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Exploring horizontal pressure gradient (HPG) schemes for general vertical coordinates.

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Terrain following coordinates allow for better representation of physics at the sea-bed than traditional z-coordinates but result in numerical discretisation errors in the calculation of the horizontal pressure gradient (HPG) which manifest as spurious currents. As of NEMO r4.0.4, there were two HPG schemes available for use with terrain following coordinates, the traditional 2nd order sco scheme and the 3rd order prj scheme. The prj scheme, while highly accurate in the ocean interior, shows unphysical behaviour at the sea-bed for steeply sloping bathymetry. A task in the IMMERSE project was set up to identify, implement and test promising HPG schemes suitable for general vertical coordinates that are accurate, robust and physically consistent. As part of this task, the 3rd-order accurate density Jacobian scheme (djc) as proposed by Shchepetkin and McWilliams (2003) has now been implemented in the NEMO trunk (as a rewrite of the previously existing but non-operational djc scheme). Idealised testing has shown this scheme to be significantly more accurate than the sco scheme, and more robust than the prj scheme in coping with steeply sloping bathymetry. Initial results from applying the djc scheme in a challenging realistic configuration (the AMM7 with hybrid s-z-coordinates and non-uniform vertical discretisation) show a reduction in spurious currents with respect to the sco scheme. The prj scheme is highly sensitive to the rmax (maximum permitted slope) criterion. In cases where the bathymetry is so steep that a velocity-point may lie multiple levels below one of its neighbouring tracer-points, the nature of the prj near-bed HPG calculation leads to sudden spin-ups of spurious velocities which can exceed those of the djc scheme in the longer-term. Performance-wise, the djc scheme is 3 times slower than the sco scheme, but less expensive than the prj. Further work is planned to reduce the memory footprint. In addition to continued testing of the djc scheme, further work will look at alternative formulation (finite volume) HPG schemes, and high order variants.