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Simulation of tropical-cyclone-like vortices in shallow-water ICON-hex using goal-oriented r-adaptivity

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The simulation of binary tropical cyclone (TC) interaction requires high resolution in certain sensitive areas of the model domain to ensure accurate predictions of the cyclones' final position. By applying an a posteriori error estimator, these sensitive areas can be identified. We present a hexagonal C-grid shallow-water model (ICON-hex) with goal-oriented r-adaptivity, in which grid points are moved to regions where higher resolution is required. This model is based on ICON, the next generation numerical weather prediction and general circulation model, developed by the Max Planck Institute for Meteorology and the German Weather Service.

The error estimator necessary to perform goal-oriented grid adaptation is, to our knowledge, not yet available for the numerics used in ICON-hex. Our approach to determine the sensitive areas consists in using the estimated error distribution provided by a finite element package that applies the dual-weighted residual method. We explain in detail how such estimated error distribution can be used to control the adaptation of the ICON-hex grid.

The investigation of the TC scenario reveals a high sensitivity of the predicted cyclone tracks to the resolution, in particular in the initial orbiting phase. With increasing resolution, the solutions converge towards a highly resolved reference solution. In addition, we see a significant influence of shape and extent of the refined areas on the accuracy; investigating the parameters that control the grid adaptation, we identify a parameter range that yields grids that show accurate cyclones' final positions. When the sensitive areas are entirely and smoothly resolved, the degree of accuracy is determined by the size of the smallest cells within these refined regions. Consequently, by adapting the ICON-hex grids according to the estimated error distribution, we are able to reduce the degrees of freedom by a factor of four compared to runs on uniform grids, while keeping the same accuracy in the cyclones' final position.