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New Directions in Seismic Hazard Assessment through Focused Earth Observation in the Marmara Supersite

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Deliverable 3.8. Release of subsampling & modelling analytical model & 3-D numerical model of the observed displacements

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Dissemination Level		
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RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

Before the occurrence of earthquakes, faults are loaded by tectonic stresses, which may be affected by other geological activities (such as the post-seismic effect and nearby volcano eruption). Fault segments may experience different states during a seismic cycle: co- and post-seismic slip, aseismic creep or interseismic locking, which change the loading condition along faults and associated hazards. The status of a fault is routinely recorded by geodetic and seismic techniques, which allow for estimations of the location and magnitude of the fault slip, creep or slip deficit. These parameters are essential for the assessment of potential earthquake hazards.

The North Anatolian Fault Zone (NAFZ) is one of the most active faults worldwide, extending approximately 1200 km from eastern Turkey to the northern Aegean Sea. Along the fault, the Anatolian Plate moves westward relative to the Eurasian Plate at a rate of approximately 24 $mmyr^{-1}$. During the 20th century, a series of damaging earthquakes occurred along the NAFZ, which generally propagated westward towards Istanbul, a city with more than 14 million inhabitants. The latest event in this series of earthquakes occurred in 1999, approximately 80 km east of Istanbul. No large earthquake has occurred on the Princes' Islands fault (PIF) since 1776. Therefore, the PIF, located just offshore of Istanbul, is considered to be a slip-deficient segment. Previous studies have indicated that the stress on the PIF has been enhanced by stable tectonic loading and adjacent earthquake activity, resulting in high earthquake potential in the near future.

Assessing the locking status of a seismogenic fault is essential for evaluating future seismic hazards at the same fault or at adjacent fault segments, and requires robust tools for data handling and modelling. At the PIF south of Istanbul, two end-member hypotheses may result in different hazard assessments. If this fault segment has been completely locked since the last large event in 1776, a large slip deficit would have been built up. In contrast, if the fault is not completely locked or is subject to creep, the total accumulated strain may be smaller. Thus, the fault-locking status is critical for assessing the current potential of seismic hazards near the PIF. Crustal deformation in the vicinity of the PIF can be recorded by geodetic techniques and provide direct evidence relating to fault locking and the slip rate. Ergintav et al. (2014) analysed Global Positioning System (GPS) observations and inferred that the PIF is locked with a slip rate of 10–15 $mmyr^{-1}$. The few GPS sites available, however, do not permit a locking depth analysis of the fault segment, although additional observation sites could potentially provide stronger constraint of strain accumulation on the fault segment. In MARSITE, we investigated the fault-locking status at the PIF segment by using Interferometric Synthetic Aperture Radar (InSAR) and GPS observations, and improved modelling techniques for such data set. Because deformation signals are influenced by other processes, such as the post-seismic viscoelastic relaxation of the adjacent 1999 Izmit/Düzce earthquakes, we performed model-based signal decomposition and then studied the decomposed data to determine the fault-locking status near Istanbul.

In order to investigate deformation occurrence and also overlapping processes (e.g., coseismic, postseismic), interpretation of data based on GPS and InSAR technologies was improved. We separate postseismic, coseismic and other deformation processes, in an attempt to further identify and model the wanted compartments of observed displacements. Modelling routines then aim to investigate the structure of the elastic and viscoelastic earth and the nature of fault slip associated with coseismic ruptures. Results of this are published in Diao et al., (2016).

We further investigate the post-seismic deformation processes following earthquakes. We explore two different inversion modelling strategies: (i) we simulate pure afterslip and (ii) we simulate the combined effect of afterslip and viscoelastic relaxation. The inversion code, SDM, developed by Wang et al. (2013) is used to derive the afterslip distribution, and is released online through http://www.gfz-potsdam.de/sektion/erdbeben-und-vulkanphysik/daten-produkte-dienste/downloads-software/.

The name SDM stands for steepest descent method, an iterative algorithm used for the constrained least-squares optimization. The physical constraint is introduced to get a smooth slip model, which is realized through a roughness term to be minimized with the misfit to data. In difference to most previous inversion codes, the smoothing can be optionally applied to stress-drop on the whole fault. Actually, a constant or fairly smooth stress drop within slip asperities is usually assumed in the seismology. The objective function can be written as $F(b) = ||Gb - y|| + \alpha 2||H\tau ||2$, (1)

where τ is the shear stress drop caused by the distributed slip on the whole fault plane, H is the finite difference approximation of the Laplacian operator multiplied by a weighting factor relating to the slip amplitude and α is the smoothing factor. b is the slip on each patch to be solved, y is the observed GPS displacements and G is the Green's function. The weighting factor is imported to the Laplacian operator to resolve the slip concentrations effectively. We choose the smoothing factor based on the trade-off curve between the stress roughness of the model and the fitting residual. Green's functions are calculated by using a layered earth model. Results are highly promising and we do expect a wider use of the developed routines.

References with MARSite reference and relationship to this deliverable:

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