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Slip rate variability and distributed deformation in the Marmara Sea fault system south of Istanbul

Tobias Hergert (1,2), Oliver Heidbach (3), Anne Becel (1,4), Mireille Laigle (1), and Alfred Hirn (1)

(1) Institute de Physique du Globe, Paris, France (hergert@ipgp.jussieu.fr), (2) Karlsruhe Institute of Technology, Karlsruhe, Germany (tobias.hergert@gpi.uni-karlsruhe.de), (3) GFZ German Research Centre for Geosciences, Potsdam, Germany, (4) CSIC-Instituto de Ciencias de la Tierra 'Jaume Almera', Barcelona, Spain

We investigate the relationship between structural elements and contemporary kinematics in the Marmara Sea region by means of a 3D geomechanical model. The recently imaged details of the fault system beneath the Sea of Marmara (Becél et al., Tectonophysics, 2009; Laigle et al., EPSL, 2008) are incorporated into the model as frictional surfaces. Topography, basement-topography and the Moho is also implemented in order to account for the changes in density and elastic parameters across these horizons. The model is subjected to gravity and to kinematic boundary conditions derived from a reginoal large-scale model.

We quantify from the model the long-term fault slip rates, sense of fault slip, internal deformation, rotations and vertical motion in the Marmara Sea region and compare these results with model-independent data from geodetic observations, paleoseismological fault slip rates, paleomagnetic measurements and geomorphology. The model results fit these observations well and resolve the systematic discrepancy between fault slip rates derived from geodetic observations and geological fault slip rates. The slip rate on the main Marmara fault varies in our model between 12.8 and 17.8 mm/a, whereas previous models that use the same geodetic data propose a greater and more uniform slip rate. We interpret that this deviation is due to the incorporated structural complexities that cause a more distributed deformation and to the fact that fault slip in our model is driven dynamically consistent from remotely acting boundary conditions whereas in other models the slip on faults is imposed below the locking depth (Hergert and Heidbach, Nature Geosciences, 2010). We suggest that the inferred variability in slip rate on the main Marmara fault favours segmented release of seismic moment during consecutive events over the failure of the whole seismic gap in one large earthquake.

Furthermore, our tectonically-driven vertical velocities can be linked to landscape and basin evolution and to features of sedimentation. The dip-slip rates and rake direction on the Main Marmara Fault reveals that the prevailing tectonic regime is strike-slip with a small normal faulting component at a few places such as the Prince's Island segment. At the second order fault in the Marmara Sea the normal faulting component, i.e. the dip-slip rate, is larger in dependence of the orientation of the fault with respect to the regional stress field. The consistency of modelled horizontal and vertical velocities with model-independent observations from time scales which range from interseismic periods to several thousand years gives confidence that the main structural details of the fault system are considered by the model.