Summary

This project outlines the development of efficient and portable adaptive hybrid mesh generation capabilities applicable to a wide range of field simulations. Applications include, but are not limited to, climate modeling, large scale multi-physics based simulation, computational chemistry, computational biology, material sciences, and environmental sciences. The primary objective of this project was to research and develop parallel hybrid mesh and discretization technologies for field simulations. We focused on the generation of high quality polygonal meshes for geometrically-complex domains in two and three dimensions. These methods are applied to parametric as well as non-parametric (discrete) geometric models. The successful methods and algorithms developed in this research are currently deployed in support of climate modeling, material sciences, computational plasma physics.

Adaptive Hybrid Mesh Optimization for Climate Modeling

Mesh generation has emerged as a major pacing item with regards to computational modeling and simulation. And it is a crucial first step for the solution of multi-dimensional problems in field simulation. In addition, the accuracy and convergence of computational solutions using mesh-based numerical methods are strongly dependent on the quality of the mesh being used.

Part of the Computational Mathematics Group mission in conjunction with the SciDAC Terascale Simulation Tools and Technologies (TSTT) project is the interaction with climate scientists at ORNL. We have focused our efforts on developing technology to create and adapt high-quality hybrid meshes for climate modeling and simulation. Applications of this technology include the generation and adaptation of smooth mesh transformations for General Circulation Models (GCMs) that attempt to simulate the Earth's climate system. Mesh adaptation plays a crucial role in atmospheric-ocean-land models that calculate physical quantities such as temperature, humidity, wind speeds which have direct effect on sea ice cover, soil moisture, and cloud formation. In climate modeling, mesh adaptation can also reduce the simulation error in prediction of (1) the dynamics of the climate system that describe the large-scale movement of air masses and transport of energy and momentum; (2) the physics of the climate system such as radiation transmission through the atmosphere, thermodynamics, and evaporation; and (3) other factors such as air-sea interaction, topography, and vegetation parameters.

Our goal is to achieve better prediction of climate simulation via mesh/grid refocusing and adaptation. PDE based smooth quasi-conformal mapping is used to produce the adapted grids. For example, mesh refocusing can be used to obtain higher resolutions over the Rocky Mountains. This would lead to better predictions of long-term rainfall over the Northwest that has major effects on agriculture and wild fires. In addition, adapted moving meshes are possible to track special weather features like hurricanes. Another application is that, stretched meshes are best used to resolve scales and processes...
associated with topography where the mesh is focused over high altitude mountains.

The developed adaptive meshing methods are currently utilized at ORNL for the generation of refocused adaptive meshes applied to fine scale processes in climate modeling. In particular, we concentrated our efforts on producing high quality meshes that are adapted to the earth’s orography field, i.e., earth’s surface height. We have generated a variety of meshes (structured and unstructured) with the feature of mesh refocusing in and around areas high altitude without changing the resolution of the initial meshes (see Figure 1). In return, the pay off in computational cost is reduced while achieving the desired simulation results. The climate code would spend much less computational time using adapted optimized mesh to obtain a high quality solution verses using non-adapted mesh.

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Figure 1. Adaptive Hybrid Mesh Generation For Climate Modeling