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## Scaling and Performance Analysis of Underworld: Towards the One Billion Particle Target

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We investigate the scaling performance of Underworld, a geodynamic modeling framework, on high performance computing resources. These results inform the configuration and allocation of resources committed to study the complex geodynamic processes in and around subduction zones. We use a 3D thermal convection model that includes a temperature and stress dependent rheology as a proxy for the computational difficulty of the eventual subduction problems. This proxy model is designed with significant variation in viscosity, in conjunction with the non-linear temperature and stress dependent rheology this results in a computational problem that is significantly more challenging than the similar isoviscous convection problem.

Using an allocation of 30000 service units on Texas Advanced Computing Center (TACC) cluster, Ranger, we ran a suite of models that exercised Underworld by solving problems with element sub-

domain sizes of  $16 \times 16 \times 8$  and  $16 \times 16 \times 16$  per core. For each of subdomain size we ran the models at several global resolutions, from what we call "tiny" models ( $32 \times 32 \times 32$ ) to what we refer to as "huge" ( $192 \times 192 \times 192$ ). The global resolutions selected require CPU core allocations from 100's to 1000's.

Underworld supports both a basic FEM solution method and Particle In a Cell (PIC). We solve the thermal convection problem using both methods to verify the equivalence of solutions. At the highest resolutions using the PIC method the number of particles approaches 1.5 million. We continue to explore this model with an eye towards systems populated by up to 1 billion particles.

Timing results are measured as the walltime per model timestep. A common steady-state model is first calculated over several thousand timesteps. This steady-state model is then restarted at the appropriate resolution whence the performance data is gathered.

## Stress modeling in the Central Asia crust, importance of gravity stresses

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The Southern and Central Asia is a tectonically complex region which characterized by the great

collision between the Asian and Indian plates. Its tectonic evolution is strongly related to the active