**Space-time Adaptivity for Climate Models**

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Earth science phenomena often exhibit large variations in scale which can be addressed by local spatial and temporal refinement techniques like Adaptive Mesh Refinement (AMR). Continued progress toward higher-resolution and exascale computing means algorithmic innovations coupled with framework-driven software improvements promise to make AMR even more useful. We present relevant examples.

Ice sheets demand extremely fine (sub-kilometer) resolution near rapidly-evolving grounding lines and ice streams, remaining relatively quiescent over much of the remaining continental-scale domains. Using AMR, the BISICLES ice sheet model fully resolves Antarctic ice sheet dynamics at a computationally-tractable cost. For moist non-hydrostatic global atmospheric dynamics, horizontal and vertical time-adaptive refinement allocates computational effort where greater accuracy is needed for dynamic features occurring below hydrostatic scales, like tropical cyclones. At the cost of some software complexity, solution accuracy can be greatly improved, with 10-100x fewer grid points and greatly reduced computational expense. The Stratified Ocean Model with Adaptive Refinement (SOMAR) brings AMR to ocean modeling, solving the non-hydrostatic, baroclinic flows encountered in regional and coastal ocean simulations. Finally, the process of sea ice formation produces narrow brine-rejection channels which control salt and nutrient transport between porous ice and the ocean. Dynamically complex as they form and evolve, these channels require fine resolution and exhibit strong transient behavior; we have collaboratively developed an AMR model with Oxford University.

The Chombo framework includes high-order finite-volume methods on mapped grids, with ongoing application development. With their increased arithmetic intensity, these will be particularly useful as applications move into the exascale era.