Assessing Adaptive Grid Refinement Techniques with the Chombo-AMR Shallow Water Model

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Introduction

• Current global climate and weather models are challenged by multi-scale intense atmospheric phenomena such as tropical cyclones and squall lines
• Adaptive mesh refinement (AMR):
  - Dynamically increases resolution locally over areas of interest when needed
  - Balances benefits of fine-scale resolution with increased computational burden
• Working to assess the effectiveness of AMR and various refinement strategies within the Chombo-AMR dynamical core using a series of 2D shallow water test cases
• Will use these refinement strategies in 3D-dycore simulations with simplified physics parameterization schemes

Model Description

Chombo-AMR Dynamical Core

• Development led by Applied Numerical Algorithms Group (ANAG) at LBNL [MU2015] in collaboration with the University of Michigan
• Uses the Chombo framework library, an open-source toolkit for solving PDEs on structured grids
• Multi-block grids on a cubed-sphere
• 4th-order finite-volume discretization of the shallow water equations
• Adaptive in both space and time

3D-Dycore Plans

• Non-hydrostatic model with a vertical time integrator that is implicit for “wave” terms and option to use Strang-type or IMEX coupling approaches
• Will implement a simplified physics parameterization scheme base on [RR2012] and a more complex Kessler-type warm precipitation microphysics scheme
• Will use a variety of baroclinic wave, orographic precipitation, and idealized tropical cyclone test cases
• Goal is to assess the effectiveness of AMR and the affects of AMR and changing grid resolutions on the physics parameterizations

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References


Conclusions

AMR techniques show promising results in the 2D shallow water tests:
• Able to achieve similar errors to uniform runs with significantly fewer grid cells
• AMR grid does not degrade large scale smooth flows
• Multiple possible refinement criteria
• Able to resolve localized fine-scale features accurately

Future Work: Begin similar analysis using the full 3D Chombo-AMR with the simplified physics parameterization schemes discussed. Focus will be on assessing the dependence of these sub-grid parameterizations on the resolution and grid structure in AMR runs using idealized tropical cyclones and other test cases.