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$\tilde{z}$-coordinate, an Arbitrary Lagrangian-Eulerian coordinate separating high and low frequency motions

Matthieu Leclair (1) and Gurvan Madec (1,2)

(1) Laboratoire d'Océanographie et du Climat: Expérimentation et Approches Numériques - Institut Pierre Simon Laplace (LOCEAN-IPSL), Paris, France (matthieu.leclair@locean-ipsl.upmc.fr), (2) National Oceanography Centre, Southampton (NOCS), Southampton, United Kingdom (gurvan.madec@locean-ipsl.upmc.fr)

Until recently, primitive equation ocean models were unavoidably using one of the three main historical vertical coordinates: the geopotential(z-) coordinate, the terrain following (σ-) coordinate and the isopycnal (ρ-) coordinate (Griffies et al., 2000a). The first two describe vertical motions in a purely Eulerian way, while the last one is a purely Lagrangian vertical coordinate.

None of them being obviously more suitable than the others, the general tendency in the ocean modelling community is to express the primitive equations in an Arbitrary Lagrangian Eulerian (ALE) vertical coordinate and try to optimize its properties. The HYCOM model, mostly based on a ρ-coordinate, was the first model using an ALE vertical coordinate. The later is isopycnal in the ocean interior and evolves toward geopotential and terrain-following coordinates respectively in the vicinity of the ocean surface and bottom (Bleck, 2002; Halliwell, 2004). Other ALE coordinates appeared more recently. White et al.(2009) developed a coordinate based on high order regridding and remapping schemes. Hofmeister et al.(2004) produced an adaptive σ-based coordinate allowing vertical resolution to follow strong shear and stratification regions.

The $\tilde{z}$-coordinate presented here is an ALE coordinate determined by temporal rather than spacial considerations. It aims at following barotropic and high frequency baroclinic vertical motions in a Lagrangian way and allow cross-level velocities for the description of low frequency ones. It can thus be seen as a generalisation of the z^*-coordinate that treats barotropic vertical motions in a Lagrangian way (Stacey et al., 1995; Adcroft and Campin, 2004) to low frequency baroclinic motions.

The coordinate is designed so that it keeps the z-coordinate advantages at low frequencies and benefits of the isopycnal coordinate qualities at high frequencies. Staying in a z-coordinate like framework at low frequencies allows the truncation error on the hydrostatic pressure gradient to remain negligibly weak and preserves an accurate treatment of the surface boundary layer and the non linear equation of state while the Lagrangian behaviour at high frequencies addresses the spurious diapycnal mixing issue present in z-level models (Griffies et al., 2000b).

An idealized experiment illustrates this property in an internal wave propagation framework. The spurious diapycnal mixing is reduced compared to a z-coordinate model for the two following reasons. The reduction of Eulerian vertical velocities enables a proportional reduction of the associated advection schemes truncation errors. As it follows high frequency motions, the $\tilde{z}$-coordinate lets lateral schemes operate along tracer anomalies created by these motions.

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