Geophysical Research Abstracts
Vol. 15, EGU2013-6025-1, 2013
EGU General Assembly 2013

Viscoelastic convection with a free surface: Implications for subduction initiation

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The initiation of subduction on Earth is a yet unresolved question in geodynamics. It has been extensively investigated by many authors, but still remains poorly understood. It has been shown that it is rather difficult to initiate subduction in a stagnant lid regime . To obtain subduction zones, one needs to introduce either weak faults (e.g. (Toth & Gurnis, 1998)) or a relatively low upper strength limit of the lithosphere (the yield stress) (e.g. (van Heck & Tackley, 2008)) to produce subduction-like features in numerical models. As an alternative to prescribed weak zones, lithospheric-scale models have also employed different weakening mechanisms to create lithospheric-scale shear zones (e.g. (Thielmann & Kaus, 2012)).
In this study, we investigate the effect of a free surface upper boundary condition on bottom heated viscoelastic convection. As the lid is allowed to bend under external forces (an up- or downwelling), large bending forces may be created which might then help to break the stagnant lid. Using 2D viscoelastoplastic numerical models, we investigate the dependence of the lid stress on the Rayleigh number and the Deborah number. Results show that stresses in the lithosphere reach critical values when using a free surface boundary condition. In a further step, we then employ a weakening mechanism to assess if localized lithospheric-scale shear zones can be formed which then enable subduction to initiate.

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