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Interactive comment on "Icosahedral Shallow Water Model (ICOSWM): results of shallow water test cases and sensitivity to model parameters" *by* P. Rípodas et al.

P. Rípodas et al.

maria-pilar.ripodas@dwd.de

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Response to anonymous Referee #2

The authors want to thank the Referee for his comments and suggestions.

Response to general comments

About the "interesting discussion points" mentioned by the referee before the "suggested general improvements":

-About the loose of convergence with increased resolution.

The model shows a computational instability that is overcome with relative large values of the Asselin filter parameter (0.05-0.08). In the revised paper, it is mentioned that a new implementation for the RBF reconstruction of the wind at the velocity points is available in a new version of the code (not the one reported in this work). It implies a new discretization of certain terms in the momentum equation and eliminates the instability, allowing for very small (or even zero) Asselin parameters. When test case 6 is run with the new code using the RBF reconstruction at the velocity point together with a small Asselin parameter (0.01), the height l2 norm for the higher resolutions is reduced increasing the height l2 norm convergence rate.

In the revised paper a run of test case 6 with higher diffusion coefficients improved the l2 norm errors of the vorticity for the higher resolutions. This particular case need more numerical diffusion to prevent the generation of small scales and a cascade towards unresolved scales (Thuburn and Li, 2000).

-About comparison with results in the literature.

More reference and comparison to published works will be done in the revised paper. The loose in convergence is stronger in the case of the vorticity field. In this case a comparison to other models is not possible because convergence of the vorticity field is not usually shown.

In Wako and Avissar (MWR,2008) convergence of normalized errors are only shown for test case 1, and test case 3 after 5 days. No convergence plots or calculation or normalized errors is done for test cases 5 and 6 where the loose of convergence is observed. Therefore a comparison can not be done.

The height and velocity error norms for test case 5 after 15 days and test case 6 after 10 days shown in figure 15 in Tomita et al (2001) for his grid level 7, are very similar to the ICOSWM errors for the same cases and days for our grid level 6, that correspond to similar resolutions.

-About new ways to improve the accuracy in ICOSWM.

The ICON project is still in development and new possibilities for the operators are also in consideration. This is not finished work.

-About the phase delay in test case 6

In the here documented ICOSWM model, not phase delay is apparent in test case 6.

- About the competitiveness of the ICOSWM computational performance.

A test comparing the current version of the ICON hydrostatic dynamical core (Wan, 2009) and the GME dynamical core shows that the ICON hydrostatic dynamical core is faster than GME. Any case it must be taken into account that the current ICON hydrostatic dynamical core has been optimized for the NEC computer where the test has been performed.

-About the Gallewsky et al. test case

Adding a more challenging test case, as the suggested barotropic instability test case by Gallewsky et al. (2004) would be very interesting and could help in the understanding of the model results. The authors leave open this possibility for the future but not for the present paper.

- About the suggested general improvements:

1.- As the model has been described in previous publications, the authors had focused in the results of the model in this paper. The authors agree with the Referee that it is better to include enough information to give the reader a stand-alone picture of the model equations and numerical technique. In particular the Referee is right that the RBF reconstruction in the context of ICON has not been documented in the peer-reviewed literature so far.

The Raviart-Thomas implementation allows a first order wind reconstruction and the RBF allows higher order wind reconstructions when bigger stencils are used.

The authors have included in the revised paper the model equations, the description of the operators (that are identical to the operators in Bonaventura and Ringler) and a brief description of the RBF technique and the URL link where the reference Ruppert(2007) is available. The minor difference to Bonaventura and Ringler (2005) are detailed in the revised paper.

2.- In the figures mentioned, the number of colors will be reduced an a different color scheme is used in the revised paper. In figures with differences between the ICOSWM output and the analytical or reference solution, the zero line is not hidden by the new color scheme. More details follow in the response to the specific comments.

Response to specific comments

1.- The sentence has been removed in the revised paper.

2.- The continuity equation is in flux form and is discretized by a finite volume approach, approximating the cell averaged value of the geopotential. The discrete velocities, instead, are approximations of the pointwise values at the velocity points. The gradient operator is based on the finite differences approach.

The sentence will be replace by:

The new model will be based on finite volume (for the continuity equation) and finite difference discretizations of the fully elastic, ...

3.- Bonaventura's main reasons for the new model development is the challenging of facing the current problems in modeling developments like mass conservation and monotonicity of tracer concentrations, local mesh refinement and the use of massively parallel computers for high resolution modeling. The main reasons are already summarized. The sentence will be changed, to make it clearer, to:

Bonaventura (2004) discussed the current problems in NWP and climate modeling like mass conservation and monotonicity of tracer concentrations, local mesh refinement and the use of massively parallel computers for high resolution modeling. The ICON project joins DWD and MPI-M resources to face these problems in the development of new models.

4.- The tangential velocity components at the edges are obtained as the projection in the tangential direction of the edge average of the reconstructed wind vectors at the cell centers. It is mentioned in the revised paper.

5.- The presentation of A. Gassmann and T. Heinze in PDE on the sphere in Exeter in 2007 is not available online. The reference is omitted in the revised paper. It is mentioned in the paper that there are different options to optimized the grid. But as only the Heikes Randall optimization is considered in the manuscript, it is not necessary to refer to the publication where other optimizations are presented.

6.- Ruppert(2007) reference is available online. The URL is provided in the revised paper.

7.- The model equations and operators are shown in the revised paper.

8.- The finite volume approach to integrate the continuous equation is used, with the triangles as control volumes. The Gauss' divergence theorem is applied and the mass fluxes are computed at the edges. In the revised paper there is a more detailed model description.

9.- The model runs for several days without explicit horizontal diffusion, also for test cases 5 and 6. In the manuscript, results are shown for the three test cases 2 (10-day run), 5 (15-day run) and 6 (10-day run) from Williamson et al. (1992) without explicit diffusion, Asselin filter parameter 0.1 and RBF reconstruction with 9-point stencil and scale factor 0.5. It has not been tested how long can be run the model without explicit diffusion, that could also depend on the model parameters chosen. In general the model results improve when explicit diffusion is applied. In test case 2, the vorticity errors improved definitely when explicit diffusion is applied, reducing the bigger errors near the special points (vertices of the original icosahedron). In test case 6 a dissipation mechanism is necessary to prevent the generation of small scales and a cascade towards unresolved scales (Thuburn and Li, 2000).

10.- The section about the numerical diffusion has been reformulated in the revised paper. The parameter e-folding time is renamed to damping time parameter, because for the discrete case it is more appropriate. The damping time parameter is the characteristic time in which the grid scale noise is removed.

The discrete Laplacian operator is described in the revised paper. The relation between the damping time and the diffusion coefficient is derived for a planar grid of equilateral triangles (Wan, 2009) and therefore is an approximation for the grid actually used.

Numerical diffusion is applied to the velocity field to prevent the growth of kinetic energy for the small scales due to non linear interactions. There is also an option to apply diffusion to the mass field, but it is not used here because it is considered unphysical as the continuity equation does not contain a turbulent mixing term in the full atmospheric equations. In addition, it could lead to a violation of mass conservation for our implementation of the diffusion coefficient.

11.-The numerical scheme is conditionally stable with respect to the explicitly treated advection terms, in the sense that u*dt/dx must be smaller than 1 if u is the flow velocity.

Using the minimum distance between triangular cells and the time step given, then the maximum velocity that fulfills the CFL condition is about 220 m/s. The velocities in the test cases consider in the present work are much smaller and then the CFL number is much less than 1 in all the model runs.

12.-Some of the scale factors were typos. The abbreviations used in the plots will be introduced here.

13.-It is true that the test is smooth and does not show a lot of differences. But at the same time, when inappropriate RBF options are chosen (like Gaussian kernel, 9-point stencil and scale factor 0.2), big differences are shown.

14.-The Gill reference has been removed.

15.-With the spectral coefficients of the reference solution, the reference solution could be evaluated at any grid point. It is true. But the subroutine to do this transformation to any grid point is not available. A subroutine of the NCAR STSWM model transforms the spectral coefficients to the physical space variables using the Gaussian grid and the associated Legendre polynomials. This subroutine is used to have the solution at the Gaussian grid and then a bi-cubic interpolation is performed to have the solution at the ICON , GME or any other grid. The spectral reference is a high resolution solution (T426 in test case 5 and T511 in test case 6) and the number of points of the associated Gaussian grid is big enough to get a good interpolated solution.

16.-The native prognostic variable is used.

17.-Test case 6 can be run with the ICOSWM model for 14 days and the wavenumber 4 is not broken. The new figure in the revised paper shows the model solution at day 14 in a better color scheme and contour lines for the NCAR STSWM reference solution are superimposed for comparison. No phase delay is observed.

From Thuburn and Li (2000) it is known that this test case is unstable. The instability implies that for long enough times, the solutions are strongly sensitive to small perturbations in initial conditions or to small numerical errors (Thuburn and Li, 2000). After 10 or 14 days, ICOSWM is still stable, but we have considered that it is better to test the convergence of the solutions after a shorter time than the 14 days proposed by Williansom et al. (1992), that is at day 10.

18.- It is true that the n^{-3} of the spectrum can not be compared to the observed atmospheric kinetic energy spectra.

19.- In the revised paper the section is re-written and the sentence reformulated.

20.- The conclusion section has been re-written. Test cases 2 and 6 have been run with the non-opt grid and the results are commented in the revised paper.

21.-An effort has been done to improve the figure mentioned. Small scale noise is observed, with error spikes near the special points (original vertices of the icosahedron). A wavenumber 5 pattern is observed. Comments to this figure will be added in the test. Units are provided in the caption in the revised paper.

22.-Day 14 with a contour interval of 200 m is shown in the revised paper. Also contour black lines with the reference solution are superimposed for comparison.

Response to Technical corrections

The typos have been corrected in the revised paper.

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