

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

Anonymous Referee #1

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Authors couple the CESM1 Earth system model (ESM) with the GCAM integrated assessment model (IAM). They design a methodology in which the net primary production and heterotrophic respiration outputs from the land carbon cycle component (CLM) of the CESM1 model are used to adjust the long-term steady-state carbon pools in the GCAM model. The topic is broadly of interest to both the earth system modeling community and the integrated assessment modeling community. However, in its current form the manuscript is extremely difficult to follow and as a reader I am unclear about several aspects of the coupling. Indeed, coupling of an ESM and an IAM is a difficult task given that the two models are extremely different and have been developed over time by entirely different communities.

My major comments are that

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1. I am unable to understand the basic premise of how the coupling works since the GCAM model hasn't been introduced properly.
2. There are terms in the paper that probably both the ESM and the IAM communities are unfamiliar with.
3. The basic concept of the long-term pools changes hasn't been explained properly and is unclear.
4. It is also unclear what the final iESM simulation was. Was this a 2006-2100 RCP 4.5 simulation?
5. CESM1 is not just CLM. It seems that the authors forgot about other components of the Earth system model. Is the CLM the only place in the CESM1 where it is coupled to the GCAM. What about the simulated climate in the CESM1? Doesn't it affect the behavior of the GCAM IAM.
6. It is also unclear how is this a problem of steady-state as the title of the manuscript suggests. My impression after reading the title was that the manuscript must somehow deal with the drift in GCAM when it is coupled to CESM1, similar to the problem of coupling ocean and atmospheric components about 10 years ago when flux adjustment was needed.
7. In fact, if the CRUNCEP data is being used to drive the CLM model then how is this even a coupling of the CESM1 and GCAM models. In this case, it's not the ESM and IAM that are being coupled. It is coupling of CLM and GCAM models, driven offline with CRUNCEP data or climate from the CESM1 RCP 4.5 simulation. At least, that's the impression I got as a reader after reading page 1505.

Other comments

Abstract. The opening sentence of the abstract seems a bit difficult to follow. In addition, it reads like as if a modeller is complaining – “Human activities are . . . posing a significant problem for ESMs . . .”

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Abstract. Lines 3-4. "... which may incorporate static land-use change inputs ...". The term "static land-use change inputs" doesn't mean anything to me even as an ESM person. Maybe the authors actually mean "static land cover".

Abstract. Line 10. Land use driven flux changes of what quantity?

Page 1501

Line 5. The following sentence is not exactly true.

As a result, different policy choices vis-à-vis LUC and carbon are projected to result in greatly different configurations of the future carbon cycle and climate system.

If anything, the Brovkin et al. (2013) paper shows that the future land use change emissions and any effect on climate is much smaller compared to what the effect of historical land use change has been. Houghton estimates that historical LUC emissions are around 150 ± 75 Pg C. Figure 7b in Brovkin et al. (2013) shows that the effect of LUC in RCP 2.6 and 8.5 scenarios is around 10-50 Pg C, if the outlying large values from the MPI model are neglected. And, we know MPI generates such large LUC emissions because of its large initial pool sizes.

Lines 8-13. The sentence ...

"Such models may incorporate static LUC inputs, but do not actively, or interactively, simulate policy options or economic forces, except for example in simple (in a policy sense) "thought experiments"

... is unclear and confusing. Again static LUC inputs doesn't mean anything. Do the authors mean static land cover?

Page 1502

After the introductory section, the authors delve straight into the details of the CLM model without telling the user what purpose does CLM serves in the CESM1 model. A simple sentence telling that CLM simulates land-atmosphere fluxes of energy, water

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and CO₂ would have been very helpful. Just throwing off big terms - carbon and nitrogen dynamics, biogeophysics, biogeochemistry etc. isn't very helpful here. The model needs to be described in a much better way. Also note that, CLM doesn't do the hydrologic cycle. It models the surface hydrological process. Hydrologic cycle is modeled by the full Earth system model.

The following sentence ...

The model's C and N cycles are closely coupled and include assimilation, plant growth and mortality, allocation, and subsurface cycling.

... is another example of a poorly written sentence. Assimilation of what? Mortality of what? Allocation of what? Sub-surface cycling of what?

Page 1503

Line 5. "... is a dynamic recursive economic model ...". Just like carbon and nitrogen dynamics mean nothing to an economic modeler, the term "dynamic recursive economic model" means nothing to me as an ESM person. The paper needs to serve both communities and this means some extra effort needs to be put to make it palatable to both.

Line 13. What does "optional policy scenarios" mean?

Lines 21-25. The IAMs focus on land use change, while what is actually needed by ESMs is land cover. ESMs need to know what kind of PFT grows (or can grow) in a grid cell. The intermediate step of going from GCAM's land use change decisions to a land cover product that CLM can use is an important coupling step. Yet, this hasn't been explained properly and the reader is pointed to two references. In my opinion, this important coupling step must be explained properly in the manuscript.

Line 30. "... the former tracks real-time ...". What authors mean here is probably "time-varying" and not "real-time".

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Line 10. “real-time” on this line and elsewhere probably also means “time varying”.

I am a bit confused after reading Section 2.3 (lines 21-28). In principle, it is straightforward to derive long-term steady-state pools by using the fluxes. For example, if an average turnover time of carbon (k) in the vegetation pool (C) can be calculated, for a given grid cell, then

$$dC/dt = NPP - kC$$

where NPP is the net primary productivity. Given the changes in NPP or the new NPP value it is possible to determine what the steady-state value of C will be, i.e. when $dC/dt = 0$.

The solution is, of course,

$$C = NPP/k$$

An introduction to a simple equation like this and somehow relating this to what GCAM needs will likely help to understand how the coupling is being performed.

Page 1505.

Line 1. Authors say “We tested the feasibility of these proxies in two ways”. What does “these” refer to in this sentence. Is it the vegetation, litter and soil carbon pools? Again, it would have been helpful to introduce the basic equations that describe the terrestrial carbon balance in the CLM and GCAM models, so that the linkages between the two can be easily explained by the authors.

I am also unclear why the primary terrestrial carbon cycle fluxes and pools are described as proxy variables.

Line 14. Please start a new paragraph when start discussing the CRUNCEP data.

The way the simulations S1 through S6 are described it seems CESM1 was never run

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coupled to GCAM and all the simulations are offline in which CLM is driven with either CRUNCEP data or data from CESM1’s RCP 4.5 simulations.

Lines 17-18. “. . . and land use boundary conditions constant at their 1850 values.” Again, probably what is meant is land cover was kept constant corresponding to year 1850.

Page 1506

Lines 1-9. I am unable to grasp the basic concept here. For example, I am unsure why the following is necessary. - “We examined the degree to which (i) NPP in the first 5 years of simulation S5 predicted total vegetation carbon in the final 5 years . . .”.

In absence of equations relating the output from the CLM model to the needs of the GCAM model, I am unable to understand this. It is also possible that, as an ESM person I am unable to follow the simple world of GCAM in which only equilibrium values of the pools matter. If this is the case, then the GCAM’s philosophy needs to be explained properly.

Line 10 reads – “The overall control run—our base reference simulation—was based on the RCP4.5 stabilization pathway . . .”. Yet, on page 1505 simulation S1 was introduced as the control simulation driven with CRUNCEP data for period 1901-1920 used repeatedly. Are there two kinds of control simulations?

Lines 25-26. “For the iESM, even a perfect proxy variable will be subject to both climate and LUC during a CESM run, both before the run starts . . .”. I am unable to follow this sentence.

Page 1507

Lines 3-5. “Conversely, significant expansion of a PFT (e.g., agriculture reverting to forest) during the iESM run might appear to have drastically lowered productivity, leading GCAM redirect resources away from that region”. First, is the agricultural productivity higher than forests in CLM because of the higher per unit leaf area maximum photosyn-

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thesis rates for crops. Second, what does “redirect resources away from that region” means. You have to keep in mind as authors that the ESM community is not familiar with the GCAM model, and vice versa.

Line 9-10. “GCAM will, if it sees out-of-line values, potentially pour more resources into those cells, leading to a runaway feedback”. Sorry, I have no clue what this means. What are the units of resources? Is it money (\$), energy (W/m^2) or something else? Without being introduced to the basic manner in which GCAM works, very few people in the ESM community can understand what this means.

Line 11-12. “. . .and profit maximization is the fundamental decision-making criterion in GCAM.” What is the currency of profit, money (\$) or carbon? Profit is what context?

I am unable to follow the basic premise of Sections 3.1 and 3.2.

Page 1511.

Lines 17-18. “By allowing climate effects from a full earth system model to modulate, in real time, the economic and policy decisions of an integrated assessment model . . .” . I am confused if a full ESM simulation was performed in this study or not.

Page 1522. Figure 3. To which year of the RCP 4.5 simulation does the result correspond to? Color figures are free in online journals. Please consider using a color version of Figure 3.

Page 1524. Figure 5. What are the units on x-axis? Yes, the authors have explained LUC effect equals to 1 means no LUC. But what does a value of 5 means?

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