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Interactive comment on "Improving the representation of anthropogenic CO_2 emissions in climate models: a new parameterization for the Community Earth System Model (CESM)" *by* Andrés Navarro et al.

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Review of the manuscript "Improving the representation of anthropogenic CO2 emissions in climate models: a new parameterization for the Community Earth System Model (CESM)" by Andrés Navarro, Raúl Moreno, and Francisco J. Tapiador, submitted to the Journal Earth System Dynamics, European Geosciences Union (EGU).

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Decision:

Because of the importance of the topic, I would recommend the publication of this manuscript after major revisions in the presentation of the work as described below.

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General Comments:

The authors acknowledge (but not completely clearly) a major shortcoming of the Earth System Models (ESMs) and Integrated Assessment Models (IAMs). Even though the Human System has become the dominant driver of most components of the Earth System since about 1750, and especially since about 1950, IAMs use independent, exogenous projections of the Human System (HS) variables in order to drive ESMs to create future projections. Not including essential bidirectional feedbacks between ES and HS can lead to missing important dynamics that is critical to the sustainably of our planet and people. This problem is discussed in detail in the "Modeling Sustainability" paper by Motesharrei et al. [2016]:

Motesharrei, Safa, Jorge Rivas, Eugenia Kalnay, Ghassem R. Asrar, Antonio J. Busalacchi, Robert F. Cahalan, Mark A. Cane, et al. "Modeling Sustainability: Population, Inequality, Consumption, and Bidirectional Coupling of the Earth and Human Systems." National Science Review 3, no. 4 (December 11, 2016): 470–494. https://doi.org/10.1093/nsr/nww081.

The manuscript is closely related to a recently published paper by the same team of authors (and, unfortunately, there is much overlap with that already published work):

Navarro, Andrés, Raúl Moreno, Alfonso Jiménez-Alcázar, and Francisco J. Tapiador. "Coupling Population Dynamics with Earth System Models: The POPEM Model." Environmental Science and Pollution Research, September 16, 2017, 1–12. https://doi.org/10.1007/s11356-017-0127-7.

These two papers take a step toward including at least parts of the Human System

(human population and emissions) explicitly in the ESMs, however, the somewhat inaccurate presentation of the work (and occasional over-statements) may lead to readers' confusion about the extent and novelty of this work. During my initial reading of the manuscript, I was very impressed by the model and thought that it is a bidirectionally coupled Human System + Earth System Model. (It seems Anonymous Referee 3 has this same impression.) But upon further reading of the manuscript as well as Navarro et al. [2017], I realized that POPEM is essentially a demographic projection model (although it uses dynamic variables for age cohorts) that is used to drive CESM. By contrast, I believe the use of local population projections to project emissions at each grid point is novel, and is advantageous to the current practice of using global emissions projections to drive ESMs.

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Suggested Revisions:

The other three referees already provide many helpful, important suggestions to improve the manuscript. Here, I outline some additional suggestions to help accurately present the model, its value for the Earth System modeling community, and possible future steps that needs to be taken by the modeling community to make the projections of the "Earth–Human System Models" more realistic. I do not ask for any changes to model, since such changes would require major effort and could be implemented in future versions.

(A) Clarify that POPEM is, after all, a demographic projection model. It is true that its 18 age cohorts are dynamic variables, however, they still change based on exogenous fertility and mortality rates. (POPEM does not model Migration, which has become a major driver of population change, especially recently.) These rates are projected into the future using statistical methods such as in the UN Population Projections. Therefore, the projections using POPEM could not be much different from traditional demographic projections, as can be seen from comparisons of POPEM to UN projections in Navarro

et al. [2017]. I believe indeed POPEM cannot properly capture demographic change details for some regions and for certain age cohorts. Therefore, the value-added from this 'dynamic' population model is limited, at least from a demographic perspective.

(B) Because ES and other components of the HS do not feedback onto the demographic variables in POPEM, POPEM will not be able to capture non-trivial dynamics that can arise due to such bidirectional feedbacks [Motesharrei et al., 2016]. For basic examples of how these bidirectional feedbacks (in a minimal model) can lead to surprising behavior, see:

Motesharrei, Safa, Jorge Rivas, and Eugenia Kalnay. "Human and Nature Dynamics (HANDY): Modeling Inequality and Use of Resources in the Collapse or Sustainability of Societies." Ecological Economics 101 (May 2014): 90–102. https://doi.org/10.1016/j.ecolecon.2014.02.014.

(C) I strongly recommend adding a schematic diagram at the begging of the paper to show how POPEM interacts with CESM (e.g., variables, parameters, input/output, couplings).

(D) If POPEM + CESM is indeed the first model that calculates emissions at a local scale, as opposed to using global emissions projections, please emphasize that as the novel accomplishment of this research.

(E) Remove any parts of the manuscript that overlaps with Navarro et al. [2017], and instead refer to specific parts of that publication.

(F) Be more careful with the definitions of, and distinctions between, ESMs and IAMs. Navarro et al. [2017] write, for example: "[RCPs] provide simplified versions of human activities and processes, such as population density and economic development, from non-coupled Integrated Assessment Models (IAMs)." It is not true that IAMs are 'non-coupled'; they are indeed one-way coupled.

Then the authors write "researchers in the iESM Project (Collins et al. 2015) developed

a global integrated assessment model, the GCAM, to address human impact on climate dynamics, with special emphasis on the representation of the human earth system." GCAM was not developed in the iESM project, but has been in development since 1990s and is one of the leading IAMs. The rest of the description of the sentence is also incorrect. iESM couples land use and agriculture to ES via bidirectional feedbacks.

(G) In the last section of the manuscript (4), emphasize that dynamic models of various Human System components need to be developed and coupled to ESMs via bidirectional feedbacks in order to produce realistic projections and to capture counterintuitive and unexpected dynamics.

(H) Please go over your citations carefully and make sure that they appear at proper places. Also, the manuscript can benefit from additional important, relevant references. (The bibliography of Motesharrei et al. [2016] could be helpful for this manuscript.)

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End of the review of the manuscript "Improving the representation of anthropogenic CO2 emissions in climate models: a new parameterization for the Community Earth System Model (CESM)" by Andrés Navarro, Raúl Moreno, and Francisco J. Tapiador, Earth System Dynamics.

Submitted by Safa Motesharrei on 2018 MAY 05.

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