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The development of an advanced vertical discretisation scheme for a regional ocean model

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When designing an ocean model, the choice of the vertical coordinate system must be pursued very carefully (Griffies et al., 2000); especially in those regional areas where local multi-scale processes interact with large-scale oceanographic features. Three main vertical coordinates are usually used in ocean modelling, namely the geopotential, terrain-following and isopycnic, but each one presents its own limitations and strengths. In the last decades, much research has been spent to investigate and develop hybrid approaches able to combine the advantages of each vertical coordinate system but minimising their disadvantages.

Here we propose the hybrid s-s-z vertical discretisation scheme, an advanced version of the approach used by Shapiro et al. (2013). In our new scheme, the vertical domain is divided into three zones: in the upper and middle zones use s-coordinates while the deeper zone uses z-levels. The s-s-z vertical grid is introduced into the NEMO (Nucleus for European Modelling of the Ocean) model code and we compare the model skill of our new vertical discretisation scheme with the NEMO vertical grid using z-levels with partial steps through a set of idealized numerical experiments for which analytical solutions or theoretical models exist.

Modelling results demonstrate that the magnitude of spurious currents arising from the horizontal pressure gradient errors are of the same order (10ˆ-3 m/s) both with z-partial steps or with s-s-z vertical grids for the conditions favourable for the geopotential grids (horizontal initial density levels). For a number of more realistic conditions representing a general cyclonic circulation in the sea, the new discretisation scheme produces smaller spurious currents and hence is more accurate than the z-level approach. Moreover, the enhanced capability of the s-s-z scheme to reproduce dense water cascades as compared to the z-partial steps grid is shown. Finally, we show how the new s-s-z grid can be useful to improve lateral sub-grid-physics parametrisation in ocean model with s-levels.

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