Monitoring geophysical activity from Space, in the framework of BEYOND Center of Excellence

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A major objective of BEYOND Centre of Excellence is the operational monitoring of geohazards in Southeastern Europe. BEYOND primarily builds upon state-of-the-art optical remote sensing technologies and differential interferometry techniques. The resulting products are integrated with in-situ observations from the National Seismological Network, and the NOANET GPS network established at the National Observatory of Athens, to monitor the geodetic activity in Greece and beyond, interpret geophysical phenomena, assess and map damages after catastrophic events. Additionally, the ENIGMA magnetometer network is used in an attempt to address the issue of earthquake predictability by studying electromagnetic signals attributed to the coupled lithosphere-atmosphere-ionosphere system as one of the most promising potential pre-seismic transients.

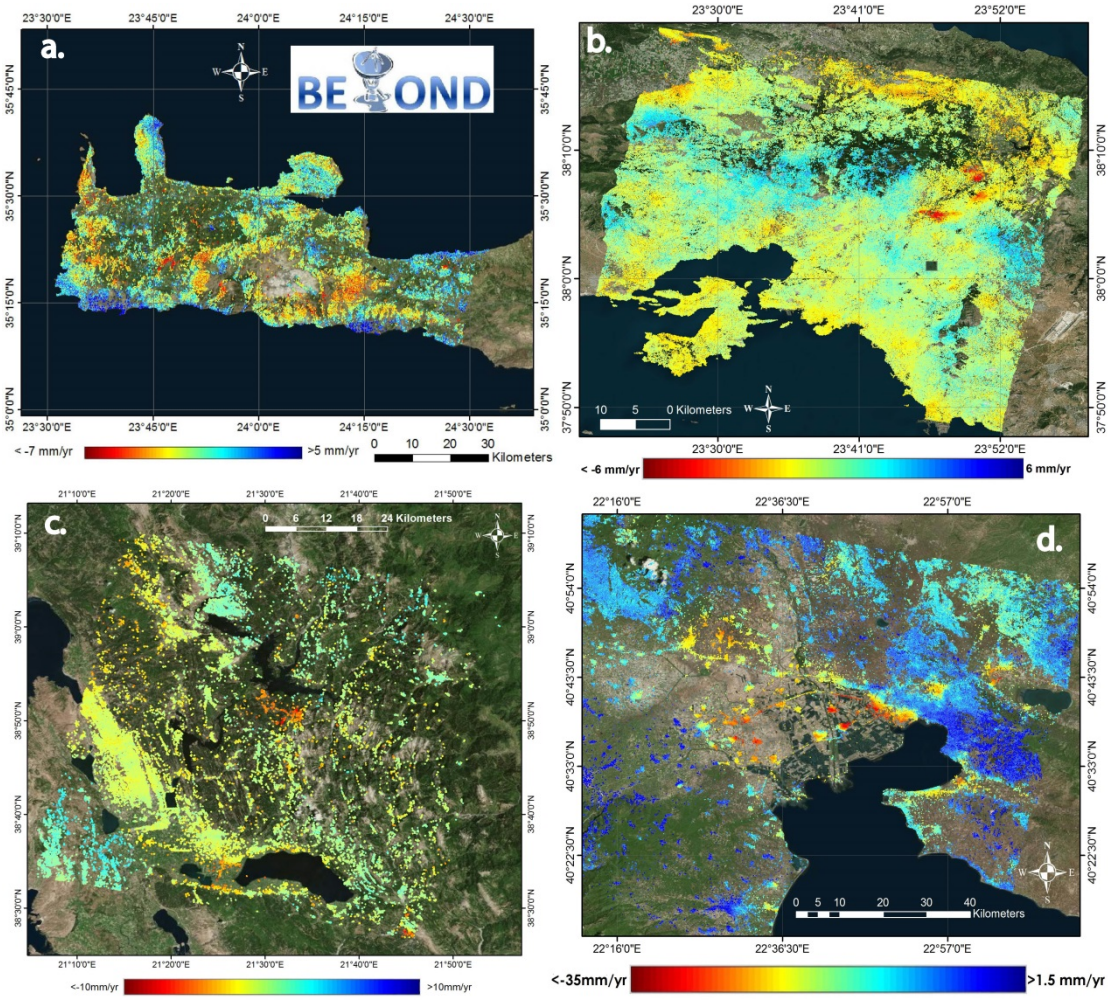
Characteristic examples of services offered in the framework of BEYOND will be highlighted, to address different phenomena and processes in Greece. Three thematic pillar services are offered on a systematic basis, namely ground deformation estimation following catastrophic earthquakes, time-series analysis for mapping ground velocity patterns and signals in large scale and damage assessment using UAV technology for prompt response during or immediately after a crisis.

Persistent scatterer techniques are employed for a number of test sites. Firstly we discuss the 2011-2012 volcanic unrest in Santorini volcano. Using Envisat data, up to 15 cm/yr line-of-sight uplift was observed in the highly touristic villages of Fira and Imerovigli. Since February 2012, when the rapid episode ceased, the latest InSAR and GPS data show a significant decline in the observed displacements, signaling a new phase of relative stability for the island complex. At the moment, TerraSAR-X and COSMO-SkyMed data are being used to ensure the seamless monitoring of Santorini.

Several Greek cities are analyzed by mapping diachronic surface displacements and showcasing the significance of accurate and consistent monitoring of subsidence in an urban environment. The displacement rate field for the wider Athens metropolitan area is estimated for the 1992-2010 period using using ERS and Envisat data with two adjacent and overlapping descending tracks and one ascending track. The extended spatial coverage of the ground velocity maps provide valuable information for the local displacement patterns, a benchmark for surface deformation studies in the region. Decomposition to vertical and horizontal components reveals zones of horizontal motion with opposite direction near the Athens 1999 earthquake epicenter (Mw 5.9), relating to strain accumulation. This motion pattern is not seen during the 2002-2010 period. In Thessaloniki, situated in a tectonically active environment, mainly characterized by normal faulting with a roughly E-W striking, we

process ESA imagery for the 1992-2010 period. Results indicate deforming areas such as Kalochori at the western part of the city, suffering from extensive land subsidence phenomena (over 15 mm/yr), and Athemountas basin at the eastern part, where the "Macedonia Airport" lies, delimited by potentially active and active tectonic structures. Observed surface deformation in Athemountas follows known fault networks, providing new information for the geohazard characteristics of the area. Finally, Volos city in Central Greece is investigated to examine the seasonal deformation patterns close to irrigated lands.

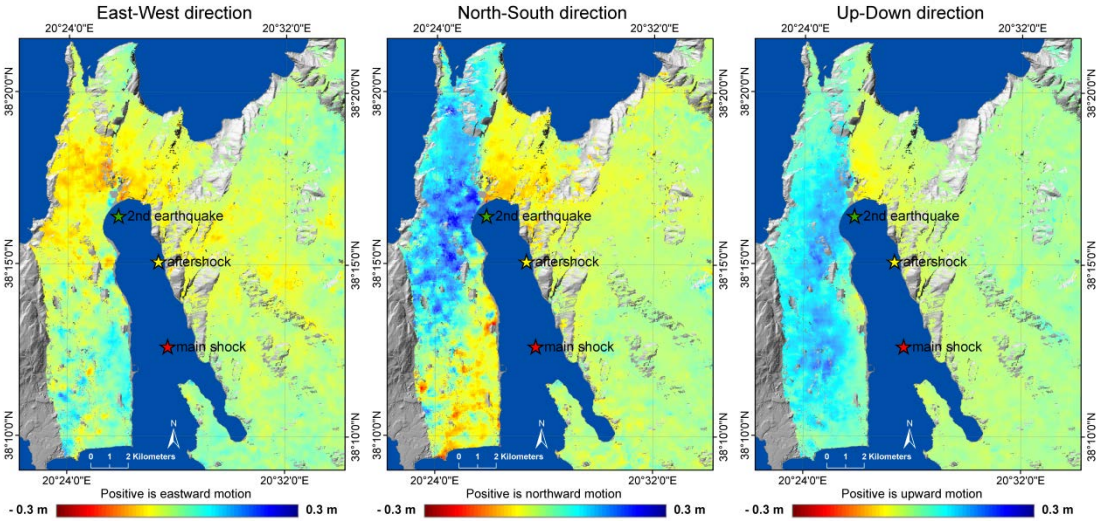
The Southern part of mountain range Pindus, the "backbone" of Greece's mainland, is also investigated to detect slow moving landslides and to update landslide susceptibility maps towards hazard estimation. Due to the mountainous and vegetated setting of the area of interest, PSI processing is demanding. The integrated geo-information, namely PSI velocity rate maps and time-series displacements with in-situ observations, reveal areas prone to landslides, their activity and intensity state, movement type, as well as their cause and frequency of occurrence. A fully updated landslide inventory map is developed for two regional units, Evrytania and Aetolia-Acarnania, (4000km^2) located in Central and Western Greece respectively.



Ground motion maps using PSI for several case studies in Greece: a. Crete, b. wider Athens, c. South Pindus, and d. wider Thessaloniki

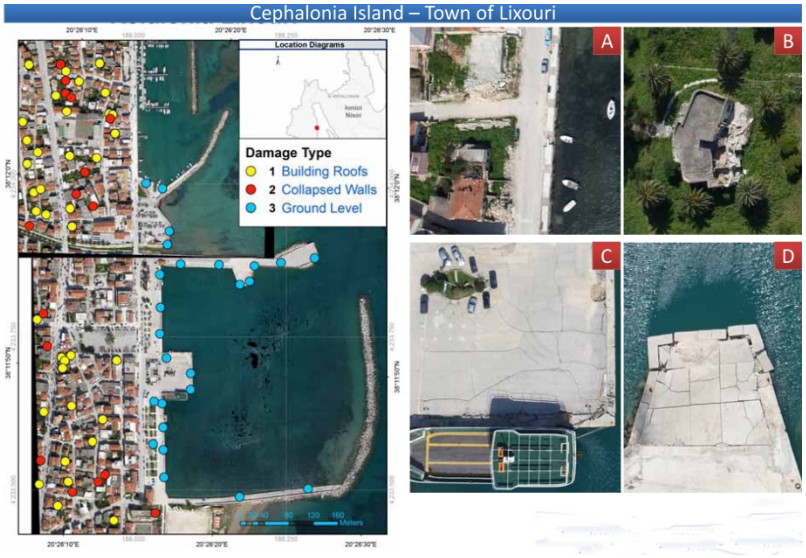
The boundary between the Eurasian plate and the African plate is widely referred to as the Hellenic Arc. It is an arcuate tectonic feature of the Eastern Mediterranean Sea related to the subduction. Crete is part of the non-volcanic arc characterized by high seismicity (highest in Europe), and capable of producing M8+ earthquakes. We process ERS and Envisat imagery to derive the ground velocity regime in the island of Crete. Uplift associated with the plates convergence is observed in the south and southwest of the island. The geodynamic implications of this process are further discussed.

Another example service is the derivation of the 3D surface deformation field associated with the Mw 5.9 Feb. 3, 2014 earthquake that struck the island of Cephalonia, Greece, based on the application of three independent measurement techniques to SAR acquisitions from the COSMO-SkyMed satellites and the TanDEM-X satellite. Exploiting sensor diversity we were able to reconstruct the 3D surface deformation field associated with the Cephalonia and to characterize the seismogenic sources of this region.



Cephalonia 3D deformation after the 3/2/2014 earthquake

Last, a key service is the fast and accurate post-earthquake damage assessment using a UAV. BEYOND flew in Cephalonia a mission over of the urban area of Lixouri, five semi-urban areas and two rural areas. Orthorectified imagery was imported to a GIS and earthquake related damages were detected and classified. Three types of damages were monitored via simple ortho-interpretation: damages a) on ground level such as damages on roads, harbor infrastructure, cemeteries etc. and also small landslides, b) on walls and c) on roof-tops.



Mapping damages in Cephalonia, using UAV technologies

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