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The effects of nonhydrostaticity on the simulated exchange flow through the Strait of Gibraltar

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The Mediterranean Sea is a semi-enclosed basin displaying an active thermohaline circulation (MTHC) that is sustained by the atmospheric forcing and controlled by the narrow and shallow Strait of Gibraltar (hereinafter SoG). The atmospheric forcing drives the Mediterranean basin toward a negative budget of water and heat, and toward a positive budget of salt. Over the basin, evaporation exceeds the sum of precipitation and rivers discharge, while through the surface a net heat flux is transferred to the overlying atmosphere. Mass conservation in the basin represents the last ingredient necessary to activate the MTHC.

Within the SoG the MTHC takes the form of a two-way exchange: at surface fresh and relatively warm Atlantic water spreads in the Mediterranean basin, while at the bottom colder and saltier Mediterranean water sinks as a tongue in the North Atlantic at intermediate depths becoming one of the factors preconditioning the surface water column of the convective cells in the North Atlantic.

The interaction between the intense tidal forcing and the complex geometry of the SoG influences the two-way exchange via hydraulic control. The exchange is subjected to vigorous mixing and entrainment as well as intermittent hydraulic controls over the main sills and in narrowest sections.

In the last years the exchange through the SoG has been studied by means of numerical models of different complexity. Among others, the only three-dimensional model ables to reproduce in a quite realistic way the transports and hydraulic regimes was the one based on the sigma-coordinate Princeton Ocean Model.

Such model has been used in the recent past to test the applicability of the classical two-layer one-dimensional hydraulic theory to the SoG as well as the most recent three-layer two-dimensional hydraulic theory. The model has been also used to asses the Mediterranean outflow at the western end of the SoG in a combined observational and modeling work.

In these works it has been demonstrated that POM is able to capture most of the main features of the exchange flow through the SoG. However, some features were poorly simulated. In particular the hydrostatic assumption made POM unable to properly simulate the internal tidal wave train propagation.

The primary objective of this work is to show, for the first time, the effects produced by the hydrostatic limitation on the simulated SoG two-way circulation, in terms of transports, bore propagation and hydraulics.

To this aim, a detailed comparison between the circulation simulated by POM and a very high resolution (less than 50 m), non-hydrostatic, z-coordinate numerical model, based on the MITgcm, will be shown.

Here we stress that the non-hydrostatic version of the MITgcm, when implemented at very high resolution, is able to explicitly capture the largest-scale mixing processes responsible for entrainment. In other words the presented MITgcm model represents the first mixing permitting model used to study the SoG circulation.

Consequently the results that will be presented provide a benchmark against which other models at lower resolution may be compared.