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## Comment on gmd-2021-82

Darren Engwirda (Referee)

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Referee comment on "Topography-based local spherical Voronoi grid refinement on classical and moist shallow-water finite-volume models" by Luan F. Santos and Pedro S. Peixoto, Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-82-RC1>, 2021

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This is a nice paper that explores the use, benefits and pitfalls of variable-resolution atmospheric simulations based on unstructured dycore formulations a'la MPAS. Using a simplified (moist) shallow water formulation, the authors compare a range of quasi-uniform and variable resolution configurations, detailing differences in simulation quality/skill, as well as identifying various numerical oscillations/artefacts.

While I am definitely supportive of publication, there are a number of questions and potential revisions that I feel could be addressed:

- It appears an unlimited, centred-difference scheme is employed for tracer fluxes --- using the 'standard TRSK' discretisation of the divergence operator when solving for advective transport. This approach can be expected to lead to significant grid-scale noise and oscillation in the tracer fields, as per all results shown for the moist SWE system. As noted by the authors, the full MPAS model does not use centred-differencing for tracer transport for this reason, instead using flux-limited upwind-biased advection schemes. I feel that a better quasi-monotone advection scheme should be implemented and these runs re-analysed. With such significant grid-scale noise present, it is not clear the current comparisons between the UR and VR results for the moist SWE are necessarily as fair as they could be.

- Is PV stabilisation (eg. APVM or LUST [3]) employed in the SWE dycore? TRSK supports an unstable-mode/grid-scale oscillation in PV dynamics that upwinded PV fluxes are needed to control. The PV contours in Fig. 10b show very significant grid-scale checkerboarding, and it would be interesting to understand the nature of PV stabilisation applied here, and to re-run with upwinding active if needed.

- The need to apply momentum dissipation/damping, especially for longer runs, seems

consistent with practical experience. The nature/magnitude of the dissipation required is of interest though. In MPAS-O, dissipation is applied as a combination of  $\text{del}^2$  and  $\text{del}^4$  operators [2], with mesh scale dependent coefficients. Such higher-order dissipation could be expected to offer more selective damping of grid-scale noise, and potentially less impact on overall energy conservation.

- The barotropic jet case is known to be a challenging problem, with the nature of the turbulent vortex roll-up a strong function of mesh resolution/alignment [1,4]. I think it is interesting to use the jet as a test case, though I don't think close agreement between the UR and VR approaches should necessarily be expected.

- I feel that additional discussion/explanation on constraints on mesh generation for TRSK could be of interest, detailing, for example, why generating eg. 'well-centred' meshes (triangles contain their own circumcentres) is important for the TRSK scheme in particular (ie. ensuring primal and dual edges intersect, 'kite' areas associated with PV remapping are positive, etc). There are many good references that could be relevant here --- previous work of mine [5] is one option.

[1] Exploring a Multiresolution Modeling Approach within the Shallow-Water Equations  
Todd Ringler, Doug Jacobsen, Max Gunzburger, Lili Ju, Michael Duda, and William Skamarock (2011)  
MWR, doi.org/10.1175/MWR-D-10-05049.1

[2] A multi-resolution approach to global ocean modeling  
Todd Ringler, Mark Petersen, Robert Higdon, Doug Jacobsen, Philip Jones, Mathew Maltrud (2013)  
OM, doi.org/10.1016/j.ocemod.2013.04.010

[3] Controlling the Computational Modes of the Arbitrarily Structured C Grid  
Hilary Weller (2012)  
MWR, doi.org/10.1175/MWR-D-11-00221.1

[4] Computational Modes and Grid Imprinting on Five Quasi-Uniform Spherical C Grids  
Hilary Weller, John Thuburn, and Colin Cotter (2012)  
MWR, doi.org/10.1175/MWR-D-11-00193.1

[5] JIGSAW-GEO (1.0): locally orthogonal staggered unstructured grid generation for general circulation modelling on the sphere  
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