Moinat et al. – biogeodyn-MITgcmIS (v1): a biogeodynamical tool for exploratory climate modelling.

Summary

Moinat and colleagues present the "biogeodyn-MITgcmIS", a global climate system model that is designed to encompass relatively low computational costs and yet couple extended components of the earth system – ocean, atmosphere, land surface, sea-ice, and ice-sheets. They do so by coarsening the grid of the MITgcm and, in regards to the land surface vegetation and ice-sheet models, by performing offline equilibration runs using the outputs of the MITgcm. This asynchronous running minimises computation costs that would otherwise be required in multimillennial simulations. Their procedure is to run the MITgcm, followed by offline runs of the ice-sheet model, water shed runoff model and vegetation model in that order.

The authors run two experiments: pre-industrial and a modern day simulations. They compare the preindustrial run to two CMIP6 models and they compare their modern day run against a suite of observational products. The model shows broad agreement against these datasets in this assessment.

The work is presented in a clear manner and the figures and writing are of good quality. The authors do not over-reach and the paper is appropriate for the journal.

My only major comment is that the authors talk about climate tipping points in the introduction and conclusion, and yet, the authors and the experiments they have performed have not convinced me that this model is indeed able to simulate a climate tipping point where the system rapidly shifts to a new attractor. I challenge the authors to provide such an experiment and talk to this within a new section of their results. Given the low computational costs of their model, the authors could achieve this by performing a 4x CO2 experiment, for instance, both with and without their ice-sheet model and then assessing the impact of including that model on the system. Or perhaps the authors have better ideas about this sort of feedback response could be achieved?

Minor comments:

Line 33: "are fast reaching a stationary state" → "can reach a stationary state rapidly"

Line 44: "such as **the** deep ocean"

Line 47: "However, high computational costs makes these models appropriate for"

Line 59: I think it's best to remove all future tenses from the paper. Please make your writing either present tense or past tense.

Line 85: "to capture mixing by mesoscale…"

Line 101: "will be" → "is"

Lines 100 – 106: Are all these features done automatically by the model or do you have to do these manually?

Line 114: Define what a PFT is. Also, make sure to correct your acronyms to "PFT", not "PTF".

Line 133: How is this different to your new model? Do you use these models together in the same runs?

Line 135: Can you spell out SMB instead of adding a new acronym? You already have a lot of acronyms.

Line 169: It's interesting to me that you assign "a" as constant when making it vary with temperature or something else would actually provide your model with the kind of feedback that would create non-linear tipping points in the system.

Line 217: What is w_{ss}. Please define.

Line 267: How many models actually do this amongst the CMIP6 contingent?

Line 284: "corrections"

Line 292: "and giving a new runoff map as output".

Fig 1: Can you add numerals "1" and "5" to your steps in this figure? You have "2", "3" and "4".

Line 316: "This map was…"

Table 2: Please make the caption more informative. Tell me what all variable are.

Line 372: "… reproduce Hadley cells (Figure 4). In run2 our…"

Line 390: "model captures…" rather than "module captures…"?

Line 398: Why don't you include this energy in your calculations? Shouldn't' you? Would it be too difficult?

Line 416: Your ocean under modern day is incredibly fresh, and I am shocked that the ORA is that fresh. It can't be. Can you please recheck your calculations of ORA. It should be around 34.5 psu.

Line 432: Please include a citation or citations for your statement that the behaviour is expected.

Line 446: Please include a citation or citations for your statement that the behaviour is expected.

Line 446: Why is this linked to excess precipitation in SPEEDY? Seems the opposite of what I'd expect.

Line 462: Your correlations are not close to one. Please be more honest about this.

Figure 10: Can you provide a new column of differences? The differences in Antarctica are hard to see.

Line 493: Are these runs done with an IS model at equilibrium? If so, surely the response at 360 ppm of an IS model at equilibrium would be a good reason for the simulated flux of freshwater and ice sheet loss to be much greater than the observations? Please explain and make clearer here what was done.

Final paragraph before conclusions: I find it really interesting and actually a bit disappointing that you don't' showcase how the model could simulate a climate tipping point to a new regime. This hasn't been shown even though you talk about it in the introduction.

Line 535: "agree broadly with…"