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Biogeosciences Discussions

Interactive comment on "Projections of ocean acidification over the next three centuries using a simple global climate carbon-cycle model" *by* C. A. Hartin et al.

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Interactive comment on "Projections of ocean acidification over the next three centuries using a simple global climate carbon-cycle model" by C. A. Hartin et al. Anonymous Referee #3 Received and published: 19 February 2016

General comments: The paper presents a fast and, as it seems, relatively competent model tool for future projections. This is excellent, and something I think is needed as complement to the more complex, computationally expensive earth system models. It is however a letdown that this study doesn't actually use the model for anything new, a flaw that reduces its scientific value. The manuscript would greatly improve if the

models capability was used to actually investigate something.

**We could not agree more with the reviewer. This paper lacked any significant investigation. Since then, we have run a series of simplified sensitivity analyses to investigate the sensitivity of Hector's inputs on its outputs, particularly pH and aragonite saturation.

The paper is otherwise interesting, generally well written, and presents a promising concept, but it needs more work.

Specific comments: In the introduction the authors mention the oceans storage capacity for carbon, and its potential decline of anthropogenic CO2 uptake. Since the model seems to calculate these fluxes anyway, why not show how they change over time? Maybe also with some different model-setting (i.e. wind speed, air-sea transfer velocities) and emission scenarios to see get an ensemble and see the sensitivity.

**We think these are all excellent ideas for future studies using Hector. We decided to run a series of model sensitivity experiments to quantify how influential some of Hector's parameter inputs are on its outputs (in particular, pH and âĎęAr). Sensitivity analyses are important to both to document model characteristics, explore model weaknesses, and to check to what degree the model behavior conforms with what we know of the ocean system. We selected eight land and ocean parameters, varying each by $\pm$10%. Wind speed, for example was one of the parameters varied and we find that the high latitude surface pH is sensitive to changes in wind stress. We think this analysis adds significantly to the manuscript.

How realistic is it to keep the total alkalinity constant? I think this should be stated/cited in the manuscript.

**The authors added some more text to clarify this issue. "TA is calculated at the end of spinup and held constant in time, resulting in 2311.0 μmol kg-1 high latitude box and 2435.0 μmol kg-1 for the low latitude box. These values are within the range of open ocean observations, 2250.0 – 2450.0 μmol kg-1 of solution (Key et al., 2004; Fry

et al., 2015). We assume negligible carbonate precipitation/dissolution and assume no alkalinity runoff from the land surface to the open ocean. Most studies hold alkalinity constant with time and this is a reasonable assumption over several thousand years (Lenton, 2000; Zeebe and Wolf-Gladrow, 2001; Glotter et al., 2014; Archer et al., 2009). After thousands of years the dissolution of CaCO3 will restore ocean pH, thereby increasing the uptake of more CO2. On ∼10,000 year scales Hector will underestimate the CO2 uptake, however, we are interested in 100-300 year timeframe."

The authors should really consider creating an appendix describing the model in full, and move some of the tables with model settings (and maybe also some of the equations) there, thus focusing the main manuscript on research questions.

**We have increased our discussion of Hector within the manuscript as well as adding more detail of the model to the Appendix. We hope the reader can now better understand the details and workings of Hector without having to read Hartin et al., 2015 - GMD.

Please specify throughout the manuscript that you with "carbon" mean dissolved inorganic carbon (DIC), as I assume you do. It is unnecessary unclear as of now.

**We have tried to clarify between carbon and DIC within the text.

Line-by-line corrections: Line 10: "series" is probably a typo for "serious". **Corrected.

Line 20: (>55) indicate that the authors mean the high latitudes, not the low? **Corrected. Line 97: Insert "latitude" after "low" to make the text clearer. **Corrected.

Line 101: Repeated info from line 96, please rewrite.

**A large portion of the model description was moved to the Appendix and rewritten.

Line 112: Change to: ". . .simulating a simple thermohaline . . .". I'm guessing you mean thermohaline instead of thermocline? **Yes, thank you for catching this typo. We do mean thermohaline.

Line 155-156 I don't understand what you mean with this; "We assume surface waters are fully equilibrated with the overlying atmosphere. . ." I agree that with that time step, yes, sure, it should be fully equilibrated, disregarding seasonal variations. But if it was equilibrated, shouldn't then the flux be zero and pCO2 in the ocean surface and air be the same? Please correct me if I get this all wrong, or rewrite the text.

**We agree with the reviewer that this sentence was not clear and inaccurate. We have since removed it from the manuscript.

Line 168: Remove the second comma. **Corrected.

Line 242 and 244: The decreases are presented in different units, which makes it impossible to compare the two.

**We corrected the percentages to 0.19 yr-1 and 0.25 yr-1.

Line 286: Total alkalinity should be added to this list.

**This paragraph was broken apart and added to different sections of the manuscript. Constant TA is now addressed within the model description. See general comments for more detail on this.

Line 300-302: I agree! Please add something of this sort to this paper.

**We hope the restructuring and reorganization and add sensitivity analyses helps to highlight Hector's potential in being a critical tool to understand future changes to the marine carbonate system.

Table 5: The table needs to be better organized/presented. Consider dividing into two.

**The table was divided into high and low latitude.

Figure 2: Add units to the y-axis. Redo the colors so that all measurement data is clearly visible, the pink data in particular disappears into the light red fields. Have the data on top the model lines for better visibility. And remove the legend headline, all

these data are not “Model”. Figure 3: Add units to the y-axis. Have the data on top the model lines for better visibility. And remove the legend headline, all these data are not “Model”. Figure 4: Redo the colors so that all measurement data is clearly visible, the pink data in particular disappears into the light red fields. Have the data on top the model lines for better visibility. And remove the legend headline, all these data are not “Model”. Figure 5: Redo the colors so that all measurement data is clearly visible, the pink data in particular disappears into the light red fields. Have the data on top the model lines for better visibility. And remove the legend headline, all these data are not “Model”. Figure 6: Redo the colors so that all measurement data is clearly visible, the pink data in particular disappears into the light red fields. Have the data on top the model lines for better visibility. And remove the legend headline, all these data are not “Model”. Figure 7: Increase size of legend and preferably also the size of the markers.

**All figures have been updated, removed legend, increased font size, more descriptive terminology, and fixed the color scheme. Also, Figure 7 was removed the manuscript as it didn’t add anything substantial to the study.

Interactive comment on Biogeosciences Discuss., 12, 19269, 2015.