RELOCATABLE OCEAN MODELLING FOR DOWNSCALING TO THE SHELF AND COASTAL AREAS

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Abstract

A new operational service is being developed for the provision of high resolution oceanographic forecast data for safety of offshore operations. The service includes the provision of high-resolution ocean sea level, currents, temperature and salinity forecasts at 1/64° resolution in the following areas: Gulf of Mexico, Caribbean Sea, Britain, Mediterranean, Black Sea, Caspian Sea, Red Sea, Guinea Gulf, Angola, Mozambique, South China Sea and Australia.

The nested model is the Structured and Unstructured grid Relocatable ocean platform for Forecasting (SURF, Trotta et al., 2016) that is a modelling system rapidly deployable in any world ocean region based upon the NEMO code. The present implementation considers the nesting of SURF in the large-scale Global Ocean Forecasting System (GOFS16) at 1/16° resolution (Iovino et al., 2016, 2017) and a horizontal grid resolution of 1/64° with about 100 vertical levels.

Keywords: relocatable ocean model, nested ocean model

1. Introduction

The Structured and Unstructured Relocatable ocean model for Forecasting, SURF, (Trotta *et al.*, 2016) provides a numerical platform for the short-time forecasts of hydrodynamic and thermodynamic ocean fields in limited regions at high spatial and temporal resolutions. The system is designed to be nested in any portion of a large-scale ocean prediction system and can be rapidly implemented in any region of the word by taking specific choices of model parameters with respect to the nesting model. It represents a component of an advanced decision support system to increase safety of offshore operations, oil spill forecasting, search and rescue operations, navigation routing such as described by Coppini *et al.*, (2017).

SURF has been already implemented in various regions in the Mediterranean Sea where it has been coupled with the large-scale ocean prediction system, called Mediterranean Forecasting System-MFS (Pinardi and Coppini, 2010). In the Tuscan Archipelago during the Serious Game oceanographic campaign carried out from 17 to 21 May 2014 (Trotta *et al.*, 2016) and in the Gulf of Taranto during the Mrea14 campaign from 1 to 11 October 2014 (Trotta *et al.*, 2017). Using the CTD data collected during the observational surveys, SURF has been shown to improve the forecasts and simulations compared to the coarse-resolution MFS model.

The aim of this study is to realize a new operational oceanography service which will provide operational forecasts of the circulation in several areas of the world with horizontal grid resolutions 1/64° and about 100 vertical levels, starting from 1/16 and 98 levels GOF16 forecasts and analyses. Fig. 1 shows the SURF model domain of all proposed areas.

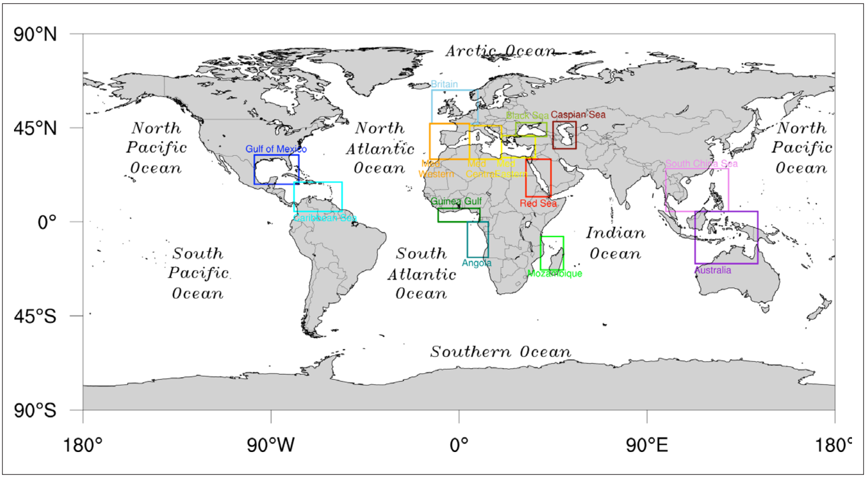

Fig. 1. The fourteen SURF model domains: Gulf of Mexico, Caribbean Sea, Britain, Mediterranean (western, central and eastern), Black Sea, Caspian Sea, Red Sea, Guinea Gulf, Angola, Mozambique, South China Sea and Australia.

2. Nested-Grid Ocean Circulation Modellig System

SURF provides a numerical platform for the short-time forecasts of hydrodynamic and thermodynamic fields in limited regions at high spatial and temporal resolutions. In this application it is nested in 14 regions of a large-scale Global Ocean Forecasting System at 1/16° resolution (GOFS16; Iovino *et al.*, 2016, 2017). The parent coarse-grid model provides initial and lateral boundary conditions for the SURF child model application. SURF requires an initial spin up period from a few days to a week in order to develop the new dynamical structures allowed by the higher resolution starting from the initial interpolated fields of the parent model. The SURF workflow connects the NEMO simulation code (Madec, 2008) to several pre- and post-processing procedures, making each platform component easy to deploy in a limited region which is part of the parent model domain where SURF is nested.

NEMO solves the three-dimensional (3D) primitive free-surface ocean equation under hydrostatic and Boussinesq approximations along with turbulence closure schemes and a nonlinear equation of state, which couples the two active tracers (temperature and salinity) to the fluid velocity. The 3D space domain is discretised by an Arakawa-C grid where the model state variables are horizontally and vertically staggered. In the vertical direction, we use stretched z-coordinates distributed along the water column, with appropriate thinning designed to better resolve the surface and intermediate layers and partial cells parameterisation in order to fit the real bathymetry.

Density is computed according to Jackett and McDougall's nonlinear equation of state. A horizontal biharmonic operator was used for the parameterisation of lateral subgrid-scale mixing for both tracers and momentum. The horizontal eddy diffusivity and viscosity coefficients were parameterised as a function of the parent coarse resolution model. If a0 is the parent biharmonic viscosity or diffusivity, the nested model equivalent coefficient is initially set to $a = a0 (\Delta xF / \Delta xL)^4$, where ΔxF is the nested, SURF grid spacing and ΔxL is the large-scale, parent model grid resolution.

The vertical eddy viscosity and diffusivity coefficients were computed following the Pacanowsky and Philander's Richardson number-dependent scheme. For cases where unstable stratification is a possibility, a higher value (10 m^2/s) is used for both the viscosity and diffusivity coefficients.

The Monotonic Upstream Scheme for Conservation Laws (MUSCL) is used for the tracer advection and the Energy and Enstrophy conservative (EEN) scheme is used for the momentum advection. No-slip conditions on closed lateral boundaries are applied and the bottom friction is parameterised by a quadratic function. The surface air-sea fluxes are computed through the CORE formulas as implemented in GOFS16.

The open boundary conditions are: for the barotropic velocities, the Flather scheme is used, while for the baroclinic total velocities, active tracers and sea surface height, the flow relaxation scheme is used. In the future all these choices will be managed by a machine learning algorithm that will choose the best values of the free model parameterizations for the child model.

3. Conclusions

An innovative oceanographic service has been implemented in several regional and coastal areas of the world ocean at 1/64o resolution using the Structured and Unstructured Relocatable ocean model for Forecasting-SURF based on the NEMO code. SURF is nested within the GOFS16 global ocean operational forecasting model and can produce 5 days forecasts every day. The high-resolution ocean forecast data will be provided to the offshore oil spill companies in order to define optimal and safer conditions of work at sea and in the future establish risk and hazard mapping.

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