This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No [308417]".

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

Grant Agreement Number: 308417
co-funded by the European Commission within the Seventh Framework Programme
THEME [ENV.2012.6.4-2]
[Long-term monitoring experiment in geologically active regions of Europe prone to natural hazards: the Supersite concept]

D3.7

Identification and localization of primary and secondary fault branches

Project Start Date	1 November 2012
Project Duration	36 months
Project Coordinator /Organization	Nurcan Meral Özel / KOERI
Work Package Number	3
Deliverable Name/ Number	3.7
Due Date Of Deliverable	30. April 2014
Actual Submission Date	2. May 2013
Organization/Author (s)	Thomas R. Walter, Faqi Diao, Rongjang Wang

Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

TABLE OF CONTENTS

1. SIGNAL DECOMPOSITION AND FAULT SLIP MODELLING 3
1.1 ABSTRACT... 3
1.2 INTRODUCTION.. 3
1.3 EXECUTIVE SUMMARY.. 4
1.4 DISCUSSION AND CONCLUSION………………………………………………………… 4
REFERENCES..6

LIST OF FIGURES

Figure 1. Tectonic background of the north Anatolia fault in Turkey……………………………..5

Figure 2. Slip rate distribution along the eastern MMF inferred from InSAR velocity…….5

1. SIGNAL DECOMPOSITION AND FAULT SLIP MODELLING

1.1 ABSTRACT

One aim of this work package was to investigate various interfingered deformation processes based on GPS and InSAR data. To this aim we develop a method to separate the regional and local deformation processes, in order to further utilize data for kinematic and physical models. At first glance, deformation occurrence along the Main Marmara Fault (MMF) is dominated by the interseismic strain. Consideration of a fault block model allows to focus on localized deformation occurrence and gradients, that for the first time reveal a significant complexity near the MMF. Although no secondary fault branches have been clearly identified, a proportion along the MMF close to the Princess Islands is shown to be subject to a strain gradient relevant for seismic hazard analysis. Therefore the deliverable has been successfully achieved, the results of the fault model can be used for further studies. The deliverable was realized because of the vast GPS and InSAR data that were made available by collaboration within the MarSITE project and highlights the need to share data and models.

1.2 INTRODUCTION

The North Anatolian Fault (NAF) is one of the most active faults on the earth, extending about 1200 km from Karliova Triple Junction in eastern Turkey to the northern Aegean Sea. Along the NAF, the North Anatolian plate moves westward relative to the Eurasia plate with a rate of ~ 2.5 cm y-1. During the 20th century, a series of devastating earthquakes have occurred along the NAF, which generally propagated westward towards Istanbul except the 1912 Ganos earthquake in the west end (Fig. 1). As no large earthquakes occurred since the last rupture in 1776, the main Marmara fault (MMF) is considered to be an earthquake-deficit segment, where the stress has enhanced seriously by stable tectonic loading and the adjacent earthquakes, resulting in high potential of a large earthquake in near future. Here we test first the presence of hidden fault structures and the occurrence of overlapping deformation signals along this proportion of the MMF.

The present-day slip character of the MMF is essential for seismic hazard assessment in near future. In other words, whether there are evidences of secondary fault branches and whether the MMF remains locked is a key point. Investigation of current slip activity along the MMF is critical for time-dependent seismic potential assessment.

Recent microseismic observation in the MMF zone indicates a ~30-km-long seismically quite patch along the eastern section of MMF, near the Prince Islands (PI), where almost no seismic activity above 10 km during the period of 2006-2010 (Bohnhoff et al., 2013, Nature Geoscience). Based on this observation, the PI segment was inferred to be completely locked and has the potential for nucleation of future earthquakes. However, the other possibility that the PI segment slips silently during the observation period, cannot be ruled out directly based on the microseismic observation. Near-field geodetic observations can sort out these two end-member hypotheses, however, due to the limited geodetic observation, the understanding of present-day slip activity along the eastern MMF is still insufficient.

1.3 EXECUTIVE SUMMARY

We investigated the response of the eastern MMF to the loading of adjacent the 1999 Izmit and Duzce earthquakes and decomposed the deformation signals derived from InSAR and GPS recording. InSAR observations were processed to get the pre- and post-seismic deformation using the SBAS technique. The difficulty to combine various satellites (ERS1, ERS2 and ENVISAT) was solved in a solid and expandable database (Berardino et al., 2002; Pepe et al., 2005). To achieve this we consider 89 images from descending track recorded between 1992 and 2009, process smaller groups of interferograms (subsets) and relate to each other in time and space. As a result we obtain deformation velocity maps and time series of the Istanbul metropolitan area spanning the past 17 years. The InSAR results show several ongoing deformation phenomena that were studied in modelling approaches. Our inversion results indicate that the PI segment along the MMF began to slip with a decreasing rate since the 1999 earthquakes, which may partially release the strain accumulated on this segment and delay the possible rupture of the eastern MMF. Additional hidden fault structures could not be revealed parallel to this segment of the MMF. The reasons might be various, such as due to the limited resolution in the offshore fault segments, or due to a spatial proximity that does not allow such additional constraints. Nevertheless, the decomposition of the signal reveals an activity along the MMF that might dramatically affect future hazard assessment and modelling in the region. In the region close to the Princess Island segment, a significant strain gradient was found that almost perfectly agrees in space with the localization of microearthquakes (figure 2). The further investigation of this hidden structural complexity is planned in accompanying work packages.

1.4 DISCUSSION AND CONCLUSION

A high data quality is needed for achieving the herein summarized results. This is because the analysis of hidden and secondary fault activities in the area considers displacement rates that are orders of magnitudes below the general interseismic displacement rates. Only after reduction of the long term trends these subtle and local complexities can be investigated, which is made possibly only by free data policies and sharing of data processing details. The vision is that similar free data policies will remain also after the present project so that such important studies may follow or be detailed. Nevertheless, the solutions of the studied models have also some room for improvement. In specific, as both InSAR and GPS data are located on land, but the to be studied fault segment(s) are deeply buried in the sea, additional offshore geodetic measurement s will in the future allow even better assessment of the fault complexity and the identification of secondary fault branches in the MMF segment that is potentially the site of an anticipated large earthquake.

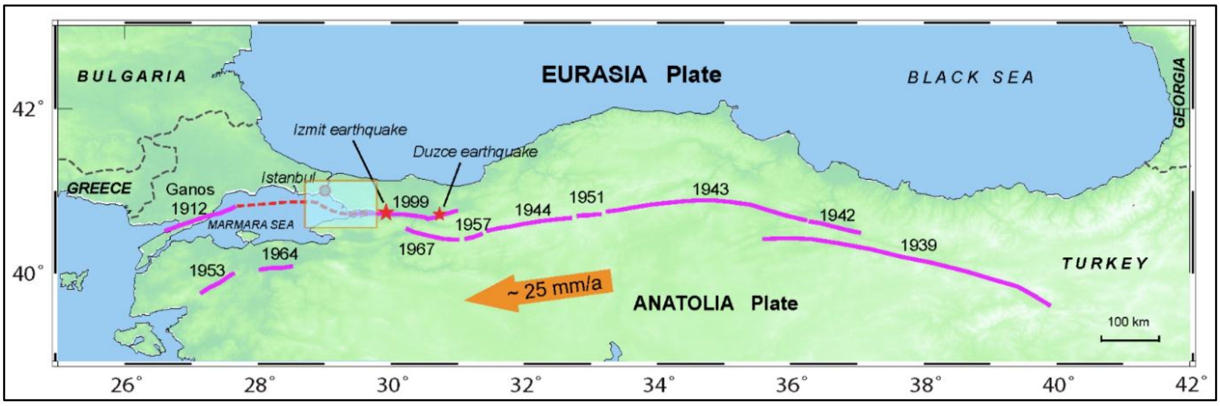

Figure 1. Tectonic background of the north Anatolia fault in Turkey. The purple solid lines indicate surface ruptures of large earthquakes in last century. The dashed red line represents the 'seismic gap' below the Sea of Marmara that has not rupture in the earthquake sequence over last century. The two red stars represent the epicenter of the 1999 Izmit and Duzce earthquake. The rectangular represents the research area of this study.

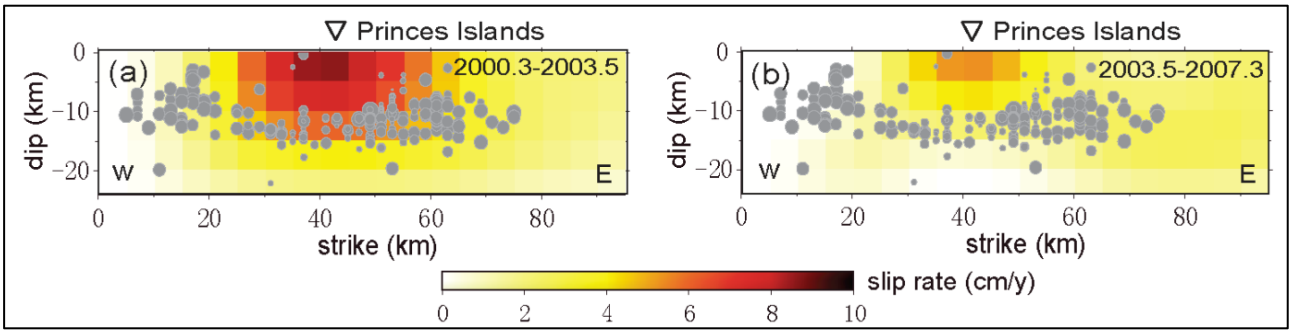

Figure 2. Slip rate distribution along the eastern MMF inferred from InSAR velocity. Red colours suggest an area of fault segment complexity that is located just offshore the Princess Islands. Gray dots are relocated microseismicities observed during 2006-2010 (Bohnhoff et al., 2013which were projected onto the fault and scaled with magnitude of associated earthquakes.

REFERENCES

Bonhoff, M. *et al*. An Earthquake gap south of Istanbul, *Nature Communications*, **4**, 1999, doi: 10.1038/ncomms2999 (2013).

Berardino, P., G. Fornaro, R. Lanari, and E. Sansosti A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms, IEEE Trans. Geosci. Remote Sens., 40, 2375– 2383, (2002),

Pepe, A., E. Sansosti, P. Berardino, and R. Lanari (2005), On the generation of ERS/ENVISAT DInSAR time-series via the SBAS technique, IEEE Geosci. Remote Sens. Lett., 2, 265–269, doi:10.1109/LGRS.2005. 848497, (2005).