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Systematic variations of fault creep along the Marmara seismic gap, north-western Turkey, based on the observation of earthquake repeaters obtained from a high-resolution regional earthquake catalogue

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The occurrence of earthquake-repeaters, i.e. co-located seismic events of comparable magnitude with highly similar waveforms breaking the same fault patch with an almost identical mechanism, is generally regarded as an indication that the fault surrounding the earthquake asperity is (aseismically) creeping. Earthquake repeaters can either occur during transient loading, e.g. within the afterslip of large earthquakes, or during the constant tectonic loading of tectonic faults. In this study we consider the latter.

The Main Marmara Fault (MMF) belongs to the western part of the North Anatolian Fault Zone (NAFZ) between the Anatolian and Eurasian plates and runs close to the population centre of Istanbul below the Marmara Sea. While the main NAFZ branches to the east and west of the MMF ruptured in $M > 7$ earthquakes in the last century, the MMF itself is regarded as a seismic gap with the potential to host an $M > 7$ event in the near future. Knowledge about the amount of aseismic creep of the off-shore MMF strand is important for a better seismic hazard assessment for the city of Istanbul and is heavily debated.

Building on earlier studies that identified repeating earthquakes in the western part of the MMF, we investigate a newly compiled seismicity catalogue of the Sea of Marmara for repeating events along the complete MMF. The catalogue spans the time period 2006-2020, comprises almost 14,000 events in the magnitude range $M_{0.3}$ - $M_{5.7}$ and was compiled from regional permanent stations operated by AFAD and KOERI. Phase onset times were automatically picked with a two-step procedure using higher-order statistics and an AIC-representation of the waveforms for crude and fine-tuned estimation of the P- and S-onsets. The resulting onset-times were used in the Oct-tree location algorithm of the probabilistic NLLoc software using a regional velocity model and station corrections to obtain the final hypocentres.

To search for earthquake repeaters, we divide the MMF into overlapping segments and perform a station-wise cross-correlation analysis for all available event waveforms in each segment. Correlated waveforms start 1 s before the P-wave arrival and include the complete waveform including the S-wave coda. Waveforms were bandpass filtered between 2 and 20Hz to retain a

rather wide frequency spectrum. We apply strict selection criteria and identify repeating events only as those with a normalized cross-correlation coefficient larger than 0.9 at at least 3 stations and a temporal separation of more than 30 days to exclude bursts of highly similar events in aftershock sequences or earthquake swarms.

The highest density of repeating earthquakes is found below the western Marmara Sea (Central Basin and Western High) with a systematic decrease of repeaters towards the east (Kumburgaz Basin) and none at all in the presumably locked Princess Islands section of the MMF immediately south of Istanbul. These results for the first time provide a consistent image of the amount of creep along the entire overdue Marmara section of the NAFZ derived from permanent onshore stations refining earlier results obtained from individual spots using local seafloor deployments.