BEYOND: A centre of Excellence in south-eastern Europe for monitoring natural disasters from space

Final publishable summary

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Executive summary

BEYOND project has managed to develop, flourish and establish a Centre of Excellence within the National Observatory of Athens, for Earth Observation based monitoring of Natural Disasters in south-eastern Europe, and the Balkans. BEYOND has achieved to (i) set up innovative integrated observational solutions that allow a multitude of space-borne and ground-based monitoring networks to operate in a complementary and coordinated mode, (ii) create databases of long series of observations and higher level products, and (iii) make these observations available for exploitation with the involvement of stakeholders, scientists and/or institutional users, applicable for down-streaming to their specific needs.

The research portfolio of BEYOND covers a broad spectrum of phenomena such as earthquakes, volcanoes, extreme weather events, fires, fire smoke and toxic gasses, emission concentrations, dust storms, air quality and impacts to human health, which are grouped into three research domains: RD1 - Meteorological and human induced hazards, RD2 - Geophysical hazards, and RD3 - Atmospheric pollution and air quality, with direct and indirect effects on public health and ecosystems.

In the framework of BEYOND, critical infrastructure was developed, including an integrated Earth Observation Ground Segment and atmospheric Lidar stations, and important software modules, e.g. SARscape for the processing of Synthetic Aperture Radar data, ArcGIS, ENVI, MATLAB, etc. The new equipment was framed by new researchers that conveyed unique know-how to the Center of Excellence.

This report outlines the concept and objectives of BEYOND, while at the core is a structured summary of the services that are available through BEYOND, and which were developed as a direct outcome of the capacity building activities of the project. The cornerstone of these services is **FireHub**, now protected via a patent, a novel platform which assists stakeholder agencies by providing a real-time satellite-based Overall Fire Situation Picture.

BEYOND has been a social responsible venture, with an impact to the society, economic prosperity and leaving an environmental footprint. Caring for the sustainability of the Center of Excellence, BEYOND has adopted a smart positioning in strategic areas: BEYOND has (i) been established a Copernicus Service Provider in the Emergency Management Services thematic pillar, and (ii) become a focal point for EO-based infrastructure and downstream services for the Balkans, Middle East and Northern Africa by coordinating the GEO-CRADLE H2020 project (http://www.geocradle.eu/). Overall, 11 new projects have been awarded to NOA, attracting sufficient funds to sustain BEYOND's operations for at least 3 years more.

BEYOND has achieved to become part of large European and/or global scientific and infrastructure networks, such as joining UN-SPIDER as a Regional Support Office, participating to AERONET atmospheric network and to EARLINET Lidar network, connecting with the Committee of Earth Observation Satellites and joining iSPEX air pollution citizen network. These networking activities have increased the visibility of BEYOND, along with the other communication mechanisms established, and strengthened its position in the respective European Research Area, towards attracting new funds and capitalising on the capacities that were developed with EC resources.

1. Project concept & objectives

BEYOND expanded the existing state-of-the-art and developed interdisciplinary collaboration with twining organizations in the European Research Area, for Building a Centre of Excellence dedicated to the Earth Observation Monitoring and Management of Natural Disasters. The area of interest of the BEYOND Center of Excellence was initially defined to be the SE Europe, including the Balkan countries. This AOI has been expanded, and the operations of the Center cover the wider Mediterranean area, through harmonizing the observational capacities installed and put in full operation in the framework of the project.

BEYOND successfully achieved its objectives such as: a) set up, and put in full operation integrated observational networks (space borne and in-situ) which meet the hazard monitoring needs over the Mediterranean, b) generate archives of long series of observations and higher level products, and c) make the raw observations and the generated products freely available through web for exploitation with state-of-the-art science and models, hence providing the involved stakeholders, scientists and institutional users, with substantial information for downstreaming to local needs for handling natural and human induced disasters.

The works for accomplishing the above goals were structured around six Work Packages:

- WP1-Project Management,
- WP2-Personnel Recruitment, allowing highly skilled scientists to be actively involved,
- WP3-Infrastructure and capacity building, which delivered unique observational solutions for SE Europe, and high performing processing nodes, and EO data archives,
- WP4-Dissemination" which expanded the visibility of the BEYOND Center of Excellence across the wider EO stakeholder community inside and outside Europe
- WP5-Exchange of know-how and experience, which increased the level of the research capacity by allowing experts from the partnering organisations to meet often for sharing and developing innovative research, and
- WP6-Exploitation and Intellectual Property development, which has set a concrete exploitation roadmap for using the developed IPR, and the patented foreground.

The BEYOND Center of Excellence has established and currently maintains, in the framework of official agreements and MOUs, high level scientific collaborations with research organizations over Europe, and exchanges EO data (space, and in-situ), models, tools, methodologies, and know-how, with institutional authorities, data owners, satellite operators, and international bodies (e.g. UN-SPIDER, UK Meteo Office, Serbian Hydro Meteo Office, ESA, NASA, WMO, Ministerial Bodies, Local & Regional Authorities). It is worth noting that the exploitation of the developed capacity (research, human, technological) in the framework of competitive funding calls (e.g. H2020, as well as EU, ESA, and National ITTs), has secured the Center's operation in the years following the project's end, and the positions of the recruited researchers. Similarly the targeted dissemination actions referring to the organisation of regional workshops, publication of innovative research, operation of the BEYOND web portal (http://www.beyond-eocenter.eu), and circulation of newsletters will remain active.

BEYOND covered all the priorities defined in the work program, substantially contributing to human, institutional and infrastructure capacity building. The research & service portfolio of the Center of Excellence provides today solutions for a broad spectrum of hazards such as earthquakes, volcanic eruptions, lava flow, landslides, floods, fires, smoke and toxic gasses, dust storms, atmospheric disturbances, and heat waves. Several institutions, research organisations, public authorities, and large scale disaster risk reduction initiatives, including the UN-SPIDER, and the Risk & Recovery pillar of the Copernicus Emergency Management Service benefit from the research outcomes and services delivered through the BEYOND Center of Excellence, under signed MOUs, and contracts. In conclusion the Center of Excellence BEYOND:

1. Sets new creative perspectives and plays a leading role in EO-based disaster management in the wider Mediterranean.
2. Boosts innovative cutting-edge research and services in its thematic domains. Several of the BEYOND services received a wide recognition, and won excellence prices in international competitions (e.g. the FIREHUB service which was selected as the Best Service Challenge in the 2014 Copernicus Masters Competition, and the DisasterHub service which was distinguished between the top level applications in the 2015 MyGEOSS competition, etc).
3. Maintains on a 24/7 basis fully operational and innovative space based and in-situ monitoring networks, and data processing infrastructures. It offers a unique monitoring capability in the wider Mediterranean, and constitutes an integral part of worldwide monitoring, and research infrastructures such as the ACTRIS, Earlinet, and Direct Broadcasting satellite networks, and the Federated Coll Ground Segment for Sentinel data.
4. Offers services for the benefit of national, regional, and European stakeholders, and assists in the development of the EO market and relevant research through the free and open provision of tools, cloud computer capacities, and repositories of core products, and raw satellite data. It addresses societal priorities in the domains of Disaster Risk Reduction, and Emergency Response as set out in the large scale initiatives and European work programs such as GEO, GEOSS, and Copernicus.
5. Applies a robust Intellectual Property scheme, providing the maximum from the derived information, without breaching the background IPR, and the patented solutions and foregrounds developed in the framework of the project.
6. Timely follows the research advances made in the respective research fields, and supports the excellence of the engaged researchers, and the production rate of scientific publications. It is worth noted that researchers acting in BEYOND claim the role of European pioneers in their research domains, and are highly ranked in evaluation processes for receiving high level European awards and distinctions (e.g. ERC awards).

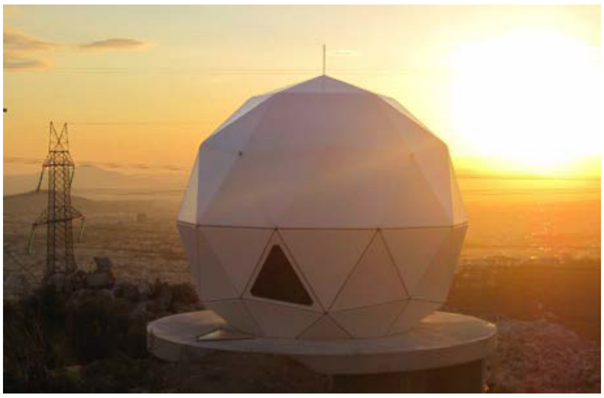
7. Improves the researchers' expertise, giving them skills in new techniques and state-of-the-art methodological approaches to analyse the data and generate useful information.
8. Involves industry, SMEs and public entities across south-eastern Europe, who have interest in exploiting the research potential that will be generated in BEYOND by adding new value to observations and derived information products, supporting their individual application domains.
9. Identifies and collaborates with leading experts across Europe in the relevant research domains addressed by BEYOND.
10. Develops sustainable interdisciplinary collaborative schemes across Europe.
11. Examines the conditions, and get exact knowledge on the procedures and even more take actions for patent issuing in the lifetime of BEYOND.
12. Identifies potential in commercially exploiting research outcomes after BEYOND.
13. Essentially increases the production rate of scientific publications by the end of BEYOND.

2. Key infrastructure

This section summarises the main infrastructural components that were procured in the framework of BEYOND, to complement existing capacities.

2.1 Ground Segment for satellite data acquisition

The IAASARS/NOA Ground and EO based Natural Disaster Application Segments have been expanded in the framework of the BEYOND project with the installation of an X-, and L-band satellite acquisition station for reception, acquisition, and processing of the direct broadcast downlinks from the current EOS Aqua & Terra, the NPP, the Fengyun, the NOAA and Metop as well as the future NPOESS satellites. The Ground Segment facilities foster the development of a wide range of environmental monitoring services, such as: aerosol pollution indexes assessment, dust and volcanic ash alerts, smoke dispersion forecasts, wildfire detection and monitoring, geo-hazard activity monitoring and assessment (earthquakes/ volcanoes/ landslides), and urban heat Island mapping.

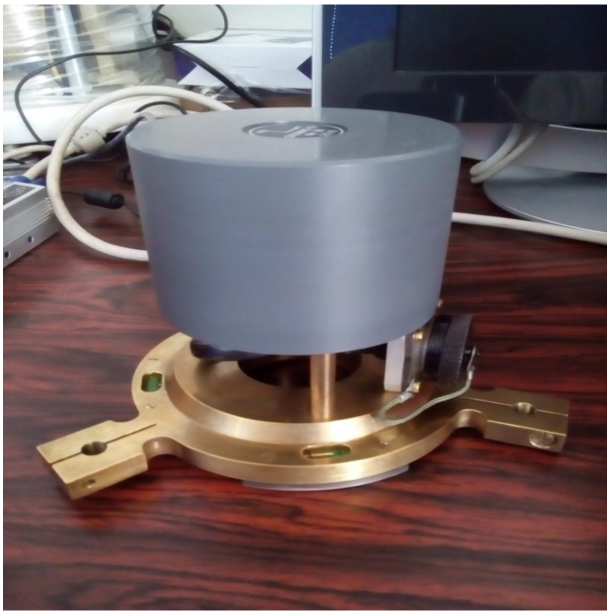


2.2 Development of a ground-based prototype lidar

A prototype backscatter/Raman/dual-wavelength polarization system for atmospheric light detection and ranging (lidar), specially designed to monitor atmospheric episodes and support the validation of BEYOND atmospheric models and satellite products has been. The lidar was constructed in the first year of BEYOND implementation plan and is operational through the end of the project in 24/7 basis, in order to accomplish the following scientific tasks: (i) Optimization of the smoke dispersion model through its validation, (ii) Validation of desert dust model forecasts and (iii) Volcanic ash monitoring.

2.3 Upgrade of the Hellenic Geomagnetic Array ENIGMA

The National Observatory of Athens currently operates ENIGMA (HellENIc GeoMagnetic Array), an array of 3 ground-based magnetometer stations in the areas of Trikala (Klokotos), Attiki (Dionysos) and Lakonia (Velies). Within the framework of BEYOND, the magnetic station of Klokotos in central Greece has been upgraded by replacing the existing outdated fluxgate magnetometer with a new GEOMAG-02 magnetotelluric instrument capable of performing simultaneous magnetic and electric (telluric) field measurements. The rationale for this purchase is to acquire homogeneous geomagnetic field recordings across Greece in order to be able to make intercomparisons between the measurements at various stations since in the other ENIGMA stations the same magnetic field sensor is already in operation. The particular upgrade of instrumentation will also allow for real-time monitoring of geomagnetic disturbances due to its modern and up-to-date electronic components and subsequent correlation with real-time seismicity.



2.4. UAV units

This fully autonomous drone, eBee SenseFly Professional mapping drone, was purchased be the BEYOND team, in order to capture high-resolution aerial photos that can be transformed into accurate orthomosaics & 3D models. The eBee sets the standard for easy flight planning and management, thanks to its acclaimed eMotion software. The users are able to choose or create their preferred background map. Then, by using the eMotion software, they are able to define the region they wish to map. Afterwards, they simply specify their desired ground resolution (down to 1.5 cm / 0.6 inches per pixel) and set the required image overlap. The rest of the procedure is automatic: eMotion automatically generates a full flight plan, based on GPS waypoints, calculates the eBee's required altitude and displays its projected trajectory. To ensure the mission's success, eMotion even offers a confidence-building simulation mode. This virtual flight simulates wind strength and direction, allowing users to make any flight plan enhancements needed before launch.

In addition, ATLAS 8 mini VTOL UAV is a compact UAS solution of high performance and quality. The octacopter system is based on a user friendly approach and through the Autopilot System and the UAS navigation software, the platform can be completely autonomous while on air, following the pre-determined flight plan set by the operator prior to the flight.

The specific version of the UAV was especially configured to meet the N.O.A. operational and technical requirements, as a tailored turnkey solution.

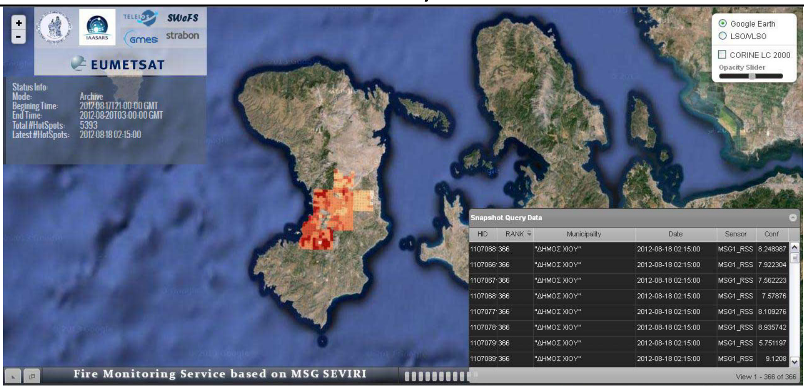
Four members of N.O.A. have been certified as ATLAS UAV operators after successfully completing the one-week theoretical and practical (hands-on) training program.

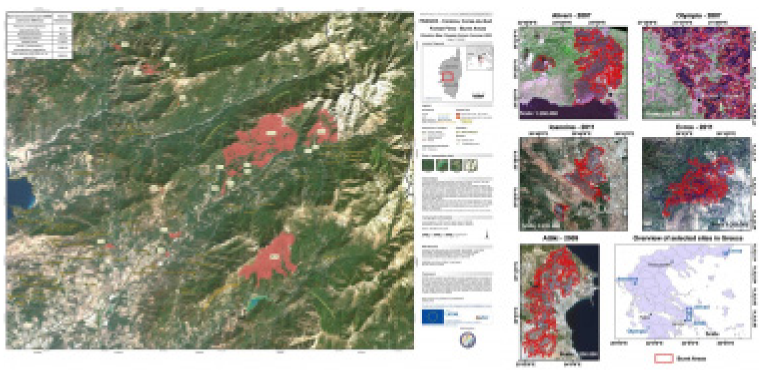
3. Portfolio of services

This section provides a structured summary of the services that have developed and are made available from BEYOND Center of Excellence. These services have used resources from BEYOND, namely satellite acquisition stations, software modules and know-how on new processing techniques.

3.1 Fires & floods monitoring

3.1.1 Forest wildfires

Name of the service	FireHub – Real-time fire monitoring		
Main technological/ algorithmic innovation	Downscaling of satellite data to improve spatial resolution of fire detections	**Satellite data used**	MSG/SEVIRI, MODIS, NPP, MetOP
Hardware	Ground segment for multi-satellite data reception	**Software**	In-house patented processing chain
Level of maturity	Operational	**Scale**	National
Transferability	Direct transferability to other areas	**Access**	http://ocean.space.noa.gr/FireHub
Short description of the service	The Real-time fire Monitoring System is continuously fed with new satellite acquisitions every 5 minutes from the MSG SEVIRI (EUMETSAT) satellite. Satellite receptions from other sensors complement the core observations. The system accounts for the wind direction, the ground morphology characteristics, the elevation zones, as well as the fuel characteristics of the affected areas, to downscale the initial observation of MSG SEVIRI sensor, from 3.5km spatial resolution to 500 meter resolution. The system incorporates a fully automatic processing chain, integrating efficient algorithms for image processing and classification, and producing maps of active fires. FireHub platform is install and used in an operational basis by the Greek Fire Brigade. The system is also used by the Directorate General of Forest Protection of the Min. of Environment, several institutional users and private entities all over Greece, the Local Authorities and the national Forestry services.		
Pilot / Use case examples	 *Figure 1. Detection of forest fires in Chios island, Greece based on FireHub system.*		

Name of the service	FireHub – Diachronic Burnt Scar Mapping		
Main technological/ algorithmic innovation	Automatic processing of a vast archive of HR optical satellite imagery	**Satellite data used**	Landsat & Sentinel-2
Hardware	PC cluster	**Software**	In-house software, complemented by NASA LEDAPS
Level of maturity	Operational	**Scale**	National
Transferability	Direct transferability to other areas	**Access**	http://ocean.space.noa.gr/FireHub
Short description of the service	Developed and implemented a fully automatic processing chain for Burnt Scar Mapping (mapping of burned areas), which is based on the exploitation and analysis of the full USGS archive of about 600 Landsat TM images, since the first satellite image was ever recorded over Greece (1984). NOA has developed a fully automatic single and/or multi date processing chain that takes as input satellite images of any spatial and spectral resolution and produces precise diachronic burnt area polygons and LU/LC damage assessments over the Greek territory. The entire BSM service chain was extensively evaluated in the framework of the GMES project SAFER, by subjecting it through a thorough standardization procedure using several criteria (thematic accuracy, user support, sustainability of the means used, transferability, timeliness, etc.). Following a test scenario for the island of Corsica, the NOA BSM service was qualified – top of its class – as an end-to-end service for fire related Emergency Support activities for integration to operational scenarios all over Europe.		
Pilot / Use case examples	 *Figure 2. (right) BSM mapping and damage assessment for selected fire events in the period 2007-2011 over Greece, and (left) Map product following the Emergency Support activation in Corsica.*		

<table>
<tr><td>Name of the service</td><td colspan="3">DisaterHub</td></tr>
<tr><td>Main technological/ algorithmic innovation</td><td>Integrating crowdsourcing information with satellite derived products</td><td>Satellite data used</td><td>Multi-satellite, based on the incorporation of different natural hazard monitoring services</td></tr>
<tr><td>Hardware</td><td>Sentinel Collaborative GS, and NOA GS</td><td>Software</td><td>In-house software, tailored for mobile/table use</td></tr>
<tr><td>Level of maturity</td><td>Pre-operational</td><td>Scale</td><td>National</td></tr>
<tr><td>Transferability</td><td>Transferability depends on the level of maturity of the different services that are being incorporated</td><td>Access</td><td>Not released yet</td></tr>
<tr><td>Short description of the service</td><td colspan="3">DisasterHub is exploiting the legacy of FireHub. It uses the FireHub architecture as an architectural paradigm upon which a strong representation tier is built for the better dissemination of the BEYOND EO services ecosystem. A powerful toolbox is being developed enabling the ingestion, processing and proper fusion/co-registration of multimodal big EO data along with information generated through crowdsourcing and participatory sensing. It will further consolidate, integrate and strengthen the communication between the four main sub-ecosystems of BEYOND ecosystem: (i) infrastructures ecosystem, (ii) data fusion/modelling ecosystem, (iii) processing chains ecosystem and (iv) products and services on the cloud ecosystem. This new EO services ecosystem will form the DisasterHub EO services ecosystem.</td></tr>
<tr><td>Pilot / Use case examples</td><td colspan="3">

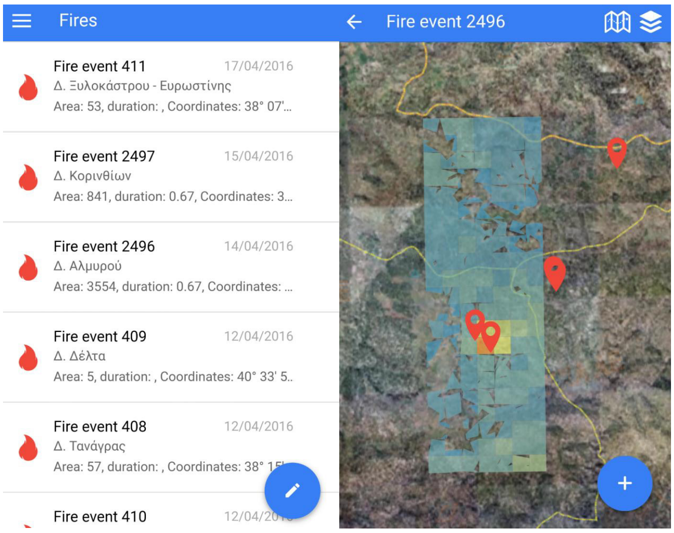


Figure 3. (left) mockup of the DisasterHub mobile application and (right) integrated use of FireHub satellite detections and participatory sensing (pins)

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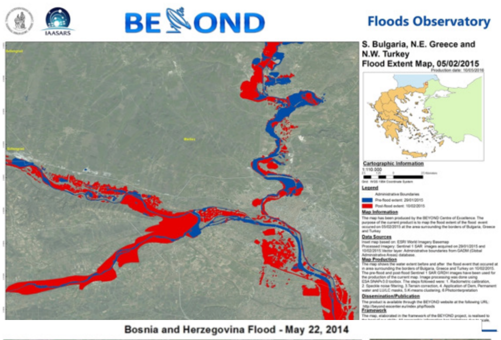
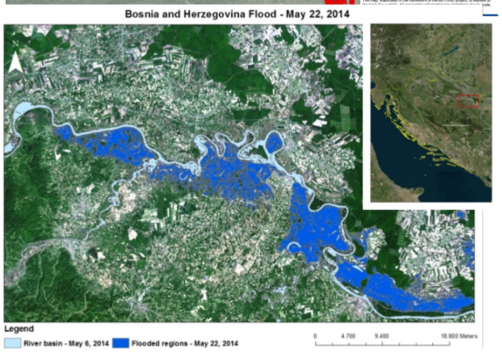
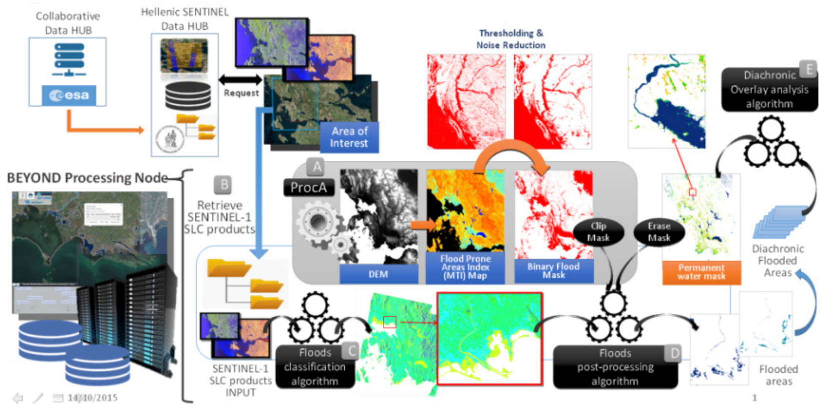
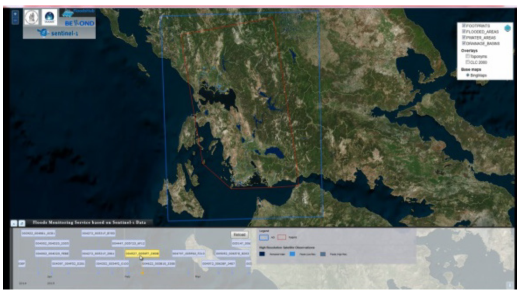
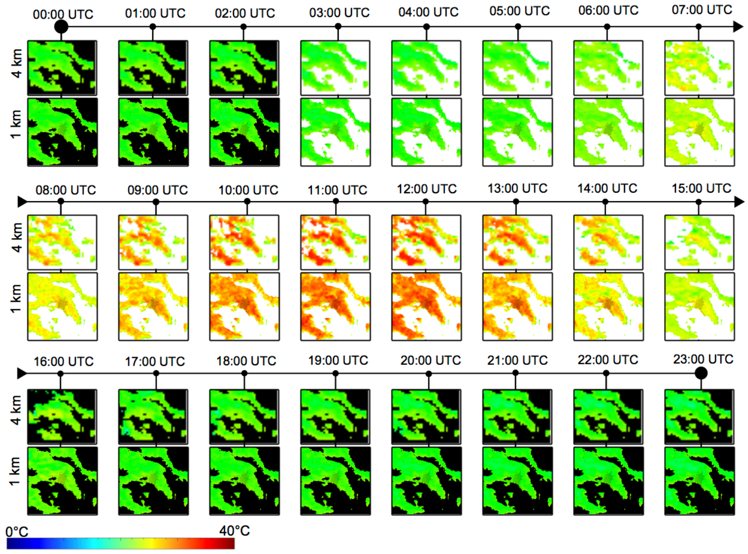
2.1.2 Floods

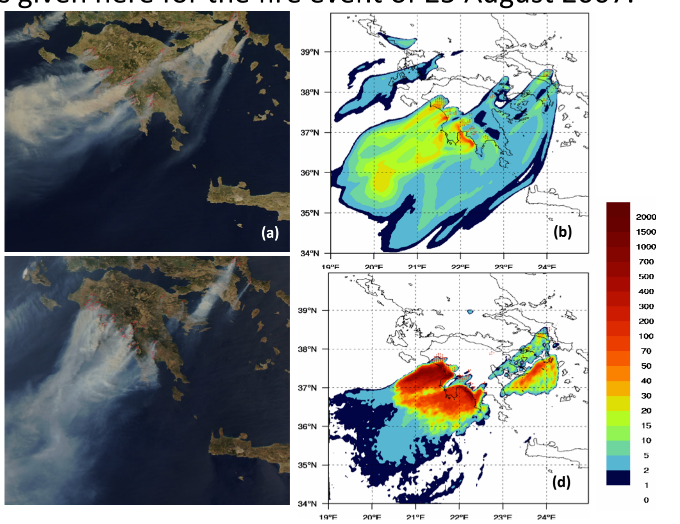
Name of the service	Floods Observatory		
Main technological/ algorithmic innovation	Combine different satellite data at high spatial scales to produce the best possible flood mapping results following the processing and photo-interpretation of satellite images.	**Satellite data used**	Both optical and SAR images can be used of different spatial and temporal resolutions.
Hardware	PCs	**Software**	ArcGIS as well as special software for the processing of each type of satellite images. GoogleMyMaps for the interface.
Level of maturity	High	**Scale**	Greece & South-Eastern Europe
Transferability	Applicable to other areas too.	**Access**	http://www.beyond-eocenter.eu/index.php/floods/floods-observatory
Short description of the service	The service is operational since 2014. Major flood events are registered and the flood mapping results produced following the processing and photo-interpretation of satellite Optical and SAR images are published on the online platform.		
Pilot / Use case examples	1) Floods in Greece, Bulgaria, Turkey, Evros river, 05/02/2015 Sentinel 1 SAR images were used: a pre-flood image of 29/01/2015 and a post-flood image of 10/02/2015. Pre-flood water extent is show in blue and post-flood water extent is shown in red.  2) Floods in Bosnia and Herzegovina, 22/05/2014 Landsat 8 satellite images were used: a pre-flood image of 06/05/2014 and a post-flood image of 22/05/2014. Pre-flood water extent is show in light blue and post-flood water extent is shown in dark blue.  		

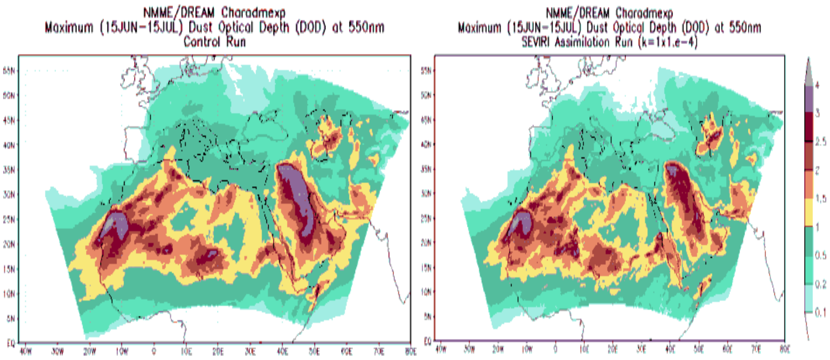
Name of the service	FloodsHUB		
Main technological/ algorithmic innovation	The first fully automated process based on the Hellenic National Sentinel Data Mirror Site to monitor all the flood events in selected river basins.	**Satellite data used**	Sentinel-1 images from the Hellenic National Sentinel Data Mirror Site at NOA's premises.
Hardware	BEYOND Processing Node at the Hellenic SENTINEL Data HUB	**Software**	Python, GDAL, Graph, PostgreSQL, PostGIS
Level of maturity	High	**Scale**	West Greece
Transferability	Adaptable to other areas.	**Access**	http://www.beyond-eocenter.eu/index.php/floods/floodhub
Short description of the service	The service is pre-operational since 2015. All the flood events in selected river basins are monitored, and the flood mapping results are published on the online platform following the processing of Sentinel-1 images from the Hellenic National Sentinel Data Mirror Site. The service provides floods mapping and floods extent measuring per flood event, as well as diachronic flood classification results. After the retrieval of S1 products, the floods monitoring application also uses a number of input data layers and applies a series of processing modules: Binary Flood Mask extraction, Floods classification algorithm, Floods post-processing algorithm, Diachronic Overlay analysis algorithm. 		
Pilot / Use case examples	The first pilot study is Arachthos & Acheloos river basins in west Greece, where the Public Power Corporation S.A. Hellas is operating major hydroelectric plants. The processing and analysis for the first hydrological year with available Sentinel-1 images (2014-2015) is completed; and the second hydrological year (2015-2016) is now being processed. 		

3.2 Monitoring of the urban environment

Name of the service	**Monitoring of the thermal urban environment**		
Main technological/ algorithmic innovation	Operational and real time downscaling of Land Surface Temperatures at Cities from 4-5 km down to 1km at a temporal resolution of 5’	**Satellite data used**	MSG SEVIRI RSS MODIS (MOD11A1, MYD11A1, MOD13A2) Shuttle Radar Topography Mission (SRTM) CORINE Land Cover
Hardware	MSG-SEVIRI EUMETCast station; EUTELSAT 10A; NOVRA decoder	**Software**	Complete operational processing chain; Automatic extraction of Surface UHI patterns from LST products
Level of maturity	High	**Scale**	Athens
Transferability	European Cities	**Access**	http://beyond-eocenter.eu/index.php/urban-environment/urban-real-time-products
Short description of the service	The system comprises separate modules: satellite image acquisition, cloud screening, and sharpening of LST. The cloud screening (integrating SAFNWC software component) delineates the cloud-free pixels allowing the LST derivation to be applied only to clear sky thermal infrared radiances. Lastly, LST imagery is downscaled down to 1 km spatial resolution using Support Vector Regression Machines (SVM) and iterative gradient boosting. Evaluation showed that the accuracy of the produced data is comparable or better to other published LST sharpening methods.		
Pilot / Use case examples	 *Figure 4. Example of the original (4km) and sharpened (1km) distribution of Land Surface Temperature for Athens, Greece during a summer day (29/8/2014*		

3.3 Atmospheric modelling

Name of the service	FireHub-Smoke Dispersion Service		
Main technological/ algorithmic innovation	Employ geostationary satellite data and models at high spatial and temporal scales to resolve local scale atmospheric features and forecast smoke dispersion	**Satellite data used**	MSG SEVIRI
Hardware	128 CPU cluster PollyXT for validation	**Software**	FLEXPART-WRF model
Level of maturity	High	**Scale**	Greece
Transferability	Easily adaptable to other areas within Europe	**Access**	http://beyond-eocenter.eu/index.php/fires/fire-smoke-dispersion
Short description of the service	The smoke dispersion service in BEYOND is operational since 2014. The service is based on a satellite / modeling synergy and incorporates MSG SEVIRI detections of wildland fires (FIREHUB) to trigger smoke dispersion simulations over Greece with the Lagrangian model FLEXPART-WRF. The forecasting results include smoke particulate matter concentrations near the surface as well as integrated columns of smoke concentrations.		
Pilot / Use case examples	The advanced capabilities of the new system are demonstrated through a series of detailed simulations of complex case studies over Greece and modelling results are evaluated against independent satellite observations from MODIS and MISR satellite sensors. An example is given here for the fire event of 25 August 2007.  *Figure 5. a) MODIS image on 25 August 2007 20:00 UTC; b) Simulated column concentration of smoke TPM (mg m-2), 25 August 2007 20:00 UTC; c) MODIS image on 26 August 2007 09:30 UTC; d) Simulated column concentration of smoke TPM (mg m-2), 26 August 2007 09:30 UTC*		

Name of the service	Atmospheric dust modelling including satellite assimilation		
Main technological/ algorithmic innovation	Assimilation of satellite dust optical depth from a geostationary satellite sensor (MSG-SEVIRI) in an atmospheric dust model (NMM-DREAM).	**Satellite data used**	MSG-SEVIRI
Hardware	128 CPU cluster PollyXT for validation	**Software**	NMM-DREAM
Level of maturity	High	**Scale**	Europe-North Africa
Transferability	No	**Access**	http://beyond-eocenter.eu/scripts/dust_static/dust.html
Short description of the service	Until recently, the lack of atmospheric observations over the dust source areas (usually deserts and arid regions) did not allow the retrieval of sufficient data at spatial and temporal scales that could be useful for driving the dust modeling simulations. In-situ meteorological information is very sparse over dust source areas and air-quality information is even more difficult to obtain. This situation is now improved with the use of satellite data. In this direction a new modelling tool has been developed in the frame of BEYOND incorporating the assimilation of satellite dust optical depth (DOD) from the Meteosat Second Generation - Spinning Enhanced Visible and Infrared Imager (MSG-SEVIRI) into the Dust Regional Atmospheric Model module of the Nonhydrostatic Mesoscale Model. This service is running in test mode since October 2015.		
Pilot / Use case examples	A comparison between the standard model configuration (NO-ASSIM) and the run that includes assimilation of satellite DOD (MSG-ASSIM) is studied for the maximum DOD values during the period 15 June-15 July 2014.  *Figure 6. Maximum DOD: left) NO-ASSIM; right) MSG-ASSIM*		

Name of the service	Volcanic Ash Dispersion Service

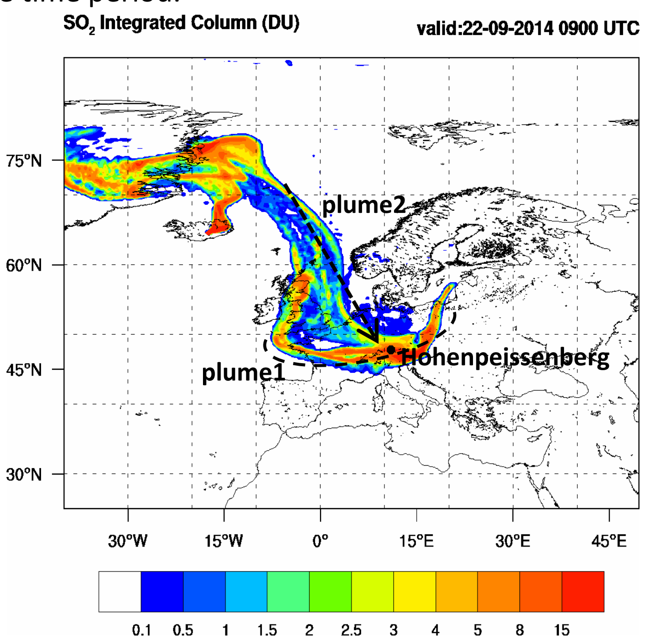
<table>
<tr><td>Main technological/ algorithmic innovation</td><td>Development of near-real time warning system regarding volcanic emissions (volcanic ash and SO_2)</td><td>Satellite data used</td><td>None</td></tr>
<tr><td>Hardware</td><td>128 CPU cluster</td><td>Software</td><td>FLEXPART-WRF</td></tr>
<tr><td>Level of maturity</td><td>High</td><td>Scale</td><td>Global</td></tr>
<tr><td>Transferability</td><td>On demand</td><td>Access</td><td>On demand</td></tr>
<tr><td>Short description of the service</td><td colspan="3">In the frame of BEYOND, the FLEXPART-WRF Lagrangian dispersion model has been configured to perform forward and backward simulations of volcanic plumes and thus contribute in the development of a near-real time warning system regarding volcanic emissions in the atmosphere. The model is driven by hourly meteorological fields from the Weather Research and Forecasting (WRF) atmospheric model. A total of 40,000 tracer particles are assumed for each release in FLEXPART simulations. Source-receptor relationships between station measurements and volcanic activity are also analyzed with the use of the model.</td></tr>
<tr><td>Pilot / Use case examples</td><td colspan="3">An example of this application has been studied for the eruption of the Icelandic volcano of Bardarbunga on September 2014. The secondary plume is advected southwards by the intense northerly winds over the North Sea and the two plumes overlap at about 09:00-11:00 UTC over the Brewer station of Hohenpeissenberg that reported maximum columnar concentrations of SO_2 during the same time period.


Figure 7. Integrated column of SO2 (DU) from Bardarbunga emissions as simulated with FLEXPART-WRF model on 22nd of September 2014 09:00 UTC</td></tr>
</table>

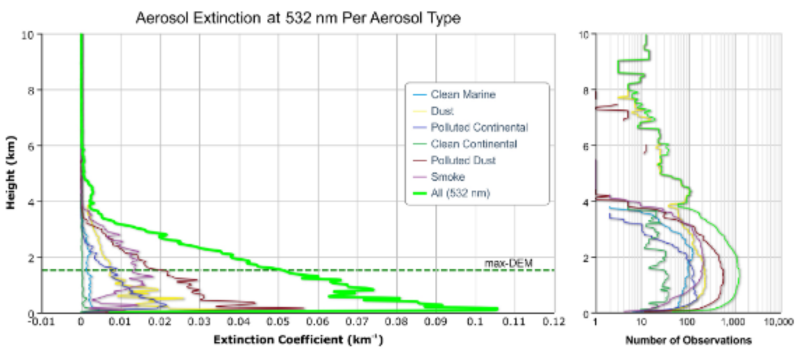
<table>
<tr><td>Name of the service</td><td colspan="3">Lidar Climatology of Vertical Aerosol Structure (LIVAS)</td></tr>
<tr><td>Main technological/ algorithmic innovation</td><td>A new database with global profile statistics of aerosol and cloud properties</td><td>Satellite data used</td><td>CALIPSO</td></tr>
<tr><td>Hardware</td><td>EARLINET aerosol network</td><td>Software</td><td>ArcGIS, Matlab</td></tr>
<tr><td>Level of maturity</td><td>High</td><td>Scale</td><td>Global</td></tr>
<tr><td>Transferability</td><td>-</td><td>Access</td><td>http://lidar.space.noa.gr:8080/livas/</td></tr>
<tr><td>Short description of the service</td><td colspan="3">LIVAS provides a global 3-dimensional aerosol and cloud optical climatology and a collection of case studies focused on atmospheric episodes related to specific aerosol/cloud types (extended atmospheric scenes, i.e. Saharan dust events, smoke and volcanic eruption events, polar-stratospheric clouds etc).</td></tr>
<tr><td>Pilot / Use case examples</td><td colspan="3">The final LIVAS aerosol/cloud database contains multi-wavelength 4-year averaged vertical distributions and statistics for a global grid of 1°x1°. The database is installed on an integrated system that stores and exposes the aforementioned datasets available for exploitation and analysis. An example is presented in the following Figure (from Amiridis et al., 2015), showing the LIVAS product on one grid cell corresponding to Athens.


Figure 8. LIVAS aerosol extinction products. Vertical distribution of the averaged aerosol extinction coefficient per aerosol type (left) and number of observations used in averaging (right).</td></tr>
</table>

3.4 Geo-hazards monitoring

Name of the service	Estimation of crustal deformation due to abrupt phenomena		
Main technological/ algorithmic innovation	Integrated use of differential interferometry (DInSAR), multiple aperture interferometry (MAI) and offset tracking	**Satellite data used**	SAR data: Sentinel-1, ERS, Envisat, ALOS PALSAR, COSMO-SkyMed, TerraSAR-X, Radarsat-2
Hardware	Sentinel Mirror Site + PC cluster	**Software**	Sarscape, SNAP (Sentinel Toolbox), ROI_PAC
Level of maturity	High	**Scale**	Regional
Transferability	Directly transferable to any geographic region	**Access**	http://www.beyond-eocenter.eu/index.php/geophysical/earthquakes
Short description of the service	Radar interferometry has highlighted the value of remote geodetic measurements for estimating ground displacement with unprecedented spatial coverage and accuracy. Interferometry is based on the simple idea that by sensing the same object or scene twice, in separate times, one can identify the changes that the observed object or scene has undergone between these two distinct time instants.		
Pilot / Use case examples	On 26 January 2014 a Mw 6.0 earthquake struck the island of Cephalonia, Greece, followed five hours later by a Mw 5.3 aftershock and by an Mw 5.9 event on 3 February 2014. Shortly after we ordered and processed Very High Resolution COSMO-SkyMed and TerraSAR-X SAR data, employed different interferometry techniques. The diversity of the observations and algorithms lead to the estimation of the three-dimensional deformation the occurred due to the earthquake.		

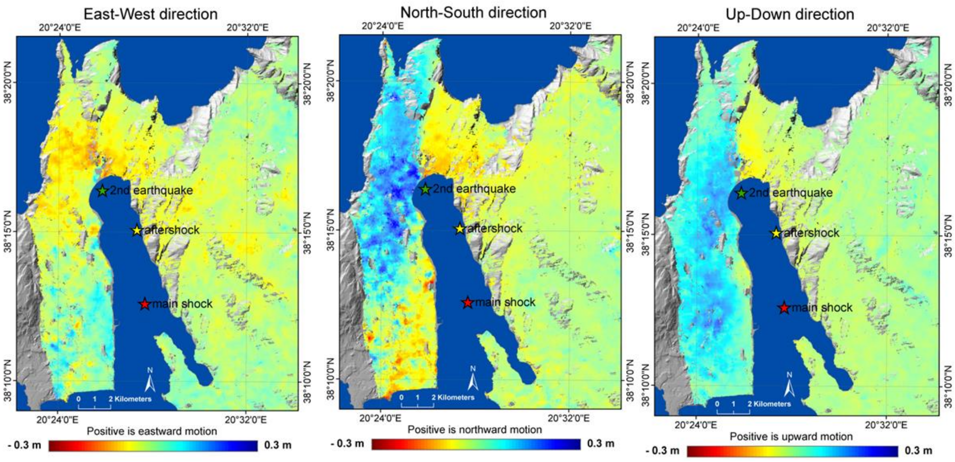


Figure 9. Crustal deformation in the east-west (left), north-south (middle) and vertical dimensions.

Name of the service	Estimation of diachronic small scale deformation in geohazardous areas		
Main technological/ algorithmic innovation	Persistent Scatterer Interferometry, tailored to monitor diverse geohazards	**Satellite data used**	SAR data: Sentinel-1, ERS, Envisat, ALOS PALSAR, COSMO-SkyMed, TerraSAR-X, Radarsat-2
Hardware	Sentinel Mirror Site + PC cluster	**Software**	StaMPS, Sarscape, ROI_PAC, DORIS, SNAP
Level of maturity	Dependent on the geohazard: Tectonic motion: Research Urban subsidence: Operational Volcanic activity: Research Landslide: Research	**Scale**	Regional Tectonic motion: Regional Urban subsidence: City-wide Volcanic activity: Site specific Landslide: Local
Transferability	Directly transferable to any geographic region. Landslides monitoring require prior knowledge	**Access**	http://www.beyond-eocenter.eu/index.php/geophysical
Short description of the service	Persistent Scatterer Interferometry relies on the processing of a time series of differential interferograms to estimate millimetre scale displacements on the ground. The technique relies on the detection of stable targets that do not change their scattering characteristics over time and remain coherent under all imaging geometries. The technique is applied to systematically monitor different geohazards (urban subsidence, volcanic activity, tectonic motion and landslide creep), and estimate the regional hazard potential.		
Pilot / Use case examples	2011 Santorini inflation episode, due to the intrusion of magma in a chamber 4 km beneath the caldera		

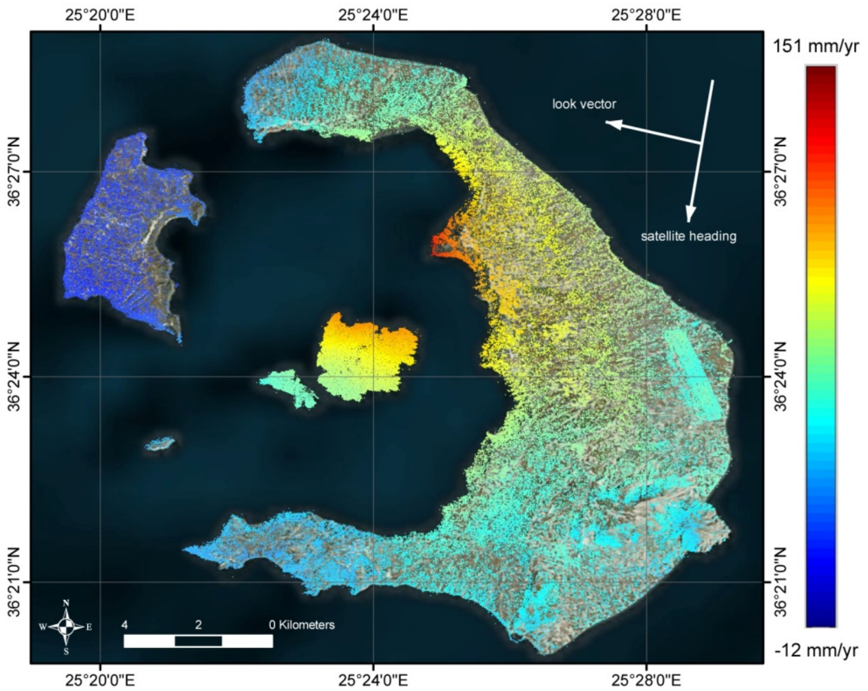


Figure 10. Line-of-sight velocities of Santorini in the period 2011-2012, rising up to 15cm/yr

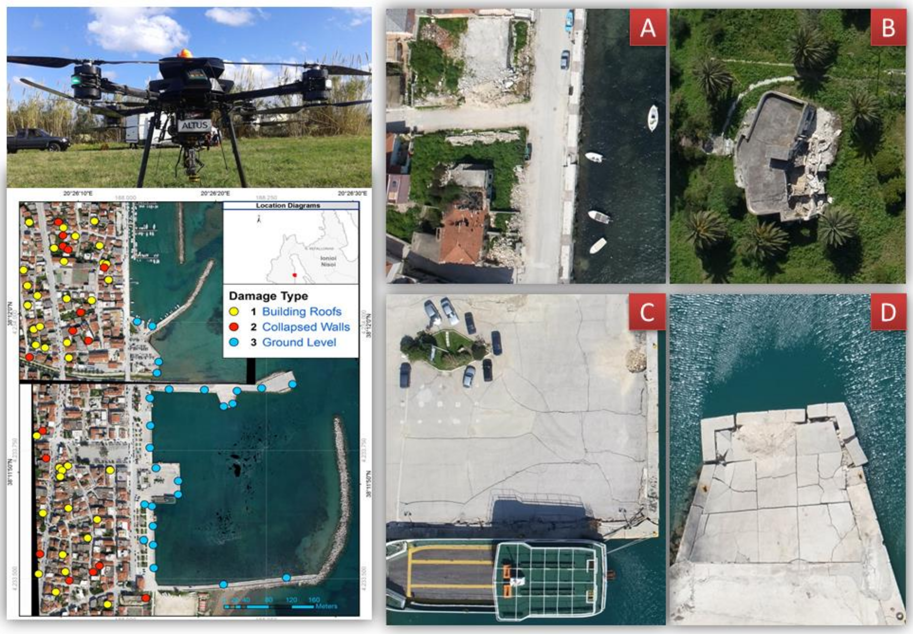
<table>
<tr><td>Name of the service</td><td colspan="3">UAV based damage assessment</td></tr>
<tr><td>Main technological/ algorithmic innovation</td><td>Robust and timely classification of very high resolution aerial data</td><td>Aerial data used</td><td>VHR aerial data</td></tr>
<tr><td>Hardware</td><td>UAV and Octocopter</td><td>Software</td><td>On-board classification s/w</td></tr>
<tr><td>Level of maturity</td><td>Operational, available on demand</td><td>Scale</td><td>Local</td></tr>
<tr><td>Transferability</td><td>Portable to inflicted areas in Greece</td><td>Access</td><td>http://www.beyond-eocenter.eu/index.php/geophysical/uav-based-loss-recording</td></tr>
<tr><td>Short description of the service</td><td colspan="3">UAV technology assist in mapping damages following a catastrophic event and assessing the Mercalli Intensity of the earthquake.
A few hours following the event, local authorities and public bodies can ask for a quick assessment of the main areas inflicted, to assist in the effective deployment of their human resources on the ground.
We now have two units, a UAV airplane and an Octocopter, available upon request.</td></tr>
<tr><td>Pilot / Use case examples</td><td colspan="3">Following the 2014 Cephalonia earthquake sequence, we run a successful pilot by making a total of 10 flights over several villages and Lixouri city, to map the damages on the ground (roof collapses, wall damages, landslides etc.).


Figure 11. Recorded damages over Lixouri city, Cephalonia</td></tr>
</table>

4. BEYOND impact

4.1 Environmental dimension

4.1.1 FireHub

In Mediterranean basin fire has been one of the main driving forces in the evolution of plants and ecosystems from the onset of Mediterranean climate, determining the current structure and composition of Mediterranean Landscape. The effect of fire on the evolution of plants and ecosystems has been so important that only species possessing adaptive or exaptive traits allowing them to overcome the detrimental effects of a particular fire regime, could survive in the fire prone areas of the earth. In the same region, significant alterations in the fire regime have occurred, primarily as a result of socioeconomic changes, increasing dramatically the catastrophic impacts of wildfires as it is reflected in the increase during the 20th century of both, number of fires and the annual area burnt.

A careful reconsideration of the wildfire management strategy appears to be necessary in order to avoid the devastating impacts of wildfires in ecosystem's ecological integrity, society and economic activity. Such a strategy has to take seriously into account the historical and ecological role of fire as well as the contemporary patterns of wildfire distribution and behavior. Comprehensive, spatially consistent and highly accurate digital maps of burnt areas at large national scales are indispensable for the in depth understanding of wildfires phenomenon and subsequently the planning of an effective wildfire management strategy.

Assessing burnt areas in mountainous regions is a difficult task due to landscape complexity, highly accentuated morphology and the heterogeneity and mixture of land cover. Previous attempts for burnt area mapping using conventional surveying methods allowed only partial and rough assessments of burnt areas. Fire Hub realized in **BEYOND** as a national scale service, promotes the use of satellite data as an alternative to conventional monitoring and aerial mapping, which have proven to be more labor-intensive and time-consuming and less exhaustive and accurate. The results have revealed a wealth of information not available before for monitoring and mapping the environment.

4.1.2 Smoke

Emissions of smoke from open biomass burning (BB) are an important feature of the Earth system as they include numerous gas and aerosol species many of them associated with climate change. According to most climate change scenarios (IPCC, 2014) the number of large fires worldwide is expected to increase in the coming decades. In this context the effects of BB emissions on weather and climate need to be carefully assessed. Emissions of gases such as CO, CO2 and CH4 have long been associated with climate change, but significant uncertainty remains regarding the role of black carbon (BC) and organic carbon (OC) aerosols in the atmosphere. Smoke aerosols affect also radiative transfer and serve as Cloud Condensation Nuclei (CCN) and ice nuclei (IN) affecting the formation of clouds. The net effect of BB emissions on climate change becomes even more uncertain when the change in surface albedo from the deposition of BC on ice and snow and the decline of sensible heat flux over the burned area that persists for decades are taken into account. The overall uncertainty in the composition and magnitude of the BB aerosol emissions in climate models makes the quantification of BB net radiative forcing uncertain as well and emphasizes on the need for a more accurate representation of smoke emissions and dispersion in relevant modeling studies. Apart from the atmospheric forcing, smoke emissions from both agricultural and forest fires deteriorate air quality and can result in serious health hazards. The principal health threat related to BB smoke is the possible inhalation of smoke particulate matter (PM) since the smoke particles are usually within the fine particle size range (PM2.5). In Europe, more than 50,000 fire episodes per year result in about 5000 km2 of burned forests. Although this is much less than for example in Asia or North America, these fires are still important because of the high population density in Europe. Vegetation fires are also significantly contributing to trans-boundary pollution. In general, intense fire events that last for several days are capable of producing elevated smoke plumes that can travel over thousands of kilometers. The fate of smoke plumes in the atmosphere is determined by the initial properties of the fire itself (i.e. fuel type, load, and moisture, pyrocumulus convection, injection height) and by the local and regional atmospheric conditions (atmospheric stability, mixing layer depth, wind shear, etc.).

The development of **FireHub / Smoke dispersion service in BEYOND** allows for the first time the real time coupling of SEVIRI hotspot detections with FLEXPART-WRF simulations of smoke dispersion. Quantification of these emissions provides an important tool for climate and atmospheric considerations related to the environmental smoke effects.

4.1.3 Urban Thermal Environment

Heat waves are extended periods of extremely hot weather that have a major impact on human health, socio-economics and natural systems. According to the European Environmental Agency in the decade between 1998 and 2009 heat waves were the most prominent hazard in Europe causing more than 70 000 excess deaths during the extreme summer of 2003 (EEA 2010). Extreme temperature events are normal features of inter-annual temperature variability, but their frequency and intensity have increased both in SW, Midwest and SE United States, in Western and Central Europe as well as in Mediterranean regions. Furthermore, the Intergovernmental Panel on Climate Change (IPCC 2007) projected impacts included a 'very likely' increase in frequency of heat extremes and heat waves in Europe (WMO 2011). Increased attention has been drawn to natural hazards and the European Commission has published guidelines (EC 2010) for risk assessment and mapping for appropriate disaster management following a Council Conclusions call (Council of the European Union 2009).

The delineation of high risk zones is critical for the adoption of effective targeted measures in areas of public and private activity rather than in the whole city agglomeration. The evaluation of extreme events may support decision makers, stakeholders and interested parties to agree on the preventive measures to take and to prepare in ways to avoid the immediate heat wave consequences, most notably in citizens' health as well as energy demand in future events. Therefore, in order to answer how severe a heat wave is, an expert will have to consider the intra-urban variability of the hazard, as well as the local socio-economic factors and their geographical variation. In that context, the continuous monitoring of the distribution of urban temperatures at 1km every 5’ that was made possible within the framework of **BEYOND** has offered a big step forward.

4.1.4 Floods

Floods are the most common and most costly natural disasters in Europe. Severe floods with devastating effects happen every year. Floods may cause fatalities, displacement and economic losses. The assets at risk of flooding can be enormous. In addition to economic and social damage, floods may have severe environmental consequences, as for example when waste water treatment plants are inundated or when factories holding large quantities of toxic chemicals are also affected. Floods may also destroy wetland areas and reduce biodiversity. In parallel, Europe's biodiversity is under severe pressure from many forms of human activities while other issues such as water scarcity and droughts are becoming more pronounced.

The EU Floods Directive (2007/60/EC) on the assessment and management of flood risks aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. The Directive requires Member States to first carry out a preliminary assessment to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood risk maps and establish flood risk management plans focused on prevention, protection and preparedness.

The BEYOND **Floods Observatory and the FloodHub service** contribute to the implementation of the EU Floods Directive, and support the integrated flood risk management. On the one hand, BEYOND’s Floods Observatory registers all major flood events in South-Eastern Europe and publishes the flood mapping results produced following the processing and photo-interpretation of satellite Optical and SAR images. On the other hand, BEYOND’s Floods Monitoring Service FloodHub monitors all the flood events in Arachthos & Acheloos river basins in Greece (where the Public Power Corporation S.A. Hellas is operating major hydroelectric plants) and publishes the floods mapping and floods extent measuring results produced following the processing of Sentinel images from the Hellenic National Sentinel Data Mirror Site, through a fully automated process.

4.1.5 Atmospheric Dust

Mineral dust is one of the most important aerosol types. Dust particles significantly impact radiation, while they also interact with liquid or ice clouds modifying their optical properties and lifetimes and affecting the precipitation processes. Once dust particles are deposited at the surface, they provide micro nutrients to the ocean or to land ecosystems. For these reasons, the recent report of the IPCC identified mineral dust and its impacts on weather, climate and biogeochemistry as key topics for future research.

The development of satellite/modeling synergies in the frame of **BEYOND** contributes in the description of the dust cycle in the atmosphere. Dust optical depth retrievals from the MSG-SEVIRI sensor are assimilated in the operational dust forecast cycle of NMM-DREAM model. Initial fields are nudged towards satellite observations and dust emissions are represented in greater detail in the model. This coupling of real-time geostationary information of dust with atmospheric dust modeling tools is an important achievement of BEYOND and the dust related environmental services will benefit for all future improvements in both satellite and modeling sectors.

4.2 Economic growth opportunities

4.2.1. Geophysical

Employing Persistent Scatterer Interferometry (PSI) techniques to estimate ground deformation velocities has several economic implications. Assessment of the hazard potential in regional scale for several geophysical disasters, such as landslides, volcanic eruptions and earthquake, can lead to the deployment of more effective crisis preparedness plans and application of mitigation measures from the local and governmental authorities. Such actions plans lead to increasing resilience and its impact to assets of economic value, such as industrial units, national infrastructure, agriculture, etc.

In the Oil & Gas industry, PSI is used for over producing reservoirs to optimize field operations, to calibrate geomechanical models and to compartmentalize reservoirs, while within the mining industry, PSI is used to monitor subsidence in open pit mines, waste piles and tailings, as well as in underground mines.

Ground velocities are also used to monitor the stability of civil engineering works, such as construction of underground stations and lines and large buildings (e.g. stadiums). PSI can also reveal water over-pumping in agricultural areas, alarming for a decrease of the aquifer levels, and hence allow for recovery measures to be considered for optimum water management.

4.2.2. Urban Thermal Environment

The Urban Heat Island (UHI) effect refers to the relative higher temperature of the dense urban areas in respect to their suburban/rural surroundings. This thermal anomaly may occur during daytime or nighttime and exhibits strong spatial and temporal variations. These variations depend on the different rates of warming and cooling that characterize each land cover type and material.

In quantitative terms, the annual mean air temperature of a city with 1 million people or more can be 1-3°C warmer than its surroundings. In the evening UHI can be as high as 12°C. One of the detrimental impacts of the UHI is the increased energy consumption as cities use more electricity for cooling in summer. In the United States, Hashem Akbary's Heat Island Group in Berkeley University have found that this increase in air temperature is responsible for 5-10% of urban peak electric demand for a/c use, and as much as 20% of population weighted smog concentrations in urban areas. Research shows that electricity demand for cooling increases 1.5-2.0% for every 1°F (0.6°C) increase in air temperatures, starting from 20 to 25°C, suggesting that 5-10% of community-wide demand for electricity is used to compensate for the heat island effect. Apart from the increase of the overall electricity demand, UHI also increases the peak demand. During heat waves, which are exacerbated by urban heat islands, the resulting demand for cooling can overload systems and require measures to avoid power outages.

The continuous monitoring of UHI that has been realised in BEYOND can therefore be used as basis for energy demand assessment and better management of energy resources.

4.2.3. Atmospheric composition and air quality

Volcanic eruptions are an important source of natural emissions into the troposphere and the stratosphere. Ash particles and gases injected into the atmosphere by large volcanic eruptions can affect solar radiation and climate, air quality and may also impact local environments. Volcanic ash can reach different heights in the atmosphere and can be transported in different directions. Limited visibility inside the ash plumes as well as injection of volcanic particles in jet engines can have impacts far from the source and can be responsible for air travel disruptions with obvious economic impacts.

There have been various efforts in the last years to monitor volcanic eruptions focusing mostly on aviation, e.g. ESA's Support to Aviation Control Service (SACS). These initiatives together with modeling forecasting tools provide valuable information to the established Volcanic Ash Advisory Centers (VAAC). The development of a detailed modeling application in the frame of BEYOND allows the accurate description and forecast of volcanic plumes trajectories. Coupling of the regional atmospheric model WRF with the Lagrangian dispersion model FLEXPART has been demonstrated to effectively forecast volcanic dispersion up to five days ahead. This service can have significant economic impacts on aviation operations and provide a reliable tool to reschedule air traffic during volcanic episodes.

4.2.4. Floods

Catastrophic floods endanger lives and cause human tragedy as well as heavy economic losses. Between 1998 and 2002, Europe suffered over 100 major damaging floods. Between 1998 and 2004, floods caused some 700 fatalities, the displacement of about half a million people and at least € 25 billion in insured economic losses (European Environment Agency, Mapping the impacts of recent natural disasters and technological accidents in Europe). A 2011 EEA report "Mapping the impacts of natural hazards and technological accidents in Europe" reported that between 1998-2009 flooding and storms were still the most costly hazards, and that by 2009, the number of fatalities had reached 1126 in 213 recorded flood events. The overall losses recorded for this period now added up to about EUR 52 billion for floods and EUR 44 billion for storms. The assets at risk of flooding can be enormous. For example, more than 10 million people live in the areas at risk of extreme floods along the Rhine, and the potential damage from floods amounts to € 165 billion. Coastal areas are also at risk of flooding. The total value of economic assets located within 500 meters of the European coastline, including beaches, agricultural land and industrial facilities, is currently estimated at € 500 to 1,000 billion (EUrosion, European Commission, Floods and their impacts).

The BEYOND Floods Observatory and the FloodHub service contribute to the implementation of the EU Floods Directive. These services together with an early warning system which is currently under development in a pilot study in Greece can contribute significantly to the reduction of the economic damage, bringing a considerable added value and improving the overall level of flood protection. The first case study is the river basin of Arachthos in west Greece, a river with several flood events, just upstream of the city of Arta, where the Public Power Corporation S.A. Hellas (PPC S.A.) is operating two hydroelectric plants of high economic value. In the framework of BEYOND, NOA has signed a MoU and established cooperation with the PPC S.A., as there is a mutual interest in the field of studying floods and developing a methodology for monitoring and managing flood risks.

4.3 Exploitation directions

The exploitation of BEYOND to ensure its sustainability beyond the project's lifetime relied onto four main pillars: (i) the formal protection of IP generated, (ii) attracting new funds in European frameworks, (iii) formally participating in large scientific and infrastructure networks, and (iv) developing a concrete exploitation plan to capitalise on the assets and research potential developed though this capacity building project.

Patent submission:

The National Observatory of Athens participated in the Best Service Challenge of the Copernicus-masters competition with the operational EO based fire management service, which was developed in the framework of the BEYOND project. The submitted service is entitled "*FireHub: A Space Based Fire Management Hub*", and has been elected as the **winner of the Best Service Challenge of the Copernicus Masters 2014** by an experts committee. A patent application was submitted to the Hellenic Industrial Property Organization (OBI), with identification number 20150100061. After being evaluated, OBI **tentatively granted the patent on 16/03/2016**, the first ever patent awarded to the National Observatory of Athens.

Figure 12. The FireHub Winning Team (Photo: © Jan Kobel).

Research funding proposals:

Continuity of BEYOND is secured through seamless funding. The new projects that were awarded to BEYOND and NOA are summarised in the next figure.

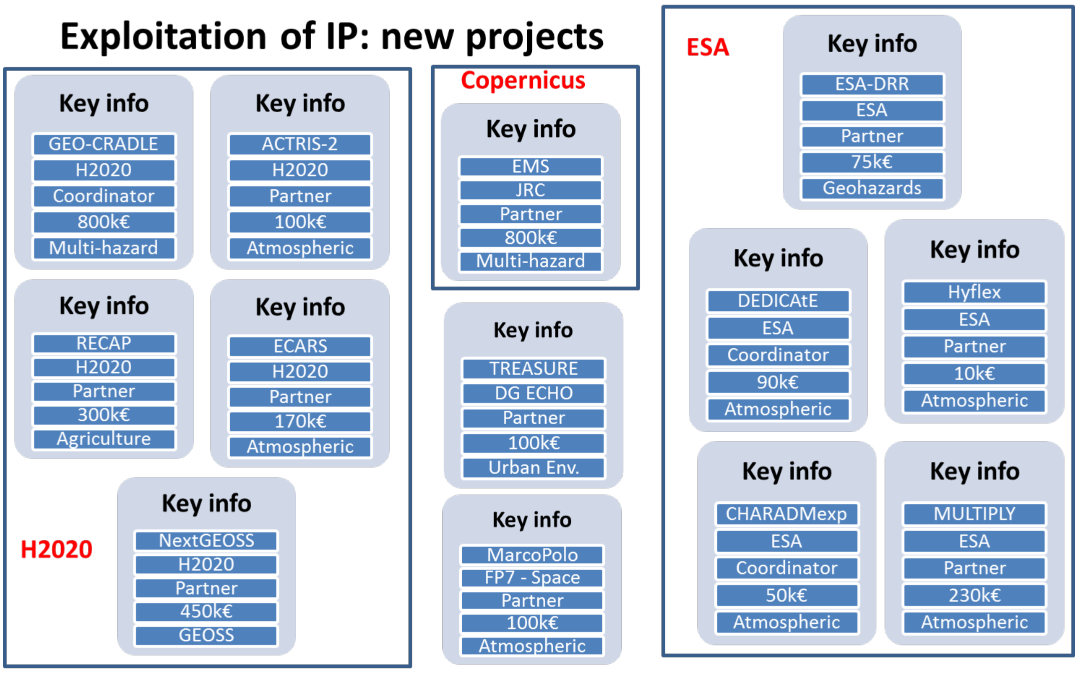


Figure 13. New funds that were attracted based on the use of the BEYOND human and infrastructural resources

The cornerstone of our efforts was securing the coordination of H2020 project GEO-CRADLE (Coordinating and integRating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East, and Balkans and Developing Links with GEO related initiatives towards GEOSS).

GEO-CRADLE brings together key players representing the whole (Balkans, N. Africa and M. East) region and the complete EO value chain with the overarching objective of establishing a multi-regional coordination network that will (i) support the effective integration of existing EO capacities (space/air-borne/in-situ monitoring networks, modelling and data exploitation skills, and past project experience), (ii) provide the interface for the engagement of the complete ecosystem of EO stakeholders (scientists, service/data providers, end-users, governmental orgs, and decision makers), (iii) promote the concrete uptake of EO services and data in response to regional needs, relevant to the thematic priorities of the Call (adaptation to climate change, improved food security, access to raw materials and energy), and (iv) contribute to the improved implementation of and participation in GEO, GEOSS, and Copernicus in the region. In this context, GEO-CRADLE lays out an action plan that starts by inventorying the regional EO capacities and user needs, which in turn leads to a gap analysis, the definition of region specific (G)EO Maturity Indicators and common priority needs. Through showcasing pilots, it demonstrates how the priorities can be tackled by the GEO-CRADLE Network, and provides the roadmap for the future implementation of GEOSS and Copernicus in the region, building on the GEO-CRADLE Regional Data Hub, which abides by the GEOSS Data Sharing Principles.

International networks:

- Involvement and Leadership in several GEO activities, including:
  - GEO SB-04: Global Urban Observation and Information

  - GEO DI-01: Informing Risk Management and Disaster Reduction

- BEYOND has officially become a Regional Support Office (RSO) of UN-SPIDER. A RSO is a regional or national centre of expertise that is set up within an existing entity by a Member State that has put forward an offer to set up and fund the proposed RSO. An RSO can be hosted by a space agency, a research center, a university, or a disaster management institution. These offices communicate and coordinate with UN-SPIDER on a regular basis, covering the realms of Outreach and Capacity building, as well as Horizontal Cooperation and Technical Advisory Support. BEYOND, in this role will make available space-based resources for disaster management and emergency response and focus on capacity building & outreach activities.
- Participation to iSPEX Citizen network: BEYOND successfully contributed to the European iSPEX network for enlisting the general public to contribute to the understanding of air pollution. Thousands of citizens in major European cities went out to their streets, squares and parks to measure air pollution with their smartphone. Participating cities included: Athens, Barcelona, Belgrade, Berlin, Copenhagen, London, Manchester, Milan, and Rome. The iSPEX-EU network of citizens has been organised by the iSPEX and LIGHT2015 projects in close co-corporation with the local partners in the nine European cities. BEYOND participated in the activities that have been running during the International Year of Light, a worldwide celebration of light and light-based technologies this year and targeted at promoting the importance of photonics to young people, entrepreneurs and the general public in all Member States of the EU during the International Year of Light and Light-based Technologies 2015 (IYL 2015).
- Participation to the NASA-AERONET network: Since February 2009, IAASARS/NOA has been operating a ground-based Atmospheric Remote Sensing Station (ARSS) to monitor ground solar radiation levels and aerosol pollution over the city of Athens, Greece, a member of the global AERONET network of NASA (Aerosol Robotic Network - http://aeronet.gsfc.nasa.gov/). BEYOND contributed by supporting the station operations, as for example the systematic calibrations of the basic instrument, the CIMEL sunphotometer. During BEYOND, the station has been relocated and installed at the Thiseion premises of NOA. The data are processed on a daily basis and are available at AERONET's webpage.
- Participation to EARLINET network: Through BEYOND, IAASARS/NOA became an institutional member of the European Aerosol Research Lidar Network (EARLINET - https://www.earlinet.org/). IAASARS/NOA is represented in EARLINET by Vassilis Amiridis starting from November 2015. The aim is to operate a lidar station at the Finokalia site in Crete, in a 24/7 schedule and contribute to the EARLINET database with routine climatological products as well as a large dataset of Saharan dust, marine and smoke retrievals.
- Remained a member of the Committee of Earth Observation Satellites (CEOS) that has a mandate to coordinate and harmonize Earth observations to make it easier for the user community to access and use data. BEYOND specifically participates to the Seismic Hazard

Pilot of the Disasters Working Group, aiming at developing and demonstrating advanced science products for rapid earthquake response. CEOS has provided so far priority access to Very High Resolution COSMO-SkyMed data to study the Cephalonia (2014) and Lefkada (2015) earthquakes, providing NOA a leading edge in responsively producing high impact scientific results.

- Became a member of SuperMAG a worldwide collaboration of organizations that currently operate more than 300 ground based magnetometers.

Development of an exploitation plan

BEYOND has managed to create strong research capacities. Exploiting these resources we were able to develop several new services. However, some of these services have had a high impact to BEYOND's brand name, they are considered to be our flagship services, and hence we will rely on these to ensure that BEYOND is sustainable in the future.

There is potential however in expanding and developing new services, beyond BEYOND. We have selected these services on the basis of the interaction with twinning organisations, the end-users and other stakeholders, and with respect to the accumulate expertise and interdisciplinary knowledge of BEYOND's research team. Such services are:

- Migration to Disaster Hub: EO-based multi-disaster monitoring, coupled with crowdsourcing information. In this context BEYOND developed the concept of DisasterHub, a mobile application for enabling crowd generated data fusion in Earth Observation disaster management services. The idea was submitted to MyGEOSS1 competition, and it was eventually funded for development.

Figure 14. Evolution of FireHub: DisasterHub, supported in the context of MyGEOSS competition

- Saharan dust forecasts
- Urban Thermal Monitoring as a downstream service in new application areas (Health, Fitness, Environment, Heat stress, Energy, Smart Cities)
- Near-real time InSAR applications using Sentinel Collaborative Ground Segment
- Floods Early Warning System

From a high level point view, we believe that the sustainability of BEYOND is ensured through strategic choices that have been made through the project, and upon which will we will elaborate and focus:

1. Smart **positioning** in strategic areas where BEYOND has a **competitive advantage**, either due to enhanced technological know-how or the superior networking insights:

[1] http://digitalearthlab.jrc.ec.europa.eu/mygeoss/

a. Establish BEYOND as a Copernicus Service Provider. We aspire to adhere to this direction and expand our involvement by participating to the EMS Rapid Mapping component.
b. Become a focal point for EO-based infrastructure and downstream services for the Balkans, Middle East and Northern Africa. This is being served through GEO-CRADLE H2020 project that BEYOND team is coordinating.

2. Develop **self-sustained competitive services**, which will be supported by our user-base upon request. Indicatively, our drone units can be used on demand for damage assessment, where the users can financially support the investments required in human capital for training flight operators and for technologists to use UAV imagery and apply classification processing chains to extract pertinent information.

3. Effectively exploit **infrastructure** (satellite receiving stations, antennas, Lidar, etc.) that is unique at a regional level, by forming strategic partnerships and being active in the relevant European Research Infrastructure Networks.

4. Investigate opportunities for the commercialization of products and technologies developed within BEYOND Center of Excellence. To this end BEYOND:

a. has submitted to the Greek Industrial Property Organization a patent dossier for the FireHub platform developed in BEYOND. The application was successful and a patent is now awarded. It has been forwarded to the European Patent Office (EPO) to secure the extension of its applicability.
b. participates to RECAP H2020 project that aspires to offer farmers and public services with a tool for supporting them to comply with regulations imposed by the European Common Agricultural Policy. A key component of the platform is the ingestion and exploitation of EO-based products, with direct commercialization potential.

4.4 Dissemination strategy

Dissemination was a key element in the BEYOND project. In order to maximize the project's impact, efficient and robust communication channels were established between BEYOND and the end users of the project's products and services (e.g. policy makers, general public, scientific community, public and private enterprises). Our awareness strategy can be codified as follows:

- Act as an ambassador of the international partnership **GEO** to what concerns its regional activities in south-eastern Europe and the Balkans. In this context BEYOND has (and will continue) organized regional GEO workshops (e.g. the 2014 2nd South-Eastern Europe GEO Workshop).
- Create a pool of professional contacts by engaging to active networking activities. To this end, a list of 3,000 BEYOND stakeholder entities and individuals has been identified and approached, and who are being informed for BEYOND achievements.
- Sign Memorandums of Understanding to establish sustainable collaborations with selected organizations and other research programs
- Increase visibility by demonstrating research excellence, through publishing scientific papers in peer-reviewed journals.

- Implement e-based dissemination activities, including a) maintaining and updating out Twitter and Facebook pages, b) webinars for students, researchers of related fields, private sector and end-users, c) information streaming for the public authorities through dedicated links, d) online multimedia resources about natural disasters and related research to educate stakeholders, available through BEYOND portal. A documentary on BEYOND activities has also been released.
- Develop media links on national and international channels to reach the general public. BEYOND has published several articles in newspapers, magazines and blogs, and has been interviewed by local TV channels.
- Publish and distribute conventional promotional material: brochures, newsletters, posters, leaflets, print-outs, etc.

Finally, the described dissemination Strategy will be active after the end of the Project. The BEYOND project website will remain functional and will be frequently updated for the public and the national authorities, a Newsletter related to BEYOND services will be distributed to our network (more than 3.000 recipients) every year, and the BEYOND team will continue to participate in public awareness events, such as "The Research Night 2016 -2017".