Geoscientific Model Development Discussions

Geosci. Model Dev. Discuss., author comment AC2
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Reply on RC1

James Kent et al.

Author comment on "A mixed finite-element discretisation of the shallow-water equations" by James Kent et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2022-225-AC2, 2022

Thank you for your review.

In response to your general comments:

We have produced a figure that shows the mixed finite element spaces used in the model and have included it in section 3.2 of the manuscript.

We agree that at lowest order these types of methods often become very similar. However, in Thuburn and Cotter, JCP, 2015, it is shown that the lowest order FE discretization has more benefit when it comes to consistency of the Coriols on non-orthogonal meshes than the FV model of Thuburn et al 2014. Another benefit of FE is the flexibilty to go to a higher-order element model. We have included this discussion in the introduction of our manuscript.

We've added some discussion to the conclusions. We highlight that the cubed sphere grid has fewer cells than a corresponding lat-lon grid, and that the cubed sphere removes the pole and associated issues with parallel computing. Regarding the stencil size, the MoL transport scheme uses a small stencil for each reconstruction, but it must compute a reconstruction for each stage of the RK scheme. It is not clear at this stage whether this improves communication cost when compared to a scheme with a large stencil that is only called once.

In response to your specific comments:

1) This is true, even if alpha $\neq 1/2$. This is consistent with Wood et al. 2014, and is used to get the second-order time discretization. Currently we use alpha=0.5 in the model configuration. For shallow water we have not seen the need to off-centre.
We agree that this is important for a full 3D model.

2) It seems to take around 2-3 iterations for GMRES to converge to a tolerance of 10^-4 on the C24 and C48 grids for both the mountain and Galewsky test. We have stated this at the end of section 5.

3) We have rewritten parts of this section, including adding a sentence describing a linear element to make things clearer. For the quadratic elements all the nodes lie on the sphere.

4) The different function spaces is not why we use the sphere parameterisation. Representing the sphere with elements removes the need for analytic transformations. This means we can use an arbitrary grid (although in this paper we only consider the cubed sphere grid). A down side is we are parameterizing the sphere, but as shown using quadratic elements on the C96 grid gives a maximum error of 0.0018 m.

5) You are correct that the fourth-order is for the spherical surface, and the second-order is for the Williamson 2 test case. We have edited the text here to make the distinction clearer.