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Geoscientific Model Development Discussions

Interactive comment on "Coupling earth system and integrated assessment models: the problem of steady state" *by* B. Bond-Lamberty et al.

Anonymous Referee #2

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In this paper, Bond-Lamberty and colleagues describe the methodological steps they have followed to incorporate aspects of the carbon-cycle of the community land model (CLM) into a specific socio-economic integrated assessment model (GCAM). By means of single-forcing experiments, potential proxy variables that could be fed into GCAM were assessed, including soil organic matter, net primary production (NPP), and heterotrophic respiration (HR). They find that NPP and HR are the "most robust proxy variables" to feed into GCAM, although it is unclear to me how precisely they have made this assessment.

The main issue with this paper is that the core objective of the paper, explaining the coupling of CLM with GCAM, remains extremely opaque and hard to understand. As the paper stands now, it is impossible for the reader to understand and reproduce the

basic dynamics that govern the interactions between CLM and GCAM, or to understand/assess why specific modelling choices were made.

Major points:

a. The title does not reflect the content: While the paper describes a small step in the coupling of the land component of the CLM model with the GCAM model, the title makes the reader believe something much larger: a full integration. Only one specific step in the CLM-GCAM coupling is described in detail in the manuscript. It would therefore be appropriate that the title reflects this content.

Also it is unclear to me after reading the paper what the "problem" with steady state actually is, except for the fact that one needs to take into account that GCAM uses assumptions of long term ecosystem steady-state carbon to guide its economic decisions.

b. The abstract is unclear and does not reflect what is presented in the paper. For instance, the abstract states that "By allowing climate effects from a full earth system model to dynamically modulate the economic and policy decisions of an integrated assessment model, this work provides a foundation for linking these models. . .". As indicated above, the coupling is very limited and thus therefore not correspond to what was written above.

c. The methodology is unclear, as the basic mechanics of how carbon pools are taken into account in the GCAM iterations are not explained in detail. Although often referred to, the reader has no chance to understand and reproduce these mechanics. A clear, structured introduction to the carbon mechanics within the GCAM model is required, as well as a clear overview of the possible land-use changes that can be imposed by GCAM (forest harvest, deforestation and transformation into crop land, crop change, etc.).

d. A clearer discussion of the modelling/design choices is required. For example,

stating that some proxies are considered "better" or "best" only makes sense after comparing them for clear predefined criteria.

Minor/technical/editorial points: (P = page, l = line/s)

Abstract P1500, l2-4: Quite strange wording which seems incorrect. Human activities do not pose a problem to ESMs as such. Many CMIP5 models were able to run the RCPs, which represent a set of widely varying societal forcing outcomes (in terms of well-mixed greenhouse gases, land-use patterns, and also - to a lesser degree - aerosols). Other variations are possible, but these would also not necessary pose fundamental modelling problems to ESMs. If at all, human activities pose a problem to the ESM modelers and users, rather than to the model itself. The “significant problem” lies at the integrated assessment modelling (IAMs) side. Scenarios are being developed based on simplified representations of the physical and chemical environment and at this point are not equipped yet to handle more complex earth system information. Changing biogeochemical cycles due to human activities is thus mainly a fundamental modelling problem for IAMs than for ESMs.

P1500, l15-18: It is unclear to me why LUC effects need to be short-term. To me this seems to be strongly scenario dependent and can thus not be ruled out from the beginning, particularly not with the limited amount of testing available in this manuscript.

P1500, l18-21: As indicated in major point b (see earlier), this sentence does not reflect what is achieved in this paper.

Main manuscript

P1501, l6: Suggestion: also include a reference to a paper that presents RCPs or their CMIP5 outcomes results.

P1501, l8-15: As my earlier comment on the first sentence of the abstract. This problem seems to rather affect the IAM side of this coupling, as currently IAMs generate scenarios that have potentially inconsistent evolutions of society and their environment.

For the ESM, there is no problem to run alternative scenarios in which the environment is disturbed under varying policy assumptions, and the RCP experiments (and many other papers) are an illustration of this fact.

P1501, l19-20: This is an interesting point. While the spatial resolution argument is obviously correct when looking at simple climate models, it is unclear if the authors mean “process fidelity” or “process resolution” (or if they are used here as synonyms). Given that these aspects are provided here as limitations of current approaches, it would be necessary to include a discussion of how the “process fidelity” of the proxy choices and approximations described in this paper compares to incorporating emulations of the ESM instead.

P1502, l8-10: The manuscript does not present a study that develops and tests a coupling of GCAM to CESM’s climate and biogeochemical cycles. As far as I understand, the coupling is far more modest: land carbon pool projection changes from the CLM model are fed into GCAM. This manuscript does not describe how GCAM would adjust crop choices to changing climatic conditions in terms of temperature, precipitation and soil moisture.

P1503-1504, model description: please include a traceable technical description of how changes in carbon pools affect the behaviour of GCAM, either in the main text or in supplementary information.

P1504, l10-12: GCAM simulates carbon emissions and sequestration from changes in land use between modelling simulation periods (P1503, l19). As emissions constraints are part of the possible policy scenarios that can be run with GCAM, I don’t understand why LUC effects simulated by CLM, should not affect GCAM’s decision-making. The few explanatory sentences following these lines do not necessary help a lot. Does GCAM decide when forests are harvested, or does GCAM decide that a forest is replaced by crop land? In the former case regrowth would cancel out the initial emissions over time, and thus doesn’t pose a problem if it were correctly taken into account by

GCAM. In the latter case, the effects are long-term and should thus affect GCAM's decision-making. If this is a design-choice in order to keep the CLM-GCAM coupling rather loose, this has to be clearly described. If this is a result of the analysis described in this manuscript, this should come up in the conclusions and not in this section.

P1504, l21-22: Without a clear description of the mechanics of the GCAM decision-making processes this is not obvious at all.

P1505, l1: Maybe "applicability" or "appropriateness" instead of "feasibility"?

P1505, l9-and following: Is there a particular reason why one doesn't start from a normal pre-industrial control run and then adds variations to them?

P1505, l22-26: The end-of-century climate of RCP4.5 is much less perturbed than the RCP8.5 climate. What does this imply of the extendibility of this approach for high-forcing scenarios.

P1506, l19-22: This would be better placed in the model description section.

P1506, l24: Define "environmental changes".

P1507, l23: CLM's ("s" lower case)

P1509, l16-17: This statement makes me wonder whether filtering CLM output in order for it to fit GCAM's expectations instead of improving GCAM in order to deal with ESM's noisy carbon pool data is really the best modelling way to go. This design choice, its strengths and weaknesses, need discussion in the manuscript.

P1510, l20: It is unclear which criterion has been used to define "best" here, based on the results discussed in the previous sections. When looking at Figure 2, it is not necessarily clear why one proxy is deemed better than others. This needs some clarification and discussion.

P1511, l7-8: This sentence can serve as a basis for a new title, as it describes more precisely what was done.

P1511, l9-12: The presented analysis did not clearly include a comparison/discussion of the robustness of the various proxies. I find this conclusion currently thus not supported by the provided information.

P1511, l17-24: These two sentences appear rather repetitive to me.

P1514, l14-16: The IPCC SAR was published in 1995, not in 2001. In case this is supposed to be IPCC TAR (published in 2001), page 20 contains part of the table of contents, and it is thus unclear to me what the page number is referring to. Page 20 of SAR contains the technical summary on tropospheric and stratospheric aerosols. Please provide a correct reference and a correct page range.

P1521, Figure 2: Define all acronyms and use the same acronyms in caption and legend/labels. Please use same acronyms and scenario codes in the figure and text.

P1522, Figure 3: Please use colors or make differences visible in some other way.

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