Geosci. Model Dev. Discuss.,
doi:10.5194/gmd-2015-275-RC1, 2016

Geoscientific Model Development Discussions

Interactive comment on "A High-order Staggered Finite-Element Vertical Discretization for Non-Hydrostatic Atmospheric Models" *by* J. E. Guerra and P. A. Ullrich

C. Cotter (Referee)

colin.cotter@imperial.ac.uk

Received and published: 10 February 2016

In this paper, the authors introduce higher-order extensions to vertically staggered grids by using a spectral element approach which was originally introduced in the shallow-water context by Ullrich in another GMD paper. This is very useful and important work, for example in the Gung Ho project we are also considering finite element versions of vertically staggered grids along these lines (although we are currently considering a fully Galerkin weak-form approach) and these initial explorations are very useful to us. I also understand that there are ongoing questions about how to treat the vertical coordinate in the non-hydrostatic version of IFS at ECMWF, since the higher-order splines approach does not work for non hydrostatic IFS and so the standard Lorenz grid

is used. Hence, these ideas have the potential for plenty of impact at these operational centres and elsewhere.

I strongly recommend this paper for publication, but would like the authors to consider a few points to address.

1) around line 18, page 3. The statement about resolving boundary layers troubles me. In a Galerkin finite element setting, the results are basis independent, so the clustering of node points makes no difference. In a spectral element approach, incomplete quadrature is used, so it is not so clear if it helps or not. It would be a shame if the non-specialist reader came away with the impression that the clustering matters in all finite element settings, perhaps it might be better to remove this remark unless the authors can come up with some demonstration or reasoning why it would actually help.

2) p4, l18: perhaps emphasise that you make the comparison at the same DOF count, i.e. lowering p leads to more elements.

3) For structured in the vertical, there is probably not such a big issue here, but for higher p with the same number of elements you get denser blocks in matrices. A naive implementation would see a big increase in cost here, but careful design of kernels that encourage compiler vectorisation can offset this, do you address this or observe any of these effects?

4) section 3.2 I think this could be explained better to the non-expert. I would suggest to first emphasise the split between continuous and discontinuous expansions and then introduce the Gauss and GL points for each. I personally find the term "interfaces" a bit confusing, because many of these are points in the interior of an element, and I would otherwise assume that interfaces are on the boundary between elements. I appreciate where this comes from, but wonder if you might find a less confusing term.

5) eqn (28) I would find it useful to explain here that this works due to the exact mapping from the CG to the DG space under the vertical derivative.

6) eqn (29) Please explain these boundary conditions and their relevance.

7) p18, line 10. Why no preconditioner for GMRES? Are there any implications in terms of scaling of iterations with resolution? Please report the number of iterations.

8) p24, bottom of page. Please explain the issue about CP staggering and transport a bit more - I didn't follow it. In our FEM with CP-type staggering, this doesn't appear to be an issue.

9) p25, please explain this statement: "In general, it is not recommended to use hyper-diffusion with a higher order than the dynamical discretization (bottom left) since the impact of the hyper diffusion will be in the truncation order of the method."

10) p28. "High-order vertical discretizations are typically associated with strong oscillations that can induce perturbations that grow into unstable eddies." Please emphasise that this is only true when advection is present and discretised using a central/unstabilised scheme.

Interactive comment on Geosci. Model Dev. Discuss., doi:10.5194/gmd-2015-275, 2016.