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Slip-deficit estimation with a 3D fault model of the North Anatolian Fault by using InSAR time series

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Crustal earthquakes are events of sudden stress release through rock failure, for example as a consequence of continuous and long-term stress buildup at tectonic faults that eventually exceeds the strength of rock. Before failure, under increasing stress at a fault, the surrounding crust is slowly deforming. The amount and pattern of crustal deformation carries information about location and potential magnitude of future earthquakes.

Time series of space-borne interferometric Synthetic Aperture Radar (InSAR) data can be used to precisely measure the surface motion, which corresponds to the crustal deformation, in the radar line-of-sight and across large areas. These observations open the opportunity to study fault loading in terms of location, size of locked parts at faults and their slip deficit. Here we study the North Anatolian Fault (NAF), a major right-lateral strike-slip fault zone of about 1500 km length in the north of Turkey and we create its first large-scale 3D finite-fault model based on InSAR data.

We use the InSAR time series of data recorded by ESA's Envisat SAR satellite between 2002 and 2010 (Hussain et al., 2018 and Walters et al., 2014). We represent the fault with several vertical, planar fault segments that trace the NAF with reasonable resolution. The medium model is a layered half space with a viscoelastic lower crust and mantle. Several GNSS velocity measurements are used to apply a trend correction and calibrate the InSAR time series data to an Eurasia-fixed-reference frame. We use the plate motion difference of the Anatolian and the Eurasian plates calculated through an Euler pole to set up a back-slip finite-fault model. We then optimize the back-slip as the slip deficit, the width and the depth of the locked fault zone at each segment to achieve a good fit to the measured surface motion.

We find shallow locking depths and small slip deficits in the eastern and westernmost regions of the NAF, while the central part shows both deeper locking depths and larger slip deficits for the observation period. For both parameters the trends are in an overall agreement to earlier studies. There, InSAR-time series data have been used to calculate slip deficits at the North Anatolian fault with 2D models and/or assuming a homogeneous and purely elastic medium. Local modeled differences therefore might be connected to differences in the modeling approaches, but also remain subject to further investigations and discussions.

Our model provides a very suitable basis for future time-dependent modeling of the slip deficit at the NAF that includes also more recent InSAR time series based on data from the Sentinel-1 radar satellite mission of ESA.