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Interactive comment on "MIROC-INTEG1: A global bio-geochemical land surface model with human water management, crop growth, and land-use change" *by* Tokuta Yokohata et al.

Anonymous Referee #2

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Review of gmd-2019-184: MIROC-INTEG1: A global bio-geochemical land surface model with human water management, crop growth, and land-use change

Summary

The authors present a new land model that includes the effects of climate on land allocation by constraining irrigation due to water availability and by calculating yield based on current climate. The primary novelty here is that the land allocation scheme has been included in the land component of an earth system model. This enables land allocation to be determined by the changing state of the earth system in conjunction with estimates of demand for food and other land-based commodities. The

model reproduces historical conditions well, and future projections show reasonable results. Future goals include full coupling with the atmosphere and ocean components to incorporate additional human-earth system feedbacks.

Overall impression

This is a big step toward full human-earth system coupling, with a couple of novel developments including the impacts of water scarcity on land allocation and the inclusion of land allocation in the land model. My main concern is that these developments presented in this paper are not highlighted as providing new information. The examples do not show the benefits of these developments over not having them, and as such their value is not made clear. The paper can be strengthened by some reframing that brings these novel improvements to forefront, along with more critical examination of their strengths and weaknesses. I recommend some considerable revisions, and please see the detailed comments that follow.

1) There are two novel developments here: water availability effects on irrigation/land allocation, and the inclusion of land allocation in the land model. They each have unique contributions that should be highlighted. The inclusion of land allocation in the land model is unique and enables direct response of land use to changing conditions, including both the climate and the water availability as determined through the hydrological model. While there is not yet feedback with the atmosphere, the response of growth/yield to climate is more detailed than is otherwise considered in IAMs and some other land use models, and is also directly embedded in the full land model, which is a feat in itself. The water/irrigation linkage to land allocation is even more novel, as there have been only regional studies on this with loose coupling, I know of only one IAM that has just finally made this work but without connections to a full land model. The uniqueness of this new system should be more clearly defined such that your examples show the benefits of these developments.

2) Provide examples that show the benefits of your novel developments. This will

require additional simulations that shut off water scarcity effects on potential irrigation and alternatively shut off the climate effects on yield. As it is, your examples just show outputs that can be generated by a variety of other models. You want to highlight the value added of your developments.

3) Discuss how these developments relate to existing alternatives and what the limitations are. For example, IAMs and other land models can project land use/cover under changing climate and feed this information to a land model. Why not just do this in AIM and feed it to MIROC? What do you gain and lose with TeLMO inside MIROC? How is TeLMO different from AIM and when do you expect one to be more robust than the other? The same questions could be asked with respect to water.

4) One concern I have about the model itself is the inconsistency between the crop model for growth/yield and the biogeochemical/biophysical model for cropland. You may not be able to fix this right now, but it is a problem that there are two different crop growth models to represent different processes of the same land area. In particular, your yield model does not have explicit fertilizer, but your VISIT model does. For a variety of reasons, the growth values will not be the same between the two representations, but they should be because the growth determines the geochemical and physical characteristics of the cropland. In the end your yields are not consistent with how cropland affects the geochemical and physical processes in the land model that will eventually feedback to the atmosphere. This should be fixed before full coupling with the atmosphere.

5) Some of the description is not very clear or complete for the reader to understand what has been done or how the components interact. See comments below for details on what needs clarification. In particular, it isn't clear how the non-cropland is affected by climate in this model.

Specific comments and suggestions

Abstract

The abstract is not clear about what is presented here or what the outcomes of evaluation are. While some interactions from climate to land allocation are included, feedbacks between the land system and climate are not because the atmospheric inputs are fixed. Be clear about the novelty here, and state how well the evaluation performs.

Introduction

page 2, line 21: Bond-Lamberty this reference is incorrect throughout

Model structure

Sub models

It seems that there are two crop models: PRYSBI2 and also one in HiGWMAT Please clarify how these are different and why they are separate.

VISIT

page 8, lines 12-13: abandoned cropland recovers to mean biomass of what? and is always considered secondary, or can secondary land revert to primary?

page 8, lines 14-16: these fertilizer and crop calendar inputs seem inconsistent with the crop model. if the crop model doesn't use fertilizer inputs, then how are they used in VISIT? if crop growth is calculated with implicit fertilizer, then this specific nitrogen input doesn't match. And why would VISIT be using a crop calendar and not the crop model? your biogeochemical fluxes are not going to correspond with your crop growth.

Model coupling

Experimental settings

page 11, lines 3-19: which SSPs for which RCPs?

Historical simulations

page 13, lines 1-3:

The results in figure 5 do not all line up along the 1:1 line. You have to adjust this statement.

page 14, lines 1-2: TeLMO crop area is not very similar to AIM, and it is more similar to FAO in most cases presented. Since AIM is a driver of TeLMO, more explanation is required here of why they are different. Furthermore, the similarity to FAO is more compelling as evidence for usability of TeLMO, than any similarity to AIM.

Future simulations

page 15, line 8: why the maximum value? this would underestimate the land area because each crop may be grown in a cell, with varying yields.

page 15, lines 19-21: what is the basis for your bioenergy crop calculations here?

page 16, lines 23-24: Not sure what you mean here. You haven't untangled land use effects here, just showed results of land area changes and the biomass affected. Many ecosystem and earth and integrated assessment models do this. what is unique here? If you were to show how the land allocation and the biomass effects differed due to the climate effects on yields, then this would show the benefit of this model. To do this you have to do another set of runs where the yields are the base year yields plus the non-climate changes in yield, and compare these to the runs you have done. Alternatively, you could show how the inclusion of water availability in determining irrigation changes the crop area/production by turning off the irrigation dependence on the available water.

Implications

page 16, lines 30-31: this is where things get more interesting

page 17, lines 6-8: it seems like you have outputs in this paper that could be used for this

Figures and tables

Figure 3 What do you mean by multi-model mean? You are using only one model here.

Figure 10 What is the vertical axis? Is it the annual change in cropland area as a fraction of total land area, or is it the cropland in that year as a fraction of total land area?

Appendix A

page 17, line 28: what are these? can you give the types of data if not able to list them all here?

page 19, line 3: i think you mean water stress and shouldn't this go into section A.5?

page 19, line 11: so there is a cold stress factor applied on top of the temperature dependent equation?

page 20, lines 7-16: it isn't clear what this is or how it is applied. is it a fraction that is applied to a given yield and then added to that yield? what are equations 32 and 33?

Appendix B

page 22, lines 7-11: it isn't clear why you are using the max yield, and it sounds like it is per crop here, while in the text it sounded like it was the max across crops. don't you need to apply each crop yield to its own prices in the 30sec cells to get distinct ASI values for crops? maybe a crop with a lower yield has higher ASI due to higher price. so are you essentially just selecting one crop for the half-degree cell? this will underestimate cropland.

page 25, lines 20-21: for bionenergy crops, does this mean that these are fixed values, or are they dependent on the atmospheric inputs? More info is needed here.

page 26, lines 8-24: Is this NPP for pasture calculated beforehand, offline? Does it include matching climate drivers to the scenarios here? Or are these NPP numbers independent of the climate change?

page 27, line 10: where is the base-year managed forest area from?

page 27, lines 14-19: also for forest, are these NPP values calculated beforehand, offline? and are there matching values corresponding with the scenarios here, or are they a single set of values for all sims?

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