

Rochester Institute of Technology

RIT Digital Institutional Repository

Articles

Faculty & Staff Scholarship

8-20-2022

MimiBRICK.jl: A Julia package for the BRICK model for sea-level change in the Mimi integrated modeling framework

Tony E. Wong

Rochester Institute of Technology

Lisa Rennels

University of California - Berkeley

Vivek Srikrishnan

Cornell University

Alexander Bakker

Delft University of Technology

Klaus Keller

Dartmouth College

See next page for additional authors

Follow this and additional works at: <https://repository.rit.edu/article>

Recommended Citation

Wong et al., (2022). MimiBRICK.jl: A Julia package for the BRICK model for sea-level change in the Mimi integrated modeling framework. *Journal of Open Source Software*, 7(76), 4556, <https://doi.org/10.21105/joss.04556>

This Article is brought to you for free and open access by the RIT Libraries. For more information, please contact repository@rit.edu.

Authors

Tony E. Wong, Lisa Rennels, Vivek Srikrishnan, Alexander Bakker, Klaus Keller, and David Anthoff




MimiBRICK.jl: A Julia package for the BRICK model for sea-level change in the Mimi integrated modeling framework

Tony E. Wong ¹, Lisa Rennels ², Frank Errickson ³, Vivek Srikrishnan ⁴, Alexander Bakker ^{5,7}, Klaus Keller ⁶, and David Anthoff ²

¹ School of Mathematical Sciences, Rochester Institute of Technology, USA ² Energy and Resources Group, University of California, Berkeley, USA ³ School of Public and International Affairs, Princeton University, USA ⁴ Department of Biological and Environmental Engineering, Cornell University, USA ⁵ Rijkswaterstaat, Ministry of Infrastructure and Water Management, The Netherlands ⁶ Thayer School of Engineering, Dartmouth College, USA ⁷ Department of Hydraulic Engineering, Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands

DOI: [10.21105/joss.04556](https://doi.org/10.21105/joss.04556)

Software

- [Review](#) 
- [Repository](#) 
- [Archive](#) 

Editor: [Mehmet Hakan Satman](#)  

Reviewers:

- [@Zitseronion](#)
- [@svchb](#)

Submitted: 17 June 2022

Published: 20 August 2022

License

Authors of papers retain copyright and release the work under a Creative Commons Attribution 4.0 International License ([CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)).

Statement of need

Assessing strategies to manage climate risks requires sound projections of future climate. For coastal risks, this includes projections of future sea levels. Major contributors to sea-level change include glaciers and ice caps, thermal expansion, land water storage, and the Greenland and Antarctic ice sheets. Characterizing coastal hazards and managing the associated risks requires resolving the tails of distributions. While many practitioners can obtain sea-level scenarios from synthesis reports, including the Intergovernmental Panel on Climate Change (IPCC, ([Fox-Kemper et al., 2021](#))), improving our understanding of the importance and impacts of the many inherent uncertainties often requires fast and efficient models to explore these uncertainties. Semi-empirical models for sea-level rise offer a computationally efficient method for studying uncertainties in future coastal hazards and fusing observational data with models ([R. Kopp et al., 2017](#); [Mengel et al., 2016](#); [Nauels et al., 2017](#); [Wong et al., 2017](#)). These models can also be flexible and modular, which enables their use in integrated frameworks for assessing climate damages and examining the efficacy of climate risk management policies. Interfaces such as the Framework for Assessing Changes To Sea-level (FACTS, ([Garner & Kopp, 2022](#))) enable users to access these models and facilitate experimentation and intercomparisons. FACTS, coded primarily in Python, advances the older LocalizeSL MATLAB modules ([R. E. Kopp et al., 2014](#)). FACTS offers users a set of modules through which various forcing scenarios and modeling workflows can be combined to interrogate uncertainties in sea-level projections, particularly in structural uncertainties. FACTS is open source and freely available, and is a suitable source for local sea-level projections for many users.

MimiBRICK.jl is a Julia ([Bezanson et al., 2017](#)) implementation of the Building Blocks for Relevant Ice and Climate Knowledge (BRICK) semi-empirical model for sea-level change ([Wong et al., 2017](#)) in the Mimi integrated modeling framework (<https://www.mimiframework.org/>). The Mimi modeling framework is a coding platform that facilitates coupling models and running coupled modeling experiments. Mimi is explicitly employed in more than 10 peer-reviewed studies, as of this writing, with more presently in review. MimiBRICK.jl is flexible, efficient, and modular, to facilitate incorporating BRICK into coupled models and integrated assessments of climate impacts in a modular fashion to provide global average as well as local sea-level projections ([National Academies of Sciences & Medicine, 2017](#)). This focus on tight model coupling ([Srikrishnan et al., 2022](#)) and integrated modeling is a distinction between FACTS and

MimiBRICK.jl and the broader Mimi modeling framework.

This implementation includes examples for using observational data to calibrate the model, as well as various configurations in which MimiBRICK is coupled to other climate model components. For users who do not wish to re-run computationally intensive model calibration algorithms, this implementation also includes scripts for using existing calibration output for standard future climate change scenarios, and examples downscaling these global projections for assessments of local impacts.

Summary

BRICK is a semi-empirical model for global and local mean sea-level change (Wong et al., 2017). The core model includes component sub-models for the major contributors to global mean sea-level change - glaciers and ice caps, thermal expansion, land water storage, and the Greenland and Antarctic ice sheets. The resulting global mean sea levels can be downscaled via a data set that represents the “fingerprint” of each sea-level component on local mean sea level (Slangen et al., 2014). In this way, BRICK provides information about local sea-level changes, including characterizations of key uncertainties. BRICK is flexible and efficient enough to resolve high-risk upper tails of probability distributions. BRICK has been used in a number of recent assessments, including for examining the impacts of sea-level rise as a constraint on estimates of climate sensitivity (Vega-Westhoff et al., 2018), estimates of deep uncertainty in coastal flood risk (Ruckert et al., 2019), and most recently was noted in comparisons of sea-level projections in the Sixth Assessment Report of the IPCC (Fox-Kemper et al., 2021).

By working with annual global mean temperatures and sea levels, BRICK is suitable for embedding within, and coupling to, other models for climate change and its impacts. MimiBRICK.jl is written in compliance with the Mimi integrated modeling framework to facilitate incorporating BRICK into larger-scale coupled modeling efforts. The MimiBRICK.jl repository includes three such examples: (i) standalone BRICK, which takes as input temperature and ocean heat uptake; (ii) BRICK coupled to a simple one-dimensional Diffusion-Ocean-Energy Climate model (DOECLIM), which takes as input radiative forcing scenarios such as the standard Representative Concentration Pathway (RCP) scenarios; and (iii) BRICK coupled to a Simple Nonlinear Earth System model (SNEASY), which takes as input radiative forcing and greenhouse gas emissions and concentration scenarios (such as the RCP scenarios).

The standalone BRICK model requires as input annual mean time series for global mean surface temperature and oceanic heat uptake. In the DOECLIM-BRICK and SNEASY-BRICK configurations, those temperatures and ocean heat uptake inputs are provided to BRICK through output from the DOECLIM and SNEASY models. In the examples provided in the MimiBRICK.jl repository, the temperature time series is from the maximum *a posteriori* simulation from the ensemble run using the SNEASY-BRICK configuration. In all Mimi modeling experiments, model output and parameter values can be explored using the Mimi `explore()` function (Figure 1). The `explore()` function allows users to easily view and zoom in on different features in the model simulation set-up or results. Coding BRICK in the Mimi style enables the user to more easily couple the BRICK model to the suite of other models already implemented in Mimi, and builds on the extensive documentation and community support online (<https://www.mimiframework.org/Mimi.jl/stable/>).

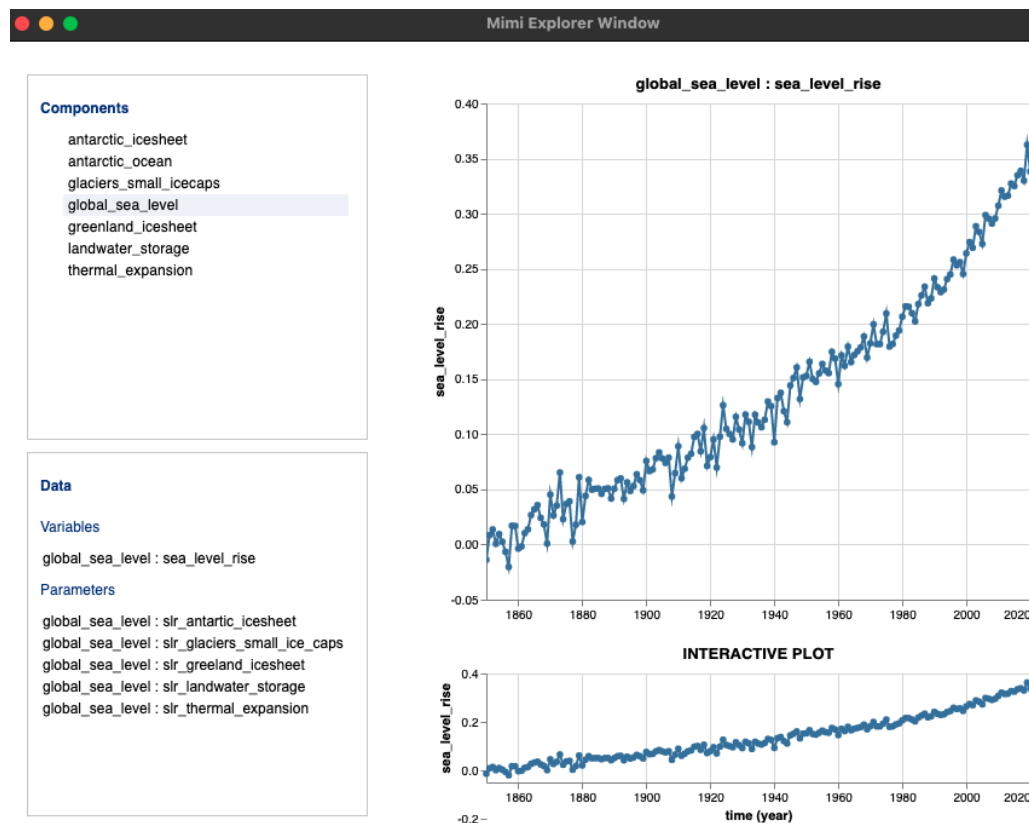


Figure 1: The Mimi explore() function allows users to interactively explore the coupled model output variables and parameters associated with each model component.

Acknowledgements

We gratefully acknowledge Corinne Hartin, Matthew Hoffman, Catherine Ledna, Radley Powers, Ryan Sriver, Nathan Urban, and Benjamin Vega-Westhoff for valuable contributions. This work was co-supported in part by the Penn State Center for Climate Risk Management and the Thayer School of Engineering. All errors and opinions are those of the authors and not of the supporting entities.

Software License: The MimiBRICK.jl code is distributed under GNU general public license. The authors do not assume responsibility for any (mis)use of the provided code.

References

- Bezanson, J., Edelman, A., Karpinski, S., & Shah, V. B. (2017). Julia: A fresh approach to numerical computing. *SIAM Review*, 59(1), 65–98. <https://doi.org/10.1137/141000671>
- Fox-Kemper, B., Hewitt, H. T., Xiao, C., Aðalgeirsdóttir, G., Drijfhout, S. S., Edwards, T. L., Golledge, N. R., Hemer, M., Kopp, R. E., Krinner, G., Mix, A., Notz, D., Nowicki, S., Nurhati, I. S., Ruiz, L., Sallée, J.-B., Slangen, A. B. A., & Yu, Y. (2021). Ocean, Cryosphere and Sea Level Change. In P. Z. [MassonDelmotte V. & B. Zhou (Eds.), *Climate change 2021: The physical science basis. Contribution of working group i to the sixth assessment report of the intergovernmental panel on climate change*. Cambridge University Press.
- Garner, G. G., & Kopp, R. E. (2022). *Framework for Assessing Changes To Sea-level (FACTS)*

- modules, scripts, and data for the IPCC AR6 sea level projections (Version 20220406) [Computer software]. Zenodo. <https://doi.org/10.5281/zenodo.6419954>
- Kopp, R. E., Horton, R. M., Little, C. M., Mitrovica, J. X., Oppenheimer, M., Rasmussen, D. J., Strauss, B. H., & Tebaldi, C. (2014). Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. *Earth's Future*, 2(8). <https://doi.org/10.1002/2014EF000239>
- Kopp, R., DeConto, R. M., Bader, D., Hay, C. C., Horton, R. M., Kulp, S., Oppenheimer, M., Pollard, D., & Strauss, B. H. (2017). Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections. *Earth's Future*. <https://doi.org/10.1002/2017EF000663>
- Mengel, M., Levermann, A., Frieler, K., Robinson, A., Marzeion, B., & Winkelmann, R. (2016). Future sea level rise constrained by observations and long-term commitment. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*, 113(10), 2597–2602. <https://doi.org/10.1073/pnas.1500515113>
- National Academies of Sciences, Engineering, & Medicine. (2017). *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide*. The National Academies Press. <https://doi.org/10.17226/24651>
- Nauels, A., Meinshausen, M., Mengel, M., Lorbacher, K., & Wigley, T. M. L. (2017). Synthesizing long-term sea level rise projections - the MAGICC sea level model v2.0. *Geoscientific Model Development*, 10, 2495–2524. <https://doi.org/10.5194/gmd-10-2495-2017>
- Ruckert, K. L., Srikrishnan, V., & Keller, K. (2019). Characterizing the deep uncertainties surrounding coastal flood hazard projections: A case study for Norfolk, VA. *Scientific Reports*. <https://doi.org/10.1038/s41598-019-47587-6>
- Slangen, A. B. A., Carson, M., Katsman, C. A., Wal, R. S. W. van de, Köhl, A., Vermeersen, L. L. A., & Stammer, D. (2014). Projecting twenty-first century regional sea-level changes. *Climatic Change*, 124(1-2), 317–332. <https://doi.org/10.1007/s10584-014-1080-9>
- Srikrishnan, V., Lafferty, D. C., Wong, T. E., Lamontagne, J. R., Quinn, J. D., Sharma, S., Molla, N. J., Herman, J. D., Sriver, R. L., Morris, J. F., & Lee, B. S. (2022). Uncertainty analysis in multi-sector systems: Considerations for risk analysis, projection, and planning for complex systems. *Earth's Future*, 10, e2021EF002644. <https://doi.org/10.1029/2021EF002644>
- Vega-Westhoff, B., Sriver, R. L., Hartin, C. A., Wong, T. E., & Keller, K. (2018). Impacts of Observational Constraints Related to Sea Level on Estimates of Climate Sensitivity. *Earth's Future*, 7(6), 677–690. <https://doi.org/10.1029/2018EF001082>
- Wong, T. E., Bakker, A. M. R., Ruckert, K. L., Applegate, P., Slangen, A., & Keller, K. (2017). BRICK0.2, a simple, accessible and transparent model framework for climate and sea-level projections. *Geoscientific Model Development*, 10, 2741–2760. <https://doi.org/10.5194/gmd-10-2741-2017>