




1 regional-mom6: A Python package for Automatic  
2 generation of regional configurations for the Modular  
3 Ocean Model v6

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DOI: [10.xxxxxx/draft](https://doi.org/10.xxxxxx/draft)

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Submitted: 01 January 1970

Published: unpublished

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11 **Summary**

12 regional-mom6 is a Python package that provides an easy and versatile way to set up regional  
13 configurations of the Modular Ocean Model version 6 (MOM6).

14 **Regional ocean modeling**

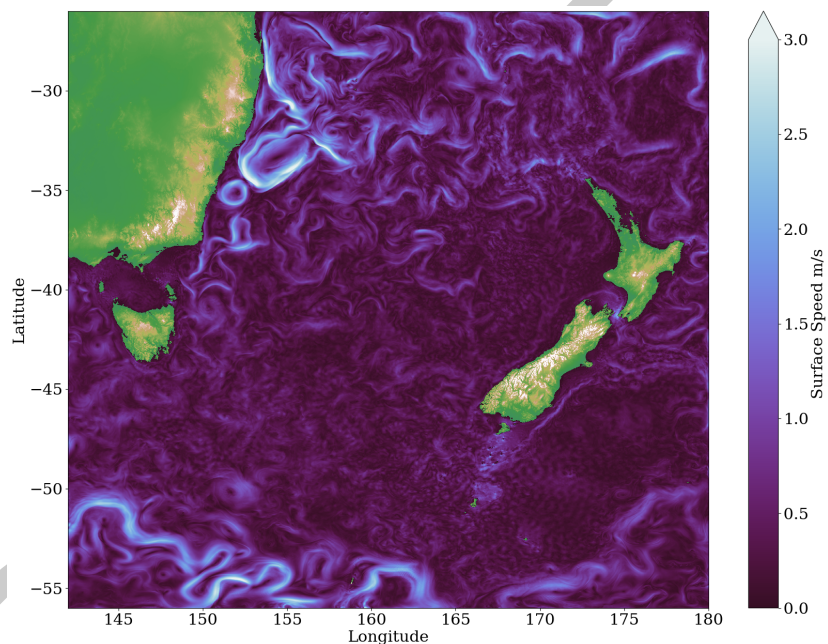
15 In the ocean, fast and small-scale motions (from ~100m to ~100km varying at time scales of  
16 hours to days) play an important role in shaping the large-scale ocean circulation and climate  
17 (length scales ~10,000km varying at decadal time scales) ([de Lavergne et al., 2022](#); [Gula et al., 2022](#); [Melet et al., 2022](#)). Despite the increase in computational power and the use of  
18 graphical processing units that can bring breakthrough performance and speedup ([Silvestri et al., 2023](#)), there are always processes, boundary, or forcing features that are smaller than the  
19 model's grid spacing and, thus, remain unresolved in global ocean models. Regional ocean  
20 models can be run at higher resolutions while limiting the required computational resources.

21 A regional ocean model simulates the ocean only in a prescribed region, which is a subset  
22 of the global ocean. To do that, we need to apply open boundary conditions at the region's  
23 boundaries, that is, we need to impose conditions that mimic the oceanic flow that we are  
24 not simulating ([Orlanski, 1976](#)). For example, [Figure 1](#) shows the surface currents from a  
25 regional ocean simulation of the Tasman sea that was configured using the regional-mom6  
26 package. The boundaries of the domain depicted in [Figure 1](#) are forced with the ocean flow  
27 from a global ocean reanalysis product. Higher-resolution regional ocean models improve  
28 the representation of smaller-scale motions, such as tidal beams, mixing, mesoscale and  
29 sub-mesoscale circulation, as well as the oceanic response to smaller-scale bathymetric or  
30 coastal features (such as headlands, islands, sea-mounts, or submarine canyons) and surface  
31 forcing (such as atmospheric fronts and convective storms). Regional modelling further allows  
32 for the “downscaling” of coarse-resolution global ocean or climate models, permitting the  
33 representation of the variation in local conditions that might otherwise be contained within  
34 only a few (or even a single!) model grid cells in a global model.

37 **Modular Ocean Model version 6**

38 MOM6 is a widely-used open-source, general circulation ocean-sea ice model, written in  
39 Fortran ([Adcroft et al., 2019](#)). MOM6 contains several improvements over its predecessor

40 MOM5 (Griffies, 2014), including the implementation of the Arbitrary-Lagrangian-Eulerian  
 41 vertical coordinates (Bleck, 2002; Griffies et al., 2020), more efficient tracer advection schemes,  
 42 and state-of-the art parameterizations of sub-grid scale physics. Pertinent for our discussion,  
 43 MOM6 provides support for open boundary conditions and thus is becoming popular for regional  
 44 ocean modeling studies (see, e.g., Ross et al. (2023), Ross et al. (2024)) in addition to global  
 45 configurations. However, setting up a regional configuration for MOM6 can be challenging,  
 46 time consuming, and often involves using several programming languages, a few different tools,  
 47 and also manually editing/tweaking some input files. The regional-mom6 package overcomes  
 48 these difficulties, automatically generating a regional MOM6 configuration of the user's choice  
 49 with relatively simple domain geometry, that is, rectangular domains.



**Figure 1:** A snapshot of the surface ocean currents from a regional ocean simulation of the Tasman sea using MOM6. The simulation is forced by the 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).

## 50 regional-mom6

51 The regional-mom6 package takes as input various datasets that contain the ocean initial  
 52 condition, the boundary forcing (ocean and atmosphere) for the regional domain, and the  
 53 seafloor topography. The input datasets can be on the Arakawa A, B, or C grids (Arakawa  
 54 & Lamb, 1977); the package performs the appropriate interpolation using xESMF (Zhuang  
 55 et al., 2023) under the hood, to put the everything on the C grid required by MOM6. This  
 56 base grid for the regional configuration can be constructed in two ways, either by the user  
 57 defining a desired resolution and choosing between pre-configured options, or by the user  
 58 providing pre-existing horizontal and/or vertical MOM6 grids. The user can use MOM6's  
 59 Arbitrary-Lagrangian-Eulerian vertical coordinates, regardless of the native vertical coordinates  
 60 of the boundary forcing input. The package automates the re-gridding of all the required  
 61 forcing input, takes care of all the metadata encoding, generates the regional grid, and ensures  
 62 that the final input files are in the format expected by MOM6. Additionally, the tricky case  
 63 of a regional configuration that includes the 'seam' in the longitude of the raw input data  
 64 (e.g., a 10°-wide regional configuration centred at Fiji (178°E) and forced by input with  
 65 native longitude coordinate in the range 180°W–180°E) is handled automatically, removing  
 66 the need for any preprocessing of the input data. This automation allows users to set up a

67 regional MOM6 configuration using only Python and from the convenience of a single Jupyter  
68 notebook. Herzfeld et al. (2011) provide rules of thumb to guide the user in setting regional  
69 grid parameters such as the resolution.

70 regional-mom6 is installable via conda, it is continuously tested, and comes with extensive  
71 documentation including tutorials and examples for setting up regional MOM6 configurations  
72 using publicly-available forcing and bathymetry datasets (namely, the GLORYS dataset for ocean  
73 boundary forcing (Copernicus Marine Services, 2024), the ERA5 reanalysis for atmospheric  
74 forcing (Copernicus Climate Change Service, 2024), and the GEBCO dataset for seafloor  
75 topography (GEBCO Bathymetric Compilation Group 2023, 2023)).

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

82 We designed regional-mom6 with automation of regional configurations in mind. However,  
83 the package's code design and modularity make more complex configurations possible since  
84 users can use their own custom-made grids with more complex boundaries and construct the  
85 boundary forcing terms one by one.

## 86 Statement of need

87 The learning curve for setting up a regional ocean model can be steep, and it is not obvious  
88 for a new user what inputs are required, nor the appropriate format. In the case of MOM6,  
89 there are several tools scattered in Github repositories, for example those collected in Earth  
90 System Modeling Group grid tools (Simkins et al., 2021). Also, there exist several regional  
91 configuration examples but they are hardcoded for particular domains, specific input files, and  
92 work only on specific high-performance computing machines (e.g., Ross et al. (2023)).

93 Until now there has been no one-stop-shop for users to learn how to get a regional MOM6  
94 configuration up and running. Users are required to use several tools in several programming  
95 languages and then modify – sometimes by hand – some of the input metadata to bring  
96 everything into the format that MOM6 expects. Many parts of this process are not documented,  
97 requiring users to dig into the MOM6 Fortran source code. Recently, the Climate, Ecosystems  
98 and Fisheries Initiative gathered some tools into a single repository (Teng et al., 2023) but, at the  
99 moment, they are written for specific inputs and computational environment and not installable  
100 as a Python package. Other ocean models have packages to aid in regional configuration setup,  
101 for example Pyroms (Hedstrom & contributors, 2023) for the Regional Oceanic Modelling  
102 System (ROMS; Shchepetkin & McWilliams (2005)) and MITgcm\_python (Naughten & Jones,  
103 2023) for the Massachusetts Institute of Technology General Circulation Model (MITgcm;  
104 Marshall et al. (1997)). With MOM6's growing user base for regional applications, there is  
105 a need for a platform that walks users through regional domain configuration from start to  
106 finish and, ideally, automates the process on the way. Other than reducing the barrier-to-entry,  
107 automating the regional configuration process renders the workflow much more reproducible;  
108 see discussion by Polton et al. (2023). regional-mom6 precisely meets these needs.

109 By having a shared set of tools that the community can work with and contribute to, this  
110 package also facilitates collaboration and knowledge-sharing between different research groups.  
111 Using a shared framework for setting up regional models, it is easier to compare and contrast  
112 examples of different experiments and allows for users to gain intuition for generating their  
113 chosen domain.

114 regional-mom6 package can also be used for educational purposes, for example as part of  
115 course curricula. With the technically-challenging aspects of setting up a regional configuration

116 now being automated by the regional-mom6 package, students can set up and run simple  
117 MOM6 regional configurations and also change parameters like the model's resolution or the  
118 forcing, run again, and see how these parameters affect the ocean flow.

## 119 Acknowledgements

120 We thank the vibrant community of the Consortium for Ocean–Sea Ice Modeling in Australia  
121 ([cosima.org.au](https://cosima.org.au)) and also Josué Martínez-Moreno and Callum Shakespeare for useful discussions  
122 during the development of this package. We acknowledge support from the Australian Research  
123 Council under DECRA Fellowship DE210100749 (N.C.C.) and grant LP200100406 (A.E.K.).  
124 We would also like to acknowledge the code and notes by James Simkins, Andrew Ross, and  
125 Rob Cermak, which helped us to troubleshoot and improve the algorithms in our package.

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