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A new approach for the reduction of spin-up time of ocean models

E. Bernsen, H.A. Dijkstra

Institute for Marine and Atmospheric research Utrecht, Faculty of Sciences, Department of Physics and Astronomy, Utrecht University, The Netherlands (e.bernsen@phys.uu.nl)

In ocean and climate modeling equilibrium solutions are of critical importance. To obtain these solutions the model is usually run for 1000–1500 years corresponding to the spin-up time scale determined by the slow processes in the deep ocean. However, since most ocean models use explicit rather than implicit time stepping methods, the maximum time step is usually very small, severely limited by the CFL condition. Consequently the spin-up run is very costly in terms of CPU hours. Obviously a reduction of spin-up time would be very desirable. Traditionally false-transient methods have been used to achieve this goal. We propose a new approach with potentially a very large reduction in spin-up time. This new approach is based on Jacobian Free Krylov Newton methods. These methods combine Newton's method for solving non-linear systems with Krylov subspace methods for solving large systems of linear equations. As there is no need to construct the Jacobian matrices explicitly they are easily derived from existing time stepping codes. To test the method we apply it to a 3D planetary geostrophic ocean model with prognostic equations only for temperature and salinity, and compare the new method to an ordinary spin-up run for several model configurations. Special attention will be paid to the choice of the preconditioner, which is very essential for the convergence of the method. As a result we find that a considerable reduction of spin-up time is indeed possible.