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Diploma Thesis

Megathrust seismic cycle surface deformation in subduction forearcs – a comparison between elastic dislocation, analog seismic cycle models and nature

Submitted by:

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Affirmation

I certify herewith that I composed this diploma thesis independently, and that I did not use any sources or auxiliary means other than mentioned.

Rainer Nerlich

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Abstract

My diploma thesis focuses on the surface deformation of subduction zone forearcs in the course of multiple seismic cycles. To study seismotectonic forearc deformation, experimentally observed deformations of an analog subduction zone model monitored using particle imaging velocimetry (PIV) were compared with the predictions of a purely elastic dislocation model (EDM) and tested against natural observations. Based on a thorough sensitivity analysis of the EDM and PIV system, respectively, a computer tool was developed to ease analysis of the experimental deformation patterns with respect to elastic and permanent plastic components using the EDM. The handling of the program is described in here in form of a user guide. By analyzing an experiment using the new tool, I derived a data base of 83 analog earthquakes and 60 interseismic periods. Each coseismic deformation pattern was separated into elastic and plastic deformation components and discussed with respect to scaling relationships between surface deformation extent and earthquake slip as well as its similarity to naturally observed deformation patterns. The typical coseismic analog model surface deformation pattern of differential uplift and subsidence, which is known from great earthquakes in nature, is seen to be predominantly elastic. For instance the coseismic uplift bulge seaward of the earthquake asperity, which is shown by the elastic model and the analog model, is a robust feature. This observation justifies the use of elastic models in slip inversion studies. Uplift occurs about 30 km seawards of the asperity and is about 30 % of the maximum earthquake slip in the given setup (15° dipping plate interface). A significant number of analog earthquake patterns, however, included first- or second-order non-elastic effects, which affect the relationships between the surface deformation and the slip along the megathrust at depth. Parts of these effects are arguably artificial or setup-related, parts of them reasonably realistic. The latter include subsidence of the forearc due to potential energy release and a "new class" of subduction earthquakes: Catastrophic normal faulting is observed in the experiment, which causes thinning of the subduction channel in the area of large slip. This type of earthquake might be responsible for the global correlation between forearc basins and areas of large slip during subduction earthquakes. The analysis of the interseismic deformation patterns showed that more than 50 % of the interseismic deformation in the analog model is plastic. If applicable to nature this implies that locking of the megathrust as inverted from geodetic observations using elastic models is notoriously overestimated. Permanent interseismic uplift occurs close to the trench and in the coastal region which causes a morphotectonic segmentation of the forearc as seen in many subduction zones in the world.

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