

# BEYOND

annual report  
two thousand  
nineteen

Centre of Earth  
Observation Research &  
Satellite Remote Sensing

2013 → 2019 →



# BEYOND

Centre of Earth Observation Research  
& Satellite Remote Sensing

**NATIONAL OBSERVATORY OF ATHENS**  
Institute for Astronomy, Astrophysics,  
Space Applications and Remote Sensing (IAASARS)

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# Imagination takes us BEYOND our limits

The BEYOND Centre of Earth Observation Research and Satellite Remote Sensing has been operating since 2013 under the auspices of the National Observatory of Athens. It was developed under the European Union (EU) FP7-REGPOT-2012-2013-1 program, with total funding amounting to 2.3 million €. It generated unique excellence and EO research infrastructure for the region. It maintains a fully operational and self-sustained activity, through competitive funding from Space (Copernicus).

This Annual Report aims to inform Greek operational stakeholders involved in Risk and Natural Disaster Management about the services and capabilities of the BEYOND Excellence Center. The services target the entire crisis management cycle: from risk assessment and preparation to planning of mitigation measures, early warning, monitoring of the development of natural disasters and, lastly, recording of all relevant damages..

2019 was yet another year where natural disasters, including fires and floods, massively impacted the natural and man-made environment of Greece. Wildfires burned a total of 9,405 hectares of forest areas, while severe flooding caused significant damage and once again led to the unfortunate loss of lives (Prefecture of Chania, Crete 2019). The big natural disasters that affected Greece are documented in detail in the following chapters of the report.

Scientists from around the globe are being called upon to develop monitoring, early

warning and forecasting systems to effectively prevent natural and man-made disasters, and to devise strategies in order to deal with their consequences.

Satellite monitoring of natural disasters is one of the key scientific pillars of the BEYOND Center of Excellence. The Center's active participation in European programs and operations, such as the EU's earth observation program Copernicus and related projects of the European Space Agency (ESA), ensures the maturity of relevant research as well as the development of operational services required at the top decision-making level.

Our service systems and our team of researchers remain at the disposal of the state and civil protection authorities, for any need that arises in the decision-making process regarding risk management and reduction of disasters from natural and man-made causes.

In closing, I would like to thank the Hellenic Petroleum Group (ELPE) for the generous € 150,000 grant provided to our center with the aim of upgrading satellite data collection infrastructure at the BEYOND Center, ensuring the improvement of services provided for the protection of citizens in real time.

Sincerely,

**Dr. Haris Kontoes**

Research Director, National  
Observatory of Athens -  
Director of BEYOND Centre  
of Excellence

# 1. BEYOND Center of Earth Observation Research & Satellite Remote Sensing

2013→2019→



The BEYOND Center of Earth Observation Research and Satellite Remote Sensing is an operational unit of the National Observatory of Athens (NOA). It is conducting research and providing innovative services to reduce the risk of natural and man-made disasters in the wider region of Southeast Europe, the Balkans, the Middle East and North Africa, by utilizing the large-scale, antenna infrastructure that collect satellite data, which is located in its premises. The aim is to inform relevant operational bodies involved in disaster management and emergency situation in a timely manner, providing them with useful information throughout the cycle of crisis management.

Through the systematic activation of the Copernicus “EMS-Risk & Recovery” program (<http://beyond-eocenter.eu/index.php/thematic-areas/disasters/ems-activations>), the BEYOND Center also serves the global community of Disaster Management and Risk Assessment Agencies and Services in a wide range of natural disasters. Among others, these include fires, extreme weather conditions, volcanic activity, landslides, soil erosion, lack of water resources, toxic industrial accidents, earthquakes, flood, transfer of Sahara dust and smog.

Moreover, through its participation in key European and international programs (GEO, EuroGEO, ESA, IFIs)\*, the Center also develops research and provides services in a number of critical areas of economic development and citizen protection. These include food security, solar energy forecasting and equivalence estimates, public health, agricultural policy, exploitation of raw materials and cultural heritage preservation.

The following report presents:

- The most important services provided by the BEYOND Center on a global scale to crisis management and citizen protection agencies.
- Indicative examples and case-studies of natural disaster monitoring
- Specialized services which were developed in a complementary manner in 2019
- Information on the center’s activities in the fields of education, communication and scientific publications.

\* Group on Earth Observations (GEO), EuroGEO is Europe’s part of the Group on Earth Observations (GEO), European Space Agency (ESA), International Financial Institutions (IFIs)



## Services

### Hellenic Mirror Site (Copernicus satellite missions)

THE HELLENIC NATIONAL SENTINEL DATA MIRROR SITE (HNSDMS) is part of the ESA Mirror Sites of Collaborative Ground Segment ecosystem. The HNSDMS is a hub for the collection, management and distribution of large volumes of satellite data and products gathered by Sentinel -1, -2, -3, 5P missions, serving the needs of a wide user community based mostly in Europe, but also in the Middle East and North Africa. Users of the Hellenic Mirror Site belong to the entire spectrum of value-adding processes active in providing services with Earth Observation products, as well as in the decision-making sector, such as ministries, civil protection agencies, research teams etc. The Greek Mirror Site is a key infrastructure of the BEYOND Centre.

<http://beyond-eocenter.eu/index.php/web-services/hellenic-mirror-site>

### Sentinels GreekHUB

SENTINELS INTERNATIONAL operational ground-based collection and global distribution centre for satellite missions (known as Sentinels GreekHUB) is part of the EU’s ground-based space program infrastructure for Global Observation and Monitoring (Copernicus). Its scope is global, serving users worldwide - including NASA, NOAA, Australia Geophysics and the United States Geological Survey (USGS) - who are interested in gaining free access to Sentinel satellite data for the development of space applications. The GreekHUB Centre meets the growing demand of users by providing immediate access to satellite data, just few hours after the initial reception at the Payload Data Ground Segment (PDGS), as well as access to the Sentinels product archive of the past 4 weeks that geographically covers the entire planet. GreekHUB is one of the 3 sites maintained by the European Space Agency (ESA) in order to make Sentinels available worldwide. It distributes 2.85 Petabytes of S-1, S-2, S-3, S-5P data per month across the globe, at a speed of 10 Gbps, using the GEANT network and computational resources provided by GRNET SA - National Infrastructures for Research and Technology. GreekHUB is a key infrastructure, operated on 24/7 basis by the BEYOND Centre.

<http://beyond-eocenter.eu/index.php/web-services/sentinels-greekhub>

**FireHUB**  
Forest fire  
monitoring and  
management  
service based on  
satellite remote  
sensing

**FireHUB SYSTEM OF SERVICES** detects and monitors the evolution of wildfires in Greece every 5 minutes at a spatial resolution of 500 m, while it simultaneously models the smoke dispersion. FireHUB also provides dynamic daily burnt areas and damage assessments at medium (250-400 m) and high spatial resolution (10-20 m). These products use satellite imagery collected in realtime by the ground stations of BEYOND, as well as high spatial resolution Copernicus Sentinel II data accessed from the Hellenic Mirror Site Hub operated by BEYOND. The FireHUB system of services provides fire risk assessments for settlements worldwide, and provides historical fire behavior assessments at country level. Towards this, it regularly updates a unique database of burnt scars for all fire events of Greece for the last 35 years.

<http://beyond-eocenter.eu/index.php/web-services/firehub>

**EFFIS**  
European  
Forest Fire  
Information  
System

**IN COLLABORATION WITH OTHER EUROPEAN ORGANIZATIONS**, NOA's BEYOND Center of Excellence operates the European Forest Fire Information System (EFFIS), after an invitation by the EU. As part of EFFIS, our Center is responsible for providing a range of high-speed satellite fire detection products and burn mapping-assesments covering the entire region of Europe, North Africa, the Black Sea and the Middle East around the clock: on a 24 hours basis, 7 days a week and 365 days a year. The Center processes data gathered by the ground satellite data-collection station that operates in BEYOND's facility in Penteli. Through this operation, reliable and updated information on forest fires is provided on a daily basis, assisting the fire services of the EU Member States, the European Commission Monitoring and Information Center and other services operating in this field. This information includes critical maps, data on the location and scale of individual fire outbreaks, as well as descriptions of the magnitude of the hazards, all made available on the official EFFIS website.

<http://beyond-eocenter.eu/index.php/web-services/effis>

**FloodHUB**  
Flood  
monitoring  
service

**THE FloodHUB SYSTEM OF SERVICES** is activated as soon as a major flood event occurs and gives a near-real-time picture of the disaster using hydrological and hydraulic modeling and special machine-learning technologies. It dynamically leverages objective satellite remotesensing observations and crowdsourcing data from networks of citizens and volunteers, as well as in-situ data from in-field visits in the area (as appropriate). The FloodHUB service can potentially be activated for any flood event, in any watershed. Moreover, the service builds on the history of flood events in an area, and gives estimates of flood risk in advance accounting for both routine and extreme weather scenarios, in order to support emergency response plans and early preparedness and mitigation measures against flood risk.

<http://beyond-eocenter.eu/index.php/web-services/floodhub>

**GeoHUB**  
Geohazards  
monitoring service  
using satellite radar  
interferometry

**GeoHUB SERVICE** is an ecosystem of services for monitoring geohazards. It exploits primarily Synthetic Aperture Radar imagery and employs interferometric techniques to assess ground deformation. GeoHUB generates products for the systematic and diachronic monitoring of earthquakes, volcanoes, landslides and urban subsidence, attributed to construction activities and other manmade interventions to the natural environment. The GeoHUB system is providing also the service GeObservatory that is activated fully automatically whenever an earthquake or a volcanic eruption takes place over the world. It consists a global observatory of geophysical phenomena depicting the corresponding deformation fields calculated from the differential interferometry processing of Sentinel-1 SAR satellite data.

<http://beyond-eocenter.eu/index.php/web-services/geohub>

## Copernicus Emergency Management System (EMS)

Rapid Exposure,  
Vulnerability  
and Risk Assessment  
Service for  
Natural Disasters

THE COPERNICUS EMS RISK & RECOVERY MAPPING SERVICE is activated by the European Civil Protection authorities around the world, and entities of the European Union. It has global coverage and is a totally operational action. Its products and studies on risk assessment are delivered within 20 business days after the Copernicus EMS activation arrives at the BEYOND Centre. This service provides exposure, vulnerability, and risk assessments, and offers plans for dealing with a wide range of natural hazards such as: fires, floods, earthquakes, volcanoes, tsunamis, landslides, industrial accidents, as well as soil and coastal erosions. In addition to that, BEYOND conducts studies following the EMS standards for the needs of various users that operate under European programs or national programming agreements, such as the needs of the International Organization for Migration (IOM) under the ERAPLANET / SMURBS program (<http://smurbs.eu/>).

<http://beyond-eocenter.eu/index.php/thematic-areas/disasters/ems-activations>

## SolarHUB Nowcasting

Solar energy  
continuous  
monitoring  
service

THE SolarHUB Nowcasting SERVICE provides data and maps of the surface solar radiation and energy in real-time for the European and North African regions. The data are based on the continuous monitoring and forecasting systems SENSE and nextSENSE, which were developed and scientifically evolved at the BEYOND Centre of Excellence in collaboration with the World Radiation Center in Switzerland (PMOD/ WRC) in the framework of project awarded through European and other competitive funding schemes (e.g. GEO-CRADLE <http://geocradle.eu/en/>, e-shape <https://e-shape.eu>). These systems combine satellite data collected in real time at the acquisition facilities of BEYOND (e.g. satellite data antennas, Hellenic Mirror Site) with machine learning and neural network techniques.

<http://beyond-eocenter.eu/index.php/web-services/solarhub>

## AgriHUB

Satellite  
Technology  
as a tool to shape  
agricultural policy  
and ensure  
food security

THE BEYOND CENTRE has developed and successfully applied state-of-the-art artificial intelligence algorithms for the monitoring of food security, the control of the Common Agricultural Policy (CAP), but also for precision agriculture. The effective, efficient and general monitoring of the obligations imposed by the CAP, but also the timely food security related decision making at national and international scale, demand the systematic observation of agricultural land. Therefore, there is an obvious need for the effective management and the efficient processing of Big Earth Observation Data associated with such applications. In view of the aforementioned realizations, AgriHUB invests in the exploitation of parallel and distributed processing algorithms in High Performance Data Analytics (HPDA) environments, developing large scale agriculture monitoring applications.<http://beyond-eocenter.eu/index.php/thematic-areas/agriculture>

## DustHUB

Desert Dust  
Monitoring  
Service

DustHUB provides a three-day forecast of desert dust concentrations and dispersion in the atmosphere over the regions of North Africa, Middle East, Mediterranean and Europe. The forecast is based on mesoscale simulations with NMME-DREAM model at 20 kmx20 km spatial resolution. The system assimilates the satellite data of dust from the MSG-SEVIRI sensor received in real time by the BEYOND acquisition antennas and also initial and boundary meteorological conditions from the global GFS-NOAA model. DustHUB products include dust particle concentrations at all heights of the atmosphere, as well as dry and wet depositions of dust on the surface.

<http://beyond-eocenter.eu/index.php/web-services/dusthub>

# 2. Satellite Monitoring and Evaluation of Natural Disasters



2013 → 2019 →



In the duration of 2019 - the year covered in this annual report - BEYOND Center of Excellence closely monitored all major natural disaster events that occurred in our country, as well as many that took place overseas.

In Greece, during the summer of 2019, a total of 38 forest fires were detected in real time, and 9,405 hectares of burned land were mapped. More detailed reports of the fire outbreaks in Zakynthos, Evia, Elafonisos and Corinthia are provided in the following pages.

The FloodHUB service was also activated and monitored the largest flooding events of the year. More specifically, the floods of Messinia (November 20, 2019), Kavala (November 21, 2019), Messolonghi (January 3, 2019) and Crete (February 24-26, 2019) were mapped.

In addition to that, the GeObservatory application of the BEYOND's GeoHUB Geophysical Disaster Monitoring Service was activated 29 times to automatically map surface deformation associated with significant seismic events that occurred globally.

The Center also received activations in assessing and mapping risks from a number of other agencies outside Greece and Europe, through the Copernicus EMS service. In particular, it was called upon/activated to provide information on the management of a humanitarian crisis in Yemen, as well as in several natural disasters caused by fires and floods in South Croatia and the wider Balkan region.

Lastly, the Rapid Mapping Team of our center mapped the fires in the wider region of Syria and Lebanon (October 16, 2019), where there was a massive outbreak (100 fires in the Lebanese region) due to a combination of dry weather, high temperatures and strong wind currents. These fires have been described as the most devastating in the last decade, causing catastrophic damages on settlements and critical infrastructure and destroying forests brimming with biodiversity. The same team also mobilized in a timely manner and mapped the evolution of the oil slick in the Red Sea caused by the spill from the Iranian tanker SABITI on October 11, 2019.

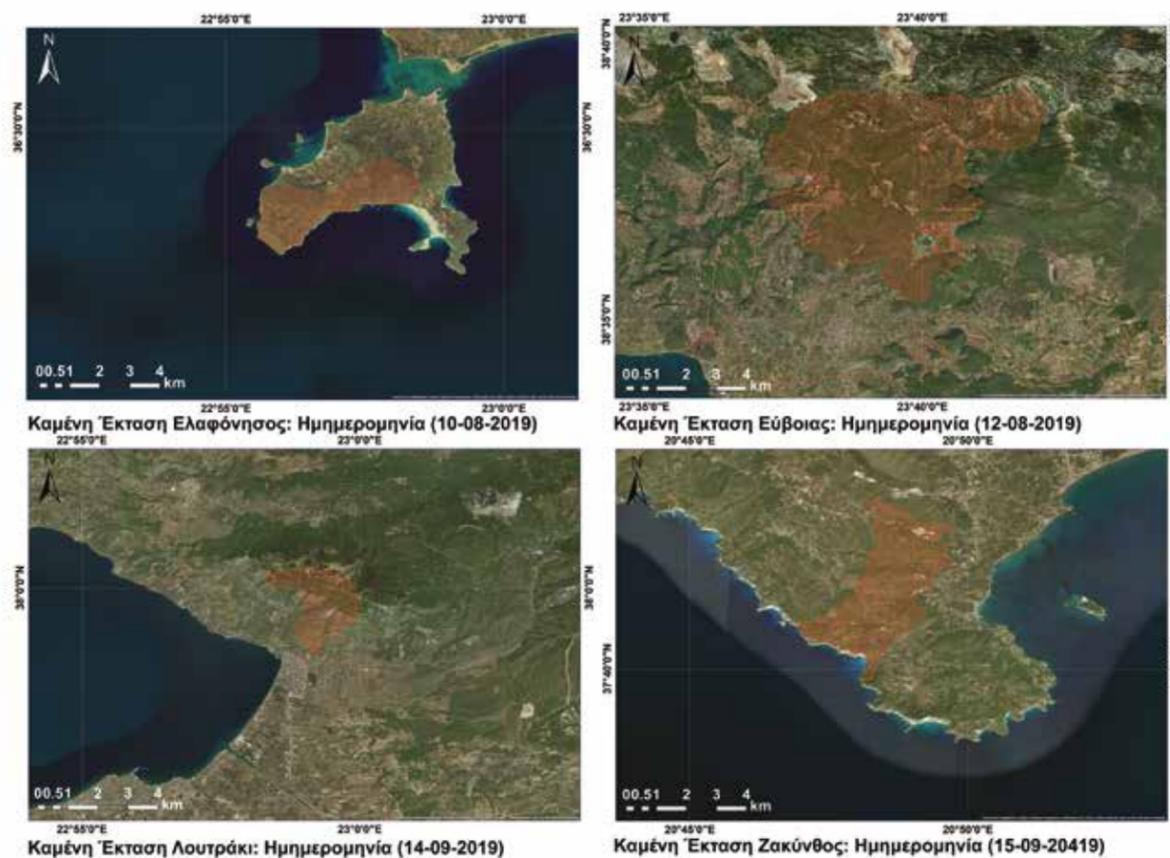
The following chapters present a number of indicative cases of detailed studies and related products that emerged from different cases of natural disasters and types of activation.



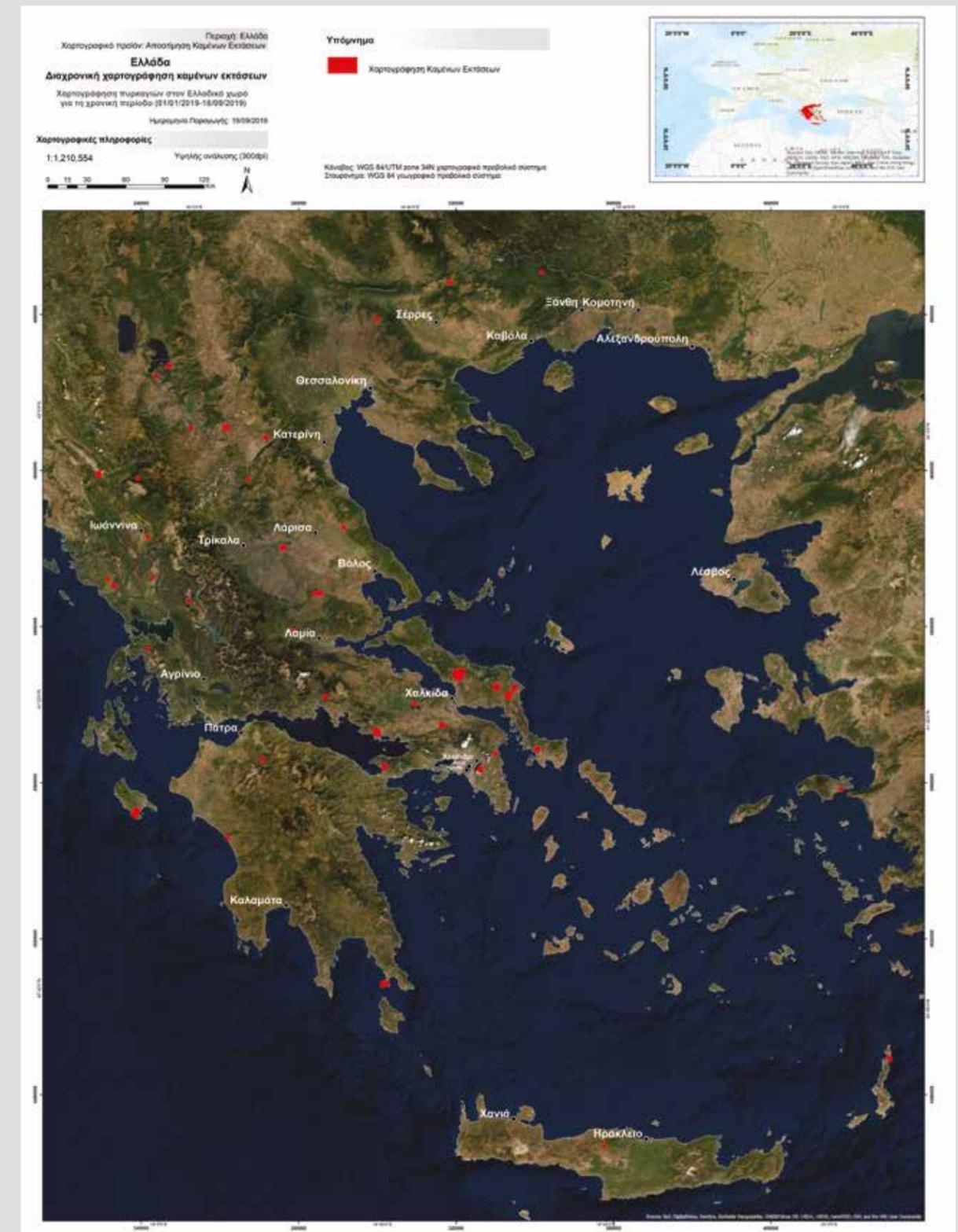
# Fires

The FireHUB system is a unique tool in the hands of the state, and is provided to the Fire Service Operation Center free of charge by the BEYOND Center of Excellence. It offers four (4) original core services: (1) timely detection of forest fires anywhere in Greece, (2) monitoring of the evolution of the fire front, with new observations every 5 minutes and at a spatial resolution of 500m, (3) modeling and forecasting of smog dispersal, and (4) delineation of burned areas after destruction and damage assessment on infrastructure, citizen property and the natural environment.

This summer as well, the BEYOND Center recorded the evolution of all major fires, from beginning to completion, and consequently provided the state with maps detailing the burned areas and assessing the damages in ecosystems, property and agricultural land.



The four most notable fires at Elafonissos, Evia, Loutraki and Zakynthos



Mapping of the burnt areas in Greece the period 01/01/2019 – 18/09/2019

According to our Center's estimates, the total burned area recorded in Greece during the summer period of 2019 was 9,405 hectares. Detailed mapping indicated that most of the burned land corresponded to sclerophyllous vegetation (3,601 hectares), forest and bushy areas (1,626 hectares) and coniferous forests (1,440 hectares). It is worth noting that for 2019, 46% of the total burned area (4,306 hectares) was located in the prefecture of Evia,

The districts of Evia and Boiotia marked the highest frequency of wildfires. Specifically, this summer, Euboea recorded five incidents of wildfire. It is also worthy to note that the region of Messapia had previously recorded another fire in 2012, when 565 hectares were burned, compared to 919 hectares in the same region this year. Additionally, in the prefecture/district of Boiotia 3 large fires occurred, burning a total of 1,013 hectares

The island of Zakynthos recorded the highest number of burnt hectares proportionally to the island's size. A total of 747 hectares were burned, with catastrophic consequences mostly to sclerophyllous vegetation ecosystems and crops. The same area had also been burned in the past, during the summer of 2012.

In Loutraki, Attica, the burned area amounted to 303 hectares, destroying mostly bushy vegetation. The area, which belongs in its entirety to a Natura 2000 protected zone, had also been burned again in 1986.

One of the biggest fires that broke out in 2019 was in Elafonisos. It burned 510 hectares of land in a protected Natura zone, and had particularly devastating effects on animal organisms and endemic species of flora found, exclusively on the coasts of Elafonisos and the wider area.



## Lithakia Zakynthos Wildfire, September 15th 2019

The fire in the Lithakia area of Zakynthos broke out on Sunday, September 15th 2019. The FireHub system monitored the event from the very first minutes of its break out at 10:55am, via the Meteosat Second Generation satellites 2, 3, and 4 which are detected by the BEYOND Center's antenna infrastructure.

One of the first actions was to detect the fire spatially, as well as to address diachronic and near real-time Burnt Scar Mapping needs ([http://ocean.space.noa.gr/diachronic\\_bsm/](http://ocean.space.noa.gr/diachronic_bsm/)) in order to determine the criticality of the situation, as that largely depends on whether the fire is located on an area that is highly susceptible to burning or has a high concentration of bushery, as well as on whether the area in question has been previously burned. The above study showed that the area was covered in sclerophyllous vegetation (bushy and herbaceous), olive trees and coniferous forest - all types of land with great susceptibility to ignition and fire expansion. Additionally, the study revealed that a small segment of the same area was burned again in 2012. Taking into account the type of vegetation as well as meteorological conditions in the area at the time, it became clear that the fire would create a particularly difficult situation for operations on the ground (e.g. Fire Service department), as was eventually confirmed by the continuous monitoring of the FireHUB system.

From the instant of the first detection, every 5 minutes, and for about 12 hours, an operational update of the extent and intensity of the fire was continuously provided, as illustrated in the following images. The devastating fire continued to burn in the wider area with high intensity and dispersion for more than 10 hours (Figures 1a-d). At around 9:30pm local time, the containment and limitation of the fire incident (Figure 2) became apparent in the FireHUB system. The last observation of active fire fronts by the system occurred at midnight, 13 hours after the initial spark.

On September 15, at 2.30pm local time, the BEYOND Center collected additional imagery by the VIIRS satellite (375m resolution) through its satellite antennas, and provided an image of the active hotspots (Figure 3) and a mapping of the burned area in a primary, average resolution approach (Figure 4).

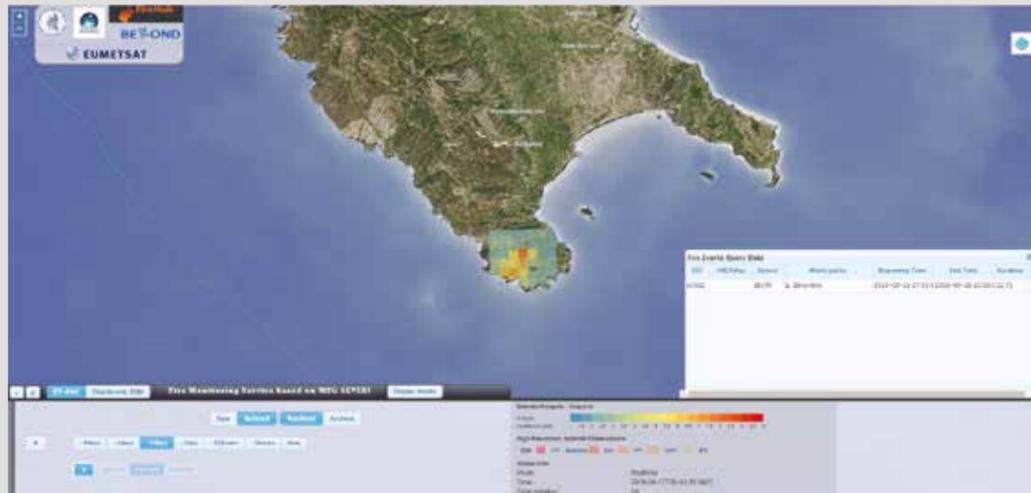


Image 1a. A preliminary estimation of burn scar in Lithakia area at 10.55 (local time)

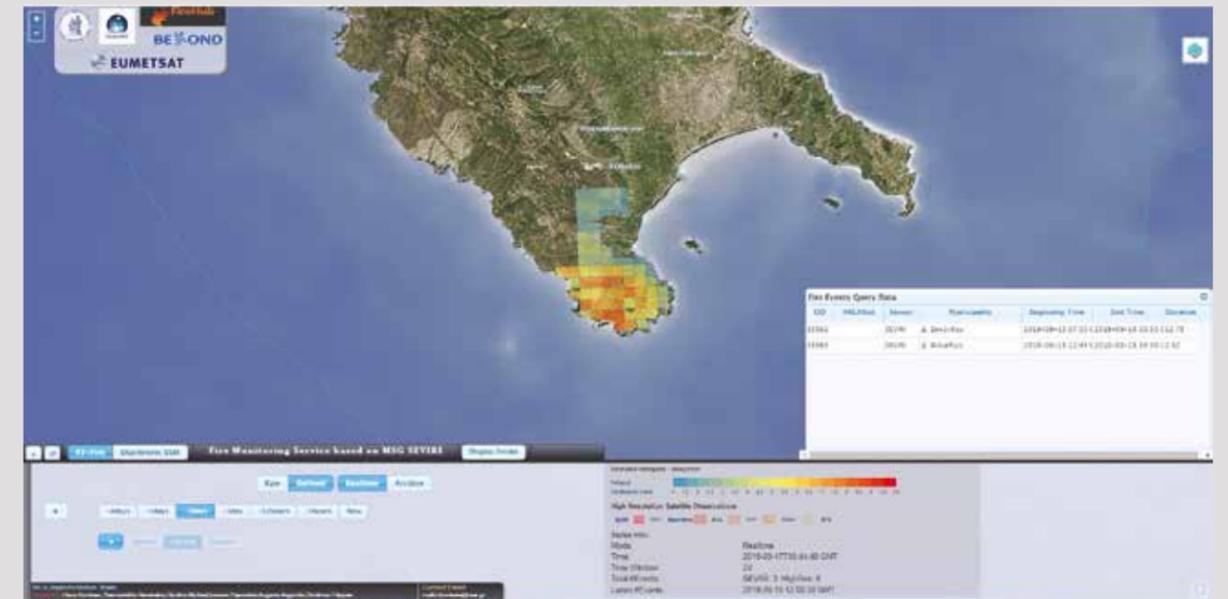


Image 1d. Snapshot of fire evolution from FireHUB system

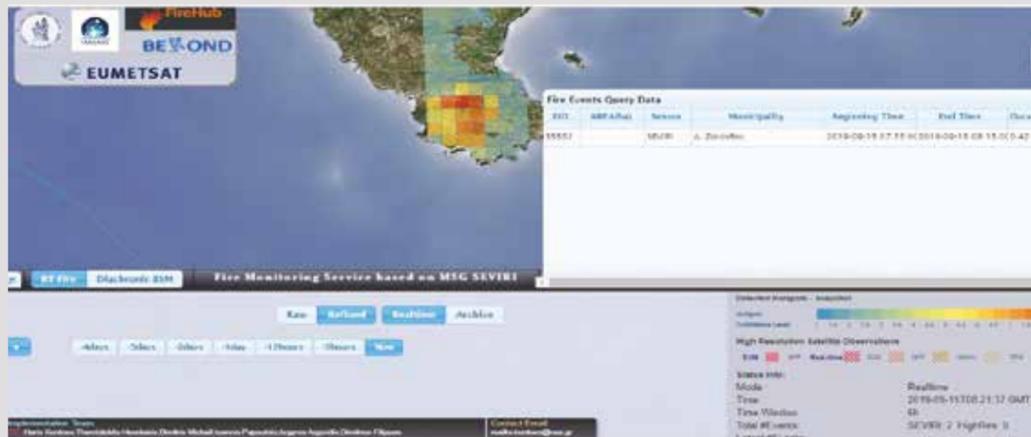


Image 1b. Snapshot of fire evolution from FireHUB system



Image 2. Fire suppression at 21.30 (local time)

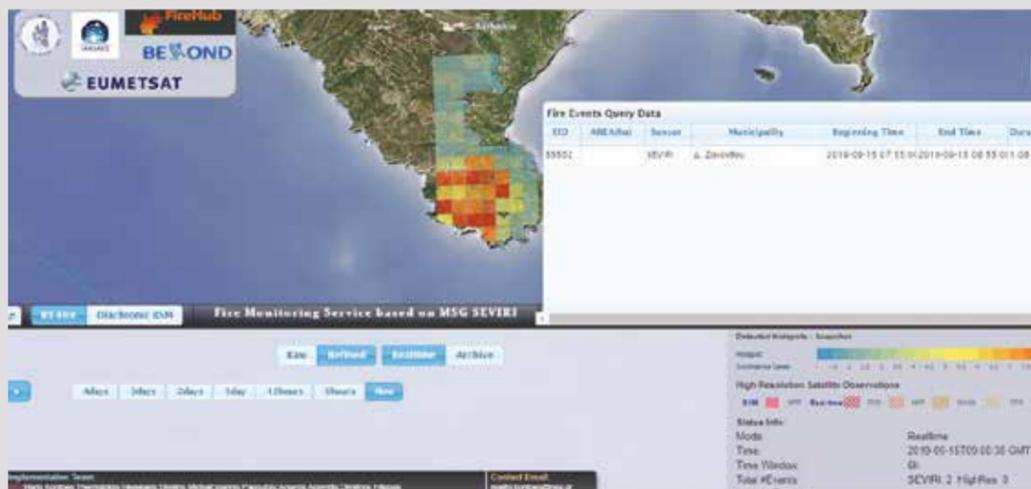


Image 1c. Snapshot of fire evolution from FireHUB system

On September 16, at 12:20pm local time, BEYOND's Rapid Mapping team harvested from the available Copernicus Hubs high-resolution images of the Sentinel-2A satellite (one prior to the disaster 6/9/2019 and one after the disaster 16/9/2019) and updated its reporting, publishing the first detailed mapping and estimation of the burned area. Image processing revealed that the burned area of Zakynthos amounted to roughly 747 hectares (Figure 8). Specifically, the fire burned 580 hectares of sclerophyllous vegetation (78% of total burned area), 89 hectares of olive trees (12%), and lastly, 61 hectares of coniferous forest (8%).



Images 3, 4.  
A first estimate of the burned areas from VIIRS satellite images (15/9/2019, 14.30 local time)



Image 5. Mapping of the of the burned areas from 2A Sentinel satellite.

# Floods

For the monitoring of floods, the BEYOND Center of Excellence has developed a system of services that uses synthetic-aperture radar (SAR) satellite data, which are harvested from the Sentinel-1 satellites of Copernicus. Through this service, the FloodHUB system diachronically monitors selected river basins of special interest in Greece through a fully automated process, and maps the flooded areas using satellite remote sensing. Additionally, the system can also be supplied by ground-based observations, which allows for more in-depth knowledge of the affected area. Lastly, an important part of the services of the FloodHUB system concerns the day after the disaster, providing assessments of the damage caused by the catastrophic event.

**A typical example** of a comprehensive study by BEYOND's team was the flood in Mandra in November 2017. Mandra was the subject of a detailed study that was shared with all civil protection authorities in the country, which concluded that the risk analysis should be done on two levels. The first concerns the time before the disaster (offline) - the preparedness stage - and aims to collect information using satellites in order to provide better knowledge of the area. The second concerns the real time - the management stage - and focuses on the production of useful information during the crisis. At the crisis level, the models use the information collected by satellites and combine it with the picture transmitted by mobile phones from the field, both by firefighters and organized volunteers, in order to produce a trustworthy, operational depiction of the situation in real time. In this study, in addition to remote sensing data, manned or unmanned aerial vehicles (drones / UAVs) were used to assess the magnitude of the disaster in detail, thus assisting the DAEFK ( Natural Disasters Damage Recovery Directorate) of the Hellenic Ministry of Infrastructure, Transport and Networks in its damage assessment and compensation schemes, by confirming the validity of relevant requests.

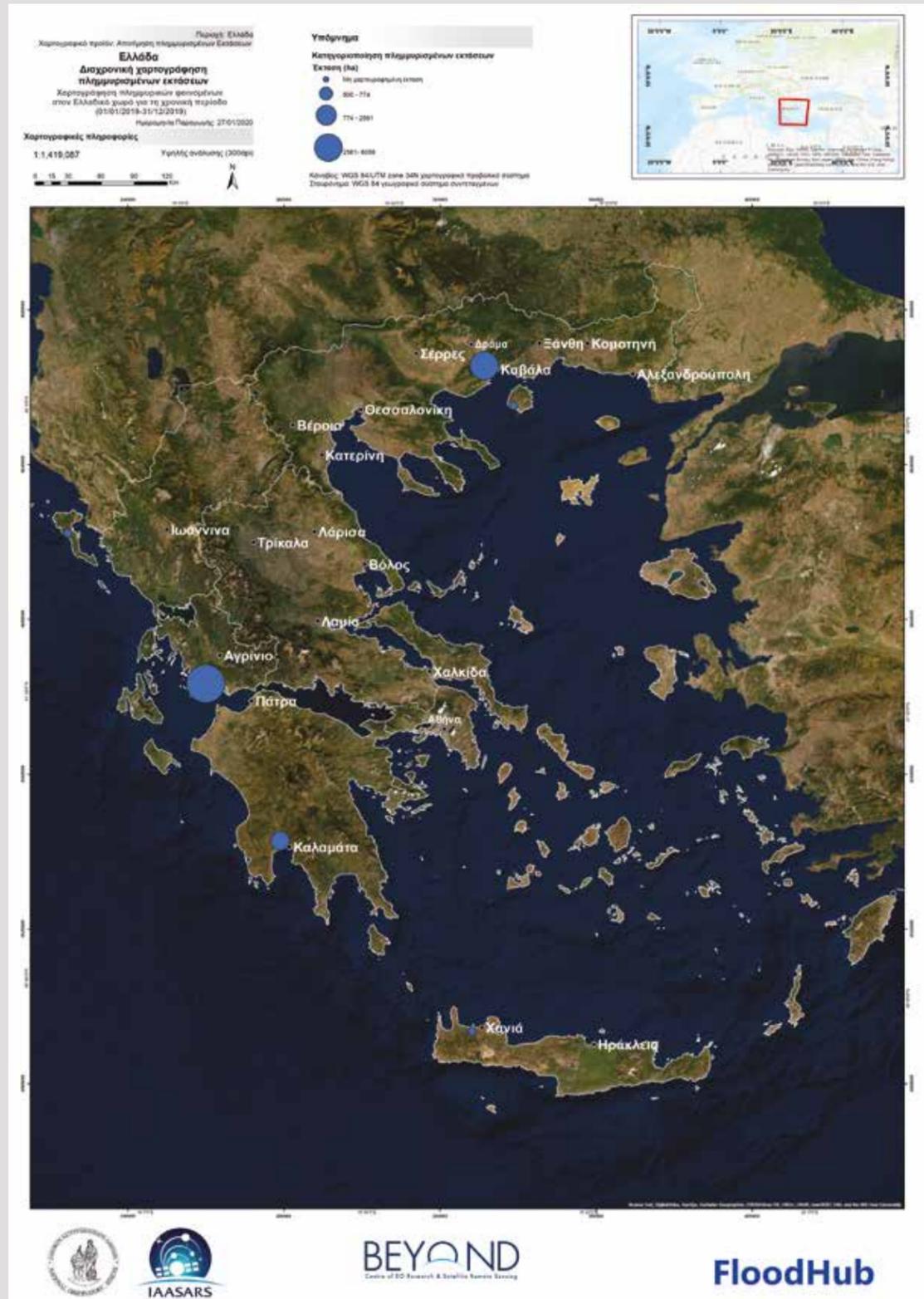


Flood of the Keritis stream and collapse of the historic Alikianos bridge. Excerpt from the satellite image WorldView-2of very high spatial resolution (50 cm) in a pseudo-color display with acquisition date 1/3/2019.

In 2019, there were 4 major floods mostly affecting rural areas, along with one fatal flood in Crete in February 2019.

Specifically, between February 24th and 26th, 2019, the island of Crete was hit by catastrophic floods caused by heavy rainfall, leading to the tragic consequences of five fatalities and incalculable material damage. Among other damages, in the prefecture of Chania two bridges collapsed - the historic Alikianou Bridge and the Platanias Bridge adjacent to the old National Highway. Both bridges were located in the Keriti stream (February 25, 2019).

The FloodHub service was activated immediately and monitored the evolution of the floods. Initially, all Sentinel-1 and Sentinel-2 satellite images of high spatial resolution (10 m) concerning the areas of interest were collected and processed through the Hellenic Mirror Site of the NOA (<https://sentinels.space.noa.gr/>). Subsequently, WorldView-2 satellite images of very high spatial resolution (50 cm) were acquired, in order to produce estimates of higher accuracy. The center's Rapid Mapping team processed the first available image without cloud cover (March 1, 2019). The image above depicts one of the two damaged bridges as well as the large flood extent.



Mapping of flood events in Greece, 2019.



**Flood in Messolonghi, October 3, 2019**  
Flood extent assessment from satellite data

On October 3, 2019, the Municipality of Messolonghi was hit by a flood. After heavy rainfall, houses, shops, agricultural crops (cotton, olive trees, citrus fruit trees, vegetables, corn), livestock units and infrastructure (road network, telecommunications) inside and outside the urban fabric flooded. Immediately after the declaration of a State of Emergency in the Municipality of Messolonghi by Civil Protection authorities, the FloodHUB service mapped the flooded area through processing and photo-interpretation of two satellite images Sentinel-1 and Sentinel-2.



**Flood in Messinia, November 20, 2019**  
Flood extent evolution mapping

The flood in Messinia took place on November 20, 2019 and was caused by heavy rainfall. The flood affected mostly arable land. The FloodHUB service mapped the evolution of the flooded area through processing and photo-interpretation of two Sentinel-1 (A&B) satellite images, which were acquired at different times of the day of the disaster (morning and afternoon).



**Flood in Kavala, November 21, 2019**  
Flood extent mapping

The flood in Kavala took place on November 21, 2019 and was caused by heavy rainfall. It mostly affected arable land, sections of the National Highway of Kavala-Drama as well as facilities along the highway. In the municipality of Kavala, the municipal unit of Philippi and the local communities of Polystylos and Datos were put under a state of emergency. The FloodHUB service mapped the flooded area, after processing and photo-interpreting two Sentinel-1 satellite images.

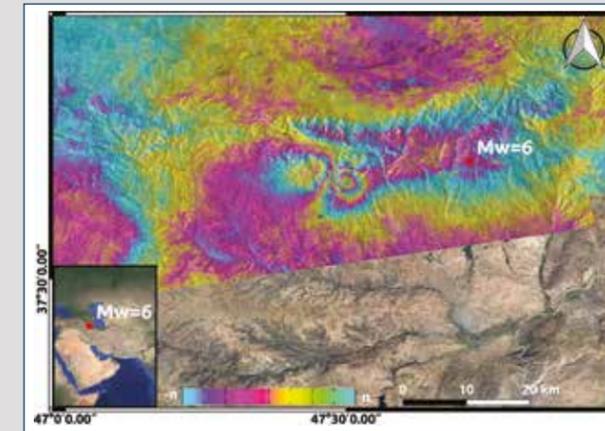
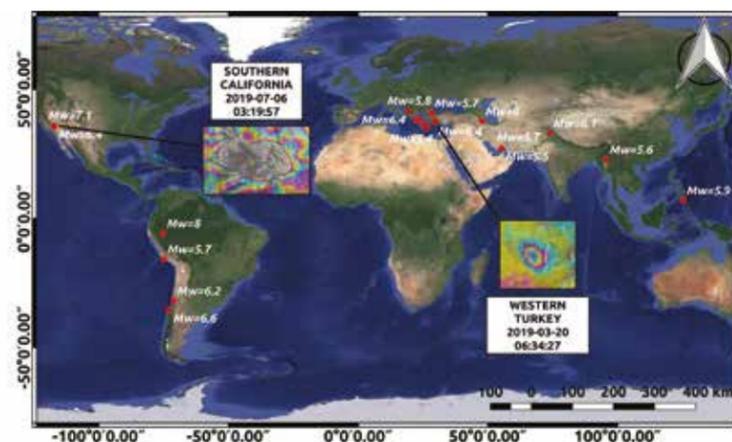
# Geohazards

In addition to massively damaging infrastructure, geohazards such as earthquakes, volcanic eruptions, landslides and subsidence in the urban environment are often a major threat to human life. The systematic monitoring of these natural phenomena and the study of their characteristics contribute to the understanding of the physical mechanisms that govern their creation and evolution and allows scientists to assess the risk associated with geohazards. From 2018 to today, BEYOND Center of Excellence provides uninterrupted monitoring and recording of all events related to deformations of the Earth's surface globally, through the GeoObservatory application.

Satellite differential radar interferometry (DInSAR), is a valuable tool for identifying and recording ground deformations and associate these with the physical properties of the triggering source. Our geObservatory application is activated in major geohazard events (earthquakes, volcanic activity, landslides, etc.) and automatically produces a series of Sentinel-1 based co-event differential interferograms to map the surface deformation associated with the event. The role of geObservatory is twofold: firstly, it provides to emergency management authorities with a rapid assessment of ground deformation, secondly it produces and maintains a global observatory of differential interferograms associated with catastrophic geo-events. The interferometric products are made available to the scientific community as well as the general public, free of charge, through the platform <http://geobservatory.beyond-eocenter.eu/>.

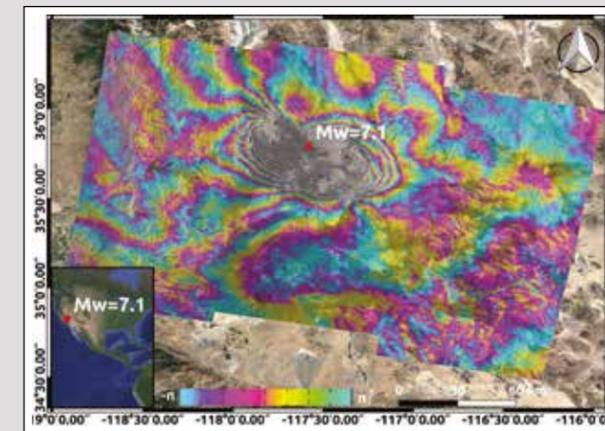
In 2019, the GeoObservatory recorded reports for 29 global seismic events (Figure 1). Below is a sample of the GeoObservatory's actions in recording land deformations from critical geological disasters in 2019.

GeoObservatory map of activations for the year 2019 on a global scale. The inserted images show two characteristic interferograms created to record the earthquake in Southern California (July 6, 2019, Mw = 7.1) and Western Turkey (March 20, 2019, Mw = 6.4).



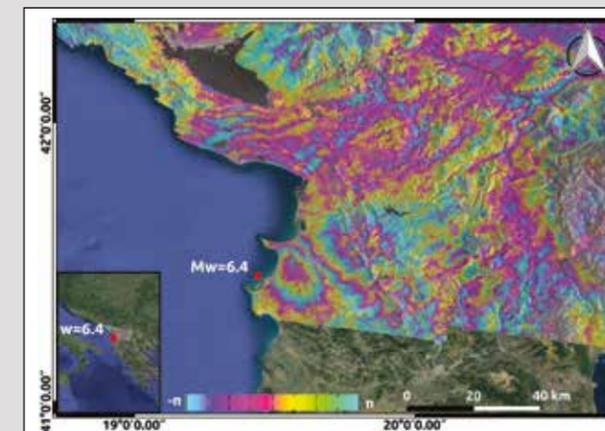
## Earthquake in Iran, November 7th, 2019

An earthquake with a magnitude of 6.0 earthquake shook Iran's East Azerbaijan province on November 7th, 2019, followed by more than 50 aftershocks. According to the University of Tehran the quake had a depth of 8 km, and caused severe material damage and multiple casualties. Iran is characterized by a high seismic activity area due to its location, as it is situated on the junction of the Arabian and Eurasian lithospheric plates. This was further evidenced by the devastating Bam earthquake in November 2017, with an intensity of Mw = 7.1. In this catastrophic event, the GeoObservatory service was activated and immediately exploited two ascending orbit images (November 3, 2019 and November 15, 2019) collected by the Sentinel-1 satellite, to produce a wrapped interferogram. The interferogram recorded the deformation of the ground caused by the catastrophic disaster, and estimated that the maximum level of observed deformation was 5.6 cm.



## Earthquake in Southern California, USA, 4th and 5th of July 2019

The 2019 Ridgecrest earthquakes of July 4 (Mw 6.6) and 5 (Mw 7.1) occurred north and northeast of the town of Ridgecrest, California (approximately 200 km north-northeast of Los Angeles). The USGS issued a red alert for economic losses meaning that extensive damage is probable, and the disaster is likely widespread. Estimated economic losses were at least \$1 billion dollars, less than 1 % of GDP of the United States. GeoObservatory was activated for the event of the 5th of July 2019. The first available image arrived on the 10th of July 2019, in ascending mode. The ascending interferogram was produced on the 16th of July, a few hours after the reception of the SAR image. The interferogram highlights the strong line-of-sight ground deformation pattern associated with this earthquake.



## Earthquake in Albania, November 26th, 2019

On November 26th, 2019, in the Northwest of Albania and with an epicenter 16km west of the city Mamurras, one of the strongest earthquakes in the area in the last 40 years took place. The earthquake had an intensity of Mw = 6.4, and was felt at a distance of up to 370 km from the epicenter. The earthquake caused extensive damage to infrastructure and multiple fatalities. Albania is a tectonically active region, as it lays on the junction of the Adriatic and Eurasian lithospheric plates. The GeoObservatory service recorded the deformation caused by the catastrophic earthquake. A pair of satellite images (descending orbit), collected by Sentinel-1 on November 25th and December 1st 2019, was used to create the wrapped interferogram. The ground deformation was located near the epicenter of the earthquake, and was estimated to be around 2.8 cm.

## Copernicus Emergency Management Service (EMS)

Rapid Assessment Service of the Exposure, Hazard, Vulnerability and Risk of areas from Natural Disasters

The BEYOND Center of Excellence has been activated by the Copernicus Emergency Management System (EMS) 21 times to date for specific natural disasters by different countries around the globe. Respectively, BEYOND has also been activated to serve the needs of international institutions such as the United Nations, UNESCO, the World Bank, and others. A characteristic example is the activation of the EMS in 2018 by UNESCO, in order to provide hazard, vulnerability and risk assessments for three different regions: Arica (Chile), Tacna (Peru) and Maputo (Mozambique). The goal of the activation was to protect local communities, public spaces, critical public infrastructure and schools from disasters caused by earthquakes, landslides, soil erosion, loss of coastal areas and floods.

In 2019, the Center undertook three Copernicus EMS projects related to risk assessment and mapping of disasters in Yemen, South Croatia and the Balkans.

The service was activated by the United Nations Program UN-Habitat to assist in the creation of appropriate rehabilitation plans for the cities of Sana'a and Aden in Yemen, a country plagued by civil war since 2015. In this case, the damaged buildings were mapped (in terms of location, type of building and intensity of the damage) as well as the urban sprawl in selected periods of reference. According to the tragic account there was a destruction of 50% of civilian homes and 30% of public and private service buildings (schools, hospitals, public services, companies).

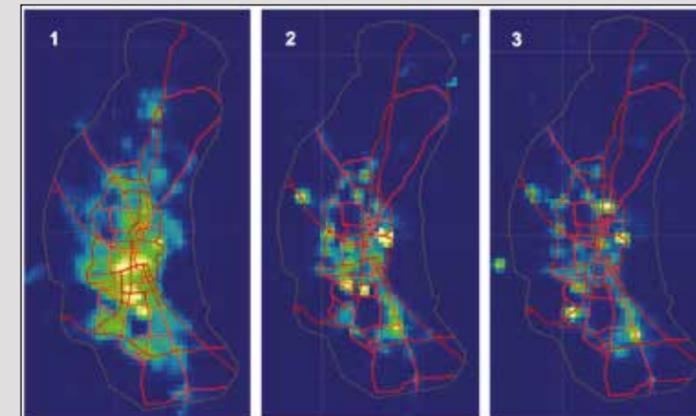
Also, the German Federal Office of Civil Protection and Disaster Assistance (BBK), on behalf of the German Society for International Cooperation GmbH (GIZ), activated the EMS in the context of the agreement on sustainable water resources management of the Drin river basin, which extends to 4 countries: Albania, Kosovo, North Macedonia and Montenegro. The aim was to deepen the analysis of the occurrence of floods by providing useful information on risk preparedness and sustainable development (flood risk, historical floods, mapping of buildings and critical infrastructure, financial risk assessment).

Lastly, the Ministry of the Interior of the Republic of Croatia activated the service for the Forest Fire Risk Assessment for two areas near Dubrovnik and Split, in the south region of the country. A total of 72 cartographic products of risk and vulnerability assessment to forest fires, as well as measures to mitigate the disaster were provided.



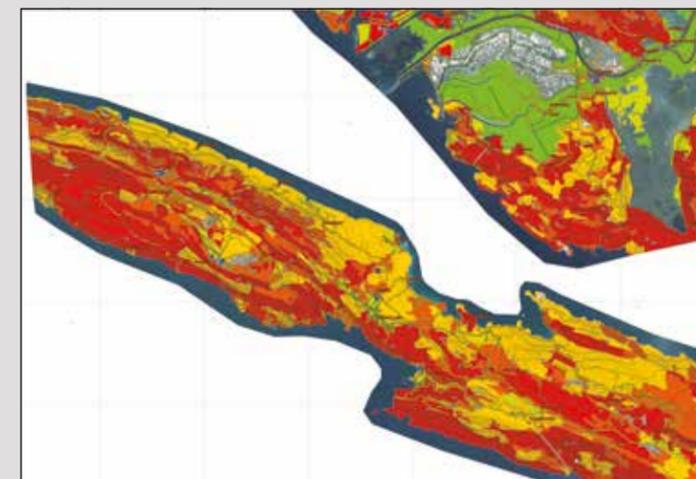
**EMSN054**  
Detailed flood extent mapping in the transboundary Drin river basin, Balkans

The map is one of the products of the diachronic flood events mapping from 1992 to 2017 in the Drin river basin. Specifically, it depicts the extent of the flood that occurred between December 2009 and January 2010. It was implemented by processing Synthetic Aperture Radar (SAR) satellite imagery at three time periods (before, during and after the flood) taking into account the Topographic Wetness Index (TWI).



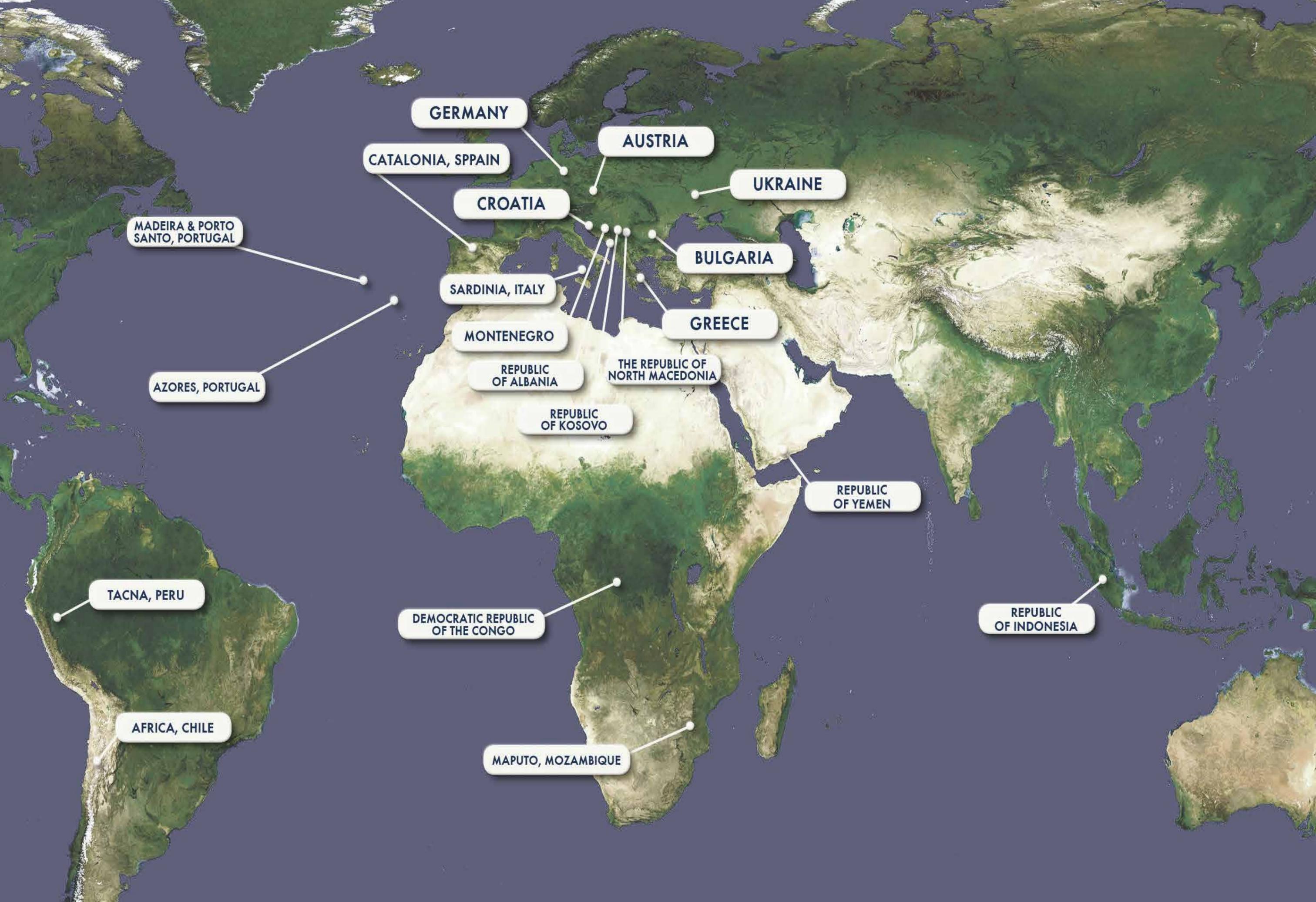
**EMSN058**  
Depiction of the war damage through night lights in Sana'a, Yemen

These maps are indicative of the consequences of the civil war in Yemen. Using VIIRS (DNP) SUOMI-NPP satellite data, the Sum of Lights (SOL) index was calculated, and the intensity of night lights in the capital Sana'a was mapped in three phases: 1) before the war (February 2015), 2) in the middle of the war (end of 2016), and 3) in the third phase of the war (2018).



**EMSN059**  
Forest fire risk assessment in the Dubrovnik region, Croatia

The map depicts the estimated forest fire risk in the Dubrovnik region. The risk index for forest fires is calculated taking into account the geomorphological and climatic characteristics, the land cover map, the vulnerability of the anthropogenic environment to forest fires and the increase in population density during the tourist season. The map provides additional information on first response infrastructures (e.g. essentials stock location) and disaster mitigation measures.



GERMANY

AUSTRIA

UKRAINE

CATALONIA, SPAIN

CROATIA

BULGARIA

MADEIRA & PORTO SANTO, PORTUGAL

SARDINIA, ITALY

GREECE

AZORES, PORTUGAL

MONTENEGRO

REPUBLIC OF ALBANIA

THE REPUBLIC OF NORTH MACEDONIA

REPUBLIC OF KOSOVO

REPUBLIC OF YEMEN

TACNA, PERU

DEMOCRATIC REPUBLIC OF THE CONGO

REPUBLIC OF INDONESIA

AFRICA, CHILE

MAPUTO, MOZAMBIQUE

# 3. Specialized Services



2013→2019→

The BEYOND Center is a living organism that constantly evolves its services through the development new scientific methods, and the exploitation of emerging technologies and state-of-the-art infrastructure for the extraction of higher level information and knowledge for the benefit of the citizen and the environment. It is a key objective of the BEYOND Center to not merely follow the Big Data paradigm shift and the unprecedented ICT penetration into the Earth Observation domain, but function as a pioneer and key player in the field. The BEYOND Center has been actively participating into pertinent European projects, conducting research and developing services in new domains other than natural disasters, which demand or benefit from the exploitation of enabling technologies; such as Machine Learning (ML), Artificial Intelligence (AI) and Distributed Computing. Over that last years the team has conducted advanced research and had developed mature services, through the combination of mature Remote Sensing technologies and state-of-the-art ICT and AI solutions, in the domains of sustainable agriculture, food security and energy.

The following are indicative examples of our specialized applications and services

## Earth Observation, Machine Learning and Distributed Computing at the service of Food Security monitoring

(EOPEN H2020 project)

The monitoring of agricultural production for the purposes of food security, the control of the implementation of sustainable agricultural practices and the improvement of the global agricultural productivity is top priority for the European Union. In this diverse field of agriculture monitoring, the BEYOND Center has invested in the development of user driven Earth Observation services, targeting operational solutions in the thematic areas of food security, the monitoring of the Common Agricultural Policy (CAP) and precision agriculture.

More specifically, the Center has developed advanced machine learning algorithms and successfully employed big data technologies to build a nationwide food security monitoring framework for South Korea (H2020 EOPEN project). South Korea's food security concerns have to do with the overproduction of rice and the low self-sufficiency in the production of other major grains. For this reason the systematic and large scale monitoring of the paddy rice extent has been identified as key knowledge for the high-level decision-making in regard to food security. This work addresses the Big Data implications, derived from a large scale and high-resolution paddy rice mapping application. In this regard, a distributed Random Forest classifier has been implemented, using the cluster-computing framework Apache Spark in a High Performance Data Analytics environment.



Rice map of Northeastern South Korea produced using a distributed Random Forest implementation on a High Performance Data Analytics environment.

## Earth Observation data and methodologies for the continuous monitoring of solar energy.

(<http://solea.gr/real-time-service/>)

Ramping up renewables is essential to meet the sustainable development goals of the United Nations like affordable and clean energy (SDG7) without decelerating economic growth and reducing welfare. Since the most widespread technologies for the use of energy potential of sun privileged locations are the photovoltaics and the concentrated solar power plants, the specific solar irradiance and energy resource monitoring is crucial for decision making and optimized solar farms installation and management.

At the BEYOND center we develop and provide high-resolution solar energy monitoring services running operational and in real-time using Earth Observation data in conjunction with radiative transfer models and machine learning computing architectures. These services are co-designed with electricity handling entities and solar energy producers and are currently applied in Europe, North Africa, Middle East and Southern Asia. More information on the technical background, applications and end-users can be found at the solar energy applications website (<http://solea.gr/>).

The Beyond's SolarHUB nowcasting and atlas services provide the opportunity for efficient planning and management of solar energy using Earth Observation data and technologies (e.g. SENSE). In Egypt, the official solar atlas was created for the



ministry of electricity and renewable energy and 29 specific locations were selected for the construction of new solar farm projects. In Benban, a 1.8 GW solar farm was completed at the end of 2019 providing green energy to more than 80K houses and actively contributing to the energy production and diversity of Egypt. The Madgi Yacoub Heart Foundation in Aswan has also used energy production monitoring solutions for a photovoltaic park currently under construction, that will cover the energy needs of the hospital and the wider residential area, affecting almost 15K people. The contribution of the SolarHIB services to the Egyptian society was awarded and highlighted in official declarations by the Minister of Electricity and Renewable Energy, the Minister of State for Emigration and Egyptian Expatriates' Affairs, and the Minister of Defense and Military Production.

## Early Warning System for Mosquito-borne diseases based on Satellite Earth Observation Data

(<http://beyond-eocenter.eu/index.php/thematic-areas/epidemics>)

Mosquito-Borne Diseases (MBDs) infect almost 700 million people every year and are recognized in over 100 countries, causing millions of deaths annually. The changing climatic and ecological conditions, global travel and trade, human behavior, as well as the rapid and unplanned urbanization, are key factors that influence the seasonal and geographic distribution of vectors' population and therefore the transmission of the pathogens, causing the re-emerging and even more emerging of these diseases in countries where they were previously unknown. West Nile Virus (WNV) infection, caused by the *Culex Pipiens* vector, have been recorded in humans and animals in various areas of Greece, during the years 2010-2014 and 2017-2019, but also in other regions in Europe reaching an unusual high record in 2018. The Asian tiger mosquito (*Aedes albopictus*) is another important vector in Europe for transmitting viral diseases, including Zika, chikungunya and dengue. Several disease outbreaks transmitted by *Aedes albopictus* have been reported in Europe: chikungunya in Italy and in France in 2010, 2014 and 2015, as well as local transmissions of dengue in France and Croatia in 2010.

BEYOND Center of excellence has been working on the development of an Early Warning System (EWS) that utilizes big satellite Earth Observation (EO) data that get collected by the antennas and the Hellenic Mirror Site maintained by NOA. The big satellite data serve as input parameters in dynamic models (seasonal predictions) and machine learning algorithms (short-term predictions) with the purpose of forecasting and risk mapping the outbreak of mosquito-borne diseases using Data Cube architecture. The EWS proves its transferability by being applied for multiple diseases such as WNV, Dengue fever, Chikungunya and Zika virus in the geographical areas of Italy, German and France.

## Multiple natural disaster risk assessment and design of preventive measures for the open refugee housing facility in Ritsona.

As part of BEYOND's collaboration with the European SMURBS ERA-PLANET program ("Smart Urban Solutions for Air Quality, Disasters and City Growth", <http://smurbs.eu/>), a new scientific action is being developed to provide support for the safe design and implementation of a holistic refugee accommodation unit. This action assesses the most likely risks potentially faced by the population of the facility and records critical information and the facility's infrastructure, and consequently makes risk mitigation proposals, and introduces measures to support all relevant risk management and evacuation decisions, in case of emergency. A prime example of that is the study of mitigation measures in cases of fire and flood at the Ritsona Refugee Reception Unit - the largest relevant infrastructure in Greece. This action is designed in collaboration with the Greek office of the International Organization for Migration.

## Mapping area affected by oil spill in the Red Sea

The Center's rapid mapping team immediately mobilized following the oil slick in the Red Sea triggered by the spill caused by the attack on the Iranian tanker SABITI on October 11, 2019, and closely monitored its evolution. The extent of the oil spill was mapped with high spatial resolution images of European Sentinel satellites, collected in the Copernicus Hubs of the BEYOND Center. In particular, two satellite images of the Sentinel-1B satellite were processed and photo-interpreted on October 13, 2019, estimating the radius of the oil slick to be 489 km, followed by two satellite images of Sentinel-1A on October 14, 2019, which estimated its radius to be 710k. The event was undeniably a major natural disaster, causing extensive pollution in the wider Red Sea region.



## Education - Training

Space technologies, data and services have become indispensable in the daily lives of European citizens: when using mobile phones and car navigation systems, watching satellite TV or withdrawing cash. The EU's document on Space Strategy states that "The potential of space solutions has not yet been fully exploited, and nor have the wider possibilities offered by space data [...] The goal [...] is to optimize the benefits that space brings to society and the EU's wider economy."

Nevertheless, in recent years there has been a negative trend towards the Natural Sciences, Technology, Engineering and Mathematics, raising concerns about the level of STEAM (STEAM: Science, Technology, Engineering, Art, Mathematics) education in Europe. Thus, the educational activities planned by BEYOND Center of Excellence aim to highlight the benefits that space offers to society and the wider EU economy to various social and scientific groups.



Our team has been invited several times to date by schools and educational institutions to present the uses of satellite technology in the daily lives of citizens, in the context of the physics course. The purpose of these visits is to inform members of the educational community that new technologies are an excellent tool in the hands of scientists that can produce services to the benefit of the state, as well as to introduce young people to the world of satellite remote sensing. The visits to the schools highlighted the need for large-scale implementation of educational programs on new technologies and Earth Observation.

In collaboration with the PRAXI Network and in the context of the "Caroline Herschel Framework Partnership Agreement" (HORIZON 2020), NOA's BEYOND Center of Excellence, undertook the implementation of educational activities on the use of satellite remote sensing at a national level, as well as in the wider region of North Africa, the Balkans, and the Middle East and (GEO-CRADLE coordination action - <http://geocradle.eu/en/>). In 2019, the implementation of the program began with presentations in schools (1st High School of Keratsini, 2nd General High School of Kamatero) while coordinated visits have already been scheduled for 2020, with the aim of informing students in secondary education. Additionally, the Center will conduct three training courses for organizations operating in areas of Civil Protection on the subject of "Rapid Exposure, Vulnerability and Risk Assessment Service for Natural Disasters - The Use of EMS Risk and Recovery".

# 4. Infrastructure - Programs



2013 → 2019 →



BEYOND Centre of Excellence operates infrastructure for the regular acquisition, management, and redistribution of real-time Earth observation data from space-based satellite missions and terrestrial systems. The coverage of this infrastructure is international and addresses the needs of the research community as well as institutional decision-makers throughout SE Europe, North Africa, the Middle East and the Balkans.



## Ground infrastructure of BEYOND Center of Excellence

1. The Hellenic Mirror Site HNSDMS (<https://sentinels.space.noa.gr/>) provides real-time data to the international research community and the private sector on Sentinels satellite missions (S-1, S-2, S-3 , 5P) (Copernicus) covering the wider region of SE Europe. The infrastructure is supported in computing units by GRNET SA.
2. The GreekHUB center of Sentinels satellite missions is higher in Sentinels data transmission architecture than the Hellenic Mirror Site. Every month, it distributes 2.85 Petabytes of S-1, S-2, S-3, S-5P data worldwide with a speed of up to 10 Gbps using the GEANT network and the computer infrastructure of GRNET SA. GreekHUB is a key infrastructure offered by BEYOND Center of Excellence in a continuous fashion.
3. Collection antenna (X- / L-band) and ground real-time satellite data archiving system for EOS (AQUA, TERRA) / NASA, SUOMINPP / NASA, NOAA / AVHRR, METOP, FY satellite missions. The range of the antenna covers the whole region of SE Europe, North Africa, the Balkans and the Middle East
4. Collection antenna (DVB-2) and ground real-time satellite data archiving system of EUMETSAT satellite missions (MSG1, MSG2, MSG3).
5. Advanced ground PollyXT lidar atmospheric system, as well as EMORAL mobile lidar system station.
6. Processing center consisting of high computing power servers as well as 300TBytes file for data processing and implementation of research and provision of services of FireHUB, FloodHUB, GeoHUB systems, etc.
7. Unmanned aerial vehicles (UAV, Drones), e-Bee SendeFly fixed-wing for long distances and ATLAS eight-wing vehicle for lifting multiple larger load receivers (~ 5 kgr).

The following is a list of programs undertaken by the center in 2019 or currently in progress.



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## European research projects\*

**2019 -2023**

Rapid-Response EO-Based Solutions to Development Aid Project Requests –EO CLINIC

**2019 -2023**

e-shape «EuroGEO Showcases: Applications Powered by Europe»

**2019 -2026**

EXCELSIOR CoE – ERATOSTHENES: Excellence Research Centre for Earth Surveillance and Space-Based Monitoring of the Environment

**2019 -2022**

Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake – FPCUP

**2019 -2022**

An Industry-Led Forum for Innovation and Research in European Earth Observation – FIRE

**2018 -2021**

Framework Service Contract for Copernicus Emergency Management Service Risk and Recovery Mapping - The European Forest Fire Information System (EFFIS)

**2018 -2021**

EO for Sustainable Development in the Climate Resilience Domain

**2017 -2020**

EOPEN: Open Interoperable Platform for Unified Access and Analysis of Earth Observation Data Program

**2017 -2020**

MARINE-EO: Bridging Innovative Downstream Earth Observation and Copernicus Enabled Services for Integrated Maritime Environment, Surveillance and Security

**2017 -2020**

Sentinels Rolling Archive Products User Access, Operations, Maintenance and Evolutions

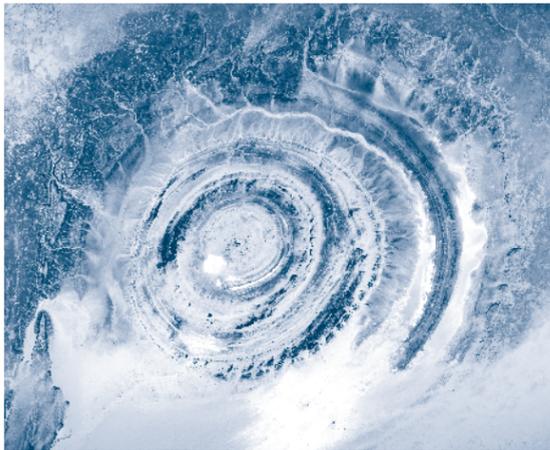
\*ongoing or started within 2019

# What inspire us



## UN 2030 Agenda for sustainable development

The EU is fully committed to be a frontrunner in implementing the 2030 Agenda for Sustainable Development, together with its Member States. The Agenda is a shared roadmap for a peaceful and prosperous world, of paramount importance to the values of the EU and the future of Europe.



## SENDAI Framework for Disaster Risk Reduction

The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) was the first major agreement of the post-2015 development agenda and provides Member States with concrete actions to protect development gains from the risk of disaster.



## PARIS Agreement on Climate Change

The Paris Agreement central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change.



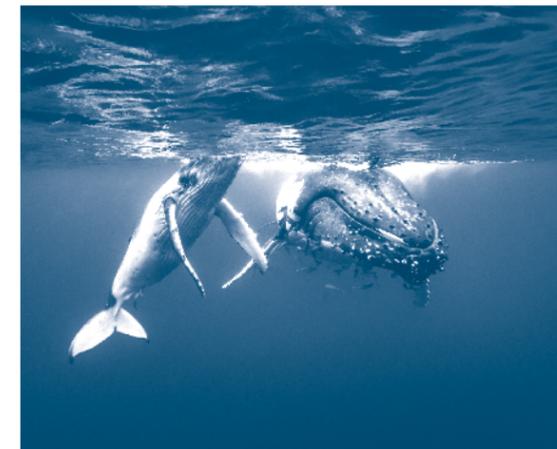
## EU Floods Directive

Directive 2007/60/EC on the assessment and management of flood risks requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk.



## EU Civil Protection Mechanism

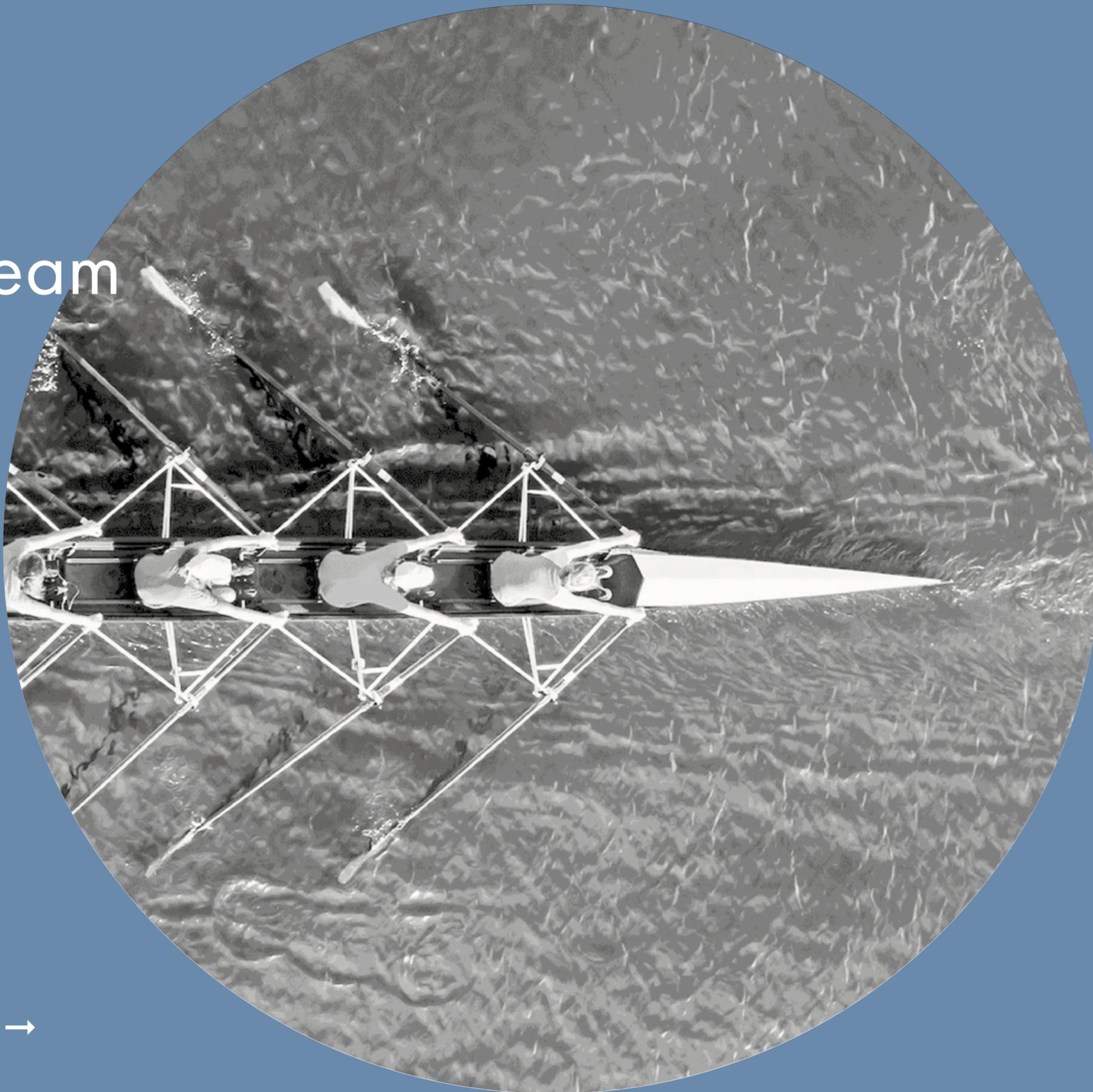
The overall objective of the EU Civil Protection Mechanism is to strengthen cooperation between the EU Member States and 6 Participating States in the field of civil protection, with a view to improve prevention, preparedness and response to disasters.



## EU Adaptation Strategy to Climate Change

In 2013, the European Commission adopted an EU strategy on adaptation to climate change, welcomed by the EU Member States. The strategy aims to make Europe more climate-resilient. By taking a coherent approach and providing for improved coordination, it aims to enhance the preparedness and capacity of all governance levels to respond to the impacts of climate change.

# 5. Our Team



2013 → 2019 →

The interdisciplinary team of the BEYOND Center of Excellence consists of a number of esteemed researchers with an international presence, who administratively belong to the Institute of Astronomy, Astrophysics, Space Applications & Remote Sensing (IAADET) of the National Observatory of Athens (NOA). The team also includes internationally renowned researchers from other NOA institutes who support the center's services. Moreover, the Center cooperates with more than 173 internationally recognized organizations in the field of Space Applications (Universities, Research Centers, Industry Stakeholders, International Organizations, Institutions and Ministries).

The Center's members are actively involved in disseminating research results by participating in scientific conferences as well as engaging in public speaking engagements. The fundamental goal of the BEYOND Center of Excellence is the promotion of space technology at the disposal of the state, the cultivation of social consciousness, and awareness raising on the public's vigilance on issues of protection and prevention of natural disasters.



In 2019, our team participated in more than 20 conferences, workshops and public speaking engagements. Below are some examples from such engagements with the general public:

- 84th Thessaloniki International Fair (September 8, 2019). Conference entitled «Innovative services in Forecasting, Detection, Monitoring, Recording and Management of Natural Disasters».
- French Institute of Thessaloniki (October 10, 2019). Conference entitled «Science and Innovation in the Service of Natural Risk Management», where French and Greek pioneers in innovation shared their ideas, research, projects and progress in the area.
- Attica Region (October 4, 2019). Presentation of the services of the BEYOND Center of Excellence to representatives of Civil Protection and Municipalities from across Greece.
- Municipality of Elefsina and Association of Volunteers of “Thrasio Pedio” (November 13, 2019). Conference entitled «Floods of Mandra 2017 - The role of Volunteers».

In parallel to the speaking engagements, members of our team actively participated in the global research community with their writings. In total, during the period 2018 - 2019, 9 research papers were published in scientific journals by members of our team.

## Recent scientific publications (2018-2019)

- Alatza, S.; Papoutsis, I.; Paradissis, D.; Kontoes, C.; Papadopoulos, G.A. Multi-Temporal InSAR Analysis for Monitoring Ground Deformation in Amorgos Island, Greece. *Sensors* 2020, 20, 338. doi:10.3390/s20020338. <https://www.mdpi.com/1424-8220/20/2/338/htm>
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- G. Vingione, G. Scarpino, L. Marzell, T. Pettengell, I. Gialampoukidis, S. Andreadis, S. Vrochidis, I. Kompatsiaris, B. Valentin, L. Gale, W. - K. Lee, W. Lee, M. Gienger, D. Hoppe, V. Sitokonstantinou, I. Papoutsis, C. Kontoes, F. Baruffi, M. Ferri, H. Yoon, A. Karppinen and A.-M. Harri, “EOPEN: Open interoperable platform for unified access and analysis of earth observation data”, Proc. of the 2019 conference on Big Data from Space (BiDS’19), pp. 1–4, Munich, Germany, 2019, doi:10.2760/848593
- Solomos, S., Abuelgasim, A., Spyrou, C., Biniotoglou, I., and Nickovic, S.: Development of a dynamic dust source map for NMME-DREAM v1.0 model based on MODIS Normalized Difference Vegetation Index (NDVI) over the Arabian Peninsula, *Geosci. Model Dev.*, 12, 979–988, <https://doi.org/10.5194/gmd-12-979-2019>, 2019
- Sitokonstantinou, V.; Papoutsis, I.; Kontoes, C.; Arnal, A.; Andrés, A. P.; Zurbano, J. A. Scalable Parcel-Based Crop Identification Scheme Using Sentinel-2 Data Time-Series for the Monitoring of the Common Agricultural Policy. *Remote Sensing* 2018, 10, 911
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- ☎ Τηλ: +302103490125
  - ✉ email: [beyond@noa.gr](mailto:beyond@noa.gr)
  - 🌐 [www.beyond-eocenter.eu](http://www.beyond-eocenter.eu)
  - 📘 [facebook.com/Beyond-EO-Center](https://www.facebook.com/Beyond-EO-Center)
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**NATIONAL OBSERVATORY OF ATHENS**  
Institute for Astronomy & Astrophysics,  
Space Applications and Remote Sensing  
Metaxa & Vas. Pavlou, penteli, 15236, Athens

