

Overview of the revisions

We greatly appreciate the positive comments and constructive feedback of the two anonymous reviewers. We have updated the manuscript accordingly and hope to have accommodated all the questions raised. Next to addressing the more specific comments, we have reworded the abstract, making it more precise, and strengthen the link to the title of the paper in the introduction, the discussion and the concluding section. Below, we indicate more specifically how we addressed the specific comments by the two reviewers, by quoting the referees comment, indicating our response and the proposed changes.

REVIEWER 1:

GENERAL COMMENTS

In this article, the authors address the state-of-the-art regarding the use of models to answer questions related to the planetary boundaries. They create a typology of "key questions" related to the planetary boundaries (though they say the typology can also be used more generally). They use this typology to explore how different type of models currently are being used to answer these questions.

This is a very useful and timely paper. The literature cited will be very useful to anyone attempting to model planetary boundaries. The typology also makes a lot of sense.

Thank you for your positive comments.

General comments for improving the paper:

- Title: "Horses for courses" – the metaphor is that you should use the correct model (horse) for the research problem (racecourse). This point does not come out clearly enough in the paper. First of all, it would be friendly especially for non-native English speaking audiences, to spell out this metaphor somewhere. And then, as per the following points.

Thank you. We indeed did not spell out the title in the article. This is now added.

- Introduction: The background to the PBs is discussed comprehensively, but models are hardly discussed at all. (OK so the third paragraph is about disciplines, which are loosely connected to the models they use, but still this would be clearer if models were motivated here.) As a result section 2 is a little hard to follow as it's only in section 3 the reader gets to the discussion of the models which are, as I understand it, the main point of the paper. Can you motivate in the introduction a bit where the state of modelling is at and what you want to achieve with this paper? What is the problem or gap this paper will help people address?

Again, this is a very useful comment. There is clearly a wealth of tools that can be used to answer the questions identified in Section 2. In Section 3, however, our attempt is to further develop the research agenda in terms of identifying the use of different key tools and the need to integrate these, or instead, establish other forms of cooperation. In the discussion, we decided to focus on a specific set of tools, i.e. models. We have now introduced that much better in the introduction.

- Discussion: Most of the discussion is little more than a summary of the previous two sections. I would like to see more synthesis, or at least comparison (e.g. which models

are most useful for which Types? What are the big gaps?) This is another opportunity to connect back to “horses for courses”.

The relationship between question types and models is actually addressed in Section 3, while in Section 4 we provide examples focused on specific planetary boundaries.. In the final Section, we deliberately derive more abstract conclusions, but we now start the conclusion section with a more clear formulation that relates directly to the horses for courses and the questions raised in the introduction.

SPECIFIC COMMENTS

- p1713 line 23. The SDGs obviously have been accepted by now.

Text was changed.

- P1718 line 16. A reference or further explanation for the effect on deforestation on water availability would be nice.

Text and a reference have been added.

- The title of section 2 involves ‘a systems view’. It is not clear to me how the typology constitutes a ‘systems view’. It is useful but not particularly systems.

We think the problem here is that the word “systems view” means different things to different people. We have reformulated the title to be more specific on the contents and avoid the broad “system” wording.

- Why the “dose-response” terminology? I think it’s confusing, especially when on p1718 you start acknowledging that the earth system is actually an interlinked social ecological system.

The word “dose-response” is an attempt to clearly define the essence of the type 2 questions, i.e. identifying the relationships between impacts, drivers of change and acceptable levels. The term can actually be interpreted rather broadly. We have slightly changed our formulation but find the metaphor still useful.

- First sentence on p1719 (“The question whether: : :”): True, but I don’t see how this connects to the rest of the paragraph

We have reworded the text.

- P1724 line 16 “A key question is”: : : Yes this indeed is a key question, please don’t just leave it hanging, try to answer it!

We have now added text indicating why it is very hard to identify tipping points in a meaningful way in model studies (given all complexities).

- P1725 line 3 “Other IAMs” – which ones? Please reference!

We have added references.

- Table 2: “Process-oriented”. What is this? It is not defined in the main text. The “alternative approaches” at the top of p1726 are not analysed at all. Should they be in the table? Social-ecological models are one of the key frontiers, is this not what the authors are saying? So shouldn’t they be in the table? And which Types of questions are they best suited to answer?

The two terms refer to the same category. Unfortunately slightly different wording was used in the text and table. That is solved now. Still, this is by definition a very large group of models. We wanted to mention them in the text, but it is challenging to represent such a diverse “group” (other) in the Table and thus only represented a subset.

REVIEWER 2:

The paper is rather different from the majority of the climatological papers I have reviewed, as it takes a high-level view on modelling and climatology. I appreciate that such philosophical attempts are necessary, although the first take on reading the abstract caused me to ask myself very many questions. I presume I could be considered as a guinea pig of general readership, especially of those who are not familiar with planetary boundaries (which may be the case of many researchers).

In my opinion, the abstract should be re-written to avoid constructions like "research on developing a set of sustainable development objectives", or expressions like "different exposure levels" (to what?), "key indicators" (of what?), "available options to implement changes" (to what?), "different response strategies" (of what?), "four categories of questions" (without explanation) etc. The abstract is difficult to read, indeed. It sounds like slang policymaking in a specialised area of climate change.

Thank you for your comments. We have reworded the abstract to make it more precise.

The caption of table 1 sounds similarly vague. “Summary of key questions and indications of relevant characteristics of analytical tools” – can’t it be formulated more specific? The structure of the table looks unusual, too: I would rather expect its rows to be column and vice versa.

The title has been made more specific. Regarding the column and rows we think that the current set-up is the most practical, both in relation to content and to ensure that it can be easily printed on one page.

In page 1716, the authors discuss tipping points under the division of Type 1 questions (biophysical system dynamics) – in my opinion, this is a more general topic, which can be placed in the Introduction.

In Section 2, we are identifying key research questions regarding planetary boundaries. In our view the further identification of tipping points forms a key part of the research on type 1 questions, and therefore, it should be discussed under the division of Type 1 questions.

In page 1727, item 3, when talking about “full detail” of modelling, it is better to say “full possible detail”, as truly full detail is rather impossible.

We have changed the text as suggested.

In general, the paper is an interesting read, although for me it is difficult to estimate its novelty.

Thank you.

3) Author's changes in manuscript

A revised version of the manuscript with everything indicated in track changes has been included.