# Satellite-based Services for Disaster Risk Management

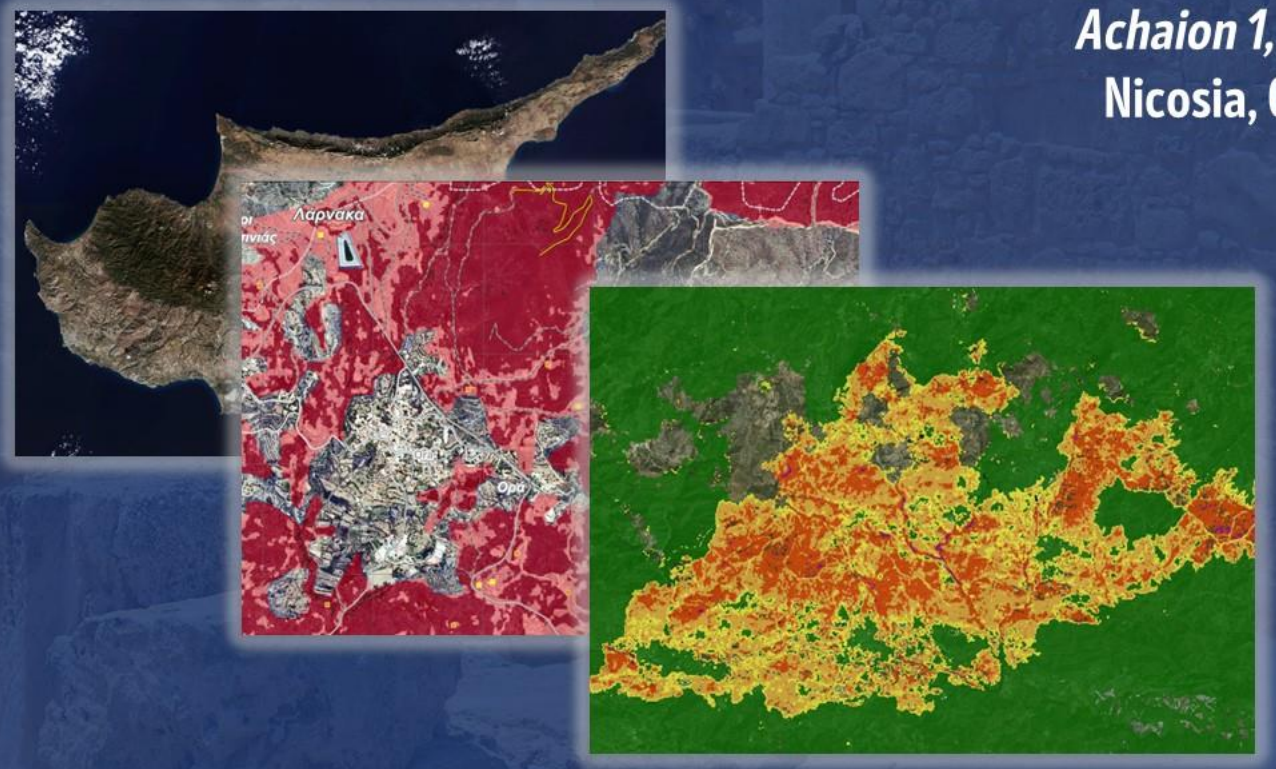
**17th May 2023**

**9:30 - 15:30 EEST**

**HILTON NICOSIA**

***Achaion 1, Egkomi***

**Nicosia, Cyprus**




In cooperation with the Department of Electronic Communications | Deputy Ministry of Research, Innovation and Digital Policy

"Satellite-based Services for Disaster Risk Management"


# Disaster Risk Management for Cultural Heritage:

## Examples from Cyprus and beyond

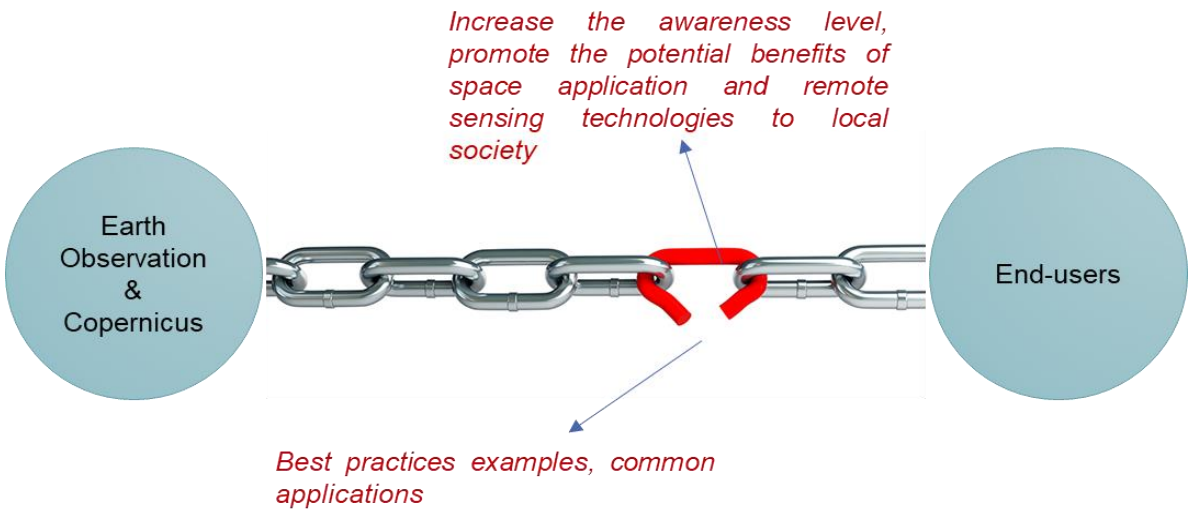
Dr Athos Agapiou
Earth Observation Cultural Heritage Lab
Department of Civil Engineering and Geomatics
Cyprus University of Technology

| Wednesday 17th of May 2023 |

# Overview: Copernicus Services in Support of Cultural Heritage

- **10.7%** of user requirements can be fully covered by Copernicus core services products and/or Sentinels capabilities
- **39.1%** of overall user requirements could be fully covered by Copernicus contributing missions
- **14.2%** of overall user requirements could be partially covered by Copernicus contributing missions meaning that one (or more) Copernicus contributing mission exists but its spatial resolution and/or temporal resolution could only be partially covered
- **35.9%** of overall user requirements could not be covered by existing Copernicus contributing missions


EC, 2018, Copernicus services in support to Cultural Heritage



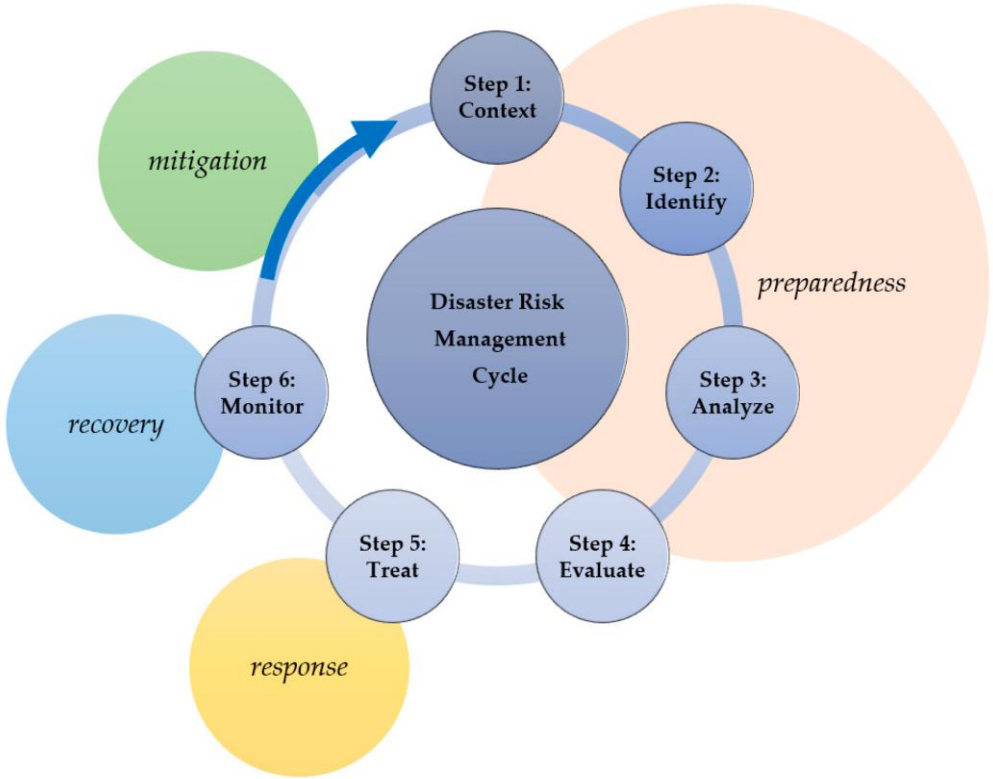
# Overview: Copernicus Programme…today!

- Even though the Copernicus Programme has been introduced recently (operational since 2014), the full, free, and open data policy, known as FFO, has increased the number of relevant applications.
- Since then, several studies dedicated to cultural heritage monitoring, management, etc., have been presented in the literature. Despite the medium spatial resolution of the radar and optical Sentinel sensors, their high-temporal revisit time combined with other legacy space programmes (e.g., the Landsat space programme) can provide useful information to local and regional stakeholders, and other national agencies.
- New developments in the domain of image processing like the use of big-data earth observation cloud platforms already showcased the potentials for dedicated space-based cultural heritage services.

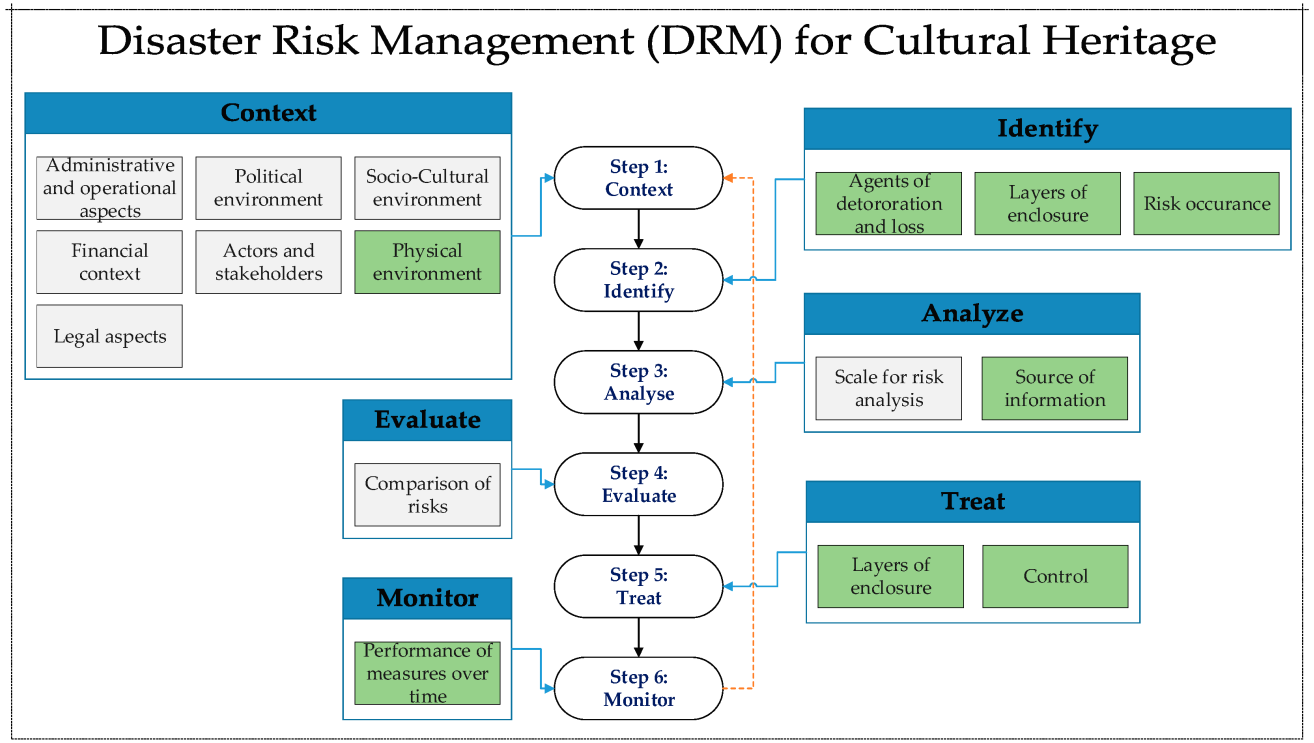
…but

- However, this technological shift remains still within the scientific and theoretical research domain. Therefore, much effort is still needed for the implementation of national policies.

# Overview: Copernicus programme and Cultural heritage: Disaster Risk Management (DRM)




Disaster risk management (DRM) cycle steps represented by blue circles, while other accepted components of the DRM cycle used beyond cultural heritage applications are shown in the outer circle.




The potential contribution of satellite observation within the various steps of the risk management plan proposed by the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) is highlighted in the green rectangle.

Agapiou, A.; Lysandrou, V.; Hadjimitsis, D.G. Earth Observation Contribution to Cultural Heritage Disaster Risk Management: Case Study of Eastern Mediterranean Open Air Archaeological Monuments and Sites. *Remote Sens.* **2020**, *12*, 1330.

# Overview: Copernicus programme and Cultural heritage: future perspectives

| | | | |
|---|---|---|---|
| Diachronic observations | Wide spatial extent | Georeferenced data | Open access datasets |
| Systematic observations | Free access/low cost datasets | Remotely monitoring | Ready products |

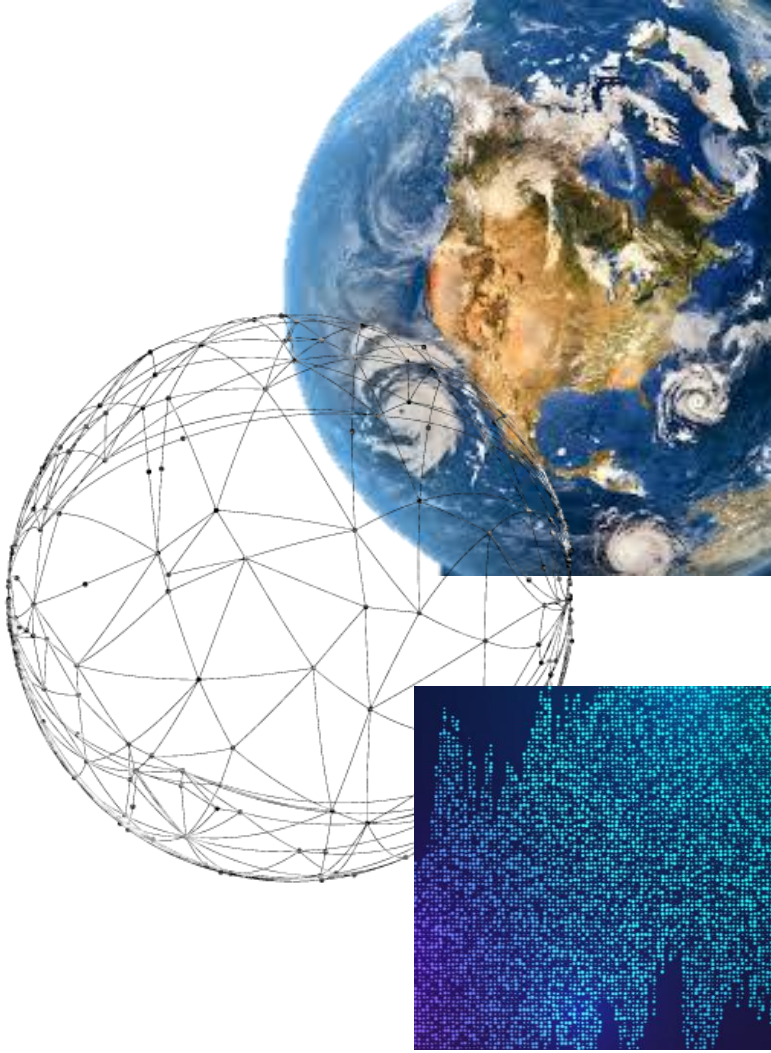

The six thematic Copernicus-based services

Favorable characteristics of satellite observation datasets for Disaster Risk Management of cultural heritage.


Source: Agapiou, A.; Lysandrou, V.; Hadjimitsis, D.G. Earth Observation Contribution to Cultural Heritage Disaster Risk Management: Case Study of Eastern Mediterranean Open Air Archaeological Monuments and Sites. *Remote Sens.* **2020**, *12*, 1330.

# Overview: Digital Earth…

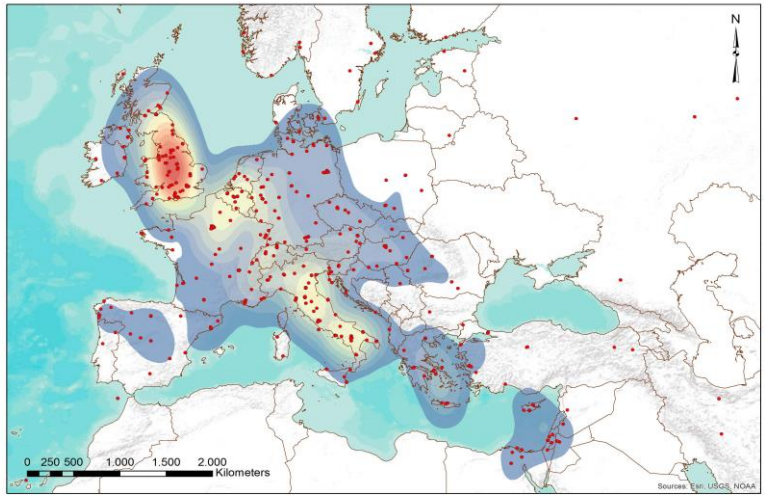
"A new wave of technological innovation is allowing us to capture, store, process and display an unprecedented amount of information about our planet and a wide variety of environmental and cultural phenomena. Much of this information will be "georeferenced" - that is, it will refer to some specific place on the Earth's surface…. The hard part of taking advantage of this flood of geospatial information will be making sense of it. - turning raw data into understandable information. Today, we often find that we have more information than we know what to do with….".



Al Gore, former U.S. Vice of President at California Science Center at Los Angeles,

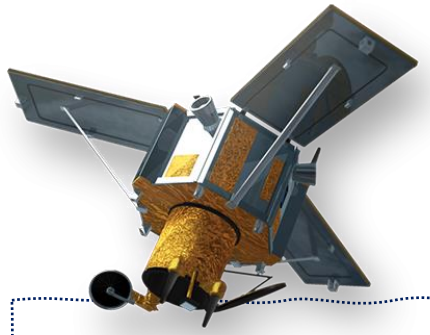
*"The Digital Earth: Understanding our planet in the 21st Century", putting forward another hot topic in earth science, the concept of Digital Earth.*

## Scientific literature: Publications related to remote sensing and CH




Density map indicating clusters according citations for remote sensing archaeology in European level. Red colour indicates areas with high density of institutions received a high number of citations. Regions with no colour indicate that the citation number was very poor.

*Agapiou A. and Lysandrou V., 2015. Remote sensing archaeology: Tracking and mapping evolution in European scientific literature from 1999 to 2015, Journal of Archaeological Science: Reports, 4, 192-200.*

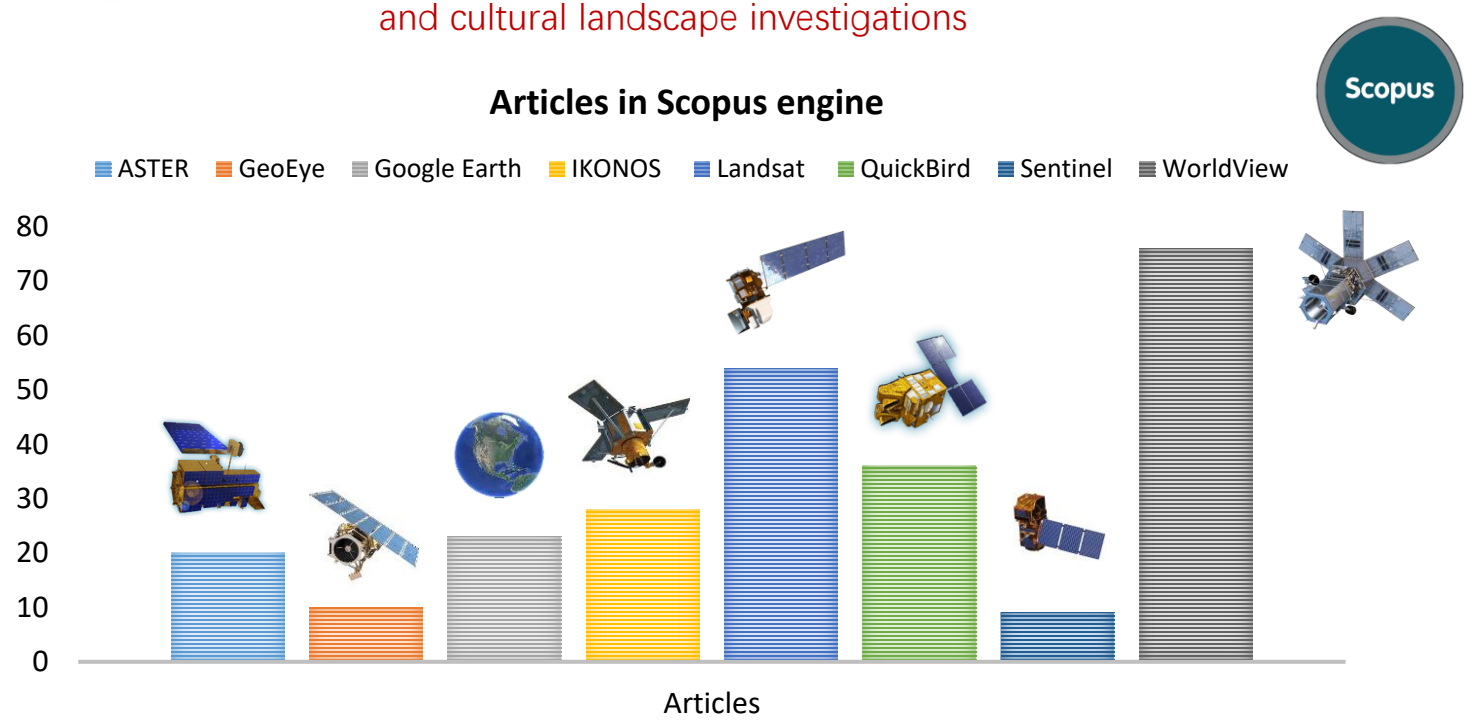


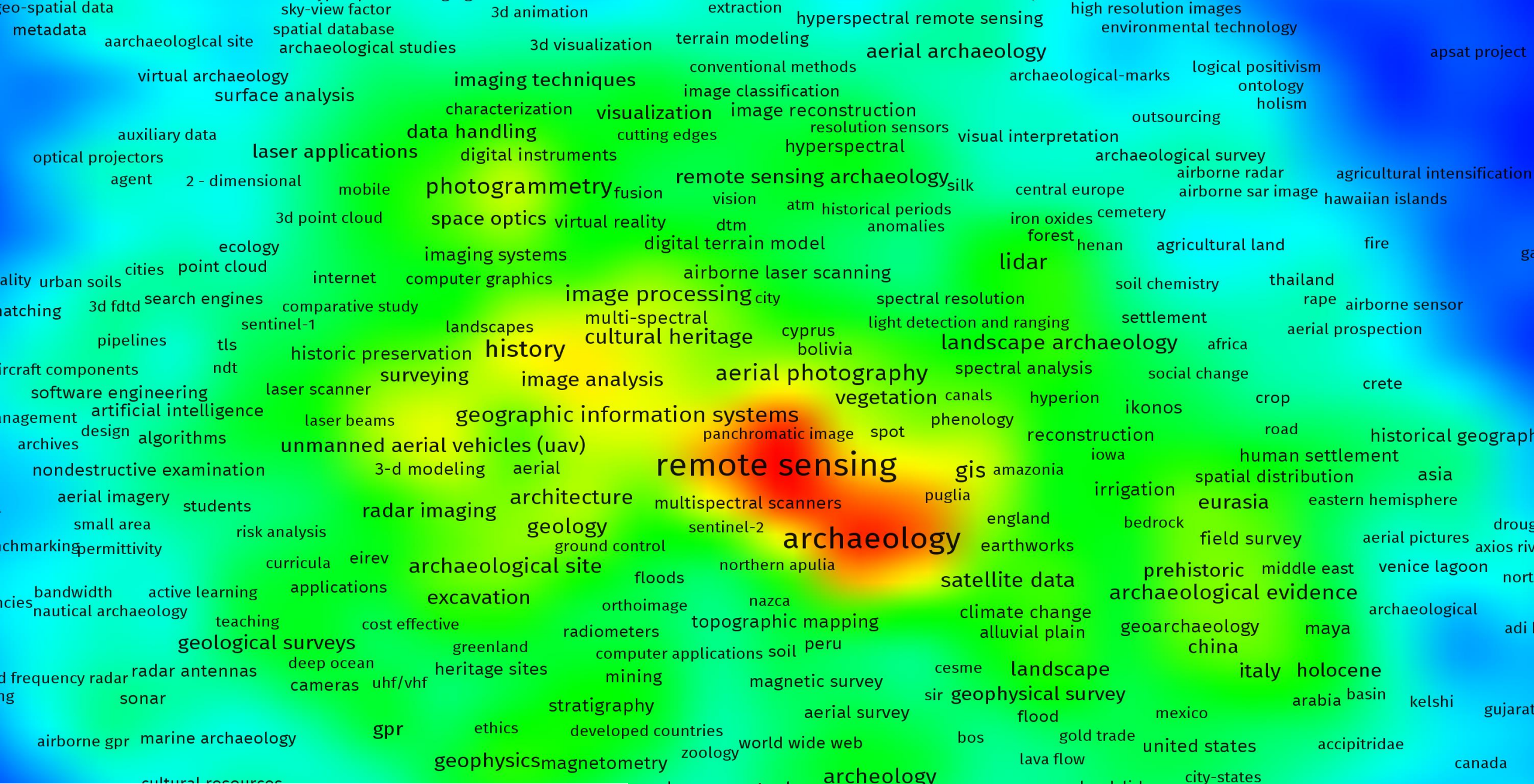
IKONOS,

the first high resolution commercial

earth observation sensor --1999

An overview of the most common remote sensing technologies in use today for archaeology and cultural landscape investigations






“Remote sensing archaeology” co-occurrence analysis of the keywords based on the Scopus engine.

Cyprus University of Technology

Department of Civil Engineering and Geomatics

# EOCULT

## Earth Observation Cultural Heritage Lab

Research activities and projects

web.cut.ac.cy/eocult

UNESCO uniTwin

unesco Chair

# Lab overview

- Our focus is on developing and applying earth observation based and ground remote sensing methods to better explore and understand landscapes.

- We concentrate on advance our understanding of the landscape and natural environment by systematic mapping and image processing analysis.

- Applications are particularly extended from observations of single monuments to archaeolandscapes and their diachronic changes.

- The core research areas of the team are the use of multispectral, hyperspectral and radar data from Copernicus and other high-resolution sensors, supported by UAVs campaigns and ground measurements.

# Advancements of geoinformatics and remote sensing for cultural heritage

*I. Site detection*

- Enhancement of crop maps to detect buried archaeological remains
- Develop archaeological proxies' maps through various geodata sources
- Archaeological prospection though remotely sensed data and GIS analysis

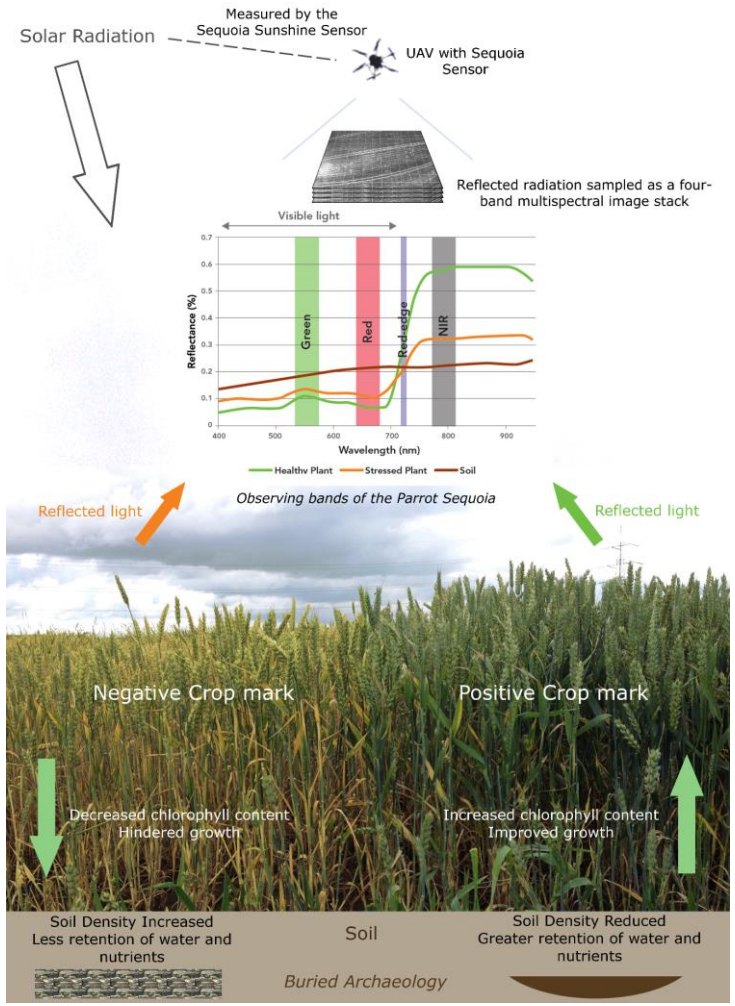
*II. Heritage monitoring*

- Land use pressure (e.g. urban sprawl) pressure in the vicinity of cultural heritage sites
- Looting
- Natural hazards such as earthquakes / soil erosion

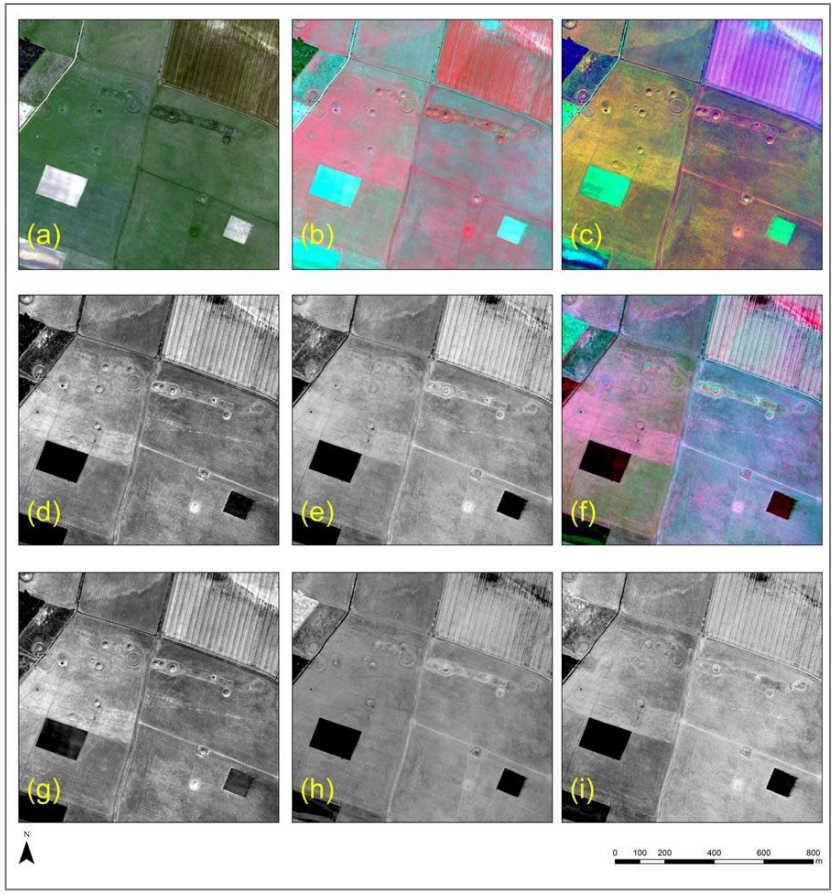
Cultural Heritage

Geoinformatics / Remote sensing

# Detection of underground  buried remains

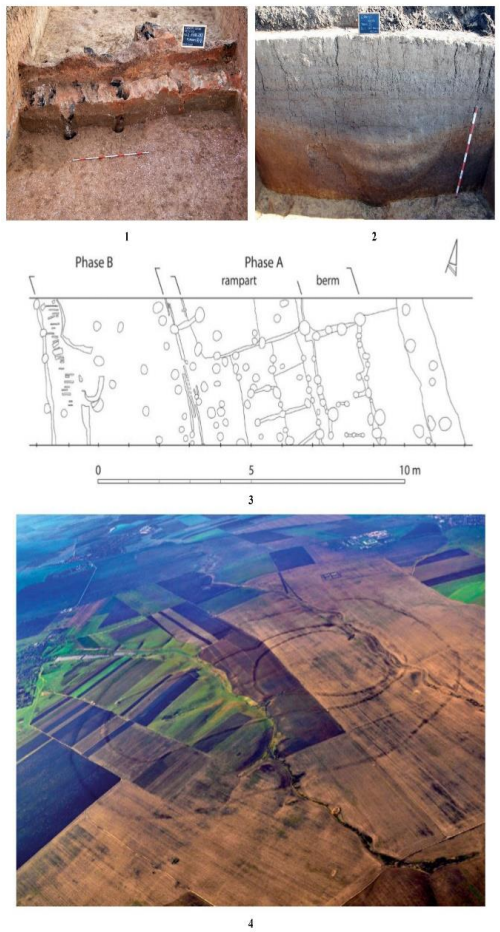


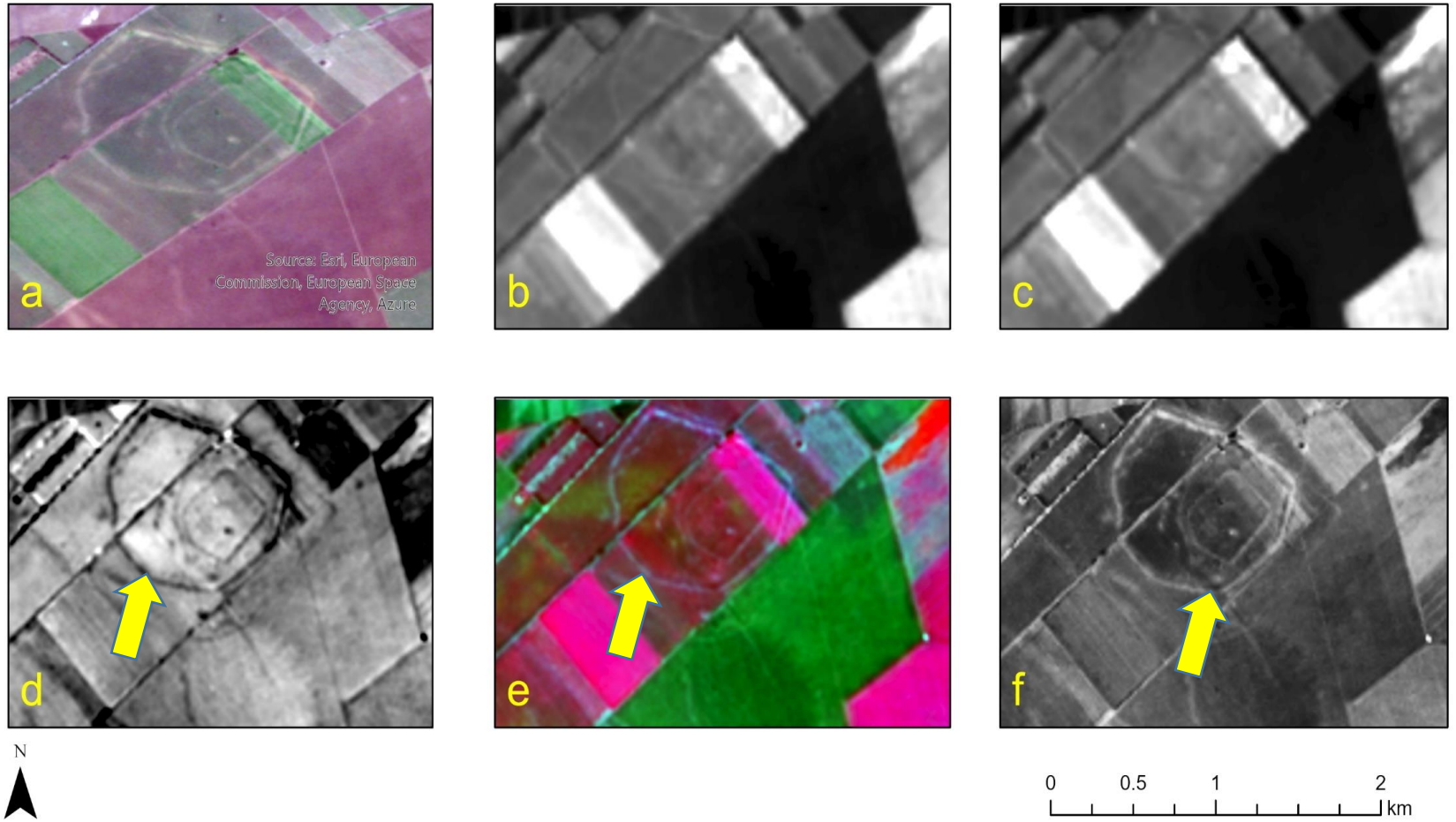

C. Moriarty (2017) Deploying multispectral remote sensing for multitemporal analysis of archaeological crop stress at Ravenshall, Fife, University of Edinburgh https://www.geos.ed.ac.uk/~mscgis/16-17/s1617975/




Agapiou A., 2016, Orthogonal equations for the detection of archaeological traces de-mystified, Journal of Archaeological Science: Reports, 14, 792-799, 10.1016/j.jasrep.2016.07.004

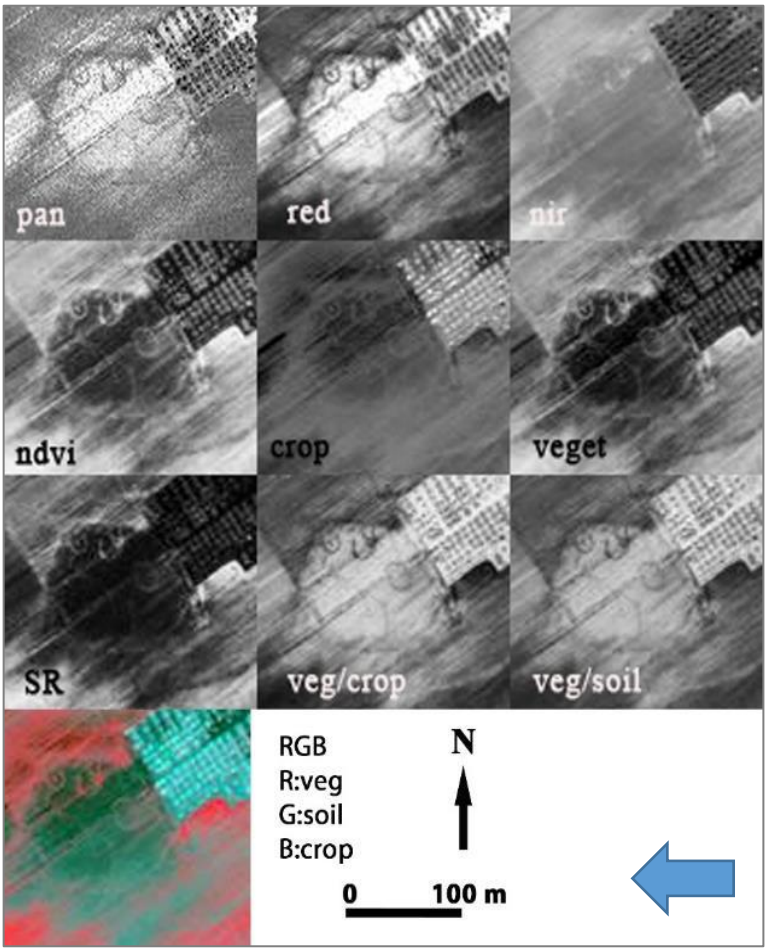
# Detection of underground  buried remains

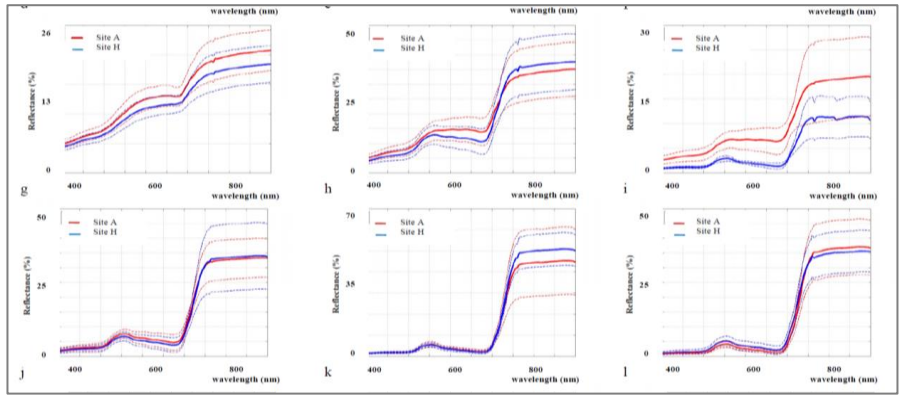


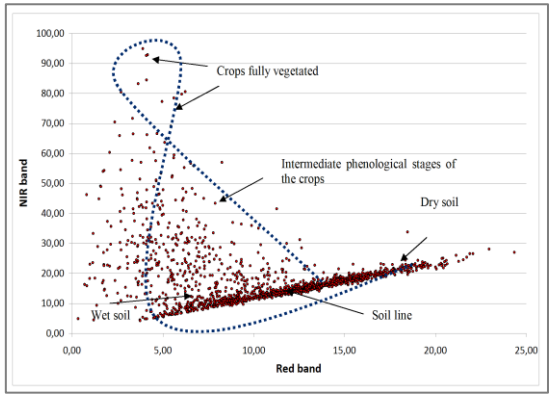




Agapiou A., Hegyi A., Gogâltan F., Stavilă A., Sava V., Sarris A., Floca C., Dorogostaisky L., 2023, Medium Resolution Multispectral Satellite Images for Archaeological Prospection: Exploring the **Largest Known Bronze Age Earthworks in Europe**, International Journal of Applied Earth Observation and Geoinformation, https://doi.org/10.1016/j.jag.2023.103239

# Detection of underground buried remains



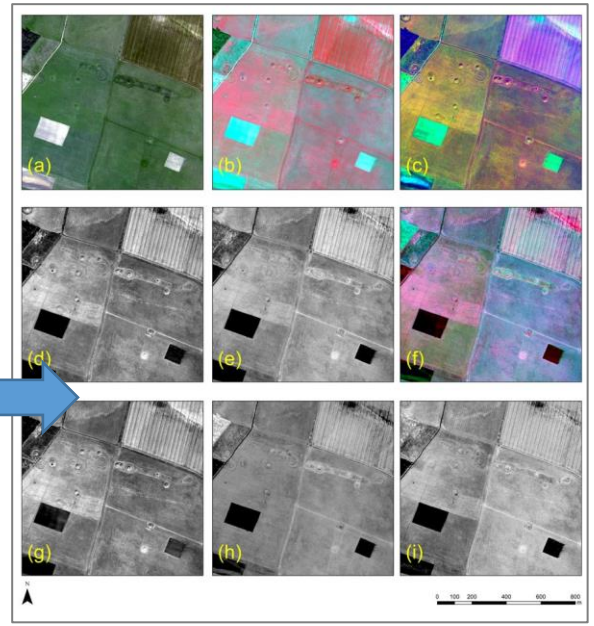






Agapiou A., Hadjimitsis D. G., Sarris A., Georgopoulos A., Alexakis D. D., 2013. Optimum Temporal and Spectral Window for Monitoring Crop Marks over Archaeological Remains in the Mediterranean region, *Journal of Archaeological Science*, 40 (3), 1479–1492, doi: 10.1016/j.jas.2012.10.036

Agapiou A., 2016, Orthogonal equations for the detection of archaeological traces de-mystified, Journal of Archaeological Science: Reports, 14, 792-799, 10.1016/j.jasrep.2016.07.004

Agapiou A., Lysandrou V., Lasaponara R., Masini N., Hadjimitsis D. G., 2016, Study of the variations of archaeological marks at Neolithic site of Lucera, Italy using multispectral high resolution datasets, *Remote Sensing*, 8(9), 723; doi:10.3390/rs8090723



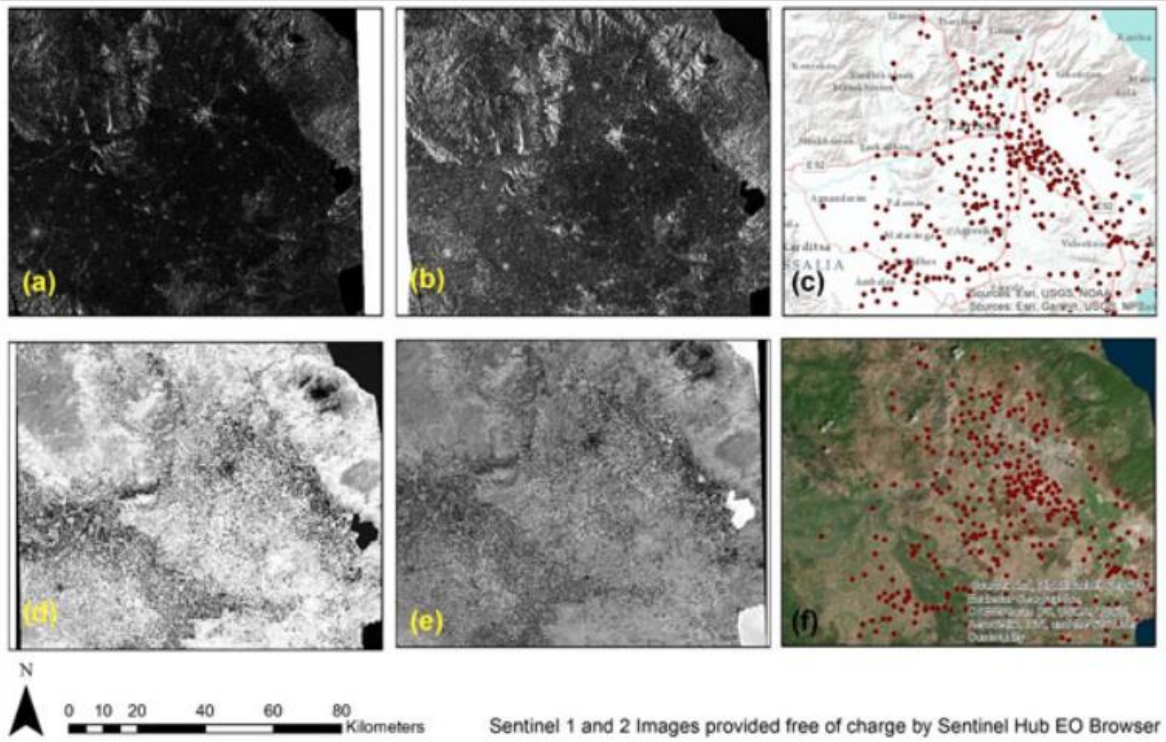
# Copernicus Sentinel and Landsat data work together to support archaeological research

## Sentinel Success Story

Dr Athos Agapiou, Senior Researcher in the Department of Civil Engineering and Geomatics of the Cyprus University of Technology and the Eratosthenes Centre of Excellence recently presented a preliminary study following this trend.

Sentinel-1 and -2 images of the European Union's Copernicus programme satellites were obtained through the Sentinel Hub, over the Thessalian plain in central Greece.

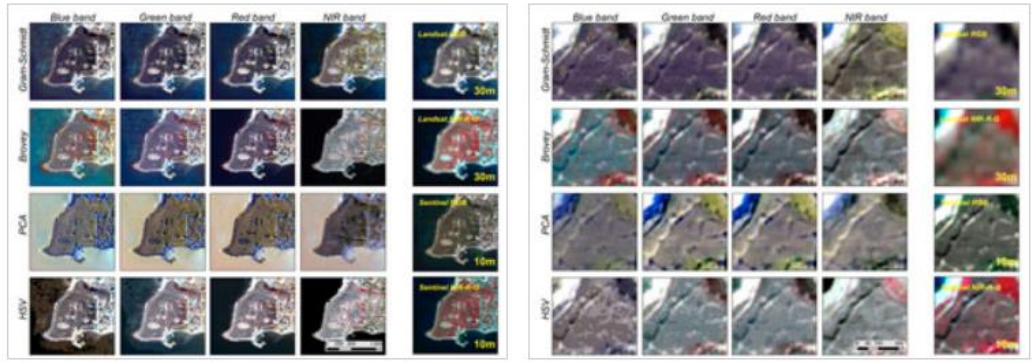
Copernicus Sentinel-1 data were acquired in interferometric wide swath (IW) mode, with a 250 km swath, processed to Level-1 ground range detected (GRD) at a resolution of 10 m, orthorectified at VV intensity (vertical transmit and vertical receive) and VH intensity (vertical transmit and horizontal receive) polarisation. The VV and the VH polarisations were also extracted from the herein featured Copernicus Sentinel-1 image.




Sentinel 1 and 2 Images provided free of charge by Sentinel Hub EO Browser

Also, optical Copernicus Sentinel-2 data at Level-2A (orthorectified Bottom-Of-Atmosphere reflectance) were downloaded from the Sentinel Hub platform. Based on the reflectance values of the optical Copernicus Sentinel-2 image, the normalised difference vegetation index (NDVI), the normalised archaeological index (NAI), the normalised difference water index (NDWI) and the normalised difference moisture index (NDMI) were calculated.

For the archaeological site of "Nea Paphos", different known fusion models were implemented and evaluated, namely Gram–Schmidt, Brovey, principal component analysis (PCA), and hue-saturation-value (HSV) algorithms. All four 10 m available spectral bands of the Copernicus Sentinel-2 sensor, namely the blue, green, red, and near-infrared bands (Bands 2 to 4 and Band 8, respectively) were assessed for each of the different fusion models (following images).



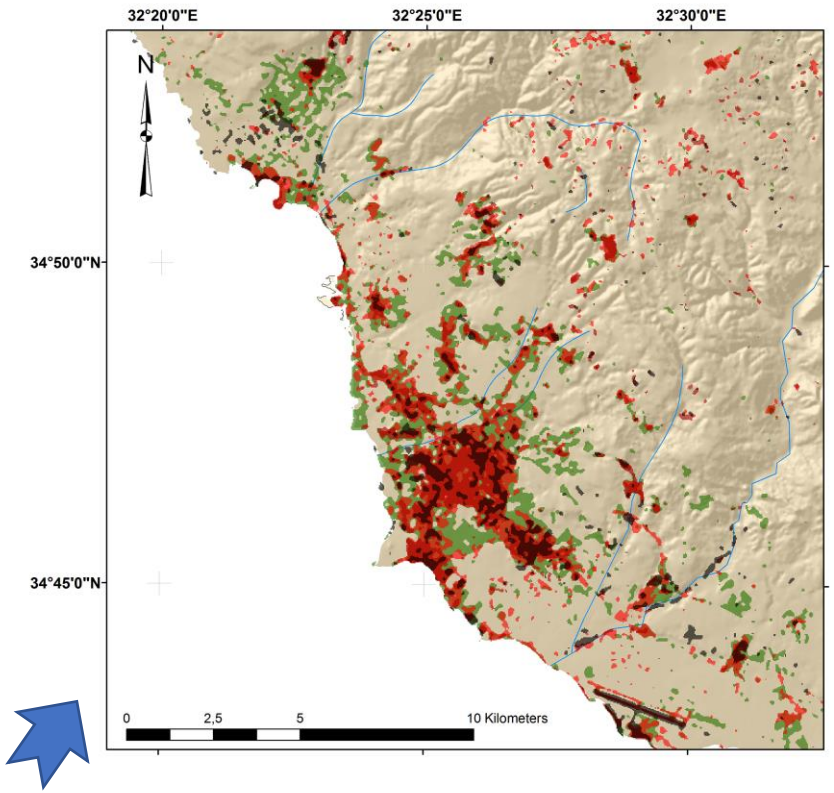

The next step of the study focused on the image segmentation process, through the evaluation of different scale factors. This process is an important step moving from pixel-based to object-based image analysis. The overall results showed that the Gram–Schmidt fusion method based on the near-infrared band of Copernicus Sentinel-2 (Band 8) at a range of scale factor segmentation to 70 are the optimum parameters for the detection of standing visible monuments, monitoring excavated areas, and detecting buried archaeological remains, without any significant spectral distortion of the original Landsat image.

Dr Agapiou relates his personal motivation to carry out such studies, by explaining the idea behind the integration of sensors, "This fusion example over the archaeological site of "Nea Paphos" and the Thessalian Plain, relied on the recent trends observed in Earth Observation towards the synergistic use of different space sensors. New opportunities can be raised by understanding potential synergies between various sensors, supported by big data analysis.

"New developments of Earth Observation sensors and developments of advanced image processing are some fundamental changes observed recently in the archaeological research domain. Synergies between existing and forthcoming sensors, especially those that are free and with open access, enable researchers to explore new ways of fusion and better integration of various datasets," further explained Dr Agapiou.

"These synergies could also support heritage management and archaeological prospections. This integration is not an easy task, but it could fill gaps observed using established methods. As our results have shown, difficulties still exist, and thus further research is needed. At the same time, efforts for integrating archival data (satellite and aerial), which are essential to better understand landscape changes, are fundamental for Earth observation applications in archaeological research," concluded Dr Agapiou.

# Monitoring Urban Sprawl

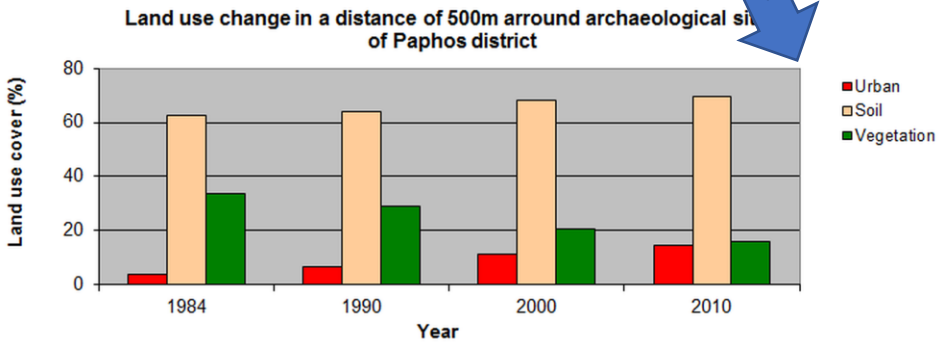


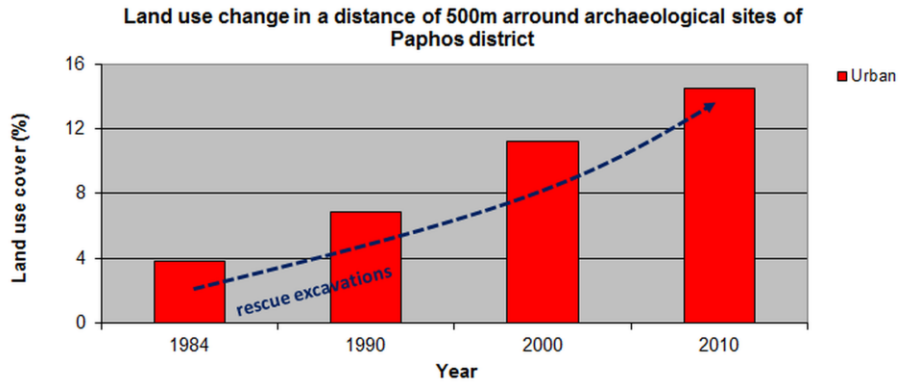

Urban expansion of the Paphos city from 1984 to 2010

| | |
|---|---|
| Black colour: | urban areas of 1984; |
| Orange colour: | urban areas of 1990; |
| Red colour: | urban areas of 2000; |
| Green colour: | urban areas of 2010. |

- In the past studies using Landsat archives have shown an urban expansion of more than 300% in the Paphos city for the period 1984-2010.
- During the last years, rescue excavations by the Department of Antiquities have been increased according to the yellow line shown in the graph

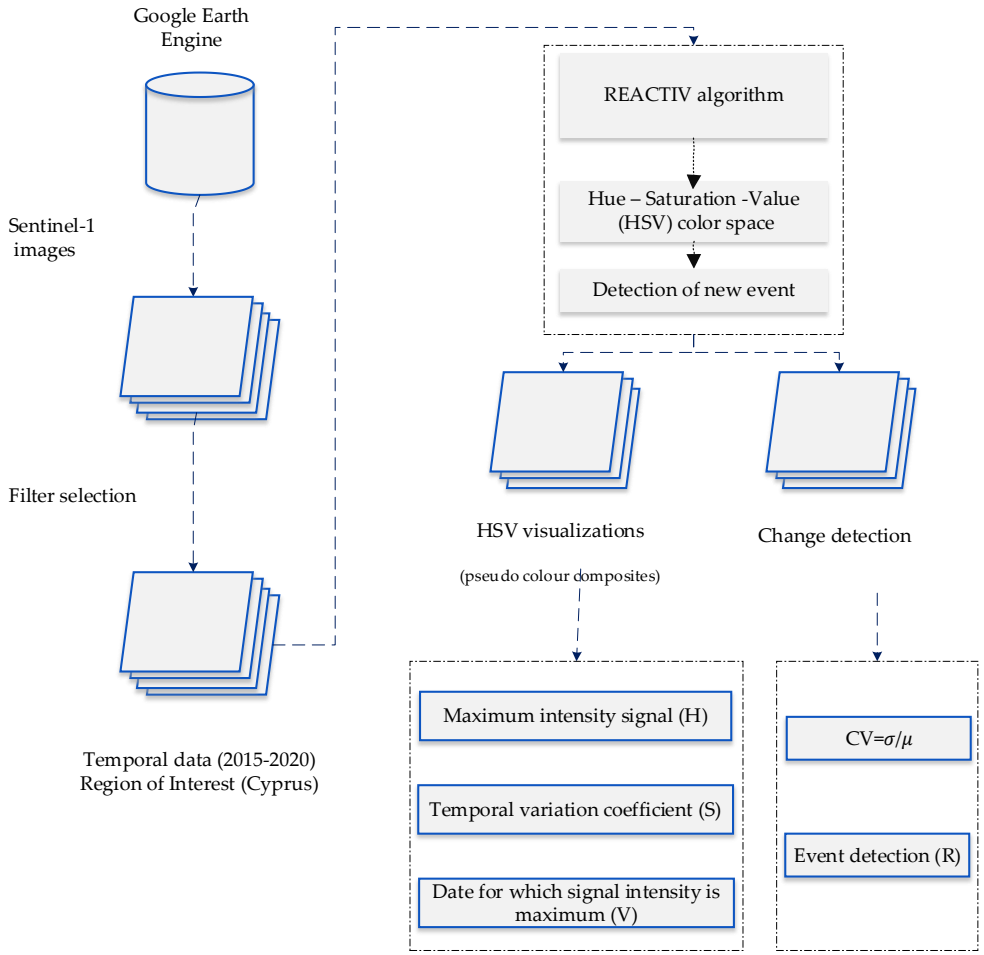
*In situ photographs taken from the necropolis at the site Meletis of Peyia village, showing the expansion of buildings in the vicinity of Cultural Heritage sites.*

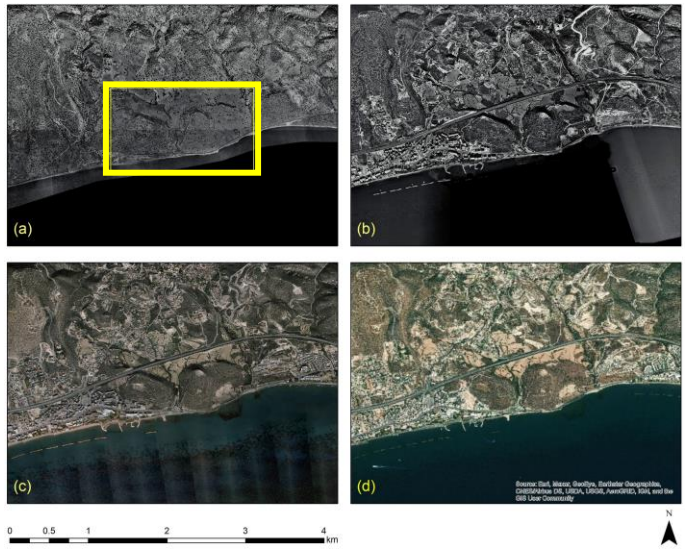



Agapiou A., Alexakis D.D., Lysandrou V., Sarris A., Cuca B., Themistocleous K., Hadjimitsis D.G., 2015, Impact of Urban Sprawl to archaeological research: the case study of Paphos area in Cyprus, Journal of Cultural Heritage, 16(5), 671-680, http://dx.doi.org/10.1016/j.culher.2014.12.006

# Monitoring Urban Sprawl



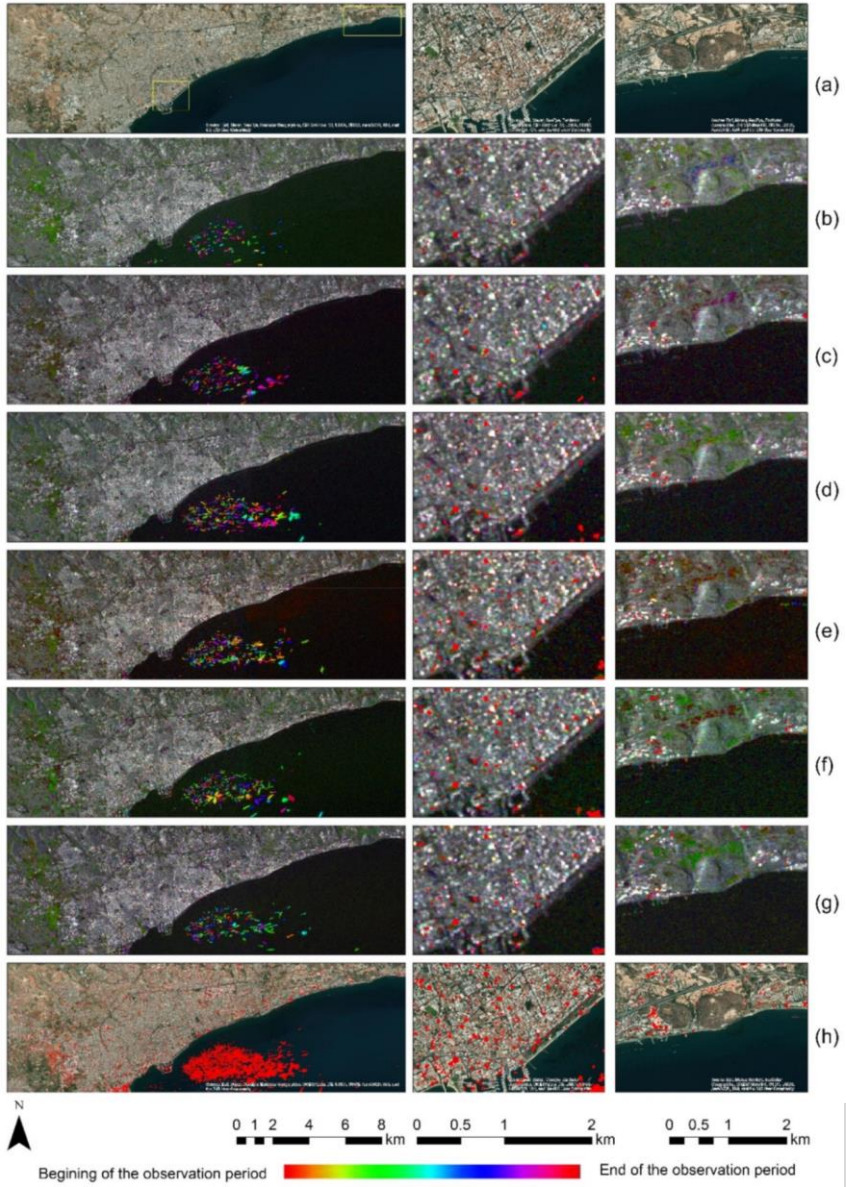




Agapiou, A. Multi-Temporal Change Detection Analysis of Vertical Sprawl over Limassol City Centre and Amathus Archaeological Site in Cyprus during 2015–2020 Using the Sentinel-1 Sensor and the Google Earth Engine Platform. *Sensors* **2021**, *21*, 1884. https://doi.org/10.3390/s21051884

***More about REACTIV:***

Koeniguer, C.E.; Boulch, A.; Trouve-Peloux, P.; Janez, F. Colored Visualization of Multitemporal Data for Change Detection: Issues and Methods. In Proceedings of the 12th European Conference on Synthetic Aperture Radar Electronic Proceedings, Aachen, Germany, 4–7 June 2018.

Koeniguer, C.E.; Jean-Marie, N.; Beatrice, P.-P.; Lagrange, J.-M.; Janez, F. Visualisation des changements sur series temporelles radar: Methode REACTIV evaluee à líechelle mondiale sous Google Earth Engine. *Rev. Française Photogrammétrie Télédétection* **2018**, *217–218*, 99–108.




High-resolution optical satellite image over the broader area of Limassol (left), city centre of Limassol (middle) and the Amathus archaeological site (right)

change detection analysis for the year 2015

change detection analysis for the year 2016

change detection analysis for the year 2017

change detection analysis for the year 2018

change detection analysis for the year 2019

change detection analysis for the year 2020

*A colour ramp indicates the relation of the colour according to the observation period for each sub-figure.*

Google Earth Engine

Search places and datasets...

ipts Docs Assets

Scripts

LandTrendr Examples

LandTrendr Greatest Disturban...

LandTrendr Greatest Growth M...

UI LandTrendr Pixel Time Series Plotter

Get Link | Save | Run | Reset | Apps

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1  //#################################################################################################
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4  //#                                                                                               #\\
5  //#################################################################################################
```

Inspector Console Tasks

Use print(...) to write to this console.

ine Year Range

rt Year 1984

l Year 2020

ine Date Range (month-day)

rt Date: 06-10 End Date: 09-20

ect Indices

NBR ☑ NDVI ☐ EVI ☑ NDMI

TCB ☑ TCG ☑ TCW ☑ TCA

B1 ☐ B2 ☐ B3 ☐ B4

B5 ☐ B7

ine Pixel Coordinates (optional)

ngitude: 33.15547 Latitude: 34.71359

ine Segmentation Parameters

x Segments: 6

ke Threshold: 0.9

tex Count Overshoot: 3

vent One Year Recovery: true

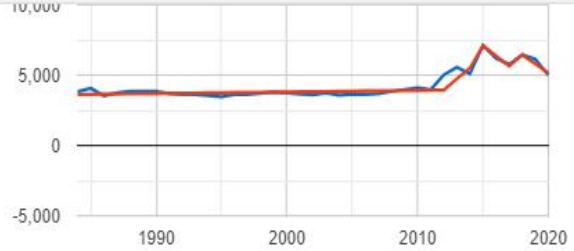
covery Threshold: 0.25

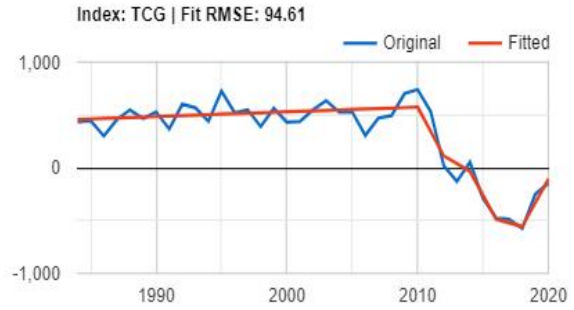
Click a point | Layers | Map | Satellite

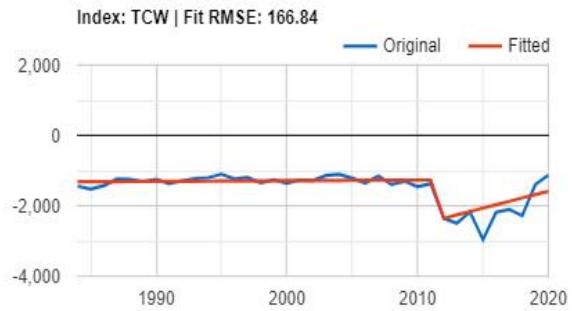
Temporal trend investigation over archaeological sites in Cyprus, through integrated harmonized Landsat observations (Landsat 5 TM; Landsat 7 ETM+ and Landsat 8 OLI)

website: https://github.com/eMapR/LT-GEE

More info




# Monitoring Urban Sprawl


VV and VH polarisation visualisation change detection for the period 2015-2020 over Limassol city. Bright colours indicate areas of changes in this period.



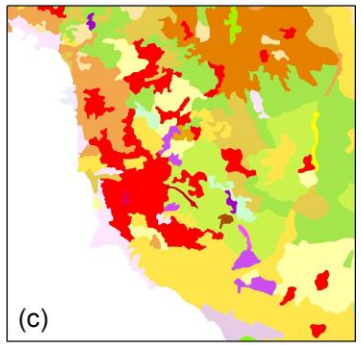

0 1 2 4 6 8 km

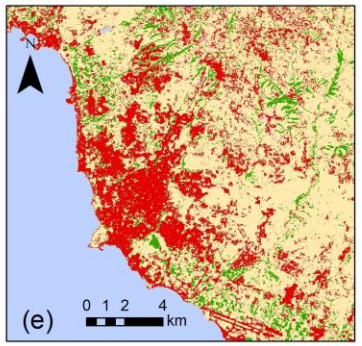
N

Agapiou, A. Multi-Temporal Change Detection Analysis of Vertical Sprawl over Limassol City Centre and Amathus Archaeological Site in Cyprus during 2015–2020 Using the Sentinel-1 Sensor and the Google Earth Engine Platform. Sensors 2021, 21, 1884. https://doi.org/10.3390/s21051884

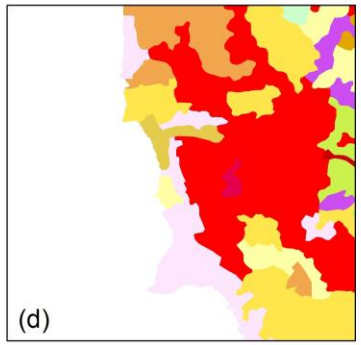
# Land Surface Temperature at Historic City Centres

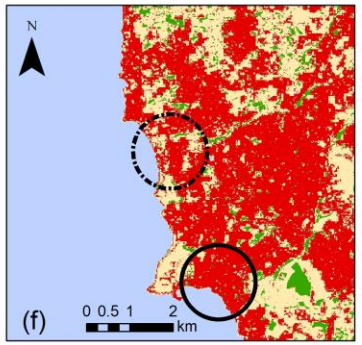
## Anthropogenic hazards as observed from legacy satellite data



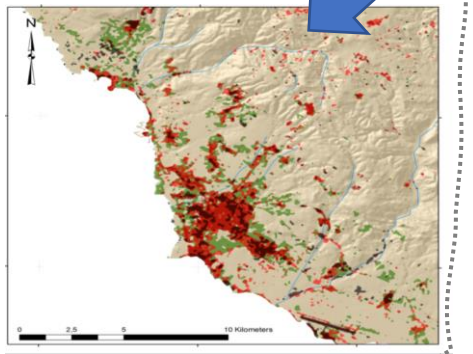



(a) High-resolution satellite image over the UNESCO World Heritage site of "Paphos". (b) a closer look at the archaeological sites of "Nea Paphos" and the "Tombs of the Kings". (c) CORINE Land Use Land Cover dataset over the area from the 2000 campaign. Urban areas are shown with red colour. (d) a closer look of the CORINE dataset as before. (e) Classification results of the Sentinel-2 image taken in 2020. Urban areas are shown with red colour and (f) a closer look of the classification results of Figure 7e as before.

*Agapiou A., Alexakis D.D., Lysandrou V., Sarris A., Cuca B., Themistocleous K., Hadjimitsis D.G., 2015, Impact of Urban Sprawl to archaeological research: the case study of Paphos area in Cyprus, Journal of Cultural Heritage, 16(5), 671-680, http://dx.doi.org/10.1016/j.culher.2014.12.006*

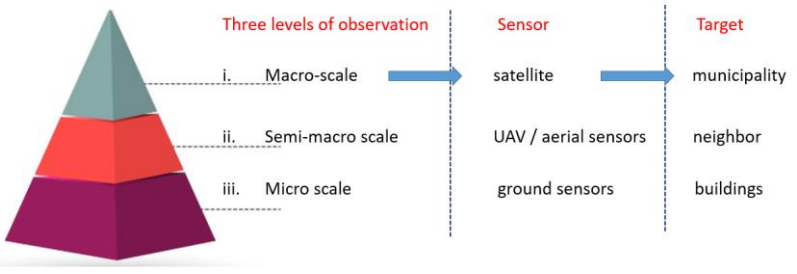
Increase of 300% in urban areas around cultural heritage sites

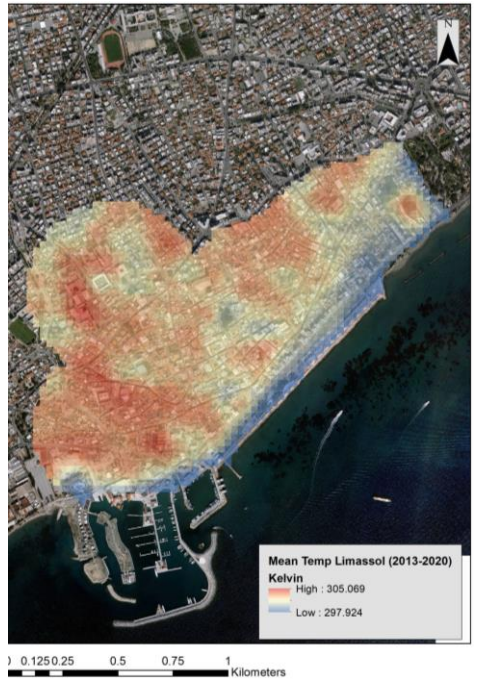



Examples of buildings to be investigated during the lifetime of the project, from Limassol case study area (photograph sources: Municipality of Limassol©).

*Agapiou A., Lysandrou V., Hadjimitsis D., Analysing the thermal conditions of historic buildings in Cyprus using archive Landsat satellite data and Google Earth Engine big data cloud platform, 2020 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage Trento, Italy, October 22-24, 2020.*

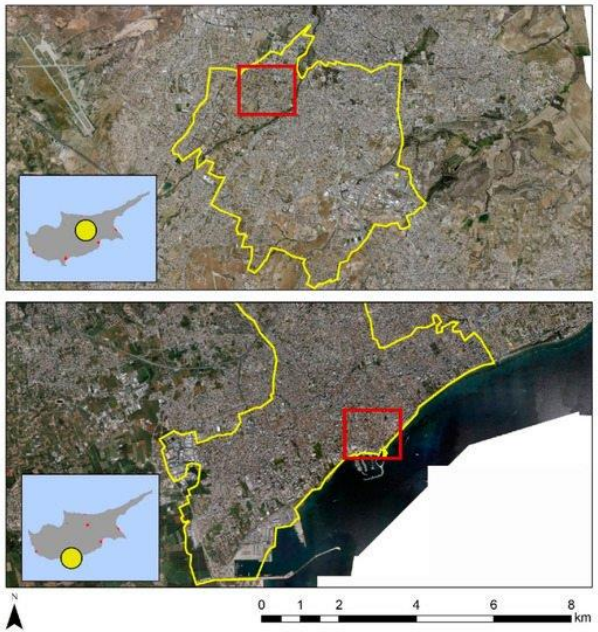
Levels of observation

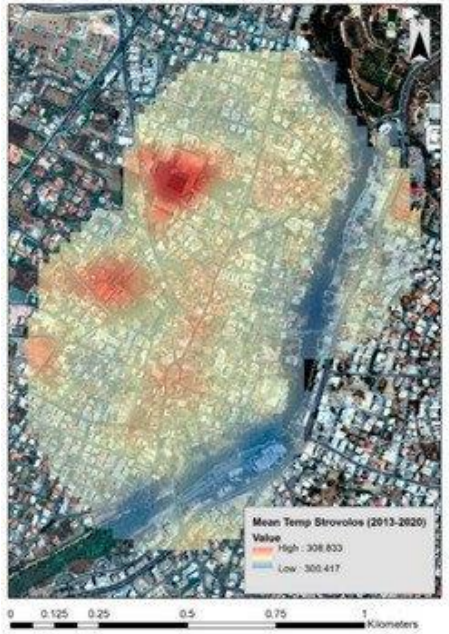


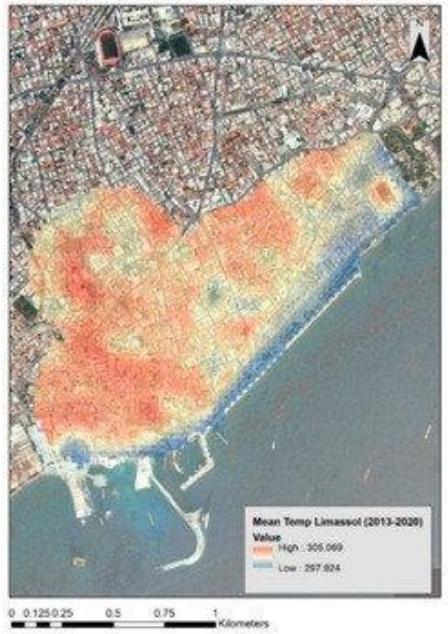



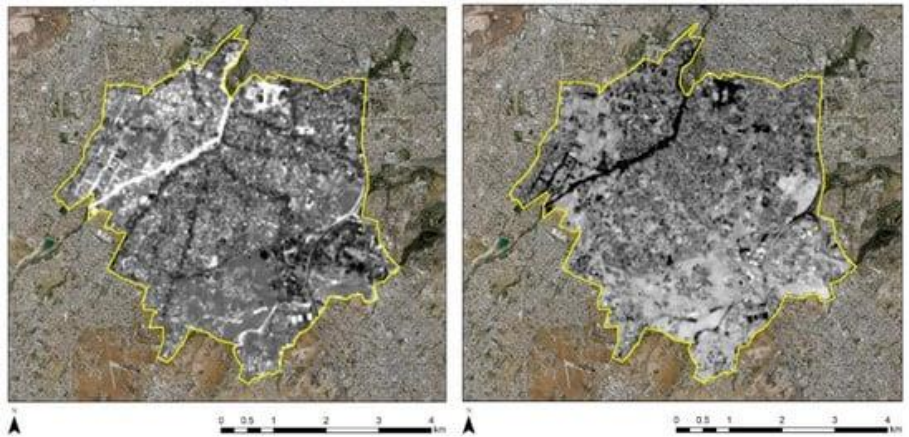

*Source: Agapiou A., UNESCO World Heritage properties in changing and dynamic environments: Semi-automatic change detection methods using optical and radar satellite data, Springer Nature, Heritage Science, (under review)*

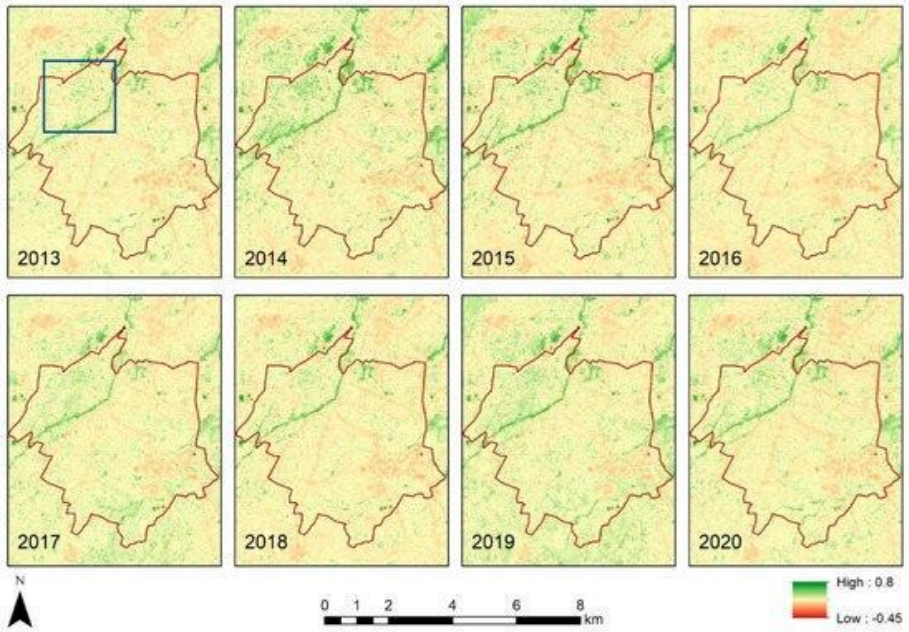
# Land Surface Temperature at Historic City Centres

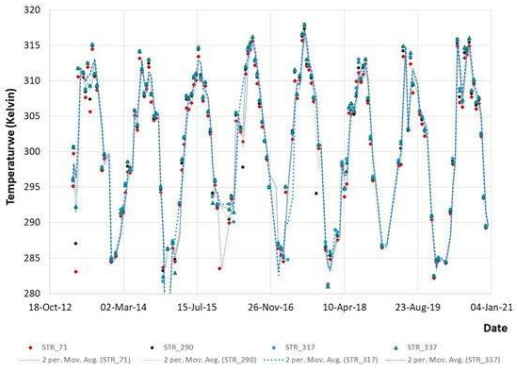


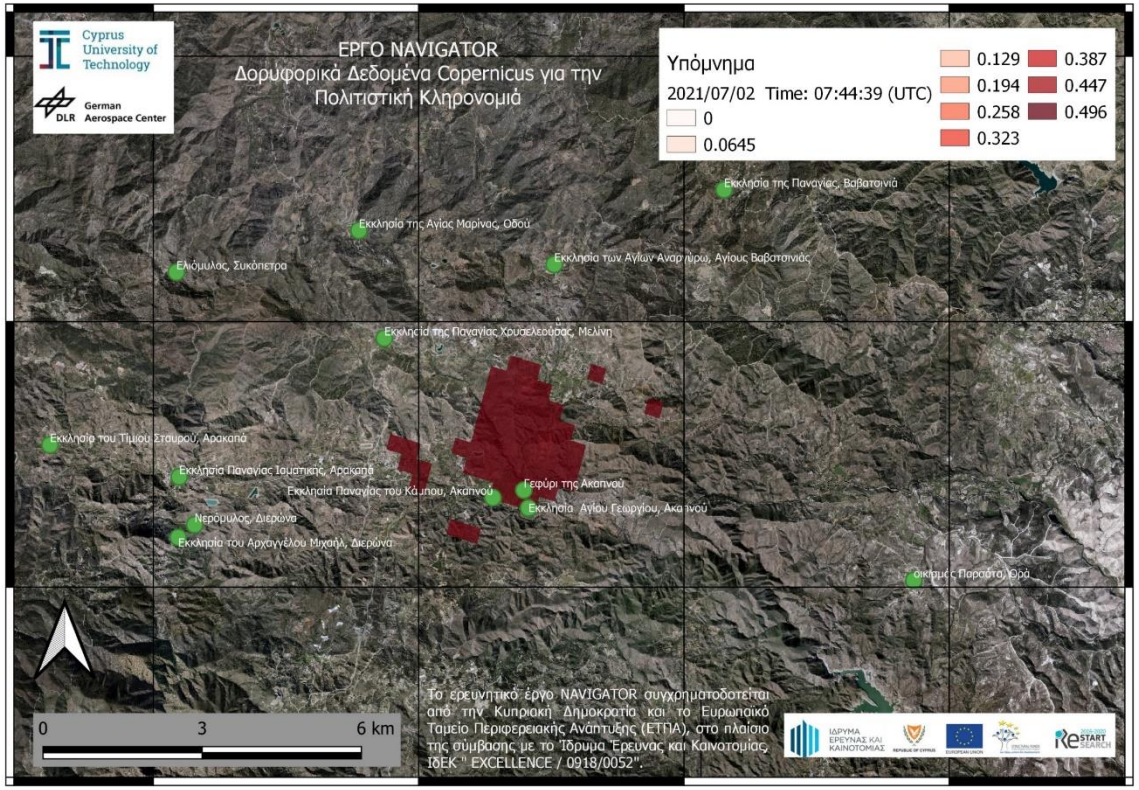



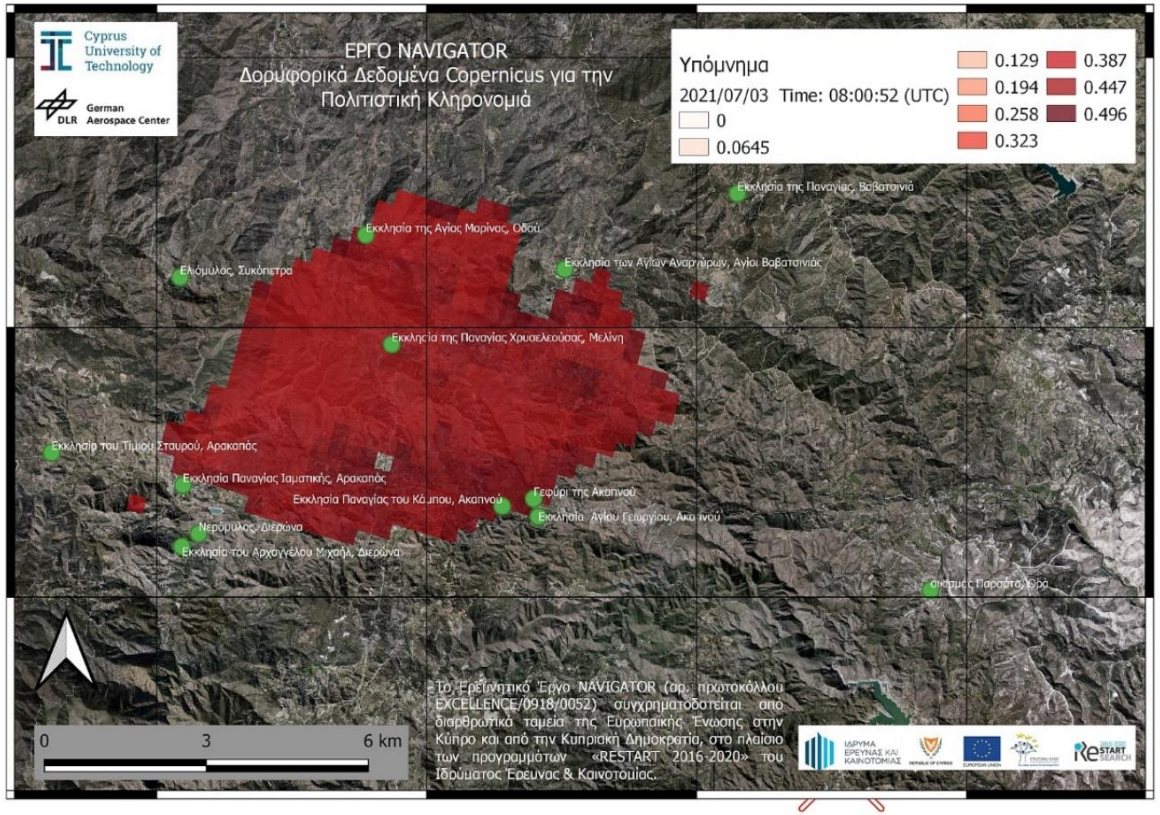



Agapiou, A.; Lysandrou, V. Observing Thermal Conditions of Historic Buildings through Earth Observation Data and Big Data Engine. Sensors 2021, 21, 4557. https://doi.org/10.3390/s21134557

# Natural Hazards - fires




Cyprus University of Technology

German Aerospace Center DLR

EUSPA European Union Agency for the Space Programme

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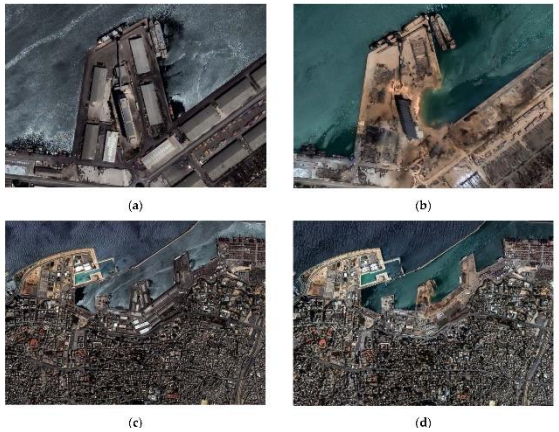
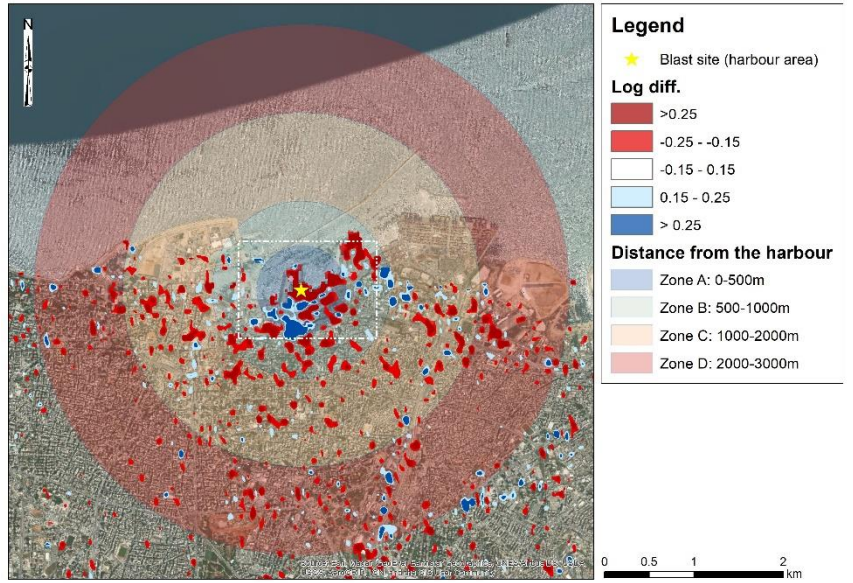
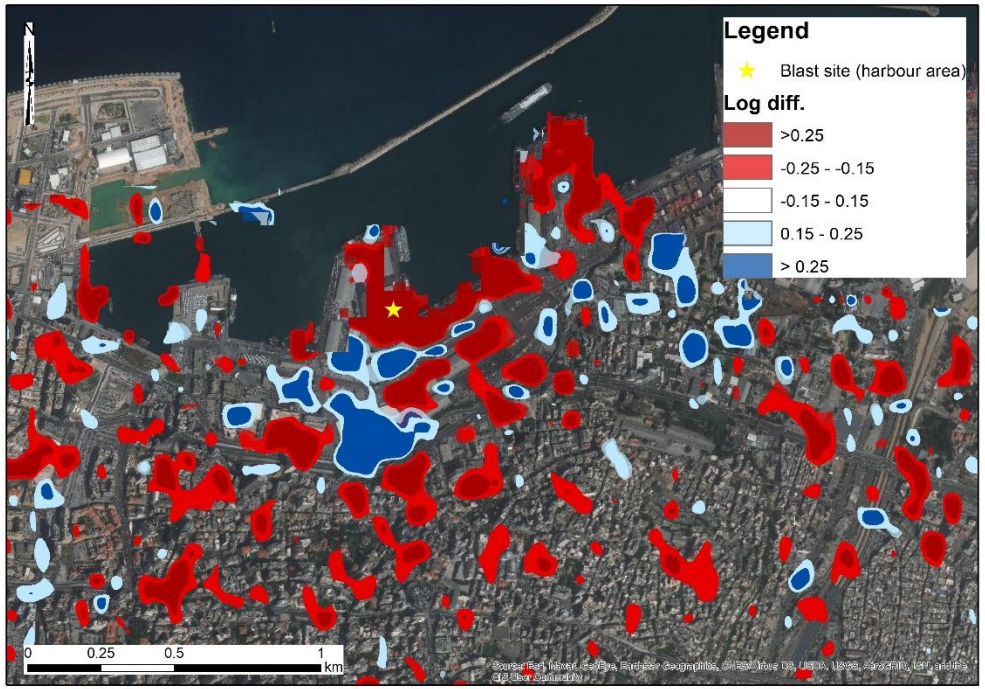
# Technological hazard

60 heritage sites risk collapse after Beirut blast

The UN's cultural agency UNESCO vowed Thursday to lead efforts to protect vulnerable heritage in Lebanon after last week's gigantic Beirut port blast, warning that 60 historic buildings were at risk of collapse.



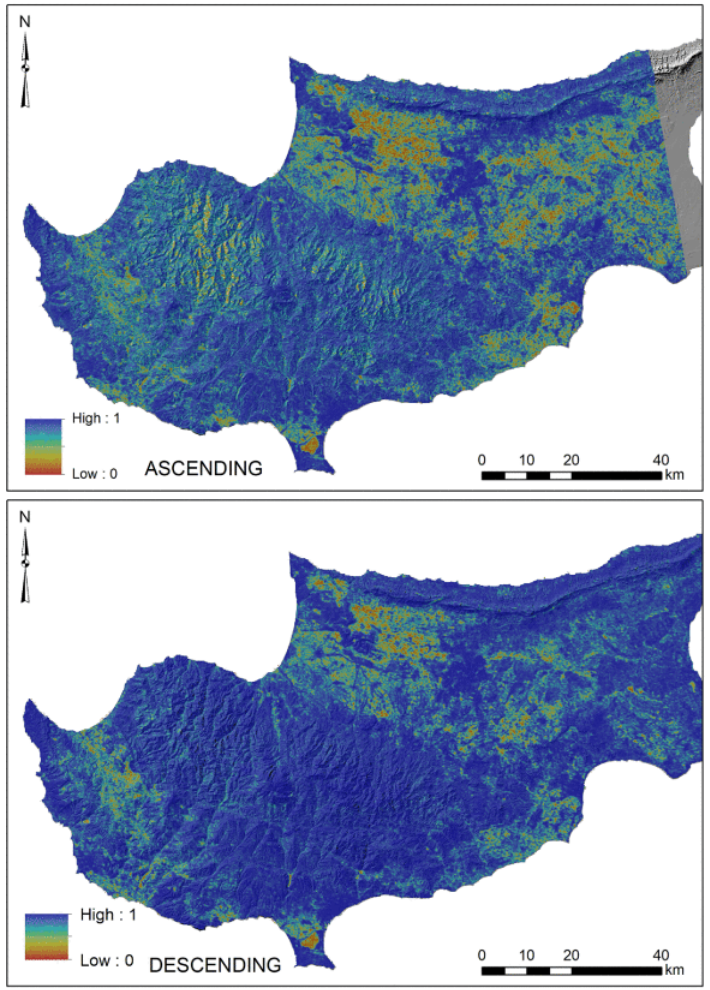




Damage Proxy Map of the Beirut Explosion on 4th of August 2020 as Observed from the Copernicus Sensors

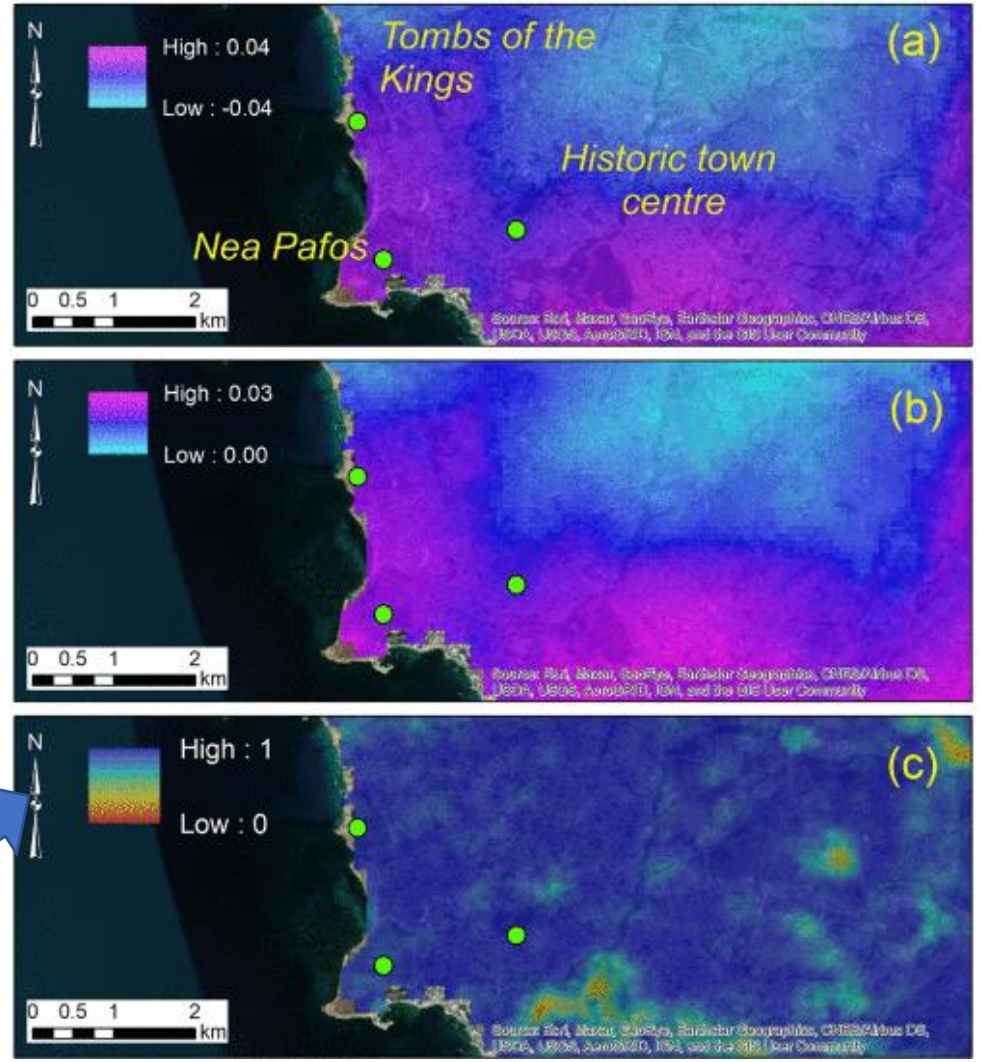
Agapiou, A. Damage Proxy Map of the Beirut Explosion on 4th of August 2020 as Observed from the Copernicus Sensors. Sensors 2020, 20, 6382. https://doi.org/10.3390/s20216382

# Natural Hazards – earthquakes




Coherence map as derived from the Sentinel-1 SAR images in ascending orbit (top) and descending orbit (bottom).

(a) Unwrapped interferogram.
(b) Vertical displacements.
(c) Coherence map, enveloping important archaeological sites of the area.




**Detecting Displacements Within Archaeological Sites in Cyprus After a 5.6 Magnitude Scale Earthquake Event Through the Hybrid Pluggable Processing Pipeline (HyP3) Cloud-Based System and Sentinel-1 Interferometric Synthetic Aperture Radar (InSAR) Analysis**

A. Agapiou and V. Lysandrou, in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 13, pp. 6115-6123, 2020, doi: 10.1109/JSTARS.2020.3028272.

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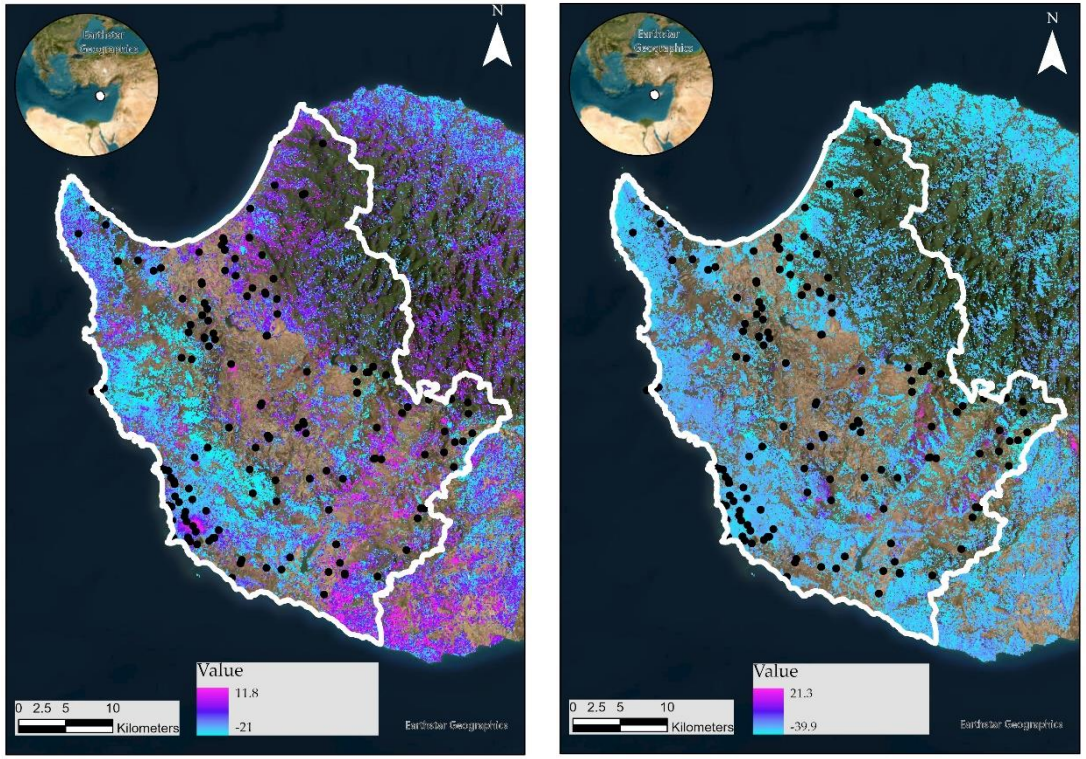
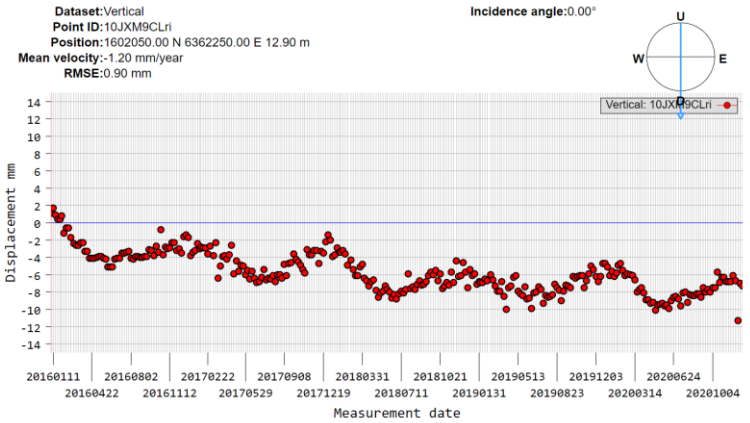
# European Ground Motion Service (EGMS)

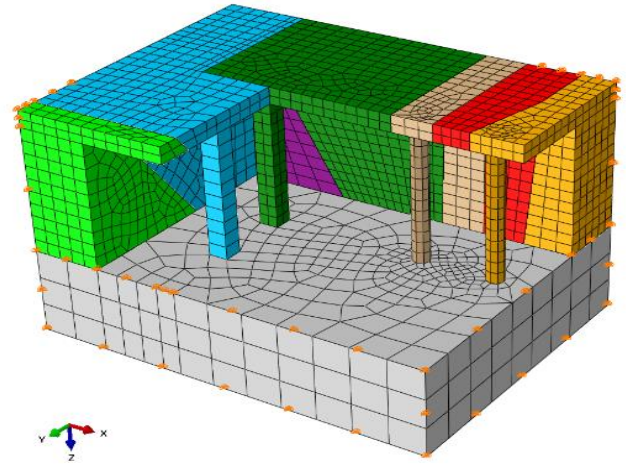
Kyriakides N., Lysandrou V., Agapiou A., Illampas R., Charalambous E. (2016), "Correlating damage condition with historical seismic activity in underground sepulchral monuments of Cyprus", *Journal of Archaeological Science: Reports*



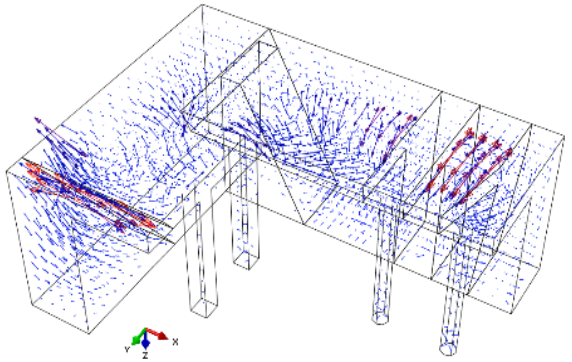

Horizontal (E-W, left) and Vertical (Up, right) ground displacements over the Paphos district as obtained from the EGM platform. Archaeological sites and monuments are depicted as black dots.




Time-series interferometric results over the archaeological site of "Tombs of the Kings", an UNESCO world heritage site. A mean velocity of -1.20 mm/year is reported.



**3D FE model developed for examining the seismic behaviour of the T4 tomb. Interacting stone blocks separated by cracks are shown in different colors.**

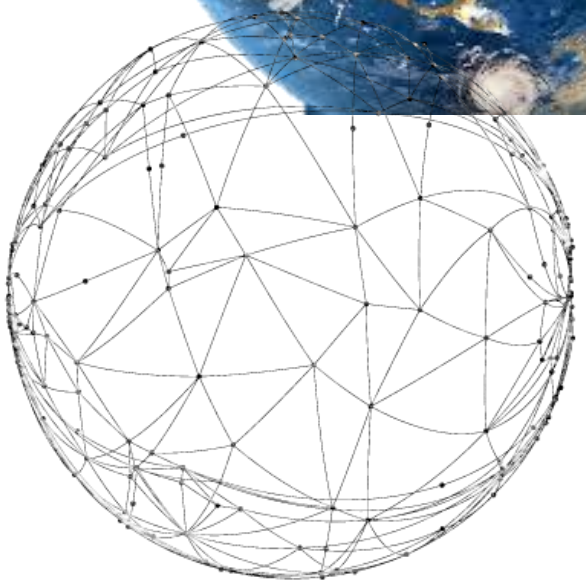


**Tensor diagram showing the computed distribution of the maximum principal stresses when the peak ground acceleration is imposed.**

"We have an unparalleled opportunity to turn a flood of raw data into understandable information about our society and our planet"

.....

Clearly, [this] will not happen overnight. Working together, we can help solve many of the most pressing problems…."



1998

Al Gore, former U.S. Vice of President at California Science Center at Los Angeles,

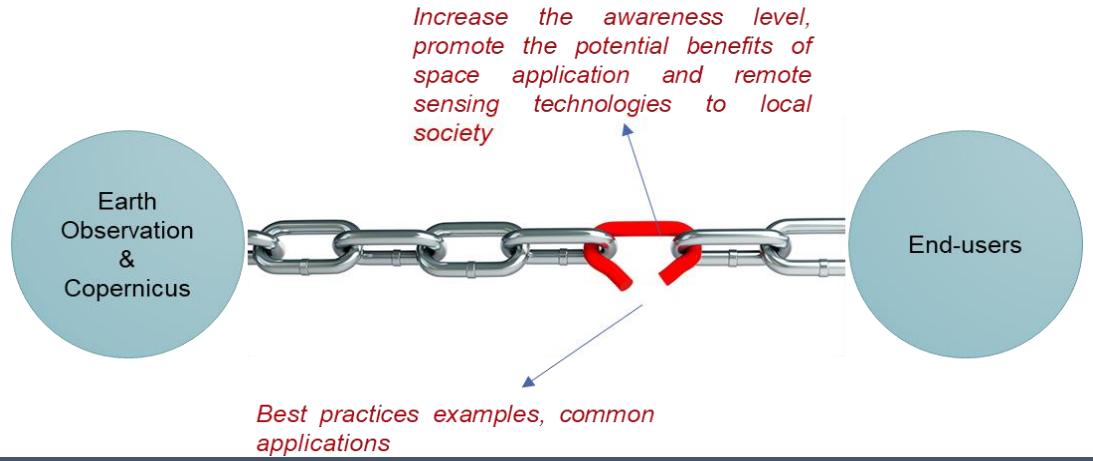
*"The Digital Earth: Understanding our planet in the 21st Century", putting forward another hot topic in earth science, the concept of Digital Earth.*

# The purpose of the workshop is twofold

| ICT / Space community | End-users (policy makers /governmental departments / society) |
|---|---|

On one hand, to **raise awareness** on the existing and operational satellite-based services, especially **how they can be integrated into daily workflows and translated into actionable information.**

On the other hand, **develop a roadmap to smoothen the integration** path of satellite-based services by providing decision makers and EU Institutions **feedback on the obstacles users are currently facing throughout this process.**



"Satellite-based Services for Disaster Risk Management"


athos.agapiou@cut.ac.cy

# Disaster Risk Management for Cultural Heritage:

## Examples from Cyprus and beyond

Dr Athos Agapiou
Earth Observation Cultural Heritage Lab
Department of Civil Engineering and Geomatics
Cyprus University of Technology

| Wednesday 17th of May 2023 |