Geosci. Model Dev. Discuss., 6, C374–C377, 2013
www.geosci-model-dev-discuss.net/6/C374/2013/

Geoscientific
Model Development
Discussions

Interactive comment on "The ICON-1.2 hydrostatic atmospheric dynamical core on triangular grids – Part 1: Formulation and performance of the baseline version" *by* H. Wan et al.

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Received and published: 19 April 2013

We appreciate the editor's comments and encouragement. A revised manuscript has been prepared. Our reply regarding the specific issues is given below.

1. Equivalent resolution

Firstly we clarify that the equivalent resolution we have in mind is the resolution that produces the same solution quality. The total degrees of freedom (DOF) is not a good index because it contains no information about the order of accuracy of a discretization scheme. (It is not a good index for model cost either, because the algorithm complexity is not taken into account.) The effective number of mass points suggested by

Dr. Gassmann (i.e., half of the total number of mass points on a triangular-C grid) is mainly based on the consideration of discrete dispersion relationship, and does not reflect other properties of a discretization scheme (cf. our reply to Dr. Gassmann). The use of the actual number of mass points, on the other hand, has issues of inhomogeneous distribution and redundancy in the case of the Gauss grids for spectral transform models. Having considered the above-mentioned possibilities and elements, we believe that the equivalent resolutions in terms of solution quality can not be easily established a priori between the ICOHDC and the spectral transform dynamical core of ECHAM, but need to be identified by comparing results from numerical simulations. This is in line with similar attempts in the literature, e.g. the work of Williamson (2008a). Regarding the manuscript, we have attempted to improve the corresponding section by making the following modifications:

- Section 6.1.2 is divided into three parts, (a) convergence, (b) phase speed, and (c) equivalent resolution in terms of solution quality, to clearly separate the subtopics.
- Part (c) is shortened, and what we mean by equivalent resolution is clarified. The discussion on DOF and the reference to other models (GME and the NCAR FV core) are removed from the main body of the manuscript, while Table 2 is still kept because we believe it provides useful information to the potential model users.

2. Semi-implicit time stepping scheme

In the revised manuscript we clarify that this particular time stepping scheme is selected for the baseline version of the new dynamical core for the purpose of having a clean evaluation of the spatial discretization employed on the triangular icosahedral grids. We agree with the reviewer that the semi-implicit scheme, which leads to a set of 2-D Helmholtz equations, is more straightforward to implement in a spectral transform dynamical core where there is no need for a linear solver. However, such methods are also commonly used in conjunction with finite-difference or finite-element discretizations. For example, the operational weather prediction model GME of the German Weather Service (Majewski et al., 2002) employs the same semi-implicit method as used here. In the baroclinic wave tests presented in our manuscript, the typical number of iterations needed for the fastest propagating wave is about 10 regardless of the horizontal resolution, when the time step is chosen proportional to the average grid spacing (i.e., 600 sec at R2B4, 300 sec at R2B5, etc.). Test results have shown that if the semi-implicit correction is switched off, a reduction of time step by a factor of approximately 5 will be needed to ensure stability. More elaborate explicit integration schemes, e.g., the strong stability preserving Runge-Kutta methods, can significantly increase the maximum time step, but the use of multiple stages leads to substantial increase in computational cost because the evaluation of the R.H.S. of the governing equations is expensive. There is hence a clear advantage for semi-implicit methods employing solvers that entail reasonable computational costs.

On the other hand, we are aware that in massively parallel simulations, especially when the dynamical core consumes a significant portion of the total computing time, linear solvers that require global communications will pose constraints on the computational performance in terms of efficiency and scalability. In such cases, explicit time stepping schemes are an option to consider. For example, the ICON nonhydrostatic model uses a two-time-level predictor-corrector scheme, with implicit treatment restricted to the vertically propagating sound waves. In the hydrostatic model, we have implemented and tested various two-time-level integration schemes for the purpose of achieving tracer-and-air-mass consistency, but these are considered beyond the scope of the baseline model.

3. Access to model code

The two partners of the ICON development, the German Weather Service and the Max Planck Institute for Meteorology, plan to make the model code available to researchers at universities and other institutions as well as to weather forecasting agencies for the

purpose of research applications. The infrastructure for the code distribution under a software license agreement is currently in preparation, and a major revision is planned to make the code suitable for public release concerning its performance, the technical quality and the documentation. Before these preparations are finished, access to the code is restricted to the ICON model developers and the established collaborators.

At the end of the revised manuscript, we add the information that readers who are interested in getting the source code of the hydrostatic dynamical core described in the paper (revision 6489) can contact Dr. Günther Zängl at the German Weather Service (Guenther.Zaengl@dwd.de) or Dr. Marco Giorgetta at the Max Planck Institute for Meteorology (Marco.Giorgetta@mpimet.mpg.de).

References:

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