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regional_mom6: Automatic generation of regional configurations for the Modular Ocean Model 6 in Python

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Summary

Modular Ocean Model 6 (MOM6) is a widely-used general circulation open-source ocean-sea ice-ice shelf model developed mainly at the Geophysical Fluid Dynamics Laboratory (GFDL) (Adcroft et al., 2019). Among other improvements over its predecessor MOM5 (citation), MOM6 allows open boundary conditions and thus it is becoming popular also for regional ocean modeling studies (see, e.g., Ross et al. (2023), Ross et al. (2024)). However, setting up a regional configuration for MOM6 can be challenging and time consuming and often involves using several programming languages, a few different tools, and also editing/fiddling some input files by hand. The `regional_mom6` python package automates the procedure of generating a regional MOM6 configuration.

The `regional_mom6` package takes as input various datasets that containing the ocean initial condition, the boundary forcing (ocean and atmosphere) for the regional domain, and the bathymetry. The inputs datasets can be on the Arakawa A, B, or C grids (Arakawa & Lamb, 1977); the package performs the appropriate interpolation using `xESMF` (Zhuang et al., 2023) under the hood, to put the everything on the C grid required by MOM6. Thus, the package automates the re-gridding of all the required forcing input, takes care of all the metadata encoding, generates the regional grid, and deals with few other miscellaneous steps required. This allows users to setup a regional MOM6 configurations using only Python and from a single Jupyter notebook.

`regional_mom6` is continuously tested and comes with an extensive documentation that also includes documented tutorials/examples for setting up regional MOM6 configurations using publicly-available forcing and bathymetry datasets (namely, the GLORYS dataset for ocean boundary forcing (Copernicus Marine Services, 2024), the ERA5 for the atmospheric forcing (Copernicus Climate Change Service, 2024), and the GEBCO dataset for bathymetry (GEBCO Bathymetric Compilation Group 2023, 2023)).

Having the entire process for setting up a regional configuration running in a Jupyter notebook dramatically reduces the barrier of entry for first-time users, or those without a strong background in FORTRAN, experience in compiling and running scripts in terminals, and manipulating netCDF files. Besides making regional modelling with MOM6 more accessible, our package can automate the generation of multiple experiments (e.g., series of perturbation experiments), saving time, effort, and improving reproducibility.

We designed `regional_mom6` with automation of regional configurations in mind. However, the package's code design and modularity allows makes more complex configurations possible since users can use their own custom-made grids with more complex boundaries and construct the boundary forcing terms one by one.

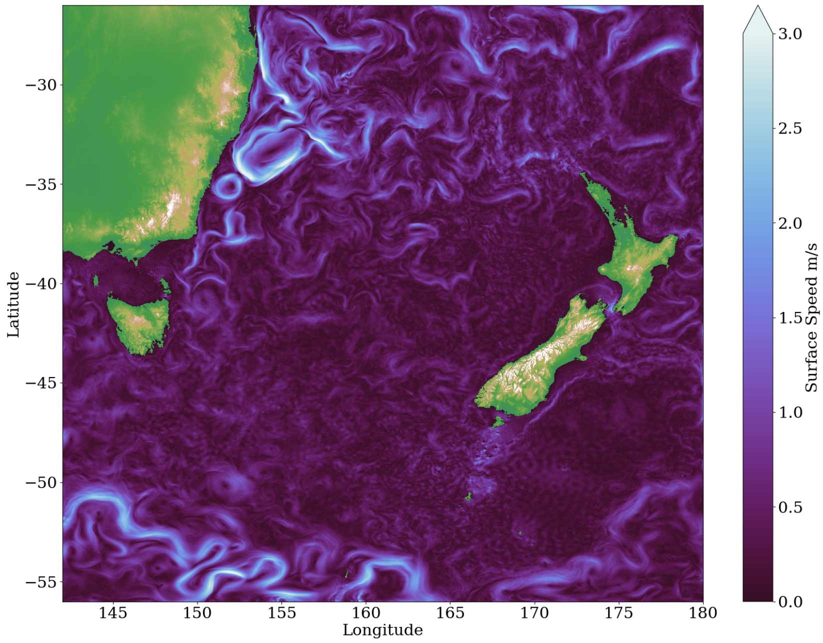

Figure 1: A snapshot of the ocean surface currents from a MOM6 regional simulation of the Tasman sea. The simulation is forced by GLORYS and ERA5 reanalyses datasets and configured with a horizontal resolution of 1/80th degree and 100 vertical levels (see Barnes (2024) for the source code).

Figure 1 shows the surface currents from a regional ocean simulation of the Tasman sea that was configured using the `regional_mom6` package.

Statement of need

The learning curve for setting up a regional ocean model can be quite steep. In the case of MOM6, there are several tools scattered in Github repositories, like, for example, those collected in ESMG's grid tools (Cermak et al., 2021). Also, there exist several regional configuration example but that are hardcoded for particular domains, specific input files, and work only on certain HPC machines.

There is no one-stop-shop for users to learn how to get a regional MOM6 configuration up and running. Users are required to use several tools and in several programming languages and then modify –sometimes by hand– some of the input metadata to bring everything in the format that MOM6 expects. Often parts of this process are not documented bringing users down to their knees since they end up having to figure it out a lot of things by themselves, e.g., by deciphering FORTRAN code. Other ocean models have packages to aid in regional configuration setup. Characteristically, `Pyroms` (Hedstrom & contributors, 2023) for the Regional Oceanic Modelling System (ROMS; Shchepetkin & McWilliams (2005)) and `MITgcm_python` (Naughten & Jones, 2023) for the Massachusetts Institute of Technology General Circulation Model (MITgcm; Marshall et al. (1997)). With MOM6's growing user base for regional applications, there is a need for a platform that walks users through regional domain configuration from from start to finish and, ideally, automates the process on the way. `regional_mom6` comes to fill in precisely this need.

By having a shared set of tools that the community can work with and contribute to, this package also facilitates collaboration and knowledge-sharing between different research groups.

Using a shared framework for setting up regional models, it is easier to compare and contrast examples of different experiments and allows for user to gain intuition for generating their chosen domain.

Another potential advantage of a package that allows users to automatically obtain regional configurations of MOM6 is in education. With the technically-challenging aspects of setting up a regional configuration now being automated by `regional_mom6` package, students can setup and run simple MOM6 regional configurations and also change parameters like resolution or forcing, run again, and see how these parameters affect the ocean flow.

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References

Adcroft, A., Anderson, W., Balaji, V., Blanton, C., Bushuk, M., Dufour, C. O., Dunne, J. P., Griffies, S. M., Hallberg, R., Harrison, M. J., Held, I. M., Jansen, M. F., John, J. G., Krasting, J. P., Langenhorst, A. R., Legg, S., Liang, Z., McHugh, C., Radhakrishnan, A., … Zhang, R. (2019). The GFDL global ocean and sea ice model OM4.0: Model description and simulation features. *Journal of Advances in Modeling Earth Systems*, *11*(10), 3167–3211. https://doi.org/10.1029/2019MS001726

Arakawa, A., & Lamb, V. R. (1977). Computational design of the basic dynamical processes of the UCLA general circulation model. *Methods in Computational Physics: Advances in Research and Applications*, *17*(Supplement C), 173–265. https://doi.org/10.1016/B978-0-12-460817-7.50009-4

Barnes, A. J. (2024). Tasman-tides. In *GitHub repository*. https://github.com/ashjbarnes/tasman-tides

Cermak, R., Simkins, J., Hedstrom, K., & Gibson, A. (2021). ESMG gridtools. In *GitHub repository*. Github. https://github.com/ESMG/gridtools

Copernicus Climate Change Service. (2024). *ECMWF Reanalysis v5*. European Centre for Medium-Range Weather Forecasts. https://doi.org/10.48670/moi-00021

Copernicus Marine Services. (2024). *Global ocean physics reanalysis*. Mercator Ocean International. https://doi.org/10.48670/moi-00021

GEBCO Bathymetric Compilation Group 2023. (2023). *The GEBCO_2023 Grid - a continuous terrain model of the global oceans and land*. NERC EDS British Oceanographic Data Centre NOC. https://doi.org/10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b

Hedstrom, K., & contributors. (2023). Pyroms. In *GitHub repository*. Github. https://github.com/ESMG/pyroms

Marshall, J., Adcroft, A., Hill, C., Perelman, L., & Heisey, C. (1997). A finite-volume, incompressible Navier Stokes model for studies of the ocean on parallel computers. *Journal of Geophysical Research: Oceans*, *102*(C3), 5753–5766. https://doi.org/10.1029/96JC02775

Naughten, K., & Jones, D. (2023). MITgcm_python. In *GitHub repository*. Github. https://github.com/knaughten/mitgcm_python

Ross, A. C., Stock, C. A., Adcroft, A., Curchitser, E., Hallberg, R., Harrison, M. J., Hedstrom, K., Zadeh, N., Alexander, M., Chen, W., Drenkard, E. J., Pontavice, H. du, Dussin, R., Gomez, F., John, J. G., Kang, D., Lavoie, D., Resplandy, L., Roobaert, A., … Simkins, J. (2023). A high-resolution physical–biogeochemical model for marine resource applications in the northwest Atlantic (MOM6-COBALT-NWA12 v1.0). *Geoscientific Model Development*, *16*(23), 6943–6985. https://doi.org/10.5194/gmd-16-6943-2023

Ross, A. C., Stock, C. A., Koul, V., Delworth, T. L., Lu, F., Wittenberg, A., & Alexander, M. A. (2024). Dynamically downscaled seasonal ocean forecasts for North American East Coast ecosystems. *EGUsphere*, *2024*, 1–40. https://doi.org/10.5194/egusphere-2024-394

Shchepetkin, A. F., & McWilliams, J. C. (2005). The regional oceanic modeling system (ROMS): A split-explicit, free-surface, topography-following-coordinate oceanic model. *Ocean Modelling*, *9*(4), 347–404. https://doi.org/10.1016/j.ocemod.2004.08.002

Zhuang, J., Dussin, R., Huard, D., Bourgault, P., Banihirwe, A., Raynaud, S., Malevich, B., Schupfner, M., Filipe, Levang, S., Gauthier, C., Jüling, A., Almansi, M., Scott, R., RondeauG, Rasp, S., Smith, T. J., Stachelek, J., Plough, M., & Li, X. (2023). xESMF: Universal regridder for geospatial data. In *GitHub repository*. Zenodo. https://github.com/pangeo-data/xESMF