Geophysical Research Abstracts
Vol. 18, EGU2016-16873-1, 2016
EGU General Assembly 2016

Rheological behavior of the crust and mantle in subduction zones in the time-scale range from earthquake (minute) to mln years inferred from thermomechanical model and geodetic observations

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The key achievement of the geodynamic modelling community greatly contributed by the work of Evgenii Burov and his students is application of "realistic" mineral-physics based non-linear rheological models to simulate deformation processes in crust and mantle. Subduction being a type example of such process is an essentially multi-scale phenomenon with the time-scales spanning from geological to earthquake scale with the seismic cycle in-between. In this study we test the possibility to simulate the entire subduction process from rupture (1 min) to geological time (Mln yr) with the single cross-scale thermomechanical model that employs elasticity, mineral-physics constrained non-linear transient viscous rheology and rate-and-state friction plasticity. First we generate a thermo-mechanical model of subduction zone at geological time-scale including a narrow subduction channel with "wet-quartz" visco-elasto-plastic rheology and low static friction. We next introduce in the same model classic rate-and state friction law in subduction channel, leading to stick-slip instability. This model generates spontaneous earthquake sequence. In order to follow in details deformation process during the entire seismic cycle and multiple seismic cycles we use adaptive time-step algorithm changing step from 40 sec during the earthquake to minute-5 year during postseismic and interseismic processes. We observe many interesting deformation patterns and demonstrate that contrary to the conventional ideas, this model predicts that postseismic deformation is controlled by visco-elastic relaxation in the mantle wedge already since hour to day after the great (M>9) earthquakes. We demonstrate that our results are consistent with the postseismic surface displacement after the Great Tohoku Earthquake for the day-to-4year time range.