Geophysical Research Abstracts
Vol. 18, EGU2016-16010, 2016
EGU General Assembly 2016

Bayesian geodynamic inversion to constrain the rheology of the flat subduction system in southwestern Mexico

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The flat slab in southwestern Mexico differs from others at the present-day because (1) it is associated with abundant arc volcanism, (2) it is associated with extension in the arc and a neutral state of stress in the fore-arc, (3) it generates relatively low seismic activity, (4) the continental mantle lithosphere is very thin or nonexistent, (5) it is not directly caused by the subduction of thickened oceanic crust, and (6) there is no nearby cratonic keel.

In a recent study, we showed that the topography in the area is controlled by both isostatic and dynamic contributions. The Trans-Mexican Volcanic Belt is either isostatically supported or slightly buoyed up by a low-density mantle wedge. To the contrary, the forearc is pulled downward by the flat slab, resulting in about 1 km of subsidence.

Using a two-dimensional instantaneous Stokes flow finite-elements model, we found a combination of slab, mantle, and subduction interface properties that can predict the observed topography, plate velocities, and stress state in the continent. However, this solution is not unique, and there are trade-offs between these properties such that several combinations can provide a similarly good fit to the data.

In this work, we present a geodynamic inversion to further investigate what viscosities and densities are required in different zones of the subduction system to explain the observations collected at the surface. The inverse problem is cast in a Bayesian framework, where model parameters (e.g. the viscosity in the mantle wedge and along the subduction interface) can be reconstructed in a probabilistic sense, and where trade-offs and uncertainties can be quantitatively constrained. We use a direct parameter search approach based on a Markov chain Monte Carlo (McMC) scheme to test a large number of potential scenarios.