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A new parameterisation of convection that eliminates the occurrence of artificial multiple equilibria

Matthijs den Toom and Henk A. Dijkstra

Institute for Marine and Atmospheric Research Utrecht (IMAU), Department of Physics and Astronomy, Utrecht University, The Netherlands (m.dentoom@uu.nl)

The application of bifurcation analysis to primitive equation ocean models is currently hampered by difficulties associated with the parameterisation of convection (vertical diffusion is greatly enhanced whenever the water column becomes statically unstable). When tracking solutions in parameter space, problems arise due to the occurrence of a multitude of bifurcations that are related to minor reorganisations of convection. In this work the characteristics of the convection parameterisation scheme are explored within the framework of a simple one-dimensional column model. Using numerical continuation techniques parameter regions are identified where multiple steady states coexist for the same forcing conditions. In agreement with previous studies the manifestation of the multiplicity is found to depend on grid resolution. With increasing resolution the multiple states become less distinct, suggesting that their occurrence is not physically relevant. It is shown analytically that this undesirable feature can be eliminated by changing the formulation from one in which both temperature and salinity are mixed to one in which only density is mixed. The proposed parameterisation does not affect spice (the combination of temperature and salinity that does not contribute to density) and produces density compensated profiles. Observational support for the relevance of this formulation for coarse-resolution models is shortly reviewed. In addition, the authors present results from a fully implicit primitive equation model indicating that the physically relevant expressions of the nonlinear character of oceanic flow, notably the bifurcations related to Stommel's salt advection feedback, are preserved under this alternative formulation.