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Geoscientific Model Development Discussions

Interactive comment on "GCAM v5.1: Representing the linkages between energy, water, land, climate, and economic systems" *by* Katherine Calvin et al.

Anonymous Referee #1

Received and published: 29 October 2018

General comments:

The authors provide a comprehensive, clear, and succinct description and documentation of the GCAM v5.1 model. They include eleven scenarios that span a wide range of socioeconomic and climate policy assumptions to illustrate the results. The manuscript provides a valuable resource for potential future users of the model, as well as other researchers wanting to understand the modeling structure, inputs, outputs, and data sources for comparison to other modeling frameworks.

Scientific significance: While this article does not describe and document an entirely new modeling framework, the GCAM model and related analyses make a major con-

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tribution to our understanding of the linkages between energy, land, water, climate and socioeconomic systems. It is a widely used and widely cited modeling framework. Version 5.1 appears to represent a substantial advance and update in the data sources, individual model components, as well as the linkages between the key systems. I do have some suggestions, however, to improve the discussion of what is new relative to earlier versions.

Scientific quality: The approach and results are robust. Data sources are valid and well documented. The modeling framework is compared to other models such as IMAGE and MESSAGE (Section 1), and the results of scenarios are compared with other projections (Section 4.3.7) and to historical data (Section 4.7.1.)

Scientific reproducibility: The GCAM model is an open source model with all code and inputs available on GitHub, as well as users guides and trainings. Each individual model component is concisely documented and described, with resources for additional information as needed. The authors provide information on how to obtain the model in the manuscript.

Presentation quality: The authors do an excellent job succinctly and clearly describing the model structure and data sources, and summarizing the key results of their SSP and 2.6 W/m2 scenarios.

Specific comments:

page 2, lines 14-15: Can you be more specific or quantify what is meant by "computationally inexpensive." Very briefly, what are the general system requirements and associated run time for a scenario (e.g., run on the order of minutes, hours?) Can you give the reader a ballpark idea of the run time, say with a standard desktop/laptop versus a higher-end computing cluster? You highlight the growing complexity and computational requirements at the end of the paper, but what does it require now for this model version?

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page 3: In this section, I would like to see some additional discussion of what the critical updates are to version 5.1 relative to earlier versions. The authors briefly touch on the differences in the SSP results due to updates in technology costs relative to work published in Muratori (2017). However, can you highlight here, and then briefly summarize in the discussion, the most significant updates to this version of GCAM? I would suggest including that early on in Section 2, or flagging major changes from previous GCAM versions in the individual sections (energy, land, etc) where appropriate. The documentation is very comprehensive, but it was often unclear what was new versus what has been in the model database in previous versions. Please be more explicit about what is new.

page 4, lines 8-17: I would like to see a bit more detailed discussion and additional specifics on the share weights in terms of their role in both model calibration, but also to what extent these can constrain future technology and market shifts. This could be here, or in the individual sections. This may be something more for the discussion section at the end, but given the long time horizon of the model, to what extent are the share weights relaxed or overwritten for future periods. The authors note that these are "on occasion over-written." But, how would user know where and when share weight may be constraining results versus where they can be overwritten to enable more transformative market shifts? How does a user know when a share constraint may be constraining the model in way that perhaps make it harder to reach deep decarbonization targets, for example? These are important model levers and are often not documented with the same rigor and transparency as something like technology cost, for example.

page 6, lines 32-34: I would suggest flagging that this approach, while a fine approximation at a general level, does not capture the changes in emissions factors of non-CO2 emissions that may be induced by policies and air emissions control technologies that individual regions, countries, etc. may adopt in specific time periods.

page 7, line 6: The resources supply curves are now 20 years old. Are there plans to update these?

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page 7, line 8: All other biomass energy is supplied from the land component, correct?

page 7, line 24: Do liquid refining plants include both petroleum and biofuels? If so, are biofuels plants modeled separately?

page 8, line 9: It would be useful to know how many crops are modeled, and maybe list the major commodities.

page 8, line 21-22: Is there a mechanism to represent cropland that is idle/fallow in a particular period?

page 9, line 11: What it meant by bioenergy constraints? Lower or upper volume mandates to meet a renewable or low carbon fuel standard? Or are these done as shares of liquid fuel markets?

page 10, line 3: GCAM models water supply as an unlimited resource, but does the model provide the capability to constrain or price water use. It seems there are prices for municipal water use. Are there any prices, or the ability to price or limit quantities of water for cooling technologies or irrigation?

page 10, lines 11-20: The authors introduce the term blue water. It might be helpful to briefly define the terms blue, as well as green and grey water use. Otherwise, I'd suggest omitting.

page 10, lines 27: There is mention of regions that primarily use seawater for electric power cooling system demands. It is unclear, however, whether the water component of the model differentiates between water sources in terms of groundwater, surface water, or water types, fresh, brackish, saline, reuse. Please clarify if these differences are captured or not. Otherwise, I think it's important to highlight in model results that water withdrawals and consumption include all freshwater as well as seawater, since other energy-water analysis may exclude saline/seawater withdrawals.

page 12, line 25: Nice. The example of bioenergy as an example of a coupled system is well described and highlights ones of the key strengths of this type of model, which

is the interactions between systems.

page 13, line 12: Maybe at the end of this section perhaps briefly highlight other examples where the components are tightly coupled.

page 16, line 5: Please clarify what causes the increases in pollution controls, is this solely due to the changes in emissions factors in response to growth in per capita-GDP?

page 17, line 24-25: The data is from CDIAC, but there is no reference. Please provide a citation or link to the website (this data is being transitioned to a new data archive site, correct?)

page 19, line 10-29: See my earlier comments about summarizing the most significant advances in the version 5.1 of GCAM. I think you could tighten up the discussion in paragraphs 2-4 of the discussion to create some space if you are word limited, and still get those key points across to the reader.

page 27, Figure 2: In the caption, maybe describe what the regions are based upon, e.g., are they based on AEZs? Other than getting across a general sense of the spatial scale this graph doesn't convey too much. Perhaps add some descriptions in the Figure caption regarding the basis for each of the regional breakouts.

page 30, Figure 6: In the caption, do you mean that data are aggregated up for both land allocation and crop types? Or just for land allocation? Are there more crop types than this? See my earlier comment for page 8.

page 32, Figure 10: The letters labels seem unnecessary, (a oil, b natural gas). It would be cleaner if you left them off the legend.

page 34, Figure 12: Can you make the data points bigger? It's hard to make out the ones on the line. Also, wasted space with the lower right quadrant. I'd add something or drop the CDIAC versus GCAM data and just summarize in words.

page 35, Figure 13: This mapping onto the AR5 data is very useful for comparison.

Technical corrections:

In the references, please provide the links for the data from EIA, EPA, FAO AQUASTAT, IBNET, IEA, IHA, etc...

References need a lot of clean up, e.g., Kriegler, this looks to be a thesis. Please cite as such. Macknick et al is missing information, this is a report.

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