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Nondissipative Velocity and Pressure Regularizations for the ICON Model

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A challenging aspect in the numerical simulation of atmospheric and oceanic flows is the multiscale character of the problem both in space and time. The small spacial scales are generated by the turbulent energy and enstrophy cascades, and are usually dealt with by means of turbulence parametrizations, while the small temporal scales are governed by the propagation of acoustic and gravity waves, which are of little importance for the large scale dynamics and are often eliminated by means of a semi-implicit time discretization. We propose to treat both phenomena of subgrid turbulence and temporal scale separation in a unified way by means of nondissipative regularizations of the underlying model equations. More precisely, we discuss the use of two regularized equation sets: the velocity regularization, also know as Lagrangian averaged Navier–Stokes system, and the pressure regularization. Both regularizations are nondissipative since they do not enhance the dissipation of energy and enstrophy of the flow. The velocity regularization models the effects of the subgrid velocity fluctuations on the mean flow, it has thus been proposed as a turbulence parametrization and it has been found to yield promising results in ocean modeling [HHPW08]. In particular, the velocity regularization results in a higher variability of the numerical solution. The pressure regularization, discussed in [RWS07], modifies the propagation of acoustic and gravity waves so that the resulting system can be discretized explicitly in time with time steps analogous to those allowed by a semi-implicit method. Compared to semi-implicit time integrators, however, the pressure regularization takes fully into account the geostrophic balance of the flow.

We discuss here the implementation of the velocity and pressure regularizations within the numerical framework of the ICON general circulation model (GCM) [BR05] for the case of the rotating shallow water system, showing how the original numerical formulation can be extended to the regularized systems retaining discrete conservation of mass and potential enstrophy. We also present some numerical results both in planar, doubly periodic geometry and in spherical geometry. These results show that our numerical formulation correctly approximates the behavior of the regularized models, and are a first step toward the use of the regularization idea within a complete, three-dimensional GCM.

References

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