ICON: Development of an icosahedral, non-hydrostatic global model

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The German Weather Service - Deutscher Wetterdienst (DWD) and the Max Planck Institute for Meteorology (MPI) have started the development of a new GCM, including a new gridpoint dynamical core based on a icosahedral spherical grids, within the ICON (ICOsahedral Non-hydrostatic) project.

MPI has developed in the past general circulation models for climate research applications, the latest being ECHAM5. The ECHAM dynamics is solved by the spectral transform method following the ECMWF implementation. This method is still very successful when applied to the dynamics of the atmosphere, but it has displayed several inconveniences when coupled to the simulation of conserved or long-lived chemical constituents of air. Furthermore, application to stratospheric and higher atmospheric studies are gaining increasing importance within the research plans of MPI and their optimal development would also profit from a general reformulation of the available models.

DWD operates the German weather forecast system from the global to the regional scale. The current global model, GME (see e.g. [4]), operates entirely in grid point space using a triangulated icosahedral grid. This development has been driven by the idea that the impact of localized atmospheric forcing related to detailed land characteristics on the circulation is modelled more accurately in grid point space models than in spectral transform models. Furthermore, the icosahedral grid approach allows a quasi uniform coverage of the sphere. DWD intends to include more detailed physical processes and a more detailed coupling of the atmosphere to the surface, specifically to the ocean surface. Furthermore, there is a desire to integrate the current global and local forecasting systems in a unique model with a local grid refinement capability.

The project has started in May 2002 and the new complete model should be available by the end of 2005. Various universities and research institutions have joined the project and a more complete description is available at http://icon.enes.org.

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The ICON model is being designed to employ a set of fully compressible, non-hydrostatic equations. Many standard meteorological approximations, e.g. constant acceleration of gravity, constant distance from the Earth's center, neglection of the Coriolis terms associated with the vertical velocity, which are not motivated by clearcut computational advantages or by theoretical analysis, will be avoided. The continuity equation will be formulated in flux form and the total density of air will be considered as the prognostic variable in the continuity equation, along with the baricentric velocity of air and of the moist species.

A prototype shallow water model is under development, starting with a basic second order discretization of the vector invariant form of the shallow water equations on a C-grid staggered variable arrangement on on both the hexagonal and triangular icosahedral grids, along the lines of a semi-implicit extension of [3]. A mass conservative formulation of the continuity equation is employed and compatibility with later three-dimensional extensions of the horizontal discretization approach is going to be ensured. Semi-lagrangian schemes will also be empoyed in the final implementation. Other efficient higher order methods (discontinuous Galerkin, spectral finite volume) will also be considered, along with mass conservative local grid refinement options. The different discretization options are being compared and evaluated on the standard test case suite (see e.g. [5]). A prototype, x-z two-dimensional nonhydrostatic model will also be developed. Various choices of coordinate transformations will be compared, including hybrid terrain following height coordinate, hybrid isentropic coordinates and natural height based coordinates, without terrain following normalization. Efficient higher order methods (discontinuous Galerkin, spectral finite volume) will also be considered. Special effort will be devoted to include in the model the local computation of a well balanced hydrostatic state at each time step along the lines of [2]. This may possibly lead in the complete model to the intermediate computation of a three-dimensional state in geostrophic and hydrostatic balance. The different discretization options will be evaluated on appropriate test case suites (see e.g. [1]).

References

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