Stony Brook University
The Graduate School

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Abstract

Elucidating lithosphere-mantle coupling by modeling the Earth's lithospheric stress field and plate motions

By

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Even after the establishment of the plate tectonic theory nearly four decades ago, some fundamental questions have still not been satisfactorily answered. What drives the Earth's plates? Are plates and mantle coupled, and if so, what is the nature of that coupling? What is the role of density buoyancy-driven flow in driving the plates? These are some of the questions we try to address in our study through a joint modeling of lithosphere dynamics and mantle convection. If the initial coupling model is correct, the predicted stresses will match the observed deformation along the plate boundary zones and the predicted velocities will match the observed plate motions. We model the lithospheric deviatoric stress field from gravitational potential energy (GPE) differences and compare our modeled stress tensor field with velocity gradient tensor field along the Earth's deforming plate boundary zones (from GSRM). The deviatoric stresses due to active basal tractions acting at the base of the lithosphere, arising from density buoyancy-driven mantle convection, are also compared with the strain rate tensor dataset from GSRM. We find that the combined stresses from lithosphere and mantle buoyancies yield the best fit to the deformation indicators, especially in areas of continental deformation. This is most likely due to driving shear tractions induced by the surrounding mantle, related to the history of subduction in those areas. We also generate plate motions in our convection models by incorporating lateral viscosity variations generated by major geological features of the Earth, such as the continent-ocean divide, the presence of cratonic roots as well as age differences in the oceanic lithosphere. For each structure, we predict the deviatoric stress field, the pattern of poloidal and toroidal flow and the partitioning ratio between toroidal/poloidal velocities. The predicted deviatoric stress field is added to the deviatoric stresses generated by lithosphere buoyancies and the total stress field is compared with strain rate tensor information from GSRM. The best-fit model has to satisfy both the constraints of matching the plate motions and the deviatoric stress field simultaneously. By using both these constraints, we are able to eliminate several types of models and narrow down significantly the set of models that fit the observations.

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