Geosci. Model Dev. Discuss., 2, C405–C411, 2009
www.geosci-model-dev-discuss.net/2/C405/2009/

Geoscientific
Model Development
Discussions

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

Received and published: 4 November 2009

Response to anonymous Referee #1

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

Response to Comments that need to be addressed

-)P586,l24;P592,l25

Reconstruction of the full vector field is performed at the triangular cell centers using the values of the normal components at the edges. These values are then averaged at the edges and the projection in the tangential direction is computed.

It is explained in the revised paper.

-)P587.

The RBF technique is better described in the revised paper. Also the link to Rupert (2007) where the application of the RBF to the ICOSWM model is more detailed, is given.

From our experience with the RBF technique, it turns out that the use of a constant scale factor for all the grid levels is reasonable. For example in the figure with the convergence plot for test case 2 and different RBF parameters, the nearly uniform distance between the error curves for g9p-1 and g9p-0.5 indicates that the choose of a constant scale factor for the different resolutions is a reasonable approach.

-)P587-588

The time and spatial discretizations are now described in the revised paper

-)P588

The mentioned sentences have been reformulated in the revised paper to:

In Bonaventura and Ringler (2005), either potential enstrophy conserving or total energy conserving variants of the same method were proposed. Equation 20 in Bonaventura and Ringler (2005) specify how to calculate the edge average of the absolute vorticity in order to conserve potential enstrophy. Furthermore, in Bonaventura and Ringler (2005) a simpler formulation was also introduced, which is essentially equivalent to the potential enstrophy preserving scheme and produces indistinguishable results. In the latter formulation, the edge averaged value of the absolute vorticity is obtained by simple arithmetic average of the values of the absolute vorticity at the neighbouring vertices. In the present paper this simpler formulation is employed, combined to the more accurate RBF reconstruction procedure described in the previous section.

-)P589

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.

The actual values of the diffusion coefficient corresponding to a damping time parameter of 2 hours are output and the minimum, mean and maximum values for grid levels 2 to 6 are listed in a table. The equivalent table for damping time of 28 hours has been omitted. The approximation that was used before to estimate the diffusion coefficients for a given damping parameter, given ratios between maximum and minimum diffusion coefficients for a given grid level of about 20 to 30, was not realistic. The actual ratios between maximum and minimum diffusion coefficients are about 3.

The numerical diffusion is applied at time level n-1.

-)P591

The sentence has been reformulated in the revised paper to:

Test case 2 of the standard shallow water suite of Williamson et al. is a steady state solution of the non-linear shallow water equations. It consists of a solid body rotation with a balanced geostrophic height field. The spherical coordinate poles are not necessarily

coincident with earth rotation axis. We denote α the angle between the coordinate and the rotational axis. We consider here only the case $\alpha = 0$: the poles of the coordinate system, that are two of the vertices of the original icosahedron, coincide then with the rotation axis.

-)P595

The reference has been removed in the revised paper.

-)P598, l18

We refer only to the fact that the RH is unstable as a solution of the shallow water equations because in this paper we are concerned with a Shallow Water Model.

-)p599, l19

Yes. The sentence is reformulated in the revised paper.

-)p600,l7

Following Stuhne and Peltier (1999) and Tomita et al. (2001), the change in energy will be compare to the available energy. The total energy is redefined as the total energy minus the initial potential energy (Tomita et al., 2001). The change in energy and potential enstrophy will also be shown for test case 5, and compare with the results of Tomita et al (2001).

-)Fig.15.

The plot with the time evolution of the vorticity will be omitted.

-)P604,605

It is true that the n^{-3} of the spectrum can not be compared to the observed atmospheric kinetic energy spectra. The NCAR STSWM model is used as reference. The kinetic energy spectrum of the NCAR STSWM evolve with time towards a n^{-3} dependence for wavenumbers $20<n<160$ (not shown here), reaching an equilibrium state between day-10 and day-15. It is not clear if the n^{-3} dependence is developed only for this range of wavenumbers or if more time is needed to develop it for larger wavenumbers or if the $n{>}160$ wavenumbers are just affected by the numerical diffusion. In the latter case, we could not use the NCAR STSWM kinetic energy spectrum as the true kinetic energy spectrum and use it as a reference to define the effective resolution of ICOSWM as it is proposed in Skamarock (2004).

The efective resolution of the model is not estimated.

-)P606

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.

-)P610

The table has been reformatted in the revised paper.

-)P612

Table 3 is omitted, table 4 is kept.

Typos, grammatical errors, etc

The typos, grammatical errors,.. have been corrected

Response to Comments for the authors' consideration

-)P592-594

*)About the need of a large Asselin parameter:

The model can run without explicit diffusion for several days, but it shows an instability that is solved using a relatively large value for the Asselin filter parameter.

The paper shows the results for the ICOSWM model at the end of 2008. Some new options have been implemented since then. It has turned out that using a new implemented RBF reconstruction at the edges of the triangles, there is no need of an Asselin filter to stabilized the model. When the vector field is reconstructed at the triangular edge, then the kinetic energy at the triangular center is interpolated from the values at the triangular edges. This means that a new discretization of the gradient of the kinetic energy is used. Hollingsworth et al. (1983) show that a computational instability can happen because of a non-cancellation of certain terms in the linearized form of the momentum equation. With the new discretization (RBF reconstruction at the velocity points) the cancellation happens, the instability is not present and no Asselin filter is needed.

*)About accuracy of the RBF reconstruction:

In Ruppert, 2007, it is shown that the RBF reconstruction itself becomes more accurate when a bigger stencil is used.

*)About the comparison of the convergence rates to second order convergence:

Some of the discretizations used are second order, and some are first order. A second order is un upper limit to compare with.

*)About vorticity errors in test case 5:

The orography in this test case is not smooth and the representation of the mountain in the spectral model might involve Gibbs phenomena at the edge of the mountain that are not present in the ICOSWM model.Some discrepancies in the lee side of the mountain between the two models seem to be propagated and amplified with time.

-)P602, l25-27, and P605

Test cases 2 and 6 have been run with the non-opt grid and the results are commented in the revised paper.

References

Bonaventura, L. and Ringler, T.: Analysis of discrete shallow water models on geodesic Delaunay grids with C-type staggering, Mon. Weather Rev., 133, 2351–2373, 2005.

Ruppert, T.: Diploma-thesis. Vector Field Reconstruction by Radial Basis Functions, Tech. Rep. 1089046, TU Darmstadt, online available at: http://icon.enes.org/references/publications/diploma_TR_RBF_vector_recon.pdf,2007.

Skamarock, W. C.: Evaluating Mesoscale NWP Models Using Kinetic Energy Spectra, Mon. Weather Rev., 132, 3019–3032, 2004.

Stuhne, G. R., and Peltier, W. R.: New Icosahedral Grid-Point Discretizations of the shallow Water Equations on the Sphere, J. Comp. Phys., 148, 23–58, 1999.

Tomita, H., Tsugawa, M., Satoh, M., and Goto, K.: Shallow Water Model on a Modified Icosahedral Geodesic Grid By Using Spring Dynamics, J. Comp. Phys., 174, 579–613, 2001.

Wan, H.: Developing and testing a hydrostatic atmospheric dynamical core on triangular grids, Reports on Earth System Science No. 65, Max Planck Institute for Meteorology, Hamburg, Germany, online available at: http://www.mpimet.mpg.de/en/wissenschaft/publikationen/erdsystemforschung.html#c2612, 2009.

Interactive comment on Geosci. Model Dev. Discuss., 2, 581, 2009.