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Long term monitoring of the micro-seismicity along the Main Marmara Fault, Turkey using template matching

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The Marmara Sea is located southwest of the city of Istanbul, Turkey, along the North Anatolian Fault (NAF). The trans-tensional fault system in the region is characterized by several onshore and offshore basins and accommodates 2.5-3.0 cm of right lateral slip yearly. This region hosts a 150 km seismic gap corresponding to the Main Marmara Fault (MMF), between two strike slip segments of the NAF which ruptured during the Ganos-Sarkoy (1912) to the west and Izmit (1999) earthquakes to the east. The MMF is believed to be capable of generating M>7 earthquake posing a significant hazard for the large cities surrounding the region. Since 2007, various seismic networks comprising both broadband, short period and OBS stations were deployed in order to monitor the seismicity along the MMF and the related fault systems using more than hundred seismic stations. Thus, it provides a unique database of seismic records to study in detail the fault seismicity and get new insights into the geometry of the fault system and its behavior at various space-time scales. The current earthquake detection level despite being high in the region, is however limited because of the sea coverage of the fault trace and the large distance of the surface seismic instruments to the fault. Furthermore a large part of the seismic activity occurs during short-lived intense burst episodes which might overlap and render difficult the recognition of all distinct events.

To face these issues, we applied a massive template-matching approach in the Marmara Sea region along the North Anatolian Fault, during the 2009-2014 period. The template-matching technique which consists in correlating a known signal (template) with the continuous waveform, has been shown to be a sensitive and robust automatic detection procedure. It is based on a template database built from existing regional catalogs. In our case, it provides a nearly threefold increase of the number of small events (more than 15000 earthquakes compare to the 4673 events of the initial catalog). Magnitudes are estimated for all detected events using relative amplitudes of the highly coherent waveforms between new events and template events. We show that the waveform template analysis provides more details on the space-time distribution of the seismic activity along and off-fault of the MMF. In particular it evidences different families of swarms in the region with short and long term behaviors which are related to different structures in the present-day deformation. High-resolution relocation of the newly detected events has been performed using a double-difference algorithm based on cross-correlation differential travel-time data. It shows the detailed migration with time of the template occurrences. The template database appears as a new framework for the long term monitoring of specific persistent structures like seismic swarms or repeating earthquakes related to aseismic slip.