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Ocean ecosystem modelling in an adaptive mesh model: a performance evaluation

Jon Hill (1), Ekaterina Popova (2), David Ham (1,3), Matthew Piggott (1,3), and Meric Srokosz (2)

(1) Department of Earth Science and Engineering, Imperial College London, London, United Kingdom (jon.hill@imperial.ac.uk), (2) National Oceanography Centre, Southampton, United Kingdom, (3) Grantham Institute for Climate Change, Imperial College London, London, United Kingdom

Ocean oligotrophic gyres are characterised by low rates of primary production. Nevertheless their great area, covering roughly a third of the Earth's surface, and probably constituting the largest ecosystem on the planet, means that they play a crucial role in global biogeochemistry. Current basin-scale models give values of primary production approximately two orders of magnitude lower than those observed, thought mainly to be due to the failure of resolving sub-mesoscale phenomena, which play a significant role in nutrient supply in such areas. However, which aspects of sub-mesoscale processes are responsible for the observed higher productivity is an open question. Existing models are limited by two opposing requirements: to have high enough spatial resolution to resolve fully the processes involved (down to order 1km) and the need to realistically simulate the full gyre. No model can currently satisfy both of these constraints.

Here, we detail the turbulence and biology features of Fluidity-ICOM: a non-hydrostatic, finite-element, unstructured mesh ocean model. Adaptive mesh techniques allow us to focus resolution where and when it is required, essential for simulating a full gyre whilst having high enough resolution in areas of interest. We show that adaptive mesh techniques can be used in conjunction with both turbulent parameterisations and generalised ecosystems models in restricted 3D water columns. We show that the model can successfully reproduce the annual variation of the mixed layer depth, via the turbulent parameterisation, and ecosystem behaviour at three different locations that demonstrate different aspects of ecosystem behaviour within an idealised gyre. The adaptive mesh algorithms produce more accurate results when comparing against measured data than the fixed mesh simulations, with far fewer elements used and hence at reduced computational cost.