



BEYOND

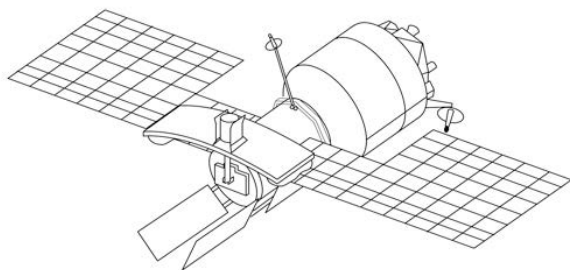
*Building Capacity for a Centre of Excellence for
EO-based monitoring of Natural Disasters*

Spaceborne and airborne geohazard monitoring

Ioannis Papoutsis

IAASARS

National Observatory of Athens



One Step BEYOND Workshop,
15/10/2015
ESA, Frascati



FP7-Regpot-2012-23-1

*Centre of Excellence for
EO-based monitoring of Natural Disasters*

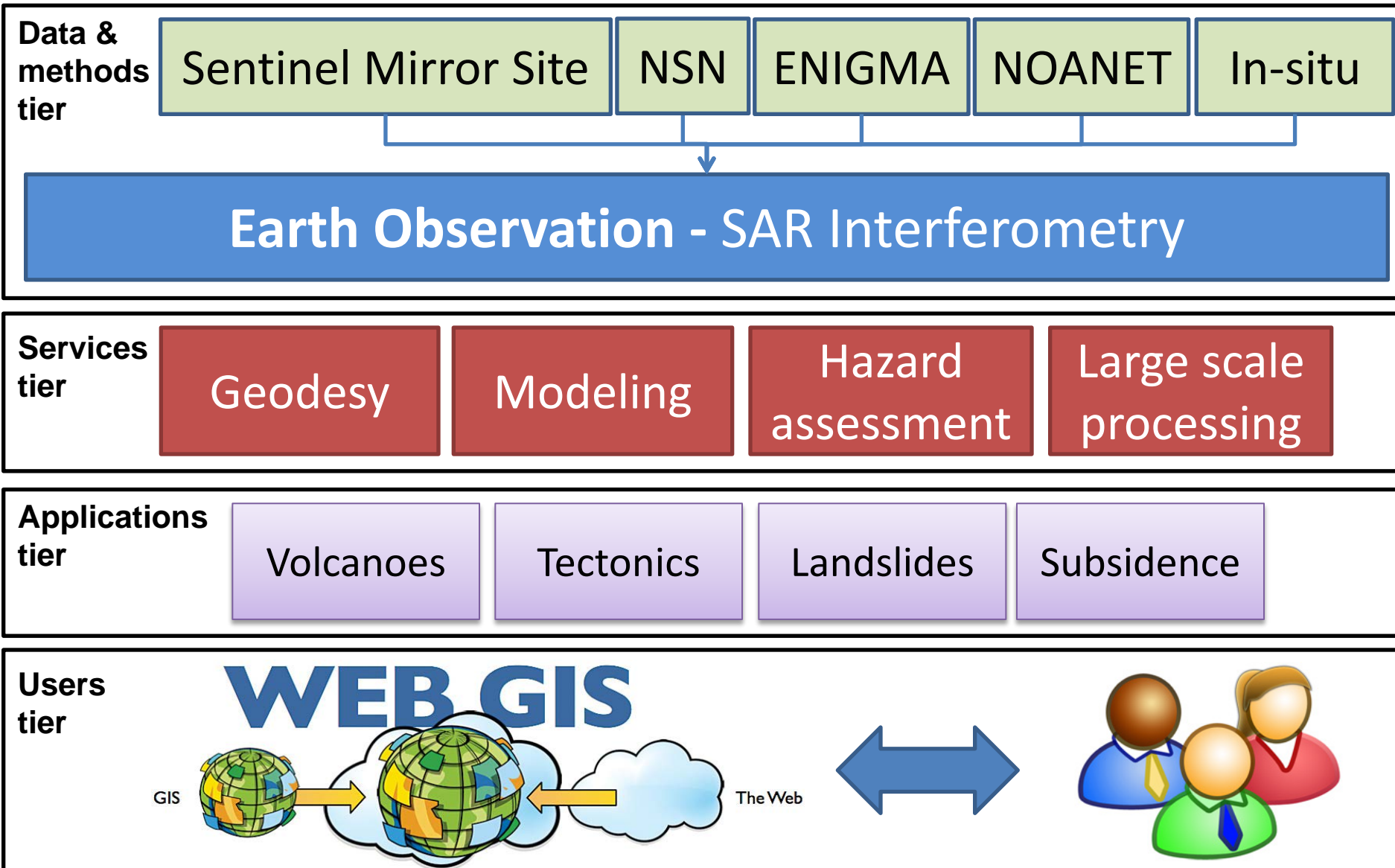
Fires & Floods

Geophysical hazards

Atmospheric disasters

Urban environment

Capacities



Geohazard applications

Earthquake deformation mapping



Data

NSN

NOANET

ENIGMA

In-situ

Services

Geodesy

Modeling

Hazard Ass.

Large Proc.

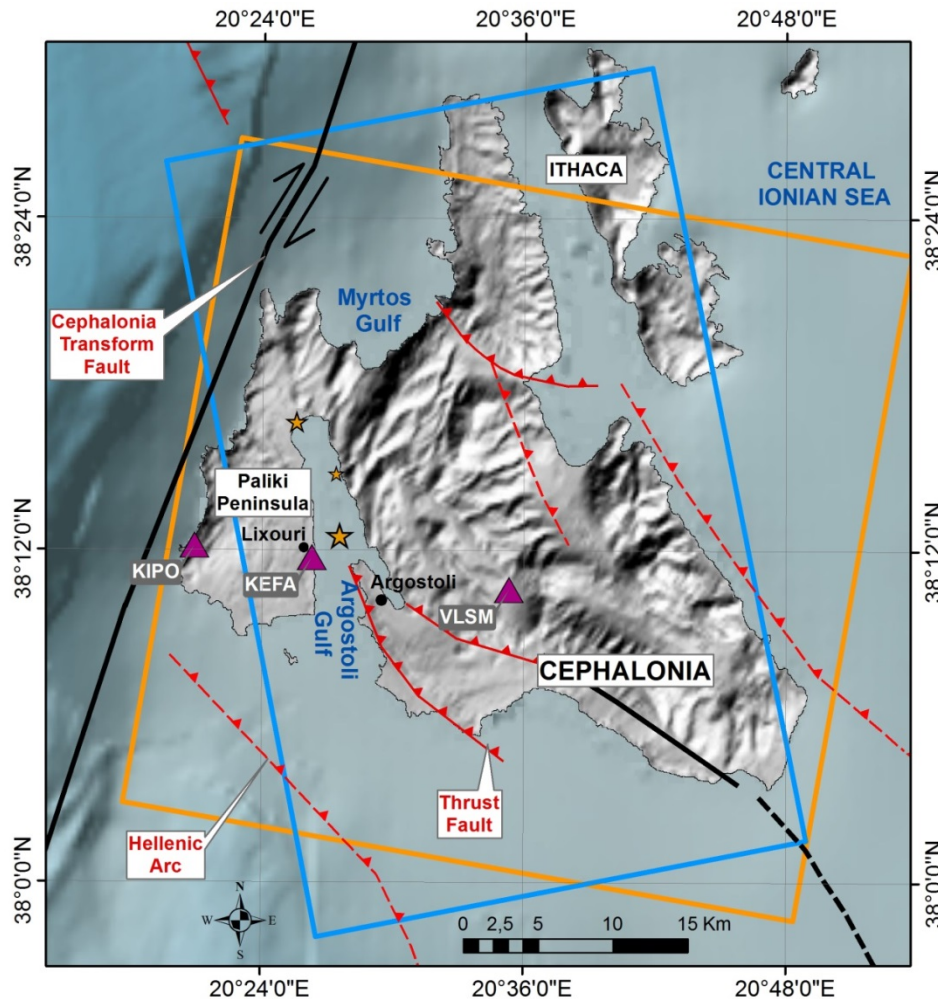
Applications

Tectonics

Volcanoes

Landslides

Subsidence



Mapped faults

- Strike-slip inferred
- Strike-slip
- - - Reverse inferred
- ▲- Reverse

GPS stations

- ▲ cGPS

Main earthquake events

- ★ 26/1/2014 ML 5,1
- ★ 3/2/2014 ML 5,7
- ★ 26/1/2-14 ML 5,9

SARframes

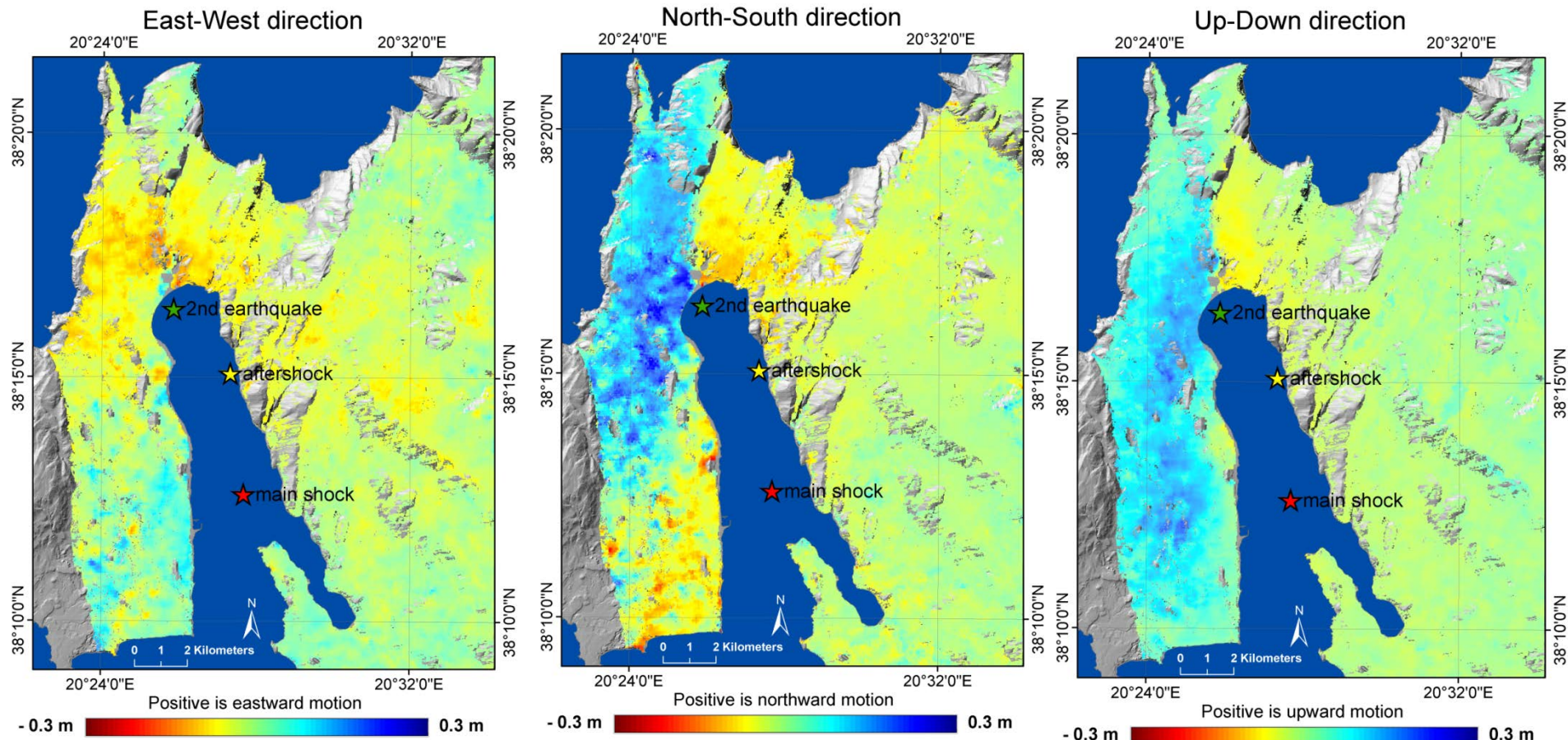
- COSMO-SkyMED
- TerraSAR-X

Geohazard applications

Earthquake deformation mapping



- 3D crustal deformation from TerraSAR-X & COSMO-SkyMed data
- Inversion to estimate fault parameters

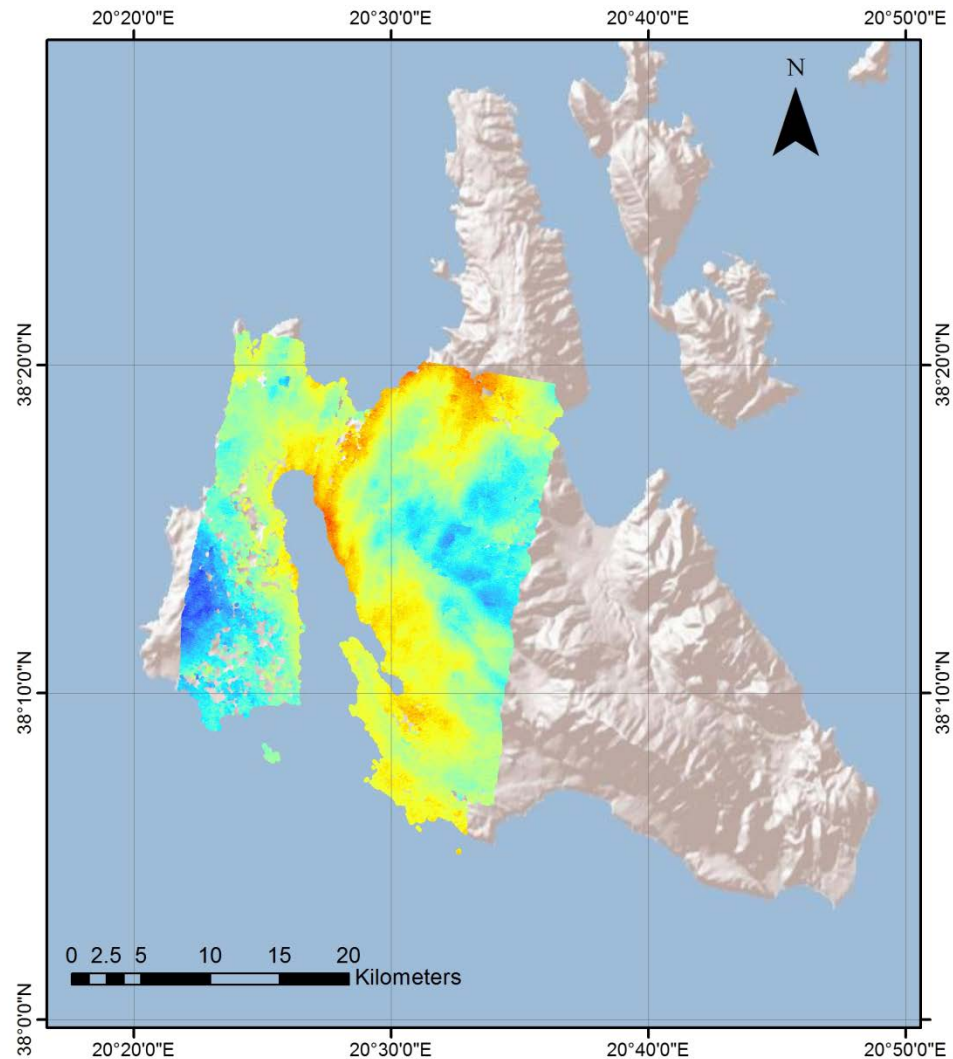


Geohazard applications

Post-seismic earthquake monitoring

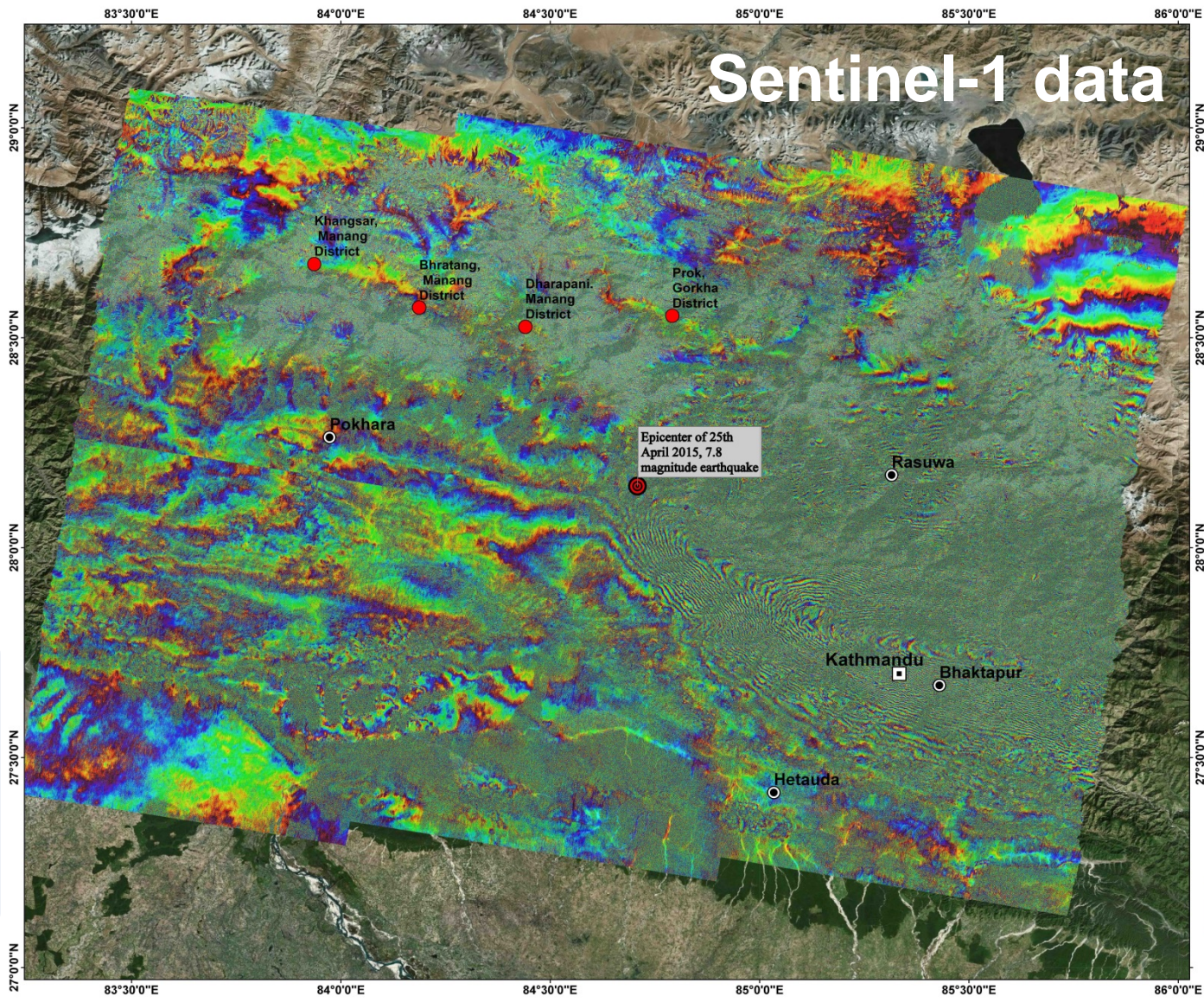


Post-seismic slip,
measured with
COSMO-SkyMed
data



Geohazard applications

Earthquake deformation mapping



Nepal, South Asia Earthquake Mapping Assessment Map: Interferogram
 Production Date 15/06/2015

Location Diagrams
 41 50 100
 Kilometer
 Location Diagrams

Cartographic Information
 Scale: 1:50 000 for A1 prints. Full color A1, high resolution (300dpi)
 Grid: Geographic Datum: WGS 1984 Tick Marks: Lat/Lon (DMS), Datum: WGS 84

Legend

- Epicenter of 25th April 2015 epicenter
- Kathmandu capital city
- Major cities
- Landslide locations triggered by 25th of April Nepal earthquake
- Area of Interest

Map Information
 On April 25 2015, a Mw 7.8 earthquake hit Nepal, 81km northwest of Kathmandu capital city. Shortly after the earthquake, two Sentinel-1 Synthetic Aperture Radar images were acquired, one before (17/04/2015) the devastating earthquake and one after (28/04/2015). They were combined to form an interferogram that depicts ground deformation due to the earthquake. This map shows the fringe pattern associated with the event, where each color cycle demonstrates phase difference of π (1), interpreted as ground deformation equal to 2.8 cm in the direction of the satellite.

Data Sources
 Sentinel-1 descending SAR data © ESA through the Hellenic National Sentinel Data Mirror Site (<http://sentinel.hnspace.noa.gr/>)
 Landslide locations © The Hellenic National Data Exchange (<https://data.hns.noa.gr/>)
 Microsoft © BingMaps TM
 World Topo Map © ESRI, ARCGIS services online

Software used
 Interferometric processing: SARscape 5.2 beta, sarmap SA
 Raster manipulation: ENVI 5.0, Exelis Inc.
 Map production: ArcMap 10.2, ESRI ArcGIS

Dissemination/Publication
 No restrictions on the publication of the mapping apply.

Framework
 The present map is generated in the context of BEYOND Center of Excellence (<http://www.beyond-centre.eu/>) established at the National Observatory of Athens and funded by the European Commission as part of the FP7 REACT framework initiative (GA: 214270). BEYOND provides products and services for its stakeholders, aimed at the systematic and operational monitoring of natural disasters from space. BEYOND activities are boosted by the Hellenic National Sentinel Data Mirror Site, also established in NCA, under the current ESA-NCA agreement, in the frame of the Collaborative Ground Segment Initiative. The goal is to support the rapid dissemination and almost near real time production of Sentinel-based products, towards the seamless monitoring and effective management of natural disasters for preparedness and risk reduction activities.

Map Production
 This map was generated by processing TOPSAR Sentinel-1 data using SARscape v5.0. Conventional radar interferometry techniques were employed, customised for Sentinel-1 data. Depending on the interferogram, noise levels (different measurement accuracy of the technique) is about 1 cm in the line-of-sight to the satellite.

Production team: Christine Pournazeri, Ioanna Pournazeri, Name of the Hellenic Inspector Quality Control, NCA, Hellenic Organization National Observatory of Athens
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Data

- NSN
- NOANET
- ENIGMA
- In-situ

Services

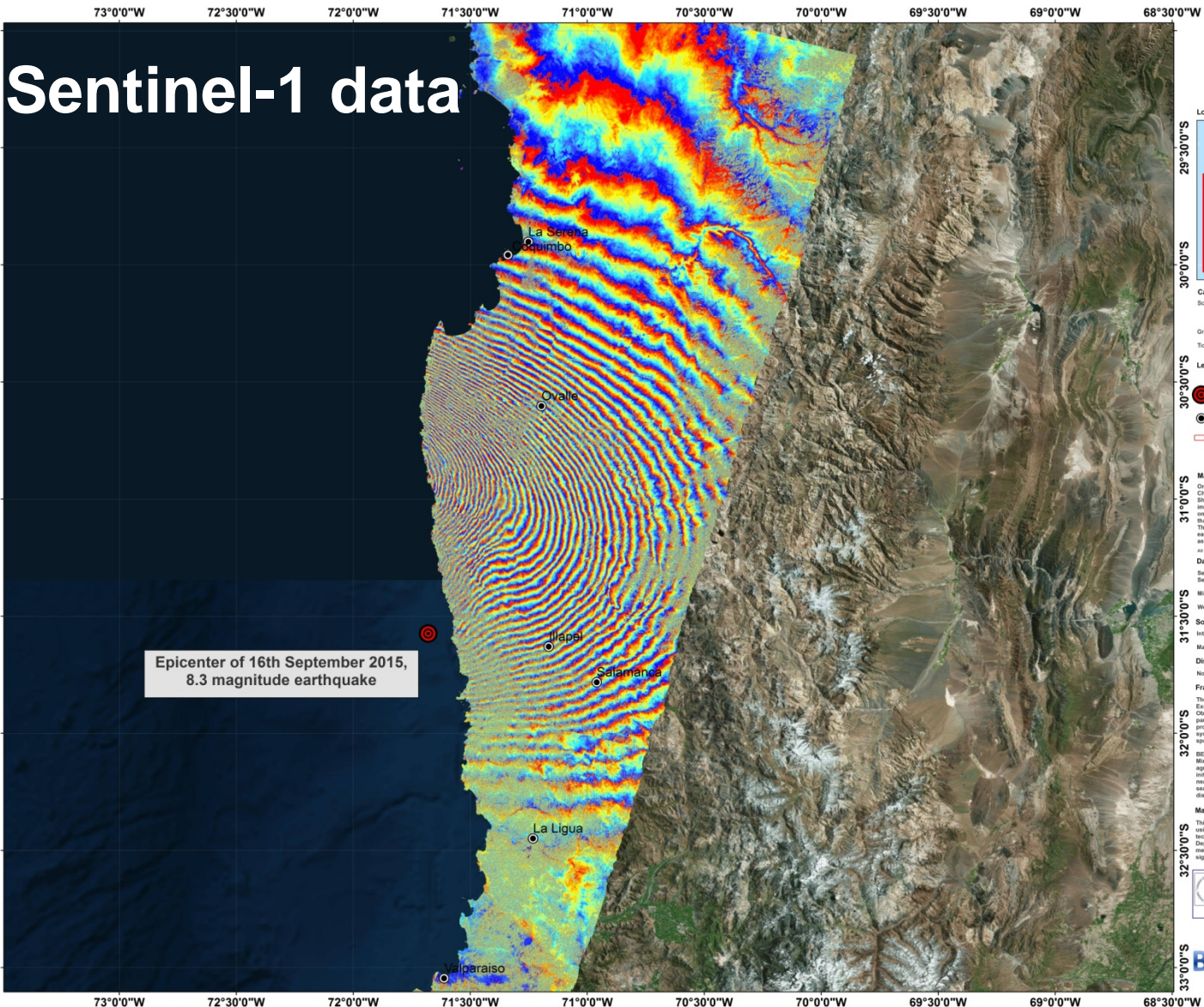
- Geodesy
- Modeling
- Hazard Ass.
- Large Proc.

Applications

- Tectonics
- Volcanoes
- Landslides
- Subsidence

Geohazard applications

Earthquake deformation mapping



Sentinel-1 data

Epicenter of 16th September 2015, 8.3 magnitude earthquake

Coast of Central Chile
Earthquake Mapping
 Assessment Map: Interferogram
 Production Date 06/10/2015

Location Diagrams

 SOUTH AMERICA
 0 70 140 280
 Kilometers
 2.5 Centimeters

Cartographic Information
 Scale: 1:60 000 for A1 prints Full color A1, high resolution (300dpi)
 Grid: Geographic Datum: WGS 1984
 Tick Marks: Lat/Lon (DMS); Datum: WGS 84

Legend

 LOS phase change
 10
 0
 -10

Map Information
 On September 16 2015, a Mw 8.3 earthquake hit the coast of Central Chile, west of Illapel city. Shortly after the earthquake, two Sentinel-1 Synthetic Aperture Radar images were acquired, one before (13/09/2015) the shake event and one after (17/09/2015). They were combined to form an interferogram that depicts the ground deformation due to the earthquake. This map shows the fringe pattern associated with the event, where each color cycle demonstrates phase difference of π (or $\pi/2$) interpreted as ground deformation equal to 2.8 cm along the line of sight (LOS). All visible topographic features are captured with the best effort but in some cases may not be complete.

Data Sources
 Sentinel-1 descending SAR data © ESA through the Hellenic National Sentinel Data Mirror Site (<http://sentinels.space.noa.gr/>)
 Microsoft © BingMaps TM
 World Topo Map © ESRI, ArcGIS services online

Software used
 Interferometric processing: Sentinel-1 Toolbox version 1.1.5
 Map production: ArcMap 10.3, ESRI ArcGIS

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Framework
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Map Production
 This map was generated by processing TOPSAR Sentinel-1 data using Sentinel-1 Toolbox v.1. Conventional radar interferometry techniques were employed, customized for Sentinel-1 data. Depending on the interferogram noise levels the inherent measurement accuracy of the technique is about 1 cm in the line-of-sight to the satellite.

Production team: Christina Psychogios, Ioanna Papadopoulou, Christoforos Koutavas (Quality control) NOA
 Responsible organization: National Observatory of Athens
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Data

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Geohazard applications

UAV damage assessment



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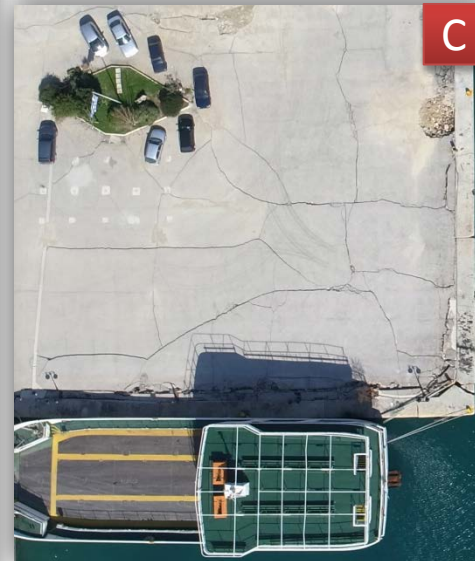
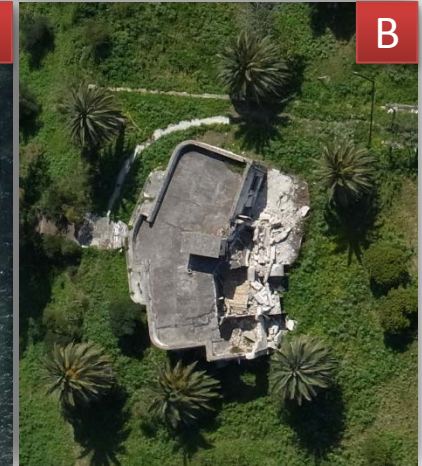
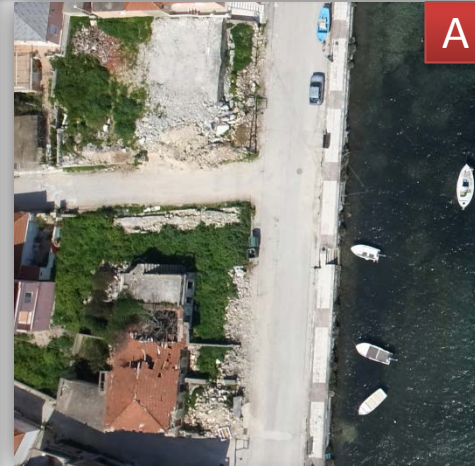
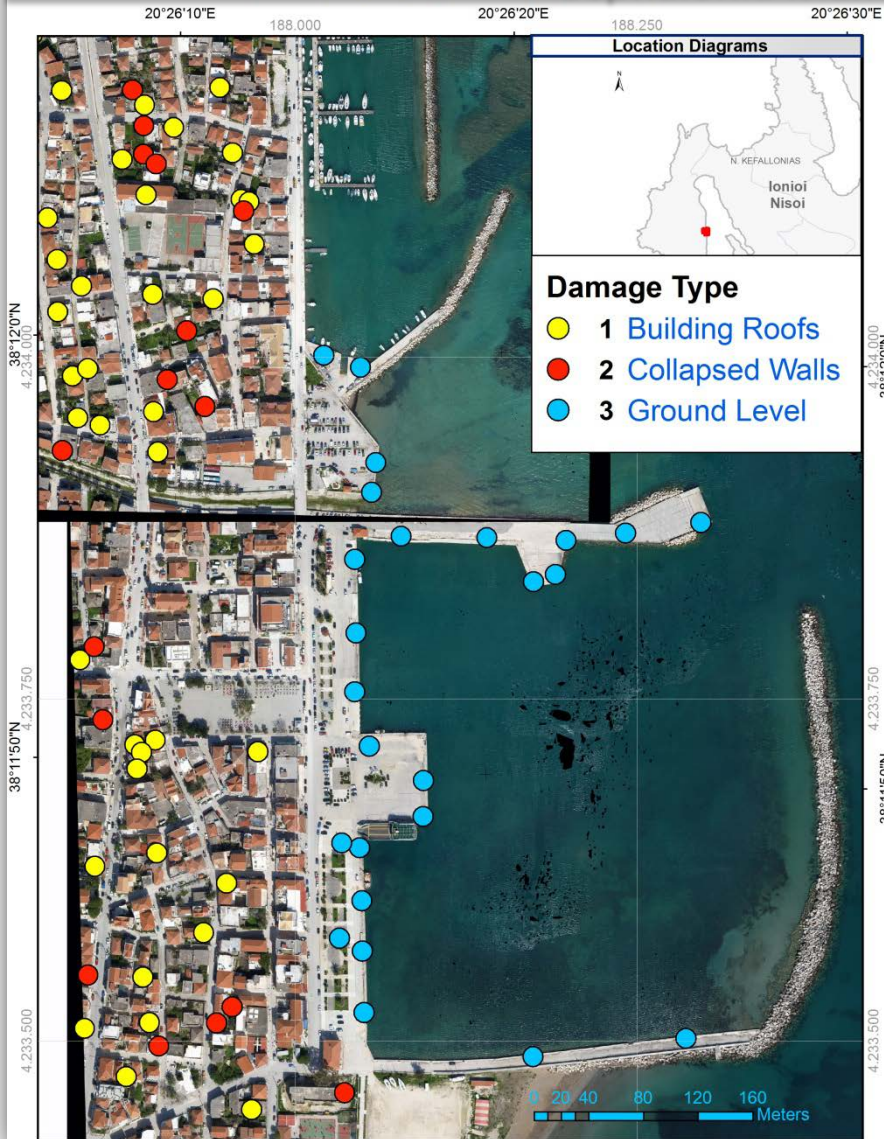
Subsidence



Geohazard applications

UAV damage assessment

Cephalonia Island – Town of Lixouri



Geohazard applications

UAV octocopter



Geohazard applications

Monitoring volcanic activity



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Large Proc.

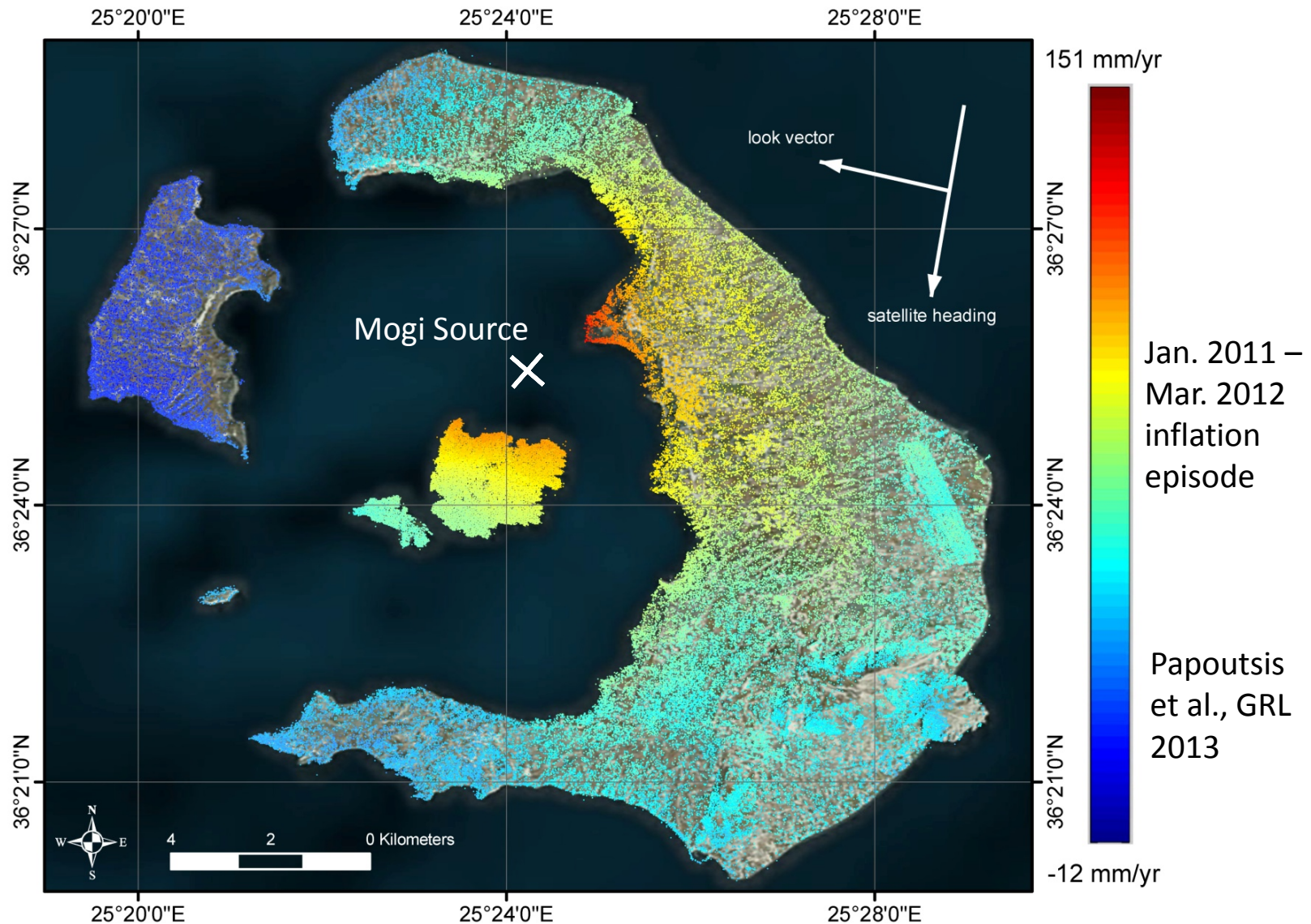
Applications

Tectonics

Volcanoes

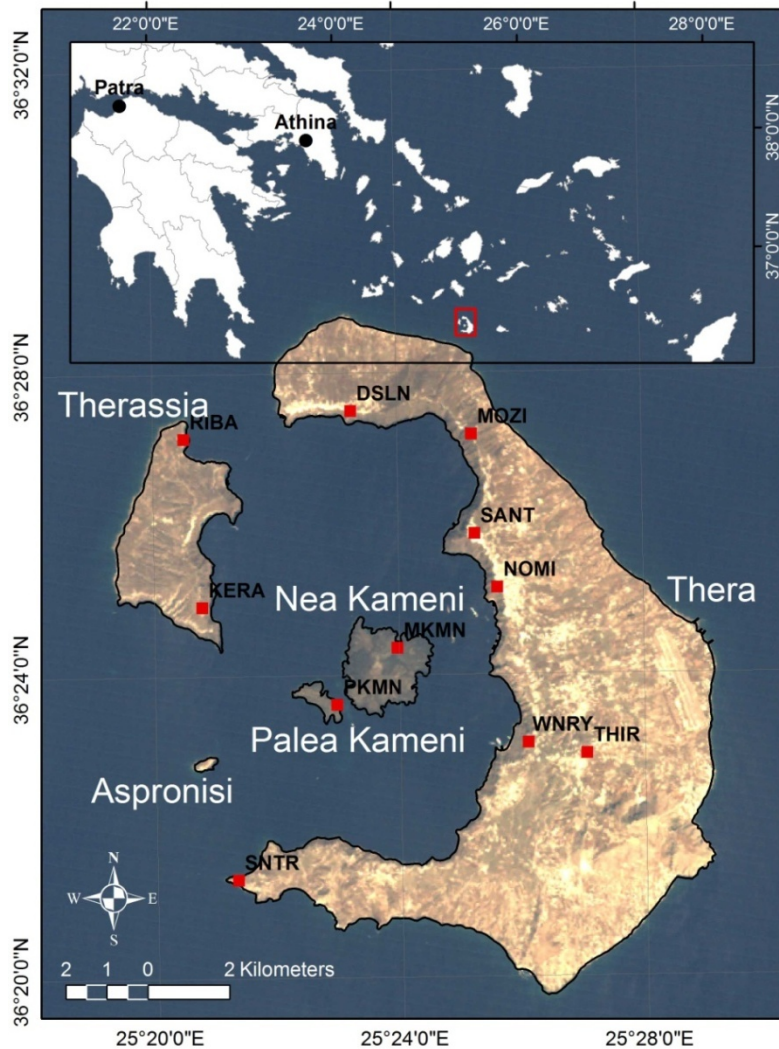
Landslides

Subsidence

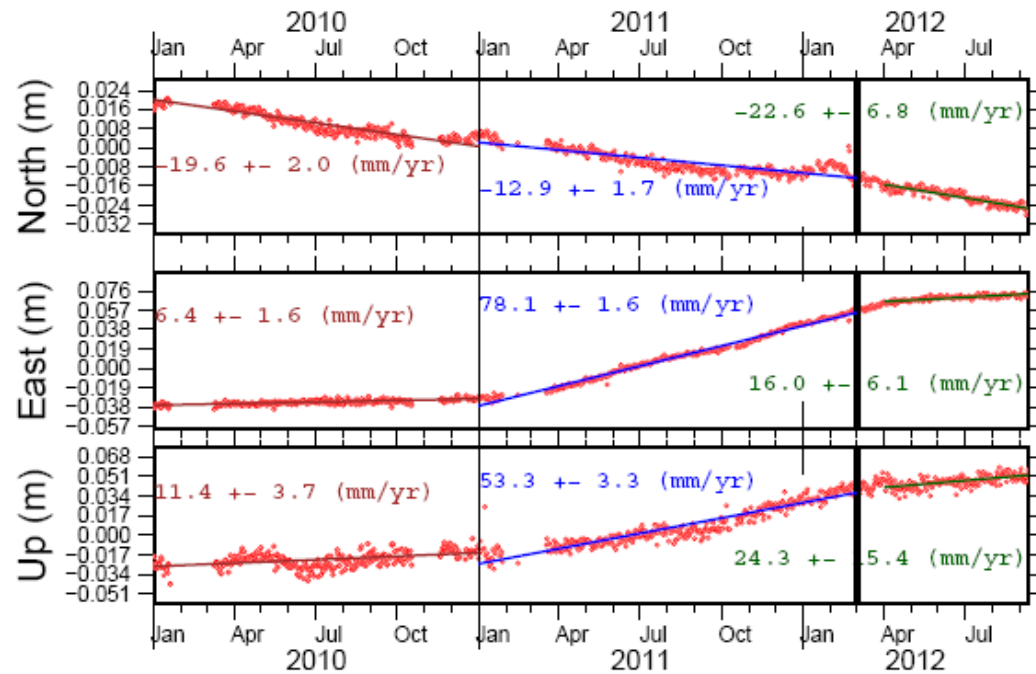


Geohazard applications

Monitoring volcanic activity



Time-series monitoring with in-situ GPS stations



GPS data processing by Dionysos Satellite Observatory

Geohazard applications

Dispersion of volcanic ash



Data

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Tectonics

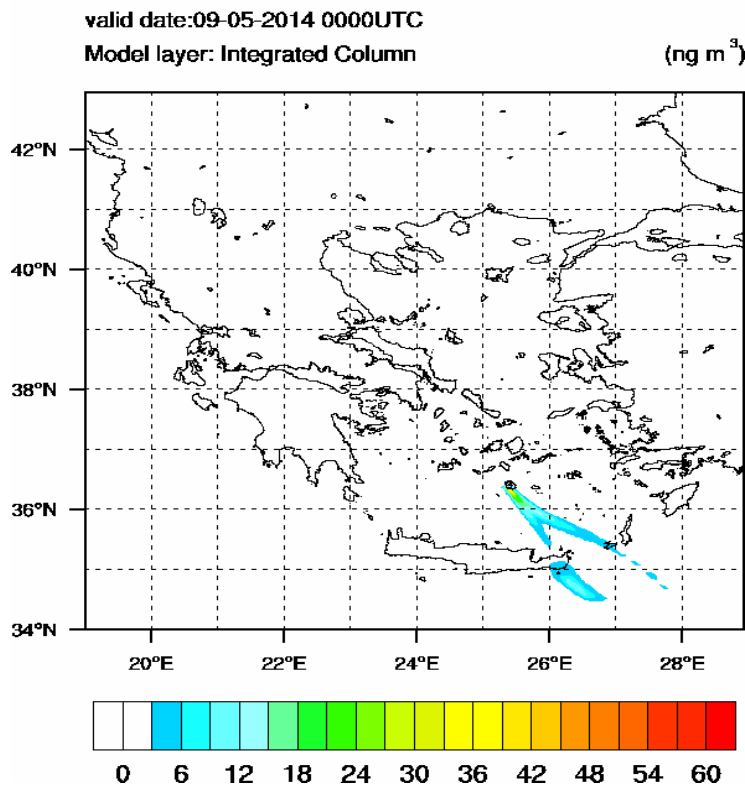
Volcanoes

Landslides

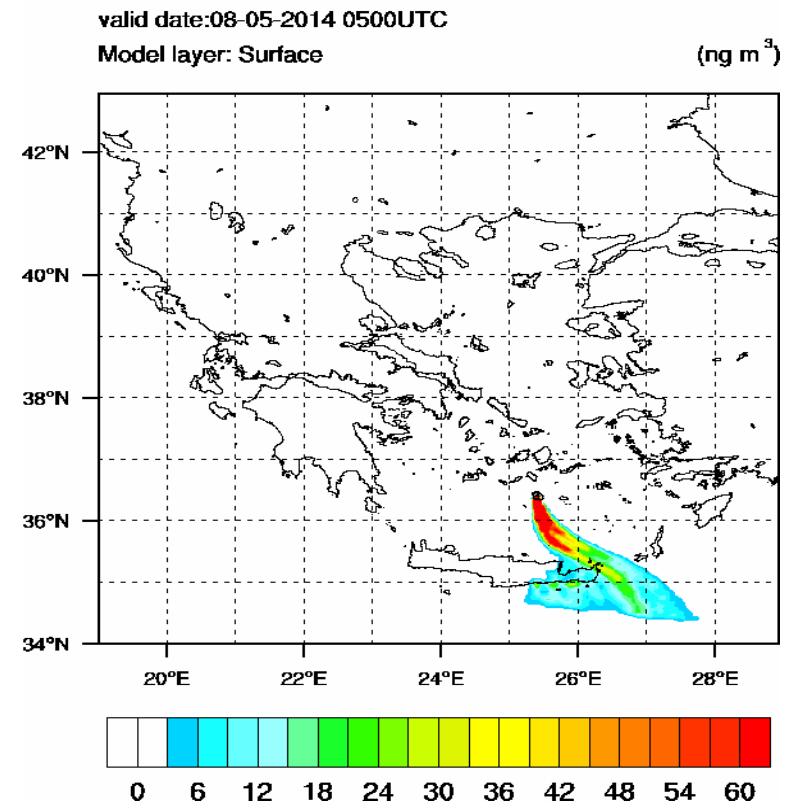
Subsidence

- Early warning system being developed in the framework of BEYOND
- The specific hypothesis assumes 60 hours of continuous emissions at 1.5 km height column

FLEXPART - NOA Airborne Volcanic Ash



FLEXPART - NOA Deposited Volcanic Ash

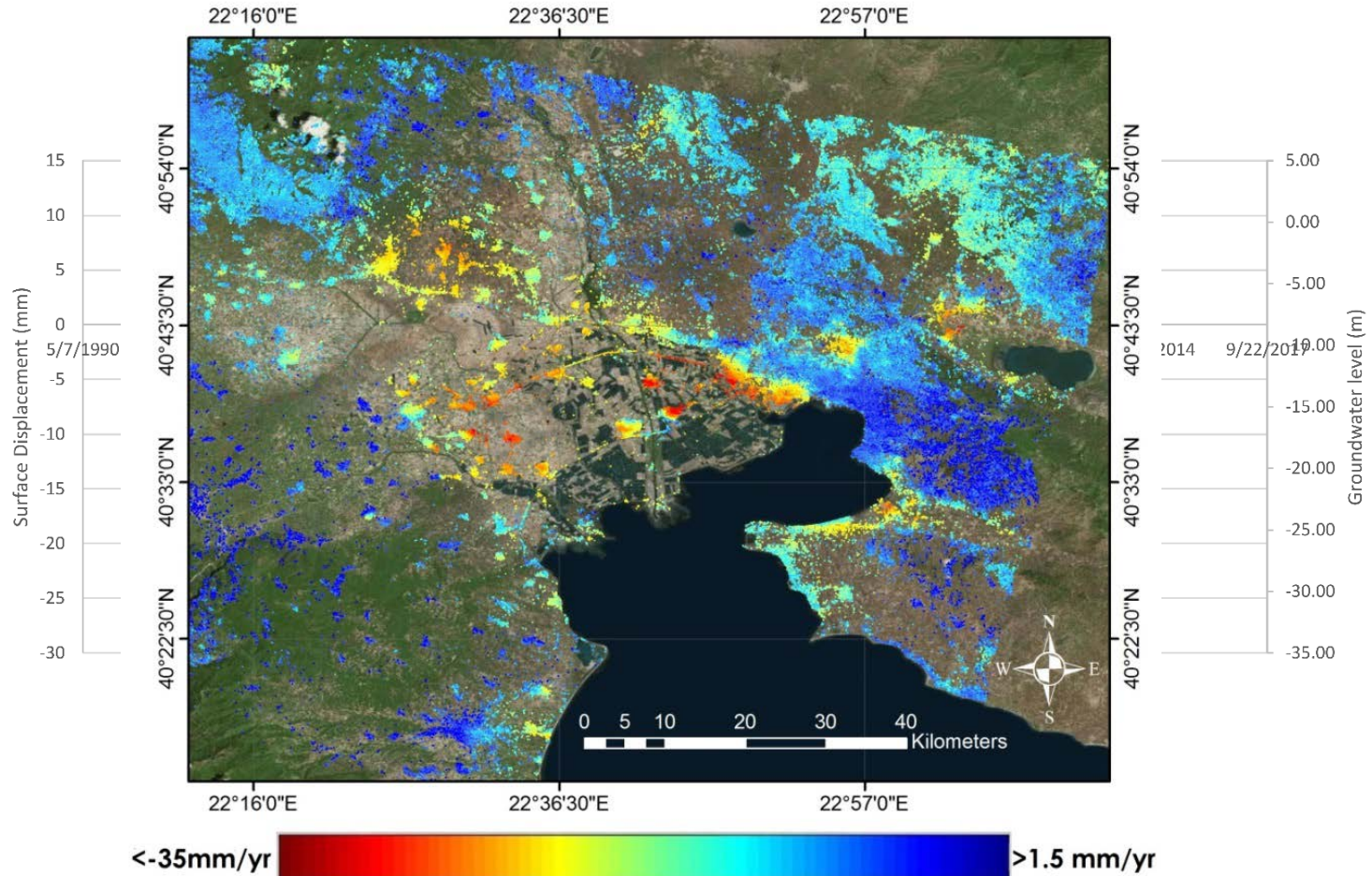


Geohazard applications

Urban subsidence & uplift tracking



Thessaloniki (1992 - 2001, 2002 - 2010)



Driver: water over-pumping, Sviggas et al., Nat. Haz. submitted

Data

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Large Proc.

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Volcanoes

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Subsidence

Geohazard applications

Seismic risk estimation



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Large Proc.

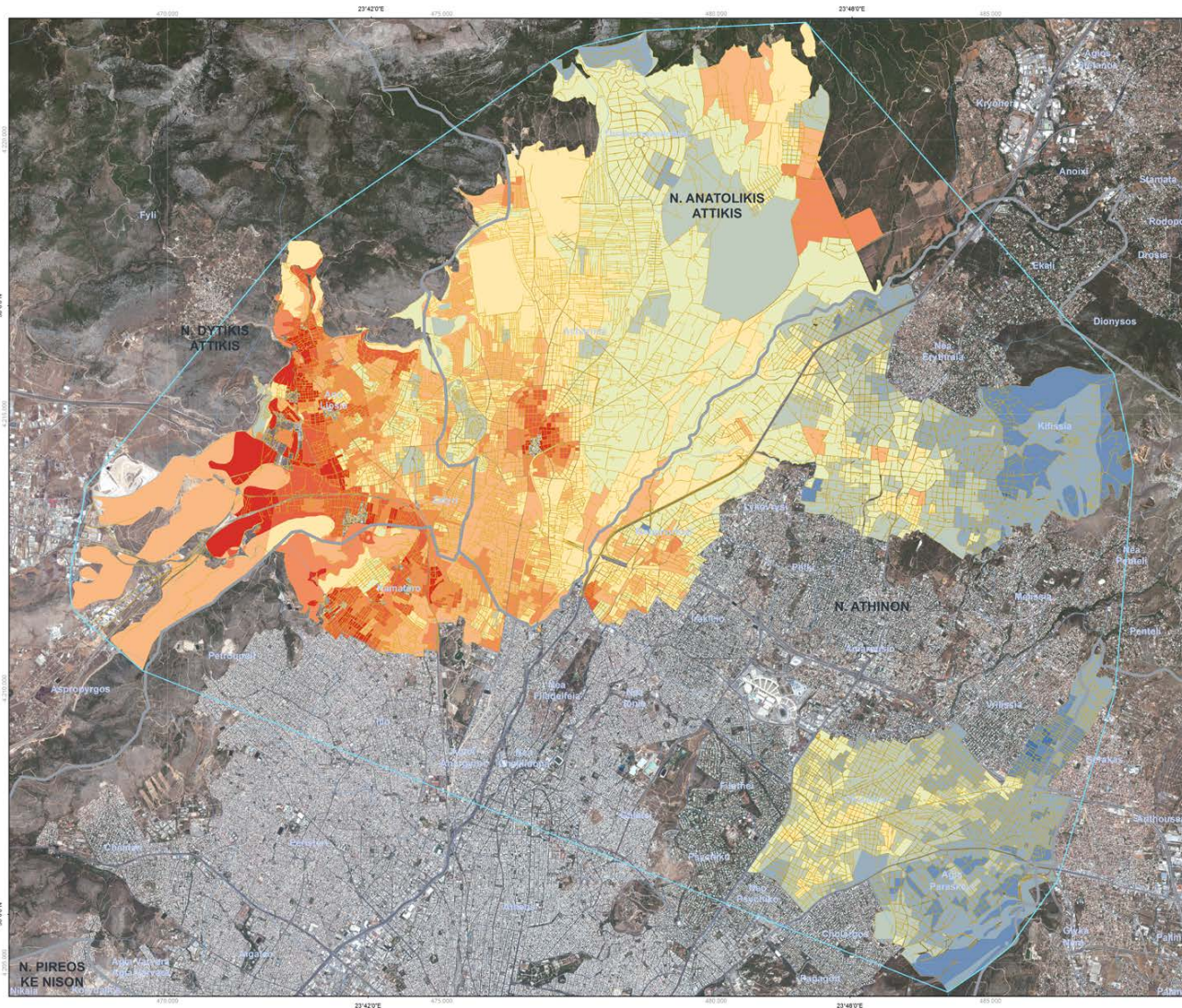
Applications

Tectonics

Volcanoes

Landslides

Subsidence



GLIDE number: EG-1999-000302-GRC Activation ID: GR-Dr-06_1 Product N.: GR-Dr-06_1 (V01)

Greece - Attiki, Ano Liosia
Seismic Risk Scenario (Athens Earthquake of 07/09/1999)
Pre-disaster Situation Map: Seismic Risk Map
Production Date: 30/11/2010



Cartographic Information
Scale: 1:31 000 for A1 prints Full color A1, High resolution (300dpi)
N
0 435 870 1 740 Meters

Legend	
	Seismic Risk
	<ul style="list-style-type: none"> 1.06 - 1.38 1.38 - 1.77 1.78 - 2.15 2.16 - 2.54 2.55 - 2.92 2.93 - 3.30 3.31 - 3.69 3.70 - 4.07 4.08 - 4.45 4.47 - 4.84

Map Information
The Seismic Risk Map used as scenario the Athens Earthquake of September 7, 1999 (magnitude M=5.8) that hit the western side of the larger metropolitan area of Athens, capital city of Greece (GR). The map was produced in the framework of the MASSIVE project which provided the Civil Protection authorities with accurate and up-to-date maps of seismic risk, urban vulnerability, and building damage risk at census block scale, together with state-of-the-art uncontrolled population evacuation models.

Data Source
© Hellenic Statistical Authority (EL-STAT), where applicable
© Copernicus Sentinel-2 (ESA) where applicable
© Copernicus Sentinel-1 (ESA) where applicable

Dissemination/Publication
Publication or redistribution of this mapping product is not allowed due to the proprietary nature of its data.
Delivery formats are GeoTIFF, GeoPDF, GeoPDF3G.

Framework
MASSIVE has attempted to provide indication as appropriate as possible, however all geographic information has limitations due to the wide mediating modeling situations, update and interpretation of the original source materials. Accordingly, MASSIVE maps are distributed as "without any warranty, either expressed or implied, including but not limited to, availability of accuracy in a particular instance or use. The entire risk as to the results of the use of these maps estimates is the user and the applicable liability for any damage or inconvenience caused as a result of reliance on the mapping.

Map Production
Seismic Risk depends on three main parameters (a) the seismic sources that produce the hazard, (b) the ground motion that is attenuated away from the earthquake epicentre (c) the local soil conditions defined from a geologic map.
The seismic risk, which is closely related to the expected damage (D) is a function of hazard (H) and Vulnerability (V): $D = H * V * I^2$. Hazard in a particular area is expressed by Peak Ground Acceleration (PGA) while Vulnerability is expressed by parameter I , related to building age hence: $D \propto PGA * I^2$.
In a particular area the relationship between PGA and macroseismic intensity (I) is denoted through an empirical relationship: $\log(I) = a + b \cdot \log(PGA)$ where 'a' is expressed in the 12-grade Mercalli-Sieberg scale.
The Area Unit in the Building Block.

All Formulas applied for Damage Computation is presented in the following table

Height	Damage
Height < 3.00 x 0.400 - 1.27 log (I - 4) - 0.100 + 0.000 (0.000)	Height < 3.00 x 0.400 - 1.27 log (I - 4) - 0.100 + 0.000 (0.000)
Height > 3.00 x 0.400 - 1.58 log (I - 4) + 0.000 + 0.000 (0.000)	Height > 3.00 x 0.400 - 1.58 log (I - 4) + 0.000 + 0.000 (0.000)
Height > 3.00 x 0.400 - 1.58 log (I - 4) + 0.000 + 0.000 (0.000)	Height > 3.00 x 0.400 - 1.58 log (I - 4) + 0.000 + 0.000 (0.000)
Height > 3.00 x 0.400 - 1.58 log (I - 4) + 0.000 + 0.000 (0.000)	Height > 3.00 x 0.400 - 1.58 log (I - 4) + 0.000 + 0.000 (0.000)

Name of the Producer: M. Theodoridis Hellenic
Name of the Disseminator: Quality Control: NGA
Responsible Organization: National Observatory of Athens
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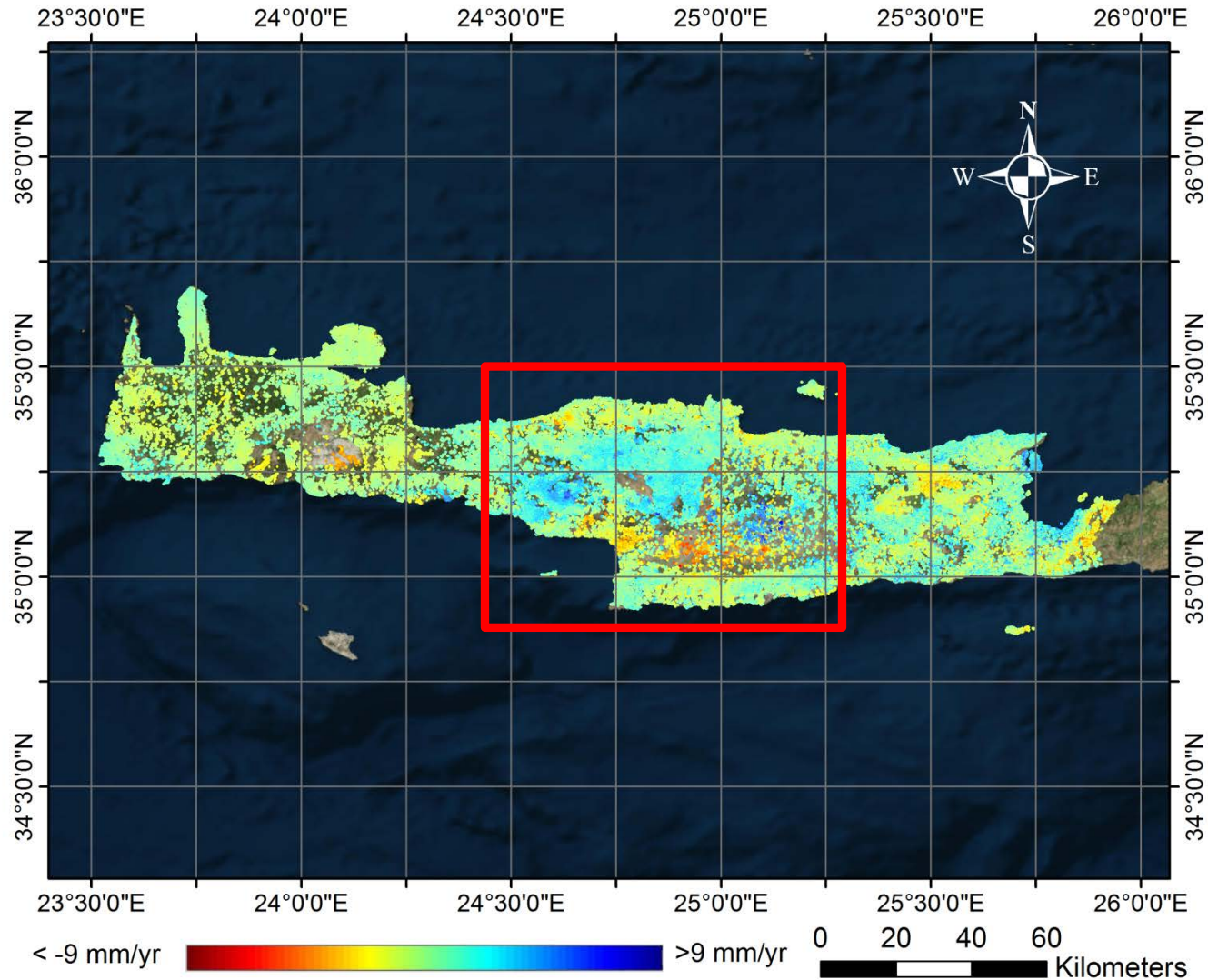


Geohazard applications

Large scale ground velocity estimation



1992-2001



Data

NSN

NOANET

ENIGMA

In-situ

Services

Geodesy

Modeling

Hazard Ass.

Large Proc.

Applications

Tectonics

Volcanoes

Landslides

Subsidence

Geohazard applications

Regional landslide hazard assessment



Hazard scale characterization of slow-moving landslides

Data

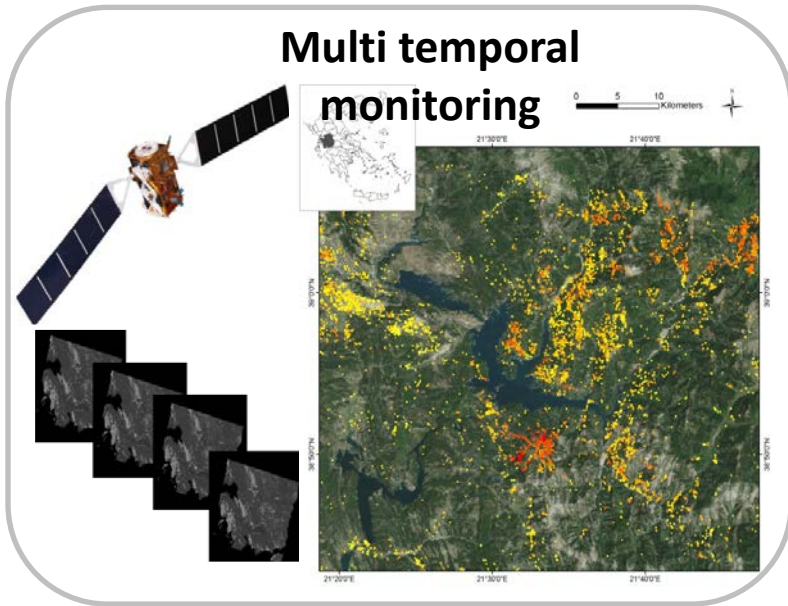
- NSN
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Geospatial layers

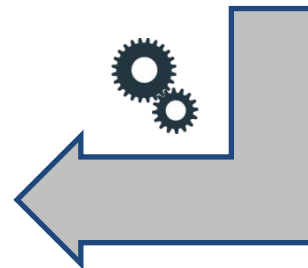
- Elevation
- Slope angle
- Slope aspect
- Geology
- Soil properties
- LU/LC
- Hydrology
- Faults
- Precipitation

A stack of seven geospatial layers, each represented by a different color-coded map showing various terrain and environmental data.

GIS-Statistical processing

Probability models

- Weights of evidence
- Logistic regression
- Neural networks

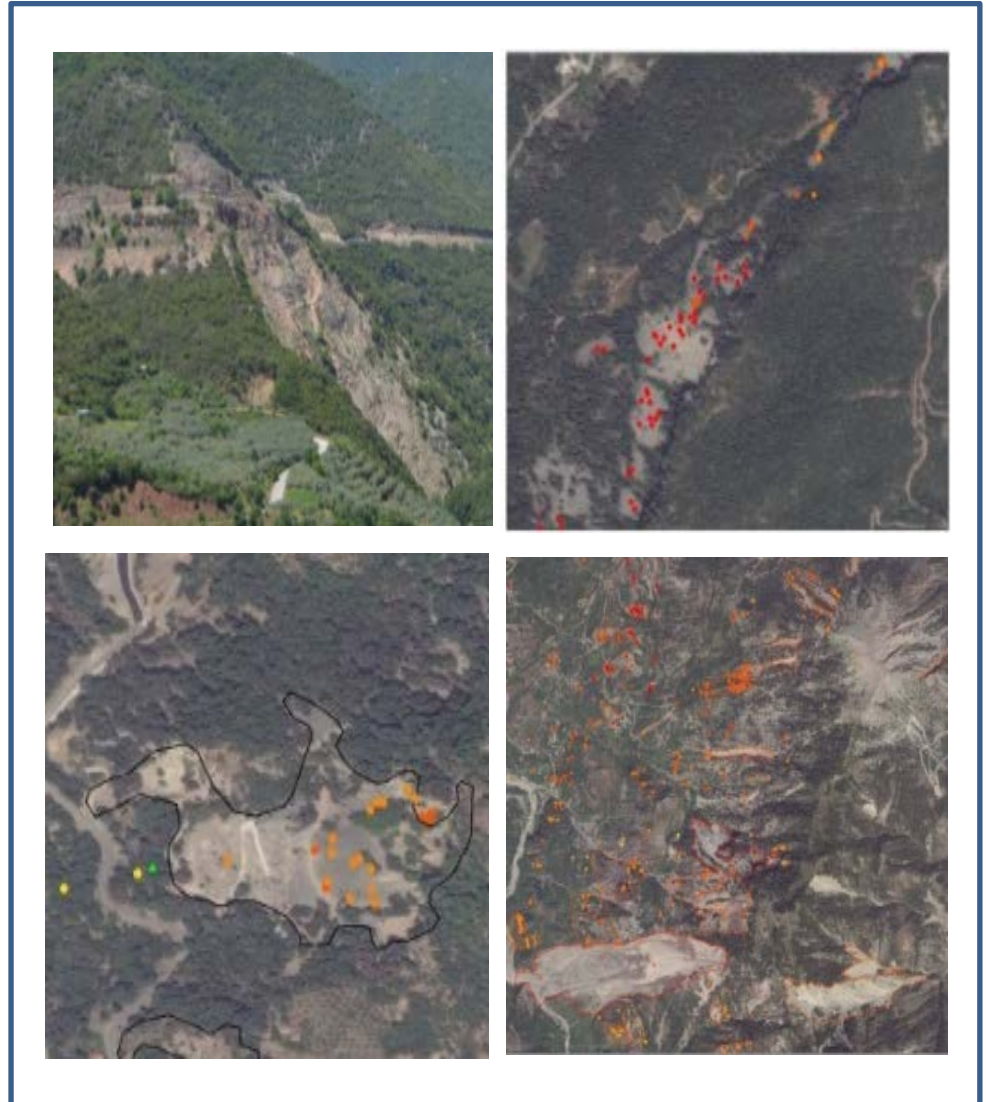
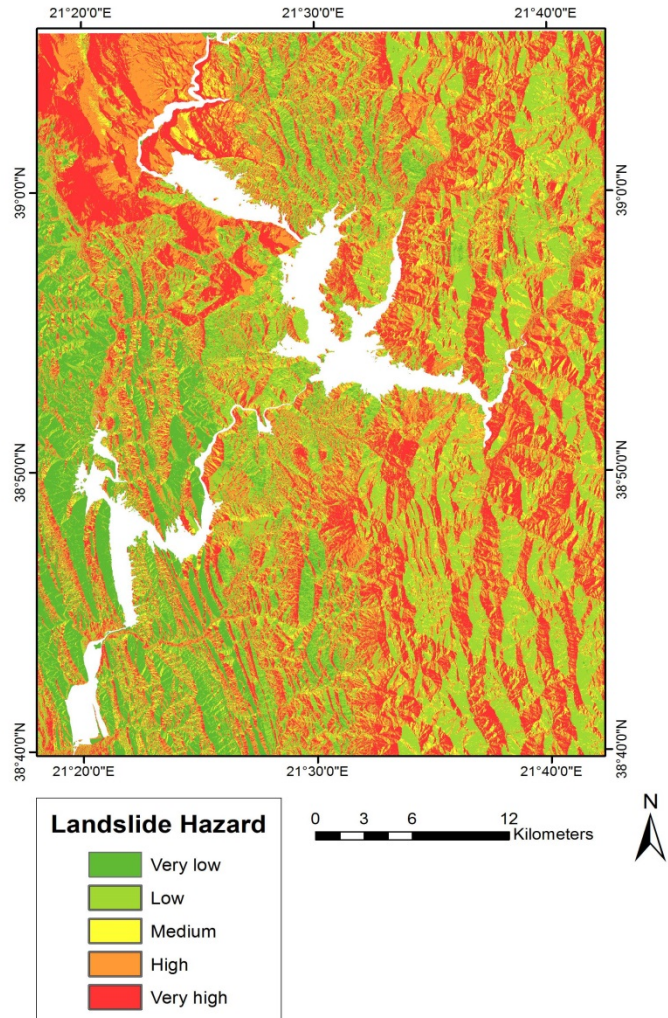


Geohazard applications

Regional landslide hazard assessment



Landslide Hazard map



Geohazard services

An overview



Service	Status	Input data	Scale
Mapping of large-scale ground velocities & 3D decomposition	Operational	SAR, GPS	National
Estimation of earthquake 3D crustal deformation	Operational	multi-angle SAR, GPS	Local
Seismic risk estimation	pre-operational	SAR, in-situ, GIS	Local
UAV based damage assesement	Operational	Aerial data	Local
Mapping of tectonic hazard areas in subduction zones	Research	SAR, GPS	Regional
Monitoring of volcanic activity	Operational	SAR, GPS, in-situ	Local
Monitoring dispersion of volcanic ash	pre-operational	Weather data	Regional
Detection of new landslides	Operational	SAR	Local
Update of landslide inventory maps	pre-operational	SAR, in-situ	Regional
Estimation of landslide susceptibility	pre-operational	SAR, in-situ, GIS	Regional
Detection of subsidence in urban & peri-urban areas due to manmade activities & physical processes	Operational	SAR, GPS	Regional
Monitoring of construction activities in urban environment	Operational	SAR, GPS	Local

Geohazard services

Outlook



NOA hosts a **Sentinel Collaborative Ground Segment**

- Adaptation of existing services, deployment of new services
- Dynamic ingestion of Sentinel data for real-time applications
- Big data management, exploitation of high revisit times
- Databases of geodetic observations

Questions?



Thank you!



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Haris Kontoes: kontoes@noa.gr