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

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Summary

The Modular Ocean Model version 6 (MOM6) is a widely-used open-source general circulation ocean-sea ice model developed mainly at the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) (Adcroft et al., 2019). MOM6 contains several improvements over its predecessor MOM5 (Griffies, 2014), including the implementation of the Arbitrary-Lagrangian-Eulerian (ALE) vertical coordinates (Griffies et al., 2020), more efficient tracer advection schemes, and state-of-the art parameterisations of sub-grid scale physics. MOM6 provides support for open boundary conditions and thus is becoming popular for regional ocean modeling studies (see, e.g., Ross et al. (2023), Ross et al. (2024)) in addition to global configurations. However, setting up a regional configuration for MOM6 can be challenging, time consuming, and often involves using several programming languages, a few different tools, and also manually editing/tweaking some input files. The `regional_mom6` python package overcomes these difficulties, automatically generating a regional MOM6 configuration with relatively simple domain geometry.

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 input 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 a few other necessary steps. This allows users to setup a regional MOM6 configuration using only Python and from a single Jupyter notebook. The package allows the user to use MOM6's Arbitrary-Lagrangian-Eulerian vertical coordinates, regardless of the vertical coordinates of boundary forcing input. Rules-of-thumb to guide the user in setting grid parameters such as the regional domains resolution, can be found in the paper by Herzfeld et al. (2011).

`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 reanalysis for 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 to entry for first-time users, or those without a strong back-

ground 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., a series of perturbation experiments), saving time and effort, and improving reproducibility.

We designed `regional_mom6` with automation of regional configurations in mind. However, the package's code design and modularity 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.

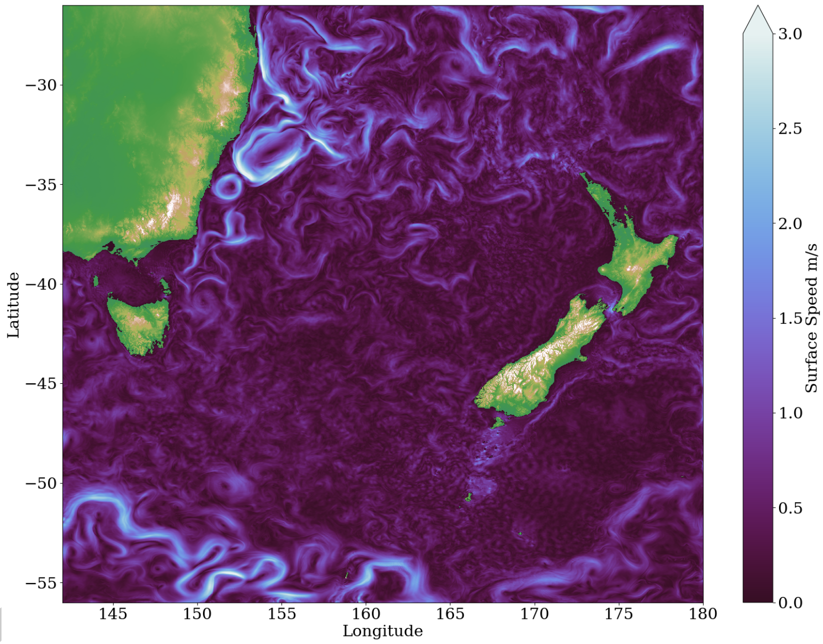

Figure 1: A snapshot of the ocean surface currents from a MOM6 regional simulation of the Tasman sea. The simulation is forced by GLORYS and ERA5 reanalysis datasets and configured with a horizontal resolution of 1/80th degree and 100 vertical levels (see Barnes (2024) for the source code).

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, and it it not obvious for a new user what inputs are required, nor the appropriate format. In the case of MOM6, there are several tools scattered in Github repositories, for example those collected in ESMG's grid tools (Cermak et al., 2021). Also, there exist several regional configuration examples but they are hardcoded for particular domains, specific input files, and work only on specific high-performance computing machines.

Until now there has been 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 in several programming languages and then modify –sometimes by hand– some of the input metadata to bring everything into the format that MOM6 expects. Many parts of this process are not documented, requiring users to dig into the MOM6 Fortran source code. Other ocean models have packages to aid in regional configuration setup, for example `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 start to finish and, ideally, automates the process on the way. `regional_mom6` fills 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 users 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 the `regional_mom6` package, students can set up 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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