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The ICON-1.2 hydrostatic atmospheric dynamical core on triangular grids – Part 1: Formulation and performance of the baseline version

H. Wan[1,4,*], M. A. Giorgetta[1], G. Zängl[2], M. Restelli[3], D. Majewski[2], L. Bonaventura[3], K. Fröhlich[1,2], D. Reinert[2], P. Rípodas[2], L. Kornblueh[1], and J. Förstner[2]

[1]Max Planck Institute for Meteorology, Hamburg, Germany
[2]German Weather Service, Offenbach am Main, Germany
[3]MOX – Department of Mathematics F. Brioschi, Politecnico di Milano, Milan, Italy
[4]International Max Planck Research School on Earth System Modelling, Hamburg, Germany
[*]now at: Pacific Northwest National Laboratory, Richland, WA, USA

Abstract. As part of a broader effort to develop next-generation models for numerical weather prediction and climate applications, a hydrostatic atmospheric dynamical core is developed as an intermediate step to evaluate a finite-difference discretization of the primitive equations on spherical icosahedral grids. Based on the need for mass-conserving discretizations for multi-resolution modelling as well as scalability and efficiency on massively parallel computing architectures, the dynamical core is built on triangular C-grids using relatively small discretization stencils.

This paper presents the formulation and performance of the baseline version of the new dynamical core, focusing on properties of the numerical solutions in the setting of globally uniform resolution. Theoretical analysis reveals that the discrete divergence operator defined on a single triangular cell using the Gauss theorem is only first-order accurate, and introduces grid-scale noise to the discrete model. The noise can be suppressed by fourth-order hyper-diffusion of the horizontal wind field using a time-step and grid-size-dependent diffusion coefficient, at the expense of stronger damping than in the reference spectral model.

A series of idealized tests of different complexity are performed. In the deterministic baroclinic wave test, solutions from the new dynamical core show the expected sensitivity to horizontal resolution, and converge to the reference solution at R2B6 (35 km grid spacing). In a dry climate test, the dynamical core correctly reproduces key features of the meridional heat and momentum transport by baroclinic eddies. In the aqua-planet simulations at 140 km resolution, the new model is able to reproduce the same equatorial wave propagation characteristics as in the reference spectral model, including the sensitivity of such characteristics to the meridional sea surface temperature profile.

These results suggest that the triangular-C discretization provides a reasonable basis for further development. The main issues that need to be addressed are the grid-scale noise from the divergence operator which requires strong damping, and a phase error of the baroclinic wave at medium and low resolutions.

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