MixClim: Exploring diapycnal mixing in the Southern Ocean

Marie Curie intra-European Fellowship for
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Background and project objectives

Because they control the rate at which water sinking at high latitudes returns to the surface in the Southern Ocean, mixing processes govern the capacity of the Southern Ocean to take up CO_2 and determine the sensitivity of the Meridional Overturning Circulation (MOC) to climate change. Mixing processes also play a key role in the formation and meridional transport of Southern Ocean mode and intermediate waters. Recent in situ estimates of turbulent mixing indicate remarkably intense and widespread turbulent kinetic energy dissipation in four Southern Ocean "hotspots". Three different processes (tidal and mean flows interacting with sea-floor topography and forcing by winds at the ocean surface) generate internal waves that lead to mixing when they break, but their relative contributions both in terms of their magnitude and distribution in the vertical remain unclear. Furthermore, these processes are not taken into account in climate and ocean circulation models.

The aim of the present project is to quantify the mixing in the Southern Ocean interior and to parameterise its effects within ocean models. To determine the distribution of energy of the internal tide, tidal forcing has been added to a realistic high-resolution ocean general circulation model (OGCM). The results of this study will be used to create parameterisations of tidal mixing in coarser OGCMs used in climate studies in order to assess the impact of mixing in the Southern Ocean on the MOC and CO_2 uptake. The parameterisations will be tested and refined by the comparison of model data with historical measurements and ARGO float data. This modelling study is very timely since it benefits and complements observations currently being made by the National Oceanography Centre, Southampton (NOCS): the SOFINE (Southern Ocean FINEstructure) project that has measured vertical diffusivity in the Kerguelen region and the DIMES (Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean) cruises that will measure isopycnal and diapycnal mixing in the South East Pacific, Drake Passage and the Scotia Sea

Results achieved and expected impact

Global simulation using the NEMO (Nucleus for European Modelling of the Ocean) model and forced by the tidal potential has been run at ¼° resolution in collaboration with Andrew Cowards (NOCS) using the high-performance computing resources of the NOCS. The main difficulties when introducing the tidal forcing in general circulation models are the necessity of resolving the barotropic variables at higher temporal resolution than the usual baroclinic fields. We have also developed an energy budget analysis to quantify the barotropic and baroclinic tidal energy evolution as well as the conversion between them. Figure 1 (left panel) shows the conversion rate from barotropic to baroclinic tides. It reproduces well the main areas of generation of internal tides, over mid-ocean ridges and along the slope of the continental shelf, in good agreement with previous studies. Figure 1 (right panel) shows the energy associated with the internal tide. Bands of high energy indicate the propagation of waves away from the generation sites.

In the Southern Ocean elevated levels of baroclinic tidal energy are seen in the Scotia Sea, to the southwest of New Zealand, and over the South Atlantic and Southeast Indian mid-ocean ridges

The spatial resolution is sufficient to start resolving the propagation of the longest internal tides and analyse part of the interaction of the waves and its environment, but the main processes of this interaction and of the propagation are not resolved. We plan to increase the resolution of this simulation first to 1/12° and then 1/36°. At the end we will have a good picture of the 3D distribution of the energy associated with the propagation of the internal tides that will help us to construct parameterisations of their dissipation in ocean or climate models that do not resolve such processes.

Overall, the project will lead to improvements in European modelling capability with the NEMO ocean model system. This will have benefits for operational ocean forecasts (with applications such as marine management and naval operations), and for climate forecasting.

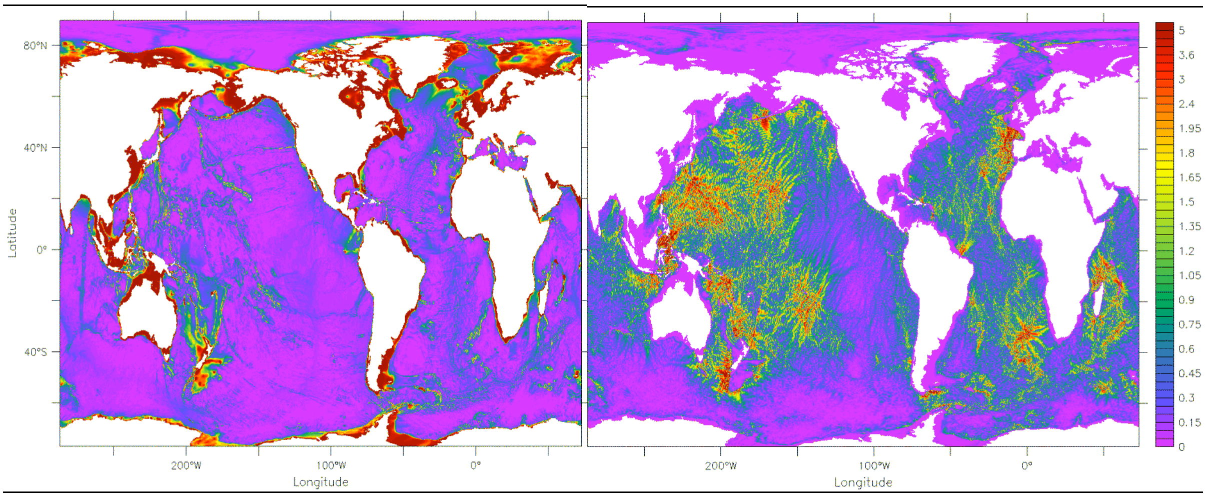

Figure 1: Left: conversion rate from barotropic to baroclinic tides for M2 constituent, ie. generation of internal tides. Right: vertically integrated 3D baroclinic energy of M2 constituent, ie. propagation of internal tides.