



Development of Customized Variable-Resolution CPAS for Meteorological Simulation

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The model performance and run-time are two major concerns in numerical weather prediction. Both are substantially dependent on the grid specification, in particular, the number of grids, resolution and coverage of the refinement regions. In the Model for Prediction Across Scales - Atmosphere (MPAS-A), unstructured Voronoi mesh is used and the infrastructure, particularly the dynamic core, is implemented to support this flexible topology. However, only several standard meshes are available for download while customization is not supported. Moreover, the use of a globally-constant time-step (determined by the smallest grid) poses challenges on high resolution forecast using meshes with large resolution variation due to impractically long-running time. A Customizable Unstructured Mesh Generation (CUMG) and Hierarchical Time-Stepping (HTS) was developed in the ClusterTech Platform for Atmospheric Simulation (CPAS), offering a potential path for high-resolution local/regional forecast in MPAS-A's framework. The CUMG algorithm enables local mesh refinement in arbitrary shape using user-defined horizontal resolution at any desired locations. Meshes with large resolution variation, for example, ranging from 128 km to 1 km can be generated. The resulting meshes are 100% well-staggered, and zero obtuse Delaunay triangle is guaranteed. The CPAS provides a web-based graphical user interface and no coding is needed for specifying the refinements. In real simulations, grids are integrated in time with heterogenous time-step according to their cell spacings using HTS. It reduces the model run-time tremendously, particularly for meshes with large resolution variation.

In this study, a comparison on the mesh quality, efficiency and performance of a CPAS customized 128-to-1 km mesh to the MPAS-A standard 60-to-3 km mesh with and without HTS was performed. Three historical weather conditions over southern China in 2018 were selected to evaluate their performance: (i) passage of a cold front (ii) heavy rainfall and (iii) passage of a tropical cyclone. In general, the CPAS 128-to-1 km mesh was found to have better quality over the MPAS-A 60-to-3 km mesh, namely cell quality, angle-based triangle quality, and triangle quality. Moreover, using HTS, the benchmarked saving of the total run-time for the CPAS 128-to-1 km mesh and MPAS-A 60-to-3 km mesh are 56.8% (2.33x speedup) and 16.5% (1.20x speedup), respectively. Furthermore, the model results were validated through comparison with the National

Centers for Environmental Prediction (NCEP) Final (FNL) Operational Global Analysis. The 5-day simulation results of various forecast variables within the area of interest (a lat-long box covering 3 km refinement region of the MPAS-A 60-to-3 km mesh) with and without HTS for both meshes show comparable performance in all cases. The promising model performance along with remarkable speedup indicates the validity and feasibility of high resolution local/regional forecast using customized global variable-resolution meshes in an operational manner.