SAR APPLICATIONS IN GREECE

With emphasis for Harokopio University/ Dep. of Geography activities

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4th Advanced Training course in Land Remote Sensing, Harokopio University

The European Remote Sensing satellite ERS-1, launched in 1991, carried a comprehensive payload including an imaging synthetic aperture radar, a radar altimeter and other powerful instruments to measure ocean surface temperature and winds at sea. ERS-2, which overlapped with ERS-1, was launched in 1995

Launched in 2002, Envisat was the largest Earth Observation spacecraft ever built. It carried ten sophisticated optical and radar instruments to provide continuous observation and monitoring of Earth's land, atmosphere, oceans and ice caps.

A very rich archive data set of SAR images from 1992 until 2011

ASAR image of Athens area (2003)

Following its ratification of the ESA Convention

Greece became ESA's 16th Member State in March 2005

Cooperation between ESA and the Hellenic National Space Committee began in the early 1990s and in 1994 Greece signed its first cooperation agreement with ESA. This led to regular exchange of information, the award of fellowships, joint symposia, mutual access to databases and laboratories, and studies on joint projects in fields of mutual interest.

2003 1st announcement of opportunity (AO for Greece)
2006 a call for Ideas
2009 and 2010 outline proposals
2010 1st call for the Greek participation to PRODEX Programme including Earth Observation

In the frame of AO for Greece a total number of 21 proposals were accepted 10 of which were based on SAR applications within the domain HAZARDS

The available Earth Observation datasets, for which the ESA Data Policy is applicable, can be split into two major groups:

1. The free dataset, representing the majority of data, and including data collections available on-line without any technical or financial constraints attached, and
2. The restrained dataset for which priorities are managed through categories of use, due to technical and financial constraints.

The restrained dataset includes:
The SAR data from the ERS and Envisat missions.

Data is provided free of charge. A CAT-1 project should be submitted

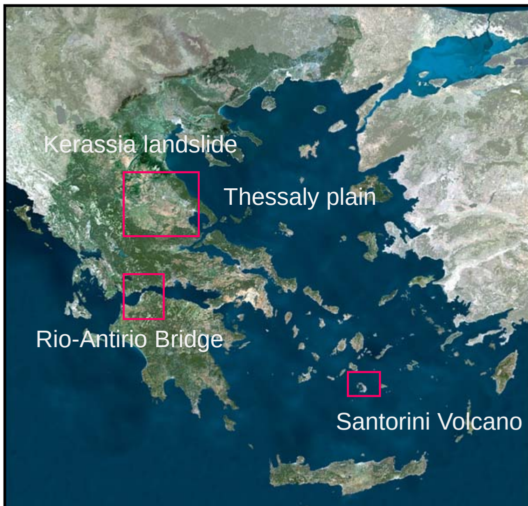
CAT-1 tool

Almost 100 proposals accepted from Greek institutions from which 1/3 concerns SAR applications mainly in the domain of HAZARDS and some for OCEANOGRAPHY.

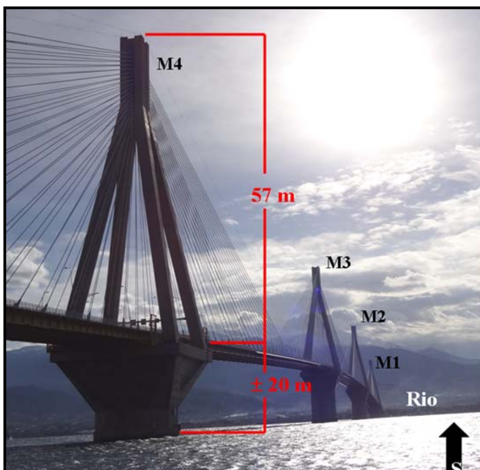
ESA GMES PROJECT **TERRAFIRMA**

Greek Partners
Interferometric data provider: Harokopio University/ Dep. of Geography
Value adders: NOA, University of Athens, Stamatopoulos and Assoc.

Terrafirma is one of ten services being supported by the European Space Agency's (ESA) Global Monitoring for Environment and Security (GMES) Service Element Programme. Terrafirma provides a ground motion hazard information service, distributed throughout Europe via national geological surveys and institutions.
The objective of this service is to help:
Identify hazards
Improve safety, and
Mitigate risk
Terrafirma is based upon the revolutionary remote sensing technique of Persistent Scatterer Interferometry.



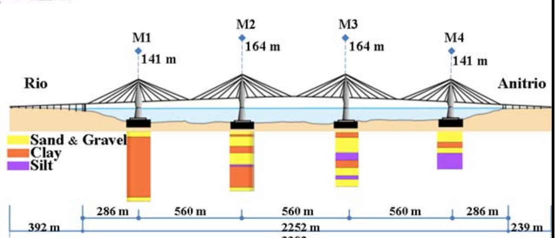
Areas under investigation



Rio-Antirio Bridge case

Opened to traffic in August 2004, the RAB crosses the Gulf of Corinth near Patras in Western Greece. Today the traffic average is 13.200 vehicles per day.
The bridge consists of: a 2,252 meter long 4 pylon cable-stayed bridge with a span distribution equal to 286 meters, 560 meters, 560 meters, 560 meters and 286 meters, two approach viaducts, with 392 meters on Rio side and 239 meters on Antirio side. Foundations are 90-meter diameter reinforced concrete caissons resting on the gravel layer.

The necessity to monitor the area and the bridge arises from a combination of hazards; strong seismic activity, tectonic movements, soft seabed etc, render the area susceptible to great ground deformation.



The crucial task was following PS interferometric processing to identify point targets over the four pylons as the pavement is suspended

A data set of ENVISAT ASAR C-band (ERS-like) comprising 37 scenes along descending orbit, track 279, and 34 TerraSAR-X in stripmap (SM) ascending mode 007R, orbit number 2803, HH polarization; this is at incidence angles between 29 degrees and 32 degrees, covering the periods 2002-2010 and 2010-2012 respectively.

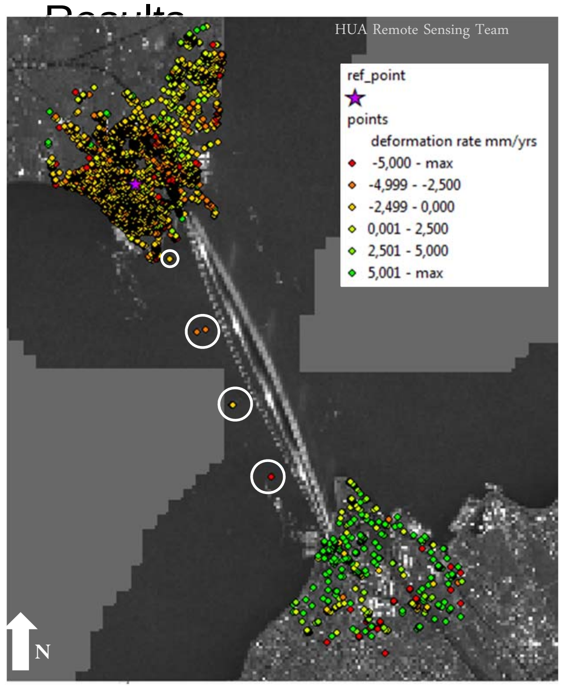
Due mainly to resolution ENVISAt data display excellent results for the broader area of the bridge but TerraSAR-X data show a number of point targets on the pylons.

Number of scenes used	34
Date range of analysis	2010-2012
Satellite data used	TerraSAR-X
Master Scene Date	20110503
Georeference (X,Y) accuracy	± 5 m (depends on the area)
Reference data used for georeference	SRTM dem v.3
Projection system used	UTM - WGS84'
Reference point location	566777.935 E, 4242926.000N (ID 176677)

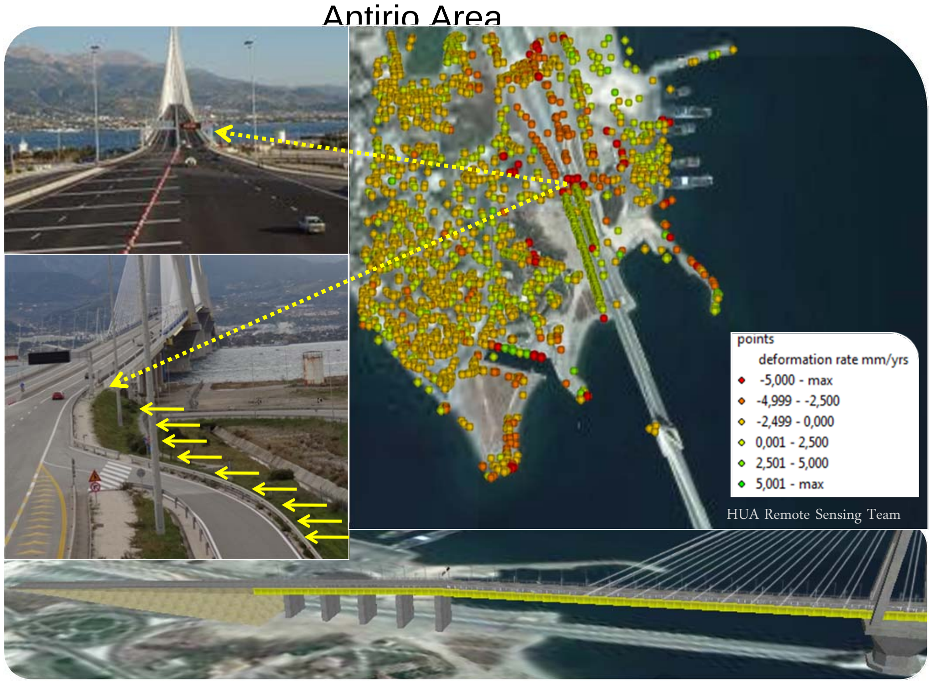
Interferograms used for analysis			
Master Date	Slave Date	Bperp (m)	dT (days)
20110503	20101119	107.3250	-164,99997
20110503	20101130	-449,3688	-153,99997
20110503	20101211	-40.6341	-142,99998
20110503	20101222	237.0263	-132
20110503	20110102	16.9768	-121
20110503	20110113	-486,5366	-110
20110503	20110124	-367,0574	-99.00002
20110503	20110204	-286,1107	-88.00002
20110503	20110215	113.3267	-77.00002
20110503	20110226	-607,7129	-66.00001
20110503	20110309	-47.8139	-55.00002
20110503	20110320	-518,1334	-44.00001
20110503	20110331	65.4503	-33.00001
20110503	20110411	78.7348	-22.00001
20110503	20110503	0.0000	0.00000
20110503	20110514	-73.2344	11.00001
20110503	20110525	-308,6015	22.00001
20110503	20110627	-397,4946	55.00004
20110503	20110810	-96.0151	99.00007
20110503	20110821	-514,2517	110.00007
20110503	20111015	-271,1634	165.00008
20110503	20111026	-203,8199	176.00008
20110503	20111106	-201,1055	187.00008
20110503	20111117	-169,3727	198.00008
20110503	20111209	-402,9961	220.00007
20110503	20120111	-371,4608	253.00004
20110503	20120328	-408,7716	330.00005
20110503	20120408	-262,8035	341.00005
20110503	20120430	-380,1148	363.00006
20110503	20120522	128.4530	385.00008
20110503	20120602	-366,2255	396.00009
20110503	20120624	-525,9998	418.00010
20110503	20120716	-336,8755	440.00010
20110503	20120807	-410,6468	462.00011

Results

Number of PS identified	5984
PS density (PS/km^2)	950/km^2 (on land)
Point motion statistics (mm/year classes)	% of points in each mm/year class
-max to -5.0	2.4 %
-5.0 to -2.5	8.7 %
-2.5 to 0	53.6 %
0 to +2.5	26.4 %
+2.5 to +5.0	2.9 %
+5.0 to +max	6.0%
Average annual motion rate of the entire processed area	- 0.11 mm/year
Standard deviation of average annual motion rate	0.51 mm/year



Antirio Area



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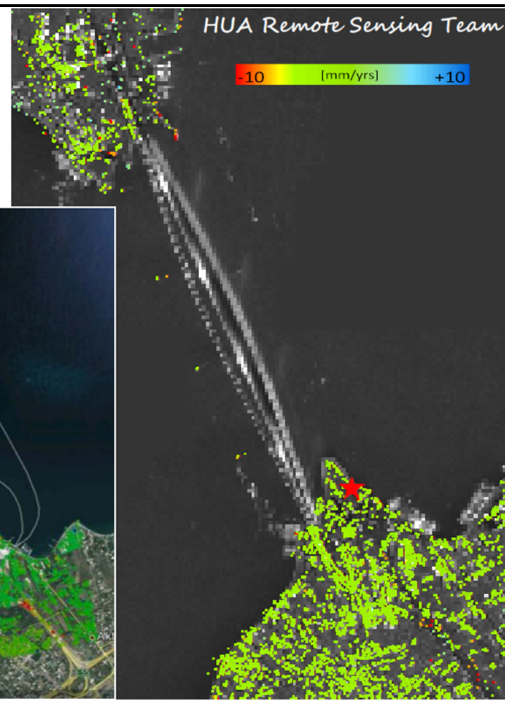
Linear Deformation

[Ref. point in Rio – Red Star]



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Department of Geography

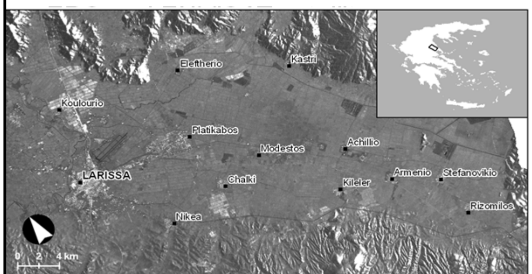
HUA Remote Sensing Team

Results Comparison – Linear Deformation (mm/yrs)

	Pylon 1	Pylon 2	Pylon 3	Pylon 4
PSI HUA (ref.point in Antirio)	-11.82	-0.04	-3.07	-2.26
PSI HUA (ref.point in Rio)	-7.13	-0.08	-3.52	-2.28
PSI DLR	-	-4.30	-3.20	-8.90

Seasonal ground deformation monitoring over Southern Larissa Plain (Central Greece) by SAR interferometry

The aim of this study is to investigate surface deformation signals associated with annual precipitations and groundwater withdrawal, demonstrating the suitability of DInSAR for examining dewatering induced subsidence. Specifically, we attempt to measure seasonal deformation and its spatial distribution. Displacement maps of high spatial resolution were generated for the broader Larissa Plain using SAR acquisitions from

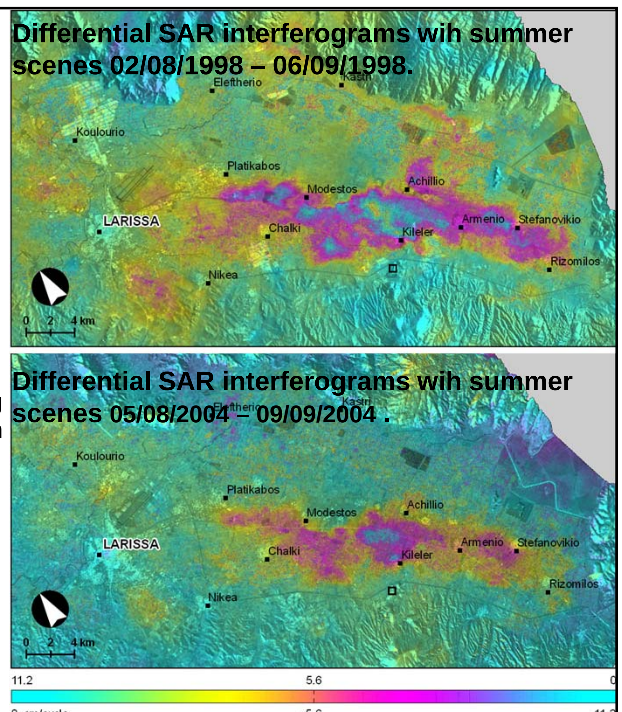


TERRAFIRMA

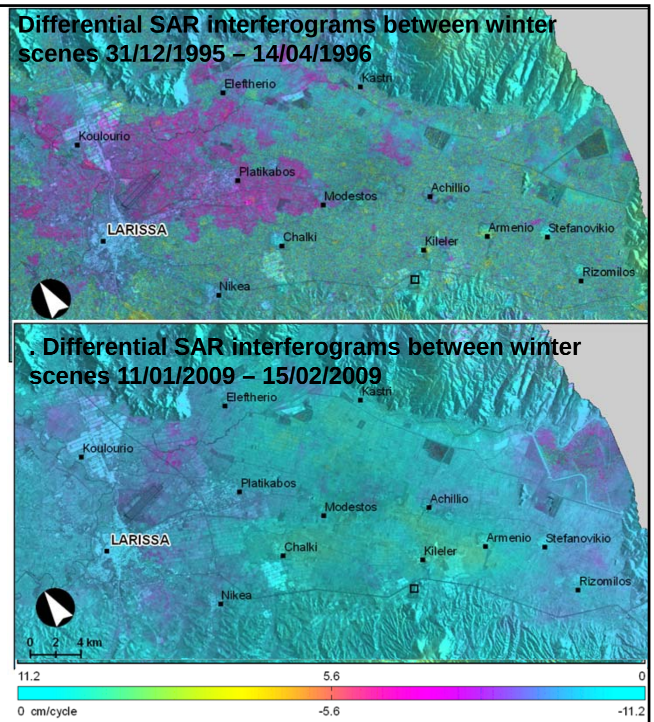
Deformation patterns corresponding to ground subsidence are evident in interferograms covering the period between May and October. The deformed area (about 180 km2) retains an elongated shape with NW-SE orientation (major axes almost 25 km), while covering only the southeastern part of the plain. The area of maximum deformation is located to the North of Kileler village, reaching -17.5 cm along the line of site in the summer of 1998 (from August to September), whereas for the same period in 2004 lower but also significant magnitudes of -12.7 cm are observed.

Differential SAR interferograms wih summer scenes 02/08/1998 – 06/09/1998.

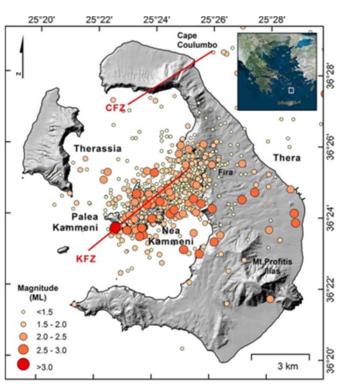
Differential SAR interferograms wih summer scenes 05/08/2004 – 09/09/2004 .



During winter seasons deformation is considerably reduced to -0.5 cm and -0.1 cm for 3.5 months (Dec.1995 – April 1996) and 1.2 months (Jan. – Feb. 2009) period respectively. Rebound phenomena with significantly lower values were observed during high precipitation periods mainly at the NE of the basin.



The case of Santorini volcano:
Is interferometry an operational tool for hazard assessment?



Santorini Volcanic Complex is an active volcanic field with the evidence of a current phase of unrest.

The local seismicity prior to 2011 represents high seismic activity in the surroundings of Columbos Volcano area and fairly low activity at the rest of the complex. However, at the beginning of 2011 an increased seismic activity of relatively low intensity began within the intra-caldera area, surrounding Nea Kammeni Volcano and Thera.

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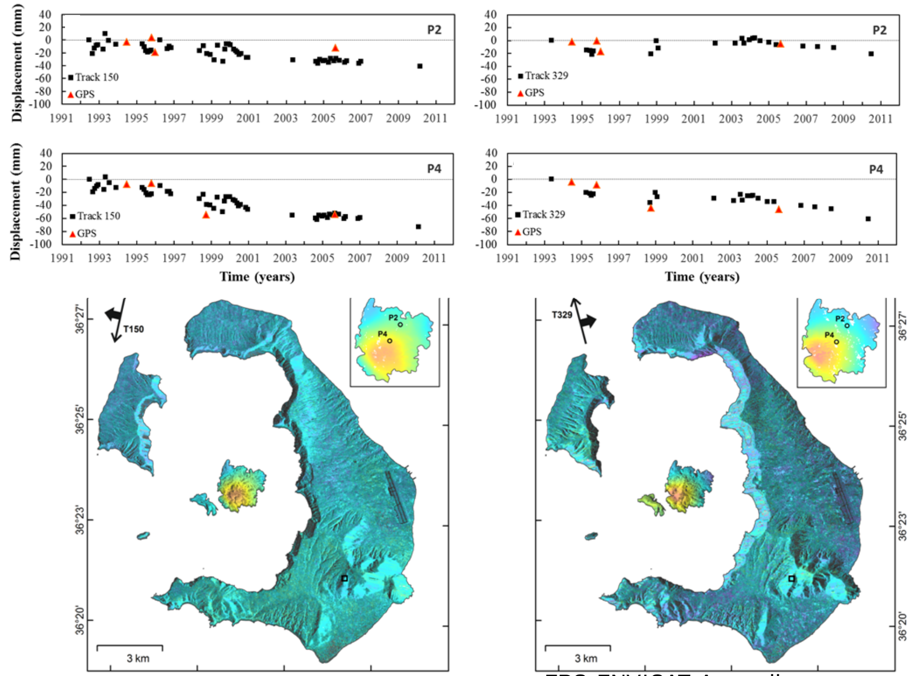
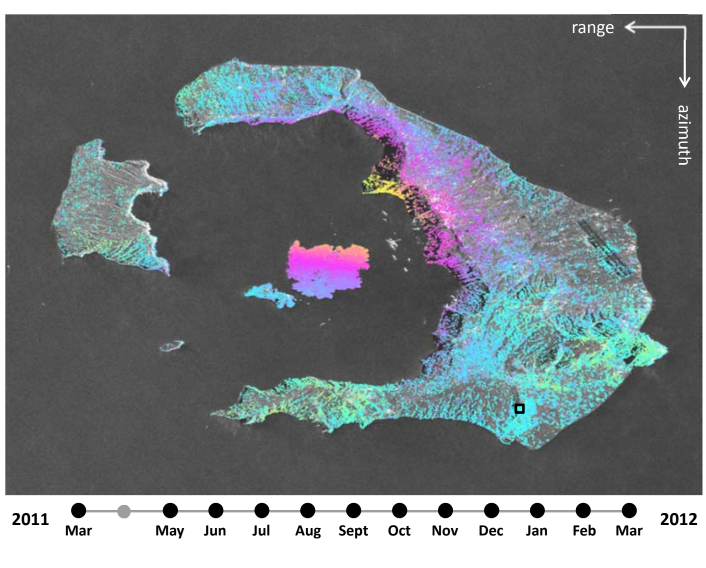
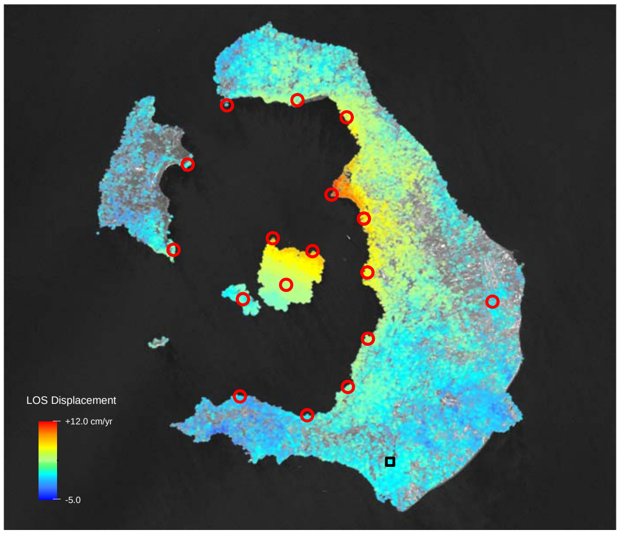


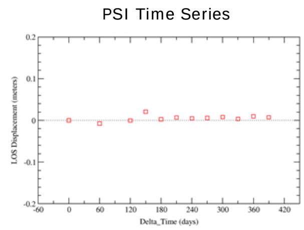
ERS-ENVISAT Descending

ERS-ENVISAT Ascending

Time series presentation of PSI results







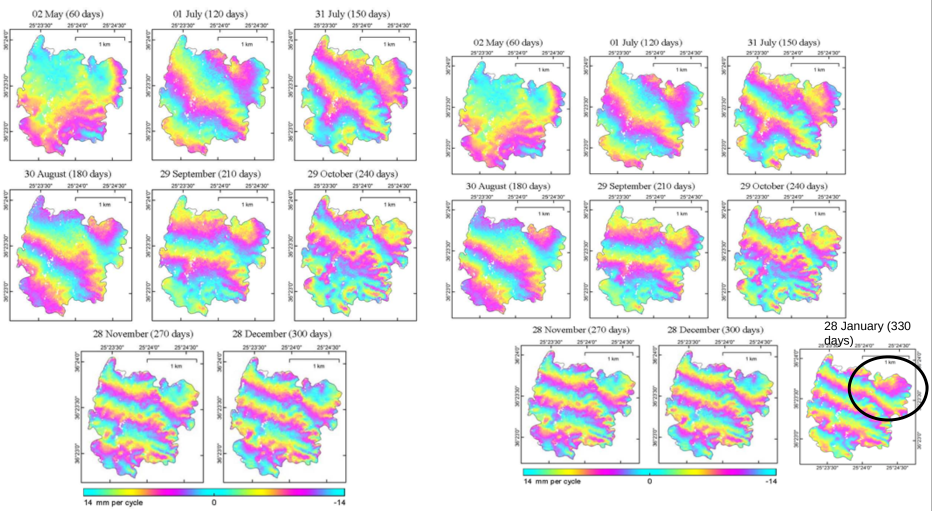
Similar results have been obtained by NOA/ Inst. For Astronomy, Astrophysics, Space Applications and Remote sensing and TREurope (Italy)

Papoutsis, I., X. Papanikolaou, M. Floyd, K. H. Ji, C. Kontoes, D. Paradissis, and V. Zacharis (2012), Mapping inflation at Santorini volcano, Greece, using GPS and InSAR, *Geophys. Res. Lett.*, doi:10.1029/2012GL054137, in press.

Lagios E., Sakkas V., Novali F., Bellotti F., Ferretti A., Vlachou K. & Dietrich V. **(2013)** SqueeSAR™ and GPS Ground Deformation Monitoring of Santorini Volcano (1992-2012): Tectonic Implications. *Tectonophysics,* doi:10.1016/j.tecto.2013.03.012.

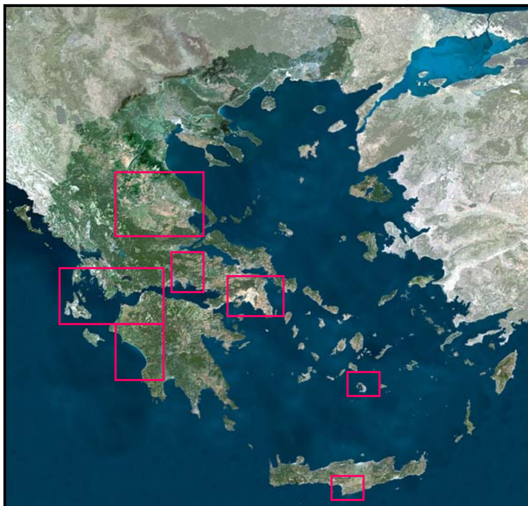
Operational used of interferometric results

Earthquake Planning and Protection Organization of Greece has the responsibility to monitor the Santorini Volcano. Harokopio University team every month starting from December sent an official report to EPPO in order to inform about ground deformation.



Within the Geography department the last 10 years a remote sensing group was founded. This group is composed by geologists, geographers and engineers. Its main research topic is space-based SAR interferometry in order to assess natural or human induced ground deformation.
The laboratory is equipped by the following hardware and s/w: Multiple high performance work stations (PCs) for extensive processing requirements
GAMMA s/w including IPTA (multiple indoor installations) as well as the open s/w StaMPS & NEST.

http://huaremotesensingteam.wordpress.com/



Areas of research interest over Greece

Our areas of interest and application of SAR interferometry through national and international support include also Egypt (Cairo, Alexandria, Sinai Peninsula), Italy (L' Acquila, Nobiallo landslide, Cita di Messina), Japan (Tohuku earthquake).

You are welcome in our University using Erasmus frame to work with us