FOCI - a new climate model

Coupled climate modeling with a high resolution ocean

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In Short

- New state-of-the-art coupled climate model with a high-resolution nested ocean at GEOMAR
- Role of an active atmosphere on the effect of mesoscale ocean eddies on decadal variability of the large-scale oceanic circulation
- First study with a high-resolution nest in the Indian/South Atlantic Ocean

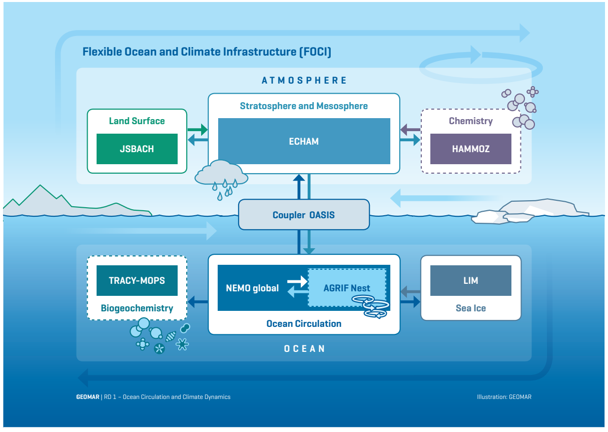

***Figure 1:** Schematic of the new model system at GEOMAR: Flexible Ocean and Climate Infrastructure - FOCI. Some components are optional.*

Mesoscale eddies are one of the most important features for the dynamic of major current systems. They also play a crucial role for the decadal variability of the global overturning circulation [1]. Yet, most ocean general circulation models still have too coarse resolution to explicitly resolve such mesoscale eddies; even most modern climate models rely on parameterizations of the eddy effect [2]. By increasing spatial resolution over the global domain to 1/10° and finer, the mesoscale can be captured at the expense of extreme computational costs and hence comparably short simulations.
Our approach is to increase ocean resolution in specific and outstanding areas of interest: so-called regional nesting (AGRIF [3]).
At GEOMAR we successfully implemented high resolution ocean nesting into a fully coupled atmosphere-ocean climate model, depicted schematically in Fig. 1. With the Flexible Ocean and Climate Infrastructure (FOCI) we can for the first time study ocean-atmosphere feedbacks in an eddying ocean and start to assess their importance for decadal climate variability.

A great advantage of the ocean nesting is its lower computational costs, as compared to globally high-resolved ocean, and hence the ability to perform series of multi-decadal simulations.
The global ocean, based on current NEMO 3.6 code, has a 1/2° spatial resolution (ORCA05), while in the nested area resolution increases to 1/10°. A first ocean nest has been configured in the Indian and South Atlantic Ocean *INALT10x* (70°W-70°E, 60°S-10°N, detailed description of precursor nest INALT01 in [4]). In the mean time, a second independent nest has been configured in the North Atlantic (VIKING10, project shk00029) focusing on the sensitivity of the climate system to freshwater input into the sub-polar North Atlantic (Greenland melting).
The atmosphere model ECHAM (version 6.3) has a horizontal resolution of T63 ($\sim$1.875°) and 95 vertical levels with a top level at 0.01hPa (80km). JSBACH deals with all land processes and does also provide river runoff for the ocean.
Exchange of momentum, sea-ice properties and heat and freshwater fluxes between both components is performed by the OASIS3-MCT coupler. Technically, the atmosphere receives the interface fields from the global ocean base grid, but a 2-way-nesting technique ensures, that information from inside the high resolution nest transfer to the coarser base model grid.
In this project our main focus lies on the impact of mesoscale ocean eddies on decadal variability of the large-scale oceanic circulation and in particular the role of an active atmosphere. With the new coupled model and the INALT10x nest we want to explore the role of mesoscale eddies for atmosphere-ocean interactions.
For our studies, the global coupled (non-nested) model is integrated under pre-industrial climate conditions for 1500 year to spin-up the climate system. The INALT10x nest experiment is from thereon integrated for another 160 years under pre-industrial and historical climate conditions. The INALT10x nested configuration runs on 53 nodes for approximately 2:30 hours to calculate a total of 76.6 mil ocean grid points, while the non-nested version needs only 43 minutes on 40 nodes for 16.9 mil ocean grid points, to simulate one model year.

Resolving smaller ocean scales reduces a

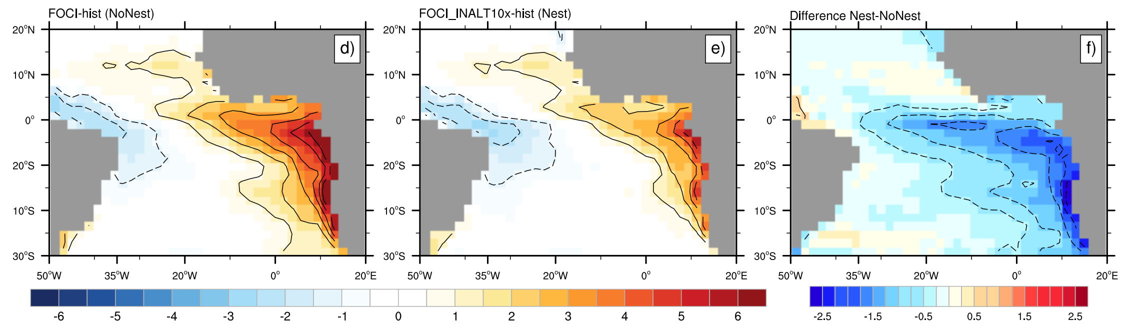

Figure 2: *Evolution of Sea Surface Temperature (SST) bias in boreal summer compared to HadISST (1980-2013), for d) FOCI non-nested, e) FOCI INALT10x nest and f) difference.*

prominent bias in current state-of-the-art climate models [7], the sea surface temperature (SST) warm bias in the tropical Atlantic, significantly, Fig. 2. The SST bias in the non-nested FOCI closely resembles the ensemble mean of the climate models participating in CMIP5, in terms of pattern size and magnitude. The cooling in the equatorial and Benguela upwelling region by about 2 K, Fig. 2f, is also reflected in improved precipitation and wind pattern along the equatorial Atlantic (not shown).

We would like to analyze the role of an active atmosphere on the impact of Agulhas mesoscale on the Atlantic Meridional Overturning Circulation (AMOC) as just high-resolution models reproduce the observed salt import into the Atlantic that impacts stability of the Gulf Stream system [5]. In the performed experiments so far, AMOC at 26°N has a strength of about 18 Sv in non-nested and nested FOCI. A secondary spin-up time of 50-60 years became apparent in the nested coupled experiments, that needs to be taken into account in future experiments.

Our research will further focus on ocean resolution dependence for e.g. tropical Atlantic warming [6] or Benguela upwelling in the context of coupled atmosphere-ocean feedbacks.

WWW

http://www.geomar.de/go/ocean-models

More Information

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[4] J.V. Durgadoo, B.R. Loveday, C.J.C Reason, et al., Agulhas Leakage Predominantly Responds to the Southern Hemisphere Westerlies. *J. Phys. Oceanogr.* **43**, (2013). doi: 10.1175/JPO-D-13-047.1

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