Review of **Earth system modelling with complex dynamic human societies: thecopan:CORE World-Earth modeling framework by Donges and Heitzig et al. (2018)**

The authors present a modelling framework for a new generation of Earth System Models that they term World Earth Models (WEM). The paper presents their theoretical framework for capturing environmental, cultural and what they term, social metabolism processes in a linked model. They then provide details of the software package copan:CORE, which builds on their theoretical framework and is implemented in Python language.

It is this reviewers opinion a new generation of Earth System Models is urgently needed to capture complex dynamics between humans and the environment and this paper is an important first step in attempting to implement a modelling framework for a WEM. However, I would like to see more argumentation for the development of the theoretical framework they set out as well as clearer description of the model implementation, with consistency between the description of the theoretical framework and the model implementation framework. In addition, I suggest some structural changes to the paper.

Paper Structure

I think the paper could benefit from a slight restructuring for sections 1-3. The introduction introduces many terms without explanation or explanation comes in section 2 and 3. One important example of this is the term social-metabolism. This is later defined along with the other theoretical framings of the Earth System: environment and culture. You should introduce this framing earlier.

So, I would recommend starting with a shorter introduction with section 1.1 outlining the current state of modelling earth system processes, the shortcomings of these approaches and the motivation for a new framework. Then section 1.2 outline briefly, and in a language that users can follow (so if you introduce a new term such as social-metabolism, explain it), your theoretical framework, what problems it addresses and how it is implemented. Then in section 2 outline the theoretical framework in more detail. Crucial here is to motivate your reasoning behind the choices you make. This is not always clear in the discussion manuscript (Theoretical reasoning behind framework).

Then section 3 outline how the model is implemented. It should be very clear how the theoretical framework links with the implementation framework. This is not currently clear to me yet. Figure 2 is helpful, but I would like to see then how that relates to model framework structure: i.e. a figure like figure 4 but then capturing what is shown in figure 2. Importantly, if you keep more consistency between the theoretical framework structure and the implementation structure, then readers and users will be more easily able to follow what you have done.

Theoretical reasoning behind framework

Page 4 Line 10: The planetary boundaries concept has come in for some criticism lately (Montoya et al. 2018). A model framework such as this can potentially explain how planetary boundaries emerge through cross-scale human-environment interactions. It would be good to explain shortly how such a model framework could illuminate how we can understand how global planetary boundaries link across scales, keeping in mind the criticisms of the concept.

Page 4 Line 25 “environmental and societal processes should be described on similar levels of complexity” – sounds good but why? And what does that mean in reality? A tree and a person is equivalent? A country and an ecosystem equivalent? If so, what is the theoretical grounds for that?

Page 4 line 30-33, page 5 line 0-5 This seems all reasonable but why? And what is your grounding for these statements? In addition, there is a large body of work on applying agent-based models in the socio-cultural domain, which seems to have been ignored here. If you want to capture that, then you should demonstrate that you are aware of this literature and have considered it, including the many pitfalls of applying agent-based models to social systems. Also relates to the statement on Page 6, Line 13-15. There has been extensive work on formal modelling of socio-cultural processes. See Netlogo References for example: https://ccl.northwestern.edu/netlogo/references.shtml

Page 5 line 9-10 Outline why it is important to capture tipping points. This should also be covered in the intro when discussing shortcomings of existing models.

Coupling or not?

It is not clear to me whether the copan:CORE framework is designed to couple to other models such as LPJ-Guess and IAMs that you mention or if it is a standalone model with different modules or both? I.e. can external models can be modules within the copan:CORE framework? I would encourage you to outline this in more detail and with more prominence in the paper as a lot of the community are interested in a framework for coupling existing models that can incorporate the kind of dynamics you set out to include.

Model description

Generally, I find the model description too vague to know what can and can't be done with it. For instance, it is mentioned you can model resources flows and migration with it. How would this be implemented? Perhaps a few simple examples of specific model frameworks would help the reader understand what copan:CORE can and cant do. E.g. explain how would you use the framework to capture the relation between migration and drought or how tragedy of the commons scenarios emerges within a river catchment?

Specific Comments

Page 1 line 1 – 3. This is quite a vague opening sentence. I would drop it. Start with: we introduce….(the abstract is already quite long)

Page 1 line 5: Not clear what is meant by user roles. Can you be more explicit, especially since this is the abstract.

Page 1 Line 14: I wouldn't include social metabolism in the abstract. Not a widely know term.

Page 3 line 30-35 Is this an agent-based model? From the abstract and introduction, I thought it was more than that. However, this concluding paragraph makes the reader think that you are going to introduce an ABM. If you view it as an ABM, fine. But then state that clearly in the abstract.

Page 5 line 8 what is time forward integration?

Page 7 Figure 2. While I like this figure, it could be clearer. It's not clear to me how each of the elements relate. Is each level of the network equivalent to Cul, Met and Env and are they then equivalent to the network on the right? It could be simpler to just show the central image (entity types) in one figure in the new intro section 1.2, for example. I like the way you show the different modelling approaches but it isn't clear with the network image how they relate or how cul,met, env relate.

Section 3.1 is very clear.

Page 10 line 4-5 delete "maybe changing numbers and"

Page 10 line 12 instead of following entity types, write entity types outlined in Section 3.2

Page 10 line 20: Give an example, such as countries to clarify

Page 11 line 4: human-designed, human-reproduced

Page 12 Line 6 – 30 Introduce this earlier in the manuscript. See my comments on structure

Page 16 Line 4: Examplary is not a word. It appears to be an obsolete form of exemplary which means "perfect".

A couple of important references "in prep". Try to find pre-existing publications to support arguments in addition to these where possible.

Page 22: Figure nested within references

References

Montoya, J.M., Donohue, I., Pimm, S.L., 2018. Planetary Boundaries for Biodiversity: Implausible Science, Pernicious Policies. Trends in Ecology & Evolution 33, 71–73. https://doi.org/10.1016/j.tree.2017.10.004