MONITORING OF AIR QUALITY USING REMOTE SENSING TECHNIQUES FOR THE CULTURAL HERITAGE PRESERVATION: THE ARTEK PROJECT

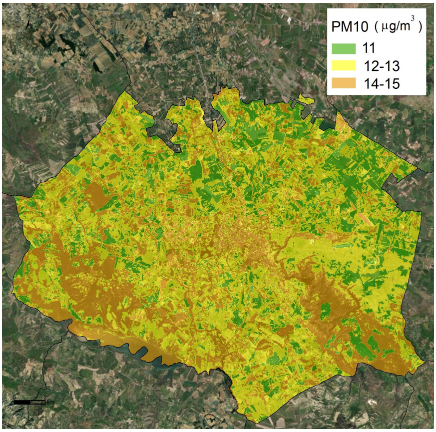
Case study description

Air pollution can cause serious damage to materials constituting cultural property, especially for monuments located nearby or within urban environments. Some of the most frequent degradation typologies, observed on architectural buildings or archaeological sites (soiling, material deterioration due to chemical dissolution, stone decay) are caused by the deposition of air pollutants generally produced by anthropic activities. Air quality monitoring networks, were located in most of the urban areas in order to provide data on the main atmospheric pollutants.
The information recorded by the monitoring air quality stations, although accurate, is punctual and the data are not spatially distributed. In this regard, satellite measurements can make a significant contribution.
In Italy, in some recent studies (MITRA, WHERE, ArTeK projects), remote sensing information is used also to evaluate the effects of air pollution on cultural heritage even if most of available data are, currently, at low spatial resolutions and not able to describe the pollution phenomenon in the territory surrounding the historical building.
ArTeK, "Satellite Enabled Services for Preservation and Valorisation of Cultural Heritage" is a project (2016-2018) aimed to the application of satellite images to the safeguard of Italian Cultural Heritage.
ArTeK was realized by NAIS srl in collaboration with ISCR, ISPRA, CNR – IMAA of Potenza, STRAGO srl, ENAV, Supereletric srl and IpTronix srl.
In this project satellite observations were used to monitor and preserve Italian cultural heritage from environmental natural and anthropic threats.
To achieve this objective, information obtained through observation of the Earth by satellite sensors (SAT-EO), satellite communication, (SAT-COM), satellite navigation technologies (SAT-NAV), by sensors mounted on drones, in situ instrumentation, national and regional environmental databases, was used.
For the demonstration phase of the project the following pilot sites were selected: Villa Adriana and the historic center of Tivoli (Tivoli), Civita di Bagnoregio (Bagnoregio), the Monte Orlando Regional Urban Park and the archaeological area of Gianola (Gaeta and Formia), the archaeological area of Baia (Bacoli) and Matera.
As part of the ArTeK project, in Matera pilot site, satellite observations were used to estimate deterioration phenomena, on the historical building surfaces, due to the deposition of atmospheric pollutants. Matera (Sassi), was recognized as a UNESCO World Heritage Site in 1993.
For this pilot site, concentrations of atmospheric particulate matter (PM_{10}) were estimated using satellite images. PM_{10} indicates the particulate matter fraction characterized by particles with an aerodynamic diameter less than 10 micrometers. This pollutant, produced by both natural (mineral dust, marine spray) and anthropogenic sources (traffic, industrial emissions, heating, etc.) is mainly responsible for soiling of the historical building materials.

Adopted satellite techniques and solution

In Matera there is an air quality monitoring station at the location "La Martella", the industrial area of the town. This station has recorded the daily concentrations of PM_{10} until 2012.
To assess PM_{10} concentrations in 2017, in absence of direct measurements, satellite observations were used. Since the available CAMS (Copernicus Atmosphere Monitoring Service) products are at low spatial resolution (about 10 km), PM_{10} data based on Landsat-5 TM satellite images, were estimated by the CNR-IMAA of Potenza (National Research Council - Institute of Methodologies for the Environmental Analysis).

The elaborations of Landsat data, available at 30 m spatial resolution, provided annual PM_{10} concentrations between 11 and 15 $\mu g/m^3$. These values are lower than the annual limit value for PM_{10} (40 $\mu g/m^3$) established by the European Directive 2008/50 for the protection of human health (limit values for the safeguard of materials have not been defined).



PM_{10} estimations (2017), in Matera, based on Landsat-5 TM satellite images. Source: ISPRA elaboration on CNR-IMAA data

The PM_{10} concentration map, produced for Matera municipality, was overlapped with the distribution of some architectural buildings georeferred in Vincoli in Rete (VIR) database, realized by ISCR (the Italian Institute for Conservation and Restoration). The overlapping of this kind of information permitted to assess the exposure of monuments to particulate deposition.

Main Results

The use of satellite data generally can provide information on the main air pollutant contributing to affect the degradation processes of cultural heritage. Remote sensing information is very useful when there is data lack or the data are not sufficient to represent spatially the pollution phenomenon. In ArTek Project, the estimation of PM_{10} concentration using satellite information at high resolution, was important to estimate the particulate matter for Matera, the pilot site where update measured data weren't available. The spatial estimation of atmospheric pollutant concentrations allows to characterize the potential air aggressiveness of a territory. towards architectural assets and archeological sites. This approach could represent an economic tool for local authorities and government agencies, since the identification of the most polluted environments could allow to make decisions regarding the conservation of cultural sites by planning of specific monitoring and maintenance interventions.

Future needs

The Copernicus products currently available are adequate for global observations and generally cannot be used for the air quality characterization at local level. Therefore, remote sensing techniques should be improved to allow the air quality characterization in the areas surrounding the cultural sites. In recent years, several researchers are investigating the potential of satellite-derived products to improve particulate matter estimates at higher spatial resolution. For instance, in the current ISPRA and ASI Framework agreement, specific statistical models are being implemented to obtain concentrations of atmospheric particulate matter at 1 km spatial resolution, starting from AOD (Aerosol Optical Depth) data, at 10 km spatial resolution, provided by the global near-real-time service (NRT) of CAMS.

Acknowledgements

Thanks to Rosa Lasaponara from CNR-IMAA (National Research Council - Institute of Methodologies for the Environmental Analysis) of Potenza.

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Monitoring ground deformation of cultural heritage sites in Cyprus

The case study presents an integrated ground deformation monitoring approach based on the combined use of Satellite SAR data and field measurement in order to identify geo-hazards within the Choirokoitia UNESCO World Heritage Site in Cyprus.

Aerial image of the Choirokoitia UNESCO World Heritage site

Case study description

The study area is the UNESCO World Heritage Site of Choirokoitia in Cyprus. the Neolithic settlement of Choirokoitia lies on the slopes of a hill, partly enclosed by the Maroni River. The site was occupied from the 7th to the 5th millennium B.C. Since only part of the site has been excavated, it forms an exceptional archaeological reserve for future study. The area is vulnerable to earthquakes and landslides. Therefore, identifying and monitoring geo-hazards are critical to ensure further excavation of the site.

Adopted satellite techniques and solution

The Sentinel 1 satellite includes the Synthetic Aperture Radar (SAR), Interferometric SAR (InSAR) and Persistent Scatterer Interferometry (PSI) processing techniques which can be used for estimating, with millimetre precision, changes in landscapes. SAR data can provide detailed information regarding ground deformation in cultural heritage sites, which is then supported by field monitoring. The local scale monitoring methodology used in the study includes in-situ observation and remote sensing, such as Permanent Scatterer (PS) techniques, which are used to validate the impact of natural hazards.. In addition, time-series Cosmos SkyMed satellite images were used to monitor the site. Topographic surveying using differential GNSS, images from Unmanned Aerial Vehicles photogrammetry and InSAR data were used to monitor slow ground movements, which are then compared and validated with ground based geotechnical monitoring in order to evaluate the extent of damage resulting from the geo-hazard and to understand its behavior over time.

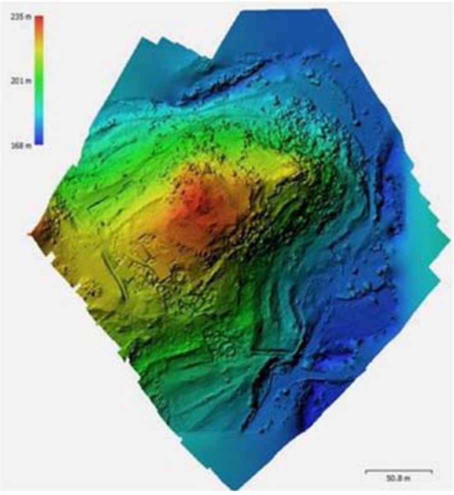
Main Results

The case study at Choirokoitia, Cyprus provides an example of detecting and analyzing geo-hazard induced ground deformation based on InSAR ground motion data and field survey techniques for cultural heritage applications. InSAR data, satellite positioning and conventional surveying techniques were employed to measure the micro-movements, while the UAV and photogrammetry were used for documentation purposes and 3D modeling comparisons.
Field monitoring includes geometric documentation of the area using UAV systems and photogrammetric techniques. This data was supported and geo-referenced using a geodetic network. The UAV images were processed with photometrical software in order to create Digital Elevation Models of the site over time, in order to measure changes on the cultural heritage site. A correlation is evident between the DEM models,

geodetic techniques and SAR images, as the PSI analysis and GNSS Control Network of the Choirokoitia site, which exhibited similar levels of displacement suggesting that longer-term monitoring of the site is required to diagnose the severity of the problem.

Future needs

Further study of geohazards will enable effective and accurate surveillance of geo-hazards which can be used to provide early warning services, risk management, and mitigation of the impact of natural hazards on cultural natural heritage sites.



DEM generated from UAV images to be used with Sentinel data

The free and open data and services provided by the Copernicus programme can be used to detect damaged cultural heritage sites, such as the Sentinel-1 satellite that provides SAR imagery that can be used to monitor the damage to the site. Also, the Copernicus SEA service can be used to assess potential damage to cultural heritage sites which are inaccessible due to conflict.

Acknowledgements

The "PROTection of European Cultural HEritage from GeO-hazards (PROTHEGO)" project HERITAGE PLUS/0314/36, Joint Programming Initiative on Cultural Heritage and Global Change (JPICH) – HERITAGE PLUS under ERA-NET Plus, FP7 of the European Commission and the Cyprus Research Promotion Foundation, contract KOINA/ΠΚΠ-HERITAGE PLUS/0314/36.

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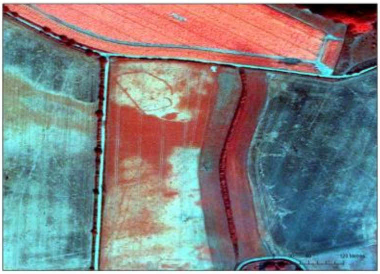
Assessing the Utility of High-Resolution Satellite Remote Sensing for Archaeological Prospection and Mapping

Our work examined the utility of archive high-resolution multispectral satellite (MS) imagery for archaeological prospection in England. We examined imagery from several sensor platforms for prospection and mapping, of crop and soil marks.



Cropmarks near Harkstead, Suffolk, UK. WorldView2 False Colour Composite.

Case study description

Work built upon previously identified national research objectives to assess the utility of high-resolution satellite imagery for archaeological prospection and mapping across a variety of English landscape types. Study areas were chosen to provide coincidence of good, cloud free archive satellite imagery from archaeologically productive seasons. Assessment of the imagery combined determination of its base suitability for detecting archaeological features and determination of a workflow for image processing, interpretation and incorporation of results of analysis within existing national heritage management systems.

Adopted satellite techniques and solution

Sub metre resolution imagery from the WorldView 1 and 2 and Quickbirld sensor platforms were found to provide consistently good imaging of cropmarks on images captured at appropriate seasons. Image processing techniques focused on emphasising near infrared image bands and production of vegetation indices, were found to enhance cropmark definition as vegetation differences were emphasised.

Main Results

In general, digital multispectral imagery was found to be most suited to detection and mapping of archaeological cropmarks. Soilmarks and illumination dependent features are less well evidenced on such imagery due to the less pronounced spectral variations in soil properties and the fact that most imagery is captured in periods of relatively even illumination where shadow features are minimised.

A selection of archaeological features visible as cropmarks were digitised as a means to see how they would fit into the English Heritage National Mapping Programme workflow.

Since satellites capture high quality image data at a landscape scale, enabling investigation of large areas (tens of square kilometres) in a single image, this greatly increases the quantity of information acquired in a single productive season.

Use of satellite imagery compliments rather than replaces traditional prospection, which has relied on conventional oblique aerial photography undertaken on repeat survey flights at appropriate times and seasons.

When cropmark formation is good, imagery can enhance the cropmark record from conventional photography, through more effective delineation of faint cropmark features and emphasis of cropmarks which are most evidence in vegetation differences beyond the visible spectrum.

When funding for archaeological prospection is challenging, single satellite images covering a large area, offer a cost-effective contribution to campaigns of archaeological prospection.

Cropmark enclosure near Ladcock, Cornwall, UK.
WorldView 2 False Colour Composite.

One of the key results from this project was the confirmation of the potential for using high resolution satellite data for the discovery and analysis of archaeological cropmarks.

Future needs

Following on from this project Historic England are once again examining the potential of using very high resolution satellite data to locate and interpret cropmarks. This is being done through the Space for Smarter Government Programme (SSGP). This is a programme established by the British government in 2015 designed to help the public sector save money, innovate and make more effective policy decisions using space enabled services.

Part of this programme, developed in 2019 aimed to look at making very high resolution data available to a selection of government bodies to assess how it might be used to improve efficiency. The aim of the current project is to assess this data and see both how it compares with that looked at in the previous project, and how beneficial it could be for the discovery and analysis of archaeological cropmarks.

Acknowledgements

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MONITORING CULTURAL-HISTORICAL LANDSCAPES IN NORWAY

In Norway, we are combining various data sources to monitor changes in land cover and land use that may threaten cultural heritage qualities.

Land cover greatly influences our experiences of cultural heritage in the landscape. Photo from Oldtidsveien-Skjebergsletta, W. Dramstad, NIBIO.

Case study description

Norway has identified and mapped “Cultural-Historical Landscapes of National Interest” (KULA). These are areas that demand extra attention in spatial planning, since changes in land use or land cover could spoil their cultural heritage values. KULA areas are scattered all over the country and differ in size. The largest are several hundred square kilometres in extent. Analysis of satellite images provides a cost-effective means to monitor whether the KULA areas are being well managed or whether their cultural heritage qualities are threatened by landscape changes.

Adopted satellite techniques and solution

The Sentinel-2 satellites provide very frequent images of Norway. Since the country lies far north, there is a big overlap in the area “seen” by the satellites on each orbit and images may be available about every third day. Typically, about 80 % are obscured by cloud, but this still leaves 10 to 20 cloud-free observations during the growing season (May to September). We use pixel-based analyses (10 x 10 m), which means that we can use any cloud-free part of every image.

Our aerial photographs have a much more detailed spatial resolution, e.g. pixels of 25 x 25 cm. However, they are taken on a single occasion between May and September and are usually not repeated for another five to seven years. Cloud cover can delay the interval between repeat photography and if a portion of the image is hidden by cloud, it may be many years before changes in land cover can be seen.

Sentinel-2 therefore significantly improves data availability for Norway. By analysing how pixels change during a growing season, we can determine how land cover and, by inference, land use change.

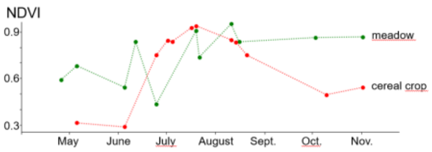
Main Results

The solutions that we are implementing for monitoring, combine different data sources: We create detailed maps based on interpretation of aerial photographs, and add information on all known cultural heritage locations from the National Cultural Heritage Database. We can then follow changes within land parcels using Sentinel data.

Relevant changes that we identify are clear-cutting of forest, afforestation, re-growth of forest on former agricultural land, changes from cereal production to permanent grassland, and building and infrastructure construction.

By combining the detailed maps with digital terrain models, we are also able to assess the degree of visibility of different changes in the landscape and assess their importance in relation to the cultural heritage values in the area.

Establishing fully operational monitoring takes time and resources. Currently baseline data has been gathered for just one KULA area: Oldtidsveien-Skjebergsletta. However, in the long-term, these methods will enable a



Changes in normalized difference vegetation index (NDVI) throughout the year. The meadow has green cover at the end of the year, the cereal crop does not.

cost-effective level of monitoring that was not previously possible. The rapid updates available from Sentinel-2 will enable us to detect changes early enough to respond quickly, before small changes accumulate to alter landscape character.

Future needs

Work is still needed to fully automate change detection methods. For reliable monitoring, accurate georeferencing is imperative. This means that pixels must be accurately matched to coordinates on the ground. During the first years of Sentinel-2, georeferencing was of poor quality in the North, especially in areas of complex topography. In 2020, the new global Copernicus digital terrain model will be completed, which we expect to significantly improve georeferencing. This will make use of Sentinel-2 for monitoring much easier and more reliable.

Acknowledgements

The establishment of a baseline for monitoring Oldtidsveien-Skjebergsletta was financed by The Directorate for Cultural Heritage.

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Ref.

Wallin, H., Fjellstad W., Dramstad W., Gjertsen, A. K., Taff, G., and Bayr U. 2019. Bruk av satellittdata I overvåking av KULA-områder.NIBIO Rapport Vol 5 nr. 94

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

Geo-hazards assessment of ancient Carsulae by DInSAR analysis

The roman city of Carsulae was affected by seismicity and sinkhole, due to its peculiar geologic setting.

3d reconstruction of the Carsulae archaeological site.

The Roman City of Carsulae

Carsulae was founded in a strategic position along the Via Flaminia and it reached the maximum expansion during Roman Empire age, as attested by many important monuments: Forum, Basilica, temples, theater, amphitheater, Thermae, arches. The settlement is located on a travertine plateau laying on recent marine clay, at the foothill of Monti Martani carbonatic range. The site is characterized by karst morphologies due to the dissolution of travertine because of the large amount of groundwater. The Romans took advantage of these environmental features by adapting the Amphitheater in one sinkhole and filling another to obtain the Forum. Historical sources attributed the progressive decline and abandoning of Carsulae, during the 4th century AD, to the construction of a new track of the Via Flaminia as well as to karst phenomena and to earthquakes.

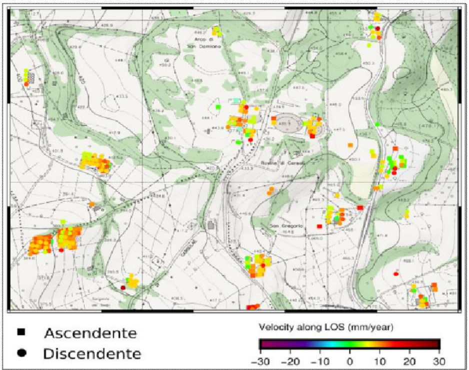
DInSAR technique

Earth Observation (EO) demonstrated its growing scientific, political and economic importance by contributing to better understanding land transformations, by supporting a wide range of applications and by providing essential data for environmental monitoring.

The goal of Copernicus programme is to provide at achieving a global, continuous, autonomous, high quality, wide range and free EO capacity. Differential Interferometric Synthetic Aperture Radar (DInSAR) technique aims at detecting ground and buildings vertical millimetric displacements by analyzing sets of images acquired over time. In fact by analyzing radar beamós phase correlation in each ground parcel between subsequent images it is possible to identify some peculiar targets (Persistent Scatterer, PS) whose displacements can be followed in a time history graph or shown in a map as mean annual velocity. A DInSAR analysis has been conducted in the Carsulae Archaeological Park using free input SAR data from Sentinel-1 mission of Copernicus Programme and open source software packages (ISCE and STAMPS) to run the SBAS technique, that optimizes the results in agricultural and natural areas, thus obtaining a map of the ground displacements during the period August 2018 ï July 2019 (see map).

Main Results

Geohazard assessment on Cultural and Natural Heritage is based on the identification of the predisposing factors and this study can be validated by measuring ground displacements. The availability from Copernicus Programme of open data, frequently acquired and of good resolution allowed EO monitoring to support traditional in situ monitoring (topographic surveys, inclinometer, extensimeter, etc.). SBAS technique applied on Sentinel-1 data allows surveying millimetric vertical ground displacements every 2 weeks by a spatial resolution of about 10 meters. Moreover, this remote sensing survey covers at a same time a wide area without the installation and the maintenance on the



Map of the PS ground motion data obtained by Satellite Radar Interferometry in the Carsulae archaeological area.

walls of reflecting devices that could limit the function or the fruition of monuments. Finally, the automation of DInSAR analysis enables the site managers to monitor natural threats through an efficient and sustainable system, selecting proper alert and mitigation measures when critical displacements are reached.

Future needs

So far, the application of DInSAR technique is limited by the availability of SAR images at very high resolution, of more spectral bands and with shorter revisit time. Targets' characteristics and distribution are very different between urban areas and natural ones, therefore it is important the availability of SAR images with resolution higher than current ones and more bands (id est X band and L band in addition to the C band from Sentinel 1) to detect more Measurements Points. This will extend the capability to monitor at a same time much more, and more reliable, data on territorial features. Furthermore, a higher survey frequency should improve the monitoring system's effectiveness, up to realize a real alert system for natural and structural threats.

Acknowledgements

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FLORENCE CITY CENTRE AND SURROUNDING METROPOLITAN TERRITORY (ITALY)

The Florence city centre enclosed within the avenues ring that follows the old medieval walls, collects the most important cultural assets and in 1982 was included in the World Heritage List of UNESCO.

Overview of Florence city center architecture.

Case study description

The city of Florence was built on the site of an Etruscan settlement and on the later ancient Roman colony of Florentia. The city became a symbol of the Renaissance between the 15th and the 16th centuries, reaching extraordinary levels of economic and cultural development. The present historic city center covers about 5 sqkm and is bounded by the remains of the city's 14th-century walls, which are represented by surviving gates, towers, and two strongholds. The Arno River runs east and west through the city and a series of bridges connects its two banks.

The city centre, which is enclosed within the avenues that follow the old medieval walls, collects the most important cultural assets of Florence and in 1982 was recognized as a World Heritage Site by UNESCO.

In particular, it includes historical urban built-up and many cultural and landscape assets that are subject to architectural and archaeological restrictions.

The setting of Florence, surrounded by the Tuscan hills and bisected by the Arno River is threatened by several risks ascribable to geo-hydrological hazard factors, i.e. Arno floods, and landslide movements in the surrounding hilly areas, subsidence and ground motions due to recent tramway roadworks and high-speed train excavations.

Adopted satellite techniques and solution

Some recent events like the Lungarno Torrigiani collapse in 2016 and the Lungarno Diaz sinkhole in 2019 as well as the historical slope instability problems of San Miniato hill demonstrate that phenomena of hydrogeological instability could be a real risk to the integrity of the historic centre of Florence city and surrounding metropolitan territory.

The exploitation of satellite Earth Observation data from the Copernicus programme can support the mapping and monitoring of the ground movements that could affect the urbanized heritage of the city by threatening its integrity and stability. Satellite remote sensing techniques are an efficient tool to this aim, given the need to adopt non-invasive techniques without direct contact with the objects of investigation in order not to damage them.

At the moment, Sentinel-1 satellite SAR (Synthetic Aperture Radar) data processed by means of multitemporal interferometric techniques, i.e. Persistent Scatterers Interferometry (PSI), are operationally exploited to analyse terrain deformations on the area with millimetric accuracy and frequent update (6-12 days following the Sentinel-1 short revisiting), allowing to dynamically and continuously update the deformational scenario and to promptly detect any critical situations.

Main results

The use of the space-based data from the EO Copernicus program provides millimetric measurements of displacement over the whole territory for periodically and regularly monitoring the area.

This systematic near-real time monitoring of ground instability scans the territory every 6-12 days by exploiting PSI Sentinel-1 data that rapidly points out the fastest deformations and most hazardous sites over

Monitoring of the Florence city center by means of radar satellite interferometric techniques exploiting Copernicus Sentinel-1 constellation.

the historical and cultural heritage of Florence city center and its surrounding territory.

This approach ensures continuity of global observations, data promptness and availability in inaccessible areas and a good cost/benefits ratio by providing an effective service reliability with near-real-time delivery for risk management applications.

Furthermore this approach of PSI data continuous streaming marks the passage from a static 'picture' of the terrain deformations to weekly satellite acquisitions, which lead to a dynamic and continuously updated 'movie' of the geo-hydrological scenario: it enables possibilities to systematically track the temporal evolution of ground motion rates for urban and environmental planning, for early warning purposes as well as for civil protection practices by local and regional authorities.

Future needs

In order to perform a non-destructive analysis and mapping of the surface positioning and moving of the built environment and landscape features of the area, the most required monitoring domains within a future routine/regular service are the high-resolution elevation modelling from Sentinel-1 SAR data, photogrammetric mapping, optical change detection from Sentinel-2 VHR imagery, as well as ground motion monitoring with Sentinel-1 data for the analysis on building structural movement patterns, with up to metric spatial resolution as horizontal component and centimetric as vertical one.

Acknowledgements

The present satellite monitoring system is founded by the Regional Government of Tuscany, under the agreement "Monitoring ground deformation in the Tuscany Region with satellite radar data."

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VENICE AND ITS LAGOON (ITALY)

Venice and its lagoon landscape are the result of a dynamic process which illustrates the interaction between people and the ecosystem of their natural environment over time.

Overview of the Grand Canal of Venice city (Italy)

Case study description

Venice, the capital of northern Italy's Veneto region, is built on more than 100 small islands in a lagoon in the Adriatic Sea. It has no roads, just canals, lined with Renaissance and Gothic palaces. The central square, Piazza San Marco, contains St. Mark's Basilica, which is tiled with Byzantine mosaics, and the Campanile bell tower offering views of the city's red roofs.

Venice and its lagoon were added to the list of UNESCO World Heritage Sites in 1987. The UNESCO World Heritage property comprises the city of Venice and its lagoon. Founded in the 5th century AD and spread over 118 small islands, Venice became a major maritime power in the 10th century. The whole city is an extraordinary architectural masterpiece, containing works by some of the world's greatest artists such as Giorgione, Titian, Tintoretto, Veronese and others.

Venice and its lagoon landscape represent a dynamic process of interaction between people and the ecosystem of their natural environment over time. Human interventions show high technical and creative skills in the realization of the hydraulic and architectural works in the lagoon area. The whole urban area is subject to sea level variations, subsidence and flooding events that lead to several environmental problems to face.

Adopted satellite techniques and solution

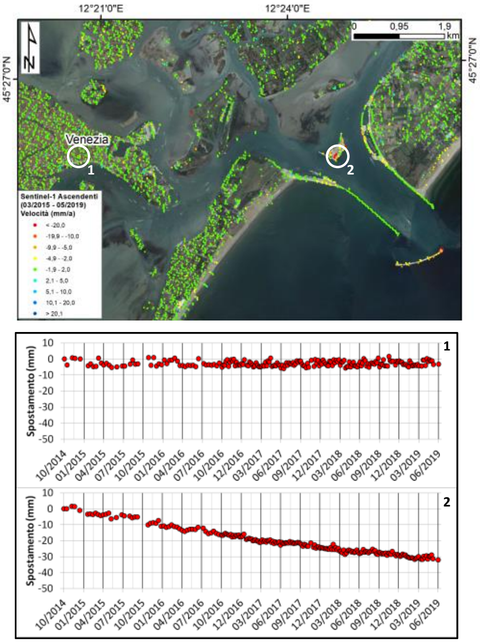
Natural land subsidence, which played an important role in the origin and the evolution of the lagoon, and anthropogenic subsidence, that has recently assumed a major importance for the Venetian environment are geological facets that characterize the hazard of the area. The sea level rise with some tens of centimetres loss in land elevation has occurred in the last century, leading to increased flooding events and environmental problems that require protective works.

The systematic use of satellite Earth Observation data from the Copernicus programme can help the temporal monitoring of the terrain movements related to ground subsidence that affects the urbanized heritage of the Venice city. This is because the satellite remote sensing techniques are effective and non-invasive that can preserve the integrity of manufacts and in the meanwhile can provide useful, precise and update information.

Nowadays, Sentinel-1 satellite SAR (Synthetic Aperture Radar) data processed by means of multitemporal interferometric techniques, i.e. Persistent Scatterers Interferometry (PSI), are operationally exploited to analyse terrain deformations motions across time with a frequent update (6-12 days following the Sentinel-1 short revisiting). This systematic monitoring permits to continuously observe and update the deformational scenario and to alert authorities in case of critical situations.

Main results

The exploitation of space-borne satellite data from the EO Copernicus program provides millimetric measures of displacement on Venice city and its lagoon for periodic monitoring of the territory.



PSI Sentinel-1 satellite data on Venice city: spatial distribution of mean yearly velocities (up) and time series of two selected measure points.

These periodic and regular observations of the area allow the monitoring of ground motions over the whole area with frequent and always updated measurements. The SAR images are acquired and processed every 6-12 days by exploiting PSI Sentinel-1 data. This service highlights the highest ground motions rates and thus the main hazardous sites where attention should be focused for further investigations and analysis.

This approach provides a dynamic and continuous movie of the geo-hydrological scenario by means of PSI data of the observed area. As a result, it can be used in terms of urban and environmental management to be used by local and regional authorities, and for civil protection purposes.

Future needs

As future needs, the most useful monitoring issue on Venice city and its lagoon is the ground motion monitoring by means of Sentinel-1 data for the analysis of subsidence phenomenon, and movements of buildings and of the integrated mobile gates of MOSE (*Modulo.Sperimentale.Elettromeccanico* - Experimental Electromechanical Module) with up to metric and centimetric spatial resolution, respectively in horizontal and vertical components.

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The present satellite monitoring system is founded by Veneto Region, agreement “Monitoring ground deformation in the Veneto Region with satellite radar data.”

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