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A family of compact high order coupled time-space unconditionally stable vertical advection schemes

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Recent papers by Shchepetkin (2015) and Lemarié et al. (2015) have emphasized that the time-step of an oceanic model with an Eulerian vertical coordinate and an explicit time-stepping scheme is very often restricted by vertical advection in a few hot spots (i.e. most of the grid points are integrated with small Courant numbers, compared to the Courant-Friedrichs-Lewy (CFL) condition, except just few spots where numerical instability of the explicit scheme occurs first). The consequence is that the numerics for vertical advection must have good stability properties while being robust to changes in Courant number in terms of accuracy. An other constraint for oceanic models is the strict control of numerical mixing imposed by the highly adiabatic nature of the oceanic interior (i.e. mixing must be very small in the vertical direction below the boundary layer).

We examine in this talk the possibility of mitigating vertical Courant-Friedrichs-Lewy (CFL) restriction, while avoiding numerical inaccuracies associated with standard implicit advection schemes (i.e. large sensitivity of the solution on Courant number, large phase delay, and possibly excess of numerical damping with unphysical orientation). Most regional oceanic models have been successfully using fourth order compact schemes for vertical advection. In this talk we present a new general framework to derive generic expressions for (one-step) coupled time and space high order compact schemes (see Daru & Tenaud (2004) for a thorough description of coupled time and space schemes). Among other properties, we show that those schemes are unconditionally stable and have very good accuracy properties even for large Courant numbers while having a very reasonable computational cost.