Planetary Scale Simulations of Geodynamics with Multipole Boundary Elements

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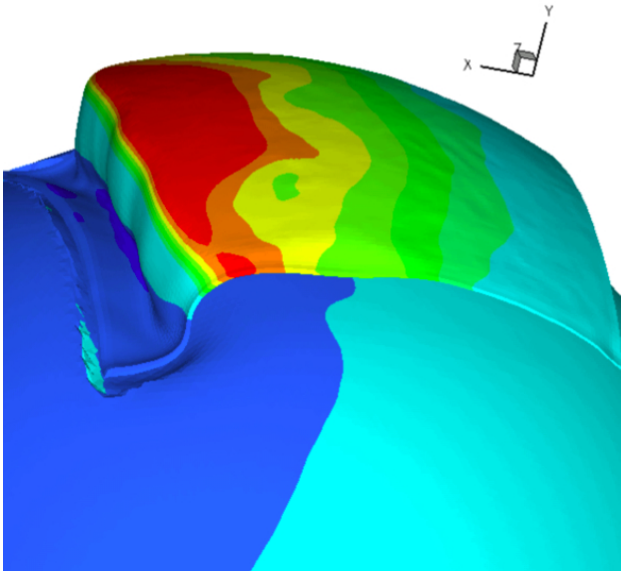

Figure 1: Subduction of a giant slab in spherical coordinate and plot of the interaction with the 660km discontinuity. Colors represent horizontal velocities in the subduction direction (x).

We present a novel computational approach for modeling geodynamics in a spherical setting using a fast multipole acceleration of the boundary elements method. The technique makes it straightforward to run models of plate tectonics at the planetary scale with great computational efficiency. We analyze the effect of size, earth curvature, and slab-slab interaction for large subducting plates, in order to extract general laws for the collective behavior of tectonic plates.

The numerical approach is based on a fast multipole method (FMM) for the evaluation of the integrals, which scales as $N \log(N)$, which is far more tractable and still allows the use of a Generalized Minimized Residual method (GMRES) or any Krylov space based method that does not rely on the storage of the full matrix. We show that the code scales linearly with the problem size for large sizes (more than 10^3 elements) and shows a very good parallel behavior that is promising for larger systems.

In order to appropriately model subduction, an adaptive mesh algorithm has been newly developed, which adapts the shape of the earth surface to the free-surface to the lithospheric topography. Consequently the density difference between the mantle and ocean self-consistently sustains the unsubducted lithosphere while the lithosphere deforms in a full free surface setting. Exploiting this innovation, for the first time FMM-BEM has been employed for modeling subduction of planetary sized plates in spherical coordinates.

References: G. Morra, P. Chatelain, P. Tackley and P. Koumoutzakos Large Scale Three-dimensional Boundary Element Simulation of Subduction ICCS 2007 Part III, LNCS 4489, pp. 1122-1129, 2007