Review of *Grid Refinement in ICON v2.6.4*
by Zängl, Reinert and Prill
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The authors present 1- and 2-way grid nesting algorithms for the ICON model. Grid nesting has a long history in atmospheric modeling and the authors focus their attention on describing differences from existing implementations in other models, with these differences arising primarily from the authors use of a triangular primal grid in ICON compared to the rectangular grid implementations referenced by the authors. The implementation is comprehensive and reasonably complete. The simulation test results support the algorithmic choices and suggest that the implementation is correct. The points I raise below are primarily for clarification and for missing information.

1. Lines 28-30: Implementing nesting with a hexagonal C-grid is not more difficult, for example see the regional version of MPAS (Skamarock et al 2018, doi:10.1175/MWR-D-18-0155.1), where the basic machinery exists. 2-way nesting would follow from applying the techniques described in Dubos and Kevlahan (2013, DOI:10.1002/qj.2097) which demonstrate and an adaptive mesh shallow-water model using a hexagonal C-grid.
2. Line 110: "*the wish for consistency with continuity*" does not necessitate coupling of the dynamics on the substeps $\Delta\tau$. Consistency for tracer transport only requires that the time-averaged mass fluxes (averaged over the substeps) on the cell faces are used for this transport.
3. Line 113: "*multi-grid approach*": "Multi-grid" could easily be confused with "multigrid" methods for solving PDEs. I suggest the authors recast this as, for example, *The static mesh refinement in ICON is accomplished using multiple separate grids.*
4. Line 118: "*domains having the same parent are not allowed to overlap*": Why?
5. Lines 118-119: Is the nesting configuration a compile-time specification, or a run-time specification?
6. Line 125: Why is the refinement ratio fixed at a factor of 2? Triangles can be divided by any integer division of the edges.
7. Lines 138-140, and Figure 1: It appears that the use of triangles for the primal grid results in the need for large number of cells in the boundary interpolation zone. Nested grid implementation on rectangular grids (MM5, WRF, and FV3 references) have far fewer cells in their boundary interpolation zone (also called the specified zone), as does the 1-way nesting used in the regional version of MPAS (2018, doi:10.1175/MWR-D-18-0155.1) that uses the dual of the ICON grid (hexagons). This results in more interpolations, and this should be noted.
8. Line 157: If vertical nesting is not applied, is using relaxation instead of replacement beneficial?
9. Figure 1: I was confused by this figure at first. In the light-blue region the fine-grid cells are explicitly drawn. At first I had thought that the fine grid contained coarse-grid cells in the nudging zone and boundary interpolation zone, but after reading much further in the paper I understood this is not the case. The indexing of the fine-grid edges with white lettering is not readily apparent.
10. Figure 1, figure caption: "Another child domain overlapping with the depicted domain." I do not understand this sentence because earlier the authors stated that domains cannot

overlap (comment 3). Do the4 authors wish to state this is where the child and parent domains are coincident?

11. Lines 280-285: Using the interpolation constraints (5), (6) and (7), for perfect triangles α_j = ¼ for all j, and this would be identical to an area-weighted computation for all the weights (i.e. (7) for all j). Is the problematic checkerboard pattern produced because of the necessarily non-perfect triangles in the spherical grid?
12. Section 2.4 (line 390): Is this processing sequence any different from that in WRF or FV3? I do not see any difference from the process used in WRF.
13. Figure 4: Why is only the parent grid solution plotted in this figure? I expected that the combined solutions would be plotted, where the highest resolution data is used in any region of the plot. I appreciate that the nest values are plotted in figure 5, but separating them makes it difficult to examine the continuity of the solution across the nest boundaries.
14. Lines 380-385: How is the vertical flux for scalars computed without a specified zone extending vertically away from the upper nest boundary? I appreciate how the boundary fluxes are computed, but is it the case that the flux one interface level down doesn't require values above the upper boundary?
15. How does the vertically-implicit solver in the dynamics handle an upper boundary where *w* is non-zero? Perhaps stated differently, is specifying (interpolating from the parent grid) the vertical velocity at the upper boundary sufficient?
16. Figure 6: The solution plotted here for the non-nested experiment (6a) appears to be significantly better than the ICON solution plotted in figures 8 and 10 in Lauritzen et al 2010 (doi:10.3894/JAMES.2010.2.15), where a number of models were compared using this test case. If this is the case then the authors may want to point that out. Also, results from this case are usually presented for day 9, so the authors' day 10 plots make comparison more difficult.
17. Figure 10: The vertical axis is mislabeled. It is an "RSME difference" and not an RSME. It also seems to me it would be more natural to compute it is a difference from R2B7 which is effectively the reference (higher-resolution) global solution in this case. By using R2B7, the difference (i.e., relative error) would be growing over time.
18. Section 3.2: Specific mention of this test being performed on a reduced-radius sphere might be helpful to readers unfamiliar with this version of the test.
19. Section 3.2: Should the reader understand that there is no Cartesian-plane perfect triangle version of ICON available to do idealized 2D and 3D tests?
20. Section 3.2: While the results show little issue with the upper boundary formulation in the nested simulation, the results are difficult to compare with the previous studies cited by the authors (Zängl et al 2015; Skamarock et al 2012). The nest upper boundary is at 20 km, but the Zängl et al results are only shown up to 12 km, and the Skamarock et al results are only given through 10 km and are on computed 2D Cartesian x-z plane as opposed to a sphere. Klemp et al 2015 (https://doi.org/10.1002/2015MS000435) show solutions on the sphere for this test case (although using a slightly different y variation of the mountain amplitude), again only through 10 km in height. Perhaps a grid can be constructed such that the upper boundary could be placed at 12 km and plots exactly like those in Zängl et al (2015) for easy comparison?
21. Appendix A1: The decision to reorder the grid points is an interesting one. Other models employing unstructured grids, for example Skamarock et al (2018) regional MPAS uses

masks and report low overhead associated with their usage. Is the decision to re-order in part driven by the use of triangles for the primal grid with the resulting large number of cells in the interpolation zone?

22. Appendix A2: Line 647-648: "*multiple nested domains at the same nesting level can be merged*". Does this mean the default is not to merge them?
23. Appendix A2: The WRF model distributes each domain over all the processors. This appears to be the default for ICON. Is it the case that the newer features regarding distributed memory configuration are the option of merging multiple domains on a given level, and the processor splitting described in lines 664-667?