

Geosci. Model Dev. Discuss., author comment AC2
<https://doi.org/10.5194/gmd-2021-197-AC2>, 2021
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Authors' response to RC2

Matthew Binsted et al.

Author comment on "GCAM-USA v5.3_water_dispatch: integrated modeling of subnational US energy, water, and land systems within a global framework" by Matthew Binsted et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-197-AC2>, 2021

The authors thank the reviewer for their constructive feedback on our manuscript. We have responded to each comment individually below using GMD's suggested structure of (1) comments from referees/public (we italicized this text), (2) authors' response (plain text), and (3) authors' changes in manuscript (additions are bolded, existing content is plain text). To improve readability, we have inserted a series of dashes between each comment. A zip file containing a conceptual figure explaining the water supply system in GCAM-USA (new Figure 1) and a revised Supplementary Information document is attached to this response.

(1) *The manuscript 'GCAM-USA v5.3_water_dispatch: Integrated modelling of subnational U.S. energy, water, and land systems within a global framework' presents an open-source Integrated Assessment Model version for GCAM with focus on Energy, Water Land representation of the United States. The manuscript is an important contribution to the community considering recent US climate commitments.*

(2) The authors thank the reviewer for the compliment on our contribution to the literature.

(3) There are no changes to manuscript corresponding to this comment.

(1) *The manuscript is structured in a very good manner but I felt that more of the information that should have been in the manuscript is referred to other papers which may not help the readers to fully understand the modelling framework.*

(2) The authors thank the reviewer for the valuable feedback. The reviewer is correct that some aspects of the model could be described more thoroughly in the manuscript. As with all papers, there is a balancing act between comprehensiveness and accessibility – including every detail in the main text (as opposed to supplementary information or citations to other literature) can clutter a paper's key messages and impede understanding. However, we appreciate that there are areas where more detail would be beneficial. We address each specific point below.

(3) There are no changes to manuscript directly corresponding to this comment.

(1) *The authors mentioned that the water sector is a 'key new development of GCAM-USA' while it's hard to fully grasp the water structure which is being used in the model. Line 190 explains the water supply system but it lacks an explanation of how the water supply data was obtained, processed. Additional Information on the water supply system and also data sources and spatial aggregation methods for the data could benefit the readers to know more. I highly recommend that the authors insert a figure explaining the water supply system and how it's linked to the demands within the framework.*

(2) The authors thank the reviewer for the helpful suggestions. The reviewer is correct that the original description of the water supply system was insufficient. We've added two paragraphs of additional detail on the various water resources in GCAM and how they compete to supply water needs. The suggestion to add a conceptual figure was also a good one. A conceptual figure was added as Figure 1 at line 225.

(3) Edits to manuscript

GCAM's water supply system is described in detail in Kim et al. (2016) and Turner et al. (2019); a high-level overview is provided below.

Renewable water is the least expensive source of water in GCAM and includes direct extraction of surface water as well as pumping of recharged groundwater. A global hydrology model, Xanthos (Li et al. 2017; Vernon et al. 2019), is used to calculate long-term average annual streamflow for each water basin by routing gridded runoff at 0.5° spatial resolution. 10% of this average annual flow is allocated to environmental flow requirements and thus unavailable; the remaining portion represents the maximum renewable water supply. A fraction of this renewable water supply is considered currently accessible at low cost via existing infrastructure for capturing, storing, and delivering; this fraction is adjusted to reflect the amount available even in dry years (here forth referred to as "accessible volume") (Kim et al. 2016). For most basins, this accessible volume is derived from Xanthos simulations of base flows and storage reservoirs (utilizing the Global Reservoir and Dams inventory) (Kim et al. 2016); in some basins where estimates of groundwater depletion are available, the accessible portion of renewable water is derived as the historical difference between total water withdrawals and fossil groundwater pumping (Turner et al. 2019). In model simulations, basins can withdraw greater fractions of the total renewable water supply (beyond the accessible volume) at significantly higher costs which reflect the potential costs of interventions such as river rerouting, dam construction, or water transportation (Kim et al. 2016; Turner et al. 2019).

Each water basin in GCAM also contains a volume of potentially exploitable non-renewable groundwater, divided into several grades of increasing price based on estimated drilling and pumping costs. Total physically exploitable groundwater reserves (without considering economic and environmental constraints) are estimated at a 50-km grid scale for all major aquifers from data on aquifer areal extent, porosity, thickness, permeability, and groundwater depth as described in (Turner et al. 2019) (section 2.3). An extraction cost model is used to simulate groundwater pumping for each 50-km grid to estimate extraction costs including capital costs (a function of well depth and complexity), maintenance costs, and operating costs (reflecting well depth, yields, and country-specific electricity prices). Costs associated with water treatment and conveyance / storage are not included due to lack of available data. These water quantity and cost data points are then aggregated to the HUC-2 water basin level and

organized into grades increasing cost. By default, only 25% of physically exploitable groundwater is assumed to be available for extraction to reflect environmental limits on groundwater depletion (in the absence of a global data set facilitating basin-specific environmental factors in the model (Turner et al. 2019)).

As the maximum renewable water supply is approached, non-renewable groundwater begins to become an economically competitive source of water withdrawals. However, groundwater supplies are depleted as they are exploited; non-renewable groundwater consumption leads to water price increases as each marginal unit of groundwater entails increased pumping costs. Desalinated seawater is also available in coastal basins and states (but not inland basins/states) to meet water demands excluding irrigation demands, although at a high price because due to the energy intensity of desalination. Water prices in GCAM are incurred directly by water consuming technologies and ultimately passed onto end users in the costs of goods (e.g., crops) and services (e.g., electricity). Thus, increasing water prices can motivate shifts to less water intensive production methods such as rain-fed agriculture or more water-efficient power plant cooling systems.

(1) Line 470 explains the water availability is constrained to default levels of renewable and non-renewable groundwater. Please add more explanation on the constraints here instead of referring to existing papers. A figure or table on Supplementary information explanation on the water prices for USA could help the readers more.

(2) The authors thank the reviewer for the helpful comments. A description of how resource supply curves for renewable water and groundwater (which constitute limits on their availability) is now included in Section 3.2.1 (Water supplies) based on the reviewer's previous comment. Thus, in this instance (Section 5, Scenarios), we refer the reviewer to Section 3.2.1 and briefly summarize the key limits to water availability in the scenarios. The two sentences added to Section 5 are included below in bold.

The authors agree that information on water resource cost curves and prices is also valuable for readers. These have been added as Supplementary Figures SF4 and SF5. The text has been updated to refer interested readers to these figures (additions below in bold).

(3) Edits to manuscript (section 5)

The methods for constructing GCAM's renewable water and groundwater resource curves are described in Section 3.2.1 (Water supplies). In short, this entails a 10% environmental flow restriction on renewable water, renewable water availability based on the stable volume of long-term average annual flow (i.e., not reflecting potential impacts of future climate change on water availability), and a 25% limit on physically exploitable groundwater extraction reflecting environmental limits on groundwater depletion. Renewable water and groundwater resource curves by river basin are included in Supplementary Figure SF4.

Additional edits to manuscript (section 6.3)

(The shadow prices of water for each river basin and scenario are included in Supplementary Figure SF5; broadly, we observe increasing water prices in basins/scenarios with high reliance on groundwater extraction or desalination. Note that GCAM-USA's water prices represent a shadow price on water (Bierkens et al. 2019) – the intention is not to predict real-world consumer prices, but to

reflect water scarcity and provide a price signal to water consuming sectors when basins face water scarcity and marginal water demand must be met by expensive ground water extraction or desalination (where available).)

(1) *I think energy system is explained in a well structured way whereas additional information on the water structure, prices and linkages in the framework can improve the manuscript overall.*

(2) Thank you for the compliment. We have added more detail on the water supply structure, water prices, and water market linkages as discussed above.

(3) There are no changes to manuscript directly corresponding to this comment.

References

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Please also note the supplement to this comment:

<https://gmd.copernicus.org/preprints/gmd-2021-197/gmd-2021-197-AC2-supplement.zip>