The Journal of Open Source Software

Tethys: A Spatiotemporal Downscaling Model for Global Water Demand

Isaac Thompson[1¶], **Zarrar Khan**[1], **and Chris Vernon**[1]

1 Joint Global Change Research Institute, Pacific Northwest National Laboratory, USA ¶ Corresponding author

DOI: 10.xxxxxx/draft

Software

- Review
- Repository
- Archive

Editor: Jemma Stachelek

Reviewers:

- @Mariosmsk
- @nickrsan

Submitted: 30 May 2023
Published: unpublished

Summary

Humans use water for many important tasks, such as drinking, growing food, and cooling power plants. Since future water demands depend on complex global interactions between economic sectors (e.g., demand for wheat in one country causing demand for water to grow that wheat in another country), it is often modeled at coarse spatial and temporal scales as part of models that account for complex, multi-sector systems dynamics. However, models that project future water availability typically simulate physical processes at much finer scales. `Tethys` enables coupling between these kinds of models by downscaling region-scale water demand projections using sector-specific proxies and formulas.

Statement of need

Hydrological models require finely gridded water demand data to represent the location and timing of flows into the human system, but historical inventories of water use are often only available per country, and at annual or larger intervals (Huang et al., 2018). In order to model future global economic linkages in detail, multi-sector dynamics models also operate at these coarser spatial and temporal scales. This gap in scale makes downscaling water demands a common problem.

The distribution of water demands depends on the location and timing of activities that use water, so the usual approach is to use relevant gridded datasets as spatial proxies for each water demand sector (e.g., assume that irrigation water demand is proportional to irrigated land area), then further allocate annual water demands among months according to formulas that capture seasonal variations (Voisin et al., 2013). This is typically accomplished with scripts designed for specific model-coupling workflows, but different models and proxy datasets can have different breakdowns of water demand sectors, limiting reuse of such scripts.

Building on previous versions (Li et al., 2018), `Tethys` now generalizes this downscaling process to provide a convenient and flexible interface for configuring proxy rules, as well as specifying target output resolution, allowing researchers to easily generate finely gridded water demand data that are consistent with coarser scale inventories or simulations. `Tethys` has been used in scientific publications such as (Khan et al., 2023), which downscaled water demand from an ensemble of 75 socioeconomic and climate scenarios.

Key Functionality

`Tethys` consists of 2 stages: spatial downscaling and (optionally) temporal downscaling. First, sectoral water demands by region are disaggregated to water demand by grid cell in proportion to appropriate spatial proxies, i.e.,

$$\text{demand}_{\text{cell}} = \text{demand}_{\text{region}} \times \frac{\text{proxy}_{\text{cell}}}{\text{proxy}_{\text{region}}}. \tag{1}$$

Then, temporal downscaling follows sector-specific formulas from the literature, which determine the fraction of a year's water demand to allocate to each month based on relationships between monthly water demand and other monthly variables. See the documentation for more details and example usage.

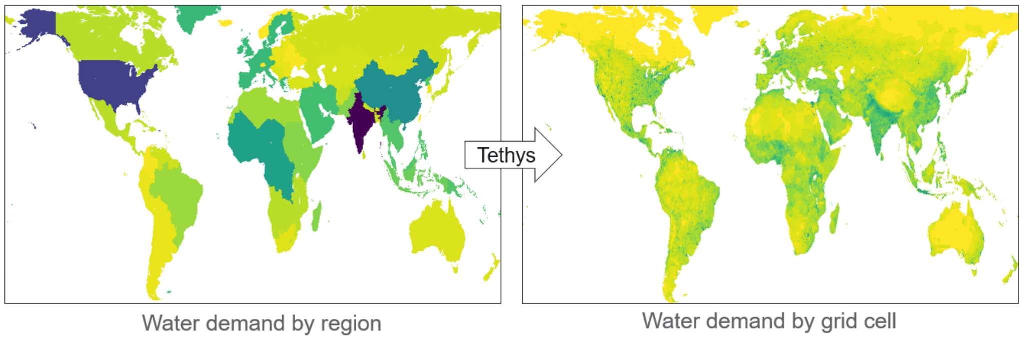

Figure 1: Before and after spatial downscaling

Acknowledgements

This research was supported by the U.S. Department of Energy, Office of Science, as part of research in MultiSector Dynamics, Earth and Environmental System Modeling Program. The Pacific Northwest National Laboratory is operated for DOE by Battelle Memorial Institute under contract DE-AC05-76RL01830. The views and opinions expressed in this paper are those of the authors alone.

References

Huang, Z., Hejazi, M., Li, X., Tang, Q., Vernon, C., Leng, G., Liu, Y., Döll, P., Eisner, S., Gerten, D., Hanasaki, N., & Wada, Y. (2018). Reconstruction of global gridded monthly sectoral water withdrawals for 1971–2010 and analysis of their spatiotemporal patterns. *Hydrology and Earth System Sciences*, *22*(4), 2117–2133. https://doi.org/10.5194/hess-22-2117-2018

Khan, Z., Thompson, I., Vernon, C. R., Graham, N. T., Wild, T. B., & Chen, M. (2023). Global monthly sectoral water use for 2010–2100 at 0.5° resolution across alternative futures. *Scientific Data*, *10*(1), 201. https://doi.org/10.1038/s41597-023-02086-2

Li, X., Vernon, C. R., Hejazi, M. I., Link, R. P., Huang, Z., Liu, L., & Feng, L. (2018). Tethys – a python package for spatial and temporal downscaling of global water withdrawals. *Journal of Open Research Software*. https://doi.org/10.5334/jors.197

Voisin, N., Liu, L., Hejazi, M., Tesfa, T., Li, H., Huang, M., Liu, Y., & Leung, L. R. (2013). One-way coupling of an integrated assessment model and a water resources model: Evaluation and implications of future changes over the US midwest. *Hydrology and Earth System Sciences*, *17*(11), 4555–4575. https://doi.org/10.5194/hess-17-4555-2013