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Using Global Plate Velocity Boundary Conditions for Embedded Regional Geodynamic Models: Application to 3-D Modeling of the Early Rifting of the South Atlantic

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The treatment of far-field boundary conditions is one of the most poorly resolved issues for regional modeling of geodynamic processes. In viscous flow, the choice of far-field boundary conditions often strongly shapes the large-scale structure of a geosimulation. The mantle velocity field along the sidewalls and base of a modeling region is typically much more poorly known than the geometry of past global motions of the surface plates as constrained by global plate motion reconstructions. For regional rifting models it has become routine to apply highly simplified 'plate spreading' or 'uniform rifting' boundary conditions to a 3-D model that limits its ability to simulate the geodynamic evolution of a specific rifted margin. One way researchers are exploring the sensitivity of regional models to uncertain boundary conditions is to use a nested modeling approach in which a global model is used to determine a large-scale flow pattern that is imposed as a constraint along the boundaries of the region to be modeled. Here we explore the utility of a different approach that takes advantage of the ability of finite element models to use unstructured meshes than can embed much higher resolution sub-regions. Here we demonstrate the workflow and code tools that we created to generate this unstructured mesh: solver based on springs, guide-mesh and routines to improve the quality, e.g., closeness to a regular tetrahedron, of the tetrahedral elements of the mesh. Note that the same routines are used to generate a new mesh in the remeshing of a distorted Lagrangian mesh.

In our initial project to validate this approach, we create a global spherical shell mesh in which a higher resolution sub-region is created around the nascent South Atlantic Rifting Margin. Global Plate motion BCs and plate boundaries are applied for the time of the onset of rifting, continuing through several 10s of Ma of rifting. Thermal, compositional, and melt-related buoyancy forces are only non-zero within the high-resolution sub-region, elsewhere, motions are constrained by surface plate-motion constraints. The total number of unknowns needed to solve an embedded regional model with this approach is less than 1/3 larger than that needed for a structured-mesh solution on a Cartesian or spherical cap sub-regional mesh. Here we illustrate the steps within this workflow for modeling the potential mantle flow associated with the early rifting evolution of the South Atlantic, in particular studying the potential effects of a 'Parana Plume' during the transition from rift to drift.