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Investigating vertical mixing and lateral diffusion parameterizations in the Mediterranean Sea

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The Mediterranean Sea, with its unique characteristics as a semi-enclosed and highly stratified basin, serves as a natural laboratory for studying oceanic processes of global relevance. Vertical mixing is a fundamental process regulating the transfer of mass, heat, and nutrients between water column layers, influencing dynamical and biogeochemical processes, and controlling the exchange with the overlying atmosphere. Due to its turbulent nature acting on small spatial and temporal scales, vertical mixing remains challenging to simulate in modern ocean circulation models. Moreover, the interaction between vertical mixing and horizontal diffusion/advection is essential in shaping the transport and distribution of heat, nutrients, and pollutants in marine environments. Finding the optimal vertical mixing parameterizations alongside horizontal advection and diffusion schemes in an ocean circulation model, able to simulate the available observations, presents significant challenges due to the need for consistent scaling, numerical stability, and accurate representation of multi-scale processes.

Here, we use the same system setup as the Mediterranean Forecasting System of the Copernicus Marine Service, that is NEMO (v4.2) general circulation model, including tides, coupled with the WaveWatch III wave model. The model features a horizontal resolution of $1/24^\circ$ (approximately 4 km) and 141 unevenly spaced vertical levels. We investigate the performance of different numerical vertical closure schemes – a Richardson-number-dependent, a one-equation and a two-equation models – as well as the effect of different lateral advection and diffusion schemes. The role played by the enhanced vertical diffusion due to Camarinal Sill at the Strait of Gibraltar in controlling the exchange of water masses between the Atlantic Ocean and the Mediterranean Sea is also investigated. We validate our model by assessing our ability to reproduce physical processes and by comparing it with in-situ data throughout the Mediterranean basin, across varying seasons and years.