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Interactive comment on "A mimetic, semi-implicit, forward-in-time, finite volume shallow water model: comparison of hexagonal–icosahedral and cubed sphere grids" *by* J. Thuburn et al.

Anonymous Referee #1

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This paper presents an interesting way to enforce physically-consistent numerics in a shallow-water solver, and demonstrates its effectiveness in a set of standard test cases. The manuscript should be published, but I have some concerns that need to be addressed before it can be published.

It is well known that some sort of special handling on the cube edges is needed to improve the results on a cubed sphere; cf. Ullrich et al (2010, JCP), Lauritzen et al (2010, JCP), and Putman and Lin (2007, JCP). Is any such edge handling peformed in this model? If not, this would explain much of why the cubed sphere's errors are so much larger than those on the hexagonal grid.

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Interactive Discussion
Discussion Paper

The numerical method of this manuscript requires solution of an elliptic operator. The necessary globally-implicit operation would then be very inefficient in parallel environments. Could you comment briefly how you intend to make this a practical method in massively-parallel environments?

You say that the undershoots are weak if the tracer is well-enough resolved, but in a real model we cannot assume features in the tracer field will be well-resolved (near grid-scale clouds come to mind) this unless there is so much artificial diffusion that the undershoots are damped. Are there any plans for some sort of monotonicity or positivity enforcement? Also, is there any explicit artificial dissipation, such as hyperdiffusion or divergence damping, in these test cases?

Minor comments:

- Many figures are hard to read! The text captions are very small and the labeling is cryptic; it would help to enlarge the text, add labels ("(a)", "(b)", etc.) and write out "height error" or "geopotential error" as appropriate. Also the "spherical" view is not very illuminating, especially in Figures 5 and 7. In these cases a latitude-longitude global plot, showing the full structure of the errors (including the grid imprinting) would be more useful. Many figures (4–7) have contouring which makes it difficult to tell the difference between positive and negative contours.
- In many places the number of grid cells in the domain is given. It would be easier if a measure of average grid-cell width were given, or if the type of grid (such as "c90" for a 90x90x6 cubed-sphere grid) were specified.
- Section 3: Why is the KE term treated as a backwards term? Otherwise the time-integration method in section 3 is the same as the forward-backward method of Lin and Rood (1997, QJ) with a time-centering parameter.
- Section 5.1: Why build the stencils iteratively? Why can you not write out the stencil exactly without iterating?

- Section 5.6: Have you done the test of a spatially-uniform tracer field in non-divergent flow to see if the tracer field indeed remains uniform?

- Tables 6 and 7: could a qualitative estimate of the convergence rate be given? A numerical convergence rate could be computed through a least-squares fit to resolution vs. error norm. Alternately, a plot of error norms vs. resolution could also be presented.

- Figure 5: Could a couple of different model resolutions be shown? We could then see how the errors decrease with resolution, and could see how errors from grid imprinting compare to numerical truncation error. Also, it would be better to show a latitude-longitude plot to see the error field; the spherical view makes it difficult to see the errors.

- Section 6.5: Is this version of test-case 2 the flow oriented 45 degrees from zonal?

- Section 6.6: In test-case 5, it is worth noting that measures of the error relative to some "converged" solution may have little meaning, particularly when results from the mimetic solver are compared to a "converged" result from ENDGame. This test case is perhaps better suited to check conservation properties than it is for computing error norms.

- Also in test case 5: is the maintenence of sharp filaments and gradients truly a consequence of mimetic properties? This is very common behavior for finite-volume methods in general.

- Again in test case 5: Energy is stated to be "well conserved". An exact energy-conserving scheme would show no change in energy. Does the mimetic scheme conserve energy better than (say) ENDGame? Could the loss of energy be due to artificial dissipation (whether explicit or implicit)?

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- Figure 6: Could the same contour interval be used in each panel, to make comparisons easier? Again, since error norms may have little meaning in this test case it may be more useful to show the full fields instead of the errors; if at the resolutions shown all three simulations have height fields that look the same then showing errors is warranted, but if not then showing the full fields could be interesting. Also, could the position of the mountain be indicated?
- Section 6: I would be interested in seeing the Rossby-Haurwitz wave, Williamson test case 6, to see how long this model can go before the wave breaks down. Many models have trouble maintaining the wave beyond 14 days. We might expect an internally-consistent mimetic scheme to better preserve this solution
- Section 6.8: It is quite interesting to see that initializing with a fully-backward (a = 0) method and then switching to a time-centered forward-backward scheme yields a better result, which implies that initialization is important even for these idealized test cases.

Interactive comment on Geosci. Model Dev. Discuss., 6, 6867, 2013.