The FP7 Marsite Project as a Supersite Initiative: Exploitation of X-Band InSAR Results for Surface Deformation Analysis over the Istanbul Area

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New Directions in Seismic Hazard assessment through Focused Earth Observation in Marmara Supersite

MARsite is aimed at providing the most complete geodetic records of crustal deformation for any major continental earthquake occurred and/or occurring in the Marmara region through:

- repeat GPS
- InSAR
- Gravity and seismological observations.
The FP7 MARsite Project

6 Countries
21 Organizations
Why Marmara as a supersite?

It is one of the highest seismic risk region in Europe!

The occurrence years and possible locations of earthquakes (redrawn from Ambraseys, 2002).

The seismicity of the Marmara Region from combined catalogues (1964-2011, M!2.5).
The FP7 MARsite objectives

- Long-term earth, sea and space monitoring of: earthquakes, tsunamis, landslides, displacements, chemical-radioactive emission and physical variables

- Improve existing earthquake early-warning and rapid-response systems

- Improve ground shaking and displacement modelling through source models

- Establishment of novel borehole observation system in western Marmara

- Interact with end users and contribute to the improvement of existing policies and programs on preparedness, risk mitigation and emergency management
Remote sensing and MARsite

Satellite remote sensing plays a key role in the near-fault Marmara Observatory context. Indeed, it allows to:

- perform long-term and wide area deformation analyses relevant to earthquakes, compaction-induced subsidence and landslides;
- support ground shaking and displacement modelling through source model development;
- move a step-forward on new concepts of preparedness, risk mitigation and emergency management.
Temporal development of radar satellites for earth observation

**First Generation**

- ERS1
- J-ERS1
- RADARSAT-1

**Second Generation**

- ENVISAT
- ALOS
- COSMO-SKYMED
- TERRASAR-X
- SENTINEL-1
- RADARSAT-2
- ALOS-2
We perform a long-term continuous geodetic monitoring of the crustal deformation affecting the Istanbul area by benefiting from large archives of satellite SAR data, made available through the Supersites Initiatives.

- **89 desc C-band ERS/ENV**
  - Revisit time: 35 days
  - Time int: 1992-2009

- **101 desc X-band TSX**
  - Revisit time: 11 days
  - Time int: 2010-2014

- **11 asc C-band Sentinel-1A**
  - Revisit time: 12 days
ERS-ENVISAT results
ERS/ ENVI SAT SBAS-DInSAR results

ERS/ENVISAT SBAS-DInSAR results
X-band results
TSX data available through the Supersite Initiatives

**Descending TSX frame** (track 153, Strip_012, $\theta \approx 41^\circ$)
TSX data available through the Supersite Initiatives

101 TSX data
(track 153, Strip_012)
TSX SBAS-DI nSAR interferometric pairs

312 SBAS-DI nSAR interferograms

(Berardino et al., 2002)
TSX results retrieved through the SBAS-DInSAR method

LOS mean velocity [cm/yr]

> 1.5

<= 1.5
TSX deformation time series retrieved through the SBAS-DInSAR method
TSX results retrieved through the SBAS-DInSAR method
TSX deformation time series retrieved through the SBAS-DI nSAR method

LOS mean velocity [cm/yr]

Displacement [cm]

Time [year]

> 1.5

< - 1.5

[Image of time series graph and satellite image]
TSX SBAS-DI nSAR time series validation

PALA

KANT

BEYK
Ascending CSK datasets

Western Track:
64 CSK data
(05-2011/07-2013)

Eastern Track:
29 CSK data
(06-2011/09-2013)
CSK STAMPS results validation

(Hooper et al., 2007)
Sentinel-1A first results
Mission: Sentinel1-A
Acquisition date: 21/10/2014
Polarisation: VV
Product Type: SLC
Orbit: Ascending
Sentinel-1A first results

Mission: Sentinel1-A
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Orbit: Ascending
Sentinel-1A SBAS first results

Only 11 SAR acquisitions in 4 months and 27 SBAS interferograms

LOS mean velocity [cm/yr]

> 10

< 10
Sentinel-1A SBAS first results

LOS mean velocity [cm/yr]

< -10

> 10
Sentinel-1A SBAS first results

LOS mean velocity [cm/yr]

> 10

LOS mean velocity [cm/yr]

> 10

Displacement [cm]

2014.8  2014.9  2015.0  2015.1

Time [years]

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DI nSAR deformation time series can be successfully exploited and integrated with other geodetic measurements to perform long-term deformation analyses, which are crucial for seismic hazard assessment.

- They provide space-time information on the ground displacements that can be effectively exploited to better understand/model/interpret the physical processes behind the observed deformation phenomena at different temporal and spatial scales.

- The effectiveness of such an integration is strictly connected with the availability of SAR data. In this context, the new Sentinel-1A/B satellite constellation reveals to be strategic for performing large scale deformation monitoring analyses, thanks to the global coverage as well as free, open-access policy.
Thank you!!!
**Objectives**

To fulfill the requirements of the call, MARsite identifies a number of objectives that drive its implementation, the definition of the activities and the composition of the consortium.

The MARsite strategic objectives are to:

- Achieve long-term hazard monitoring and evaluation by in-situ monitoring of earthquakes, tsunamis, landslides, displacements, chemical-radioactive emission and other physical variables and by the use of space-based techniques.
- Improve existing earthquake early-warning and rapid-response systems by involving common activities, participants, competences, knowledge and experts from Europe.
- Improve ground shaking and displacement modelling by development/updating of source models and the use of probabilistic and deterministic techniques with real-time and time-dependent applications.
- Pursue scientific and technical innovation by including state-of-the-art R&D in developing novel instruments and instrumentation.
- Interact with end users and contribute to the improvement of existing policies and programs on preparedness, risk mitigation and emergency management.

**Motivation**

In the last 12 years, Europe experienced destructive earthquakes such as 1999 Izmit (Turkey), 1999 Athens (Greece) and 2009 L’Aquilla (Italy).

More destructive earthquakes happened earlier: Istanbul in 1509 and 1766, Izmir in 1888, Eastern Italy in 1693 and Lisbon in 1755.

Much catastrophic event is now expected in the Marmara region, with a probability in excess of 65% in 30 years, due to the existing seismic gap and the post-1999 earthquake stress transfer at the western portion of the 1000km-long North Anatolian Fault Zone (NAFZ), passing through the Marmara Sea about 15 km from Istanbul.

Istanbul is fully aware of this impending problem and the authorities are in the process of taking all conceivable physical and social steps for preparedness and mitigation of the risk.