is necessary. I am also not sure this statement would hold true for large perturbation scenarios, such as an instantaneous doubling (or more) of CO_2. If this is how the authors perform the prescribed-CO_2 experiments, it is vital that it be described carefully else results are not interpretable.

- Which "historical conditions" are used to run Hector (page 7089, lines 17-18)?

- Which models run esmRCP8.5 (page 7090, lines 11-12)? Are these different than the 11 CMIP5 models?

- RCPs (by definition) are CO_2 concentration pathways. What does it mean for atmospheric CO_2 in Hector to be highly correlated with MAGICC for the four RCPs

(Page 7091, lines 23-27)? Shouldn't the definition of an RCP necessitate identical concentration pathways? This confusion also applies to figures 5-6, and is likely related to the confusion described in the second bullet. Please clarify.

I disagree with the statements at the beginning of section 6.2. It is incorrect that models that accurately estimate historical climate are simply "assumed" to be reliable for future scenarios. The credibility of Hector in making future projections of the climate should not be based solely on the fact that it can reproduce historical trends. In fact, we see that Hector has problems at long timescales (where short timescales are more accurate– Figures 8 and 10), and even some errors appear in the historical record itself (Figure 4). The authors must re-write this paragraph, but more importantly, must be explicit about issues with the use of Hector over long timescales.

There are issues with the fidelity of Hector at different timescales that are not acknowledged or described. Hector does not include the dissolution of calcium carbonate in its representation of the carbon cycle (to my knowledge) and therefore will not be dependable past ∼2000 years. But I do not know whether Hector is dependable up to 2000 years. Potential users of Hector would benefit greatly from a dedicated discussion of its usefulness at different timescales. Specific concerns with the fidelity of Hector include:

- Hector is unable to reproduce 1970-2010 temperatures (Fig 4). These errors should be described in the text, including possible explanations linked to underlying physics.

- Atmospheric CO_2 concentrations in figure 5 are only shown from 1850-2100. Is there a reason why this plot isn't extended to 2300 like figures 6-11? If model errors are prevalent from 2100-2300, it is essential that this plot show the entire time range.

- Hector also appears unable to reproduce temperatures in CMIP5 models past year 2100 (Fig 8). This misrepresentation is downplayed in the text (page 7092, lines 11-20). It is not sufficient to simple state that errors are negligible because correlations are high. It is unclear whether this is an error in the temperature or the carbon cycle model of Hector because the experiment is not well described. Please clarify.

- The authors do a nice job highlighting deviations in the atmosphere-ocean flux in Hector from CMIP5 models after ∼2100 (Fig 10). However, these deviations do not seem trivial, and may impact long-term projections. If Hector cannot be trusted after ∼2100, this should be stated.

Until a later version of Hector is released with an updated modeling approach, the authors should acknowledge these issues and should add discussion on the physical causes that may produce deviations from observations (or more complex models). The authors do include some discussion of the underlying physics at the end of section 6, but more should be included throughout the manuscript.

Technical corrections - figures and tables

- All figures: Figure text is too small.

- Figure 2: Describe (in caption or key) the definitions of variables T_T, E_{IL}, E_{ID}, etc.

- Figures 3-5, and 8: use consistent colors for models across figures. It is very hard to compare across figures when Hector output is shown as yellow in one plot and green in another.

- Figure 8: Label panels a, b, c, and d.

- Tables 1 and 2: Include references for initial condition values where applicable. For example, the recent IPCC estimates a pre-industrial total oceanic carbon content of $\sim$38,000 GtC. Numbers here are closer to 35,000 GtC. This difference is not likely significant for Hector, but my confidence in the model would be higher with references to justify these numbers.

Technical corrections - text

(Note that I did not provide comments for sections 4.2.1-4.2.6, and suggest a different reader with expertise in this area to review this material.)

- Page 7077, line 5: #4 (modeling the carbon cycle) seems a subset of #1 (calculating future concentrations of greenhouse gases). Either remove #4 or move it up as an explicit subset of #1 (or explain what is meant, if I am missing something). The order should reflect the general order of operations in an SCM.

- Page 7077, line 7: Recommend changing the word "policy" to "decision making".

- Page 7077, lines 12-13: Recommend changing "have a simple representation" to "rely on simple representations".

- Page 7077, lines 24-27: Consider re-writing the first sentence of this paragraph. There is also a grammatical error in this sentence: "therefore are used for run multiple simulations of future climate change. . ."

- Page 7077, line 29: Please be more specific with wording choice for "fast enough".

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- Page 7078, line 5: "This study introduces Hector v0.1, **an** object-oriented, simple . . ."

- Page 7078, line 11: Consider changing the word "basic" to "fundamental".

- Page 7082, line 19: typo– "-political"

- Page 7083, line 6: typo– "NPP is modified by a the use-specified. . ."

- Page 7083, line 7: Does (or can) beta change with time or temperature? If parameter is fixed, state that explicitly.

- Page 7083, line 14: Do you mean Eqs. (7)-(9)? Correct if this is a typo.

- Page 7083, eqs 7-9: Explicitly define all terms and/or refer to Table 1. Terms do not match those in Table 1 (e.g. F_{LC}).

- Page 7084, lines 10-12: This assumption is essentially a statement of fixed equator-pole temperature gradient. But when the Earth warms, the poles tend to warm more than the equator. This assumption should be discussed explicitly, including under what conditions it would affect the performance of Hector.

- Page 7084, lines 21-23: Carbon cycle description (section 3 up to 3.1) is incomplete. Presumably the model includes the non-linear effects in oceanic carbon uptake from changing ocean acidity as atmospheric carbon is transferred to the upper ocean, but these are not described. The relevant equations should be included here. Some discussion comes later on page 7093, but the pH dependence is not well described.

- Page 7089, line 17: Please be more specific with "other models". Do the authors mean more complex models? Or widely used models? Or both?

- Page 7090, line 8: Spell out "SD".

- Page 7090, line 24: Remove words "a few".

- Page 7090, line 25-26: Consider re-wording sentence.

- Page 7091, line 19: Is Hector actually perfectly correlated here, or is R=1.0 from rounding? Please double check.

- Page 7092, line 23: Grammatical error – "the higher the correlation and low RMSE between CMIP5 and . . .". Presumably what is intended is "the lower the RMSE".

- Page 7093, line 23: Change "see" to "estimate".

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Interactive comment on Geosci. Model Dev. Discuss., 7, 7075, 2014.

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