Aeras: Extending Albany to Solve PDEs on the Sphere

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Albany is a parallel, implicit, unstructured-grid finite element code from Sandia National Laboratories that demonstrates agile components and enables rapid prototyping. It uses, matures, and spins-off reusable libraries and abstract interfaces, and is a friendly early adopter of cutting-edge Sandia technologies Trilinos, Sierra ToolKit, and Dakota. It demonstrates transformational analysis spanning template-based generic programming, optimization, uncertainty quantification (UQ), adaptivity, and model order reduction. It serves as an attractive environment for the development of open-source application and research codes, including applications as diverse as continuum mechanics, quantum devices and an ice sheet model.

Aeras (Greek for ”air”) is a Sandia project to develop a next-generation atmosphere model by leveraging Albany. Our goal is to provide all the capabilities of the Community Atmosphere Model—Spectral Elements (CAM–SE), while also supporting UQ, performance portability, and a wider variety of discretizations.

As a first step in this project, we have recently added extensions to Albany to support the solution of partial differential equations on the sphere. These extensions include shell elements; projections from 2D, planar reference elements to spherical surface elements; specialized horizontal derivative routines; and conversions from spherical surface element space to latitude-longitude space for visualization and analysis. Once these extensions were in place, we were able to rapidly prototype the shallow water equations on the sphere discretized with bi-quadratic finite elements. This discretization produces a non-diagonal mass matrix, which we invert with a full complement of Trilinos linear solvers and preconditioners provided by Albany. Albany also automatically provided capabilities for quantifying the propagation of uncertainty through the model. This talk will present the current status of the Aeras project.

Future steps in the larger development effort will result in a full-featured, spectral element atmosphere model. Current development efforts in Albany will soon provide the capability to write numerical kernels just once, that then port efficiently to multiple modern computing architectures while maintaining performance. We will add support for families of high-order elements and explicit time stepping. We will support both the hydrostatic and non-hydrostatic equations, and have plans to support multiple discretizations, including vertical coordinates.