

Hybrid Mesh Generation for Climate Modeling

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Summary

The accuracy and convergence of computational solutions of mesh-based methods is strongly dependent on the quality of the mesh used. We have developed methods for generating and optimizing meshes that are comprised of elements of arbitrary polygonal (hybrid) type. We present in this research an overview of the developed hybrid meshing technology tailored to application areas relevant to multi-physics modeling and simulation. We have successfully introduced the hybrid meshing method for the solution of the spherical shallow atmosphere model used in climate modeling. In addition, application of this technology also covers a wide range of disciplines in computational sciences, most notably, time-dependent multi-physics, multi-scale modeling and simulation.

Mesh generation is a crucial first step for the solution of multi-dimensional problems in field simulation. The accuracy and convergence of solutions using mesh-based numerical methods are strongly dependent on the type and quality of the mesh being used. Mesh generation lies at the core of many areas in advanced computational sciences and engineering and has emerged as an enabling technology and a major pacing item in computational modeling and simulation. In particular, hybrid mesh generation and optimization plays an important role in complex high-fidelity simulation fields. Generation of a quality mesh to support these calculations is a challenging, multi-disciplinary problem.

The objective of this highlight is to present an overview of the current meshing efforts and development at the Computational Mathematics Group at Oak Ridge National Laboratory. We have focused our efforts on

developing meshing tools and technology to create and optimize high-quality hybrid meshes for climate modeling and simulation.

Our approach to the meshing problem has been the use of hybrid meshes. These meshes provide more flexibility than traditional approaches through the use of varying cell topologies ranging from hexagons, pentagons, quads, to triangles in two dimensions and hexahedra, prisms, and pyramids, to tetrahedral in three dimensions. The hybrid mesh approach attempts to combine the advantages of both structured and unstructured meshing approaches. The advantage of the hybrid meshing system is the polygonal (or icosahedra) meshes are often the best choice of solving symmetric computational problems with no mesh singularities at the poles as desired in climate modeling simulation. In addition, they have the properties of producing symmetric higher order orthogonal meshes

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and do not introduce artificial geometric interfaces. Furthermore, quadrilateral layers close to wall surfaces exhibit good orthogonality and clustering capabilities characteristic of structured mesh generation approaches.

We have focused our efforts on developing technology to create and adapt high-quality hybrid meshes for climate modeling simulation. We have utilized algebraic algorithms and partial differential equations (PDE) methods for the generation of hybrid meshes. Our meshing efforts include methods for optimizing and adapting meshes that are comprised of elements of arbitrary polygonal/ polyhedral type. We have also focused on developing advanced scalable interoperable software associated with geometry, mesh, adaptivity, and field manipulation. Our goal is to provide the necessary meshing tools to reach new levels of understanding through the use of high-fidelity calculations based on multiple coupled physical processes and multiple interacting physical scales. This meshing approach and its underlying methods can be attractive to many application areas when solving three-dimensional, multi-physics, multi-scale, and time-dependent PDE's.

The mesh example demonstration in Figure 1 showcase the generation of hybrid surface meshes applied to climate modeling. The geometry of the mesh and its symmetries are matched to the analytical and numerical methods used to solve the governing equations. In this work, we have research and develop new hybrid mesh generation and optimization algorithms with the advantages of flexibility, generation of high-quality meshes suitable for an accurate resolution of fine-scale processes in climate modeling. The geometry of the mesh and its symmetries are matched to the analytical and numerical methods used to solve the

governing equations. In turn this will reduce analysis time and increase accuracy.

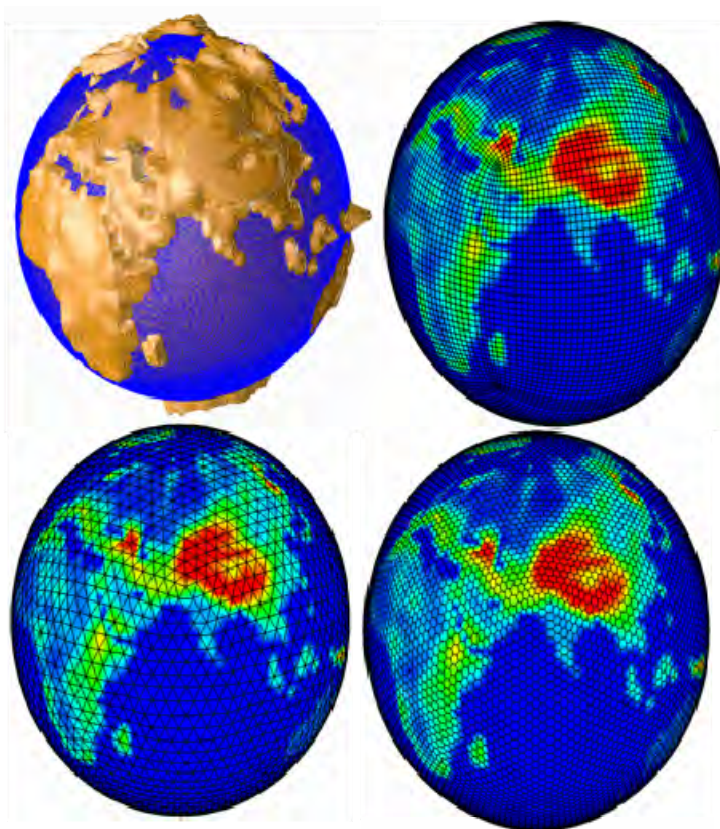


Figure 1. Hybrid Surface Mesh Generation for Climate Modeling

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