# Antarctic melt: Where will an eddying ocean take it?

## Role of Southern Ocean Eddies in a Warming Climate

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### In Short


- Nesting a 1/10° Southern Ocean in a coupled climate model
- Identifying redistribution pathways of Antarctic meltwater
- Quantifying the importance of mesoscale dynamics in the ocean's response to enhanced melting of the Antarctic Ice Sheet


The Southern Ocean (SO) is a key region of the global ocean circulation because it connects all larger basins, it is a primary sink for anthropogenic heat and carbon [1,2], it receives all runoff and discharge from the Antarctic Ice Sheet (AIS), and it is the source region of bottom water. The AIS is a giant freshwater source at the southern margin of the SO, which will affect more than just sea level when melting massively.

Unrestricted in zonal extent the Antarctic Circumpolar Current (ACC) constitutes a strong dynamic barrier for meridional exchange and so does its counterpart, the Antarctic Slope Current along the continental margin. While the former inhibits direct meridional exchange of the SO with lower latitudes, the latter controls interaction between the shelf seas and the open SO and is thus of critical importance to meltwater export.

The large-scale upwelling, ventilation and transformation of old deep waters make the SO a primary player in the global heat and carbon budgets. Sound estimates of the role of its highly energetic dynamics at the mesoscale (10–100 km) are still missing despite great advances in observational programs. High-resolution models are needed to understand and quantify the role of eddies in the long-term response of the SO to a warming climate.

We conduct a series of experiments with a global climate model featuring 2-way nesting in the SO (Figure 2). The grid refinement (from 1/2° to 1/10°) enables the explicit simulation of mesoscale dynamics. We apply this model to address the following research hypotheses:

- Mesoscale eddies significantly enhance **heat uptake** by the Southern Ocean.

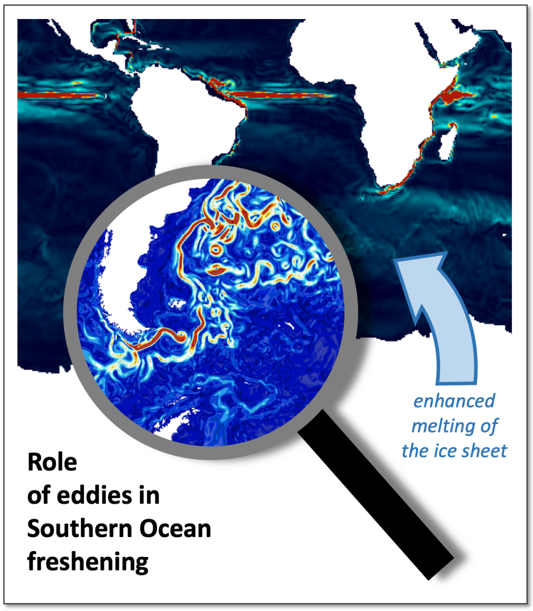


***Figure 1:*** *Zooming in on ocean dynamics: snapshot of surface velocities (range 0–1 m/s) without and with high-resolution nest.*

- The response of the Southern Ocean to an **increased freshwater flux** from Antarctica is determined by mesoscale dynamics.

All simulations will be carried out with GEOMAR's Flexible Ocean and Climate Infrastructure (FOCI). FOCI consists of the components NEMO3.6 and LIM2 for ocean and sea ice and ECHAM6.3 and JSBACH for atmosphere and land surface [3]. While the ocean runs on the ORCA05 1/2° grid with 46 vertical levels, atmospheric processes are computed on a coarser T63 (1.9°) grid but with 95 vertical levels and a high top level of 0.01 hPa (80 km). The hourly coupling is carried out using OASIS3-MCT.

In nested FOCI configurations, the regional ocean nest is forced at the surface with the same fluxes as passed to the global ocean by the coupler and at its sides by the ocean state of the global model. The global model is adjusted before every timestep to the 3-D ocean state of the high-resolution nest.

A suite of dedicated, systematic multi-decadal experiments under pre-industrial climate conditions is carried out to identify (a) the implications of meltwater entering the ocean at the surface or at depth (due to basal ice-shelf melt) as well as along the coast or spread laterally by icebergs, (b) the impact of open ocean deep convection typical for climate models but rarely observed in the SO, and (c) the importance of mesoscale ocean dynamics for the redistribution of increased meltwater input from Antarctica.

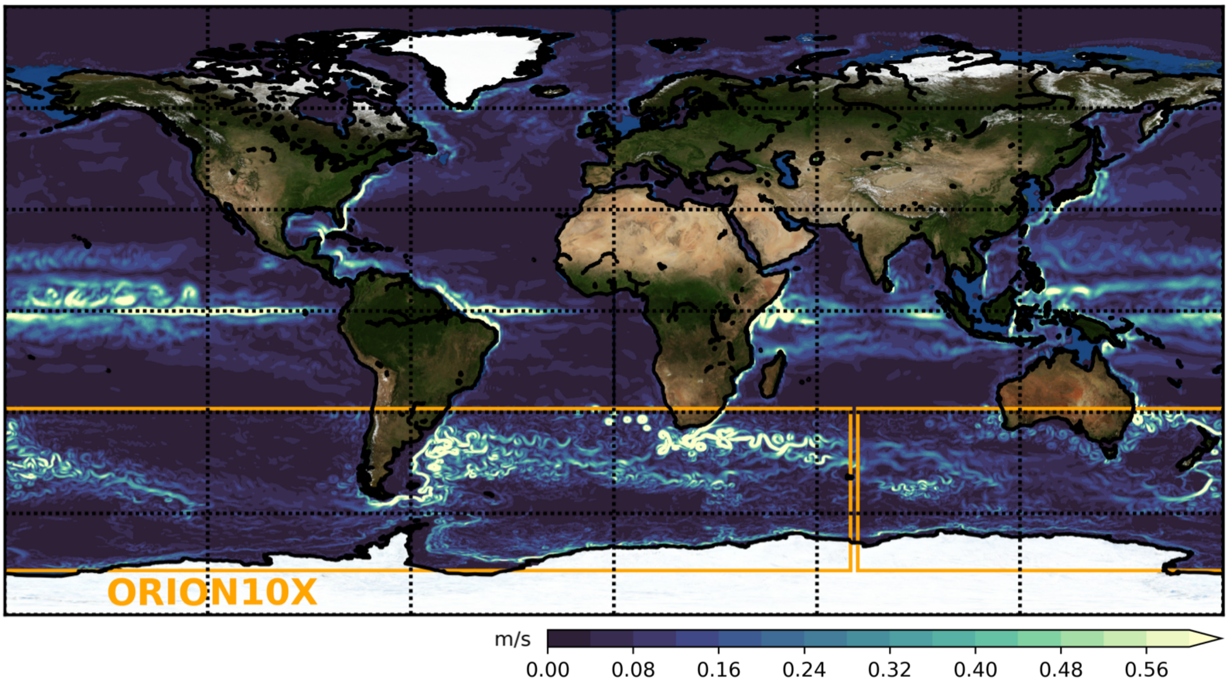


***Figure 2:*** *Snapshot of ocean current speeds at 100 m depth from the global climate model FOCI-ORION10X with 1/2° ocean grid and 1/10° regional refinement by 2-way nesting (ORION10X). The nest region is highlighted by the orange outline.*

In a second tier of experiments using a CMIP6-compatible warming scenario, we will study the emergence and robustness of the meltwater responses under global climate change in the $21^{st}$ century. Here, we apply a gradually increasing meltwater forcing with a 10-fold increase over 100 years unitl 2100 [4].

The role of mesoscale ocean dynamics is addressed by running all experiments without and with high-resolution nesting. The nest region is generously chosen to cover the entire SO from the Antarctic coast, across the ACC and into the other ocean basins for a complete representation of mesoscale effects on meltwater pathways, heat uptake and exchanges with lower latitudes (Figure 2). Using a strongly eddying model advances recent studies [4–6] and provides important new insights on the SO system.

The simulations contribute to the BMBF project PalMod2. We are particularly interested in decadal to centennial timescales, which requires unprecedented long integrations with such a high-resolution model.

## WWW

https://www.geomar.de; https://www.palmod.de

## More Information

[1] T. Frölicher et al. (2015) Dominance of the Southern Ocean in Anthropogenic Carbon and Heat Uptake in CMIP5 Models. doi:10.1175/JCLI-D-14-00117.1

[2] D. Roemmich et al. (2015) Unabated planetary warming and its ocean structure since 2006. doi:10.1038/NCLIMATE2513

[3] K. Matthes et al. (2020) The Flexible Ocean and Climate Infrastructure version 1 (FOCI1): mean state and variability. doi:10.5194/gmd-13-2533-2020

[4] S. Mackie et al. (2020) Climate Response to Increasing Antarctic Iceberg and Ice Shelf Melt. doi:10.1175/JCLI-D-19-0881.1

[5] B. Bronselaer et al. (2018) Change in future climate due to Antarctic meltwater. doi:10.1038/s41586-018-0712-z

[6] W. Park and M. Latif (2019) Ensemble global warming simulations with idealized Antarctic meltwater input. doi:10.1007/s00382-018-4319-8

## Funding

This reasearch is performed within the framework of the PalMod project phase 2 (01LP1918C), supported by the German Federal Ministry of Education and Research (BMBF) as Research for Sustainability initiative (FONA).