THE GROWING USE OF GMES ACROSS EUROPE'S REGIONS





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Dear Reader,

This joint publication from NEREUS and the European Space Agency charts *The Growing Use of GMES across Europe's Regions*. Its collection of 67 short descriptive case studies provides a broad insight into how the Global Monitoring for Environment and Security (GMES) Programme is being used in new applications and provision of services across Europe's regions. The articles constitute a record of the growing contribution of GMES towards sustainable territorial management and will serve as a key reference source on the subject for politicians, policymakers and planners alike.

The collection illustrates the value of GMES as a strategic tool for informed decision making and forward planning, providing vital information on the changing state of our coasts, forests, lands and atmosphere which our regional authorities have to manage and conserve. Regional authorities have obligations to comply with EU directives that affect territorial management, such as the water and air quality directives; GMES is an essential data source for supporting these responsibilities. GMES also provides vital support when emergency services are mobilised in cases of civil emergencies or natural disasters. In short, GMES is becoming an indispensible tool for regions and regional policies.

However, the uptake by regional administrations is far from complete as several of the case studies show. Further measures and innovative approaches are needed to help regional administrations to incorporate GMES capabilities in the definition of their specific regional needs. The GMES Programme also requires a deeper understanding of the needs of potential users in order to shape its service provision accordingly. On the other hand, some case studies provide examples where dialogue and interaction between users and providers has closed this gap effectively: these may be early exemplars of how regional authorities can play a pivotal role in the future exploitation of GMES and for the successful development of a downstream regional market sector.

The collaboration on this publication between NEREUS and ESA, with the main objective of improving the link between users and providers, was intended to address several topics: how can GMES provide benefits at regional level, in particular linked to the use of space data; what is the potential in regional economies; how to provide a reference source of information to underpin regional, national and European policy decisions? We hope that you will find many positive responses to these questions in the articles of *The Growing Use of GMES across Europe's Regions*.

We wish you an interesting reading.

Sincerely Yours,

Alain Bénéteau

President, NEREUS

Jean-Jacques Dordain

Director General, ESA

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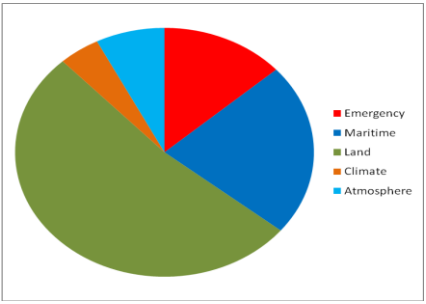
ATMOSPHERE

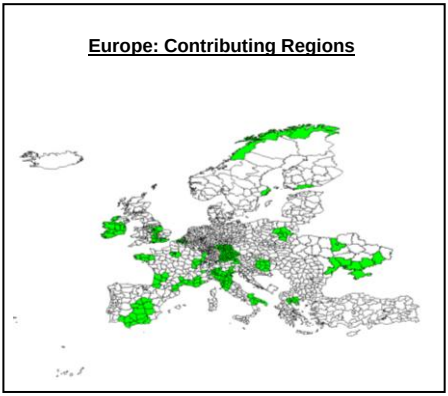
CLIMATE

EMERGENCY MANAGEMENT

The collection of case studies presented in this publication clearly illustrates the growing use of GMES across Europe's Regions. In 2010, NEREUS published its '25 Uses of GMES in the NEREUS Regions'. This new publication from NEREUS and the European Space Agency provides evidence of much wider involvement across all regions of Europe. Through an open call for papers, a rich collection of over 60 distinctive contributions has been obtained from regional end users, research institutes and industry providers, highlighting a diversity of underlying technological approaches and a wide range of uses, needs and benefits for regional organisations. The papers are grouped according to the thematic GMES domains of Land, Maritime, Emergency, Atmosphere and Climate. Around half of the papers describe land-related applications, with significant numbers also covering maritime and emergency applications. This is a clear reflection of the growing importance of GMES, and space data in particular, in applications for the management and conservation of regional territories also anticipating sustainable operational services with the imminent launch of the first Sentinel spacecraft. Conversely, there are fewer papers on regional



atmosphere and climate change applications mainly because issues currently under consideration are mainly on global or continental scales and the regional implications have so far received less attention. Furthermore, a GMES atmosphere service with operational spacecraft is still some years away. These papers, nevertheless, draw attention to the growing importance of air quality and climate change adaptation on regional and urban scales and the importance of a timely atmosphere operational service as an integral part of the overall programme. Contributions were received from 47 regionally based bodies from 17 different European countries. The geographical distribution of contributors shows a relatively even spread of activity among the western European countries but also significant uptake in Eastern Europe and Scandinavia.



Around one third of the papers involved collaborations between different regions and countries demonstrating an encouraging degree of trans-national and inter-regional cooperation. Many applications are not confined to regional borders but indicate clustering of common interests between regions and shared inter-regional environmental concerns. Of course, space-based observations naturally span beyond administrative and national borders allowing European regions to support activities outside the continent (e.g. support to European policies for Africa).

Comments from end users on the efficacy of the described applications are included in each paper. These generally convey recognition of the great potential of GMES and Earth Observation derived services especially in support of crisis management and environmental monitoring and reporting. Some of the reported applications are mature, built upon existing operational chains, whilst others are more innovative and continue to depend on availability of reliable and affordable data sources to fully realise their potential. Levels of user readiness and involvement of local administrations vary. In a few cases, public administrations are using satellite data for fulfilling their reporting obligations. However, many local and regional authorities still express caution whether integration of GMES services into their present processes for territorial management is affordable, provides sufficient added value and will be sustained long-term by operational satellite missions.

We believe that the presented collection clearly illustrates the large growth of social and economic benefits arising directly from GMES applications in the service of regions and cities across Europe. The applications will be realised as more components of the GMES system, both space-based and in situ, become fully operational.

Acknowledgements

With grateful thanks to our co-editors: Heiko Balzter, Federica Bordelot, Sonia Nicolau, Franck Durand-Carrier, Paola Carrara, Silvano De Zorzi, Volker Schumacher, Hena Ahsan.

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EARTH OBSERVATION SATELLITES – A TOOL FOR ENVIRONMENTAL OBSERVATORIES

Satellites monitor biodiversity conservation actions in the case of the Common Hamster in Alsace

The challenge

The Common Hamster is an endangered species in Alsace. The main reasons of the current critical situation are agricultural: the reduction of winter crops over the past decades is particularly unfavourable because the rodent needs food and protection after its hibernation, a very vulnerable period for the hamster. Spring crop land-parcels, mostly maize in this case, are still bare soils in early spring. Moreover the hamster habitat is lacking stability because of crop turnover and parcel enlargement. The landscape is also more and more fragmented by road infrastructure and urban development.

The challenge here is to give to French ecological institutions the baseline situation of the Common Hamster's environment in order to assess the concrete actions of biodiversity conservation and to know where actions have to be carried out.

Rodent burrow in fodder crops
© SERTIT 2012

Benefits to citizens

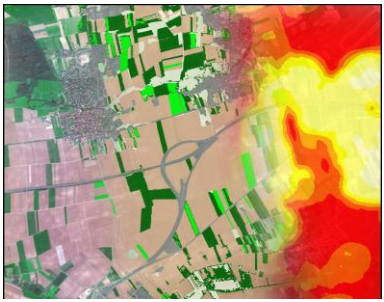
Earth Observation data analyses provide faster information than field survey and help in biodiversity conservation, so important for our current and future well-being.

The space-based solution

Recent work on the hamster case in Alsace is particularly representative of the usefulness of Earth Observation imagery for environmental observatory and biodiversity conservation.

The early spring landcover mapping of areas populated by hamsters in Alsace, using high resolution satellite imagery (SPOT5/CNES), highlights hamster-friendly crops as well as unfavorable areas – such as bare soils and artificial features – giving an accurate idea of the situation at the end of the rodent's hibernation period, which appears as a key moment for hamster survival.

'EO derived products enable a global and accelerated assessment of operational efficiency of biodiversity conservation actions.'
Florence Bonnafoux, DREAL Alsace, French Ministry of Ecology



Satellite imagery, derived landuse mapping and ecological indicator (from left to right) © SERTIT 2011

The mapping of the hamster's habitat clearly underlines land use threats to the rodent in the area: the fragmentation of their biotope by road infrastructure, isolating populations; the extent of bare soils – spring crops that do not provide food or cover for a long time after hibernation; the proximity of urban areas, which continuously erode their natural environment. Unfavorable environments and human pressures on the hamster populations are highlighted through detailed geographic analysis.

Annual hamster environment monitoring, using satellite imagery, can also emphasize the positive effects of the species conservation actions.

However, the survival and reproduction of the common hamster depends on a fairly dense spatial distribution of winter crops. The analysis through density indicators of favorable crop spatial distribution, highlighting favorable and unfavorable areas, offers a vision of possible networks and their quality or otherwise indicates if the biotopes are connected or not, and hence, reveals ecological corridors at a local scale.

Thus, the annual monitoring of winter crop densities, which shows major changes in favorable area distribution from year to year, is required to have an idea of habitat stability, network evolution, and also gives an overview concerning the efficiency of hamster protection policies and actions.

Outlook for the future

Given that this innovative action emphasising the benefits of Earth Observation data in characterising biotopes is operational for the hamster case in Alsace today, it would be particularly interesting to reproduce this work over other European regions as well as for other species – endangered or not – and to apply it to the whole green infrastructure, at different scales of work. Moreover, given the method established using SPOT5 imagery, is transferable to other high and very high resolution optical sensors, it would be very useful to make use of the benefits of new Earth Observation satellites, such as the sub-metric Pléiades, for the characterisation of small scale biotopes for environmental observatories in general.

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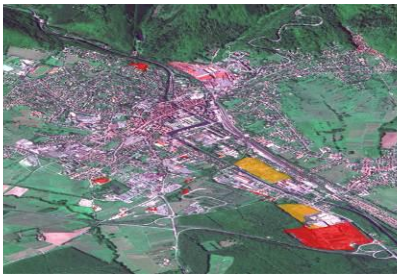
EARTH OBSERVATION SERVING EUROPE'S FORESTED REGIONS

Operational satellite-based Earth Observation services support the forestry sector



Forest clearing in Alsace over 20 years using SPOT imagery, SERTIT 2011

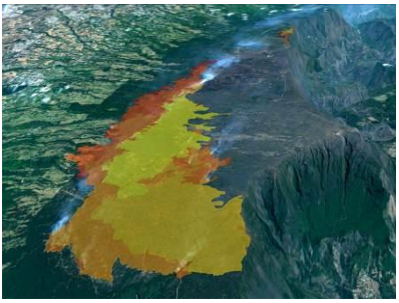
The challenge

The forestry sector is having to adapt at a fast pace and on a region-by-region basis to economic, social and environmental changes. Certain areas are under increasing pressure from human activities while others are becoming settlement deserts. Renewable energy targets are also part of the picture. One big question is how forests can maintain the multi-faceted range of services they offer. Furthermore, in a changing natural environment climatic events are also taking a toll through storm related windfall damage, droughts and fire events. Parasite attack can also affect these already weakened forests. All of this is occurring during a period when often funding cutbacks within the forestry sector in public authority management services, make the management of Europe's vast forests even more complicated. Satellite remote sensing can offer solutions, tools to help the forestry sector manage their often vast forests. The challenge is to foster understanding in collaboration and to provide operational results. Remote sensing does not replace today's foresters, but is a useful, timesaving and complementary tool to fieldwork.

Benefits to citizens

Forests and trees provide numerous services from building material and fuel to contributing to many industrial products. Together with grasslands and other permanent natural land surfaces, forests provide precious habitats and corridors for the movement of fauna and otherwise contribute significantly to biodiversity. Forests also provide healthy leisure amenities, enrich the landscape and reduce urban heat islands. They break-up urban landscapes providing diversity and reducing stresses including noise, visual and chemical pollution. Indeed, terms such as green infrastructure are being used to describe

'The use of high resolution remote sensing to analyse forestry issues is well established in Alsace.' **Alain Lefeuvre, DRAAF, Alsace**



Forest fire monitoring, La Réunion using RapidEye imagery, SERTIT 2011

our environmental assets of which forestry is a very important part. Remote sensing derived geographical information can help in the sustainable management of forests, highlighting trends in forests, an integral part of many European citizens' landscapes, locating where they are developing or are under pressure, being conserved or exploited. This information would be too expensive to obtain in the field.

The space-based solution

Earth Observation intervenes by providing a nearly instantaneous view of the state of forestry on a given date. When used for mapping, very precise and exhaustive reference geo-information can be obtained. When combined with archives, trends over as many as fifty years can be mapped and used to analyse landscape changes from the 1960s to the present day.

Moreover, rural exodus can lead to forestry expansion and inversely urban expansion to pressures on forestry. Forest clearings and plantations can be monitored. Resource monitoring can also be aided by remote sensing. Trends like the proportionately higher pressure on small forests, and hence the threat to green infrastructure can be illustrated. Storm windfall or fire damage can be mapped to indicate damage extents. Valuable information can be provided on parasite attack die-offs. This work is validated in situ by foresters.

Outlook for the future

The continuity and expansion to other geographical sectors of the above-mentioned regional services is envisaged. More regular imaging at a lower cost by ESA's Sentinel satellites should enhance the possibility of remote sensing providing data. This should enable the provision of more detailed information on the richness of our forests through species and forest structure mapping. The forest sector is requesting information on volume estimates and hence 3D applications will probably come on-line facilitated by the European Pléaides and Tandem-X resources. In other areas, emergency mapping services will improve provision to civil security authorities and foresters alike.

Acknowledgements

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SOIL EROSION MONITORING AT REGIONAL LEVEL

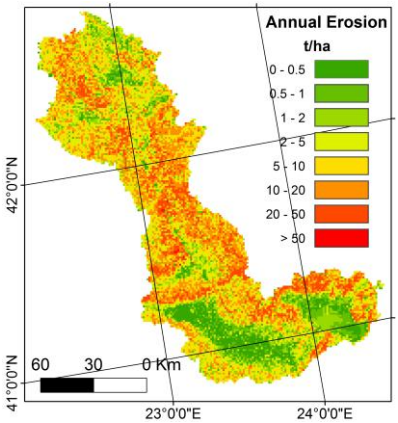
Soil erosion can be operationally mapped at monthly intervals by European regions with the recently developed G2 model

The challenge

Soil erosion caused by water is considered a big environmental threat throughout Europe. This is the reason that several European Commission Institutions are striving urgently to set up an operational soil erosion monitoring service, which could be able to:

- locate areas of high soil erosion risk
- determine which seasons of the year are critical for erosion for each land use, and
- produce harmonised and comparable maps and statistics.

As a response to the above, G2 is a new model for soil erosion, developed by the Aristotle University of Thessaloniki and the Joint Research Centre (JRC) within the framework of the 'geoland2' project.



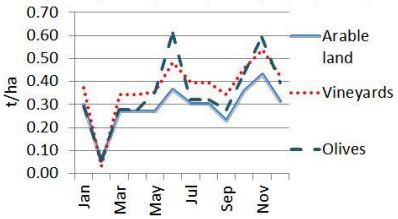
Soil erosion map of Strymonas river basin using the G2 model

Benefits to citizens

Implemented in the Strymonas river basin (a cross-border area of 14,500 km^2 in SE Europe; see figure), the G2 model proved able to:

- produce annual erosion risk maps
- produce seasonal erosion risk maps
- locate areas of high soil erosion risk
- determine which seasons of the year are critical for erosion for each land use and
- monitor changes of soil erosion risk over the years.

'G2 is a functional tool for producing easily interpretable maps and statistics for regular soil erosion monitoring.' **Ioannis Meliadis, Forest Research Institute, National Agricultural Research Foundation (Hellas)**



Monthly erosion figures for common agricultural land uses in Strymonas river basin

The space-based solution

The G2 model follows the same principles as the Universal Soil Loss Equation (USLE), the most commonly used soil erosion model worldwide. G2 is designed to be applied on a regional scale using available pan-European geo-databases (see table below).

Factors	*Sources*
Rainfall erosivity (R)	Weather stations
Vegetation retention (V)	BioPar (from MERIS satellite)
Soil erodibility (S)	European Soil Database, Soil Organic Carbon
Topographic influence (T)	ASTER DEM
Interception of slope length (I)	Image 2006 (SPOT mosaic)

In comparison to the original USLE formulas, the G2 model introduces two methodological innovations:

- the use of the BioPar products, and
- the use of the Image2006 dataset.

The BioPar products, delivered by the 'geoland2' project, are grid datasets of common biophysical parameters derived from 300 m MERIS satellite data on a monthly basis. G2 employs two out of the nine publicly available parameters, namely, the 'fraction of soil' and the 'leaf area index' in order to estimate the 'vegetation retention' factor of the G2 model.
The JRC Image2006 dataset, which is based on 25 m SPOT data, was used to extract a measure of the 'interception of slope length' factor for the G2 model.

Outlook for the future

According to the Forest Research Institute of Greece, which is one of the service end-users, the G2 model significantly supports regular erosion monitoring on a regional scale. The forthcoming mapping of soil erosion risk of Greece with the G2 model is expected to serve as an example for the further implementation of the model at European level.

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AGRICULTURAL MONITORING AND DAMAGE ASSESSMENT WITH SATELLITE IMAGES

Providing timely and objective information to the Belgian and Flemish authorities and the insurance sector

The challenge

The Belgian Agricultural Calamity Fund, the Flemish Agriculture Administration and the insurance sector have an urgent need for prompt and objective spatial information on crop state and development. In the case of disasters, particularly, information is required on the location and extent of the damage.

Benefits to citizens

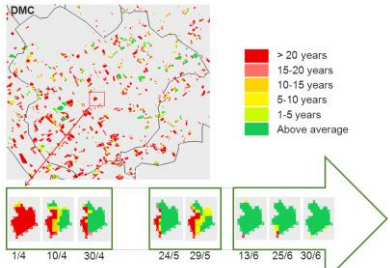
In case of a calamity, farmers can apply for compensation from the Belgian Agricultural Calamity Fund. In 2014 the system will be transferred to the Flemish authority. The current procedure, however, is very time consuming and it is often 2–3 years before compensation is paid. The system suffers from a lack of uniformity in the way losses are assessed. Furthermore, the Calamity Fund has at its disposal only limited tools to process the claims submitted by farmers. A prototype information system has been developed that offers objective, detailed information derived from satellite images (as in the figure above), together with meteorological data and output from crop growth models. It has been very positively evaluated and could potentially become operational. It can significantly improve the ability of the authorities to detect problem areas at an early stage and to better assess impacts of extreme weather events. It will allow action to control and increase efficiency of field visits to affected areas and this will not only lead to more effective management of agricultural resources but also be of direct benefit to farmers through faster payment of compensation.

fAPAR, an index measuring plants' primary productivity, derived from a DMC satellite image of 1 April 2009 (pixel size of 25 m) over Flanders. © VITO

For the insurance sector, index insurance, based on a satellite or weather index, can offer a low-cost solution for setting up and controlling insurance schemes. Compared to traditional insurance, index insurance is more objective and less expensive to

'Space-based services enable the government to improve transparency and control of farmers' claims in case of calamities." **M. Foguenne, Agricultural Calamity Fund, Belgium**

administer. Payments are based on a regional index, highly correlated with local yields. No field inspections or individual loss assessments are needed.



Monitoring winter wheat in 2009 (April–June) in Flanders with DMC images. Anomaly detection based on fAPAR return period. © VITO

The space-based solution

Since the 1980s, images from satellite sensors with 250 m to 1 km resolution have become available on a daily basis. This offers excellent opportunities for agricultural monitoring. However, their rather coarse spatial resolution means they often include different land cover types in a pixel. In recent years, constellations of micro-satellites have been launched, such as the Disaster Monitoring Constellation (DMC), providing a much higher spatial resolution (20–30 m) for monitoring of individual parcels on an almost weekly basis (cloud cover permitting). Vegetation indices of crops are derived, such as the fraction of photosynthetically active radiation (fAPAR). Anomalies are detected by comparison of the index value with the long term average. VITO has developed a method to complement modern sensors with archives of low/medium resolution satellite images. Severe anomalies during the crop's sensitive period are used to assess damage. Risk is further assessed by taking into account damage frequency over the years. Every 10 days, new anomaly maps are produced and at the end of the growing season new maps with potential damage and risk are generated for the main crops. This information can be visualised and analysed by users through a web-based interface. It can thus be used to guide field visits to problem areas or to trigger insurance payments.

Outlook to the future

The ESA Sentinel satellites and other missions will ensure continuity and further improvement of the services through better availability of high resolution imagery. Extreme climatic events are likely to happen more often, so it becomes even more important to have real time information for crop monitoring and damage assessment.

Acknowledgements

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ASSESSING REGIONAL IRRIGATION WATER CONSUMPTION FROM SPACE

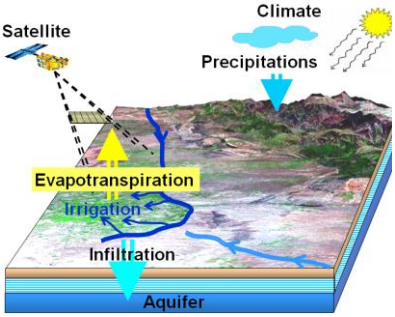
Time series of vegetation indices allow monitoring of crop development and water consumption

The challenge

The current global strain on water resources initiated the need for a better understanding and quantification of the various fluxes involved in the water cycle. Irrigation is the major consumer of water in arid and semi-arid areas, using about 80% of the scarce resources. Most of this water returns to the atmosphere through evapotranspiration. Remote sensing offers a unique capability to monitor this crop water consumption over large areas, using the combination of image time series and meteorological data.

Benefits to citizens

In these areas, surface water distribution for irrigation is often roughly monitored (especially for water diverted directly from rivers), and groundwater is usually extracted in an uncontrolled manner. On the other hand, irrigation consumption through evapotranspiration is poorly monitored. Therefore, an accurate spatialisation of evapotranspiration at regional scale would be of benefit to irrigation managers, in optimising water distribution and thus improving the agronomic and economic efficiency of the system. Quantification of evapotranspiration is also useful for watershed managers, especially to better model and monitor groundwater levels, contributing to the environmental sustainability of water uses. Considering the large areas that can be easily monitored by satellites, the cost of data processing would be far less than the potential environmental and economic benefits resulting from a more sustainable use of water. The method presented here was successfully tested in the Haouz irrigated plain in Morocco to assess crop water consumption, and



Evapotranspiration assessment using satellite is a key input for the hydrological modelling of irrigated areas.

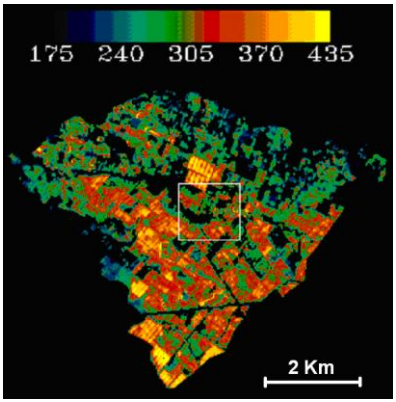
'Remote sensing estimates of evapotranspiration is a key variable that was missing to improve the groundwater modelling in our watershed.'

Brahim Berjami, Agence de bassin Hydrologique du Tensift (ABHT), Marrakech, Morocco

was also operationally used to improve groundwater modelling. The method is now currently being tested in the Toulouse area.

The space-based solution

Evapotranspiration is controlled by the amount of vegetation, the meteorological conditions (temperature, solar radiation, wind speed, air humidity), and the soil water content. Time series of high resolution (~10-30 m, for example SPOT, Landsat), acquired approximately every 15 days, allow the monitoring of the vegetation development in each pixel. The ability to know the amount of active vegetation is the major advance of this method.



Evapotranspiration (mm) cumulated over the crop season in an irrigated perimeter in Morocco. The heterogeneity shows the relevance of satellite estimates.

This knowledge is essential for evapotranspiration estimates, assuming that meteorological data can be obtained from ground stations or meteorological models. Only remote sensing is able to capture the heterogeneity of vegetation over large areas (as shown in the image opposite). The joint processing of remote sensing and meteorological data produces maps of past crop water consumption and irrigation inputs, as well as forecasts of irrigation requirements, which provide highly valuable information for managing water distribution. An interesting application of spatialised evapotranspiration is the assessment of groundwater pumping. This flux can be estimated in comparing the known inputs (rainfall and controlled irrigation) with the remotely sensed crop consumption estimates. This type of data is especially valuable considering how difficult it is to assess pumping through ground surveys.

Outlook for the future

Up until now, time series images of high resolution have been difficult and expensive to obtain. They should soon become widely available thanks to the coming Sentinel-2 mission, giving a boost to agricultural applications like the one described here. Lower resolution data of Sentinel-3 may also be used on larger areas. Integration of images from the thermal and microwave domains will further improve evapotranspiration estimates.

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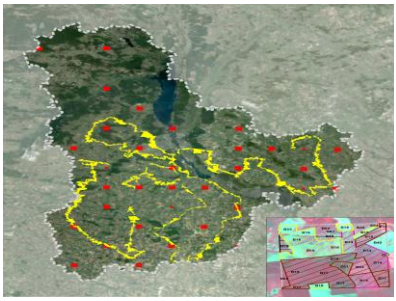
CROP AREA ESTIMATION COMBINING REMOTE SENSING AND GROUND SURVEY IN UKRAINE

Unbiased crop area statistics are collected by combining field area measurements from ground survey and satellite data

The challenge

Crop area estimates are classically derived from list frame sampling, through interviews with a sample of farmers. List sampling is useful to collect socio-economic data. However, for crop areas it may produce biased estimates if the population of farms in the region is not well known or if farmers underestimate or overestimate the area of their crops. Area frame sampling (AFS) is an alternative that involves dividing the region into units of area and surveying in the field a sample of points or segments, i.e. a set of fields limited by physical boundaries or by arbitrary boundaries (see figure). Such crop area estimates are unbiased; however budget or time constraints may mean that the size of the sample is not as high as necessary to reach the desired accuracy. The objective of this study was to show a possible contribution of Earth Observation (EO) to crop area estimation.



Location of the segments (red squares) to be surveyed in the Kiev oblast and example of 4x4 km segment on top of TM imagery

Benefits to citizens

Accurate and timely statistics on crop areas at country level are needed by governments for assessing crop production, planning imports/exports and managing markets. For instance, the United Nations Food and Agriculture Organisation (FAO) estimates the import needs of food insecure countries using the crop area statistics provided by the countries themselves. These statistics are also used to assess the impact of particular policies (e.g. biofuel) or phenomena (e.g. climate change scenarios) as well as to forecast future needs (e.g. arable land, fertilisers,

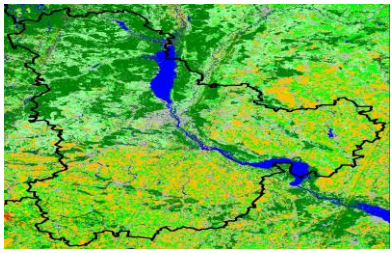
'Combining ground survey and high resolution imagery allows benefitting from the strengths of both techniques: direct field observations and exhaustive coverage of the classified images, even with biased classification.'
Elisabetta Carfagna, FAO

water). In the last decades, both the availability and quality of these statistics have declined, as noted by FAO and the World Bank in 2010. Using statistically sound and cost efficient ways of collecting crop statistics has become crucial at a time of important challenges for agricultural development and food security.

The space-based solution

Thanks to its wall-to-wall coverage, EO data contribute to crop area estimation by improving the survey design through division of the territory into strata and correcting the field survey estimates and increasing their precision through the use of a classified image (see figure). Pixel counting is not advisable as it may result in biased estimates due to classification errors.

Here we used a regression estimator, based on the linear relationship between the percentage of a crop observed in the field (e.g. wheat) and the percentage of a class (e.g. winter crops). The quality of this relationship is measured through the coefficient of determination R^2 and determines the relative efficiency of the imagery. A relative efficiency of 2 means that the precision obtained with the initial sample and the classified images is equal to the precision that would be obtained by doubling the initial sample. In this study, the average efficiency observed for the main crops was found to be around 1.5 ($R^2 \cong 0.35$). This means that the classification is equivalent to surveying 50% more segments than the 30 of the initial survey. Remote sensing will be cost efficient if the cost of EO imagery and data processing is less than the cost of surveying 15 additional segments.



Example of classified image (Landsat TM *(30 m pixel)* classification of Kiev oblast)

Outlook for the future

The techniques for crop area estimation are mature, but have been of limited cost efficiency up to now owing to image cost and scene size. Future availability of large swath, high resolution sensors such as Sentinel 2 (300 km swath, 10 m resolution) is expected to foster development of the combined use of AFS and remote sensing imagery for crop area estimation

Acknowledgements

This study was carried out in the frame of the Geoland 2 project funded by the European Commission (EC).

Kerdiles, H.[(1)], Gallego, J.[(1)], Leo, O.[(1)], Skakun, S.[(2)], Oleksii, O.[(2)] and Kussul, N.[(2)]

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SAFEGUARDING EUROPEAN BIODIVERSITY AND PRECIOUS HABITATS

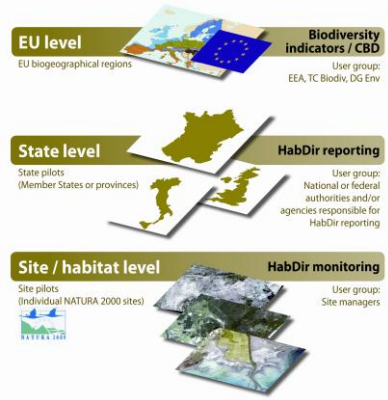
Services based on Earth Observation data are vital for the Europe-wide monitoring of Natura 2000 protected habitats

The challenge

Every six years, EU Member States have to report on the state of the natural habitats within their Natura 2000 sites. Therefore, services that enable objective, operational and economically priced information about the state of the environment within such sites are in demand.

Benefits for citizens

The FP-7 SPACE project MS.MONINA (*Multi-scale Service for Monitoring Natura 2000 Habitats of European Community Interest*) is designed to provide such services, not only for the benefit of national authorities, but also for local site managers, and the EU authorities that oversee the overall development of the Natura 2000 programme. Hence, MS.MONINA specifically aims at supporting the implementation of the Habitats Directive (Council Directive 92/43/EEC), which is considered the 'cornerstone of Europe's nature conservation policy'.

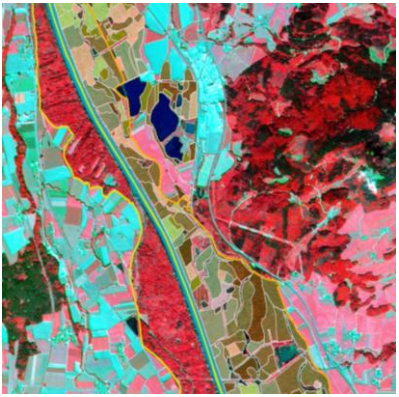


The three-level service portfolio of MS.MONINA

The project is designed to provide three different kinds of services, integrating data from satellites and in-situ measurements within the sites.

Public bodies and authorities will appreciate Earth Observation (EO) as a powerful tool for biodiversity monitoring, this being one of the critical societal benefit areas. In the longer term the observation of the conservation status of precious ecosystems will be of benefit to every single citizen, as it ensures an integral livelihood base.

'The potential of Earth observation technology for updating habitat information at site level is promising in supporting management and monitoring activities in the frame of the Habitats Directive.' **Dr. Susanne Stadler, Federal Government of the Province of Salzburg, Austria.**



Delineation and categorisation of riverine habitats within a transboundary Natura 2000 site between Austria and Bavaria

The space-based solution

The project uses EO technology to effectively monitor nature sites of community interest, thus fostering environmental legislation all over Europe. MS.MONINA tools will observe precious habitats inside and outside the existing network of protected areas to reduce the loss of biodiversity. The project has developed a series of dedicated products, targeting the specific requirements at each of the three levels of implementation, i.e. EU level, national level and site level.

The 'multi-scale' concept matches the hierarchical implementation of the Habitats Directive.

The project covers a series of pilot sites where the site-level services are being demonstrated and applied. The latest generation of very-high spatial resolution satellite data (e.g. WorldView-2) is used as well as advanced image processing routines and GIS analysis techniques.

At higher levels, broader scale representations are applied (using a grid-based approach) to provide an overview of habitat distribution within Member States and/or biogeographical regions. The variation in the types of sites, their constituent habitats and their varied management and monitoring practices means that the integration of the reported information at the EU and national level is quite challenging.

Outlook for the future

Targets for the Natura 2000 network are tough and reaching its ambitious goal will require extensive knowledge based on systematic and continuous data collection. However, many Member States are still lacking the ability to provide such information in a regular and routine fashion. Therefore, MS.MONINA offers its services to support a successful implementation of the Habitats Directive on all levels.

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LAND COVER MAPPING FOR PAN-EUROPEAN LAND MONITORING

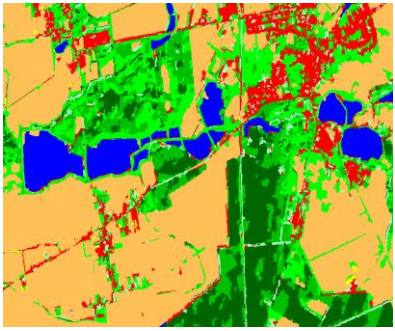
Operational land monitoring needs effective, automatic tools for land cover mapping based on satellite images

The challenge

Accurate, timely information on land cover in Europe is indispensable for proper management of land resources, allowing the building of strategies for economic development. This information can be obtained by implementing a system for data collection based on high-resolution satellite images. Such a system should deliver reliable statistics on land cover and its changes in an automated, cost-effective way, thus supporting decision-making processes.

Benefits to citizens

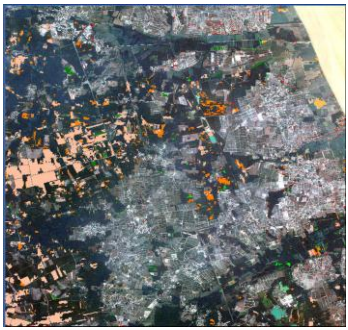
An operational service for land cover mapping at pan-European scale is one of the main issues important for society today. It should deliver crucial information at national and regional level on land status and its transformations, which in turn will have a great impact on the environment and economy. Thus development of such a service has been a primary concern within the Seasonal



Land cover map in western Poland including generic land cover classes: urban areas, forests, bare ground, water, agricultural areas

and Annual Change Monitoring Service (SATChMo) in Geoland 2. As a result of research and development work, the methodology for land cover/land cover change mapping on the basis of very high resolution (VHR) satellite images has been elaborated. This methodology allows rapid, reliable information on the distribution of generic land cover classes throughout Europe to be obtained by applying the area frame sampling (AFS) approach. Moreover, analysis of VHR satellite images in a yearly cycle enables derivation of information on relatively small land cover changes. Such information is very valuable for different spheres of the economy: physical planning, monitoring of changes in natural land cover types (forests,

'The application is valuable for deriving information useful for physical planning at regional scale.'
Bogdan Ney, State Council for Spatial Economy



Map of land cover changes in France. Changed areas were marked with orange, green or red, showing particular class transitions

grasslands), and for studying anthropogenisation processes, thus supporting land management at regional scale, e.g. at Mazowsze region.

The space-based solution

The methodology of land cover mapping for deriving information at pan-European level is based on classification of VHR satellite images (Kompsat type) characterised by 1 m resolution in panchromatic mode and 4 m resolution in multispectral mode. Such a high ground resolution enables extraction of small areas of land cover, down to 0.25 ha, and their changes. Ten generic land cover types were assumed to be identified via the prepared classification algorithm: urban/artificial, bare ground, water, snow and ice, agricultural areas, forests, grasslands, sparse woody vegetation, other vegetation, clouds. The algorithm, prepared using the object-oriented approach, allows particular land cover classes to be distinguished in a sequential manner, using a highly automated method based on spectral and textural features. This statistical AFS method has been applied to over 100 different test sites distributed across Europe in a way that represents different environmental conditions. Information on land cover distribution in different regions of Europe forms a basis for landscape characterisation and for deriving statistical data related to land coverage. Simultaneously, change detection analysis through the use of multi-date satellite images allows monitoring of land transformation and thus can support decision-making processes concerning land use.

Outlook for the future

A land cover mapping service can make an important contribution to the GMES Initial Operation (GIO) Programme, and the services beyond. New satellite missions planned by ESA in the near future, especially the Sentinel 2 satellite, will deliver appropriate source data for operational service development for the whole of Europe based on prepared technology.

Acknowledgement

Geoland-2 was funded by the EC, FP7.

Lewinski, S.[1,2], Bochenek, Z.[1], Turlej, K.[1], Aleksandrowicz, S.[1], Tomaszewska, M.[1]
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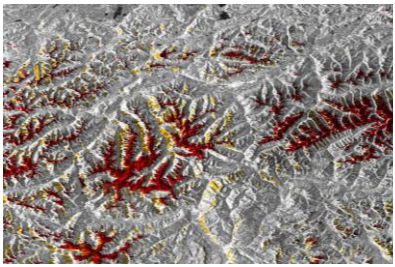
CRYOLAND – GMES DOWNSTREAM SERVICE ON SNOW AND LAND ICE

CryoLand services provide snow, glacier and lake/river ice products from satellite data to the users in near real time



Map of snow extent of Western Austria, based on ENVISAT ASAR data, 9 June 2006

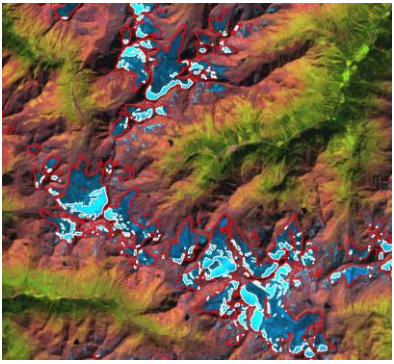
The challenge

Climate change has a strong impact on land ice and snow cover. Rising temperatures cause the retreat of snow and ice, jeopardising the supply of fresh water for human consumption, agriculture, and hydropower generation. In addition, changing snow and ice will affect ecosystems and biospheric diversity. Accurate and timely observations of snow and ice are necessary to assess the impact of climate change and to prepare for these challenges. To support the management of snow and ice resources, CryoLand implements new services for monitoring snow cover, glaciers and lake/river ice.

Benefits to citizens

CryoLand services offer accurate and timely observations of snow and land ice from satellites to support environmental and resource management in Europe. Seasonal snow cover and glaciers are important resources, supplying major parts of Europe with water and many economic activities. The presence of snow and ice affects the radiation and energy balance of the surface so that accurate characterisation of snow and ice properties is important for weather prediction and climate monitoring. Various natural hazards are related to snow, glaciers and lake/river ice, including avalanches, flooding from intensive snow melt, water outbreak from glacier lakes, ice jams on rivers. Snow load is also an important safety issue concerning buildings and power lines. The users of CryoLand services are organisations operating in the field of water resources management, hydropower production, energy trading, natural hazards mitigation, transportation and construction activities, climate monitoring and modelling, weather prediction, agriculture, and tourism.

'Up-to-date snow information supplied by satellite data is of great value for snowmelt run-off forecasting and the assessment of flood risks.'
Dr. Wolfgang Gattermayr, Head of Hydrological Service Tirol, Austria



Glacier outlines and late summer snow line Stubai Alps, Austria, from optical satellite data

The space-based solution

Snow, glaciers, lake ice and river ice are characterised by high spatial and temporal variability. Satellite observations are the only efficient means to deliver accurate and up-to-date information on these key elements of the cryosphere with appropriate spatial coverage. The operational snow service provides daily maps of snow extent and snowmelt area over Europe, as well as customised products for individual drainage basins, e.g. in the Alps and Scandinavia. Due to the large database, fully automatic and validated processing lines are needed in order to deliver the products in near real time. The snow extent products utilise high-resolution (e.g. ASTER, Landsat-5 TM, and in future Sentinel-2) and medium-resolution optical sensors (e.g. MODIS, future Sentinel-3). The algorithm relies on single sensors as well as on dual or multiple-sensors. Mapping of snowmelt area is based on multi-temporal Synthetic Aperture Radar (SAR) data.

The portfolio of glacier products includes total glacier area, time series of snow and ice areas during summer, ice velocity maps and extent of glacial lakes. The satellite database includes high-resolution optical data (SPOT-5, Pleiades, Ikonos, in future Sentinel-2) and SAR data. Lake ice extent and ice jams are observed by means of optical and SAR data. The products generated within the CryoLand project conform to the INSPIRE guidelines and are provided to the users through the CryoLand Service System applying up-to-date internet technology.

Outlook for the future

Starting in 2013, the GMES Sentinel satellite series will serve as the main EO database for CryoLand products. The operational and near real time availability of Sentinel data will greatly enhance the CryoLand snow and ice services. Of particular interest are the extended areal coverage and frequent repeat observation capabilities both in the optical and radar spectral range, providing a unique basis for timely and comprehensive cryosphere monitoring services.

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G-STEP, BOOSTING BUSINESS FROM SPACE

Removing the barriers to business exploitation of GMES

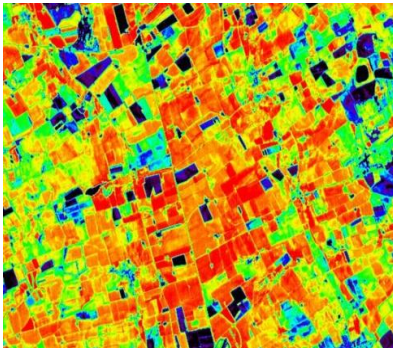
The challenge

Small businesses are often unaware of the potential value of using data derived from earth observation platforms to solve their business problems or to develop business ideas. G-STEP, a University of Leicester GMES project part funded by the European Regional Development Fund, was set up to collaborate with and assist small regional businesses to access new data streams and develop downstream satellite applications.

In the current economic climate, there is reluctance by small and medium sized businesses to invest in unknown technologies. GMES data is, therefore, underexploited and there is potential for development of novel products and services to produce financial benefits.

Benefits to citizens

Producers of what are sometimes known as High Value Crops, e.g. potatoes and other root vegetables, have a need to monitor the health of their crops throughout the growing season and to identify exactly which parts of the fields are in need of water and/or fertiliser. Availability of this information would help them to maximise the yield whilst using as few resources as possible. It would also help to predict the yield and, if necessary, allow them to place orders for produce from other sources in good time in order to meet their customers' demands.



Crops and fields imaged from space – Normalised Difference Vegetation Index (NDVI) in Lincolnshire, May 2009.

'Freely available, high resolution (spatial and temporal) images from future GMES satellites, such as Sentinel 1 (SAR) and 2 (optical), combined with core GMES products/datasets can facilitate crop management practices that save the farmer time, resources and ultimately money, whilst reducing the impact of farming on the environment.' **Kavitha Muthu, Logica**

Marabu (sickle bush) invasion – future biofuel.

The space-based solution

Satellite data was used to look at vegetation health for a consortium of companies in Lincolnshire. The application used sensor reflectance data measured in the visible and near infrared region of the electromagnetic spectrum to monitor land use and crop development. Reflectance in these wavebands is linked with vegetation variables which are indicators of vegetation health. NDVI (Normalised Difference Vegetation Index) is one method of estimating crop status and health. The NDVI can be used to differentiate thicker, healthier vegetation from thinner plant cover and bare soil which may be attributed to water stress, disease or uneven fertiliser application amongst others. NDVI data were processed to produce digital maps of vegetation health and canopy development at key phases during the growth cycle.

GMES data has been successfully trialled to aid crop management and has also been shown to help in yield prediction and targeted agronomy. G-STEP, working with Branston and Logica are developing tools to aid crop management from GMES dataset. Logica have used GMES data supplied by G-STEP to demonstrate a tool box to aid agronomist and farmers.

Outlook for the future

The mechanism by which G-STEP operates permits the identification of the needs of the 'end-user' and provides specialist assistance to develop solutions. Such a mechanism allows the formation of successful and effective working partnerships between G-STEP, associated research communities at the University of Leicester, and businesses within the East Midlands (UK). Space technology and GMES can be used to make a difference to Small / Medium-sized Enterprises (SMEs).

Monks, P.S.[(1)], Remedios, J.J.[(1)], Balzter, H.[(1)], Wells, A.[(1)], Almond, S.[(1,2)], Muthu, K.[(1,2)], Cowsill, R.[(1)] and Smith, T.[(1)]

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ASSESSMENT OF THE SUITABILITY OF ROOFS FOR SOLAR PANEL INSTALLATION

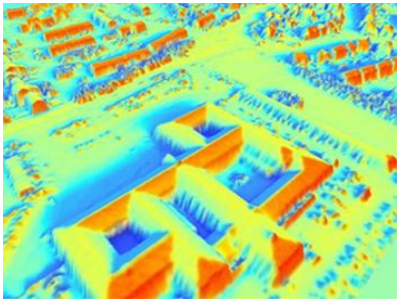
The demand for increased renewable energy generation requires efficient and effective targeting of suitable roofs. GMES provides a solution

The challenge

In order to obtain maximum benefit from a solar array on a given roof, the roof must meet certain requirements. These include slope, orientation, usable roof area, shading and irradiation as well as the location. Measurement of all of these parameters is problematic without physical access to the roof; GMES provides an accurate and proven solution.

Benefits to citizens

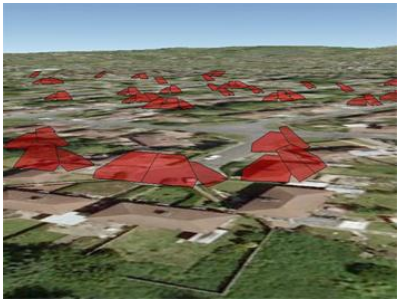
In order for the EC to achieve ambitious renewable energy targets there is a strong need to accelerate market penetration of Renewable Energy Systems (RES) in both industrial and domestic sectors. The domestic sector is of major significance, as it will reduce reliance on large centralised energy plants.



Solar irradiation modelling using a digital surface model accurately estimates solar energy received by roofs and highlights areas of shading

However, despite steady market growth, renewables technology still makes up only a small fraction of total household energy supply. One of the main reasons for this is the initial investment required, coupled with uncertainty over return on investment. A rapid- and low-cost method of calculating the return on investment would go towards breaking down these barriers. There are several parties that have an interest in which properties are most suitable for renewable solar power generation and the return on investment, such as local councils, housing authorities, power companies, solar installers and home owners. Governments have challenging renewables targets to meet. The SolAR roof mapping product saves significant time and effort and ensures each solar installation is as efficient as possible.

'The information provided by Bluesky compared very well with our on-site surveys. We can see the information you provide as a key factor in targeting our marketing.' **Wayne Allen, Sunbright Solar**



The usable area of the roof is captured as a 3D polygon. Examples are shown here over a 2D aerial photograph

The space-based solution

In order to measure the required roof parameters accurately and cost effectively, Bluesky turned to applying remote sensing techniques to GMES data to provide a solution.

Using a combination of stereo aerial photography or high-resolution stereo satellite imagery (for example 50 cm resolution WorldView 2 data) and digital models of the surface of the earth (which depict buildings and trees), it is possible to measure to a very high degree of precision, the required roof shape to allow interested parties to make informed decisions. The 3D high-resolution imagery allows the digitiser to observe disturbing objects on the roof such as chimneys, roof lights, dormer windows and air conditioning units. This enables a highly accurate assessment of the usable roof area, and therefore a precise calculation of the number of panels that will fit.

Using the information derived from the imagery (slope, orientation, number of panels, geographic location), a variety of solar irradiation models are utilised to determine the amount of energy from the sun that the roofs will receive over one year. This information, coupled with the power rating of the panels, inherent system loss, electricity prices and any government incentive allows the return on investment to be calculated to a more precise degree than by other methods. A physical survey of a property can cost as much as €100, whereas the SolAR method can cost as little as €1.

Outlook for the future

Bluesky's SolAR product is under continual development, particularly in respect to automation and modelling of irradiation and the effects of shading. On-going research has also shown that the product can be effectively produced from high-resolution satellite imagery as well as aerial photography. This would enable solar roof assessment to be carried out in areas where aerial photography is not so prevalent. Research is also on-going to determine what other building parameters can be obtained using the SolAR method, this could include roof materials, building height and age of property.

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FLOOD MONITORING IN EMERGENCY SITUATIONS

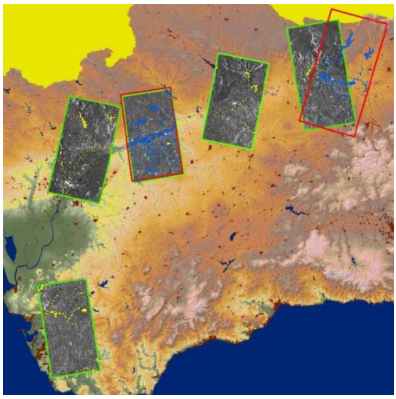
Rediam monitored the unusual floods of 2010 in Andalusia

The challenge

The intense rainfall records registered during the winter months of the hydrological year 2009-10 produced floods in different areas, mainly in those flood plain areas within the river basins. In December 2010 (the following hydrological year), new floods were registered in similar conditions.
This situation provided the best opportunity for mapping flood aspects in order to obtain real time data which were not based in simulation models. The Environmental Information Network of Andalusia (REDIAM) carried out these works in emergency phase for two flood episodes in five different areas of the Andalusian region located within the Guadalquivir and Guadalete river basins.

Benefits to citizens

Rigorous data and mapping have been produced in order to compare flooded areas with theoretical areas obtained from simulation models. Verification of flood affected areas was made by monitoring two flood episodes (February-March and December 2010) that were studied by the regional government. The study results are useful tools for local and regional government land management. On the other hand, citizens can use this information in order to analyse the damage done and seek possible compensation.



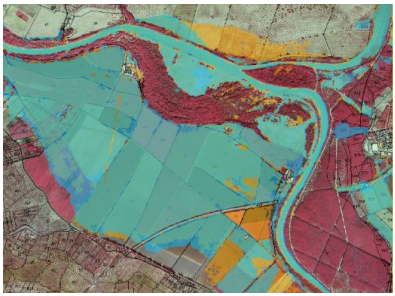
Monitored Areas in 2010: February-March, Red: December

The space-based solution.

When the authorities initially located the first signs of overflowing rivers and the early flooding in the Guadalquivir and Guadalete rivers, cloud cover was almost complete. With much data available from weather forecasts, the observation of the territory was

The immediate response is a useful tool to provide delineation of flooded areas in emergency management for future prevention plans.'

Javier Serrano Aguilar, General Director of Water Planning and Management, Regional Ministry of Agriculture, Fishing and Environment, Andalusia



Comparison between two flood episodes: Cyan – December; Yellow– February

performed with the TerraSAR-X satellite, obtaining images of 30 x 50 km size and 3 m of spatial resolutions from the areas of interest (Strip Map Mode). During the emergency phase, Orthoimages were used to perform automatic detection of the water sheet. Results were verified by visualisation on a high-detail Orthoimage (0.5m). Later, the water sheet was classified according to the affected land use using the Land Occupancy Information System of Spain in Andalusia (SIOSE). Recovery products were obtained using four types of use: Agricultural, Forestry, Infrastructure and Built Space, and Water Bodies. Water Bodies, like rivers and reservoirs, were not considered as flooded areas. This methodology was applied to both flooding episodes (February-March and December) and results (maps and statistics) were February-March and December) and results (maps and statistics) were compared. Flood mapping from satellite images together with *in situ* real-time data of water levels from rivers and reservoirs (available in REDIAM) have allowed the behaviour of flooding to be interpreted and adjusted beyond the simulation.

Outlook for the future.

The information can be used directly or integrated into a GIS with other data of interest. The analysis and conclusions will have a positive impact on flood mitigation (reduction of urban areas subject to risks and protection of riverbeds and river banks) and measures and decisions taken in similar emergency situations.
carried on by the regional government, these works are already available via GMES. It is expected that GMES services (through SAFER) will cover the needs of Andalusia during other possible floods. Image acquisition has been done with TerraSAR-X. Now, Tamdem-X is also available and shortly, Sentinels 2 and 3 (coming in 2013) will allow even better of coverage and service.

Acknowledgements

Results of our studies are available on the website of Environmental Information Network of Andalusia:
www.juntadeandalucia.es/medioambiente/rediam/inundaciones

Vales, J.J., Carpintero, I.R., Granado, L., Méndez, E., Montoya, G., Pino, I., Prieto, R., Giménez de Azcarate, F., Cáceres, F. and Moreira, J.M.
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REGIONAL LANDSLIDE AND INSTABILITY MAPPING SERVICE

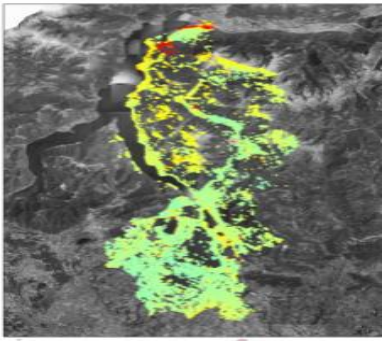
Wide-scale monitoring of ground instabilities with satellite radar data is a reliable detection tool for identifying areas at risk

The challenge

Instability maps from satellite data are interpreted by the regional geological service to delineate landslide boundaries and detect changes in the rate of ground movement, ultimately identifying areas of potential hazard, as well as updating existing inventories (e.g. IFFI, 'Inventario dei Fenomeni Franosi in Italia' project).

Benefits to citizens

A new monitoring system based on satellite radar imagery provides a high density of displacement measurements and regular updates to local authorities for landslide mapping and to experts working in the field of geo-hazard risk assessment. On a regional scale, an inventory of areas prone to geological risk was created using both conventional and remote sensing techniques to update the landslide inventory. Public departments and private citizens can now access the results via a web portal.



Displacement velocity map over Lecco province

Compared to other traditional techniques (GPS, optical leveling surveys etc.), satellite radar data is extremely cost-effective for monitoring large areas and saving public money. An evident advantage of this satellite solution was the possibility of creating a synoptic view of the areas affected by deformation at a regional level across thousands of square kilometres. Satellite radar data can also represent a valuable source of information in local analyses and for monitoring individual structures. Whenever the distribution of 'natural' radar targets (typically buildings, poles, outcrops) is insufficient, it is possible to install artificial reflectors creating new radar targets. Town-planning schemes can now benefit from another information layer in a regional GIS.

'Thanks to satellite monitoring, inaccessible Alpine areas were also analysed and classified.' **Massimo Ceriani, Lombardy Region**

A corner reflector installed in the Idro landslide area

The space-based solution

Landslides and slope instabilities, characterised by mass surface displacement, can be monitored with millimetre accuracy using satellite radar. Radar images acquired at different times over the same area are compared using a technique called PSInSAR. Very precise measurements can be obtained over a set of points identified over the area of study, allowing the end user to highlight any surface deformations. Landslide characterisation works by detecting naturally-existing ground measurement points (with no in-situ instrumentation required). Satellites provide quantitative and qualitative deformation information for mapping ground instabilities. Derived displacement maps are used to delineate boundaries, classify morphology and detect changes in the rate of movement. An extensive archive of radar satellite imagery allows the temporal evolution of landslides to be reconstructed, providing valuable insight into understanding and forecasting future slope behavior.

Landslide inventory updates benefit from the wide coverage of radar satellite images. Slope instability measurements are also used in conjunction with traditional datasets to verify and update existing landslide inventories.

Stabilisation Programme Monitoring uses satellite imagery acquired before and after the implementation of stabilisation programmes to monitor their effectiveness.

Outlook for the future

Sentinel-1A will ensure the continuation of radar data for landslide mapping. Sentinel-1B will create a more robust service with the possibility of weekly updates. The Italian COSMO-SkyMed constellation with 4 satellite platforms mounting high-resolution Synthetic Aperture Radar systems, is a very important data source that will complement sensors operated by the European Space Agency.

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A SPACE-BASED SOLUTION FOR MONITORING LAND CONDITIONS IN SUB-SAHARAN AFRICA

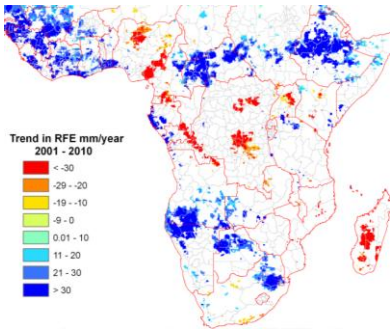
Operational environmental monitoring of land condition in Africa is essential for policy-makers and governmental agencies

The challenge

The 'African Monitoring of the Environment for Sustainable Development' (AMESD) programme is a partnership between the European Union and the African Union Commission. It extends the operational use of Earth Observation (EO) to environmental and climate monitoring. There is an increasing need for environmental information for the implementation of international cooperation policies such as aid and development. Satellites provide a cost-effective way to obtain systematic information on land conditions in Africa.

Benefits to citizens

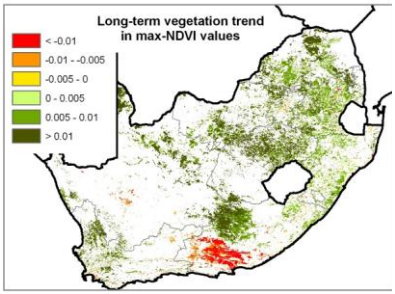
Decision makers have tended to use non-spatial indicators of environmental conditions and human impact. Thus, there is demand for new indicators of land and vegetation conditions.



Trends in rainfall estimates from FEWSNET between 2001 and 2010. Red areas saw rainfall decline and blue areas increase

Evidence-based policies need this information. Motivated by these user demands, the European Commission project Geoland 2 has provided technical support to AMESD. Its work package 'Natural Resource Monitoring in Africa' (NARMA) has developed an environmental monitoring system over 48 African countries through the deployment of an EO processing system called eStation,estation.jrc.ec.europa.eu. It serves the needs of both the EC services and African institutions. It benefits citizens by providing environmental information across vast regions and assessing changes objectively. Information from space informs country environmental profiles on the state of the environment in sub-Saharan Africa.

'I believe that the environmental data provided through the AMESD programme are imperative for decision-making. GMES-Geoland 2 gives us the privilege to directly access Earth Observation data and enables us to analyse data back to the 1980s.'
Sultan Mohammed, Director-General of the Ethiopian Mapping Agency



Trend in vegetation greenness observed from satellite between 2001 and 2010 over South Africa. Red shows a loss and green an improvement of vegetation condition

The space-based solution

The EC's user needs were focused on spatial and temporal changes in rainfall and vegetation patterns in sub-Saharan Africa. These analytical results support the process of identifying regions that are affected by droughts and floods, and show improvements or deterioration of the vegetation condition. The examination of rainfall patterns was conducted using the highest spatial resolution rainfall data currently available from a combination of satellite and ancillary data. These 8 km data are provided by the FEWSNET project by US-AID. The vegetation condition is assessed with a 1 km scale vegetation index, based on data from the SPOT-VEGETATION sensor. Through the e-station, users can download data every 10 days, and give African meteorological services an early warning if agricultural production is low. Both the rainfall and vegetation greenness data are available over long time scales, dating back to at least 2001. Annual environmental assessments can thus be derived. Rainfall and vegetation trends over the last decade have been investigated. The relationship between increases or decreases in rainfall and vegetation greenness can indicate whether a land area has changed owing to climate variability or non-climatic changes (e.g. human-induced land degradation). This solution allows the comparison of land condition for different administrative areas at national, sub-national and regional scale. This space-based information is crucial for governments and decision makers at various levels to support environmental policies.

Outlook for the future

This operational land condition monitoring for Africa will be continued beyond the end of AMESD through the 'Monitoring of Environment and Security in Africa' (MESA) programme supported by the European Development Fund and implemented by the African Union (2013–2018). MESA will improve natural resource management and sustainable development. The biogeophysical parameters will be provided by the GMES land monitoring core service. ESA PROBA-V, Sentinel 2 and 3 satellites will provide data continuity after the end of SPOT-VEGETATION.

Hoscilo, A.[1,4], Balzter, H.[1], Bartholomé, E.[2], Boschetti, M.[3], Brivio, P.A. [3], Brink, A.[2], Clerici, M.[2] and Pekel, J-F.[2]
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BIOMASS INDICATORS FROM SATELLITE DATA FOR FOOD SECURITY MONITORING

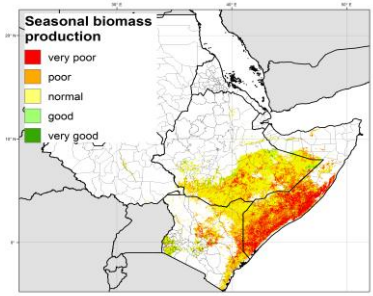
Agriculture and food security are operationally monitored with Earth Observation systems

The challenge

The Horn of Africa region (HoA) is one of the most food insecure regions in the world. This situation originates from a combination of biophysical limitations (aridity, soil fertility), socio-economic factors (small farmers and pastoralist households, fast demographic growth) and conflicts. Drought events, depending on severity, spatial scale and duration, have led to food crises or famine in Ethiopia (1972–3, 1984–5, 1998–2000), Somalia (1991–2) or Kenya (2009). Permanent monitoring is thus required to locate hot spots early and assess the severity and impact of drought, as has been the case for the severe famine of Somalia in 2011.

Benefits to citizens

Early and objective assessments of the food security situation allow timely decision making and appropriate implementation of food assistance.



Biomass production for the second season of 2010

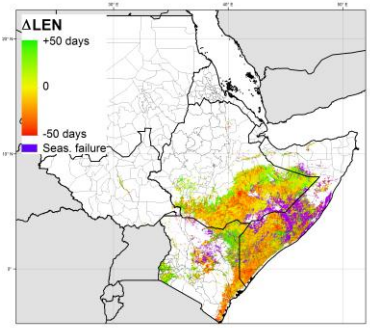
Evidence-based information from Earth Observation (EO) supports a consensus between the various stakeholders in an emergency situation. But crop monitoring is also of primary importance for longer term agricultural development projects, increasing production or resilience.

The space-based solution

The Joint Research Centre (JRC) of the European Commission applies new monitoring methods in semi-arid countries. These are based on the retrieval of vegetation indicators (biomass, phenology) from the SPOT-VEGETATION satellite.

JRC operationally produces bulletins exploiting EO data in near real time during the cropping season to assess the overall vegetation conditions and productivity. Different analyses are combined, using various EO products,

'The application of GMES has tremendously enhanced our early warning capacity with wide and extensive coverage together with timely and regular data availability as well as being highly cost-effective.' **Shukri Ahmed, Global Information and Early Warning System, Food and Agriculture Organization of the United Nations**.



Anomalies in the length of the second growing season of 2010

ranging from biophysical variables describing vegetation status to rainfall estimates**.** The analysis of SPOT-VEGETATION fraction of absorbed photosynthetically active radiation (FAPAR) is presented here. A few key numerical indicators, derived from a statistical analysis of time series of FAPAR observations, are used to characterise the spatial and temporal evolution of successive growing seasons (i.e. the phenology). Vegetation development and associated risk of poor harvest or food deficit are derived from a comparison of current-year values with long-term averages. Very poor vegetation conditions were detected in Somalia and parts of Kenya and Ethiopia in the second season of 2010 (figure on previous page). The figure above shows anomalies in the length of season, indicating that the season was much shorter or failed completely in large areas of Somalia. In fact, the rainy season of late 2010 was associated with a strong La Niña event and was one of the driest in the last 60 years. The following rainy season in 2011 was also extremely dry. The cumulative effect of the two consecutive seasonal failures on crop and pasture production was one of the causes of the food security crisis.

Outlook for the future

Space-based monitoring of vegetation provides a cost-effective and objective basis for the regional or global analysis of agriculture and food security. This information does not replace in-situ observations or specific assessment missions in crisis situations, but it does provide spatially continuous information on the most remote or inaccessible areas. The availability of long-term time series allows the computation of anomaly maps giving a synoptic view of crop conditions with a homogeneous method and appropriate timing. This service is currently feeding the MARS bulletins (http://mars.jrc.ec.europa.eu/mars/) and many other users (Food and Agriculture Organisation, World Food Program). In the future, GMES will ensure data continuity, a crucial feature of operational monitoring, through PROBA V and Sentinel 3 missions.

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DAMAGE ASSESSMENT MAPPING IN PINE FOREST

Application of hyperspectral sensors to map damage caused by pests and forest decline in conifers

The challenge

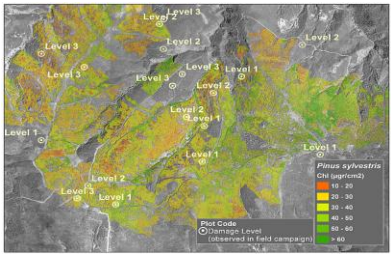
Affection by pests in conifers and forest decline are two environmental problems that Government of Andalusia has been following for years. These studies suffer from several disadvantages: the inherent difficulty of the analysis, which means major budgetary input, and the need to dimension and localize these problems.
Hyperspectral sensors allow a precise spatial vision for monitoring forest damage due to their spectral resolution and their ability to provide continuous information over large areas. Thus, they have been used for monitoring physiological changes in pine forest caused by pests (processionary caterpillar) in Almonte (Huelva) and forest decline in 'Sierra de los Filabres' (Almeria). The methodology, developed by the Environment and Water Agency of Andalusia, has consisted of mapping vegetation indices derived from hyperspectral images and relating them to different biophysical parameters, indicators of stress conditions in pine forests of Andalusia, such as chlorophyll.

Affection degrees for forest decline in *Pinus sylvestris* (left to right: least to most affected).

Benefits to citizens

Possessing knowledge of the phytosanitary status of vegetation is a key point for the Regional Ministry of Agriculture, Fishing and Environment of Andalusia in managing the Andalusian mountains and their resources. The developed methodology allows forest health mapping to be obtained – a highly valuable tool in planning and forest management. It constitutes an important element in the monitoring and evaluation of different forest policies and climate change adaptations.
The results are available on the Environmental Information Network of Andalusia website: www.juntadeandalucia.es/medioambiente/rediam/hiperespectral-forestal

'Pre-visual remote sensing indicators on conifer forest have relevant applications in the analysis and evaluation of forest decline processes.'
Rafael Navarro, Department of Forest Engineering, University of Cordoba, Andalusia



Distribution of the stress indicator 'chlorophyll' in pines in Almonte. Low values indicate more stress

The space-based solution

Images from Airborne Hyperspectral Scanner (AHS) were acquired as well as from other sensors such as Hyperion, ChrisProba, LandsatTM, QuickBird and UAV sensor to obtain a comparison of their abilities applied to this study. At the same time, field campaigns were conducted in order to characterise the biophysical parameters of vegetation in the areas of interest. The link between images and field parameters was established by statistical correlation using the vegetation indices that best correlated with measured variables. From these indices and the classes of damage observed in field, distribution maps of biophysical parameters were generated.

The difference between environmental and canopy temperature was obtained based on thermal information from AHS. It was found that this variable is related to water stress of vegetation and has since allowed mapping indicators to estimate damage before it manifests itself visually. Pre-visual damages indicate that, if adverse conditions persist, decay is just manifesting through visible damages such as chlorosis and defoliation, and death of trees as the final result. The main application of this mapping is the monitoring and description of pre-visual stress status in conifer forests through biophysical indicators, which can lead to the design of monitoring systems for plant health.

Outlook for the future

High-resolution mapping derived from the vegetation stress levels can be incorporated into forest planning processes. The developed methodology can be improved using high spatial resolution UAV sensors for sensitive areas of interest or certain control sites, using thermal information from images, and implementing techniques for the generation of predictive models of plant health in forests.

This application could be included within GMES geoland2 project as part of forest monitoring, particularly coniferous at regional scale, considering that one of its products includes biophysical variables such as those detailed above. The ESA Sentinel-2 mission could support the provision of high resolution images suitable for calculating studied vegetation indices.

Méndez, E., Cabello, A., Frieyro, J.E., Granado, L., Hayas, A., Montoya, G. and Pino, I.
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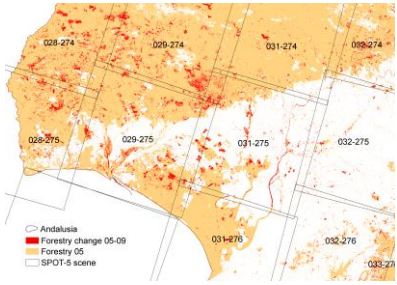
CHANGE DETECTION IN FORESTRY TO UPDATE LAND USE INFORMATION WITH SPOT-5 IMAGERY

Change detection is used in forestry to update the '2005 Land Use/ Land Cover Information System of Andalusia' to 2009 using SPOT-5 imagery



Southwest Andalusia: Forestry 2005 versus Forestry Change layer (2005-2009)

The challenge

The main problem solved with this Programme is to update Land Use/Land Cover Information System of Andalusia (SIOSE-A) at detail scale (1:10.000) for forestry (no urban, no agricultural). This update is based on change detection techniques with SPOT-5 HRG imagery of two reference dates (2005 and 2009). The motivation behind this Programme centres on the need to update the SIOSE-A System easily and economically.

Benefits to citizens

The System, equivalent to monitor changes in territory, represents a very useful and precise tool for land management, and it is some of the most downloaded information from the website of the Regional Ministry of Andalusia (www.juntadeandalucia.es/medioambiente/rediam/analisiscambios). This System is used as a cartographic reference for the work of different administrations, because it simplifies decision-making in sectors such as socio-economic (subsidies, statistics), environmental (programs of conservation, sustainable development), political (investments and incentives), security (assistance against natural disasters), among others.

The development of the 2005 Information System was performed using classical methodologies, in which photo-interpretation had to sweep large areas, which was highly cost and labour intensive However, the methodology implemented to update the System to 2009, using SPOT-5 HRG imagery, has reduced runtimes by approximately 50%, and budget by 72%, because the area to

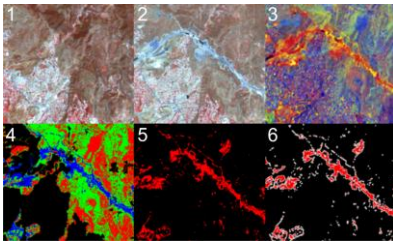
'This Programme saves costs in the production of Land Use Information System of Spain (SIOSE), in addition to strengthening the capacities of updating the system, whose temporal dynamics is central to many applications.' **Nuria Valcárcel, National Geographic Institute (IGN)**

photo-interpret has been reduced by 93.2%, so the system only has to revise 6.8% of the total original images.

The space-based solution

This update of the System has been made possible thanks to the use of SPOT-5 HRG imagery that covered the entire region of Andalusia in the same period of summer (year) of 2005 and of 2009. The combination of multi-spectral (10 m) and panchromatic images (2,5 m) has been essential to the methodology, because multi-spectral images (4 bands from green to infrared) enable changes of kind of land cover/ land use to be detected, while panchromatic images provide change detection of shape and texture. Methodology is based on a differences analysis between two dates using non-supervised classification. The differences analysis works with images and products derived from them: e.g. vegetation index, texture variables, filters, etc.

The Programme, given its size, has proved a challenge of great importance because it has developed a methodology that has been used successfully in the 40 SPOT-5 scenes covering the Andalusian territory, which has a great diversity of land uses and land cover. As result of this experience, this same methodology can be used in following years and for different zones in the rest of Europe, using images from the same or equivalent sensors in spatial and spectral resolution.



Detail of SPOT-5 scene 035-276: 1. 2005 Image; 2. 2009 Image; 3. Difference 2009-2005; 4. Change layer; 5. Refined change layer; 6. Refined change layer in vector format

Outlook for the future

The future strategy of this Programme is to regularly update the Information System with the greatest flexibility and at the lowest cost possible. The success goes hand-in-hand with the existence of satellite imagery with high spatial and spectral resolutions. In that sense, a combination of Sentinel 1 and 2 could adjust to the definition of this project perfectly. Finally, the continuity of the project will be guaranteed by the existence of other contributing ESA missions, for example, Deimos-2 and Pléiades.

Carpintero, I.R., Granado, L., Méndez, E., Montoya, G., Pino, I., Prieto, R., Vales, J.J., Giménez de Azcarate, F., Cáceres, F. and Moreira, J. M.
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DETECTING FOREST CHANGE IN IRELAND USING SATELLITES

Satellite imagery was used to map forests in Ireland in 1990, 2000 and 2006, classifying mature and young forests with different accuracies

Landsat composite 2000

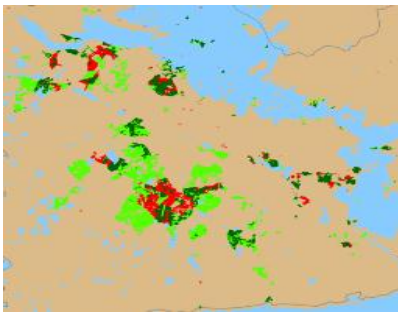
The challenge

Up-to-date information on forest resources is required for forest management, production planning and support for forest and rural policy development. Such information is required by the Irish Forest Service to formulate policies and to monitor and manage the National forest estate. Traditionally, forest maps were produced from the interpretation of aerial photographs, but this was time-consuming, costly and map updates were dependent on the sporadic acquisition of aerial photos, typically every five years. Earth observation data provide a more cost-effective approach since the cost per unit area is lower (€0.50-€5.00 per km^2). The continuous acquisition of data allows forest maps to be updated at shorter intervals using automatic classification methods.

Benefits to citizens

Ireland has had the highest rate of afforestation compared to other EU Member States. Currently, forests represent around 11% of the total land-cover and they are predominantly managed on short rotations of 35-45 years. Consequently, there is an implicit need to monitor these changes and support forest management and planning. Furthermore, these data can aid the assessment of forest biodiversity, identify illegal clearfelling of forests and help balance the environmental and socio-economic demands on forests.

'This application of GMES demonstrates an operational real-time forest land use change monitoring service using spaceborne imagery.' **Frank Barrett, Irish Forest Service**



Example of forest change 1990 - 2006

The space-based solution

During this study, forests were mapped using a minimum mapping unit of 1 ha, which was considered as a significant improvement compared to the Corine Land Cover map. The study was carried out in two regions. In the first region (located in the west of Ireland – NUTS IE01) the survey identified forests for the years 2000 and 2006 using an unsupervised classification approach (see figure). In the second region (County Wicklow – NUTS IE02) the survey classified forests using a supervised classification procedure for 1990, 2000 and 2006. The maps were then used to identify the changes that occurred in the intervening periods. Using GIS analysis, forest loss, gain and stability were mapped. This allowed for a statistical analysis of the rates of change that occurred in the study area. An accuracy assessment was carried out for each map product using pre-existing reference data from the Irish Forest Service, namely national forest inventory data, vector based forest maps and aerial photographs. While the overall accuracy of the maps was very high (above 93%), the Producer and User's Accuracies were very low (between 35 and 65% and 30 and 55% respectively) for the forest class, which meant that large areas of forests were not mapped. Further analysis found that mature plantations were correctly classified, but that many young plantations were not identified, which was attributed to limitations of the imagery and image classification techniques employed during the study.

Outlook for the future

Improvements both in the spectral resolution and the integration of field inventory data will be important aspects to incorporate in a fully operational forest mapping system. In particular, future access to ESA's Sentinel-2 imagery is seen as a new and exciting data source that will enable the system to provide up-to-date information on the spatial distribution of forests, which is a key requirement for forest policy, planning and management.

McInerney, D.[(1)], Harper, C.[(1)], Nieuwenhuis, M.[(1)], Rosengren, M.[(2)], Jonsson, C.[(2)] and Barrett, F.[(3)]

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AUTOMATED TREE MAPPING

Using GMES and GIS to streamline assessment of green space and its constituents in the built environment

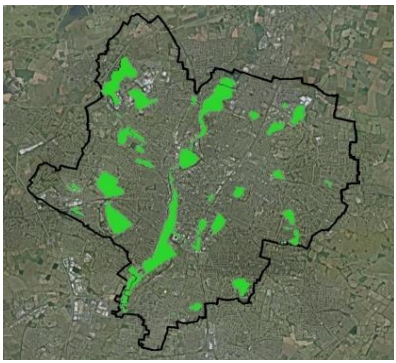
The challenge

Local authorities often need cost effective methods of accurately quantifying and mapping their existing green spaces and tree canopy (Figure 1). GMES offers that possibility.

Benefits to citizens

Mapping foliage and green spaces within the built environment has both societal and public resource implications. Local authorities are tasked with the upkeep of green spaces within urban areas, and accurate maps of the extent and diversity of their responsibility would provide a centralised and effective approach to management with cost and efficiency savings.

There is evidence to support increases in health and wellbeing from ease of access to green space by urban populations, particularly those in high density housing developments. Mapping of accessible green space to provide this amenity is of use to local authorities.



Green Spaces in Leicester

The image above demonstrates this application.

Tree and green space maps can also be used to assist with the management of woodland areas to protect wildlife habitats, particularly in urban oasis.

The traditional method of surveying the foliage types within green spaces involves manual identification of trees from aerial imagery – a time consuming and costly process. The end users of this process are local authorities to whom cost savings for the maintenance of green spaces could be passed directly. G-STEP collaborated with Bluesky, an East Midlands remote sensing SME, to develop a market-ready solution for local authorities.

'The work that G-STEP has done on Tree Mapping has helped us to develop a product that is ready for market.' **James Eddy, Bluesky International Ltd.**

Tree Map of Leicester, GIS layers

The space-based solution

G-STEP has investigated automated tree mapping using a variety of data sets including satellite and Lidar data and images to identify areas of green space and then define objects within that landscape.

Lidar (Light Detection and Ranging) data provided accurate measurement of vertical features whilst multi-spectral imagery provided high resolution information for horizontal land cover. Integrating the two data sets then supplied the basis for identifying tree location and height. Landsat and Envisat data were used to set the background mapping images from which to identify and narrow search areas. Processing combines satellite and aerial imagery and data to isolate 'objects' that fulfil a set of criteria for classification as trees. This includes height, greenness and irregularity. The results of the analysis are then exported to a standard GIS (geographic information systems) interface and displayed visually as shown opposite. By comparing the application results with those obtained from the manual method used by the local authority, G-STEP was able to demonstrate both an improvement in accuracy and speed. Combining satellite and aerial imagery allows larger areas to be analysed much faster than via traditional methods. These attributes enable the service provider – Bluesky – to offer wider area coverage and a faster service to private users as well as to the original local authority users.

Outlook for the future

G-STEP will continue its successful collaboration with Bluesky developing the tree mapping application to provide a cost-effective process. G-STEP is now investigating extending the methodology to enable identification of individual tree species. This is a direct response to interest in the applications of a species specific model from larger organisations involved in areas as diverse as transport and forestry. Bluesky has taken the current application successfully to market.

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SATELLITES HELP TO INTERPRET EUROPEAN FORESTS FOR FOREST INDUSTRIES

All European forests can be mapped within a year with satellite imaging

The challenge

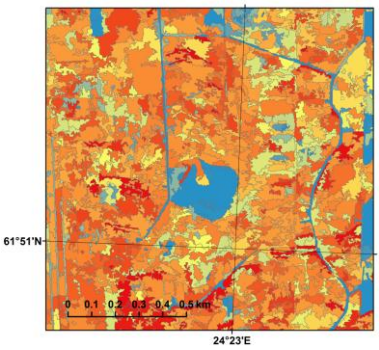
The role of forests as the main terrestrial assimilator of carbon is raising interest in forests in Europe and globally. Individual forest owners and industry are looking for ways to improve information on forest resources while keeping costs at a reasonable level.

The diverse functions of forest and possibly conflicting interests of the stakeholders necessitate provision of credible information that can justify decisions.

Satellites collect information on European forests every day. Therefore, satellite images provide excellent raw material which can be converted into useful information on forest resources.

Benefits to citizens

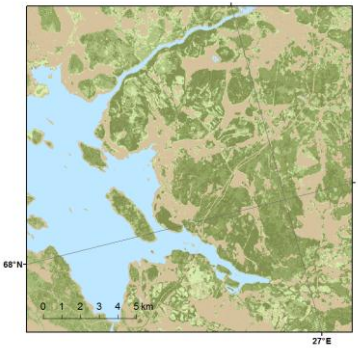
Although the economic significance of forest industry has somewhat decreased in northern Europe, forest industry products still account for a significant proportion of the export income in Finland and Sweden. Forestry related occupations are major job creators in rural areas. Another fast growing employer is nature tourism – based on the recreational function of forests. Monitoring of nature habitats is also required to preserve biodiversity.



Forest biomass map from very high resolution satellite data, site in Finland © VTT

Locally, satellites make it possible to record tree felling and damage as well as to collect principal data on forest characteristics for forest management plans. Image analysis does not completely replace field work but satellite information can dramatically reduce costs of the forest management chain. The traditional method of collecting information for management plans in northern Europe costs in the order of 10 €/ha. The cost of satellite based mapping varies from 0.01 €/ha to 0.3 €/ha, depending on the resolution of satellite data. At a European level it is hard to think any other way for the provision of up-to-date forest information

'Satellite image mapping has improved our operative wood procurement and we are looking for new ways to expand the utilization of satellite data.'
Pekka T. Rajala, Business Development Manager, Stora Enso Oyj, Finland



Forest density map from a site in Finland, Geoland 2 project © VTT

except satellite based observations.

The space-based solution

Large areas can be mapped and monitored with the same effort as small areas.

The VTT Technical Research Centre of Finland's Probability image analysis method is applied by the forest industry for forest resources monitoring. The method, developed originally in the early 2000s for the mapping of pan-European forests for the European Commission has been further tailored for wider application in forestry and land cover.

The Forest industry in Finland uses the satellite imagery method to plan wood procurement. Satellite image analysis results show the distribution of wood biomass and main tree species. The industry can target those owners who have the right type of wood in their forest estates for procurement. The mapping helps the forest owner to find a buyer for his/her wood. This also saves non-renewable resources because driving to find the appropriate forest stands can be minimized.

The Probability method is used in Finland and also in other European regions in the on-going GMES GIO land services for the European Environment Agency.

Outlook for the future

The future of forest monitoring from space to support sustainable forest management looks bright, without doubt. Outside Europe, the REDD process that has been established to reduce emissions from deforestation and forest degradation will be a major driver for remote sensing services. The GMES program also supports the REDD services.

As part of the GMES, in 2014, Europe will launch the first of the Sentinel 2 satellites. The Sentinel images of 84 000 km^2 each can perform forest mapping over areas of several hundred square kilometres at the same time with ten metre spatial resolution.

Acknowledgments

Geoland 2 and Recover (www.recover-redd.eu) projects of FP7 of European Commission, Theme Space.

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VECMAP: A 'ONE-STOP SHOP' FOR DISEASE VECTOR RISK MAPPING

Vector borne diseases are of increasing concern to public health in Europe

The challenge

Dengue, West Nile Fever, Tick-Borne Encephalitis and Lyme Disease are of increasing concern. Yet little is known about the distribution of diseases or the vectors that transmit them to humans (mosquitoes, ticks etc.). Effective strategic planning for control in the event of an outbreak is impossible.

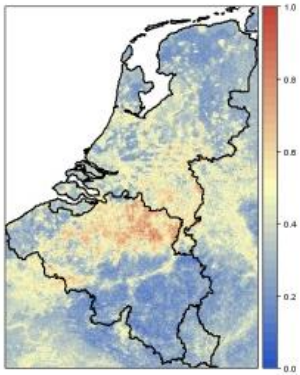
There are well established techniques for mapping vectors or the risk of spread, which are necessary inputs to planning and implementing surveillance and control strategies. They are however complex, involving field sampling, statistical distribution modelling, and satellite image processing. Only a few specialist technicians are able to use them.

Benefits to citizens

VECMAP allows clients such as public health institutes, researchers and vector control companies to do more for less. Its unique benefit is to offer a 'One-stop-shop' with extensive technical support to the end users that demystifies the methodologies, ensures continued access to state-of–the-art techniques, and makes the outputs more transparent and applicable. The VECMAP system is an enabling tool allowing stakeholders to directly produce the information needed to evaluate the risk posed by disease vectors and their potential spread. It also allows practitioners to be more cost effective, and extend their activities to new areas or maintain them in an era of declining economic resources. VECMAP will therefore directly benefit the public good by improving and extending institutional and corporate capability in Europe to respond to risks or nuisance posed by current and newly emerging vectors and vector-borne diseases.

Laboratory tests show that tiger mosquito, now spreading in Europe, is able to carry more than 20 diseases. Photo: J. Gathany/CDC

'VECMAP makes us more effective in assessing risks of vector borne diseases.' **Marieta Braks, RIVM, the Netherlands, June 2012**



A modelled vector distribution map produced by Avia-GIS

The space-based solution

VECMAP is supported by ESA's Integrated Application Promotion program. It fosters the development of sustainable user-driven services integrating multiple space technologies like Earth Observation, Navigation, Satellite-Telecommunications, Human Space-flight and terrestrial technologies. VECMAP incorporates two such assets: satellite navigation and Earth Observation (narrow band optical and infra-red imagery) processed into environmental indicators like climatic seasonality and vegetation index. The first of these is used in the design, planning and execution of field sampling to establish the vector distributions needed to calibrate the final risk models. VECMAP uses smartphones to record data and a web or network data transfer to link to a centralised data archive. In this way field work – often the most expensive element of such work – can be optimised and cost-effectiveness substantially enhanced.

Distribution modelling software is fed by VECMAP field data and using predictors derived from innovatively processed MERIS, MODIS, METEOSAT and SPOTIMAGE data. Higher resolution vector habitat models are also available as an additional service.

The VECMAP Information System is the glue that integrates all the VECMAP components and provides access to all the required supporting data as well as the means to display and analyse final mapped products.

Outlook for the future

VECMAP is being developed as a sustainable commercial venture which will improve the European capability to respond to vector borne disease risk. A major part of the consortium activities, after the System's release in late 2013, will be to maintain the inputs to the sampling and risk modelling derived from space assets such as Sentinel, and to take advantage of advances in satellite navigation and space-borne environmental monitoring capabilities to provide more reliable outputs.

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SUBSIDENCE MONITORING FOR REGIONAL AND NATIONAL AUTHORITIES

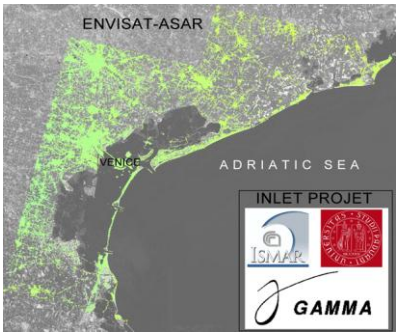
Twenty years of monitoring by SAR-based techniques in the Venice Lagoon

The challenge

Eustacy and land subsidence produce a continuous relative sea level rise (RSLR) along the Northern Adriatic coastland. RSLR seriously jeopardizes the historical centre of Venice and its lagoon. Land subsidence is due to natural processes and anthropogenic activities and has been monitored since the end of the nineteenth century.

Benefits to citizens

Synthetic Aperture Radar (SAR) Interferometry provides the best knowledge of land subsidence processes of the Venice Lagoon. An accurate understanding of the ground movements is of paramount importance for the authorities managing the coast, such as the Venice Water Authority, the Reclamation Water Authorities, Municipalities, and private engineering companies, for example, Consorzio Venezia Nuova, that are developing large infrastructures to safeguard Venice. Also, people living along the coast can benefit from this knowledge. In fact, other processes, not only sea-flooding, threaten the inhabitants and their activities, such as river flooding and salt water contamination of soils and shallow aquifers that are strongly connected to the sinking of the territory.

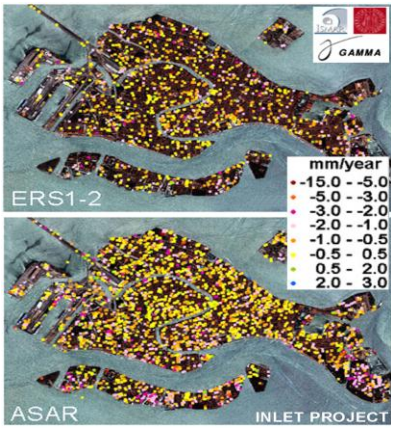


IPTA network in the Venice area

The space-based solution

Over the last two decades SAR-based interferometry has been used effectively to detect land displacements on a regional scale. In particular, the processing of ERS-1/2 and ENVISAT ASAR images acquired between 1992 and 2012 provided an excellent subsidence monitoring 'network' suitable for both scientific and coastal management purposes. The accuracy achieved by Interferometric Point Target Analysis (IPTA) is comparable to that of levelling and permanent GPS, while the impressive

'Space-based information helps in monitoring Venice subsidence that can be managed only if you have precise measurements available.'
Silvano Vernizzi, Regional Secretary for Infrastructures, Veneto region



Land movements by IPTA in Venice

number of measurement points is similar to those obtained by LIDAR. A cost-benefit analysis reveals that IPTA is much more convenient than earth-based techniques. Recently, the development of new very-high resolution X-band radar satellites has increased the applicability of IPTA to monitor land subsidence. In particular, TerraSAR-X and COSMO-SkyMed have been successfully tested for detecting movements of single structures, for example, the MOSE works, with millimetric precision and metric spatial resolution.

Results show that coastland movements are usually characterised by significant spatial variability.

Hydrogeological investigation and the knowledge of anthropogenic activities allow the factors responsible for the observed displacement variability to be identified, i.e. tectonics, differential consolidation of the Pleistocene and Holocene deposits, groundwater withdrawal, reclamation of marshes and swamp areas, and farmland conversion into urban areas.

Outlook for the future

The use of new X-band radar satellites is strongly recommended for monitoring land subsidence affecting the Venetian coastland as well as the movements of local infrastructures under development, such as the MOSE works at the three inlets connecting the lagoon to the Adriatic Sea. ESA Sentinel missions will provide an important service of SAR images. Their processing will continue to guarantee an accurate, real-time, and high-spatial resolution monitoring of the land displacements in the Venetian coastland.

Acknowledgements

The VENEZIA Project has been completed within the ESA DUP II period. INLET Project has been conducted by ISMAR-CNR and GAMMA RS and funded by Venice Water Authority, through its concessionary Consorzio Venezia Nuova.

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SNOW COVER MONITORING FOR CENTRAL EUROPE AND THE ALPS

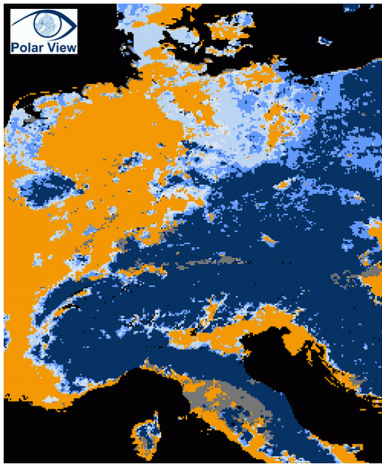
Snow Services help to improve flood forecasting by daily up-dated spatial satellite information

The challenge

Large parts of Europe, especially the Alps, are affected by snow cover for several months. The risk of flooding increases when heavy rainfall coincides with snow melt. The strong temporal and spatial dynamics of snowfall and melting in Central Europe can best be monitored by Earth Observation (EO). The extent of the snow cover and the areas of melting snow are observed by optical and microwave remote sensing satellites.

Benefits to citizens

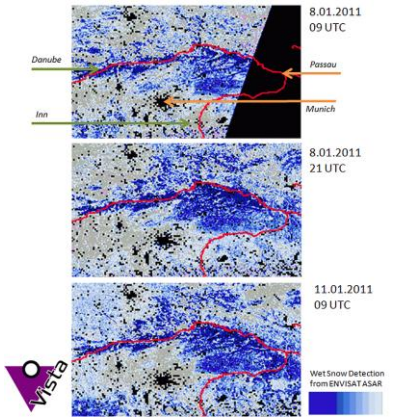
Up-to-date information on the snow cover from EO service helps regional and national authorities to improve their flood forecasts and run-off simulations. With this knowledge, the hydrological situation can be better analysed and public warnings can be announced. From the beginning, the Flood Forecast Centre of Baden Württemberg was involved in the development of the service. Snow information, together with weather station data and hydrological simulations, allow the user to quantify the volume of water stored in the snow above hydro-power plants. Both applications support decision making for public and commercial life. For almost ten years EO-based snow information has helped in the analysis of the hydrologic and climatologic situations and trends. From the beginnings of GMES, starting with the service element Polar View in 2005, user-driven snow services have been running in Central Europe, Scandinavia and the Baltic Area.



Observed snow cover over Central Europe in mid February 2012 by the Polar View snow service [dark blue: fully snow covered area]

'Without Polar View's services, we wouldn't have the same capabilities; and the quality of our forecasts could diminish for certain flood events.' **Werner Schulz, Flood Forecast Centre Baden-Württemberg**

Since 2010, their consolidated products have also been available via the Polar View Snow Service Portal www.snowsense.de.



Monitoring of the snow melt during the Danube flood event in January 2011

The space-based solution

Satellites enable the retrieval of information about a snow-covered area on a regular basis. Optical observations from polar orbiting satellites (for example, NOAA and METOP series) allow a good detection of the snow covered land. Only restricted by clouds, daily information on snow cover, snow free areas and the snow line is provided. Using fully automatic processing, the products (for example, maps) are made available to users in Near-Real-Time (NRT). Additional information from active microwave (SAR) satellite systems on board ENVISAT, RADARSAT and the up-coming Sentinel-1 can help to detect snow melt and thus support flood warning. The image on the left shows an example of the observed extension of the wet snow along the Danube during a flood in Germany in January 2011.

Additionally to the observation of satellites, snow services make use of spatial modelling of snow storage and water balance. This provides information on river run-off, including forecasts of expected hydro-power production, relevant for public and commercial applications.

Outlook for the future

Following the ESA funded Polar View GMES project (2005-2012), www.polarview.org, the service on snow and water quantity will be extended by the use of GMES Sentinel-1 observations within the Bavarian collaborative project APPS4GMES. In this context, the development and demonstration of user focused services of snow monitoring for hydrology will continue.

GMES and the Sentinel missions will improve operational snow mapping and monitoring, via rapid data dissemination, short revisit times and coherent, reliable information for large or remote regions.

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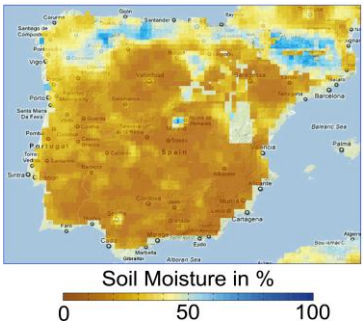
SATELLITE-BASED SOIL MOISTURE FOR DROUGHT AND FLOOD MONITORING AND FORECASTING

How relatives of your microwave oven help to monitor global soil water and why you benefit from these data



Dry soil moisture conditions in the profile of the Iberian Peninsula for late March 2012 as relative percentage (0 – 100%)

The challenge

Atmospheric processes like rainfall, evaporation and changes in temperature are crucial factors influencing weather, climate and water-related extreme events like floods or droughts. One variable that has attracted increasing scientific attention is the water stored in the pore space of soils. For decades it was only possible to measure this soil moisture on the ground via probes. A globe-covering probe-network is financially not feasible but satellite technologies now provide an opportunity to measure soil moisture from space, enabling quick and accurate measurements.

Benefits to citizens

The impact of extreme events is stronger in countries that already suffer from high levels of vulnerability. Nevertheless, industrialised countries are not immune to hydro-meteorological extreme events. Estimates for Europe indicate that 17% of Europe's territory and 11% of its population are affected by water scarcity, resulting in costs of €100 billion over the last 30 years. According to the newest Intergovernmental Panel on Climate Change (IPCC) report the frequency of extreme events is likely to increase in several parts of the world. Hence, it is important to estimate the water content in the root zone of plants for agricultural purposes or the degree of water saturation in the face of approaching flood events. Also weather forecasters have identified soil moisture as a valuable resource for improving predictions.

'The integration of satellite-based soil moisture information resulted in a positive impact in our operational forecasting system.'
Imtiaz Dharssi, MetOffice UK (HESS, 2011, Vol 8, pp. 4313-4354)

Of all natural disasters, droughts rank first regarding casualties, duration and economic loss (Image Source: Stock Free Images and Dreamstime Stock Photos)

The space-based solution

Modern active microwave systems (radars) used for soil moisture retrieval orbit planet earth close to the poles. They emit beams to 'see' so-called 'swaths', which change as the planet rotates. Each swath can be several hundred kilometres wide, while the resolution of one pixel is 25–50 kilometres.

One great advantage is that radars work independently of sunlight and weather. Additionally, active retrieval of soil moisture is based on backscatter characteristics as the only input. Auxiliary datasets are needed solely to correct, scale and classify the results.

Unfortunately, the penetration depth of microwaves into soil is restricted to a few centimetres. Therefore, a soil water index was developed at the Institute of Photogrammetry and Remote Sensing. It is based on a two-layer infiltration model that is applied to time series of surface soil moisture. This way the soil moisture content up to a depth of 1 m can be estimated. One of the first practical users was MetOffice UK, who successfully assimilated satellite-based soil moisture into a weather forecasting model. Within the GMES service GEOLAND 2 the soil water index is produced operationally.

Outlook for the future

Some regions (high elevation, dense vegetation, frozen or snow covered) still pose a challenge to active microwave remote sensing. Sophisticated research approaches are needed to minimise errors in the datasets. Cooperation between European and North American missions is required to produce data as practically oriented as possible to fulfil user needs.

The near real-time operational availability of soil moisture products has created wide-ranging scientific interest. This continues to lead to new applications, including the role of soil moisture in occurrence of water and vector borne diseases, such as malaria.

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GMES SERVICES FOR URBAN SPATIAL PLANNING IN THE CITY OF VIENNA

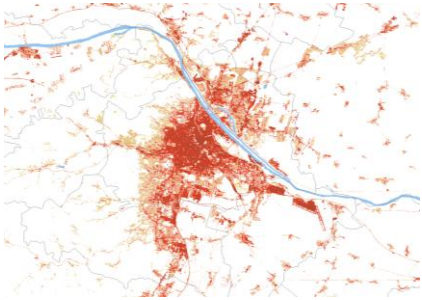
The City of Vienna employs GMES services for analysing land take and assessing urban growth

The challenge

Land is a finite resource. In Austria this is especially obvious in mountainous and metropolitan areas. With pressure rising on cities and regional governments to assess the environmental impact of urban and regional policies and activities, there is ever-growing demand for reliable land use data and information products. With more than 75% of Europeans living in urban areas, it is a similar story all across the continent. Strategies for balancing the socio-economic needs and environmental protection are therefore urgently needed.

Benefits to citizens

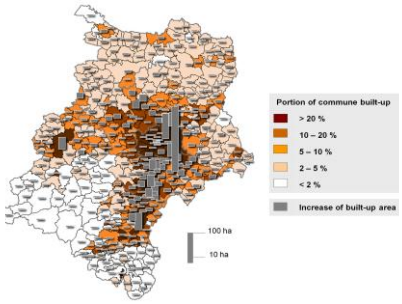
Integrated spatial planning is a key element for preserving quality of life and avoiding socio-economic losses that result from unbalanced territorial developments and climate change.
The GMES Spatial Planning service addresses these issues and supports evidence-based decision making.



GMES high-resolution map of imperviousness of the Vienna region
© EU, geoland2; Producer: GeoVille

In addition to this, the GMES Spatial Planning service helps spatial planning authorities across Europe to fulfil their monitoring and reporting obligations, arising from a number of local, regional, national and European directives and policies. Users of the service are cities and spatial planning departments within regional governments and federal ministries as well as European Commission services (DG Regio, European Environment Agency, Eurostat).
Vienna's urban development department works to ensure the city's development in line with social, economic and ecological requirements. This task requires sound data and information as input to fundamental planning tools and for cross-border cooperation with neighbouring provinces and countries.

'Recent developments in IT and space technology offer tremendous possibilities in monitoring land use. High-quality data is crucial for advanced GIS analysis and evidence-based decision making.' **Helmut Augustin, Dept. for Urban Development, City of Vienna**



Land take indicator for City of Vienna and surrounding provinces
© ESA GSE SAGE; Producer: GeoVille;

The space-based solution

The GMES Spatial Planning geo-information service offers a space- and ground-based infrastructure to provide reliable and timely Earth Observation information services from European down to regional administrative levels.
The portfolio comprises spatially referenced and consistent geo-information products, including;

- Land cover/use maps from the GMES Land Monitoring Core Service (for example, high-resolution land cover characteristics of built-up areas, Urban Atlas)
- Land take trend indicators on grid or administrative unit level and derived statistics
- Urban growth scenarios to simulate future land take trends.

Such maps derived from Earth Observation images are integrated with ancillary geospatial data and demographic and socio-economic statistics. These pieces of information are then used in the spatial information system of Vienna as a cost-efficient tool to analyse land take and soil resources. Within GMES, GeoVille and AIT have led the development of the Spatial Planning information service. The City of Vienna was among the first public organisations to be active in GMES validating and to employ this new intelligence. Vienna also participates in the national GMES initiative for developing a Land Information System Austria (LISA).

Outlook for the future

The GMES Spatial Planning service provides public authorities, such as the City of Vienna, with harmonised data on land use trends. With the availability of high-resolution land cover data from the GMES Initial Operations, supported by the upcoming ESA Sentinel satellites, European cities and regions will benefit from a boosted capacity for long-term, continuous monitoring of urban growth and soil resources.

Acknowledgements

Geoland was funded by EC-FP6 (http://www.gmes-geoland.info), GSE SAGE & Land by ESA (http://www.gmes-gseland.info), LISA by BMVIT/FFG (http://www.landinformationsystem.at)

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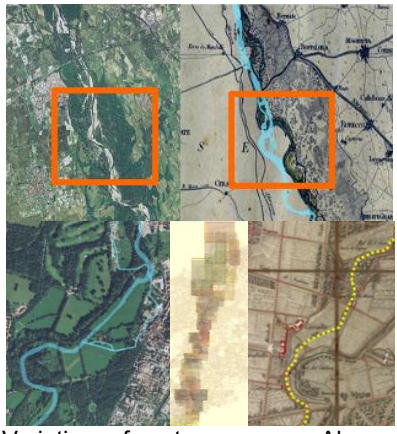
DIGITAL CARTOGRAPHIC HERITAGE FOR LANDSCAPE PLANNING IN A SPATIAL DATA FRAMEWORK

An open-source heritage spatial data infrastructure used by regional and local authorities for informed decision making

The challenge

The analysis of transformations of the landscape and inland waters relies increasingly upon integrated services based on geospatial information, creating a progressive demand for data sets and services and extensive availability of this information to different final users. The partners of the project Atl@nte (Polimi, Lombardy Region, Agency of Territory, National Archive of Milan-ASMi, City of Gorgonzola, Study Centre PIM) have set up a spatial data infrastructure (SDI) of more than 600 historical geo-referenced maps, territorial maps of Lombardy and six series of historical large scale cadastral maps, reconstructed along natural and artificial water courses crossing historical sites of Milan, Monza and Gorgonzola. Web feature services (WFS) of the portal section 'Cartographic collection' allow non-expert users to access a gallery containing 28,000 ancient, not geo-referenced maps of Milan Province. The section 'Geo-referenced maps' gives access to historic cartography within a modern geo-portal. Tools are available for the functions View, Discovery and Download, as requested by the European INSPIRE Directive.



Variation of water courses. Above: Ticino river at Boffalora, near Milan: Ortoimage, Topographic Military Institute (ITM) map and current water course from regional geo-portal. Below: cadastral geo-referenced maps along the Lambro river

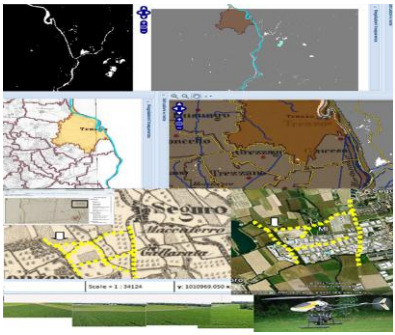
'Atl@nte services are of great support for the "Government planning of Territory". They have a significant role in awareness rising among citizens, students and children on the history of water resources.' **Arch. Lorenzo Sparago, Municipality of Gorgonzola.**

Benefits to citizens

A web geospatial repository of historic maps can contribute to a better knowledge of urban texture and landscape in general. Lombardy has an advanced process-oriented SDI and the integration of these geo-databases contributes to: (1) expanding a systematic range of spatial and satellite data usage for authorities, experts and citizens; (2) reducing time and costs of real-life archive visits; (3) supporting the region in monitoring floods, river-bed cleaning and state-owned parcels. Examples of data sharing within Atl@ante with the geoportal of Lombardy Region are underway along the test area of Lambro river.

The space-based solution

The Atl@nte geoportal, compliant with Open Geospatial Consortium standards, provides tools for multi-source data analysis, enabling the user to add remote sensing products distributed as Web Map Services as new layers on the historic maps, e.g. the European Environmental Agency layers on land use and water courses, present within the geoportal, or other external GMES services. The following figure clearly illustrates 'Add a river bed' change.



Data integration within Atl@ante. Landsat TM image and cadastral maps: 'Add a river and wetlands' changes over time. 1:100,000 Landsat TM image, classified for water content, 13 September 1999, resolution 30 m, CNR-IREA

Outlook for the future

In order to address effects on built environment and to contribute, with frequent updates, to retrieving further knowledge of territory, heritage SDI could in the future be integrated both with other available satellite image and Sentinel derived maps and also with real imagery and high resolution in-situ analysis such as multi-spectral investigations using an unmanned aerial vehicle.

Acknowledgements

FondazioneCariplo funded the Atl@nte project (http://www.atlantestoricolombardia.it/), and the National Archive and Cadastral Administration provided maps for this research.

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URBAN DEVELOPMENT IN THE COMMUNITY OF MADRID

GMES monitors the breathing of the city of Madrid and its surroundings

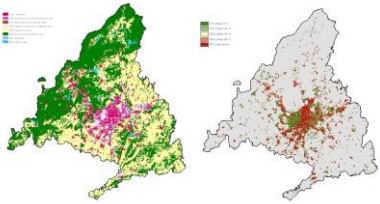
The challenge

During the last decades, the Madrid region experienced one of the highest rates of population and economic growth amongst European metropolitan areas. This 'breathing' of the city, i.e. its expansion into the hinterland, is characterized by disproportionate land consumption due to new built-up areas and transport infrastructure in comparison to the actual population growth.

Urban planning has had to cope with these challenges raised by urban growth on a regional level and functional changes in the city centre.

Key policy questions are:

- How much and in what proportions is land being taken?
- Where are the areas with the most significant land consumption and changes in functional characteristics?
- What are the driving factors in the uptake of land for urban and other artificial development?
- How many people are affected?



Urban land cover and degrees of imperviousness of Madrid region
(c) ESA GSE Land: Geoville. Indra

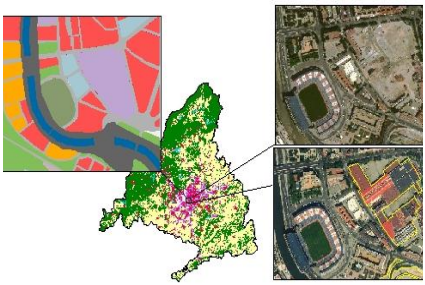
Benefits to citizens

The Land Monitoring Core Service (LMCS) developed through the joint EU/ESA initiative GMES helps to overcome today's major constraint on planning applications at local and regional level.

The LMCS delivers consistent land cover and land use maps beyond the respective administrative boundaries, following well-accepted thematic and geometric standards. With the LMCS, effective policy evaluation beyond administrative borders is facilitated. For local applications, the Urban Atlas offers a tool for decision-makers and planners to implement sustainable urban growth and to inform citizens.

Madrid user is the Ministry of Environment and Territory of the Regional Government of Madrid.

'In general, the thematic elements are very consistent, even compared with reference data of higher resolution.' **Alberto Leboreiro, General Sub-director of Regional Planning, Madrid**



GMES land monitoring of Madrid City
(c) ESA GSE Land; Geoville, Indra

The space-based solution

The GMES Service Element for Land funded by ESA has demonstrated the successful implementation of the land monitoring service in regions across nine European nations. The Madrid region was one of the agglomeration areas for which European service providers have developed and applied a highly-automated mapping application that significantly increases the reliability and data throughput of traditional mapping and change detection approaches.

High and very high resolution satellite images are used to provide reliable geospatial and statistical information, e.g. degrees of imperviousness, on the development of urban areas, transport infrastructure and other major land cover types and their changes over the time.

Outlook for the future

The Madrid case has served as an important step in the implementation of the European GMES Land Monitoring Core Service. Currently, under the GMES Initial Operations, a recent pan-European mapping of impervious surfaces is carried out for 2012, providing further useful updated information on urban growth in European agglomeration areas.

Moreover, an update of the 2006 Urban Atlas city land use maps is planned for the near future. Users' expectations for the future, if they could have a local Urban Atlas, are focused on the regular updating of the product (every one to two years). Here ESA's Sentinel-2 satellites can help by providing high resolution images with a high acquisition frequency. For land management, urban planning change assessment is a very important issue, and most of the users lack products or projects devoted to a regular monitoring of changes.

The current developments for monitoring solutions will enable city and regional governments in their efforts towards better urban planning.

Acknowledgements

GSE Land was funded by ESA (http://www.gmes-gseland.info) geoland was funded by the European Commission (http://www.gmes-geoland.info)

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USING SATELLITE IMAGES FOR SPATIAL PLANNING

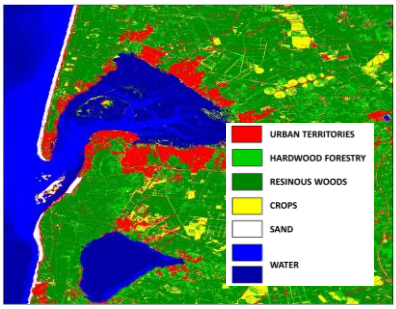
Satellite images are a precious resource for meeting the demands of spatial planning

The challenge

Public services in charge of spatial planning need a tool to observe the evolution of land use: urban sprawl, land consumption, preservation of natural areas, etc. Using satellite images in a meaningful way that is consistent with and complements other databases in order to help institutional services to achieve their mission of spatial planning for citizens is the challenge of this application.

Benefits to citizens

Spatial planning at local, regional or national scale is a major concern for citizens and organisations in charge of managing the environment, housing, agriculture, forestry and urban planning. Spatial planning issues for citizens, formalised by institutional texts (Grenelle de l' Environment, Regional Schemes for Climate, Air Quality and Energy, *SRCAE,* Modernization of Agriculture Law...), are linked to land consumption, economic management of land and space, urban sprawl cartography, and identification of ecological corridors for biodiversity. Geographical information on these issues is required at local or regional spatial scales and over a period of 10 years. To meet these demands, services in charge of these issues generally use traditional databases (in France: Topo DataBase, Ortho DataBase, property assessment files, *MAJIC files*, parcel registers, etc.). Extraction of information relevant for spatial planning is usually done by integrating these different databases using geographic information systems (GIS). Some approaches, however, use photo-interpretation of satellite images. These methods are relevant for users but have limitations. The updating of these databases is generally too slow: users need an update once a year, whereas it takes 3–10 years for an update of traditional databases.



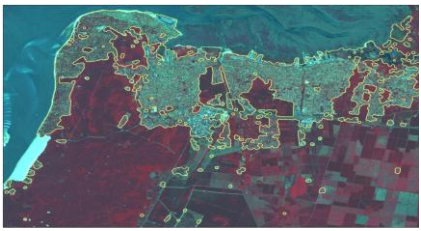
Semi-automatic classification of planning, Arcachon area

'Midi-Pyrenees is a vast region: 45,000 km²: Satellite images provide specific information on land use, complementary to traditional databases, at a lower cost and with frequent update.' **Anne Calmet, DREAL Midi-Pyrénées**

The cost of some databases can be high, data processing can be very slow, and in some cases, data required are inadequate or non-existent.
Having GMES data complementary to those databases will help management of spatial planning for citizens' quality of life.

The space-based solution

Satellite images possess interesting capabilities for the characterisation of land cover: frequent revisiting of territories (i.e. frequent updates of information), large area covered (i.e. uniform image processing), spectral richness (allowing good semi-automatic extraction of information). Moreover, the current French system for sharing data helps lower the cost for satellite images.
For this application, the GEOSUD French programme provided free rapid-eye images (5 m resolution). The service produces the equivalent of the first level of the Corine land cover typology, with the highest spatial resolution.
Supervised classification (with learning based on digitising photo-interpretation of 3% of the territory), with a pixel approach (the classification is done pixel by pixel), the addition of the Normalised Difference Vegetation Index (NDVI) and texture, has been performed to semi-automatically extract seven classes of land use.



Extraction of artificialised areas, SPOT5, Arcachon area

Results have been compared with photo-interpretation of the imagery: between 90% and 99% of land cover has been identified in the right class. This is relevant for some spatial planning applications. Then, post-treatment and vectorisation of this classification allowed analysis of specific classes, such as the artificialised areas in Figure 2. This can be very useful for analysing changes in land cover and evolution in land use every year.

Outlook for the future

The launch of the ESA Sentinel satellites will continue to improve the quality of these semi-automatic classifications. Frequent updates will be possible and could be used to observe the evolution of land use. After radiometric equalisation between images, land use mapping will be possible at regional scale, enabling wide land use management.

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THE EVOLUTION OF THE SOIL USE IN VENETO

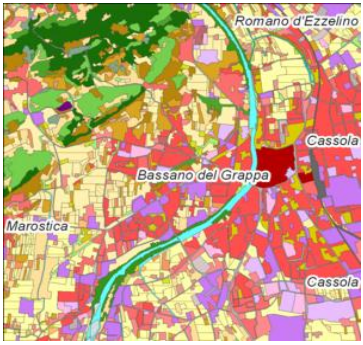
A land cover map database from satellite images to compare historical and present data

The challenge

In March 2005, the Veneto Region began a project within GMES Urban Atlas, for the creation of a Land Cover map. The Regional Major Development Scheme uses a Cognitive Framework that is constituted by data, information and cartographic representations for the description of the socio-economic and environmental structure of the territory. The first stage of the analysis describes the data mining for the evaluation of soil use, which was put into effect starting from the Land Cover map, based on the European project GSE LAND database. From this starting point the Veneto Region achieved the analysis and studies that would define the objectives specified in the preliminary document of the plan.

Benefits to citizens

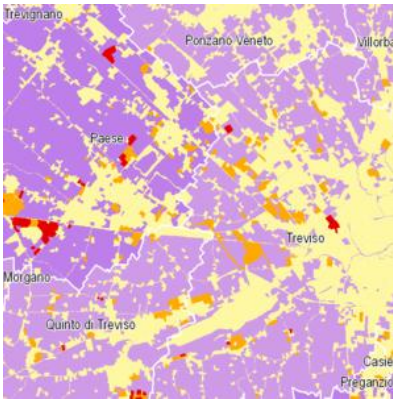
Knowledge of the dynamics leading to Land Use, is strategic for the country planning because it allows interpretation of the current condition of the area. This allows both interpretations as a consequence of the modifications occurring in the past, and at the same time monitoring for the future. The database created has proved an essential tool in providing cartographic and informational support that was subsequently processed to prepare some indexes for the town area. These indexes allow the percentage values of every land coverage category to be evaluated and compared to the territorial surface of every town in the region. The Land Consumption Map is disseminated by internet to each Local Authority interested in using it for their Town Plan. Moreover, the citizens are interested because the map gives them the opportunity to visualise on the internet the evolution of their territory over the years and to understand how



Land use in Bassano del Grappa (artificial, agricultural, forests, wet lands)

'Veneto Soil Use has transformed the territory but GMES is now giving an extra gear to keep this particular problem under control.'

Silvano Vernizzi, Regional Secretary to the Infrastructures, Veneto Region



Land use change due to urbanisation in Treviso 1983-2006

their Local Authorities have managed the land where they live.

The space-based solution

This project has analysed the trend of land consumption. In future, the use of new sensors, and in particular of the sensors of the Sentinel family by the European Space Agency, will allow observational continuity where previously observations were made using SPOT sensors.
As part of this cognitive effort, the Region has initiated and established over time a survey program aimed at the realisation of geographic databases for Land Use and Land Cover. It has used satellite data images from Worldview 2 of Digitalglobe, a high-resolution satellite collecting at 0.46 m and orbiting at 700 km above the earth.
From the database of land cover, as it has been designed, it is possible to understand the nature of the transformations of the territory. This is done by highlighting the type of the original land cover, subject to change in the time periods considered at provincial level.

Outlook for the future

Currently the project has completed an analysis of the whole Veneto region for the years ranging from 1983 to 2006.
In future with the launch of new sensors, the temporal trends can be assessed to predict and forecast the soil use in the future. The new sensors that will be used should have a daily revisit time and provide a better geometric quality of the image, which matches the GMES needs for the local operational and emergency services. The rationale and the attention to the 'consumption' of soil is therefore a key issue for the local authority planning. The soil/land is being protected and safeguarded by the Veneto regional government with the help of remote sensing in the face of the ever-present demand for land for homes/settlements.

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UrbanSAT – SATELLITE MONITORING TECHNIQUES FOR WARSAW METROPOLITAN AREA

Demonstration of the satellite imagery and added value services for the purpose of spatial planning

The challenge

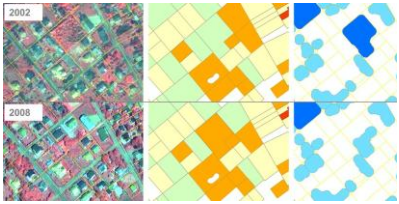
The aim of the UrbanSAT project is the implementation and broader application of satellite monitoring for geospatial analyses. The focus is on the process of development of metropolitan areas of Poland on the basis of Warsaw Metropolitan Area.

Benefits to citizens

Project UrbanSAT demonstrates the ability to use very high resolution remote sensing data for the purpose of land cover monitoring for spatial planning in Poland.

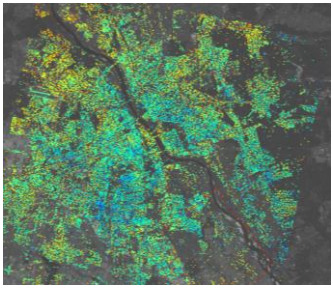
Satellite images can play an important role as a spatial information source necessary for efficient spatial planning in such areas for several reasons. In particular, they enable rapid identification of initial symptoms of sub-urbanisation processes – like new flows of population or enterprises to suburban zones. This is conducted through detection of subtle changes of spatial structure of land cover. In addition, satellite image-based information may be effectively used in the Polish spatial planning system in cases where a local spatial development act has not been established and where acts of lower materiality work as a legal replacement for a planning document.

Results of the UrbanSAT project are addressed to specialists from the spatial planning sector and the regional offices of spatial planning. The final implementation of the project's outputs has been conducted in all of those beneficiaries.



Development of built-up density and parcel characterisation (years 2002 and 2008) left: satellite image with parcels (KUAA); middle: degree of built-up area within parcel; right: parcel characterisation

'Satellite technology like UrbanSAT opens up new possibilities for the spatial planning of large metropolis. Rapid access to comprehensive information about the territory is crucial for the social and economic innovations as well as regional smart specialisation.'
Prof. Z. Strzelecki, Director of Mazovian Regional Planning Office in Warsaw



Results of radar data processing. Colour of the point corresponds to averaged relative terrain subsidence/uplift velocity (cm/year).

The space-based solution

For the generation of the products a broad range of input data has been used. Very High Resolution (VHR) satellite imagery and several ancillary data sets (digital terrain model, cadastral data) serve as input for the production of land cover, land cover change and land use maps. Cadastre data and land use zoning data are essential data sets for the calculation of the spatial planning indicators, for example building land reserves. The dataset is analysed using GIS tools to estimate degree of built-up area per parcel and potential building reserves.

Statistical reporting allows for the comparison of urban development in different municipalities. Through this, any significant decline in the building land reserves can be observed.

Additionally, usability of radar data was examined. The research performed demonstrates a high potential of radar data applications for urban planning applications. Results from processing of long term series of such data allow the monitoring of deformations that affect individual buildings and constructions. Application of coherence time series allows detection of changes in land use and in building construction activities (including illegal ones) which can be of great value for city councils.

For dissemination purposes, a webpage with all the crucial information about satellite data, products provided, documentation etc. has been created. Final products are available for users via GeoPortal. The Geoportal uses Spatial Data Infrastructure technology and is fully compatible with INSPIRE directive. All layers can be freely accessed by users via Web Mapping Services in various GIS software.

Outlook for the future

In the future all solutions tested for Warsaw Metropolitan Area can be extended to other highly-urbanised areas in Poland. In addition, the planned constellation of Sentinel satellites will be used as a source of free, good quality data.

Aleksandrowicz, S.[(1)], Kulawik, B.[(1)], Perski, Z. [(1)], Weichselbaum, J. [(2)] and Borsa, M.[(3)]
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[(2)] GeoVille Information Systems GmbH
[(3)] Institute of Spatial and Cadastral Systems

MONITORING VEGETATION DROUGHT STRESS IN ANDALUSIA

Monitoring and evaluating the state of vegetation by drought phenomenon with remote sensing data

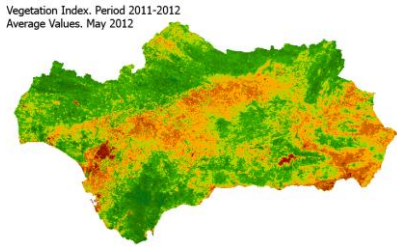
The challenge

Knowing the response of vegetation to the reduction of water resources provides extremely relevant and valuable environmental information.
However, access to this information on a global scale as well as at regional level such as for Andalusia, is hampered for two reasons: on the one hand, the insufficiency of a pluviometers network and, on the other hand, the uneven response of different vegetation types and crops, and the unequal amount of precipitations.
In order to overcome this deficiency, the Environmental Information Network of Andalucia has developed a methodology using satellite images to obtain indicators of water stress level suffered by different types of vegetation.

Benefits to citizens

The use of satellite imagery has become usual in the study of vegetation drought stress in Andalusia since 1991.

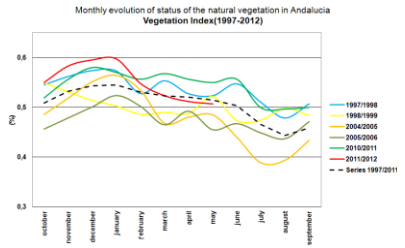
The main advantage of remote sensing data is in supplying synthetic character information for the whole region, at low cost and appropriate frequency compared with other methods that, although more accurate, cover a lower area and at a higher cost and complexity.



Temporal and spatial map of vegetation status

The ability to provide quantitative data, together with the frequency of images and their integration with other information included in the Environmental Information Network of Andalusia, has allowed the development of a methodological process to obtain quantitative and qualitative indicators of the impact of drought on vegetation in this region.

'The dynamic operational monitoring of drought stress in vegetation provides an overview of its state, to support agricultural and environmental decisions.'
José Lopez Segura, Research and Agricultural and Fishing Training Center Manager, La Mojonera (IFAPA)



Evolution of status of the natural vegetation. Time series 1997-2012

The space-based solution

The main idea is to take advantage of the potential that remote sensing provides for monitoring dynamic phenomena. To do this, images obtained from NOAA-AVHRR (until 2001), IRS-WIFS (2001–2002) and MODIS (2002–present) are used, offering special features for this type of study such as: daily repeatability, existence of historic series, quantification of parameters related to chlorophyllous vigor and density of vegetation, etc. The organisation and exploitation of this image library has enabled the comparative analysis of the evolution of the vegetation water stress, allowing the beginning of a trend analysis of this phenomenon in recent decades.

Based on different vegetation indices derived from satellite images, several environmental indicators have been generated for monitoring the state of vegetation as a global indicator of water stress (summarising the annual state of vegetation from the sum of the areas reached by the stress values of vegetation across the region) and the medium vegetation index (representing the average value of vegetation index values throughout the year).

From these vegetation indices, an analysis is made showing the phenological changes of vegetation throughout the year, and the response of vegetation cover, among other conditions, to water deficit situations.

Results are available on the website of the Environmental Information Network of Andalusia: www.juntadeandalucia.es/medioambiente/rediam/estadovegetacion

Outlook for the future

It is expected that land monitoring services and, in particular, control and better understanding services of climate change, will eventually cover all needs identified for Andalusia.

The Sentinels 2 and 3 projects (commencing in 2013) will allow an intensification of these services.

Pino, I., Granado, L., Montoya, G., Carpintero, I., Méndez, E., Prieto, R., Vales., J., Giménez de Azcarate, F., Cáceres, F. and Moreira, J.M.
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MONITORING LAKESHORE VEGETATION USING AIRBORNE IMAGERY

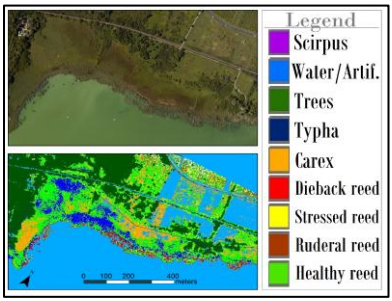
Lake Balaton is under environmental pressure from intensive seasonal recreation and fluctuating water levels

The challenge

Lake Balaton is the largest freshwater lake in Central Europe covering 596 km^2. Sustainable inhabitation and exploitation of the resources require monitoring of the shore vegetation. Regional, governmental and environmental strategies are being used to explore time- and cost-effective ways of establishing sustainable management of wetlands.

Benefits to citizens

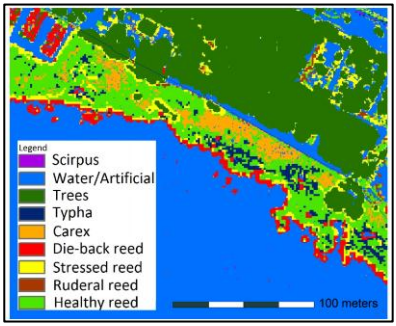
Lake Balaton is a residential area with hundreds of thousands of inhabitants dwelling in the surrounding region whose quality of life directly depends on the local environmental conditions. During summer, the region accommodates a large number of tourists; hence apart from the governmental attention in this area, there is also an economic interest. Furthermore, the area encompasses important nature conservation sites, adding a vital environmental component.



Aerial image (top) and the thematic vegetation map (bottom) produced from pertinent airborne data after processing in specialized software

With regard to the aforementioned aspects, maintaining a sustainable state of the lake is of crucial importance primarily for residents. One of the key players in preserving botanical and zoological diversity is the emergent vegetation of the littoral zone, with the common reed being the dominant species covering a substantial part of the lake shore. Traditional mapping methods with in-situ measurements have proved inflexible at a regular operational level, if not infeasible. Imagery acquired from airborne platforms provides accurate information at low cost and with enhanced visualisation capabilities. Thematic maps produced from remotely sensed data are used operationally in other regions, and are now becoming established as a valuable tool for assessing environmental conditions by

'Vegetation maps derived from remotely sensed data might prove a fruitful and effective visualisation tool.' **Piroska Pomogyi, Biologist, Central Transdanubia Water Authority**



Monitoring the stability of shore vegetation by classifying reed health condition using airborne imagery

the Central Transdanubia Water Authority, the main legislative body monitoring Lake Balaton.

The space-based solution

Monitoring a vast area with traditional field surveying practices is time- and cost-consuming, setting aside the potential inaccessibility of remote areas and surveyor errors, which might result in biased and inflexible mapping methods. Those constraints can be overcome by employing Earth observation (EO) data, which are being introduced as an effective mapping technique with ever increasing accuracy at decreasing cost. A typical field campaign costs approximately €8,000 while the project undertaken amounted to €60,000. However, the images collected are the data source for several scientific and operational projects simultaneously, splitting the cost and creating an information database accessible by any interested practitioner. It is worth noting that airborne data were used in this application to allow sub-metre resolution and advanced sensor´s capabilities, similar to those expected in future satellite missions (e.g. WV-3), thus acting as an experimental task prior to a satellite launch. Although the overall cost of our project is high, it has a low cost-to-benefit ratio if we consider the number of final users and the fact that similar data from satellites will be considerably lower.

Outlook for the future

Sustainable management of freshwater lakes requires precise and consistent monitoring. EO, by means of airborne imagery for region specific GMES applications, provides the capability to map and assess the environmental condition of vegetation cover. Sentinel-2 satellites planned to launch in 2013 with multi-spectral high-resolution sensors and a short revisit time are anticipated to provide similar data in regular intervals for accurate vegetation change detection and monitoring.

Acknowledgements

Supported by GIONET, European Commission Marie Curie FP7, PITN-GA-2010-264509.

Stratoulias, D. [1,2], Zlinszky, A.[1],Tóth, V.R.[1] and Balzter, H.[2]
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SUSTAINABLE IRRIGATION WATER MANAGEMENT AND RIVER BASIN GOVERNANCE

An operational space-based application at the service of the water irrigation community

The challenge

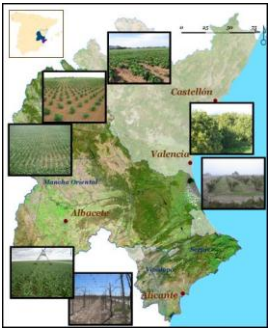
Intensive irrigated agriculture accounts for 70-80% of total water use in Mediterranean regions. Irrigation strategies based solely on practical experience tend to result in over-supply of water (up to 20%) with consequent problems related to misuse of water and mobilisation of nitrates.

The challenge for EC service providers is to bridge the gap between supply and demand for the water irrigation community.

In response to this, new, operational, space-based GMES services are being stimulated to enable land users on multiple levels to benefit from optimised irrigation water management strategies so that water can be saved without compromising production levels.

Benefits to citizens

Users include individual farmers, water user associations, river basin authorities and regional governments.



Castilla La Mancha Region

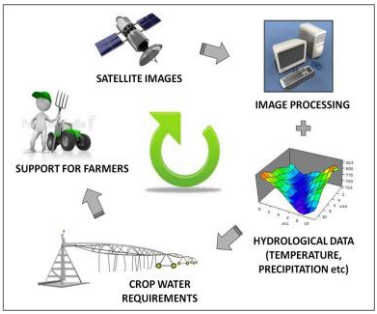
GMES products can help these users to manage water according to real crop water requirements with direct benefits such as reduced operational costs through increased equipment run time, reduced maintenance costs, reductions in energy required for pumping and optimisation of fertiliser volumes and improved yield stabilities required to secure production contracts. At the community level, other benefits accrue:

- social – through the reduction of water-related conflicts
- environmental – through limiting irrigation consumption to only the water that is needed; any excess water contributes directly to natural flow and recharge mechanisms.

The space-based solution

The Castilla La Mancha region in Spain knows from direct experience the huge potential of Earth Observation (EO)

'SIRIUS enables better decision making which supports improved water use and irrigation techniques. We are also able to detect problems in plots, applying fertiliser only where needed – all of which is reflected in higher profit.'
Trinidad Rosa, Water User Association, Mayo, Mexico



Earth Observation in support of irrigation water management

assisted tools and services for the support of irrigation water management and river basin governance. One way in which this potential is being realised is through a temporally structured sequence of images over a region of interest. Nominally, images are acquired every two weeks throughout a growing season. These images are processed to generate a suite of intermediate EO products, typically NDVI (Normalised Difference Vegetation Index), that enable the progressive compilation of a time series of vegetation condition. When combined with other, non-EO, ancillary data (such as temperature and precipitation), it is possible to generate spatially distributed estimates of crop water requirements. These products provide land users with the key information they need to optimise their irrigation usage at the field level without compromising on yield potential.

The wide-scale analytical capability offered through space-based solutions enables this spatially distributed water monitoring potential to be applied, in a cost-effective way, to entire irrigation schemes, aquifers and river basins.

Outlook for the future

The EO-based service concept described is satellite data intensive. Service sustainability must be a key objective. Thus the imminent availability of data from the ESA Sentinel satellites is excellent news. The instrument and product specifications of Sentinel-2, in particular, offer an excellent fit for the services' EO requirements.

Beyond the EO data, service sustainability is further supported by the inclusion of participatory elements to encourage committed users, sustainability elements to contribute to holistic irrigation management solutions, and business modelling components to deliver viable funding solutions.

The user base starts with the Castilla La Mancha region but has already expanded to include seven other pilot areas, both in Europe and internationally.

Acknowledgements

The GMES service described is being realised through the EC FP7 initiative SIRIUS (Grant agreement 262902). For more information, please visit http://www.sirius-gmes.es

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HYDROLOGICAL MODEL FOR WATER MANAGEMENT AND IMPLEMENTATION OF EUROPEAN DIRECTIVES

E-HYPE is a hydrological and nutrient model for water assessments across Europe

The challenge

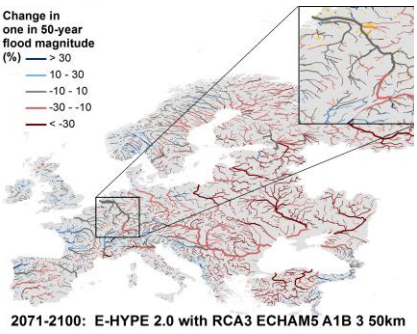
Three European framework directives have been adopted during recent years. The Water Framework Directive commits EU member states to achieving good qualitative and quantitative status for all inland and coastal waters.
The Flood Directive requires EU states to draw up a preliminary flood risk assessment**.**
The Marine Strategy Directive aims to achieve good environmental status of the EU's marine waters and establish environmental targets and monitoring programmes.
These directives ask for assessments of status and effects of measures for effective water management in Europe. The challenge for the hydrological scientific and operational communities is to provide detailed water information for large regions.

Benefits to citizens

Accelerated changes in, e.g., climate, land use and demography put pressure on nature and biodiversity as well as infrastructure and society.
Water information is essential for sustainable development and protection of nature and civilians. Rising problems may include changes in flood frequencies, drought periods, sediment production, water quality, ground water levels, and drinking water or energy supply. Most construction engineering is dependent on calculations of water amounts and fluxes, which may change under changing conditions.
The E-HYPE tool contributes uniform and homogenous estimates of several hydrological variables. These can be used in assessments on different scales and across borders and can reduce the costs of extensive field monitoring.

Flooding causes major costs for the citizens of Europe

'Thanks to you, our regional IBI ocean operational system can run with your hindcasts and daily runoff forecasts (from E-HYPE). This point has been one of the most important updates of our system!' **Sylvain Cailleau, Mercator Ocean, France**



Example of future climate scenario

The space-based solution

The E-HYPE model calculates daily water balance, hydrological and nutrient fluxes and discharge to the sea for small streams and entire river basins. The model system can be used for simulating long term past conditions, forecast and future predictions. The predictions may be used for, e.g., early warning services, hydropower regulation, water allocation, infrastructure planning, agricultural practices, shipping guidance, environmental control or climate-change adaptation. E-HYPE is operational in the SMHI production system and data can be downloaded for free at www.smhi.se/e-hype. Data is also distributed directly to marine institutes for input to operational oceanographic forecast models. Earth observation (EO) is one of many data sources needed in the E-HYPE modelling system. Satellite data products that are used include topography, land use, soil sealing, phenology, snow coverage and lake ice.

Outlook for the future

In the future, satellite-based information may become even more crucial for assessments using the E-HYPE system. Traditionally, hydrological model systems have often been site specific, for particular water bodies, rivers or catchments. E-HYPE contributes a harmonised system that can be used both for practical decision making and scientific hypothesis testing. The system is managed by SMHI and will continuously be improved. Continued collection of updated EOs and in-situ measurements will be incorporated. SMHI look forward to help to customise products based on model output from the E-HYPE system. Such products could, for instance, include flood frequency, which is important for flood risk evaluation and planning of infrastructure. Similarly, the number of days with agricultural drought is important for planning use of fertilisers and irrigation. Snow water equivalents are important for planning new power plants and renovation of existing ones as well as daily energy pricing. E-HYPE is open for international collaboration and the HYPE source code will be further developed in the recently launched open source community (http://hype.sf.net).

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SATELLITE IMAGING FOR WATER QUALITY MAPPING OF LAKE BALATON

Earth observation has potential to greatly improve the monitoring of inland waters, such as Lake Balaton

The challenge

Freshwater resources are increasingly under threat from pressures such as climate change, pollution, and overexploitation. As emphasized within the EU Water Framework Directive (WFD), baseline information and monitoring are required in order to detect and understand changes to freshwater ecosystems and resources, as well as to make the most appropriate management and adaptation decisions possible. Unfortunately, in most cases adequate data proves to be limited or non-existent.

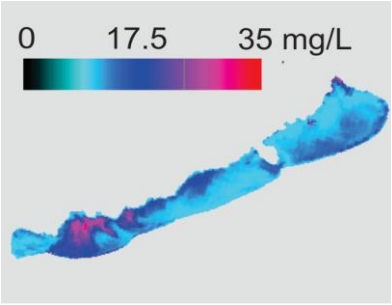
Benefits to citizens

Clean water is central to every aspect of our lives. Citizens rightfully demand responsible management and protection of their shared water resources. Lake Balaton, Hungary is of vital importance within the region due to the role it plays ecologically, recreationally, and economically. The ecosystem faces a number of environmental pressures and over the past decades has undergone extreme variations in water level and quality. The EU Water Framework Directive aims to achieve good quality for all European waters, including surface waters such as Lake Balaton. Earth Observation has the potential to provide data with spatial and temporal coverage, otherwise not possible, providing near-real time data to rapidly detect changes in water quality and mitigate negative impacts. Likewise, archive data can be used to understand and respond to longer term trends and phenomena, ensuring a longer-term perspective. With this better information both for lake management and taking planning decisions, the benefits to citizens of Earth Observation of Lake Balaton's water quality are as numerous and varied as are the uses and values of a clean, sustainable water resource.

Plume of the Zala River entering Lake Balaton, and changes to water quality visible through airborne imagery

'Satellite remote sensing could bring new perspective and facilitate water quality assessment of Lake Balaton.'

Péter Pécseli Director, Central-Transdanubian Water Authority



Map of total suspended matter (TSM) of Lake Balaton, produced using MODIS data, currently freely available

The space-based solution

Certain substances suspended or dissolved in lake water affect the condition of the water, or 'water quality'. In particular chlorophyll-a and total suspended matter can be detected and measured using satellite imagery. The Balaton Limnological Institute has undertaken the development and implementation of on-going Earth Observation monitoring of these substances for Lake Balaton. Such a monitoring system involves the integration of various data types, including the collection of optical and water quality data through satellite, airborne and ship-mounted campaigns. These are used to relate measured water quality conditions to Earth Observation data.

Outlook for the future

A framework will be established to combine, organise and diffuse Earth Observation water quality data as it becomes available for use by the local water authority, development agency and other decision makers, as well as by the research community and the general public alike. The data will be broadcast as maps and regularly updated and archived.

The framework developed for the monitoring and broadcasting of Lake Balaton water quality is intended to readily integrate future Sentinel-2 data which is foreseen to be of great benefit to this system. The spectral resolution and coverage, and temporal and spatial resolutions of Sentinel-2 are well suited to inland water quality monitoring. Data will be freely available and a series of satellites will provide data for more than 20 years, thus ensuring continuity as well as improvement in monitoring Lake Balaton and other inland waters.

Acknowledgements

Supported by GIONET (GMES Initial Operations - Network for Earth Observation Research Training), European Commission Marie Curie Programme Initial Training Network, Grant Agreement number PITN-GA-2010-264509 (www.gionet.eu). Thanks to BLI technical and administrative staff.

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IMPROVING THE MAPPING OF SEAGRASS BEDS USING HYPERSPECTRAL REMOTE SENSING DATA

The demarcation and characterisation of seagrass beds using hyperspectral remote sensing data

Image of *Posidonia oceanica* seagrass meadow

The challenge

The aim of this project is the characterisation of seagrass beds on the submerged coast of Cabo de Gata-Níjar Natural Park. These beds are one of the largest coastal ecosystems in Andalusia, and are distributed up to a depth of approximately 30 metres. At this depth the sunlight that reaches the sea bottom is not sufficient to allow the correct development of photosynthetic activity. Over time, these seagrass meadows experience changes in their distribution and density, making it necessary to invest in expensive sampling campaigns to obtain updated knowledge of the seagrass condition and to achieve the correct management of this habitat.

The sensors used have the capacity to record the response of the light after interacting with objects and to transform it into a continuous image of the area of interest. Hyperspectral airborne and remote sensors have been chosen to map the distribution of the seagrass beds. Among the characteristics of these sensors, it should be emphasized that its detailed spectral resolution (the number and width of the spectral regions in which the sensor collects data), makes them suitable to distinguish between submerged vegetation and other types of non-vegetative bottom substrate.

Benefits to citizens

Seagrass meadows constitute a fundamental coastal ecosystem, playing an important role from the point of view of biology and coastal dynamics. In addition, they are considered as bioindicators of water quality (as is reflected in the European Water Framework Directive 2000/60/EC), essential to evaluating the impact of human activities on the coastal zone.

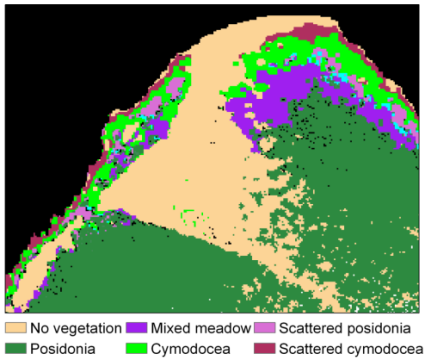
So, the regression of this biocoenosis

'Airborne and remote sensing data have made possible the characterisation of posidonia beds, considered as a bioindicator in the European water framework Directive'. **Ana Correa Peña, PAC/RAC PAM-PNUMA Consultant, CAMP Levante Almería General Coordinator (Integrated Coastal Zone Management)**

provides information on potential impact at local level of pollution by dumping, incidence of coastal port work, water eutrophication due to untreated sewage effluent, etc. Due to this, the Regional Government is carrying out work to characterise these marine ecosystems, particularly seagrass meadows which consist of *Posidonia oceanica*, a priority habitat in the Habitats Directive 92-43-EEC. The Environment and Water Agency of Andalusia has developed a methodology using hyperspectral sensors, in order to get a quick and accurate continuous mapping of the state of the seagrass beds.

The space-based solution

In order to characterise the species that form seagrass beds, hyperspectral images have been used. The image data have been acquired with the airborne Compact Airborne Spectral Imager (CASI) sensor and the Compact High Resolution Imaging Spectrometer (CHRIS) on board the Project for On Board Autonomy (PROBA) satellite, belonging to the European Space Agency (ESA). Data acquisition from both sensors has been coordinated with field radiometry campaigns, to validate the different corrections applied to images and to obtain sea bottom maps. These differentiate the two seagrass species that form the Cabo de Gata meadows and delimit bottom substrate on the basis of this composition and granulometry.



Seagrass species distribution

Outlook for the future

The methodology developed could be extrapolated to mapping the rest of seagrasses colonising the European region, especially the Mediterranean Sea, where water transparency allows enough light penetration for the sea phanerogams. This application might be considered within the MyOcean project of GMES, making possible the environmental assessment of the submerged coastal area using the seagrass beds status as a reference. To continue covering this subject, a combination of the Sentinel-2 and 3 missions could be used, as the sensor on board Sentinel-2 has a high spatial resolution and it is suitable for vegetation studies, and Sentinel-3 has been designed with spectral features suitable for ocean monitoring.

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IMPROVEMENT OF VESSEL DETECTION BY SATELLITE RADAR IMAGERY

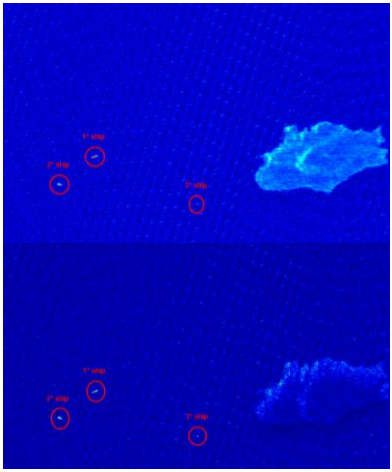
By applying state of the art algorithms to the processing of radar imagery we can find previously invisible vessels

The challenge

In the middle of the Atlantic, there are no means to observe vessels that do not wish to be observed – the so-called non-cooperative vessels. Of course, they can be spotted by other ships, namely by the authorities' ships, but a more cost-effective and global monitoring capability would be desirable. It is here that Earth Observation and particularly satellite Synthetic Aperture Radar (SAR) imagery can play an important role, with its all-weather, day and night capabilities.

However, the open sea conditions in the Atlantic, and particularly in the Azores area, are quite demanding for satellite radar processing. The SAR imagery retrieved from the Santa Maria Station (in the Azores archipelago) often shows up a very rough sea that masks smaller vessels, and this can be the difference between detecting and not detecting a suspect vessel.

This is where a call is made to more specialised algorithms than the classical techniques. EDISOFT has implemented advanced SAR processing techniques, based on image filtering in the frequency domain, which allows the reduction of the sea-based noise (sea clutter) and consequently increases the visibility of the vessels in a radar image.



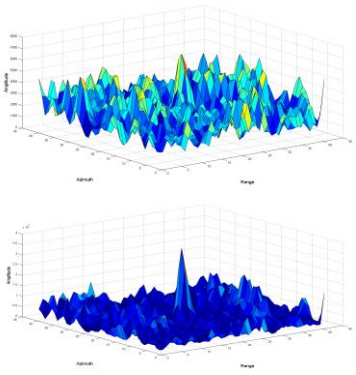
Vessels detected by the old (top) and new (bottom) EDISOFT processing technique

Benefits to citizens

Citizens may expect a more cost-effective answer from the authorities to illegal activities like drug smuggling, illegal fishery, among others, which cause a high economic and social loss every year not only to the country but also to the region and local communities.

'In the middle of the Atlantic, the Autonomous Region of the Azores has the largest exclusive economic zone of the EC, therefore it considers the insurance of the security and surveillance of this hyper-cluster of the sea economy a priority.'

José Contente, Regional Secretary for Science, Technology and Infrastructures



Ratio between the signal echoed from the vessel and noise (from the sea) for the same image

The space-based solution

With Earth Observation it is possible to monitor the Atlantic seas on a round-the-clock basis in a very cost-effective way. The strategy is as follows. Radar imagery is planned months ahead with the help of the user. This way the user may plan their assets, taking into consideration the planned satellite acquisitions. Automatically, the service chain in the Azores satellite Santa Maria station will acquire the imagery and the processing algorithms will run for the detection of suspect vessels. The results of the detection of suspect vessels are forwarded to the users, the Portuguese Navy, GNR, and others, by email, web services, fax, etc, who can then direct the available means to the location of the suspect activities. In a continuous improvement process, service feedback is provided by the users to EDISOFT.

It is possible to achieve a time as short as 10 minutes from acquisition to sending the alerts, and never more than 30 minutes. The figure to the left shows that the results for the advanced processing present much less noise, which allows a detection of a second vessel on the radar image. If you imagine that all the noise seen in the top graph of the image on the left may be caused by difficult sea conditions, it becomes clear that the processing technique used by EDISOFT allows more vessel detections, even in difficult conditions, through the Azores Santa Maria Satellite Station.

Outlook for the future

In the future, growth of investment in the Santa Maria Station is foreseen to enable higher performance Near Real Time (NRT) satellite based services not only for Vessel Detection but also for Oil Spill detection and other purposes. At the end of this year the capability to process RADARSAT-2 imagery should be operational, with the integration of Sentinel 1 data (as soon as this is available), which will allow for coverage of large areas with very high temporal resolution.

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IMPROVING COASTAL MONITORING WITH HIGH RESOLUTION REMOTE SENSING

Multi-spectral high resolution satellite sensors provide new accurate products for coastal management

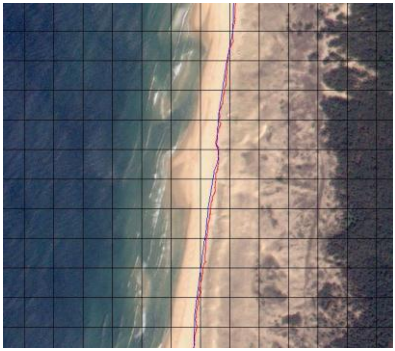
The challenge

Coastal ecosystems are controlled by complex interactions between land and oceans where processes range from seconds to decades. Whilst field access is often limited, synoptic and frequent observations achieved by high resolution satellites allow adapting the surveys to both scientific and user needs.

Benefits to citizens

Coastal monitoring is supported by either time-consuming field surveys that are spatially limited and restricted to calm sea states or cost prohibitive airborne Lidar surveys. Conversely, satellite earth observation is identified as a cost-effective solution for large and long-term monitoring of the coastal systems and henceforth for deriving environmental parameters useful for decision making. As for recreational and economic issues, dynamic coastal systems need to be regularly and accurately mapped to ensure people and goods' safety. Moreover, the impact of climate change has to be addressed. Thus, coastal transformation analysis must be based on regular and accurate surveys of key indicators in order to distinguish short - term processes from long term trends and thus project the impact of future coastal hazard.

When semi-analytical algorithmic development is combined with radiative transfer theories, the relative coastal water transparency allows environmental water constituent concentrations to be characterised.

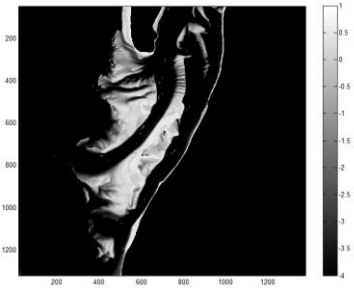


Coastline maps derived from FORMOSAT-2 scenes (1200*1400 m zoom) in 2007 (blue) and 2009 (red) (@ OCA / GEO-Transfert)

'Satellite-based maps derived from GMES are currently exploited to analyse coastal changes and refine littoral management strategies.'

Cyril Mallet, BRGM Aquitaine, Aquitaine Coast Observatory

These indicators are of importance for coastal managers as they represent key indicators of the coastal morphology and water quality.



Bathymetric derivation (in metres) from a SPOT-5 scene - Arcachon tidal inlet, South West France, September 29th 2011 (@ EPOC)

The space-based solution

Based on the radiative transfer theory, multi-spectral high resolution satellite observations allow accurate physical and biogeochemical parameter estimations to be derived. Significant improvements are required for atmospheric correction while bathymetric accuracy reaches circa 15% up to a maximum depth of 10 metres for moderately turbid coastal environments. The accuracy of the coastal features positioning, and the performance of the change analysis that can be achieved, is only limited by the resolution of the space sensors.

Lastly, remotely-sensed coastal indicators have been compiled by the Aquitaine Coast Observatory in order to derive the current trends of the Aquitaine sandy coastline and propose evolution scenarios for the next decades. With the aim of identifying erosion hazards on the north and south coasts of the Arcachon lagoon inlet, the movements of the channels and sandbanks inside the inlet have been surveyed on a seasonal basis since 1986. Thus, the scope of GMES fits perfectly the objectives of coastal regions that experience erosion and experience Integrated Coastal Zone Management at a regional scale. Also, the monitoring of the coastline and of coastal features is related to the marine project as the development of coastal activities may involve the drawing up of coastal erosion risk mitigation strategies.

Outlook for the future

Future ESA's Sentinel satellites, in particular Sentinel-2, will improve ocean colour applications dedicated to strategic defence and environmental issues as they combine high space, time and radiometric resolution. Also, coastal monitoring looks very promising for the future growth of the space sector.

Acknowledgements

Aquitaine Regional Council, OCA, SIBA and INFOLITTORAL-1 projects helped with the development of operational decision-making tools.

Capo, S.[1], Lafon, V.[2,1] and Lubac, B.[1]
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MAPPING THE ARCTIC SEA ICE IN HIGHER RESOLUTION THAN EVER BEFORE

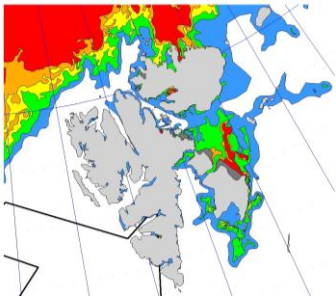
For centuries the European Arctic has been visited by hunters and explorers. Sea Ice information was always in demand, but hardly available

The challenge

Observing the sea ice was never easy or efficient before satellites were launched. When radar instruments were placed in orbit, new opportunities arose. Several countries struggled to afford data, but when GMES started the Service Element activities, experts on ice mapping were ready to develop new services with the support of data supply from the European Space Agency (ESA).

Benefits to citizens

Different user groups need accurate ice information: Tourist ships, research vessels, commercial shipping, rescue vessels,



High resolution ice chart for the Svalbard area. Colours indicate different types of ice © met.no

commercial shipping, rescue activity and the coastguard service. Also climate change research will benefit from high resolution ice charts produced regularly over a long time span. High -quality information for planning and operational use can help to run a business with greater regularity and safeguards income. Control of fisheries and territorial borders becomes more efficient than before, and rescue operations in this harsh environment can be performed with higher accuracy. Compared to earlier methods – flight reconnaissance and ship

'High resolution ice charts help the Norwegian Coastguard to work more cost-effectively in the Barents Sea.'

Lars Kioeren, Operational Officer at the Coastguard Base

observations – satellite monitoring is an extremely cost-effective way of supplying data for ice mapping. For users this means the ice charts will be much cheaper or even available for free.

The space-based solution

Traditionally, optical sensors were used to describe ice features, in addition to flight reconnaissance. Synthetic aperture radar (SAR) instruments on satellites give very accurate information, independent of clouds. The remotely sensed data must still be interpreted by trained analysts to make ice charts. In the Polar View project, supported by ESA (2005-2012), SAR data have become available for several national ice services. The Scandinavian countries produce ice charts for the Baltic Sea and European Arctic waters with seasonal or permanent sea ice.

Outlook for the future

The ice charts for Northern European waters are quite advanced and well on the way to becoming sustainable services. The high resolution ice charts for Svalbard are already integrated in the Norwegian Meteorological Institute's ice service.

The other providers of ice charts for the region have similar plans for integration in their ice services.

Norwegian Coastguard icebreaker 'Svalbard'

Sentinel-1 will carry a C-band SAR that will be essential for ice charting at higher latitudes. This will ensure the delivery of important data for ice charting in the Arctic for the whole lifespan of Sentinel-1. With sustainable services for the Arctic waters in place, it will be important to work towards improved methods for transferring information to the end users on board the vessels. Through national programs and EU-supported pilot projects, we will soon see a system for integrating the GMES ice services in the Electronic Chart Display (ECDIS) systems on the bridge, following international standards for data transfer.

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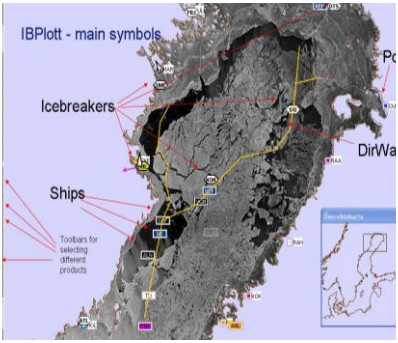
ICEMAR – A GMES PILOT SERVICE IN THE MARITIME AREA

ICEMAR provides access to ice information products to aid ships navigating in ice-infested waters in the European Arctic and the Baltic Sea



Sea ice chart in the Baltic Sea derived from satellite data

The challenge

Human activities in the Arctic are on the increase and there is a growing focus on the exploitation of the region's natural resources. The region is characterised by large ocean areas and rapidly changing weather conditions, as well as prolonged winter darkness. Reliable access to up-to-date information is crucial, but the traditional measurement network is quite limited. Remote sensing systems hence are becoming more important. The challenge for a user operating in the Arctic is to gain access to relevant meteorological, sea-state or ice information provided in a structured and standardised way.

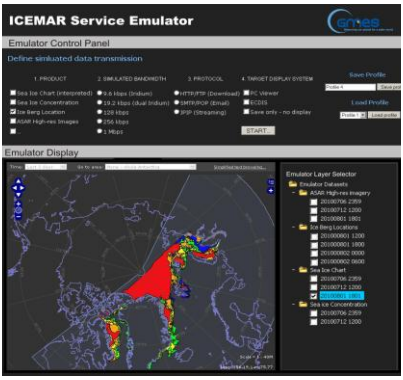
Benefits to citizens

Information about Arctic ice and weather is generated routinely by the meteorological and ice services. At present, a user needs to contact the individual providers to gain this information. ICEMAR will link the information providers and the users and offer access to information independent of the provider and available communication links. This will ease operations and reduce operational and environmental risks. Metocean, ice and tactical information on the traffic situations will be provided to support navigation and operations, reduce the risk of collisions and support the co-ordination of Search and Rescue. The main users are fisheries, shipping, coastguards services, off-shore oil and gas and tourism. The service will allow an operating vessel to identify the simplest route through the ice and to navigate around obstacles. This will improve safety and save money through lower fuel consumption, less hull maintenance and will therefore increase the number of annual operating days. Baltic icebreakers and Norwegian

'Access to detailed, up-to-date ice information around our position helps us to identify the easiest way through the ice.'

Lt Tor-Ivan Larsen, Ice Navigator on the Norwegian Coastguard vessel 'K/V Svalbard.'

Coastguard vessels are users that will contribute to testing and to making the service operational. Feedback from the Norwegian Coast Guard vessel 'K/V Svalbard' shows that updated ice information is vital to their operations.



ICEMAR service emulator interface

The space-based solution

The usefulness of Earth Observation in the Arctic has been demonstrated. It is now fully integrated into operational services. Satellite radar (SAR) is used to provide information on the sea-state, ice extent, ice conditions and icebergs, potential pollution and vessels. The 200-500 km wide coverage by satellites like RADARSAT-1 and 2 and the Cosmo-Skymed constellation (and ENVISAT until April 2012) makes them highly suited for maritime monitoring. The high Arctic latitudes are imaged several times a day. The information is updated correspondingly and available to users within 30-60 minutes. Satellite Earth Observation represents a cost-beneficial source of information as compared to traditional sources like aircrafts or vessels. Comparable costs of space- versus aircraft-based monitoring lies within app €0.10 versus €0.50 per km^2. Vessel operations costs are in the range €5,000-€10,000 per hour. A time saving of a few hours on a vessel cruise as a result of using the ICEMAR service will give a very high benefit to cost ratio.

An ICEMAR Manager on board a vessel will communicate with the ICEMAR server by submitting requests for information and receiving information products.

Outlook for the future

ENVISAT and RADARSAT satellites have been important in establishing the operational service. The GMES Sentinel-1 satellite to be launched in 2013 will assure continuity of the European service. In addition, the RADARSAT Constellation Mission, Cosmo-Skymed second-generation and TerraSAR-X2 will be important missions to maintain the continuity of the ICEMAR service as well as providing new GMES services.

The ICEMAR service is a pilot GMES service implemented through a three year pilot project funded by the GMES Bureau. The prototype service is now established and is in use by real end-users.

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IDENTIFYING SOURCES OF POLLUTION IN THE BLACK SEA

GMES/MyOcean data on currents enable 'backtracking' of oil spills and detection of polluters

The challenge

The Black Sea is the inland sea most isolated from the global ocean, connected only to the Mediterranean and to Sea of Azov. Specific features make it very vulnerable to disturbances to its environment and ecosystems. Pollution inputs and other factors have radically changed Black Sea ecosystems since the 1960s and seriously threatened biodiversity, fishing and marine activities. In May 2011, one of the biggest oil spills of recent years polluted long stretches of the coast between Odessa and Ilyichevsk.

Benefits to citizens

Collaborating since 1992 via an intergovernmental body called the Black Sea Commission (BSC), dedicated to protection of the Black Sea, Bulgaria, Georgia, Romania, the Russian Federation, Turkey and Ukraine have joined forces to combat, in particular, pollution from land-based sources and maritime transport. The damage caused in May 2011 by the dumping of 4300 tons of oil in the Ukrainian area amounted to US$1.4 million, according to the official representative of the State Ecological Inspectorate of the north-western region of the Black Sea, Eugene Patlatyuk. In 2009, the BSC started to develop an information system for the identification of illegal pollution discharges from vessels and offshore installations (through the EU MONINFO project). This tool for modelling oil spill drift, inspired by the Sea Track web system for the Baltic Sea, needs sea state analysis and forecasting data for the Black Sea as entry data. The Black Sea Track Web (BSTW), developed with the support of the EC, was deployed on a pre-production server and is

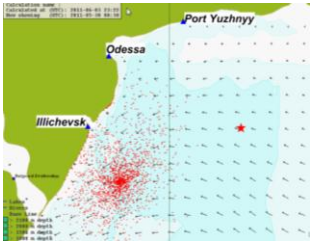
Contamination of the Ukrainian Black Sea was only discovered on the beaches between Odessa and Ilyichevsk on 28 May 2011 (image: novostey.com)

'The GMES MyOcean service is very important for the sustainability of the Black Sea Track Web and the protection of the Black Sea. The BSC plans to fully implement the system for monitoring of oil pollution in the Black Sea.'
V. Myroshnychenko, Black Sea Commission

undergoing testing utilising MyOcean forecast data for the Black Sea.

The space-based solution

MyOcean, the main project for the implementation of the ocean monitoring and forecasting component of the GMES Marine Service, covers seven marine regions including the Black Sea. The information available through this service is derived from space and in situ observations (transmitted by satellites), ESA being responsible for the provision of space data to GMES. MyOcean describes the 3D physical state (currents, temperature, salinity, sea-ice characteristics) of the global ocean and European regional seas. It successfully contributed to BSC's battle against pollution during the oil spill in May 2011.



BSTW output based on an analysis of MyOcean currents data. The oil tracking picture in red dots shows the scale of the beach pollution

To detect polluters, the information system BSTW used MyOcean currents data. BSTW is able not only to anticipate where pollution will drift but also to 'backtrack' an oil spill, simulating where the pollution came from and when the spill started. In May 2011, the local coastal services suspected two potential ship polluters owing to the type of pollution detected on the beaches but they had no evidence. BSC activated the BSTW system (still under development at the time), fed by MyOcean currents data from that exact area. The backtracking system rapidly estimated where and when the pollution started and confirmed the hypothesis: a decisive argument for the local authorities to prosecute the two tankers for pollution.

Outlook for the future

Out of 50,000 vessels yearly passing through the Bosphorus, 10,000 are tankers. Since the oil spill drift in May 2011, BSC has relied daily on MyOcean services. Oil pollution is not the only concern of the Black Sea countries: eutrophication, overfishing and species (e.g. jellyfish) invasions in coastal zones are all issues needing MyOcean state-of-the-art and reliable 3D core information derived from space (Envisat, Jason 1 and 2, Meteosat and METOP and in the future the Sentinel satellites) as well as in situ observations.

Acknowledgements

MyOcean is funded by EU under FP7.
http:/www.myocean.eu/

Korotaev, G.[1], Kubryakov, A.[1] and Thoorens, F.-X.[2]
[1] Marine Hydrophysical Institute, Ukraine, gkorotaev@mhi.net.ua
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INTEGRATED SERVICES FOR OFFSHORE WIND ENERGY

For maximising the use of favourable weather-related windows of opportunity, new innovative logistic concepts and space-based services have to be developed

The challenge

The European Commission (EC) has set the target for renewable energies to provide 20% of Europe's energy supply by 2020. The expansion of offshore wind power generated at sea is one of the main means of reaching that target. Countries like the UK and Germany are planning to build up capacity to generate up to 10–13 gigawatt (GW) by 2020. This means more than 9000 wind energy plants have to be built on locations with predominately rough weather conditions, some more than 100 km away from shore, in water depths of 30–50 m (see image on the right).

Benefits to citizens

The development and expansion of the offshore wind energy market will bring huge social and economical benefits for many European countries. The challenges involved in many technological issues offer excellent opportunities to small- and medium-sized enterprises (SME). The need for especially skilled employees in certain technical fields is huge. For the north-west region of Germany alone, in the production field of wind energy plants, 3000 new jobs have been forecast. End users include those with coordination and observer tasks (e.g. construction managers, vessel coordinators, marine warranty surveyors) and subcontractors or service providers (e.g. installation vessels, cable-laying, crew transfer).

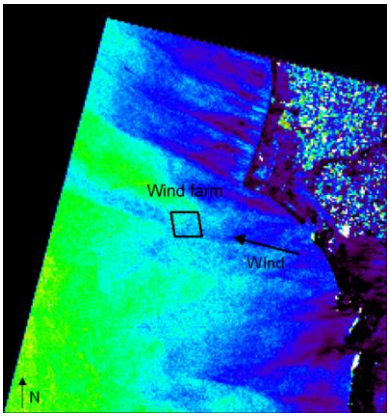
Due to rough weather conditions in the offshore environment, only about 100–120 days per year are suitable for construction work

The space-based solution

In the following fields of applications, new integrated space-based and in-situ solutions are available:

'During the installation phase of an offshore wind park, substantial benefits could be derived from a satellite-based service providing an indication of the weather-related window of opportunity resulting in a potential number of offshore working days.'
Jörg Engicht, Managing Director Deutsche Offshore Consult GmbH

Up to date overview of the situation: The main requirement during the construction phase of an offshore wind farm (OWF) is to maintain an overview of the entire supply chain. Users want to know which vessels are in the farm and whether it is possible to detect all of them with terrestrial AIS. Some OWFs are located in open sea areas with insufficient AIS coverage. Satellite-detected vessels can be used to correct and complete terrestrial AIS data.
Integrated weather services: The optimal use of the weather-related window of opportunity is another main task in the installation phase of an OWF. A wind speed map and current sea-state information derived from satellite synthetic aperture radar (SAR) in combination with in-situ measurements can be used for the planning phase of marine operations, e.g. in support of the daily planning of a turbine installation process (Image to the right).



Ocean wind speed map from ERS SAR from Horns Rev in the North Sea, Denmark (Source: Risø)

Outlook for the future

On both a national and European level, numerous information portals already exist, including marine and satellite-based data. However, many of these are not known sufficiently to potential users. It is important to demonstrate how they can benefit from the added value of integrated satellite-based and maritime in-situ data (e.g. buoys). This process takes place in a 'Trust Centre', to ensure data protection of company-owned information on the offshore wind farm. These sensitive data are available only to the partners involved and any uncontrollable and unwanted distribution of sovereign data is avoided (e.g. AIS data from national traffic centres).
Another use of Earth Observation data is in the planning phase. As described in the user statement, it would be helpful to have a statistical overview of potential offshore working days. With the technical specifications of the forthcoming twin Sentinel 1 satellites (concerning revisit, coverage, timeliness and reliability of service), several scenes from the offshore wind farm area could give first indications about environmental conditions at the offshore wind farm sites, e.g. about critical sea-states or wind speeds.

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A PROMISING ENERGY RESOURCE: OCEAN THERMAL ENERGY CONVERSION

MyOcean helps characterise most promising marine areas for this renewable energy

The challenge

Seas and oceans cover two thirds of the surface of the globe and store immense amounts of potentially usable energy. One technique for harnessing such renewable energy is Ocean Thermal Energy Conversion (OTEC), which exploits the difference in temperature between warm surface waters and cooler deep water.

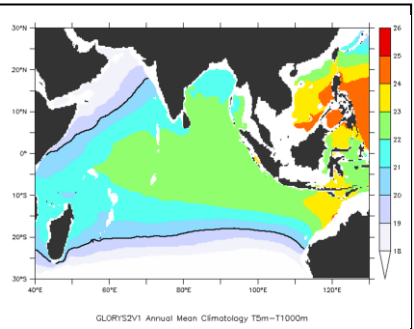
For OTEC to be economically feasible there must be a difference in temperature of more than 20 °C between the water at the surface and at depth. This means that the technique can work only in tropical regions. Also, the pipes used for pumping up the colder water are suited to depths of only about 1200 m (for both physical and economic reasons), which imposes another limit on the choice of location, not to mention the restriction of moderate currents.

Energy production is onerous on islands. OTEC will be of particular relevance to those in tropical regions

Benefits to citizens

OTEC is once again attracting interest as a potential source of renewable energy with certain undeniable advantages: the raw material, seawater, is free, abundant and stable while the technique can also be used to produce fresh water or extract nutrients trapped in the colder layers of the ocean (for aquaculture). This type of renewable energy is available 24 hours a day all year round and produces neither CO_2 nor any waste matter or toxic residues. However, it has yet to be proven that it is financially competitive with fossil fuels. For this purpose it is necessary to identify those tropical regions that are theoretically capable of producing the greatest amount of electricity. The most interesting areas are those near islands, where energy production is particularly onerous.

'This OTEC study on Reunion Island was a unique opportunity to build a first link between EDF R&D and the GMES MyOcean Team'. **Jean-Francois DHEDIN, Marine Energy Project Manager, EDF - R&D**



Annual mean temperature difference between –5 m and –1000 m in the Indian Ocean

The space-based solution

Gathering information from both satellite and in-situ observations, MyOcean provides state-of-the-art datasets including 3D models which offer the capability to observe, understand and anticipate patterns within the marine environment. The MyOcean re-analysis models simulate the past and provide global ocean data over almost 20 years on a ¼° grid (ca. 26 km at the equator). Such models make it possible to characterise the thermal energy available, by identifying those parts of the ocean where the difference in temperature between the surface and the 1000 m layer is consistently greater than 20 °C all year round and by determining the nature of the currents in these regions. A preliminary study in French tropical areas for EDF, the leading French energy supplier worldwide, was based on MyOcean data to determine promising areas. Other MyOcean models offer better resolution for studying local patterns such as seasonal temperature variability or current intensity for a water column. For example, around the Island of Reunion, the mean vertical gradient of 20 °C at a depth of 1000 m is reached during only 7 months of the year on the western side, where sea surface temperatures are higher. In Tahiti, this threshold is reached on all sides of the island from a depth of 500 m and throughout the year.

Outlook for the future

OTEC is 15–25 years behind wind energy. Marine energy overall accounted for <0.002% of electricity production worldwide in 2010. To put OTEC to practical use, it is necessary to identify as many suitable places as possible and how much energy might be potentially available. OTEC's costs are in most cases still unfavourable compared to other energy resources. Reunion Island is nevertheless considering achieving energy autonomy one day, based on ocean thermal energy.

Acknowledgements

MyOcean (http:/www.myocean.eu/) is funded by EU-FP7 and coordinated by Mercator Ocean.

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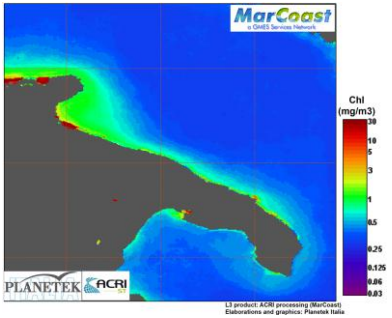
REMOTE WATER QUALITY MEASUREMENTS OF THE MARINE ENVIRONMENTAL STATE IN APULIA REGION

Since 2006 MarCoast has provided water quality data over Italian seas. ARPA Puglia is one of its users



Example of water quality MarCoast product over Apulia coasts: chlorophyll-a percentile 90 for the years 2006–2011. Spatial resolution: 1 km

The challenge

Water quality refers to the physical, chemical and biological characteristics of water. It is a measure of the state/condition of a water basin relative to certain requirements and is most frequently used with reference to a set of standards against which compliance can be assessed. Some European policy directives and international conventions actually set common rules for all the member states, e.g. the EC Water Framework Directive (WFD) of 2000 and the Marine Strategy Directive (MSFD) of 2008. The most accurate measurements of water quality are made on site; more complex measurements are often made in a laboratory using water samples. However, on-site measurements present the disadvantage of a limited temporal and spatial view of a sea area and of high operative costs. Water quality measurements from Earth Observation (EO) can provide valid support to and complement on-site data.

Benefits to citizens

The Apulian Regional Agency for Environmental Prevention and Protection (ARPA Puglia) has among its duties the tasks of monitoring the various environmental components, and of managing and supervising human activities and their territorial impact.

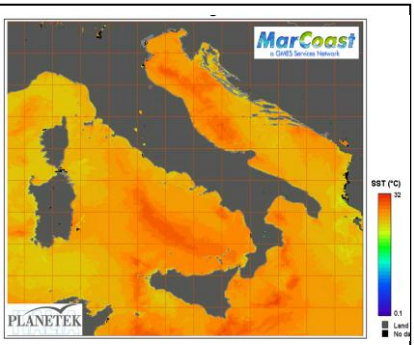
ARPA Puglia regularly performs at-sea measurements for water quality monitoring. Its responsibilities cover the application of WFD at regional level and from next year will also include duties for MSFD. Another responsibility is the evaluation of bathing water quality during the bathing season, which has a more direct impact on citizens (both residents and tourists). ARPA Puglia has identified

'The MarCoast products provide an additional information value to us, compared to the information we already have …' **Cecilia Silvestri, ISPRA**

potential benefit areas from operational use of MarCoast water quality products. These include the extrapolation of water quality information in support of WFD and MSFD, the use of EO maps for communication and presentations, as well as confirmation of observations made at-sea and looking at its evolution in near-real-time.

The space-based solution

GMES MarCoast projects (2006–2012) have aimed to develop operational services using satellite data. Planetek Italia (coordinator of water quality monitoring services) has since 2006 delivered chlorophyll-a, water transparency and sea surface temperature maps derived from MERIS, MODIS and AVHRR sensors to the Institute for Environmental Protection and Research of Italy (ISPRA) and some ARPAs. One success story (third benefit area listed) occurred during an event of toxic cyanobacteria (*Planktothrix rubescens*) bloom which reached from an artificial lake to the sea on the Puglia coast. The near-real-time MarCoast chlorophyll product available enabled confirmation of the alert and planning of the in-situ activities required for emergency monitoring, saving time and resources. ARPA Puglia has been a user since 2009, however MarCoast products are not yet fully incorporated in supporting ARPA Puglia's reporting obligations (first benefit area): to be so, ARPA needs to be mandated to use MarCoast products operationally and the products need to be further locally tuned and validated.



Example of MarCoast water quality product: Daily Sea Surface Temperature at 19/08/2011 over Italian seas. Spatial resolution: 1km

Outlook for the future

Two main challenges face GMES MarCoast water quality services: To become integrated into the monitoring duties to complement traditional in-situ monitoring campaigns; and to ensure continuity and improvements of the products by exploiting unique resolution and temporal coverage by the future Sentinel 3 mission.

Acknowledgements

MarCoast1 and 2 are projects funded by the ESA (GMES Service Element programme) (www.marcoast.eu).

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THE VIGISAT GROUND STATION: ACHIEVEMENTS AND PERSPECTIVES

Since 2009, the VIGISAT ground receiving station has paved the way to new maritime monitoring services and has boosted science and education activities

The challenge

Satellite imagery from synthetic aperture radar (SAR) technology has the unique capacity to monitor wide areas of land and oceanic surfaces, regardless of the day/night cycle or meteorological (cloud) conditions. Direct and secured access to satellite high resolution radar imagery has proved to be essential both to set up near real time (NRT) services monitoring our maritime domain, from the ocean to coastal areas, and to build efficient early warning systems for environmental and/or security threats.

Benefits to citizens

Such services include detection of oil spills and ships, identification of sources of pollution, detection of illegal activities at sea (e.g. smuggling, fishing), and high resolution measurement of coastal wind fields and sea states to support operations at sea and to resource assessment in the field of renewable marine energy. Facilitating access to satellite radar images would also contribute to stimulating R&D activities and to developing training and education in all domains related to remote sensing.

VIGISAT consists of a protected 5.4 m X-band antenna, multi-mission processing capacity (ERS-2, ENVISAT, Radarsat-1 & 2) and an operational 24/7 analysis centre

The space-based solution

With the support of regional authorities of Brittany and Brest-Iroise Science Park, the graduate engineering school Telecom Bretagne and CLS Company have joined forces to promote the installation at Brest of VIGISAT, the first French civilian ground receiving station dedicated to the reception of satellite high resolution radar imagery.

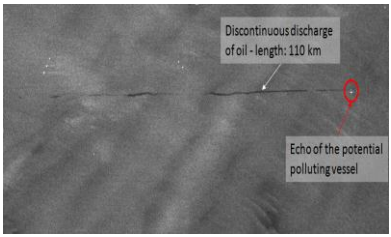
'VIGISAT increases protection of maritime approaches of Brittany and boosts regional scientific capacities in Earth Observation domain.'
Marc Labbey, President of Brest Science Park

This ground receiving station was declared operational in September 2009. In 2010, VIGISAT joined CleanSeaNet, the pan-European oil spill and ships detection service delivered by EMSA. VIGISAT took charge of NRT acquisition, processing and analysis of SAR images acquired over North Sea and Western European Atlantic waters.

This service essentially relies on satellite SAR missions operating in C-band, including the Canadian Radarsat-1&2 missions and the European Envisat mission. The recent and unexpected loss of the Envisat satellite put more stress on the urgent necessity to launch the follow-on GMES Sentinel missions to ensure service continuity.

Satellite images acquired can reveal the location and extent of potential oil spills that will be delivered in less than 30 minutes. The geographic locations of all ships detected within the observed area, with size, route and speed when available, are also provided, as well as sea state information.

Early warning can be delivered even more quickly if suspect detection is implemented at the acquisition time of the satellite image, thus increasing chances of catching the offender red-handed.



Example of a 110 km long oil spill detected using satellite SAR imagery (dark line). The bright point connected to the right side of the pollution indicates the potential source of pollution.

Outlook for the future

The upgrade of VIGISAT towards the future Sentinel 1 missions is essential to ensure service continuity in the long term. VIGISAT also aims to become the European processing platform for high resolution wind, waves and currents fields derived from Sentinel 1 imagery.

Acknowledgements

The Scientific Interest Group “Bretagne Télédétection – Brittany Remote Sensing – GIS BreTel was funded for being the carrier of the VIGISAT project and in order to federate the Brittany research teams around the developments to be made in the framework of the GMES program, the Brittany region being part of the European NEREUS initiative.

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MARINE SERVICES FROM THE GMES SENTINEL MISSIONS

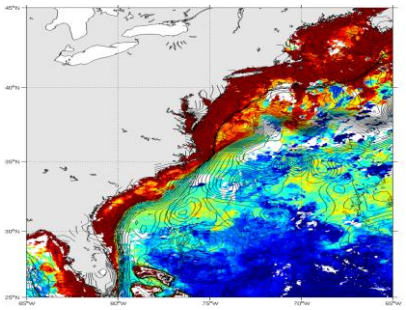
French contribution to the collaborative GMES Space Component Ground Segment, devoted to marine applications

The challenge

Earth observation (EO) techniques on board the future Sentinel satellites, such as ocean radiometry, surface topography and surface roughness, could contribute to the monitoring of the marine environment. However, the core ground segments of the GMES Space Component will mainly ensure heritage and continuity with past missions. The challenge for the Marine Collaborative Ground Segment (MCGS) is to prototype a data-processing centre for complementary bio-geophysical products and added-value services, in order to make the most of Sentinel's potential and build competitive business for marine/coastal markets.

Benefits to citizens

MCGS will provide environmental information for operational monitoring and support, optimisation of human and material resources, for the regulation of sea and coastal areas.



Chlorophyll map from GlobColour off the US East coast in 2012, with overlaid sea surface height from AVISO, as used for Tara Oceans

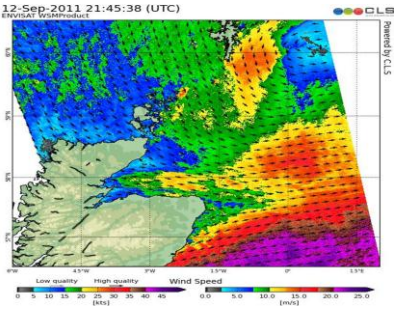
Identified areas of benefit include enforcement of laws, directives and regulation (e.g. common marine resources, marine safety, port/coastal settlement, ships), management of marine protected areas, management of fish stock, aquaculture (e.g. oyster and salmon farms), energy (gas and petrol offshore, renewable energy, e.g. wind farms), transport, tourism, services to local authorities (water agencies).

The space-based solution

Prior to the launch of the Sentinels, some of these services are currently being operationally exploited by the MCGS partners. Especially the Envisat mission was important here. The service concept is described below.

'Satellite data from MCGS precursor services have guided efficiently our boat on oceanic ecosystems of interest during our operational phase.'

Sabrina Speich, Tara Oceans Expedition



Strong wind over Scotland with sheltering effects, obtained with SAR on 12 September 2011 at 21:45:38 UTC over the Moray Firth

The bio-optical state of the ocean (e.g. plankton types, water transparency) is operationally produced by ACRI-ST from MERIS, MODIS and SeaWiFS data and is available through the Hermes portal at http://hermes.acri.fr.

Ocean topography, key information for the ocean and its forecasting, is available from CLS Toulouse, as well as iceberg detection based on currently available altimetry missions. Wind, waves and current maps are produced today by CLS Brest (see the prototype service http://soprano.cls.fr based on ENVISAT). The products offer a high spatial resolution over wide regions, up to the coasts, regardless of actual cloud coverage or day/night conditions.

Outlook for the future

MCGS aims to fully exploit the technological capabilities of the Sentinel satellites by developing three processing platforms (radiometry, topography, and wind/waves/currents) and one service portal. The platforms, currently under construction in close consultation with users, will be operated from 2014, starting with a demonstration phase. As part of MCGS, various bio-optical state variables will be produced by ACRI-ST from the Sentinel's radiometric data and customised to meet local user requirements. Ocean topography and iceberg detection will be produced by CLS Toulouse, from all altimetry satellites, including Sentinel 3. The services provided will help offshore oil and gas exploitation, and encompass customised datasets fitting users' needs. Wind, waves and current maps will be operationally produced by CLS Brest with Sentinel 1 synthetic aperture radar (SAR) instruments and distributed in near real time (NRT), after reception of the data. MCGS is essential for full exploitation of the Sentinel satellites. A first set of services will be implemented in 2013, then the aim is to progressively include new and sustainable space-based marine services for Europe.

Acknowledgements

Europe, France, PACA and Bretagne regions for funding.

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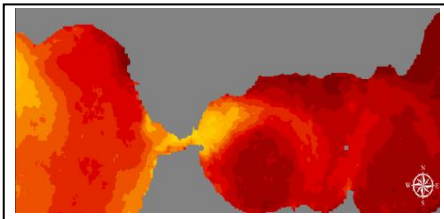
MONITORING OF COASTAL WATER QUALITY. PILOT STUDY IN GUADALQUIVIR RIVER

Application of low and medium resolution images for monitoring the quality of coastal and marine waters

The challenge

Increased pressure on the coastal strip has led to the intensification of activities with a consequent increase of pollution sources in coastal waters. Remote sensing is concise in its nature and complements traditional analysis techniques with its high temporal and spectral resolution. The spectral characteristics of water mean that certain of its properties can be easily identified by remote sensing. The work that is being developed from the Environmental Information Network of Andalusia (REDIAM) corresponds to two different lines: firstly the characterisation of the coastal waters of Andalusia on a regional scale, which allows a better understanding of their behaviour under different synoptic conditions, through temporal monitoring of certain parameters (turbidity, photosynthetic pigments and surface temperature); and secondly the specific study of particular areas of the coastline in detail, in order to obtain information about their hydrodynamic performance and water quality.

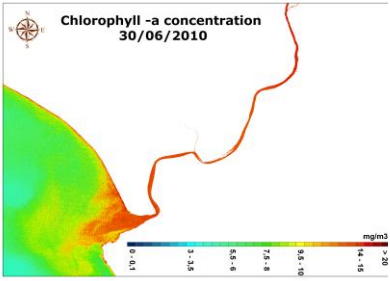


Sea surface temperature off the coast of Andalusia

Benefits to citizens

Spectral knowledge of the coastal waters of Andalusia allows their characterisation through temporal monitoring of biophysical parameters, so that it can offer a rapid response to management needs of socio-economic activities in the coastal strip. The developed methodology aims to obtain indicators that enable the annual monitoring of these parameters and to create maps that determine their spatial distribution. The main advantage of remote sensing data is in supplying synthetic character information for the whole region, at low cost and appropriate frequency compared with other methods that are more complex and higher in cost.

'REDIAM supports the activities of environmental management and planning, carrying out a study of the state of transitional and coastal waters with satellite imagery.' **Jose Antonio Dominguez, CEDEX**



Chlorophyll concentrations near the mouth of the river Guadalquivir

The space-based solution

For regional-scale characterisation of the marine waters surrounding Andalusia, images from sensors SeaWiFS, NOAA AVHRR and MODIS are acquired, obtaining chlorophyll data diffuse attenuation coefficient (K490) and sea surface temperature (SST). These images are subjected to a series of operations, obtaining the monthly, seasonal and annual means of different parameters whose results are reflected in several indicators related to the quality of coastal waters.

In the local pilot study, two Landsat TM scenes of 30 June 2010 have been used to cover the area of interest: 202034 and 202035. While it has carried out a field radiometric sampling was carried out in order to obtain precise data of water column reflectivity in situ, so that calibration of reflectivity image can be feasible after application of atmospheric corrections. On the other hand, a water sampling is also carried out for its subsequent physico-chemical analysis, where parameters like transparency, turbidity, chlorophyll-a, suspended solids concentration and sea surface temperature are measured. This study was conducted in the Lower Guadalquivir and its mouth. The theoretical foundation is based on the relationship between the spectral signatures of the image with the physicochemical parameters through statistical correlations. Once this algorithm is found, it is applied to the image and maps of various parameters of interest are obtained.

Outlook for the future

This application may become part of the GMES MyOcean project as part of monitoring the quality of coastal and marine waters since it offers information on water characterisation at regional and local levels, considering that it provides products obtained from biophysical variables such as those detailed here. The Sentinel-3 mission of ESA will support the provision of low resolution images, comprising 21 bands, suitable for measuring parameters such as accurate sea surface temperature, the nuances of ocean colour, which will then be used to analyse the water quality and water status.

Granado, L., Montoya, G., Pino, I., Carpintero, I., Méndez, E., Prieto, R., Vales, J., Giménez de Azcarate, F., Cáceres, F. and Moreira, J. M.
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WATER QUALITY MONITORING IN SPACE AND TIME IN AQUATIC ECOSYSTEMS

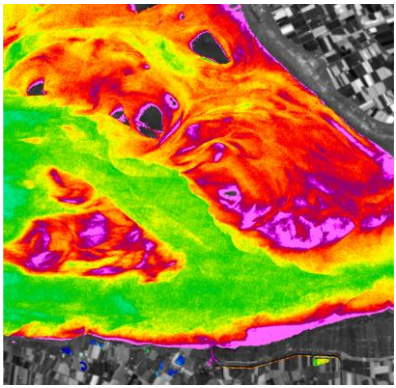
Monitoring water quality with Earth Observation (EO) data delivers vital information on aquatic ecosystems

The challenge

Monitoring water quality parameters like phytoplankton or suspended-matter content is essential to understand the behaviour and development of coastal areas and inland water bodies. Information about eutrophication, algae bloom and land erosion can be derived from such data. Therefore observation of its dynamic is required on a large scale and regular basis. Conventional methods, like in-situ sampling, are limited by manpower and cost and cannot satisfy these demands. So the challenge is to guarantee a sustainable, operational GMES service for aquatic ecosystem monitoring.

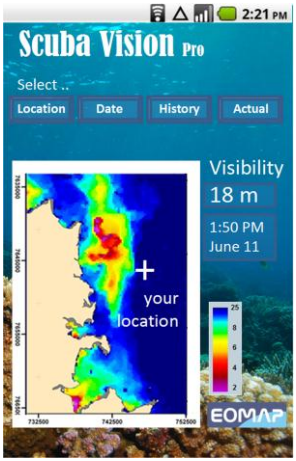
Benefits to citizens

Healthy and sustainable aquatic ecosystems are of major importance for, e.g., fishing, tourism and nature conservation. Monitoring actual status, its past and the on-going development of lakes, rivers and coastal areas is therefore vital to many topics and applications. Users are manifold: companies which care about the impact of their actions on the environment, research institutes, governmental agencies and local authorities who wish to improve their understanding and observation network for lake and coastal water quality. BAW, a German federal institute, integrates satellite-derived water quality products into 3D hydrodynamic models and can reduce costs of dredging and engineering work in the river Elbe. The current EU project FRESHMON – led by EOMAP – is bringing such users together and building a sustainable water quality GMES service for Europe (www.freshmon.eu).



Suspended-matter content of the river Elbe showing dynamic and varying concentration

'We expect that the temporal and spatial resolution of observations with the GMES satellite fleet will significantly improve our daily work.' **Norbert Winkel, Federal Waterways Engineering and Research Institute, Hamburg, Germany**



Smartphone application based on EOMAP satellite products

The space-based solution

Earth observation data provide spatial information about biophysical data on the environment. These data are used by EOMAP to retrieve information about its composition and interaction. Specifically for aquatic ecosystems, EOMAP has developed an up-to-date biophysically based algorithm designed to derive information about water constituencies. The method is fully automated with harmonised products available a few hours after recording. It is applicable for many sensors, therefore multiple products with various resolutions are available daily.

The space-based products fit well with in-situ measurements obtained by governmental agencies and research institutes. Area wide and transnational harmonised satellite products go far beyond current procedures for monitoring European aquatic systems. Retrospective observations using preceding decades of satellite data allow evaluation of long-term changes. The fully automated monitoring approach enables significant cost savings. In recent industrial dredge monitoring applications cost savings of a 6-digit Euro budget could be reached per area and year.

Outlook for the future

Within the next few years GMES products like water quality maps could benefit the daily work and life of agencies, companies and single citizens. In order to achieve this, one major issue is how to integrate satellite-derived products into existing systems (e.g. Smartphone applications, see Figure 2) and environmental models. Data must be accessible immediately and the spatial and temporal resolution must be adjustable to the users' needs. ESA's Sentinels can play a key role, not only owing to their narrow revisit time, but also because of the spectral resolution. Furthermore, the Sentinel satellites will build a base suitable for other maritime applications (e.g. bathymetry and seafloor vegetation maps).

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Belgian Region: Flanders, Wallonia & Brussels Capital

ADVANCED REMOTE SENSING MONITORS THE WATER QUALITY OF THE BELGIAN COASTAL ZONE

A satellite-based chlorophyll-a product has been developed to meet the Water Frame Directive requirements

The challenge

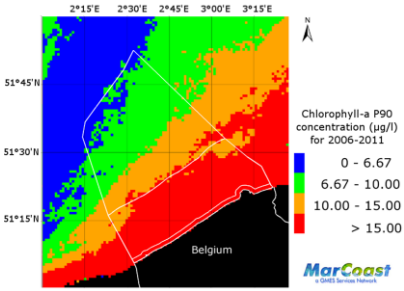
The Belgian coastal zone, located in the Southern Bight of the North Sea, is largely eutrophied, due to riverine, atmospheric and transboundary inputs of land-based nutrients, which results in the excessive development of undesirable phytoplankton species, such as *Phaeocystis globosa*. This phenomenon affects the marine ecosystem in a negative way, disrupting the food chain and resulting in the deposit of thick layers of odorous white foam on the beach. Sustainable management of this type of marine ecosystems requires detailed information of their dynamics.
While traditional seaborne observations are still considered as the main monitoring tool, there is a need to use optical remote sensing as a supporting tool to achieve the monitoring requirements due to severe resource constraints on available ship time and manpower.

Belgian marine waters (black line) and seaborne observation stations (green dots)

Benefits to citizens

Everyone aspires to live in a healthy environment, and public authorities in Belgium are making a particular effort to transform this wish into a reality. Belgium follows international initiatives such as the European Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD) in order to maintain a 'good' status of all waters (surface, ground, coastal). Operational monitoring is an essential part of implementing these directives to evaluate measures taken to improve critical situations such as the eutrophication state. Satellite remote sensing is important as it provides information with a spatial coverage and temporal frequency that is unmatched by traditional seaborne observations.

'*Optical remote sensing is necessary to bypass severe resource constraints on ship time and manpower.*'
Georges Pichot, Management Unit of the North Sea Mathematical Models



Chlorophyll-a 90 percentile product describing the eutrophication state of the Belgian coastal zone

The space-based solution

The eutrophication status of the Belgian coastal zone is established by monitoring the chlorophyll-a concentration as it is a proxy of phytoplankton biomass. More specifically, the indicator of choice for WFD is the chlorophyll-a 90 percentile for the phytoplankton growing season (i.e. March-November inclusive) of 6 consecutive years expressed in µg/l. In Belgium, seaborne measurements are made 7-9 times on average per growing season in 10 stations distributed along the Belgian coastal zone (see Figure 1). These numbers are too low to calculate chlorophyll-a 90 percentile values with sufficient accuracy.

To answer this need for information, the Management Unit of the North Sea Mathematical Models (MUMM) has developed a MERIS-based remote sensing product within the MarCoast-2 project funded by the European Space Agency (ESA). This chlorophyll-a 90 percentile product (see Figure 2) is generated using daily standard chlorophyll-a products of 6 consecutive years providing on average 35-40 observations per growing season per pixel of 1 kilometre. The resulting classified map provides a spatial overview of the eutrophication state of the Belgian coastal zone showing the problematic area in red. These specialised maps, combined with reports containing validation results and derived statistics, are delivered to the Belgian Federal Public Service of Health, Food Chain Safety and Environment to support the coordination of actions needed to reach a 'good' environmental status for the Belgian waters by 2020.

Outlook for the future

On April 8th 2012, all communication with the Envisat satellite was lost. This resulted in an abrupt stop of daily MERIS chlorophyll-a monitoring. Until the planned ESA launch of the Sentinel 3A satellite in 2014, the main source of ocean colour data for Europe will be the American MODIS-AQUA sensor which is beyond its nominal lifetime. A timely launch of Sentinel 3A will be crucial to ensure the continuation of the MarCoast-2 water quality monitoring services.

Acknowledgement

www.marcoast.eu

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A COASTAL OPERATIONAL OCEANOGRAPHY SYSTEM COUPLED TO THE GMES MARINE SERVICE

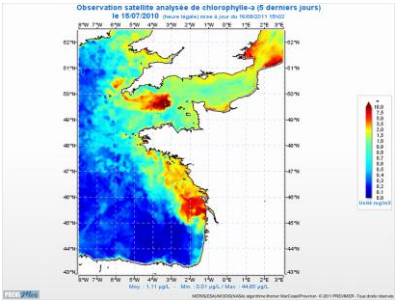
PREVIMER provides tailored ocean products and services for the French coastal zone

The challenge

Our coastal zones are subject to increasing anthropogenic pressure. Monitoring systems are required to protect them, to prevent or mitigate risks and to ensure sustainable management of their resources.

The GMES Marine Service provides a core European service (satellite observations, modelling) for monitoring and forecasting the state of the global ocean and European regional seas. In particular, the information provided by GMES is essential for monitoring and forecasting the coastal ocean.

PREVIMER provides coastal observations, analyses and 96 hour forecasts for the French coasts of the English Channel, Atlantic Ocean and Mediterranean Sea: currents, water levels, waves, temperature, salinity, turbidity, nutrients and plankton concentrations.



Karenia mikimotoi bloom in the western English Channel on a satellite synthesis map of chlorophyll, 15 July 2010

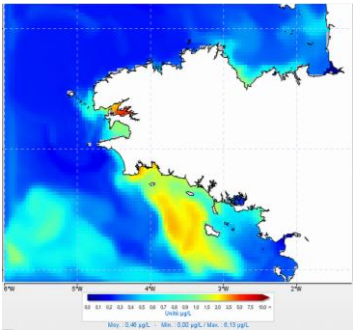
Benefits to citizens

PREVIMER services are used by French marine environment monitoring and maritime safety agencies to inform professionals (e.g. fish/shellfish farming industry), local authorities, consultants and scientists.

Many applications are targeted. Marine environment monitoring (Marine Strategy) provides alerts to users of cases of eutrophication (bottom oxygen deficiency, excess of biomass) or harmful algal bloom (e.g. amnesic shellfish poison produced by *Pseudo-Nitzschia* diatoms). It also provides online tracking in the marine ecosystem of the nitrogen loaded by a specific river, storm surge forecasts to prevent risk of

'A coastal monitoring system coupled to the GMES Marine Service is a major asset to reach a good environmental status.' **P. Camus, Coordinator Marine Strategy implementation, Ifremer**

coastal flooding, drift predictions and pollutant impacts, optimising and monitoring renewable marine energy sites.



Chlorophyll map from ecosystem model, 15 March 2012. A bloom is detected by the model south of Brittany

The space-based solution

PREVIMER products and services include information based on and satellite observations and numerical simulations.

GMES satellite observations (ocean colour, sea surface temperature, sea level, waves) are key for PREVIMER. Every day, PREVIMER issues, for example, chlorophyll-a, mineral suspended matters and sea surface temperature maps derived from satellite observations.

Users can access real-time and archived data. These observations are also systematically used to validate numerical models. For PREVIMER numerical models (physics and ecosystems), resolution varies from 2.5 km for regional models to a few hundred metres for coastal models. The regional models need boundary and initial conditions. PREVIMER is thus coupled to the GMES/MyOcean modelling and forecasting centres. This allows a seamless description of the ocean from the open sea to coastal zones.

Quarterly bulletins are also provided from in-situ and satellite observations and model simulations. These bring together information concerning the state of the coastal environment. Indicators such as the occurrence of harmful algal blooms (*Karenia mikimotoi*) or toxin risk (domoic acid), oxygen depletion probability or eutrophication alerts are provided. Annual reporting on the state of continental shelf seas prepares the monitoring network for the application of the European Marine Strategy Directive.

Outlook for the future

PREVIMER, coupled to the GMES Marine Service, will be an essential tool for the application of the European Marine Strategy Directive, and to achieve a good environmental status.

Acknowledgement:

PREVIMER is a partnership between several major French institutions and the Brittany region (www.previmer.org).

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MANAGING AIR QUALITY: SYSTEMS FOR FUTURE CITIES

Novel systems are demonstrated for air quality and traffic management in urban environments

The challenge

It is estimated that poor air quality costs the United Kingdom economy up to 20 billion euros per annum. This cost accumulates through reductions in personal productivity and life expectancy, costs to healthcare providers and damage to buildings and crops. With increasing global urbanisation, such impacts are likely to worsen unless improved systems are used to manage emissions and human exposure to them.

Benefits to citizens

With improved information on air quality, policy makers, operational decision makers and the public can make better decisions in managing exposure and risk. Within the East Midlands, two major initiatives have been employed to capture the value of space assets in this area, demonstrating benefits to users such as Leicester City Council.

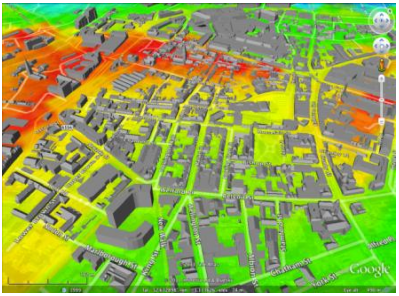
A congested urban junction, which could be improved through the use of space data

In addition to improving the quality of life of citizens, use of space data in urban management systems can also help with greater utilisation of expensive transport infrastructure. Such incremental improvements on substantial national investments further strengthen the economic and political case for using space date. For example, an iTRAQ demonstration in Leicester in 2011 illustrated a potential 4% improvement in transport efficiency with no changes to road infrastructure required.

The space-based solution

Integrated Traffic and Air Quality (iTRAQ) is a project to develop a dynamic traffic management system capable of optimising use of the road network whilst meeting demands to

'In realising a low carbon and sustainable future, traffic and air quality management are both important elements for Leicester City Council. We welcome the iTRAQ project as having new potential to integrate both these elements.' **Satish Shah, Head of Highway Design and Maintenance, Leicester City Council**



Air quality modelling within Leicester, with background import calculations incorporating satellite data

sustain high standards of air quality in urban environments. By assimilating information on traffic volumes and meteorological fields, an optimised solution for both air quality and traffic can be derived, using computational intelligence techniques, and delivered to traffic control engineers or systems.

For many urban environments, the extent of imported pollution is often largely unknown, and is not available for use within operational decision-making.

The iTRAQ system uses outputs from atmospheric models incorporating satellite data of tropospheric nitrogen dioxide to provide background air quality figures for a given city. Additionally, global positioning technologies are sourced for real-time updates of traffic volumes and congestion.

Outlook for the future

The iTRAQ service is a pre-operational system under development within the East Midlands. Demonstration within two medium-sized urban environments is currently envisaged for 2014-5. Global positioning and air quality monitoring capabilities will improve with the launch of Galileo and Sentinels 4 and 5. Given this, the capabilities of systems like iTRAQ are set to improve over the next decade.

THE ISSUE is a Regions of Knowledge project to explore best practice in Traffic, Health and the Environment (Innovative Solutions for Sustainable Urban Environments). THE ISSUE explores the application of iTRAQ and other innovative solutions throughout Europe.

THE ISSUE will run until 2015 and will share best practice across a number of European regions, exploring innovative systems and technologies to manage our urban environments.

Acknowledgements

The £2.4m THE ISSUE project is led by an East Midlands consortium, with partner consortia in Italy, France and Poland. iTRAQ is funded by the European Space Agency's integrated applications promotion programme with a project team from The University of Leicester, De Montfort University and Leicester City Council.

Leigh, R.J.[(1)], Wells, A.[(1)], Monks, P.S.[(1)], Passow, B.N.[(2)], Elizondo, D.[(2)], Goodyer, E.[(2)], Lawrence, J.P.[(1)] and Gustafsson, S.[(3)]

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[(2)] De Montfort University, Leicester, UK, [(3)] European Space Agency

MONITORING AND FORECASTING DUST STORMS

A GMES contribution to health hazard warning and cooperation with Africa

The challenge

Dust storms are of great importance to GMES because of their impact on air quality and human health. Indeed, they represent an important natural source of particulate matter, which is now considered one of the most harmful air pollutants. It may cause respiratory diseases or infections and, in some regions, can trigger serious epidemics, e.g. meningitis in the Sahel. In addition, dust plays an important role in different aspects of weather and climate, including the earth's radiative budget, the hydrological cycle and atmospheric chemistry. The impact of dust storms on the economy is also significant, affecting air traffic and road transportation, the semiconductor industry, and solar power plants. Finally, dust interacts with diverse continental and maritime ecosystems.

Benefits to citizens

Europe is close to the Sahara, which is the largest source of mineral dust in the world. Each year, Europe is hit by dust intrusions from Africa that cause the concentrations of particulate matter to exceed the thresholds established by the EU. A better knowledge of dust spatial distribution will improve the design and management of air quality policies. Also, robust real-time dust prediction will significantly improve meteorological forecasts and early warning of hazardous weather. This information is critical to air traffic management.

Dust intrusion over the Iberian Peninsula seen by the MODIS instrument on board the Terra satellite, on 6 April 2011

The space-based solution

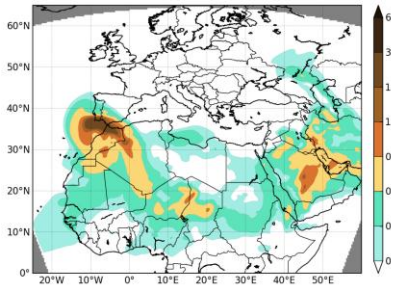
Nowadays, beyond the standard meteorological stations, the capacity to observe the atmosphere in Northern Africa, near to the major dust sources, is very limited. For this reason, dust monitoring from space becomes an essential component of any resilient

'ESA's Sentinel satellites will play a key role in the integrated European dust monitoring and prediction system.' **Emilio Cuevas, AEMET**

observational system. Atmospheric dust prediction models, born in the early 1990s, are still in an early stage, consequently dust predictions present large uncertainties.

Satellite products such as aerosol optical depth, computed from the MODIS sensor on board the Terra and Aqua satellites, are already being continuously incorporated into numerical models, thereby correcting and improving operational predictions.

Satellite observations are also used to verify and validate model-based predictions for remote areas, such as deserts or oceans, where no ground-based observations are available. On the other hand, real-time observations, like those provided by the Meteosat Second Generation, enable reliable dust 'nowcasting', i.e. the prediction of dust storms within the next few hours. This information which is critical to air traffic management, would not be possible based only in numerical models.



Aerosol optical depth forecast by BSC-DREAM8b for 6 April 2011. A Saharan dust plume is observed over the Iberian Peninsula. Dust was observed in Scandinavia on 10 April.

Outlook for the future

Synergies between the deployment of new space-borne instruments, such as those on board the ESA Sentinel satellites, and the launch of a new generation of numerical models will significantly improve the accuracy of dust prediction.

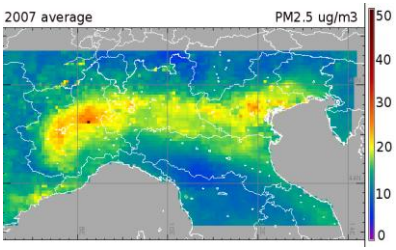
Acknowledgements

The Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS), implemented by the World Meteorological Organization, and the Monitoring Atmospheric Composition & Climate (MACC) Project, a component of GMES, contribute to improve dust monitoring and forecasting worldwide.

Cuevas, E.[1], Boucher, O.[2], Baldasano, J.M.[3], Schulz, M.[4], Terradellas, E.[1] and Morcrette, J.-J.[5]
[1] AEMET, [2] LMD-CNRS, [3] BSC-CNS, [4] MetNo, [5] ECMWF

SATELLITE-BASED PARTICULATE MATTER MONITORING OVER NORTHERN ITALY

Aerosol satellite observations are used for particulate matter monitoring in compliance with the European legislation



Yearly average of Satellite-based particulate matter concentration over Northern Italy

The challenge

Air quality represents a major issue for several areas and large cities located in Europe. At present, chemical model simulations are employed for monitoring and forecasting air quality, but evidence has arisen on systematic underestimations. In answer to this, satellite sensors' synoptic view enables a complete and homogeneous monitoring of spatial distribution of pollutant particles, whilst also complying with the European Commission Directive on ambient air quality and cleaner air for Europe.

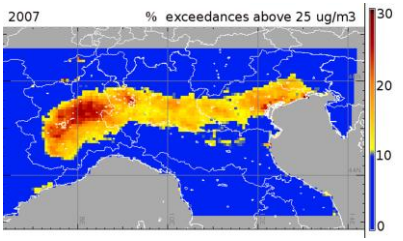
Benefits to citizens

Data coming from satellite sensors can add very useful information, providing a direct measurement of particulate matter (PM) concentration. The importance of these evaluations is linked to the negative effects on human health of anthropogenic aerosol (respiratory problems and cardiovascular and lung diseases) which is mainly due to the exposure to fine PM. PM concentration satellite-based maps, as presented in the above figure, highlight areas affected by significant levels of pollution and thus those possibly exceeding legislation limits. Pollutants concentration can also be estimated in areas where no sampling sites are available. This information can be profitably exploited by policy makers in managing air quality and also directly by citizens due also to the easy reading of a pollutants map.

The space-based solution

In recent years, the use of satellite observations for the assessment of air

'Satellite-based PM estimates are robust enough to make a realistic long-term analysis in the Po Valley area and to provide an independent verification of the final products of chemical transport model.' **Enrico Minguzzi, ARPA Emilia Romagna**



Satellite-based monitoring of percentage of days exceeding legal limit concentration for $PM_{2.5}$

quality has advanced significantly. The increase in the capabilities of Earth observation satellites in remote sensing retrieval of anthropogenic and natural aerosols can, in fact, provide very useful information for improving estimates of spatial distribution and transport of PM and, therefore, for estimating population exposure to aerosols. Satellite data can be used to map over large areas the Aerosol Optical Depth – a measure of the columnar aerosol extinction in the visible spectral range which can be related to ground-level concentration of PM. In particular, this application is based on MODIS aerosol observations combined with meteorological information and PM sampled at surface to produce maps of MODIS-based PM estimates over Northern Italy.

Examples of results in terms of maps of annual average values of satellite-based $PM_{2.5}$ (fine PM having sizes up to 2.5 μm) and annual percentage of days exceeding the legislative limits of $PM_{2.5}$ concentration, in compliance with European Directive regulations, are reported in the two figures on these pages.

This pre-operational service is one of the four *Compliance monitoring support services* developed in the frame of PASODOBLE EC FP7 project using input data from GMES atmosphere core service. End-users of this Downstream service are three Environmental Regional Agencies, namely ARPAs Lombardy, Piedmont, and Emilia Romagna.

Outlook for the future

Future Sentinels 4, 5, and 5P payloads (UVN, UVNS, 3MI, and Tropomi) will provide key information for this application both in terms of improved spatial resolution and repetition cycle.

In this context, operational satellite-based PM estimates will be successfully synergised with a chemical transport modelling system leading to a more complete and reliable assessment of air quality.

Acknowledgments

More related information can be found at http://www.myair-eu.org.

Di Nicolantonio, W. and Cacciari, A.
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EUROPEAN ENVIRONMENT AGENCY SUPPORTING SUSTAINABLE DATA PROVISION FOR GMES

GMES services require access to data to create quality products that meet end-user requirements

The challenge

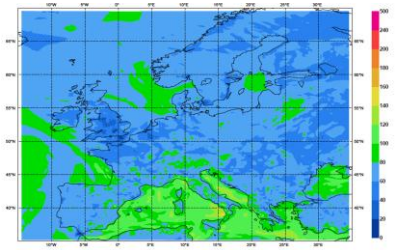
Along with the space data, information is an important part of GMES. In fact, GMES services cannot produce or verify their products without access to a large variety of in-situ information. The data is collected from air, ground, or marine observations. It is used to create maps, to calibrate and validate satellite observations and is the basis for monitoring, modelling and analyses. The collection of European data has a long history; hundreds of organisations in Europe collect and process environmental data. Their activities derive from a range of national, regional, European, and international regulatory requirements and numerous research processes. For GMES this heterogeneous landscape can lead to a number of limitations on access, timely responses to emerging challenges, and lack of sustainability and consistency.

Benefits to citizens

The European Environment Agency (EEA) coordinates networks of data providers in partnership with the European Environmental Information and Observation Network (Eionet). Through Eionet, EEA coordinates the delivery of national validated, high quality environmental data from individual countries.

Through the GMES coordination (GISC) project, EEA strengthens these coordination mechanisms and develops further partnerships with other European stakeholders and relevant networks. The goal is to ensure continuous, sustainable and operational delivery of data to GMES services. For example, near real time (NRT) measurements of air pollutants such as ground level ozone, nitrogen oxide and particulate matter are essential data needed for the creation of air quality forecasts and reanalysis of the pre-operational GMES atmosphere service (MACC-II, http://www.gmes-atmosphere.eu/). The data are part of an existing Eionet/EEA data flow.

'The proposed approach streamlines the collection of in-situ observations and enhances our geographical coverage, thus increasing the robustness and quality of our air quality products.' **Vincent-Henri Peuch, ECMWF, MACC-II co-ordinator**



MACC-II provides analyses and 3-day forecasts of European air quality in near-real-time. OZONE concentration forecast. See: http://macc-raq.gmes-atmosphere.eu/

MACC-II is currently managing bilateral agreements for provision of NRT air quality observations and related technical interfaces with 15 counties in Europe. However, it would be very time consuming and cumbersome to extend this solution to include more countries and more pollutants to enable MACC to produce air quality forecasts of the required quality during the operational phase.

The space-based solution

The solution proposed by EEA builds on the Eionet NRT data policy arrangements, air quality data flows, and a collaboration framework including e-reporting development activities. Bilateral arrangements and technical interfaces are being replaced by a single interface to NRT air quality observations collected and managed by Eionet and the EEA. Countries will send NRT air quality data to the NRT database at EEA. MACC in turn will pull this data from the EEA server and use it to produce and validate its air quality products and services.
Implementation of the solution is based on extension of existing collaboration between Eionet member countries and EEA concerning provision of NRT air quality observations, including performance monitoring, operating procedures and data formats.

Outlook for the future

GMES atmosphere service providers, such as MACC-II, will have access to data from 39 countries, i.e. more than 1600 stations providing air quality observations.
Agreements are in place and the solution is being tested to ensure a smooth transition to an operational phase. Countries and regions play an important role in the implementation of solutions like the one described, both as providers of in-situ data capacities and as users of GMES products and services.

Acknowledgements

GISC is coordinated by EEA through a CSA funded by the EC 7th Framework Programme.
http://gisc.ew.eea.europa.eu

Acosta Chan, K. with colleagues in GISC
European Environment Agency (EEA), Kongens Nytorv 6, Copenhagen, Denmark.

SATELLITE DATA FOR SOLAR ULTRAVIOLET AND PHOTOVOLTAIC MANAGEMENT SERVICES

GMES-data are used for near-real-time services dedicated to sun exposure safety and to the analysis of solar plants' performance

HappySun Mobile application on smartphone: the UV-index GIS map

The challenge

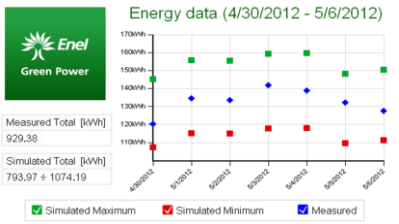
In Europe about half a million skin cancer cases occur per year. This is strongly associated with personal habits in exposing to sun with poor protection against its ultraviolet (UV) component. The need to protect oneself depends mainly on the local UV index which can be derived in near real time from satellite data. Another challenge is the monitoring of solar plants. An early detection of the decline in energy production due to any malfunction can avoid a significant loss of income, especially for big plants. This can be done by comparing the actual energy production with the expected one, which can be estimated by means of satellite data.

Benefits to citizens

The UV information service 'HappySun Mobile' was conceived for the Mediterranean area and has been delivered and continuously improved since 2006 to any interested regions. Besides the UV-index, the 'Happysun Mobile' service provides sunburn times based on personal skin sensitivity and suggestions on the sunscreen protective factor to use.

This information is delivered in near real time on the web or to smartphone users and is a valuable reference to reduce the risk of even mild skin damage. The 'PV-Controller' system provides the user with a continuous view of the energy production efficiency of his photovoltaic plant, thus allowing for timely interventions instead of periodic controls, with the benefit of achieving a fast payback and greatest income.

'PV-Controller is a very useful solution that makes us really confident in our solar plants' remote monitoring activity.' **Fabrizio Bizzarri, Enel Green Power**



PV-Controller energy monitoring service: web interface

The space-based solution

In 'HappySun Mobile', the UV index is calculated by a radiative transfer model which uses the ozone concentration and the cloud coverage retrieved from satellite sensors. The user's phototype and Minimum Erythemal Dose (MED) are derived from a questionnaire regarding skin type and other meaningful user characteristics. The sunburn time is calculated correlating the MED, the UV index and the user choices regarding sunscreen protection factor (SPF) and terrain type (to estimate the amount of UV radiation reflected towards the user). 'HappySun Mobile' has been validated by comparing the satellite UV index with ground measurements by a spectroradiometer. The results showed an agreement better than 16% between UV index derived from satellite and spectroradiometer in every meteorological condition. The 'PV-Controller' system uses solar radiation data based on MACC project core services. Using satellite based solar irradiance data and other parameters, like PV module temperature and ambient temperature, together with an accurate opto-electronic model of the PV plant, it evaluates the hourly producible energy and compares it to the produced energy. The plant efficiency is then presented on a website together with energy production, profitability and plant diagnostics. The typical error in the energy yield prediction (with respect to the real value) is always less than 10%, which is usually satisfactory for the customers

Outlook for the future

In the framework of the GMES project ENDORSE, the 'PV-Controller' system is currently being upgraded to also serve Concentrating Solar Plants. Both the UV and the solar plant monitoring services will be improved by taking into account the aerosol optical depth that is soon to be measured by TROPOMI on board the Sentinel-5 precursor and later by Sentinel-4 at an hourly rate.

Acknowledgements

'PV-Controller' and 'HappySun Mobile' services were developed by Flyby S.r.l. in the ESA-GSE project PROMOTE and the EC project MACC.
MACC: www.gmes-atmosphere.eu
PROMOTE: www.gse-promote.org
ENDORSE: www.endorse-fp7.eu

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MONITORING SNOW WATER EQUIVALENT DISTRIBUTION IN AOSTA VALLEY (NW ITALY)

The snow water equivalent of the Aosta Valley is determined by MODIS snow cover products coupled with field observations

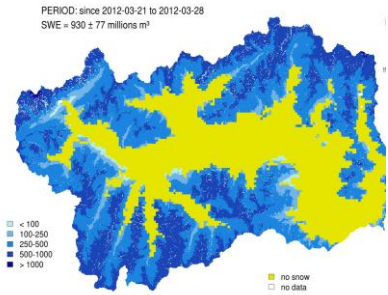
The challenge

The water availability of an Alpine continental region, such as the Aosta Valley, largely depends on the amount of water stored in the snow during the winter, also known as the snow water equivalent (SWE). Accurately predicting such water quantities is vital to manage the water resources adequately. Modelling the snow water equivalent distribution requires three input data: the snow cover area, the snow height and the snow density. MODIS TERRA 8-day composite Maximum Snow Extent (MOD10A2) data are used to estimate the snow covered area at the regional scale and hence produce periodic maps of the amount of water stored in the form of snow at a given point in time.

Benefits to citizens

The amount of water stored in the snowpack, estimated on a bi-weekly basis in Aosta Valley, is a piece of crucial information required by the local government for water resources management and for forecast purposes in cases of extreme meteorological events (e.g. summer droughts or intense downstream flow caused by warm spring temperatures). Hence a 15-day map of the snow water equivalent distribution is published on the Regional Hydrological Bulletin and on line.

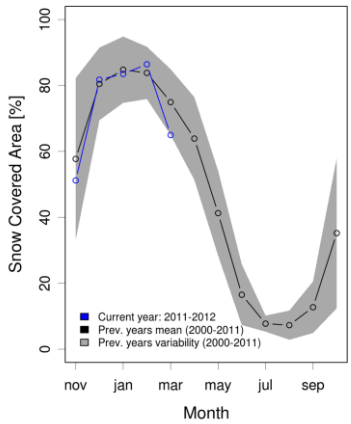
Additionally, in alpine regions hydro-power energy is one of the main sources of power, therefore the snow water equivalent and its spatial-temporal evolution is used to regulate the supply of water and to forecast water availability for energy production, allowing optimisation of water and consequently of economic resources.



Snow water equivalent distribution; period: 21-3-2012 to 28-3-2012. SWE: 930 ± 77 millions m^3

'We consider the estimation of the snow water equivalent a piece of crucial information for risk and water management'

S. Ratto, Centro Funzionale Regionale Regione Autonoma Valle d'Aosta



Monthly evolution of snow covered area (% on total area)

The space-based solution

Because of the specific spectral reflectance of snow, snow covered areas can be discriminated from snow-free areas using optical remote sensing methods. MODIS TERRA 8-day composite Maximum Snow Extent data (MOD10A2 Product –v005) are downloaded weekly from the EOS Data Gateway archive. MODIS images are reprojected from the native SIN projection to a UTM-ED50 reference system and resized on the study area.

The image is then used to mask the snow height distribution map, modelled from automatic measurements and manual observations. Snow height is measured automatically in 35 meteorological stations, and a number of manually-measured snow depths are also included in the database. The snow height is spatially distributed over the whole region by means of regression models with various morphological parameters as explanatory variables. Hence, bi-weekly quantities of snow water equivalent and its spatial distribution can be obtained for the whole Aosta Valley

Outlook for the future

Time series of snow water equivalent over multiple years will allow trends of timing and distribution of the snow cover in a changing climate to be depicted. This will improve our understanding of climate change-driven transformations in the Alpine environment. The availability of new high-resolution images (i.e. from Sentinel-2 multi-spectral optical imager) will certainly increase the temporal and spatial resolution of the snow water equivalent. The procedures illustrated are implemented via open source software and are still in development. When fully tested, the source code will be available for download from the ARPA Valle d'Aosta web site.

Cremonese, E., Filippa, G., Diotri, F., Morra di Cella, U., Pogliotti, P. and Galvagno, M.
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MONITORING TROPICAL DEFORESTATION

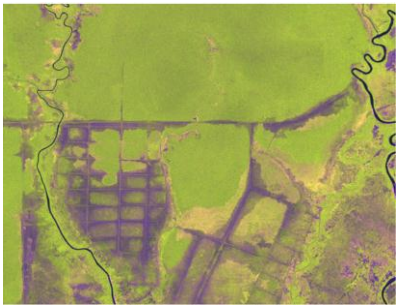
The role of GMES satellite data is increasing in global efforts to monitor the rate of tropical deforestation

The challenge

Regularly monitoring changes in the extent and quality of tropical forests is vital for efforts to reduce global carbon emissions. Sole use of ground surveys in tropical regions is impractical, time consuming and often unreliable. Use of GMES satellite datasets can provide a consistent and large-scale tool for public-sector organisations and private companies involved in environmental and development aid projects, to assist developing nations in managing their forest resources.

Benefits to citizens

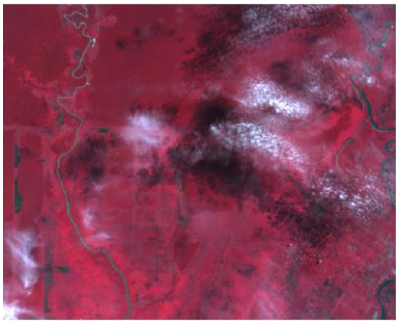
The United Nations Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiative aims to control deforestation rates to combat climate change. The UK will provide £2.9 billion to the International Climate Fund for this purpose from 2011 to 2015. For this to be effective, independent monitoring tools are needed to ensure reported deforestation rates are verifiable.



ALOS-PALSAR radar image of Borneo: intact forest – light green; burned areas/draining ditches – purple. Data ©JAXA, METI

The University of Leicester and Astrium Geo in the East Midlands region are partners in a consortium led by DMCii (Disaster Monitoring Constellation Imaging International Ltd.) selected by the Department for International Development (DfID) to support its Forest Governance Markets and Climate Framework Agreement. This programme supports developing countries in strengthening their governance of forest resources. The consortium will bid for forthcoming forest monitoring projects to introduce a financial-results-based payment system for carbon. This will help support communities in developing countries whose livelihoods depend on forests, whilst supporting UK REDD+ efforts and creating new jobs in the East Midlands.

'Deforestation is the third largest source of greenhouse gas emissions – larger than the entire global transport sector.' **Andrew Mitchell, Department for International Development, UK**



DMC image of Borneo showing patterns of burning, some cloud obstructing view. Data ©DMCii

The space-based solution

Satellites have helped to produce annual forest cover maps on a continental scale, and at a high enough spatial resolution to capture the loss occurring in major tropical forests. Data from satellite radar systems are available from the European Space Agency (ENVISAT-ASAR), the German Aerospace Research Institute (TerraSAR-X), the Canadian Space Agency (RADARSAT), and the Japanese Aerospace Exploration Agency (ALOS-PALSAR). Radar can image the forest even through dense cloud cover. Continental mosaics are compiled from radar data by teams in Europe (Joint Research Centre and University of Bordeaux), Japan (JAXA), and the USA (NASA). The images are then used to distinguish forest from non-forest areas.

At present, there are limited available radar sensors, with ENVISAT and ALOS having both ceased operating. Also, there is currently no operational system for forest carbon stocks and fluxes. Other satellite sensors record visible and infrared light. While limited by cloud and haze in humid tropical regions (figure to the left), they have greater frequency of coverage, especially from multiple satellite platforms such as the Disaster Monitoring Constellation (DMC), a GMES third-party-operated mission. DfID will commission specific national forest monitoring projects over the next 4 years in support of REDD+.

Outlook for the future

The Sentinel 1 and 2 missions will provide radar and optical data of a sufficiently high resolution and frequency to allow monitoring of deforestation. They will be critical components for continuing to monitor global efforts to reduce deforestation. JAXA plans to launch ALOS-2 in 2013. REDD+ could help reduce the risk of climate change effects endangering lives and livelihoods of populations globally.

Acknowledgements

GIONET, EC, PITN-GA-2010-264509; H.Balzter, Royal Society Wolfson Research Merit Award, 2011/R3; JAXA K&C wide-area radar mosaics: http://www.eorc.jaxa.jp/ALOS/en/kc_mosaic/kc_mosaic.htm

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EARTH OBSERVATION FOR REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION

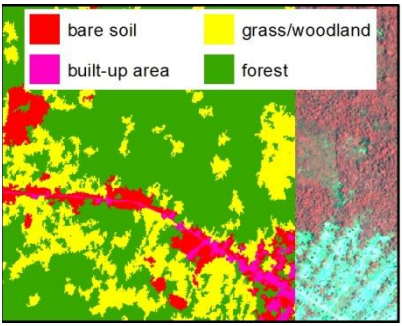
EO4REDD aims to develop a robust, affordable and reliable certified monitoring service for tropical forest carbon changes

The challenge

Reducing emissions from deforestation and degradation, forest conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+) is a major objective in climate change mitigation. The international community is encouraged to take on board the urgent need for an accurate and precise monitoring system, where Earth Observation (EO) can provide spatially explicit information over large areas. EO4REDD's approach is to reduce cost and uncertainties using operational means, rather than demonstrating EO usefulness for REDD+ initiatives.

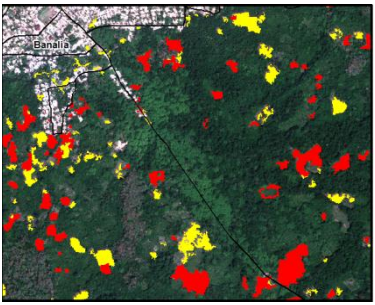
Benefits to citizens

Tested in the Democratic Republic of Congo (DRC), EO4REDD is an applied research project devoted to achieving the reliability required for an operational solution to implement REDD+.
EO4REDD's potential users include the Ministry of Environment, Nature, Conservation and Tourism of the DRC, as well as service providers of certification, verification, and validation of REDD+ projects in Central Africa.
EO4REDD brings EO primarily to the monitoring of global warming, but also addresses global challenges such as deforestation and forest governance issues (illegal logging or unsustainable practices). Indirectly, EO4REDD provides civil society with useful information for objective and active engagement in decision-making processes. The spatial information produced for EO4REDD can be used for population mapping and assessing accessibility of health, food and goods markets.



Automatic detection of land-cover classes from Quickbird, 2.4-m resolution, false-colour composite

'We need tools, such as EO4REDD, for estimating emissions and removal from deforestation in the DRC' **Christophe Musampa, Head of the Spatial Information Unit, Ministry of the Environment, Democratic Republic of Congo, 2012**



Change detection map along the road to Banalia between 2010 and 2011 (yellow=bare soil in 2010; red=bare soil in 2011). Overall accuracy=87.5%

The space-based solution

EO4REDD's methodology is currently under development. It will be implemented in 2013. The methodology is based on the combination of very high (2.5–5 m) and high resolution (10–30 m) optical imagery, airborne data (digital aerial photography and LiDAR), as well as field data for validation and calibration. WALPHOT and its partners (Cap conseil, Climact, NADAR) are capitalising on previous experience on GMES projects in land-cover changes analysis and on forest monitoring.

Users of EO4REDD will benefit from: (i) an optimal method for monitoring forests carbon emissions and removal; (ii) a method in line with the guidance of the Intergovernmental Panel on Climate Change (IPCC); (iii) robust and reportable measurements through the use of Earth Observation and field data, as well as optimised sampling plans based on geostatistical analysis; (iv) accurate and precise estimates through robust calibration and validation efforts; (v) an affordable service.

A high level of recognition and the certification of this method open opportunities to validate efforts on the carbon markets. The deliverables of this method (maps and reports) will contribute to the current UN-REDD initiatives to establish a reliable measuring, reporting and verification (MRV) system.

Outlook for the future

The consortium is looking forward to the ability of ESA's forthcoming Sentinel 2 satellite to ensure a complete cloud-free mosaic of high resolution imagery in challenging meteorological parts of the world such as in the DRC. Such a satellite is crucial for 'wall-to-wall' mapping as requested by the DRC authorities. Designed to match SPOT and Landsat sensors' specifications, Sentinel 2 will allow the historical and continuous monitoring which is essential to MRV systems.

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Danube Region (City of Hódmezővásárhely)

BASIC EUROPEAN ASSETS MAP – A STANDARDISED AND CROSS-BORDER SOLUTION FOR DISASTER PREVENTION

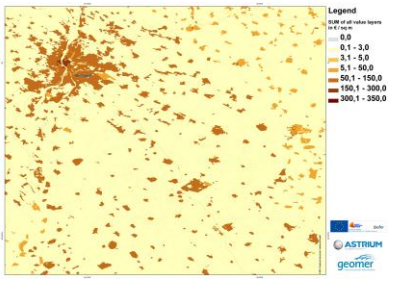
A user-driven innovative GMES service maps monetary asset values per area (€/m^2) and population potentially affected by disasters

The challenge

Natural as well as man-made disasters regularly cause significant damage across Europe. In recent years flooding, in particular has become a regular problem, and no matter the precautions, industrial accidents are not totally preventable either. At the same time, the increasing monetary values affected by such disasters result in a continuously growing amount of loss – requiring sustainable risk management solutions.

Benefits to citizens

As a consequence of this trend, at all administrative levels the authorities responsible for disaster management, civil protection, spatial and urban planning, or environmental issues face major challenges. The example here refers to the City of Hódmezővásárhely (Csongrád county, in SE Hungary).



BEAM Hungary, map section south-east of Budapest: Asset classes (0.1-350 €/m²)

As part of their disaster prevention, preparedness and response tasks, they must establish:

- an accountable prioritisation of response actions
- an efficient and effective deployment of typically limited resources
- a far-sighted coordination of measures across administrative and even national borders
- an up-to-date, highly precise knowledge of status and changes within areas-at-risk
- a justifiable cost-benefit consideration for prevention and response measures.

Basic European Assets Map (BEAM) is a unique assets map at a 1:100,000 scale: it provides monetary values per area as well as a precise geolocation of the assets. In addition, the map contains

'The products were used to provide flood risk maps for the Hungarian part of the Danube corridor as part of the Danube Flood Risk Project. The maps were essential to form flood hazard maps into flood risk maps.'

2Lt Kinga Perge, National Directorate General for Disaster Management, Hungary

information about population distribution. The various assets are displayed in individual layers. An additional layer displays population density.

Flood Information System: Display of BEAM products for Hungary and Romania – enabling cross-border evaluation of damage potential

The space-based solution

As BEAM is based on the European Environment Agency's harmonised land cover database CORINE 2006 and Eurostat's socio-economic statistical data, it is applicable across most of Europe. BEAM's asset information is ideally suitable for multi-risk analysis, as the concept separates assets from disaster-related damages. A BEAM-based damage assessment can be performed. For this purpose, individual damage functions that consider the type and intensity of a hazard or an event are applied. These functions calculate the losses following a specific event as a percentage of the overall value. They can be applied to determine damage potential of future events as well as damage assessments in the case of actual events. BEAM is scalable and can be adapted to more detailed land use and statistical data, such as multi-temporal CORINE data.

Outlook for the future

BEAM is a standardised product that fulfilled several qualification criteria in the GMES project SAFER, including service maturity analysis, operational check, and user evaluation. Civil protection organisations showed much interest in the BEAM assets mapping approach: its multi-risk and cross-border usability adds considerable value to existing solutions. The method and the operational readiness of the service proved to be robust so that the BEAM product was implemented into SAFER's final service portfolio. In addition, the BEAM product is now fully operational and is being used by disaster management organisations like the Hungarian National Directorate General for Disaster Management for flood risk mapping along the River Danube. Given the importance of 'land use' for BEAM, the upcoming Sentinel missions will be, among others, a supportive investment underpinning CORINE for the user's benefit.

Acknowledgements

Funded by EU-FP7 grant agreement 218802 (SAFER project).

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INTERNATIONAL CHARTER 'SPACE AND MAJOR DISASTERS'

A unique worldwide system for disaster response, built on operational satellite resources and cooperation

The challenge

Disasters such as floods, wildfires, earthquakes or storms bring devastation to millions of people around the world every year. Faced with a major emergency, rescue and relief organisations that are armed quickly with reliable and accurate information are better equipped to save lives and limit damage to property, infrastructure and environment.

Satellites routinely monitoring the earth from space and delivering robust data in near real time (NRT) offer a unique tool to aid disaster management. If rapidly programmed and acquired, satellite data can also help provide views of how the landscape and infrastructure have been affected, even down to street level.

The international charter 'Space and Major Disasters' has been operating since 2000 and promotes worldwide cooperation among space agencies, enabling satellite data to be made available for disaster management.

Crisis room, Courtesy COGIC
© MININT/DGSCGC/COGIC, 2011

Benefits to citizens

By combining earth observation (EO) assets from 15 space agencies, the Charter allows worldwide resources and expertise to be coordinated for rapid response to disaster situations.

The uniqueness of the initiative lies in being able to mobilise agencies around the world and benefit from their know-how and their satellites through a single access point that operates 24/7 and at no cost to the user.

The Charter satellites provide an overall picture of areas made difficult to access by the very nature of the disaster.

Rapid mapping and damage assessment products provide extremely valuable support for both decision makers in central or regional headquarters and relief teams in the field. Key updated cartographic maps of areas that are difficult to access help to identify zones where aid is still needed.

'Charter products are used as key decision-making tools, in support to the field and as information to governmental authorities.'
Pierre Chastanet, French Civil Protection (DGSCGC)

The space-based solution

The Charter has very simple objectives: to rapidly task satellites in response to requests from a user organisation, and to provide the user with fast access to satellite data to help them manage their response to the crisis. The Charter works with authorised users, typically disaster management centres in countries of Charter agencies or United Nations bodies who are mandated to submit requests. For answers to local or regional requests, authorised users can trigger the Charter 24/7 by calling a confidential telephone number.

Satellite acquisition and analysis take place on an emergency basis. A project manager who is qualified in data ordering, handling and application assists the user throughout the whole process. In Europe, to enhance efficiency in satellite acquisitions the Charter and GMES Emergency Service inform each other of their activities.

Although the Charter's mandate is limited to supplying satellite data quickly and at no cost, its members also generally collaborate on value-adding capacities, e.g. the GMES Emergency Management Service to include image analysis and interpretation. Two European rapid mapping services are very frequently involved in the framework of the Charter: SERTIT (Alsace region) and DLR-ZKI (Bavaria region).

Outlook for the future

Over the last 10 years, the Charter has fully demonstrated the importance of space in helping to optimise the capacity of relief organisations dealing with natural and technological hazards.

Floods in Alsace in 2010

In order to improve its efficiency, the Charter is increasing its resources. Pléiades optical submetric images provided by CNES, together with TerraSAR-X SAR images provided by DLR, are of major interest for disasters in urban areas. The next spatial resources that could be of major use in the response to crises will be Sentinel 1 and 2 time series, allowing monitoring of large plain floods. In Europe, a Charter/GMES emergency agreement allows European authorised users access to GMES rapid mapping services through an interface procedure. Such agreements guarantee complementarity and synergy between the two systems.

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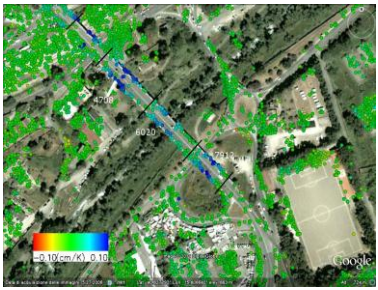
INTEGRATED TECHNIQUES FOR MONITORING TRANSPORT INFRASTRUCTURES

Roads, bridges and dams represent an integrated and interdependent system whose safety and reliability is vitally necessary



Synthetic Aperture Radar imaging of the Musmeci Bridge in Potenza. The blue points indicate the areas affected by significant deformation.

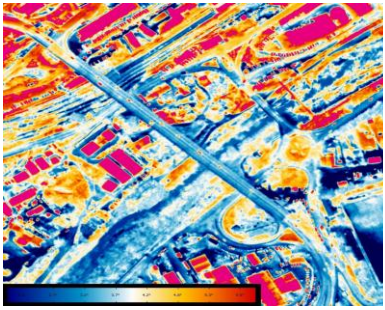
The challenge

Critical transport infrastructure needs to be monitored continuously to ensure their reliability and safety. A technological option under consideration here is the design and implementation of a monitoring and surveillance system based on the integration of remote and in situ non-invasive electromagnetic sensing technologies, which are organised in a network supervised by an ICT architecture. This has been the aim of the ISTIMES project (FP7 Joint call ICT-Security). The overall aim of the ISTIMES system is to provide the stakeholders with friendly and updated information about the status of the infrastructure with high situational awareness. The integration of remote and in-situ sensing techniques offers the advantages both of long-term monitoring and rapid damage assessment. Effectiveness of this kind of system has been shown in ISTIMES demonstration activities at two challenging test beds, namely the Silhochstrasse bridge in Zurich (Switzerland) and the Musmeci bridge in Potenza (Basilicata, Italy).

Benefits to citizens

The impact of the ISTIMES system is evident not only in providing more reliable damage assessment, but also improving the monitoring capabilities. In terms of cost-benefit, the system will lead to significant advantages, since it is so flexible to make it possible to use multi-step strategies, where the remote sensing techniques are the first stage of an acquisition chain ranging from the global to local information.

'ISTIMES system represents a technological turning point in the critical infrastructures monitoring and damage assessment.' **Gerardo Colangelo, Civil Protection Office of Basilicata Region**



Thermal image of Musmeci Bridge in Potenza from an airborne platform

This is very much the case in the Basilicata region, where the effect of natural risks is amplified by the sparseness of the infrastructure. This makes a fast and reliable response in crisis events much more difficult.

The space based solution

The use of a "constellation" of ISTIMES systems could be very important to provide near-real-time information about infrastructure status. It is important to develop tools and methodologies able to ensure the interoperability of the systems and to create "standards" for the command and control of the sensors. The ISTIMES approach has created interest from stakeholders as Dipartimento di Protezione Civile in Italy. Synthetic Aperture Radar (SAR) satellite-based platforms like TerraSAR-X and COSMO-Skymed are deployed operationally, with the aim to carry out long-term monitoring of the deformation of infrastructure. This way SAR is able to provide information on the temporal and spatial behaviour of the slow displacement of structures and of the underlying territory. It can also gain information about precursors of possible significant damage and collapse events of the infrastructure. The use of SAR technology is complemented by airborne thermal and multispectral information (figure opposite) and in situ techniques for a local high-resolution view.

Outlook to the future

Remote sensing capabilities will benefit from the continuation of GMES services and the launch of the new Sentinel 1 and 2 missions with an increased revisit time and improved spatial resolution. The systems will be able to provide more accurate information in the first phase of the crisis event, which is decisive for a proper damage assessment.

Acknowledgements

Funded by EC-FP7, grant agreement number 225663.

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A QUICKER AND BETTER RESPONSE TO CRISIS SITUATIONS

Existing shortcomings and future possibilities for further tailoring emergency mapping to user needs

The challenges

Satellite-based emergency mapping serves many different user groups. However, in the past not many end-users were able to use these services. As a consequence, the services were not further integrated into their operations. Stronger user involvement would also help to solve the two major challenges for the service: a) the demand for high geometric and thematic accuracy versus the need for very fast delivery of analysis information; b) the trade-off between the standardisation of products and the need for individually tailored products. Finally, the future and nature of the GMES service are uncertain at the moment, as is its long-term financial perspective.

Benefits to citizens

There are direct and indirect benefits for citizens. The direct benefits are that EO-based information about a disaster, such as its magnitude, damage distribution, and prompt analysis of situation dynamics increase the effectiveness of traditional crisis management (logistics, search and rescue, coordination with other authorities involved, etc.). The wider public, too, often gains better knowledge through the media about the situation.
Indirectly, rapid mapping services can lead to a faster rescue and emergency service. The rapid mapping activities can also be used for prevention and preparedness activities.

Detected damaged buildings, Haiti 2010, a DLR-SERTIT map

The space-based solution

Space-based rapid mapping is based on more than 10 years of experience; even so, significant improvements are still possible. All elements of the chain could be improved, especially data procurement.

'It was an excellent opportunity to use the services of GMES SAFER. I'm really very satisfied the way it was done.'
Didier de Thysebaert, Public Services of Wallonie, Floods 2011

The EO-based rapid mapping chain and its interactions

The analysis element has been transformed through industrialisation and standardisation over the last few years to improve speed and quality. A diagram of the components and their interactions is given in Figure 2. The value adding part of rapid mapping at SERTIT and DLR/ZKI, located in Alsace, France, and Bavaria, Germany, is based on experienced 24/7 on-call teams, always available and ready to work immediately to provide a first crisis analysis product 6 hours after receipt of data.

Both service chains follow internal quality control procedures to ensure the best quality within very limited production time. Furthermore, SERTIT and DLR/ZKI have ISO certified rapid mapping services.

Outlook for the future

After 10 years of setting the scene through the International Charter Space and Major Disasters and GMES projects, it is now time to widen further the user community and to meet user needs even more closely, no matter whether the user has an international, national or regional scope or where in the crisis cycle they intervene. After concentration on standardisation over the last years, the flexibility to meet individual user requirements needs to be reinforced.

One of the key criteria is rapid product delivery. Therefore, elements in the service chain that hinder performance should be either let go or improved. At present the most critical blockage is EO data access. This situation is improving through dedicated satellites and constellations coming online with adapted ground segments and space segments that have agile constellations instead of single-satellite missions. The service chains need to take future missions like the Sentinels into account which should bring significant benefit to emergency services. A key objective is to ensure continuity of the established infrastructure and to improve the existing system in order to better serve emergency service or risk management users at all levels.

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MONITORING THE AREA AFFECTED BY FIRES IN MEDITERRANEAN EUROPE

Summer weather makes southern Europe vulnerable to fires. Satellite images are essential for fire monitoring

The challenge

Forest fires are frequent in Mediterranean Europe when the weather is hot and dry and they can become catastrophic when winds are strong and unpredictable. Most of the fires are set by humans either deliberately or accidentally. Information on the fire affected area is crucial for assessing economic and environmental damage and when planning protection of recovering areas as well as for fire prevention and fighting forest fires.

Benefits to citizens

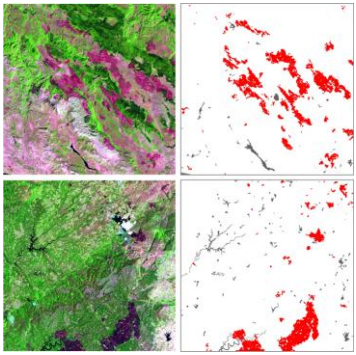
Despite the high frequency and the severity of forest fires, which affect Mediterranean regions of southern Europe, most countries lack a complete and long term archive of fire incidence. Forest services and other public institutions recognise that building annual archives of burn perimeters systematically is necessary to monitor the phenomenon and for the prevention and forecasting of future events.

Italy, Sardinia, ASTER satellite images (RGB composite is 4-3-2) acquired before and after a fire (red region at the centre of the scene) occurred in the Gallura region

Mapping burn perimeters can be carried out *in-situ,* with GPS technology, only at a local scale and over a few burns. Yet, at a national/ regional scale, systematic field data collection is difficult, time consuming and very expensive. Indeed, over large areas remotely sensed data are the unique source of information for building and updating burned area archives. In Italy, annual cartography of fire affected areas is imposed and assigned to regional bodies by law n.353/2000 ("*Legge-quadro in materia di incendi boschivi*"), and remote sensing is explicitly mentioned as a way to fulfil the task. This law certainly represents a key instrument for the implementation of activities related to fire prevention and monitoring although at present there are very few examples of its application.

'Satellite images are a valuable support for planning the activities related to prevention and fighting forest fires in National Parks.'

Bruno Petrucci, Ministry of the Environment and Territory, Directorate for Nature Protection



Landsat TM (RGB 543) over Croatia (top left) and Portugal (bottom left) and burned areas (red areas)

The space-based solution

Satellites are a cost-effective source of data for fire monitoring from regional up to global scale. Coarse spatial resolution data (1-5 km) with high acquisition frequency (15 min up to 1-2 days) have long been used for fire mapping. However, in Mediterranean regions, medium/high resolution data (< 60 m) are better suited to the heterogeneous composition of forests and to the typical burn size (few hectares), although they provide a lower frequency of acquisition. CNR-IREA has a long experience in fire mapping from satellite data and it has recently focused its attention on using medium/high resolution satellite data for fire mapping in Mediterranean regions. CNR-IREA has developed an automated approach to map burns, based on fuzzy theory, using medium/high resolution images (from NASA-ASTER, Landsat TM/ETM+). This was trialled in several Mediterranean countries and proved to be robust for future implementation in operational systems. CNR-IREA is currently working on the integration of optical and radar satellite data for burned area mapping. Fire maps are available to the public and the institutions through WebGIS technology.

Outlook for the future

A GMES operational service including a burned area mapping module requires satellite data with suitable spectral, radiometric and geometric resolutions as well as frequent and continuous acquisitions. The ESA Sentinels mission will satisfy these requirements, with the multi-spectral high-resolution sensor (Sentinel-2), as well as with Sentinel-3 for land surface temperature monitoring and Sentinel-1 with the radar sensor. This mission will be the primary source of information for a fully operational forest fire monitoring system.

Acknowledgements

This research was funded by the Italian Ministry of Environment (Progetto Incendi); burned area maps are available on the National Cartographic Portal (www.pcn. minambiente.it).

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A FREE ONLINE GEOHAZARD INFORMATION SERVICE FOR EUROPE

Geohazard information for the citizen, local authorities, policy-makers, geological surveys and business

The challenge

Geohazards in the built environment can be dangerous and costly, yet information about these phenomena and their effects can be difficult if not impossible to obtain. Mapping geohazards on the ground is a reactive and often confidential occupation. This service is about generating new satellite-based information on urban geohazards for 52 of the largest European cities, and then making this information freely available and accessible to all. Geohazards are natural or man-made phenomena that make the ground unstable. They include not only high-profile events like earthquakes and landslides, but also the more insidious effects of mineral workings, groundwater abstraction and re-charge, shrink-swell clays, soluble rocks, compressible ground, collapsible deposits, landfill and tunnelling.

Typical urban geohazards

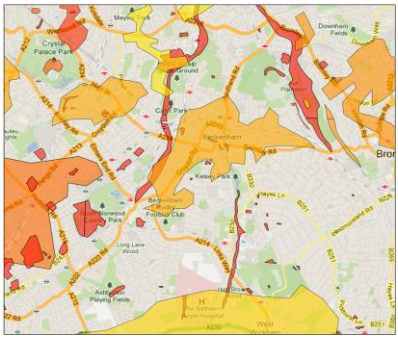
Benefits to citizens

By providing new and free maps and information on geohazards, the service benefits to five main user-groups:

- Local Authority departments responsible for building and development control have little, if any, data on geohazards, tending to work using 'past experience' and anecdotal evidence. Products will enable a systematic approach to building controls.
- National Geological Surveys are mandated to advise government on geohazards. By providing new satellite-based data for 52 towns representing 13% of the European population, a major scientific contribution is being made to geological understanding.
- In general, the public are in ignorance as to the stability of the ground beneath their feet. The service will help empower citizens.

'The product can supply precious and unique data… I can plan onsite 'problem-oriented' investigation …' **Eutizio Vittori, ISPRA (Italian Geological Survey)**

- Currently, Policy-Makers have limited information by which they might understand the social-economic effects of geohazards across Europe in general. Provision of standardised data across dozens of towns will enable practitioners for the first time to statistically model the impacts of this major cost.
- Commerce: The service licence unusually allows free commercial use of product, thereby encouraging adoption by insurance and property conveyancing sectors. It is hoped that this approach will encourage orders for new processing of other towns.



Part of the ground stability layer over London showing polygons of differing geohazard type

The space-based solution

Products are based on European radar satellites detecting terrain motions over whole cities to millimetre precision. These motions relate directly to geohazards. However, these data on their own can be misinterpreted, and expert analysis by a geologist is needed. In the service, all 27 European Geological Surveys are contracted to interpret satellite data over cities in their countries to make tightly specified and standardised products that the non-specialist can understand. A service portal also merges these products with the 1:10,000, 27-class, Urban Atlas (UA) land cover database to give derived products indicating hazard-exposure.

Outlook to the future

UA data is central to revealing what is affected by the geohazard. The UA was made for the 305 largest EU conurbations; with 52 addressed in this project, there remain 253 towns to do if further funding can be found. The service is based on European satellite data, specifically the C-band radar data from ERS-1/2 and Envisat ASAR. These satellites are no longer functioning, and so the continuity of measurements that will be afforded by Sentinel 1a/b is absolutely essential. As megacities expand, resources become scarce, and people are forced to live in hitherto unstable environments, the costs of geohazards can only grow. There is an unprecedented need for information on geohazards – provided by this service.

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FLOOD MITIGATION BY EARTH OBSERVATION-BASED SUPPORT IN POLAND

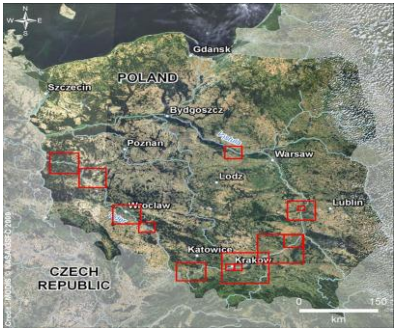
The interdisciplinary cooperation of the Polish institutions to deliver up-to-date spatial information in the crisis

The challenge

In May and June 2010 heavy rains caused serious flooding, affecting the people and infrastructure in many cities and villages of South and West parts of Poland. It was one of the biggest floods in Polish history and caused 25 fatalities and losses of about 3 billion euros. Institutions responsible for floods rescue services were lacking up-to-date spatial data for effective crisis management.

Benefits to citizens

At least 22 Polish end users in 16 regions received and used satellite maps and additional products. Institutions not only involved operationally in rescue services used the products, but also insurance companies and the largest Polish media that were using them to show and assess the scale of the problem. However, users needed to wait from 30 hours to 5 days for EO data

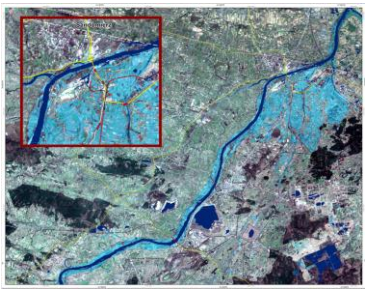


Regions in Poland seriously affected by the flood in May and June 2010 that benefited from satellite data

acquisition and processing. The satellite maps delivered by the SAFER project were used in the strategic situation assessment and planning of priority action. After the floods they also helped to estimate damage and losses. In the long run the maps are extremely helpful in the optimisation of future investments and upgrading of flood defences as well as supporting data collection for climate change studies. The users indicated that the added value of these products is in:

- offering the most up-to-date geographical information of the region,
- giving the full picture of the problem with the in situ data,
- providing information to support policy makers' action and plans,
- being delivered independently of the weather,

'Satellite-based maps should be distributed at the central level for the rescue brigades and firefighting to assess risks and plan their action.' **Representative of the Voivode State Fire Service in Warsaw.**



Flood impact maps of the Vistula River in the Sandomierz region, Poland

• easy integration with other crisis management systems.

The space-based solution

On 19th May and 7th June the National Headquarters of the State Fire Service activated the project SAFER which implements and validates preoperational versions of the GMES Emergency Response Service. The operational consortium consisted of SRC PAS, Industrial Research Institute for Automation and Measurements – PIAP, Institute of Meteorology and Water Management, Polish Geological Institute and Poznan University of Technology. Thanks to their efforts the data were processed fast and accurately. A supervised classification was then conducted to show areas which have been fully flooded during the event. The extracted information has been later converted into vector format applicable both in the GIS environment software and in Google Earth. Building upon SAFER data, a series of downstream products was developed presenting information about areas requiring water removal to prioritise recovery actions and later to monitor progress of the recovery effort.

All satellite maps were provided in the easy–to–use form, which included: situation maps in pdf and GeoTIFF, (about 30 in total), flood extent maps (shape file, binary mask, water/no water) and maps with recommendations for water-removal. Water layer depth was extracted from radar images such as: RADARSAT 2, ERS 2, COSMO Sky-Med, TerraSAR-X, ENVISAT. It is clear that access to Sentinel-1 will increase operational flexibility during similar events.

Outlook for the future

The satellite support of the floods mitigation made those involved realise that the most up-to-date geographical data is vital for crisis management centres and decision makers at every level of administration. Thanks to this, the Crisis information Centre at SRC PAS was created to provide necessary information about natural, humanitarian and political disasters based on satellite and other complementary data.

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FLOOD HAZARD EARLY WARNING SYSTEM

Operational snow monitoring service helps with hydrological flood prognosis in the regions of the Czech Republic

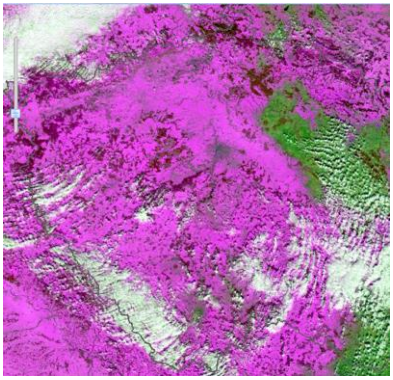
The challenge

Several regions in the Czech Republic have experienced different types of floods in recent years, such as summer floods due to lengthy periods of precipitation or flash floods but also significant floods due to snow melt. This wide range of possible flood types also puts a broad and complex demand on the input data and hydrological methods and models that are used both at central and regional level.

The Czech Hydrometeorological Institute (CHMI) is the main national organisation mandated to monitor and aid prevention of flood threat. The CHMI department in Liberec region is involved in the regular evaluation of snow quantity during the winter season and computes a prognosis for floods. Information obtained from the climate station ground network is not usually sufficient as it does not provide a spatially consistent snow cover map.

Benefits to citizens

The operational snow monitoring system was developed to support and improve the quality and reliability of the regular flood prognosis service provided by CHMI to the regional and river basin authorities. It helps to assess the flood threat during winter and the early spring season and brings new possibilities for hydrological monitoring systems used in flood risk analysis, especially in the case of snow melt or surface water run-off contributing to flooding events.

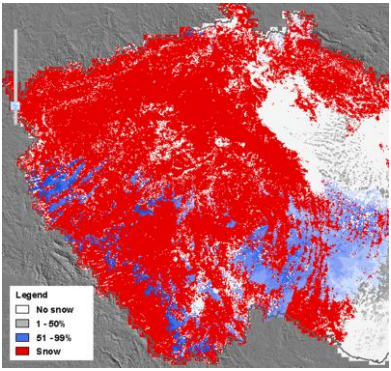


MODIS image showing snow covered regions in purple and snow-free in green (white=cloud)

The information about snow is delivered by means of Earth Observation technology which offers full coverage compared to only discrete point measurements available from ground stations. Snow mapping products allow users to derive snow cover statistics and to determine the extent of snow cover for further snow analysis, for example, water mass of the snow in the landscape.

'During the snow melt or heavy snowfall period we need more accurate information about the spatial distribution of snow cover.'

Libor Ducháček, Dept. of Hydrological Research, CHMI, Liberec region, Jablonec



Hybrid snow cover map (snow=red, snow probability=grey-blue)

The space-based solution

The applied methodology is based on combination of the different spatial and temporal scales of the satellite imagery as well as employing optical and radar technology. The use of medium- and coarse-resolution satellite imagery with high temporal resolution is focused on snow cover mapping and monitoring. Snow cover and its changes (the changing snow-line) are monitored using several satellite systems, such as Terra / Aqua MODIS imagery with spatial resolution of 250 m or Envisat ASAR radar imagery with spatial resolution of 150 m. The advantage of MODIS data is daily acquisition with full coverage of the area of interest but clouds can hide the land surface. In this instance, ASAR data are processed.

Besides this, snow occurrence probability maps are calculated based on measurements from climate stations. Missing snow information could then be substituted by the probabilities. In this way, uncertainty in the maps is reduced and so-called hybrid maps are produced. Additionally, a catchment's snow statistics are calculated including the percentage of snow coverage according to land cover types and altitude levels.

Outlook for the future

Although the service has run operationally for last two years, there are still issues to be further developed. The next focus will be on the estimation of Snow Water Equivalent, more detailed mapping of snow top characteristics and detection of snow in forest under the tree cover.

Such tools and system extension would significantly support the monitoring of the spatial occurrence of snow melting in the critical period of spring. This should further improve the early warning aspect of the current flood prognosis service.

Acknowledgements

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SHORE TYPE MAPPING TO REDUCE OIL SPILL IMPACT

Shore type mapping in order to plan and prioritise better for the possible event of oil spill at Sea

The challenge

Oil spills from ships have negative impact on the environment. The consequences vary depending on the surrounding environment, but as the oil hits the shore different actions are necessary in order to reduce the damage. Within a short time frame, it is necessary to plan and prioritize actions to save the environment, including both vegetation and animals, both in the terrestrial and the aquatic domains.

Benefits to citizens

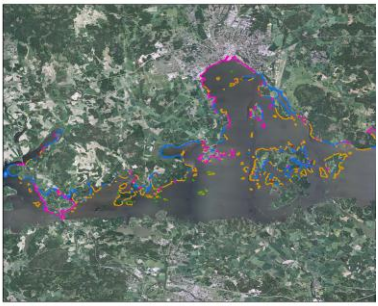
Access to the shore is considered to improve quality of life. The shore-line is frequently visited and used for recreational purposes such as swimming, fishing or leisure boating. Proximity to the shoreline is also attractive for residential establishments. The shore is also a habitat for a wide range of animals and plants.

Lighthouse in Lake Mälaren © Metria AB

This habitat is sensitive to pollution and the consequences of pollutants are often highly significant. A major risk concerns oil spills from the commercial vessels. Unfortunately, oil spills happen frequently along the shores and even in inland waters with links to the sea. In order to reduce the impact of oil spill to the shores, it is important to prioritise the rescue services to areas where most support will be needed. This will reduce the costs of the emergency activities, but more importantly will reduce the negative impact caused by the pollution. Minimising the damage may be the single most important factor in protecting the shore and here decision support systems are of great help.

'With the mapping of shore types, the base for contingency planning for oil spill has improved.'

Mr Håkan Fehne, The Municipality Rescue Services of Västerås



Shore type mapping © Metria AB

The space-based solution

For the municipality of Västerås (in Eastern Sweden) a shore-mapping was produced using optical EO data (10 metre spatial resolution) in combination with soil maps and other available in-situ databases. Mapping in EO data was performed in a 50 metre zone along the shore-line. The thematic classes of the shore types mapped were according to the handbook for environmental remediation and therefore possible to use in operational planning at once. During the mapping process, field surveys performed together with the Rescue Services showed very good compliance with ground truth. The results provided a classification of shore types presented as a vector layer along the shore line. Among the most common shore types were rocks and reed-dominated shores and cliffs. These different types require different actions when oil spills occur and, by using the information provided, it is possible to prepare different types of rescue activities and also to prioritise what shore-lines to start with in the event of an oil-spill accident.

The Rescue Services were able to include these maps in their operational planning for possible oil spills in lake Mälaren, as shown in the figure.

Outlook for the future

For each municipality with a shore-line where oil-spill may cause great damage, such shore-type mapping would be of great importance in supporting the prevention of large-scale damage to the shore-line and in reducing the need for emergency activities along the full shore-line.

The arrival of GMES Sentinel satellites will secure the continuation of useful EO data for these kinds of products. The mapping, as demonstrated, is offered to all municipalities in Sweden facing risk of oil spill to provide potential support for the Rescue Services in their contingency planning.

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