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Spatio-temporal slip rate variability of the Doruneh fault (eastern Iran) from dense GNSS and SENTINEL data and a tectonic study

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The recent activity of the 600 km long E-W trending Doruneh fault in eastern Iran is attested by clear geomorphological features along its trace, while no instrumental earthquake can be related to this fault. The only two Mw7 events in this area took place on the Dasht-e Bayaz fault, south of Doruneh. The great length of the fault, the lack of the seismicity and the active regional N-S shortening induced by the Arabian-Eurasian convergence highlight the seismic potential of the Doruneh fault. However, until today, the short- and long-term slip rate estimates of the Doruneh fault remain controversial. Geomorphological offset dating indicates long-term slip rates between 2.5 mm/yr and 8.2 mm/yr. Preliminary GNSS measurements and local InSAR data reveal rates between 1 and 5 mm/yr. This wide range of slip rate estimates suggests either temporal or spatial variability of the Doruneh fault activity.

To investigate the along-strike slip variability of the Doruneh fault, a dense GNSS survey including 18 sites has been conducted in 2012 and 2018. This network completes the 17 regional permanent GNSS stations. Combining campaign and permanent data, the horizontal GNSS velocity field constrains the slip velocity and its variability along the fault by complementary approaches, on profiles perpendicular to the fault, and by a rigid block model. Sinistral motion is maximal in the western part of the fault (1 to 4 mm/yr), and decreasing towards the east. A complementary InSAR velocity map based on Sentinel-1 images between 2014 and 2019 exploits two ascending tracks (A159 and A86) across the Doruneh fault. We followed the SBAS time series analysis approach and corrected the effects of annual loading cycles and tropospheric delay. Sand and unexpected large tropospheric effects prohibited correlation in some places, but a coherent mean velocity map in line of sight (LOS) direction to the satellites is obtained for most of our study area. This map shows no sharp variations along the fault trace that could indicate shallow fault creep. The clearest signals are zones of anthropogenic subsidence. Looking for a long-wavelength tectonic signal (less than 3 mm/yr spread over 100 km), we masked these areas of rapid and short-wavelength deformation. The resulting velocity maps for both tracks are projected on profiles perpendicular to the fault and indicate a long-wavelength signal across the Doruneh fault of less than 2 mm/yr in LOS direction. A systematic parameter search yields a first best fit on track A159 combining a horizontal slip rate of 3.25 mm/yr with a locking depth of 8 km in the western part of the fault. This approach will be pursued on track A86, covering the eastern part, after more thorough cleaning.

We finally compare the combined GNSS-InSAR present-day fault slip rates to new long-term slip rates from geomorphological offset dating, to evaluate the time variability of the Doruneh fault activity. Our multi-disciplinary study will enhance our understanding of the Doruneh fault mechanism and its role in the kinematics of the Arabia-Eurasia collision, and contribute to a better seismic hazard assessment in eastern Iran.