International Max Planck Research School on
EARTH SYSTEM MODELLING

Developing and testing a hydrostatic atmospheric dynamical core on triangular grids

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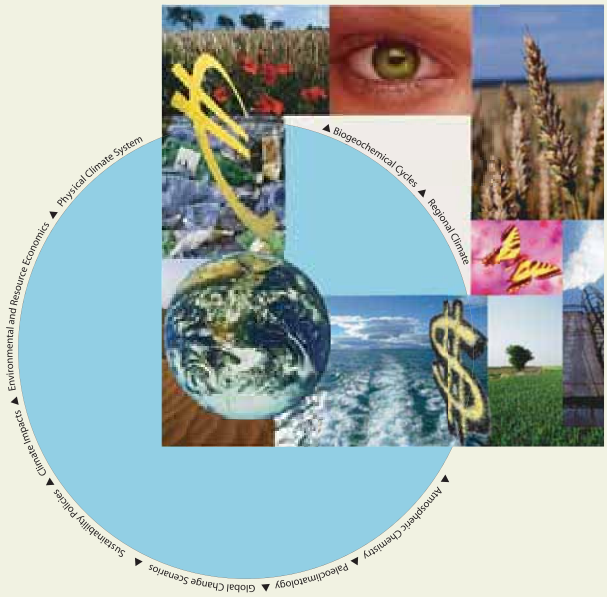

Abstract

Atmospheric general circulation models (AGCMs) view the atmosphere as a fluid, and simulate the time evolution of its three-dimensional (3D) motions. At the base of an AGCM is the so-called dynamical core which numerically solves the governing equations of the atmosphere. In recent years, non-conventional grids and finite-difference methods have gained popularity due to their suitability for massively parallel computing and for achieving important conservation properties. The joint project ICON initiated by the Max Planck Institute for Meteorology and the German Weather Service aims at developing new dynamical cores for climate research and numerical weather forecast using the spherical triangular grid. The study presented in this thesis is carried out within this project. Based on a two-dimensional (2D) testbed developed before this work, a 3D hydrostatic atmospheric dynamical core is established.

In order to facilitate the comparison with already-existing models, the new dynamical core is constructed by combining the horizontal discretization of the ICON 2D model with a set of numerical schemes widely used for vertical discretization and time integration. Since the vertical discretization scheme was originally designed for latitude-longitude mesh, adaptations are made to apply it to the triangular grid. As for the horizontal discretization, a theoretical analysis is performed to access the accuracy of the differencing operators. It is found that the divergence operator defined on a single triangle according to the Gauss's theorem introduces grid-scale noise. This noise is reduced by the leading error of the discrete Laplace operator. The impact of the compensating error terms is discussed. Possible ways to get rid of this artifact and achieve higher accuracy are also investigated.

The performance of the new dynamical core is evaluated in a series of idealized experiments. Results show that the new model can successfully simulate important barotropic and baroclinic processes. Good numerical stability is observed both in deterministic tests and in an idealized climate simulation. When the horizontal resolution is increased, a clear trend of convergence is observed in the numerical solutions. In the most challenging baroclinic vortex test, the simulations from the new model with a 64 km grid size compare well with the reference solution. In the barotropic test cases, high-quality results are obtained already at lower resolutions. The new dynamical core thus forms a good basis for a full AGCM.