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Incorporation of mantle effects in lithospheric stress modeling: the Eurasian plate

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The intraplate stress field is the result of forces acting on the lithosphere and as such contains valuable information on the dynamics of plate tectonics. Studies modeling the intraplate stress field have followed two different approaches, with the emphasis either on the lithosphere itself or the underlying convecting mantle. For most tectonic plates on earth one or both methods have been quiet successful in reproducing the large scale stress field. The Eurasian plate however has remained a challenge. A probable cause is that due to the complexity of the plate successful models require both an active mantle and well defined boundary forces. We therefore construct a model for the Eurasian plate in which we combine both modeling approaches by incorporating the effects of an active mantle in a model based on a lithospheric approach, where boundary forces are modeled explicitly. The assumption that the whole plate is in dynamical equilibrium allows for imposing a torque balance on the plate, which provides extra constraints on the forces that cannot be calculated a priori. Mantle interaction is modeled as a shear at the base of the plate obtained from global mantle flow models from literature. A first order approximation of the increased excess pressure of the anomalous ridge near the Iceland hotspot is incorporated. Results are evaluated by comparison with World Stress Map data.

Direct incorporation of the sublithospheric stresses from mantle flow modeling in our force model is not possible, due to a discrepancy in the magnitude of the integrated mantle shear and lithospheric forces of around one order of magnitude, prohibiting balance of the torques. This magnitude discrepancy is a well known fundamental problem in geodynamics and we choose to close the gap between the two different approaches by scaling down the absolute magnitude of the sublithospheric stresses. Becker and O'Connell (G3,2,2001) showed that various mantle flow models show a considerable spread in integrated shear torque orientations. They found that mantle flow models obtained from subduction derived density fields produce best fit to global plate velocities.Torque balance applied on the Eurasian plate links mantle shear torque orientations to the magnitudes of the different boundary forces. We find that force models including mantle shear based on subduction history density fields only attain equilibrium if the overriding plate effect of the subduction zones in the Sunda arc is pulling, as in a back arc basin setting. This creates great tension in South-East Asia, in disagreement with observations. Mantle shear models produced by P-wave tomographic models have an integrated effect that form a torque balance solution that produces a more realistic force set (and accompanied stress field) in south-east Asia and therefore have our preference.