Applications of

SATELLITE EARTH OBSERVATIONS:

Serving Society, Science, & Industry

FULL REPORT version

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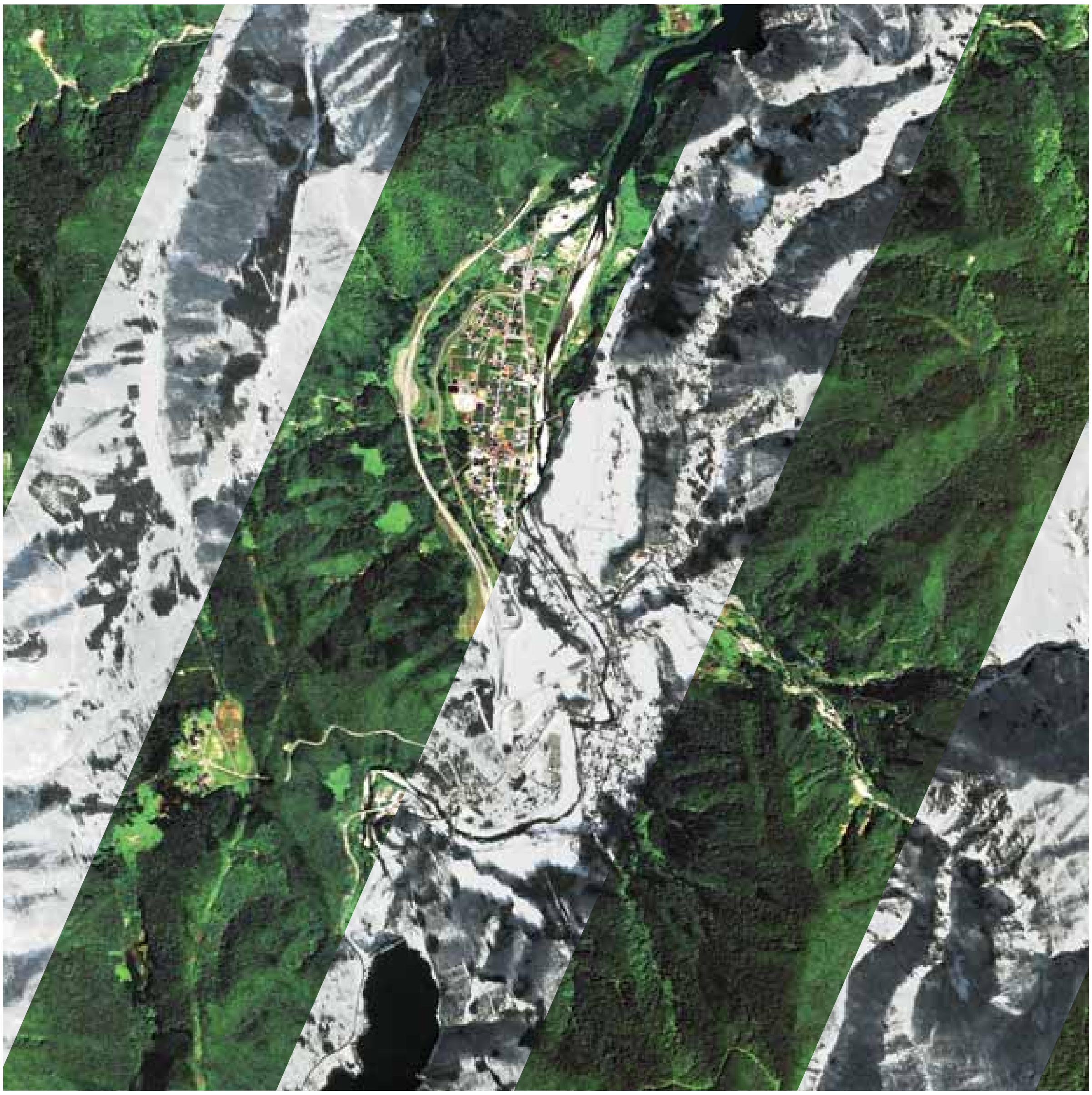
2015 edition

CEOS: Committee on Earth Observation Satellites (http://www.ceos.org)
JAXA: Japan Aerospace Exploration Agency (http://global.jaxa.jp)



The Historic Villages of Gifu Shirakawa-go (World Heritage) observed by AVNIR-2. Advanced Land Observing Satellite "Daichi"(ALOS).

Applications of Satellite Earth Observations: Serving Society, Science, & Industry

[FULL REPORT]

2015 edition

Committee on Earth Observation Satellites,
Japan Aerospace Exploration Agency

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Message from the CEOS Chair

The Committee on Earth Observation Satellites (CEOS) represents the civil Earth-observing (EO) programmes of more than 30 of the world's leading space agencies. These CEOS Agencies are collectively investing billions of dollars in space infrastructure with the capability to provide sophisticated, continuous, and sustained observations of the entire planet.

The CEOS Missions, Instruments, and Measurements Database shows that dozens of countries have active civil EO satellite missions, with around 130 individual missions of CEOS Agencies estimated to be active in 2015. Greater technical capacity worldwide, improved international cooperation, and reduced size and costs of EO satellites have all contributed to the number and diversity of countries with active EO space infrastructure. These satellites carry many different types of instruments – from high-resolution imagers to atmospheric chemistry monitors, rain radars, and lightning sensors. We all benefit from an extremely wide range of technologies and capabilities on EO satellites working in service of society today.

World leaders recognise that mankind faces some pressing challenges related to a sustainable future as the human population explodes and basic needs for food, water and shelter must be met by finite resources of the planet. Climate change and environmental degradation are complicating the already substantial challenges of food security, water resource management, and clean energy policies. A number of important inter-governmental processes aimed at ensuring a sustainable and prosperous path for mankind are underway, including (amongst many): the United Nations Framework Convention on Climate Change (UNFCCC); the Sustainable Development Goals (SDGs); the World Conference on Disaster Risk Reduction (WCDRR). Satellite Earth observation data provides a reliable and scientific information base for definition of global goals and frameworks and will contribute to monitoring of progress in their implementation in the years ahead. Without the information and knowledge provided by EO satellites, there will simply not be sufficient evidence which to inform our policy makers, and to reliably monitor, report, and verify international agreements and frameworks aimed at improved global governance.

This report has been compiled by the Japan Aerospace Exploration Agency, as the CEOS Chair for 2015, to paint a picture of the incredible breadth of applications supported by EO satellite data in the service of society, science, and industry. These applications are collected from the best practices presented by CEOS members, from a wide range of sectors including disaster risk reduction, public health, natural resource exploration, infrastructure planning and management, and environment and climate. CEOS Agencies continue to advance satellite applications in each sector, contributing solutions to the many challenges facing humankind. We hope that this report is useful for decision-makers and the public, and also that it may provide some new insights into the world of satellite applications, to those unfamiliar with space technology.

Shizuo Yamamoto
Japan Aerospace Exploration Agency
2015 CEOS Chair

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A Brief History of the Committee on Earth Observation Satellites (CEOS)

CEOS was formally established in September 1984, with Terms of Reference drawn up in response to a recommendation from a Panel of Experts on Remote Sensing from Space that was set up under the aegis of the Group of Seven (G7) Economic Summit of Industrial Nations Working Group on Growth, Technology and Employment (the Panel established in connection with the 1982 Versailles G7 Summit Meeting). Participating in the first CEOS meeting in Washington, DC were representatives of CCRS, CNES, ESA, INPE, ISRO, NASA, NASDA and NOAA. The 1985 and 1986 G7 Summits received reports on CEOS development from the Panel of Experts. The 1990 G7 Summit reiterated "the importance of coordinating and the sharing the collection of satellite data on Earth and its atmosphere." By 1990, CEOS was meeting on an annual basis and had a Working Group on Data and a Working Group on Calibration and Validation.

In April 1992, UK Prime Minister John Major invited environmental agencies of countries active in Earth observation and CEOS space agencies to an April 1992 Conference on Space and Environment to help prepare the 1992 Rio Earth Summit (UNCED). BNSC produced a CEOS Dossier for distribution at UNCED, "The Relevance of Satellite Missions to the Study of the Global Environment," with detailed mission and instrument tables. This publication served as a prototype for follow-on documents produced by ESA and the current on-line CEOS Missions, Instruments and Measurements Database.

CEOS, at its 1992 Plenary. created a permanent Secretariat (ESA, NASA, NOAA, STA/NASDA) that carries on the work of CEOS in monthly telecons under the leadership of the current CEOS Chair agency. EUMETSAT was added to the Secretariat at a later date; Japanese STA/NASDA representation changed to MEXT/JAXA following a reorganization within the Japanese government. NASDA (later JAXA) in 1993 began and has continued publication and distribution of the CEOS Newsletter as well as various versions of a CEOS brochure.

Also at its 1992 Plenary, CEOS adopted Satellite Data Exchange Principles in Support of Global Change Research, and at its 1994 Plenary adopted Principles of Satellite Data Provision in Support of Operational Environmental Use for the Public Benefit.

In 1994 CEOS set up a Task Force on Planning and Analysis to focus on gap analysis, requirements and how to make CEOS more effective. The Working Group on Data was combined with an interim Working Group on Network Services in 1995 to become the Working Group on Information Systems and Services (WGISS).

The Australian 1996 CEOS Chair proposed creation of a Strategic Implementation Team (SIT) that would meet at CEOS Principal level to address gaps/overlaps and to develop an overall strategy for the stepwise implementation of the space component of an Integrated Global Observing Strategy (IGOS); the 1996 Plenary approved the establishment of SIT which held its first meeting in February 1997. SIT Chairs have two year terms and SIT initially met twice a year.

CEOS Associate Agencies (many of them UN or S&T organizations) participated in CEOS Plenaries and SIT and worked to structure IGOS which was formally established in June 1998 with 13 founding partners including CEOS. CEOS Plenary, SIT and IGOS meetings in the period 1998-2005 focused on the development of specific IGOS Themes and coordination of space-based and in situ observational assets.

CEOS added a Working Group on Earth Observation Education and Training (WGEdu) in 1999 and organized an ad hoc Disaster Management Support Group from 2000 to 2002 that focused on development and refinement of recommendations for the application of satellite data to selected hazard areas. CEOS began to focus on sustainable development by playing a key role at the August/September 2002 World Summit on Sustainable Development (WSSD) in Johannesburg and in 2003 formally added Capacity Building to the remit of WGEdu.

CEOS Agencies played a key role in participating on their national delegations, with CEOS itself a "Participating Organization," in the convening of the 31 July 2003 Earth Observation Summit in Washington, DC that adopted a Declaration establishing an ad hoc intergovernmental Group on Earth Observations (GEO). GEO Members and Participating Organizations met in subsequent Summits in Cape Town, Tokyo and in February 2005 with their Ministers in Brussels where the intergovernmental GEO was formally created with endorsement of a Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan.

CEOS has subsequently worked closely with GEO/GEOSS as its space component to:

- take the Lead or Co-Lead of several GEO Tasks;
- develop Virtual Constellations for GEO (for Atmospheric Composition, Land Surface Imaging, Precipitation, Ocean Surface Topography, Ocean Surface Vector Wind, Ocean Colour Radiometry and Sea Surface Temperature);
- provide critical data sets for key GEO-related initiatives such as Global Forest Carbon, Global Agricultural Monitoring and GEO Supersites initiatives; and to
- actively participate on GEO Boards and in GEO Plenary and Ministerial meetings.

CEOS has likewise connected with the Global Climate Observing System (GCOS) in stepping up to address satellite-related requirements related to GCOS-identified Essential Climate Variables in connection with GCOS Implementation Plans and the GCOS request for a Satellite Supplement document. In connection with its role in support of GCOS, but also because of its key role in the "systematic research and observations" area of focus of the UN Framework Convention on Climate Change (UNFCCC), CEOS received a direct charge from the UNFCCC's Subsidiary Body for Scientific and Technological Advice (SBSTA) in 2009.

The post of a full-time CEOS Executive Officer (CEO) was established at the 2006 Plenary to bolster the resources available to CEOS. The CEO serves a two-year term and has at times had a Deputy. A CEOS Systems Engineering Office (SEO) was established in 2007 to provide systems engineering leadership to CEOS activities and improve CEOS collaboration. CEOS ad hoc teams are from time to time organized to perform specific functions. In the 2011-2013 period, CEOS conducted an intense self-study resulting in the adoption of both Strategic Guidance and Governance and Processes documents. In 2014, CEOS formally adopted a three-year rolling CEOS Work Plan.

CEOS at its 2010 Plenary approved creation of a Working Group on Climate that later became a Joint Working Group also reporting to the Coordination Group on Meteorological Satellites (CGMS). In 2011, the WGEdu was reconstituted as the Working Group on Capacity Building and Data Democracy, taking into account the CEOS Data Democracy initiative undertaken to make satellite data more broadly available to users, particularly in developing countries. In 2013, CEOS formally created a Working Group on Disasters that developed CEOS observation-related pilots for presentation at the March 2015 World Conference on Disaster Risk Reduction.

CEOS currently comprises 55 Agencies (31 Members and 24 Associates) with responsibility for operation of over 130 orbiting satellites.

Evolution in capabilities

Number of countries & missions

In 1995, only a handful of countries had the capability to develop and operate an Earth observation satellite. The CEOS Yearbook for 1995 indicates that the USA, Russia, India, Japan, China, France, Brazil, and Canada – as well as the pan-European agencies of EUMETSAT and ESA – had active EO missions at the time. Amounting to around 28 CEOS agency missions or series of missions active in mid-1995.
By the time we reach 2015, the CEOS Database shows that many more c0untries have active civil EO missions, including: Italy, Germany, Thailand, UK, Spain, Korea, Argentina, Nigeria, Ukraine, Belgium, and Vietnam – in addition to expanded membership of ESA and EUMETSAT. Around 130 individual missions of CEOS agencies are estimated to be active in mid-2015. Greater technical capacity world-wide, improved international co-operation, and reduced size and costs of EO satellites have all contributed to the number and diversity of countries with active Earth observing space infrastructure.

Diversity

In the 1995 report, of the 36 case studies, the vast majority used multi-spectral optical imaging sensors or synthetic aperture radar with only a few variations – some applications using radar altimeter or microwave radiometers.

In contrast, our 2015 examples utilise almost all of the 16 categories of instruments specified in the Earth Observation Handbook, being:
- atmospheric chemistry instruments;
- atmospheric sounders;
- cloud profile and rain radars;
- earth radiation budget instruments;
- high resolution optical imagers;
- imaging radiometers (optical and microwave);
- imaging microwave radars;
- lidars;
- lightning detectors;
- multiple direction/polarisation instruments;
- ocean colour instruments;
- radar altimeters;
- scatterometers;
- gravity, magnetic field and geodynamic instruments.

This significant diversity is indicative of the extremely wide range of technologies and capabilities on satellite Earth observation that are now in service of society in 2015.

Resolution & performance

Earth observing payloads have evolved significantly over the last two decades. In 1995, the SPOT-3 spacecraft of CNES was considered to be the gold standard for civil imaging of the land surface, with its 10-metre panchromatic and 20-metre multi-spectral imagery – available commercially. These days, the Sentinel-2 satellite of ESA/EC provides 10-metre multispectral data on a free and open basis. Commercial systems provide extremely high resolution data – 0.3m panchromatic or 1.24m multispectral (the Worldview-3 satellite) as well as rapid global coverage using multiple satellites (eg the RapidEye constellation).

Sensor technology is such that payloads being flown in geostationary orbit (35,786 kilometres above the Earth's surface) are approaching the resolutions previously only possible in low Earth orbit (100's of kilometres up typically). This is opening up a host of new opportunities for near-continuous monitoring of the Earth's surface. The Himawari-8 mission of Japan is capable of proving multispectral imagery of the full disk of the Earth from its view, every 10 minutes. New land surface and ocean monitoring applications are emerging based on this remarkable capability.

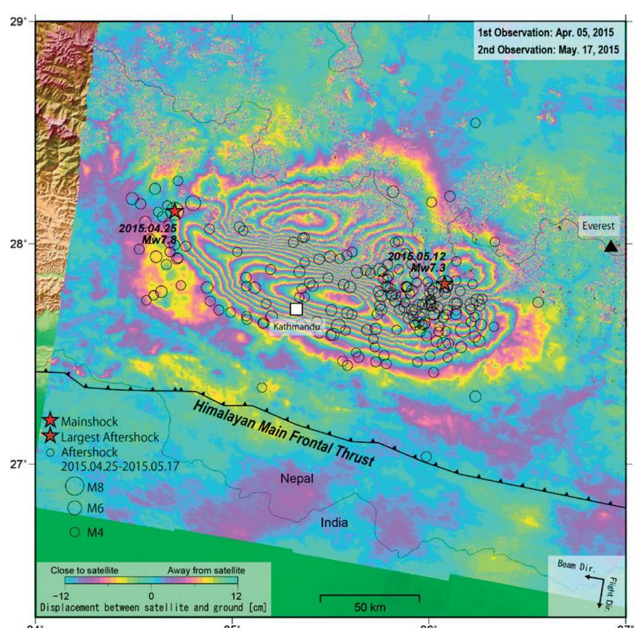
Accessibility and data handling

During the mid-1990s the typical hard disk drive for a PC cost about US$1,100 and had a capacity of about 1GB. Today, desktop computer drives have a typical capacity of 500GB to 4TB, and the average cost per GB us US$0.03. Similarly the performance-cost of both PC processors and data communications have increased dramatically; we now have a global average peak internet connection speed of over 18Mbps. The often large and sometimes complex data sets produced by EO satellites are no longer the exclusive domain of agencies with large, dedicated data storage and computing facilities. Small business, NGOs, developing country governments, even individual citizens have the means to access, download, process and extract vital information from these datasets.

GPS integrated applications

Widespread availability of GPS signals in vehicle navigation units and smartphones has opened up a new world of geospatial applications which integrate EO data with navigation and map information. These range from the ubiquitous mapping software in smartphones through to precision agriculture, with GPS units directing the application of chemicals by farm vehicles based on crop and soil status information derived by satellite. Crowd-sourced deforestation alerts can be integrated with early warning signals detected by EO sensors in support of illegal logging detection. GPS allows EO data to be translated into information of direct relevance to individual users and for the integrated information to be communicated to machines and vehicles.

Over the last two decades, we have seen increasing numbers and types of EO satellite missions collect more data for an increasing range of sectors, users, and applications – as indicated by the eclectic range of case studies collated by CEOS for this publication.



The 2015 Nepal(Gorkha) Earthquake: Crustal deformation detected by ALOS-2 data Analysis by GSI from ALOS-2 raw data of JAXA

Earth Observation Data Policy

What are the Determinants for EO Data Policy?

The issue of managing data derived from Earth observation satellites, in terms of access, pricing, data rights and other aspects is commonly referred to as Earth observation data policy. It is not a simple question under which discipline 'Data Policy' falls. Some discuss legal approaches based on treaties and principles, national and regional laws and regulations with regard to intellectual property rights or security issues; A more recent trend is to discuss the socio-economic benefit of free and open data in particular with regard to the development of industry; another related approach concerns the optimal choice of a public-private partnership and pricing policy. Data policy therefore is a combination of various concerns and interests of the operators and users.

International Legality

Earth observation from space is a powerful tool because a satellite orbit in space occurs in an area legally regarded as no one's territory. If the data gathering satellites are located in outer space, that is, international space, data gathering by satellites is in itself lawful under international law. It could be said today that States regard this as a general practice, while some national policies have taken place to prevent particularly intrusive data gathering and dissemination. The status of outer space as the "province of all mankind", the principles of free exploration and use by all States, and the non-appropriation principle has enabled States to perform global observations of the Earth from outer space. The UN Remote sensing Principles futher detail the rights and obligations of States regarding remote sensing activities.

National and Regional Policies

In principle, the U.S., Europe and Japan civil Earth Observation programmes follow the rules of the UN Remote Sensing Principles, while allowing to foster commercialization through licensing or contractual agreements. Protection of data rights under applicable legal terms include copyright, database protection, confidentiality clauses, or non-redistribution clauses, and extra legal means such as encryption or secrecy. Protection of data implies recovery of cost through its sales; open use of data suggests widespread use of public information as return to the taxpayers' investment in it. The policies and practices of respective states are diversified, mainly due to the different attitudes toward the nature of the activity, and in particular, commercialization. The U.S. seeks to optimise the effectiveness of the governmental data as public information by an open use policy, whereas Europe typically takes the approach of a two-tier policy between a marginal cost approach for scientists and a cost recover policy especially with regard to commercial distribution of the data, such as in the cases of SPOT/Plaiades, TerraSAR-X and Cosmo-skymed. A significant diversion to the traditional European approach is the recent open data policy for the Sentinel series of ESA, further discussed below. The Japanese data policy tranditionally has been somewhat close to the European approach, while some changes may be expected under the new Basic Plan on Space Policy and the remote sensing legislation that is currently being drafted.

Open Data

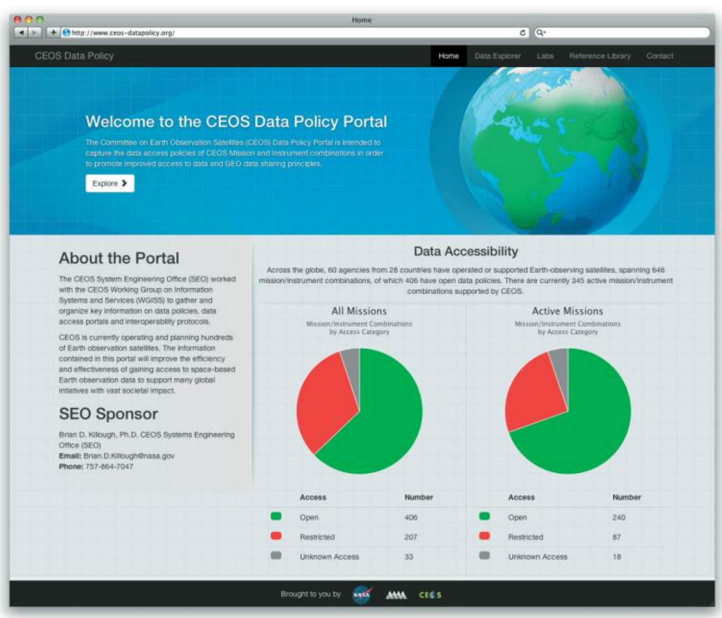
A notable recent event in the international coordination of Earth observation data policy was the GEOSS Data Sharing Principles and the resulting open data policies of Landsat and the European Sentinel satellites, all of which is part of the larger movement towards open data. The GEOSS 10-Year Implementation Plan explicitly acknowledges the importance of data sharing in achieving the GEOSS vision and anticipated societal benefits when it states that: "The societal benefits of Earth observations cannot be achieved without data sharing". The GEOSS Data Sharing Principles state that:

> *"There will be full and open exchange of data, metadata and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation; All shared data, metadata and products will be made available with minimum time delay and at minimum cost; All shared data, metadata and products being free of charge or no more than cost of reproduction will be encouraged for research and education."*

These principles have resulted in several significant data sharing examples, most prominent of which was the opening of the Lansat archives since 2008, and the open data policy of Sentinel satellites. There is a strong voice to advocate open availability of satellite Earth observation data in order to improve science and environmental information, while at least in the short term it does hinder the data distribution market development of a comperable satellite data. Therefore, balance with the commecial sector has to be achieved through appropriate lisensing schemes.

In to the Future

Data policy ideally should optimise the balances of different interests as described above, taking into account the socio-economic needs, development of the private market, security concerns, as well as the technological changes. The author's proposal is to achieve Data sharing through institutional competition: on one hand allow sound competition between the public sector and private sector information and divers economic models around data and information by segregating and standardizing access and dissemination terms, while on the other creating an open data source to serve decision making. Public global data infrastructures such as that of GEOSS could be utilized also for access to commercial data, building on initiatives such as Creative Commons, Science Commons and Open data Commons, and in collaboration with private IT companies such as Google. The global Earth observation community, above all GEO and CEOS, should be sensitive to the emerging global data trends such as open data, IP in the digital era and the use of so-called "Big Data", and adapt to and lead such trends in the domain of Earth observations.



CEOS Date Policy Portal
http://www.ceos-datapolicy.org/

Coordination Framework

Solutions to regional and global challenges, like sustainable development and disaster risk management, depend on comprehensive sustained regional, global and local data.

Satellites can provide this data, but no one nation can provide the depth and breadth of required data on its own. CEOS, and its partner coordination programmes and groups, bring together space agencies from across the globe to overcome this challenge. Through CEOS and its partners, over 130 different satellites and 300 different instruments, are coordinated to provide a comprehensive and evolving understanding of our Earth and how it is changing.

CEOS provides international coordination in satellite missions, products, services and policies to ensure validated and prioritized requirements for data are met. CEOS achieves this through external consultation with key stakeholders, and significant interagency coordination and cooperation at all levels from strategic to technical.

CEOS also provides a framework for space agencies and their partners to coordinate programme implementation to maximize complementarity of their investments in satellites and ground assets, reducing costs by eliminating unnecessary redundancy and duplication.

The Coordination Group for Meteorological Satellites (CGMS) is a key CEOS Partner. Formed in 1972, CGMS supports operational weather monitoring and forecasting as well as climate monitoring, in response to requirements formulated by the World Meteorological Organization (WMO). Since 2013, CGMS and CEOS have officially joined forces through a common working group on climate.

Satellite data requirements are identified through relationships established with CEOS by key user groups. These stakeholders consist of national governments, the intergovernmental Group on Earth Observations (GEO), and organizations participating in treaties and global programs affiliated with the United Nations (UN). These treaties, international organizations, and international programs include the UN Framework Convention on Climate Change (UNFCCC), the UN Office for Disaster Risk Reduction (UNISDR), the United Nations convention to Combat Desertification, and the Convention on Biodiversity (CBD).

GEO: Translating satellite data into information and services for societal benefit

GEO aims to apply Earth observations to deliver societal benefit across a range of areas. Since its establishment in 2005, CEOS has been a key Participating Organization in GEO. CEOS is the recognized "space arm" of the Global Earth Observation System of Systems; CEOS coordinates the design, development, launch and operation of satellites to support GEO activities which, in turn, deliver societal benefit.

GROUP ON EARTH OBSERVATIONS

GEO is committed to maintaining and strengthening its engagement in GEO as it moves into its second decade. CEOS counts on the GEO 2016-2025 Strategic Plan: Implementing GEOSS to strengthen the convening power of GEO, which will facilitate the definition of authoritative and clearly prioritized user needs, data requirements and essential variables. CEOS supports, and will continue to support, major GEO initiatives related to agriculture and forestry where it built close relations with the Food and Agriculture Organization of the United Nations (FAO) supporting among other components capacity building and operational implementation.

Space data to monitor our climate

The challenge of global climate change brings together nations and international coordinating bodies. In 2005, Global Climate Observing System (GCOS) was requested by the UNFCCC to develop an implementation plan. The decision also invited Parties with space agencies involved in global observations to request those agencies to provide a coordinated response to the recommendations in the implementation plan. Since then, CEOS together with the Coordination Group on Meteorological Satellites (CGMS), coordinate the work of space agencies on climate to respond to space-related needs of the GCOS Implementation Plan.

To do so, CEOS has adopted the set of geophysical variables – "Essential Climate Variables" (ECV) defined by GCOS as a basis for its climate-related work. This work also supports the needs of the Intergovernmental Panel on Climate Change (IPCC), whose mission is to provide a diagnosis and scientific elements on how the climate system works, the impacts of disruptions to this system and possible solutions to inform policymakers' decisions. CEOS looks forward to an even great role for coordinated satellite data in support of climate change adaptation and mitigation following the 21st Conference of the Parties (COP) to be held in Paris in late 2015.

Disaster risk reduction – a global challenge

Disasters management is another area where CEOS is playing a leading and supporting role. In the recent years, several major international organizations such as the World Bank, the United Nations Office for Disaster Reduction (UNISDR), and the European Commission have refocused their efforts on disaster risk reduction (DRR) and resilience to limit the devastating consequences of potential future crisis events.

After ensuring appropriate inclusion of satellite Earth observations in the "Sendai Framework for Disaster Risk Reduction 2015-2030", CEOS continues to shape the increased roles of space agencies in Disaster Risk Management. Other key partners from the UN are the United Nations Environment Programme (UNEP), United Nations Office for Outer Space Affairs (UNOOSA) and United Nations Development Programme (UNDP). International financial institutions such as the World Bank and regional organizations and platforms are also important partners supporting CEOS' disasters management endeavours.

Future possibilities via new technologies and services

The incredible diversity of information provided by today's Earth observation satellites is thanks to innovative programs of the space agencies and the emergence of novel technologies - such as constellations of small satellites, dual-use programs (with civil and defense uses), 'big data' and crowdsourcing. These enhance the possibilities for Earth observation data utilization and contribute to the diversity of applications.

Small Satellites

Typically, Earth observation satellites have long been large spacecraft (often over 1 tonne in weight). And indeed we still many space agency plans with large and sophisticated satellites with multiple sensors and 'missions'. However, with the increased demand for higher repeat frequency of observations – are seeing more constellations of small satellites as a cost effective solution.

Small satellites were originally the domain of university departments, with the advantage of cheaper development costs, shorter development timescales, and ease of launch. Surrey Satellite Technology Limited (UK) has the longest heritage internationally in this area, and its pioneering work has expanded the market for small satellites. An increasing number of specialized companies have emerged to address this market - such as Skybox Imaging Inc. (USA) and Planet labs Inc. (USA); and there companies are developing, launching and applying their novel constellations in support of multiple which make use of timely data. Interest in this sector extends well beyond the traditional space technology industry, demonstrated by the acquisition of Skybox by Google for US$500 million in 2014.

The challenges of population explosion, depleting resources, and issues such as climate change and food security are likely to guarantee that there will be no shortage in demand for information from space in support of sound governance of Earth and its resources. The range of technical solutions available from satellites large and small, and organisations both public and private, will ensure that Earth observation data continues to be at the forefront of solutions to the information challenges ahead.

Dual-use

Current commercial Earth observation satellites carry very high-resolution optical and radar sensors, allowing objects of less than meter to be distinguished. Such systems have the capability to support both civil and defense applications and are typically referred to as 'dual-use' systems for this reason. The major US commercial data providers - DigitalGlobe Inc. and GeoEye Inc., which were merged in 2013 – have built their business around anchor tenancy agreements with the US Department of Defense. Europe has explored its own version of dual-use systems through cooperation of defense and civil government agencies for joint development of satellites such as the Italian COSMO-SkyMed and French Pléiades systems. The core government business provides a stable foundation for the exploration of new and innovative civil applications of satellites such as these and it is anticipated that this trend will both continue and expand in future.

Big Data

Wikipedia defines[i] Big Data as "an all-encompassing term for any collection of data sets so large and complex that it becomes difficult to process using traditional data processing applications." Big Data has often been referred to as a problem but in terms of the potential for Earth observation satellite applications, we might consider it instead to be an opportunity – providing new ways for data systems to process, archive, manage, and manipulate large amounts of disparate data. "Big Data" might most commonly be characterized by data volume (how much data), p velocity (speed of data processing), and variety (various types of data). But the definition of Big Data varies depending on the system, service, and management capabilities. The volumes associated with Earth observation satellites these days certainly qualify them to be considered as Big Data.

Big Data does not involve any single technology, instead referring to multiple technologies or initiatives that may involve large, complex data sets and infrastructures. Harnessed properly, Big Data should allow real-time analysis and data mining to produce better science, more information, more benefits, from Earth observation satellites.

Analysis Ready Data

'Analysis Ready Data' are data that have been pre-processed and organised so users do not need to invest time and resources in data preparation to correct for instrument, spacecraft and orbit-specific variations. This permits the investment of all available resources on analysis and information extraction. New opportunities are emerging with the explosion in free data volumes from the new generation of sensors providing continuous global coverage at higher resolution and the potential of new high-performance ICT infrastructure and architectures to fully exploit these data.

Cloud Computing

Cloud Computing is an emerging information technology and computing architecture that seeks economies of scale for storage and processing based on the incremental use of computing resources.

Cloud Computing Types[ii] and Services[iii] are categorized as shown in Table 1 and Table2.

Table 1: Cloud Computing Types

Types	Description
Private	Typically deployed within an organization's own internal ecosystem, often leveraging the organization's own private datacenter.
Public	Hosted by a third party datacenter located off premise at multiple locations outside of an organization's building. Public clouds are often hosted on virtualized multi-tenancy datacenters where different organizations have access to shared pooled hardware and power resources, yet can run their applications and data in secure, isolated environments.
Hybrid	A combination of using some services delivered via a private cloud internally and other services delivered via a public cloud externally.

Table 2: Cloud Computing Services

Service Category	Description
Infrastructure as a Service (IaaS)	The most basic cloud-service model, which provides the user with virtual infrastructure, for example servers and data storage space. Virtualization plays a major role in this mode, by allowing IaaS-cloud providers to supply resources on-demand extracting them from their large pools installed in data centers.
Platform as a Service (PaaS)	Cloud providers deliver to the user development environment services where the user can develop and run in-house built applications. The services might include an operating system, a programming language execution environment, databases and web servers.
Software as a Service (SaaS)	The cloud provides the user with access to already developer applications that are running in the cloud. The access is achieved by cloud clients and the cloud users do not manage the infrastructure where the application resides, eliminating with this the way the need to install and run the application on the cloud user's own computers.
Network as a Service (Naas)	The least common model, where the user is provided with network connectivity services, such as VPN and bandwidth on demand.

Cloud Computing has several Pros and Cons and some examples[iv] are shown in Table3.

Table 3: Examples of Pros and Cons

Pros	Cons
✓ Cost Efficiency ✓ Convenience and continuous availability ✓ Backup and Recovery ✓ Environmentally friendly ✓ Resiliency and Redundancy ✓ Scalability and Performance ✓ Quick deployment and ease of integration ✓ Increased Storage Capacity ✓ Device Diversity and Location Independence ✓ Smaller learning curve	✓ Cost Efficiency ✓ Security and privacy ✓ Dependency and vendor lock-in ✓ Technical Difficulties and Downtime ✓ Limited control and flexibility ✓ Increased Vulnerability

Looking to the Future

The rapid and massive growth in both the variety and volume of Earth Observation satellite data presents a number of challenges. For data providers or data managers, these may include hardware (e.g. storage systems, processing systems) scalability, software capability and/or timely service provision.

For data users, these may include data discoverability, accessibility, handling and information extraction.

The new technologies emerging from Big Data and Cloud Computing can support solutions for these challenges and contribute to the uptake of EO data, and its societal impact.

The CEOS/WGISS (Working Group on Information Systems and Services), actively discusses and shares experience and best practice of different countries and agencies for these technologies. For more details, please visit the WGISS Technology Exploration Interest Group page.
http://ceos.org/ourwork/workinggroups/wgiss/interest-groups/technology-exploration/

Small satellites

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[i] http://en.wikipedia.org/wiki/Big_data

[ii] http://www.synergygs.com/Solutions/CloudServices/

[iii] http://www.synergygs.com/Solutions/CloudServices/http://www.synergygs.com/Solutions/CloudServices/http://www.javacodegeeks.com/2013/04/advantages-and-disadvantages-of-cloud-computing-cloud-computing-pros-and-cons.html

[iv] http://www.javacodegeeks.com/2013/04/advantages-and-disadvantages-of-cloud-computing-cloud-computing-pros-and-cons.html

Chapter 2:
APPLICATIONS

Analysis of Data Applications Articles

While the articles presented in this report do not represent the full breadth of activities related to the exploitation of satellite Earth Observation (EO), it is hoped that they give an indication of the ever-growing and advancing field of work. The following observations can be made from the collected articles:

Value chain: The value chains of the collected applications indicate that data, including multisatellite and in-situ from various sources, as well as more advanced processing methods for modeling, mapping and forecasting, are adding significant value to products and services that greatly benefit society. It is apparent that, as the end users become more clearly defined, the outcomes and benefits can be increasingly tailored to their requirements, underscoring the importance of data and service providers understanding their end users and applications.

Public use vs. commercial use: The majority of the 49 data applications contained herein are public use cases, as opposed to commercial applications. While there are certainly more commercial data applications in addition to those presented here, it can be said that public use cases dominate applications of the data provided by CEOS space agencies. For public use cases, the end users are usually ministries, government agencies and local governments. Operational agencies such as national weather service centers, coast guards, and sea ice monitoring centers, require large volumes of near-real time data processed into consistent products and services.

Data integration: An increasing number of applications rely upon data from multiple missions, integrated with in situ and scientific model data. For example, GEOGLAM's monitoring of major crops requires data from missions such as MODIS (on Aqua and Terra), Landsat-7/8, RADARSAT-2, Sentinel-1A and ALOS-2; meteorological and soil data; as well as crop growth model outputs. With the advent of Europe's Sentinel missions, there is greater potential than ever to create new and innovative data applications through the integration of large amounts of data from a variety of instruments.

Risk assessment: The use of satellites for risk assessment is growing, with data being used to evaluate scenarios related to natural disasters, agriculture and public health. Satellite Synthetic Aperture Radar (SAR) is being used to derive geo-hazard maps by plotting and quantifying past eruptive deposits, and risk maps for vector-borne diseases are being generated using data on environmental conditions derived from TRMM, Aqua and other satellites.

National accounting and infrastructure use: As satellite data becomes more readily available on a free and open basis, and as ICT evolves, users have the ability to collect and process much larger volumes of satellite data – promoting its application on much larger scales. For example, Australia is using satellite data to monitor and manage water and carbon stocks on a national-scale, and SPOT data has been used to create land cover maps on a national-scale in Serbia.

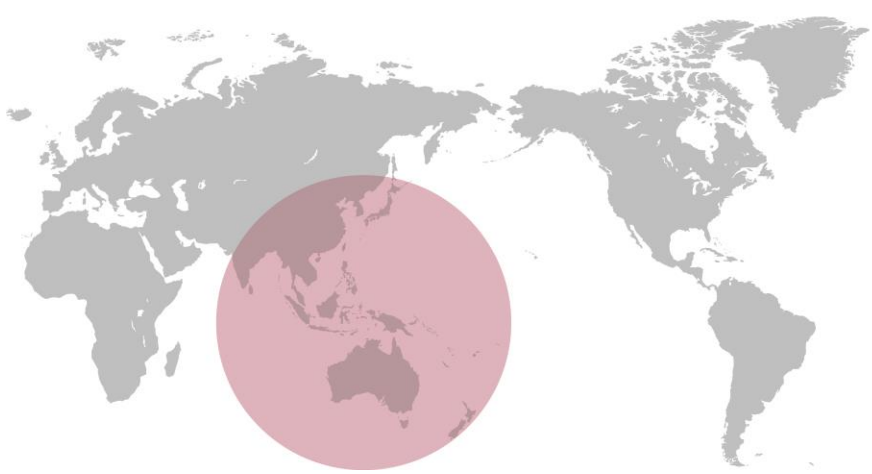
Downstream services: Collecte Localisation Satellite (CLS) is providing integrated downstream ocean services for various applications in the region. Such downstream services are being developed in Europe and made available.

New satellite EO capabilities: This past decade has seen great innovations in the application of Earth observation technology, including:

- ✓ Earth surface deformation monitoring using Interferometric SAR to detect crustal deformation caused by earthquakes and volcanic activities;
- ✓ Ground water monitoring using highly-sensitive gravity measurement instruments; and,
- ✓ Green House Gas (GHG) monitoring using satellite instruments has filled gaps in ground observations of CO_2. Thanks to international cooperation, GOSAT has achieved unprecedented measurement accuracy of 0.5% in measurements of CO_2 concentration – providing a new understanding of GHG dynamics and their relation to human activities.

An extremely wide range of observing technologies and capabilities are now in service of society in 2015 thanks to Earth observation satellites.

Chapter 2:
APPLICATIONS IN ASIA / OCEANIA



Asia/Oceania – Transportation

Monitoring Sea Ice to Provide Support for the Safe Travel of Ships

In 1970, there was a large maritime accident by drift ice in Hitokappu Bay, Etorofu Island. This accident triggered the establishment of "Ice Information Center, JAPAN" in the 1st Regional Coast Guard Headquarters,Japan Coast Guard (JCG). JCG operates Ice Information Center only during winter every year to produce and distribute "Sea Ice Condition Chart".

The Sea Ice Condition Chart indicates the distribution of sea ice around Hokkaido. It is effectively utilized for safe navigation of vessels including fishing boats, merchant vessels and tourist ships, aiming to prevent a maritime accident in sea ice areas around Hokkaido such as in the Sea of Okhotsk.

Problem

Ice Information Center, JAPAN, produces the Sea Ice Condition Chart everyday, and distributes it to users through the Internet and by fax during winter. The Sea Ice Condition Chart is produced based on information from various institutions and partners, including satellite data.

They, however, face a problem that it is difficult to get the precise information about sea iceunder cloud, because most of informationis acquired in the band of visible or infra-red.

Therefore, to address this problem, Ice Information Center cooperates with the Japan Aerospace Exploration Agency (JAXA) to produce the Sea Ice Condition Chart precisely and completely using SAR data regardless of weather conditions.

Satellite Earth Observation Data Application

Ice Information Center, JAPAN collects information from various institutions and partners to produce the Sea Ice Condition Chart. The collected information is analyzed to calculate the Sea Ice Condition Chart through the Internet and by fax at 17:00 (JST) every day. Figure 1 shows the work flow of Ice Information Center including the type of information from Japan Coast Guard, cooperating institutions and partners, and the provision of ice information.

Ice Information Center, JAPAN produces the Sea Ice Condition Chart integrating various information such as observation data by satellites, airplanes and vessels, visual observation from the land, analysis information by the Japan Meteorological Agency and notices from vessels. From this season, it became possible to acquire complete information even in cloudy area by adding data of JAXA's satellite, Advanced Land Observing Satellite-2 (ALOS-2) to existing types of information after about three and a half years, because SAR sensor onboard ALOS-2 can observe penetrating through clouds. Actually the observation under the cloudy area was possible by Advanced Land Observing Satellite (ALOS, former satellite) , but furthermore ALOS-2 allowed to increase the number of observation near the center of the Sea of Okhotsk by utilizing its performance of a variable incident angle.

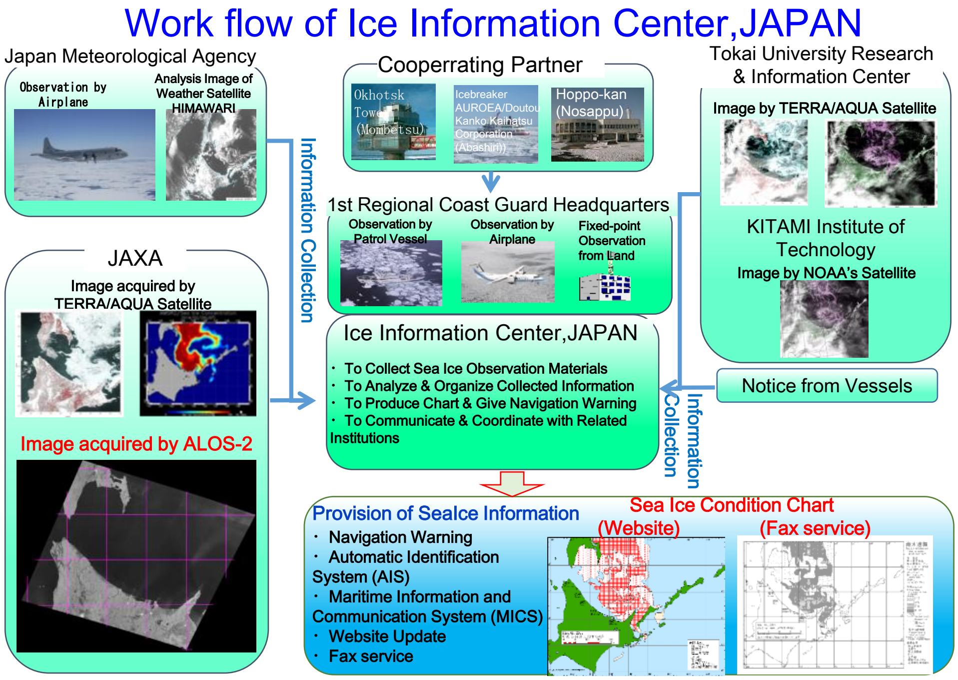


Fig 1: Work Flow of Ice Information Center

Since Hokkaido area has a lot of bad weather in winter, it is often the case that the Sea Ice Condition Chart included some intervals due to no data in cloudy areas where it was difficult to obtain sea ice information. By adding ALOS-2 data available under all weather to information source, Ice Information Center became to be able to produce and provide complete information even in cloudy days again. These effective information contribute to prevention of maritime accidents for vessels that are forced to fish during heavy weather.

Until Last Winter This Winter

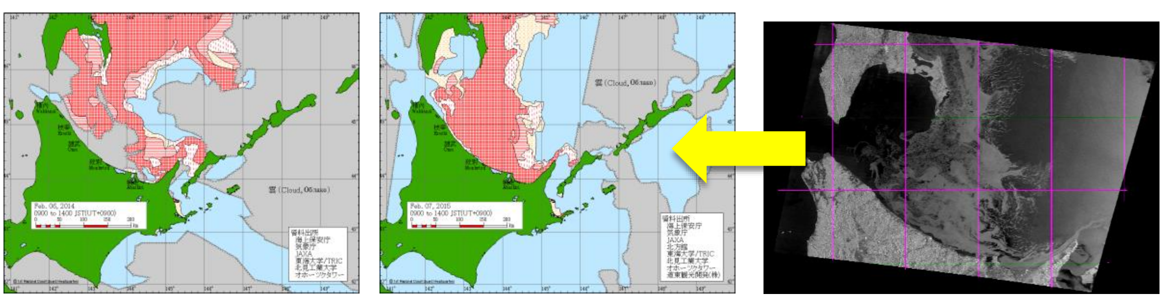
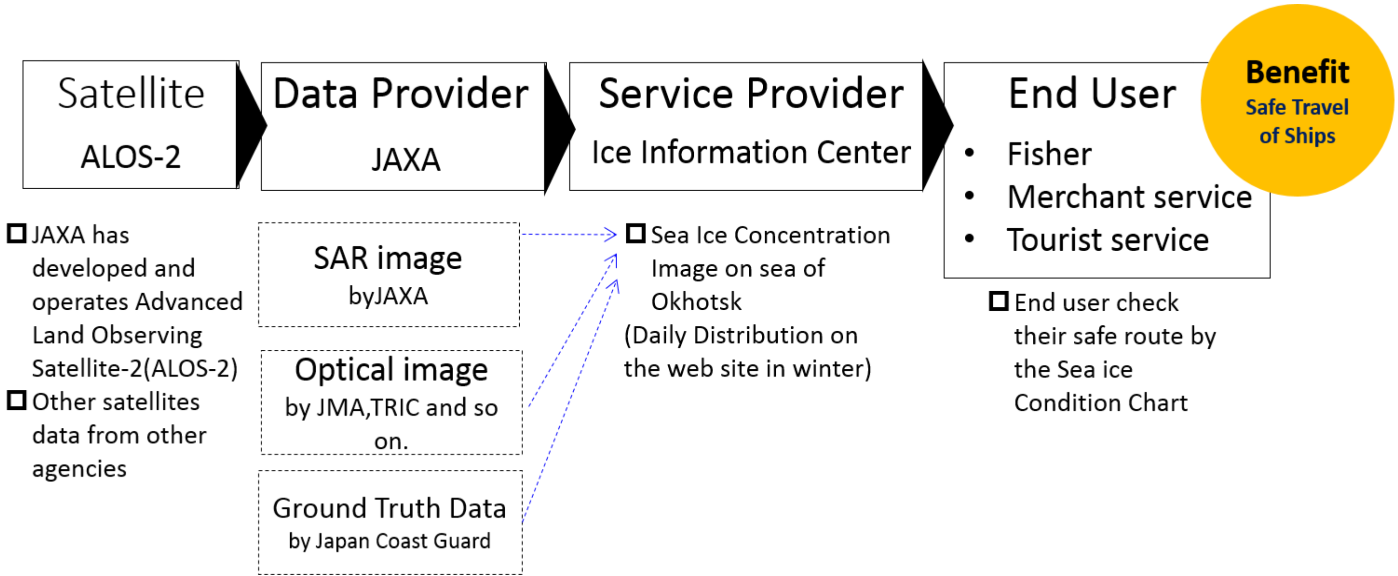


Fig 2: Sea Ice Concentration Image, (Left) Released on 6 February, 2014, (Middle) Released on 7 February, 2015, (Right) Satellite image by ALOS-2 on 7 February, 2015

Value Chain



Ice Infromation Center, JAPAN URL: http://www1.kaiho.mlit.go.jp/KAN1/drift_ice/eng.html

Asia/Oceania - Disaster

Use of SAR data to map and quantify eruptive deposits for lahar assessment

Radar images can be acquired at night and in cloudy conditions, which represents a significative advantage when using SAR data for volcano monitoring rather than optical and infrared sensors. Variation in InSAR coherence and amplitude evolution can be used to map eruptive deposits, which is a key information for assessing volcanic hazards. Based on the 2010 Merapi volcano eruption case, we developed a supervised classification method applied to dual-polarization ALOS data in order to map the pyroclastic deposits. This method will be used by the Center for Volcanology and Geological Hazard Mitigation (CVGHM) for lahar assessment in Indonesia.

Problem

When non-consolidated volcanic deposits are emplaced during an explosive eruption, they can rapidly be remobilized by rain water to form lahars. Such lahars are mixtures of water and rock fragments flowing down the slope of a volcano and represent an important risk in Indonesia because they can damage and destroy infrastructures (road, bridges, villages…) and cause fatalities. After an eruptive event, it is thus essential to rapidly estimate the volume and location of eruptive material emplaced, such parameters being the inputs of lahar models used to produce maps of areas potentially affected. Mapping eruptive deposits based on field observations takes time and is not always possible because some difficulties or dangers might prevent the access to the field area. Alternatively remote sensing data represent a useful tool to quickly map eruptive deposits after an eruption without requirement to access the field thus reducing the risk and duration of investigations.

Satellite Earth Observation Data Application

Optical data present the advantage of the high resolution with sub-metric image pixels however they cannot provide any information in presence of clouds. In contrast, Synthetic Aperture Radar (SAR) data can bring information during day or night, independent of the meteorological conditions, such providing useful information in humid tropical environments where volcanoes are covered by clouds. The radar echo is sensitive to any change in the distribution of scatterers at the ground. As a result, the emplacement of eruptive deposits can easily be detected through multi-temporal SAR images. Detection can be based, either on evolution of reflectivity, i.e. the amplitude of the radar images, or on the temporal decorrelation of the signal.

We recently developed a new method allowing to map eruptive deposits in a semi-automatic way rapidly after an eruptive event based on dual-polarization SAR data (Solikhin et al, 2015). This method takes advantage of both the ground reflectivity evolution and the decorrelation induced by deposits emplacement. It has been tested on eruptive deposits emplaced after the 2010 VEI 4 Merapi eruption in Indonesia.

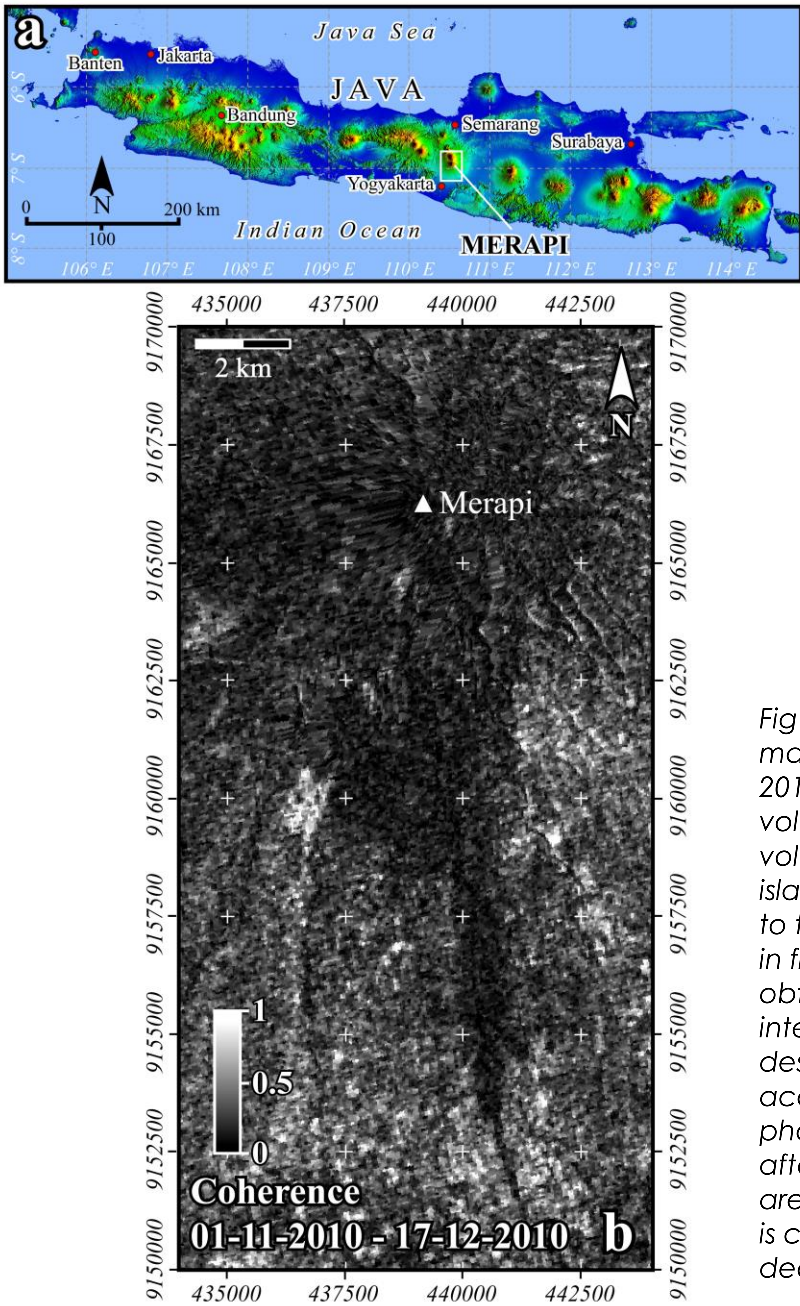


Fig 1: Application of SAR data to map the eruptive deposits of the 2010 VEI 4 eruption of Merapi volcano a) Location of Merapi volcano in the central part of Java island (the white box corresponds to the area covered in part b and in figure 2. B Coherence image obtained when forming the interferogram between two descending ALOS/PALSAR images acquired before the main eruptive phase (on 1November 2010) and after (on 17 December 2010). The area covered by eruptive deposits is characterized by a strong decorrelation and appears dark.

First a coherence image (Figure 1) is produced using a SAR image acquired just before the eruption and another one acquired after eruptive deposits emplacement. On this image, deposits are characterized by a loss of coherence and appear as dark. Then we use four amplitude images corresponding to acquisitions performed respectively before and after the eruption in two different polarizations (co-polarized, HH, and cross-polarized, HV, data) in order to distinguish the various deposits. As shown on figure 2, each type of deposits is characterized by a given evolution of the backscattering when considering both polarizations. Radar amplitudes in direct (HH) and cross (HV) polarizations decrease where the valley-confined and overbank block-and-ash flow (BAF) deposits (D1) are emplaced. Rainfall- and runoff-reworked PDC deposits (D2) are characterized by an increase in ground backscattering for HH polarization and a decrease for HV polarization. Ground backscattering transiently increases in both polarizations after tephra fall (D4) deposition. This specific behaviour is expected to be strongly dependent on the wavelength of the radar data but the important point is that it can characterize a given type of eruptive deposits when considering both co and cross-polarized data.

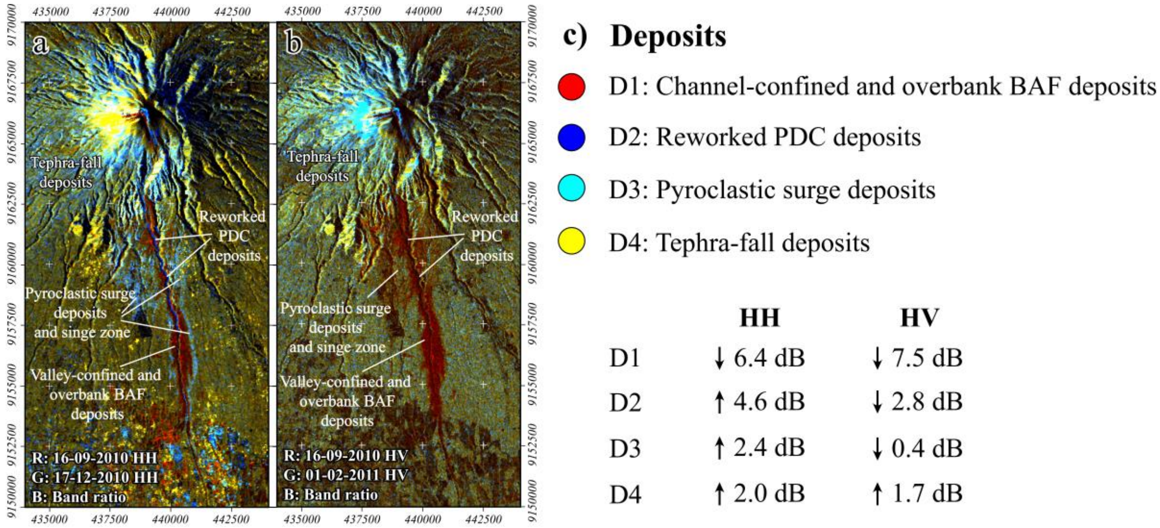


Fig 2: ALOS-PALSAR amplitude-change image of Merapi's southern flank. The false-color composite (R: earlier image; G: later image; B: ratio of the second image divided by the first image) is obtained using pairs of amplitude images acquired in before the eruption and after the event). Deposit characteristics are known from field observations and optical imagery a) HH polarization (first image acquired on 16 september 2010, second image acquired on 17 december 2010) b) HV polarization (first image acquired on 16 september 2010, second image acquired on 1 february 2011). C) Amplitude evolution for the various types of deposits.

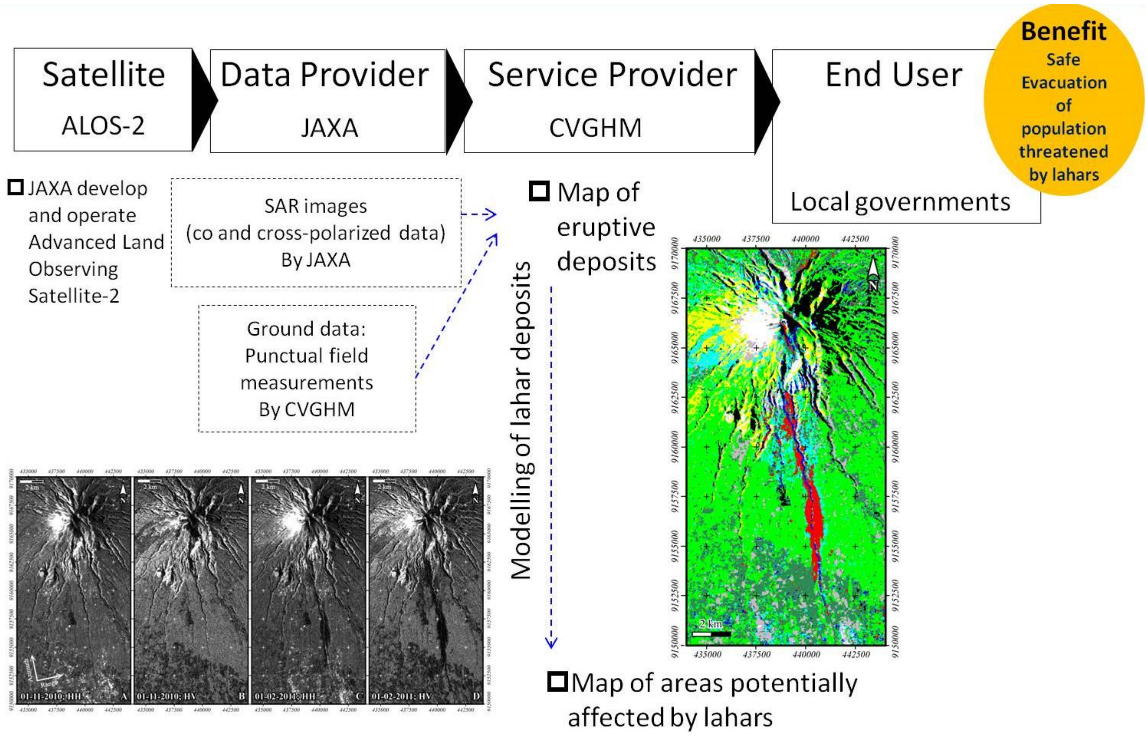
We then combine the information from the coherence image with those from the four amplitude images using a supervised classification method based on maximum likelihood to map the deposits. Classification derived from ALOS-PALSAR images using the maximum likelihood classification provides a result with 70% classification accuracy for deposits overall. We verified that the results derived based on this method are similar to the one produced from high-resolution satellite optical imagery and field-based data.

In the future, this new method will be used by CVGHM to rapidly map eruptive deposits based on SAR data in order to update risk assessment for lahars.

End users and benefit

The method developed for CVGHM (Indonesia) can be used in any volcano observatory in order to estimate the risk related to lahars formation quickly after an eruptive event and to take all the required decisions in terms of civil protection (population evacuation, road closure...). It is particularly suitable for volcanoes located in tropical environments, where clouds limit the use of optical imagery.

Value Chain



More Information

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Virginie Pinel, Institut de Recherche pour le Développement (IRD), ISTerre, Université de Savoie, 73376, Le Bourget du Lac, France, Virginie.Pinel@ird.fr.

Reference

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Asia/Oceania - Disaster

ADB's Technical Assistance project: Applying Remote Sensing Technology in River Basin Management

1) Yusuke Muraki, Infrastructure Specialist (Space Technology), Sector Advisory Service Division, Regional and Sustainable Development Department, Asian Development Bank
2) JAXA ADB Project Team

Context

Many countries in Asia and the Pacific have suffered from water-related disasters such as floods caused by typhoons and heavy rains. As one of the most powerful nonstructural measures to guard against water-related disasters, monitoring and warning systems have been implemented in Asia and the Pacific. However, there is still insufficient latency, frequency, and coverage of observation data; and inadequate dissemination of warnings to local communities. The titled ADB's technical assistance project has been conducted from April 2012 to March 2015, which is helping Bangladesh, the Philippines, and Viet Nam improve monitoring and warning systems on flood risk management at a reasonable cost and based on practical knowledge by applying space-based technology and information and communication technology. Target agencies are assisted with advisory services and financial support in formulating and implementing the following: (i) extending flood warning lead times by 1 day - 2 days in the Jamuna River basin in Bangladesh by collecting precipitation data publicly available from satellites and ground observation systems, (ii) developing existing flood analysis models in the Red-Thai Bin River basin in Viet Nam by collecting satellite precipitation data, (iii) developing a system in the Cagayan River basin in the Philippines to provide satellite-based precipitation data and transfer it to the existing flood analysis model, and (iv) developing flood warning dissemination and disaster monitoring systems using web-based GIS and cellular phones in Bangladesh and Viet Nam. JAXA is collaborating with ADB in this project as the implementing agency, supporting project management and providing technical advice.

Contribution of Space Technology and Geographic Information Systems

Global Satellite Mapping of Precipitation (GSMaP) is an hourly global rainfall map in near real time, available 4 hours after observation with a 0.1 degree (about 10 kilometers [km]) grid over a global area (60N–60S), using the JAXA Global Rainfall Watch System. JAXA and the consultant team have been developing methodologies and systems to calibrate and validate GSMaP with ground rainfall data in the pilot area of each country. The calibrated GSMaP is used as input data for flood models in the target river basin for more effective and efficient flood forecasting. These models include the Integrated Flood Analysis System in the Philippines, which was developed by the International Centre for Water Hazard and Risk Management, and the Water and Energy Budget-Based Distributed Hydrological Model, developed by Professor T. Koike, University of Tokyo.

http://sharaku.eorc.jaxa.jp/GSMaP/

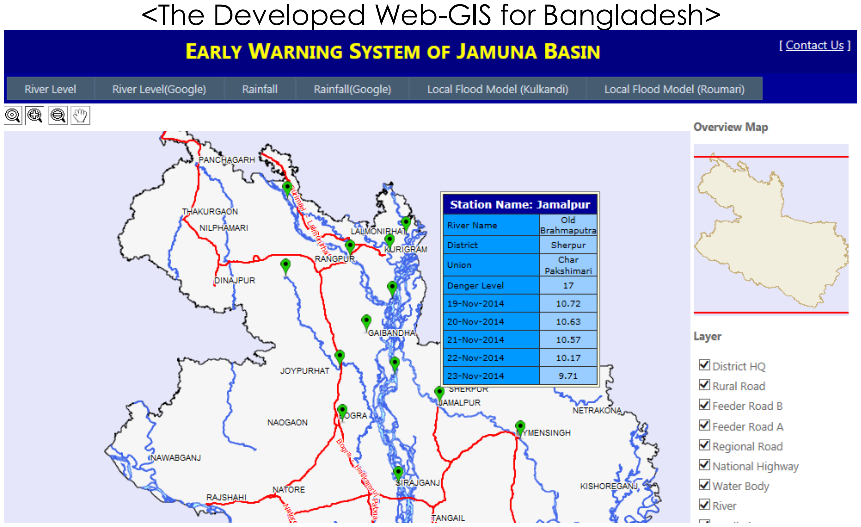
High-quality, satellite-based topographical information (digital elevation model [DEM] or digital surface model [DSM]) obtained from the Advanced Land Observing Satellite (ALOS) was used to study the effectiveness of its use for the local flood model to make an inundation map in the pilot area as an alternate source of geographic data to those obtained from spot survey. ALOS imagery and map data for the pilot area of the local flood model were used for the background layer of the web-based GIS developed under this technical assistance project.

Web-based GIS was also developed for flood warning information sharing in the pilot areas in Bangladesh and Viet Nam. Flood warning information will be used by the decision makers for their decision on alert and/or evacuation order in the pilot areas of the target countries, Bagladesh, the Philippines and Viet Nam. This makes the people in the pilot areas to take actions against the expected floods.

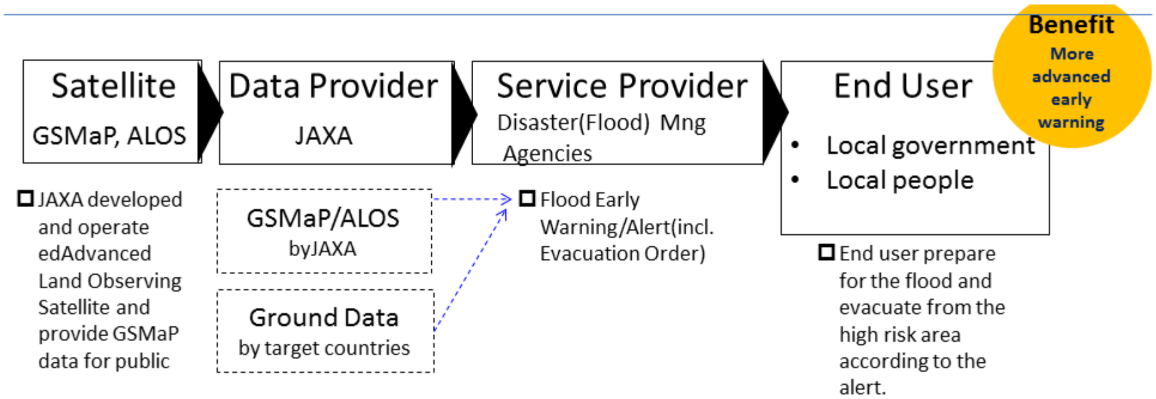
Current Status

The project has been completed end of March 2015 and operational use of the developed systems are expected in coming flood season in 2015.

<The Developed Web-GIS for Bangladesh>



Value Chain



Benefit
More advanced early warning
Satellite
GSMaP, ALOS
Data Provider
JAXA
Service Provider
Disaster(Flood) Mng Agencies
End User
• Local government
• Local people
JAXA developed and operate edAdvanced Land Observing Satellite and provide GSMaP data for public
GSMaP/ALOS byJAXA
Ground Data by target countries
Flood Early Warning/Alert(incl. Evacuation Order)
End user prepare for the flood and evacuate from the high risk area according to the alert.

Asia/Oceania - Disaster

Sentinel Asia Success Story

1) Dr. Arturo Daag, Chief, Geology, Geophysics Research & Development Division (GGRDD), PHIVOLCS
2) JAXA Sentinel Asia Project Office, Satellite Application Promotion Center(SPAC), JAXA

Sentinel Asia Success Story (SASS) is an activity aimed at:

- Cooperation for disaster risk reduction (DRR) in the mitigation/preparedness phase
- Regional cooperation including end-users
- Local awareness and knowledge transfer through capacity building
- Human resources and human network development

Content

The Sentinel Asia (SA) initiative is a voluntary, grass-roots collaboration based on best efforts between regional space agencies and disaster management institutions for regional humanitarian purposes. SA applies remote sensing and Web-GIS technologies to assist disaster management efforts in the Asia-Pacific. Sentinel Asia (SA)'s target is to provide the disaster information to end-users who are fighting against disasters and help them utilize it more. Furthermore, SA's final target is to become a community-operated system in each country or region. Some activities including more case-studies with end-users focusing on a specific country and region are requested. In this context, SA has started SASS in the Philippines. These kinds of activities should be expanded to other countries and regions. Through these end-users-oriented activities, with enthusiastic cooperation from each country and region, SA could be operated as a community system.

(1) JAXA has been implementing the SASS in the Philippines since 2009 (see Figure 1). By using Advanced Land Observing Satellite (ALOS) pansharpened imagery and a Digital Surface Model (DSM), hazard maps for lahars near Mt. Mayon, floods in Iloilo city and landslides in Antique province were created by the Philippine Institute of Volcanology and Seismology (PHIVOLCS), the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), and the Mines and Geoscience Bureau (MGB), respectively. This mapping occurred in the first phase, from the beginning of 2009 to March 2010. In the second phase, beginning in April 2010, an application of GSMaP has been used to track landslide warning in Albay; interferometry has likewise been used to monitor land subsidence in the Manila area and earthquake/volcanic eruptions at Mt. Mayon, Mt. Taal, and Valley Fault.

Fig1: Framework and activities of Sentinel Asia Success Story in the Philippines

Mt. Mayon in Luzon, the Philippines, recorded volcanic activity beginning on 14 December 2009, and the lava that flowed out from the crater was confirmed on 20 December. About 47 thousand people living near the Mayon Volcano evacuated according to warnings issued by the Province government. JAXA made emergency observations with PRISM/AVNIR-2 aboard ALOS on 25 December 2009, at the request of PHIVOLCS through Sentinel Asia, and provided observed data to PHIVOLCS. PHIVOLCS created a lava deposit map of the eruption using such ALOS imagery and other sources, which was used to understand the situation and inform the decisions of the National Disaster Coordinating Council (NDCC). A lava flow hazard map and lahar hazard map had been prepared beforehand using ALOS DEM, and with cooperation from JAXA and PHIVOLCS, which may be supplemented by updating lava deposit data during eruption emergencies as shown in Figure 2.

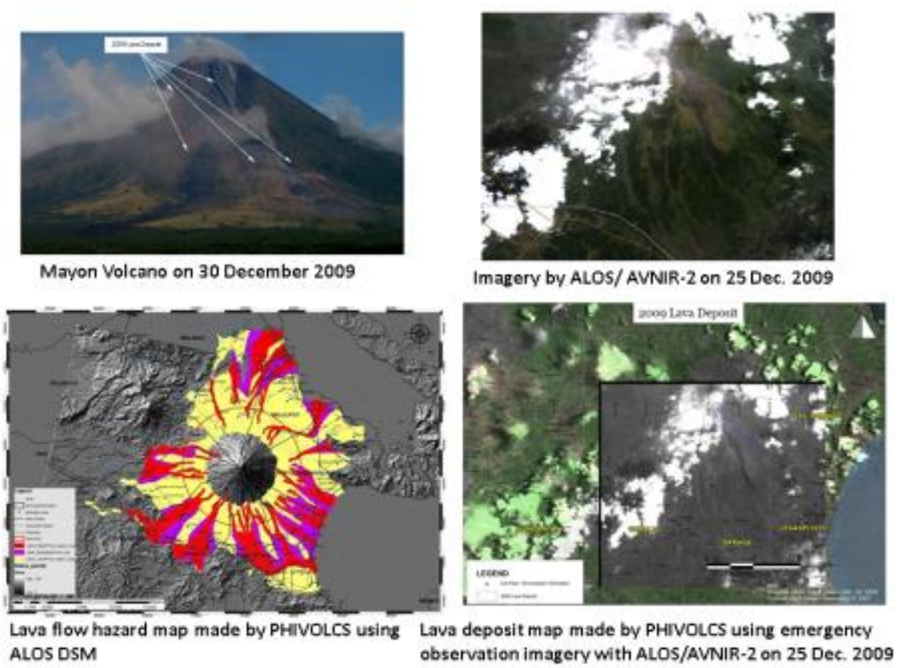


Fig 2: Eruption of Mayon Volcano in the Philippines in December 2009

(2) From 2010 to 2012, 2nd Phase was implemented. In this phase, application of GSMaP for Lnadsliges Warning and Interferometry for monitoring of Land Subsidence and Earthquake/Volcanic Eruption have been studied. The activities include: 1) To develop a prototype system of Landslise/Flood

Early Warning System for Albay, 2) To apply DSInSAR technique to monitor Land Subsidence around Metro Manila and Land Deformation at Volcanos(Mt. Taal, Mt. Mayon and Negros Island), and 3) To hold technical traning for 1) and 2).

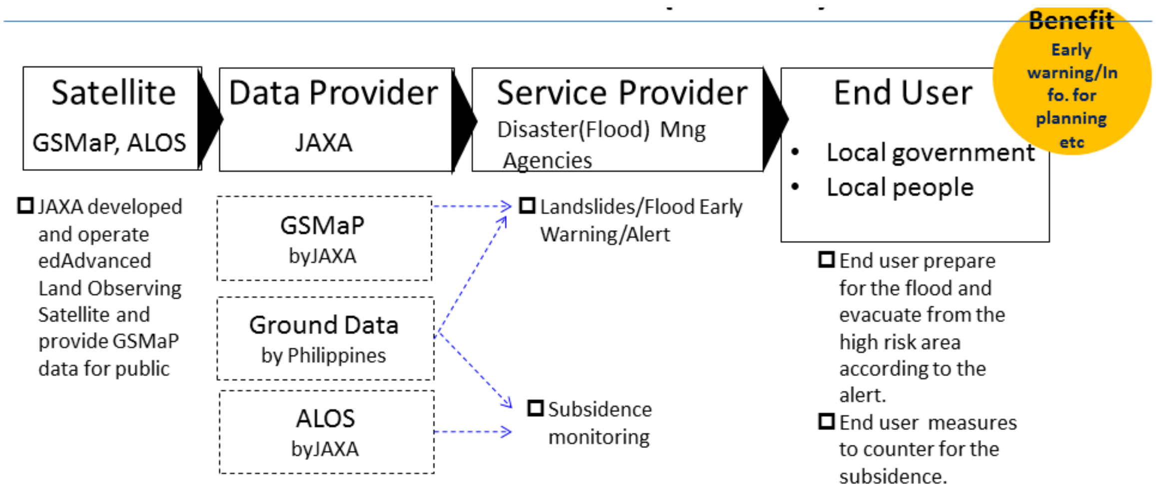
Technical Training

Summary from 2009-2011	Trainings	No. of Participants
2009	Remote Sensing	9 ++
2009	Multi-spectral and Radar Image Processing	22
2010	InSAR Processing	35
2010	Satellite-based Rainfall Precipitation	34
2011	Differential Interferrometry	27
2011	Landslide Modelling and Warning Using Satellite-based Rainfall Data	28

(3) From 2013, 3rd Phase has been started. In this phase, the Landslides/Flood Early Warning System for whole the Philippines was developed. Also, PSInSAR technique was demonstrated to monitor subsidence in the metro Manila and Volcanic area in addition to DSInSAR.

(4) From 2015, the prototype system of Landslise/Flood Early Warning System will be demonstrated by the user agencies in the specific target area. Landslides and flood early warning information will be used by the agencies for their decision on trigger a warning alert. This will support local people in the target area to take actions against the expected landslides and floods. InSAR technique by using ALOS-2 data is expected to demonstrate for monitoring Subsidence and the information taken from this technique is expected to be used for city development planning and so on in the future.

Value Chain


Benefit
Early warning/Info. for planning etc
Satellite
GSMaP, ALOS
Data Provider
JAXA
Service Provider
Disaster(Flood) Mng Agencies
End User
Local government
Local people
JAXA developed and operate edAdvanced Land Observing Satellite and provide GSMaP data for public
GSMaP byJAXA
Ground Data by Philippines
ALOS byJAXA
Landslides/Flood Early Warning/Alert
Subsidence monitoring
End user prepare for the flood and evacuate from the high risk area according to the alert.
End user measures to counter for the subsidence.

Asia/Oceania – Disaster

Living in a land prone to fire: supporting early response, and the coordination of firefighting assets, across a continent

Siqueira, A., Lewis, A., Oldfield, S.

Problem

A key lesson learnt from the fire management community is that the earlier an appropriate fire response can be mounted the better; resulting in significant community benefits. However, it can be hard to monitor a country as large as Australia and to detect fires, particularly in vast and remote areas where fire ground intelligence is not easily available.

Satellite Earth Observation Data Application

The Sentinel Hotspots monitoring system provides an important and consistent overview for management of fires across the country. The system was developed in the early 2000's through a collaborative effort between Geoscience Australia, Australian Geospatial-Intelligence Organisation and CSIRO Land and Water. The system monitors hotspots nationally and provides timely hotspots information to its end-users.

Sentinel has been a valuable input into the tools used by government and private agencies managing fires in Australia. A number of land management and emergency response agencies have taken data feeds from the Sentinel system to imbed into their routine fire management operations enhancing their situational awareness programs to assist staff, managers and the community. Hotspots data when merged with other spatial information provide a strategic picture to land managers; which allows them to understand the implications of a particular fire as well as to target resources.

In addition to displaying hotspots, the Sentinel Hotspots system provides additional products through the online interface, such as visualization and download of current and archived hotspots data to help understand previous fire behaviour, and detailed information of the detected hotspots from fire intensity and power measurements. The functionality of Sentinel was developed in consultation with stakeholders to ensure a close alignment between end-users needs and the provided services.

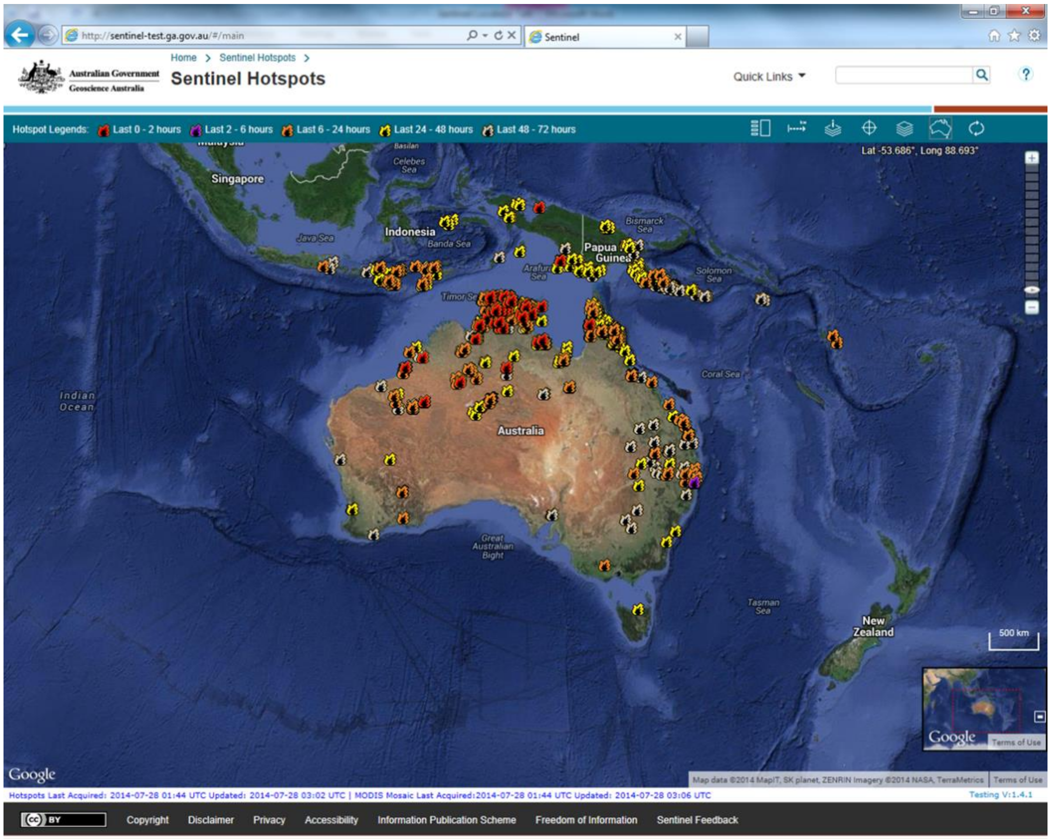


Fig 1: The Sentinel Hotspots website, showing the location of hotspots anomalies that may be fires across Australia and nearby countries.

Australians from all walks of life use Sentinel with millions of web-site hits during summer. The public use sentinel to understand if major fires are near to them, their friends or loved ones. Emergency managers use sentinel to inform broad situational awareness during the fire season. During the 2009 Black Saturday event, USA firefighters used Sentinel hotspots information to get a high level overview on the location of wildfires in Victoria. Sentinel hotspot data is openly available to the government, academics and researchers, private industry and to the general public. One private company for instance, Indji Systems, uses Sentinel hotspots information to create value added products to issue warnings when fires approach assets such as power-lines.

Sentinel Hotspots has provided fire information for over ten years, helping natural resource managers, emergency response personnel and the public to understand their fire danger. The Hotspots system has become a standard data source for the fire fighting services of all Australian states and is integrated into their data systems, such as that of the New South Wales Rural Fire Service. Forestry managers and powerline companies are also major users of the Hotspots service, using the historic hotspot search function to analyse how often and where fires have occurred over their assets.

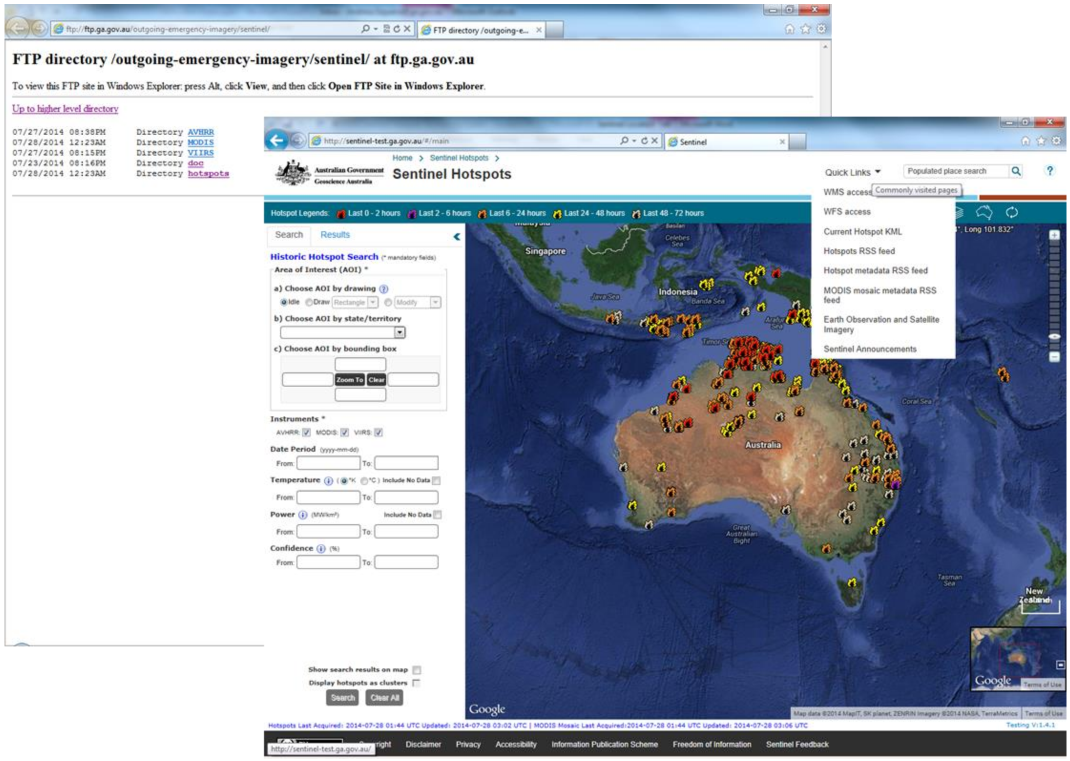
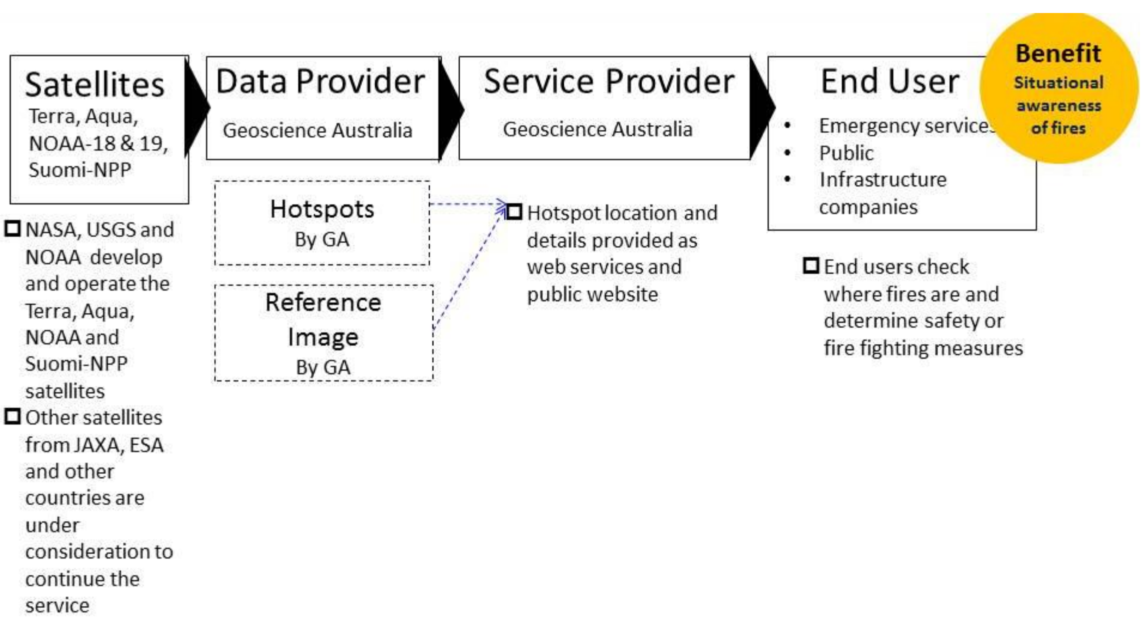


Fig 2: The Sentinel Hotspots website, showing the various available data distribution systems – WMS, WFS and FTP.

Value Chain



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More Information

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Asia/Oceania – Disaster

Great Flood Monitoring with Fengyun 3A Satellite data

Decision maker needs an overall view of the flood situation in the large affected area to implement the disaster reduction and relief when a great flood occurs. Satellite data, in particular km or lower level resolution data, may capture the flood information for a very large area with one or two times a day. So the evolution and the spatial situation of flood are also able to be monitored daily and then the information may help decision makers and public people to conduct the flood relief.

Problem

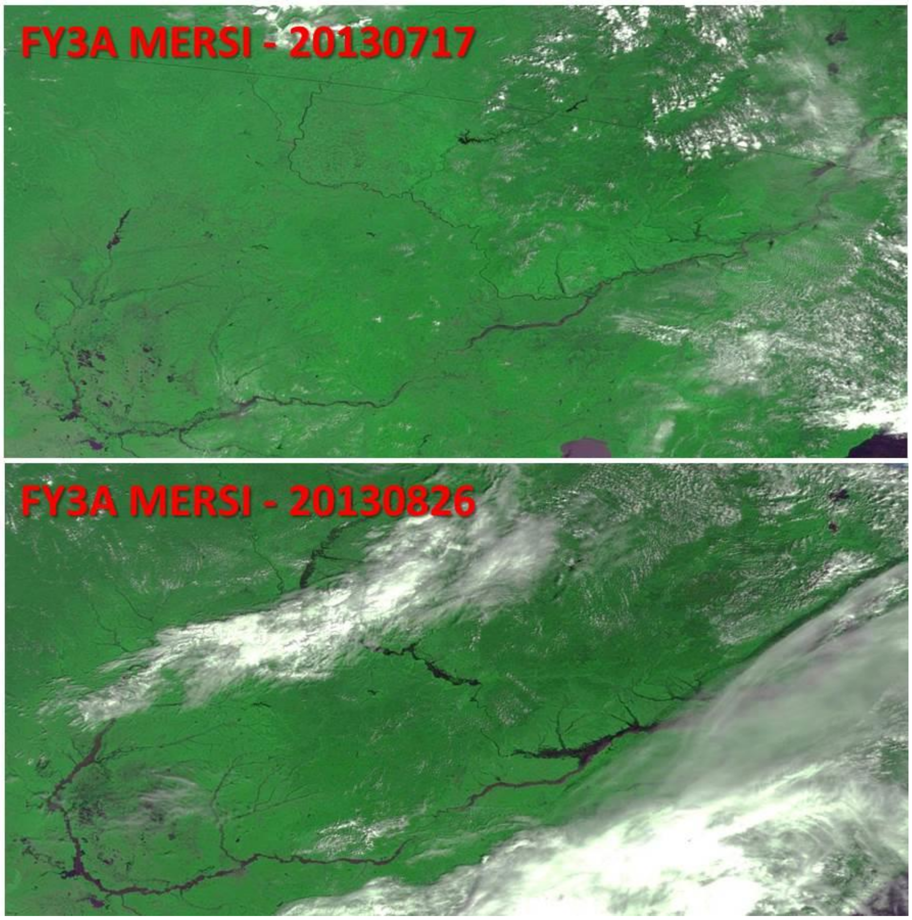
Flood, a natural phenomenon, causes the loss of people and property. Flood often affects the large areas of the both river sides. The overall situation of the flood occurring in the river basin is of importance for the decision maker to take sound measures to rescue people in the affected area and evacuate people in the downstream area in time. Public people also keep eyes on the occurring flood and look forward to have more detailed and precise information. Satellite observation is one of key means to capture the overall information in a timely manner although there are some limitations, such as cloud, swath coverage and resolution. It is able to provide the overall view information for a very large area with higher frequency, although the low resolution satellite data is unable to provide the precise damage information for a specific small area in comparison with the high resolution satellite data. So the low resolution satellite data is particularly useful to monitor and follow the evolution of flood in large area. This article is demonstrating a case of monitoring the great flood in Northeast China in 2013 with Chinese meteorological satellite data.

Satellite Earth Observation Data Application

In summer 2013, a great flood occurred and lasted 2 months in Northeast China and neighboring Russian area. It reportedly caused direct economic losses of over a billion US dollars. The driving force was the heavy sustained rainfall in July 2013 in the upstream area of the Heilongjiang River that filled to the full of the dams. Later the discharge water and the heavy sustained rainfall again in the middle area of the river in early middle August made the situation much worse. Later on the water level increased vary rapidly, finally water broke the bank and flooded lots of residential compounds, farmlands and villages.

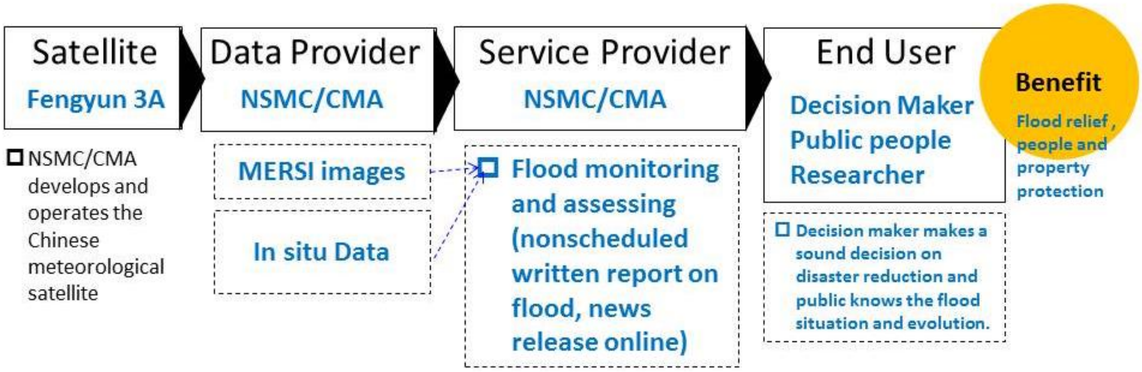
During this event, the Chinese central and local governments made scientific decisions and took sound measures to manage the flood and relief people. Some decision support information about the flood situation was retrieved from Chinese meteorological satellite (also named Fengyun Satellite) data. One of sensors onboard Fengyun 3A is MEdium Resolution Spectral Imager that provides 250 m data with 5 channels. The flood information was retrieved from these 5 channels. MERSI data were acquired, preprocessed in the National Satellite meteorological Center of the China Meteorological Administration and later made open and freely available on the data portal (http://satellite.cma.gov.cn) for the global users. The experts of NSMC/CMA further processed and retrieved the water body information from the MERSI data with the classification methods, and compiled with other reference and base data into a written report that was submitted to the decision makers and posted on the web.

With the daily water body information, the decision makers knew where and when the flood was severe and where the efforts should go. The image (above) shows normal water bodies before the flood. Water is in black. Rivers were narrow. The image (bottom) shows the water bodies in the peak flood. Rivers became wider. Water broke the bank in the downstream during the peak flood. Water bodies came back to the normal finally at the end of September.



1) End User: Decision maker, public people, and media
2) Benefit: Retrieved flood information from satellite data provide the clear pictures of water body and the changes of water body. This information helps the decision makers knew where and when the flood was severe and where the efforts should go.
3) Social Impact: the decision maker and Public people know the value of the satellite and its data. The retrieved information may help the media to follow the hotspot and release scientific news. Public people understand the efforts from the governments for the flood relief.
4) Innovative: the mothed of timely retrieving flood information from satellite data and the information used for the decision making.

Value Chain



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Global Mapping of the Earth's Land Surface Composition

The first suite of satellite-derived, scalable, continental-wide mineral maps were generated for Australia and publicly released in 2012. The seventeen geoscience products were created from data acquired by the ASTER VNIR-SWIR-TIR imaging system, which was designed specifically for measuring diagnostic mineral spectral features at 15-90 m pixel resolution for the Earth's entire land surface (<80° latitude). The resultant mineral maps are now a part of the standard geoscience spatial data suite provided by government geoscience agencies across Australia and have been readily taken up mining and mineral exploration companies worldwide (tens of thousands of image downloads from over 40 countries) with the first related mineral discovery announced on the Australian stock exchange in late 2012. These scalable mineral maps are also being used for other applications, such as farmers interested in the clay mineral composition of the surface soils across their paddocks through to government agencies concerned with improved methods for regional mapping and monitoring environmental information, such as surface clay loss by wind erosion across Australia's extensive drylands.

Problem

Meeting the world's increasing demand for minerals, like gold, copper and iron, is critical to future global prosperity. Many countries are working hard to attract investment to develop new mines in greenfield areas, and to expand existing mines. A key tool to attract investment in exploration is data; data that gives an explorer, and the investors financing them, more confidence that they will find valuable resources in a particular location. However, explorers have not had access to global data that can for example map alteration halos around deposits based on measurement of specific minerals like muscovite, kaolinite, chlorite, carbonate and quartz. To date, the only satellite sensor designed specifically for mapping this type of mineral information and which has operated successfully acquiring global land surface coverage is ASTER (Advanced Spaceborne Thermal Emission and Reflection radiometer). Since its launch in 1999, the user community has had access to inexpensive ASTER Level 1 and 2 data, though there have been no standard higher-level mineral products available for users, which has limited the value and uptake of this unique global dataset. To help address this problem, a team of twenty organisations led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), generated and publicly released a suite of seventeen geoscience products of the Australian continent (Caccetta et al., 2013).

ASTER satellite sensor

The Japanese designed and built ASTER sensor was launched in December 1999 as part of a multi-sensor payload onboard the USA's Terra platform for servicing NASA's "Earth Science Enterprise". ASTER is a polar-orbiting (<83° latitude) imaging system with a 60 km swath and sensing 14 spectral bands at a pixel resolution between 15 and 90 m. These bands include six in the shortwave infrared (SWIR, 1-2.5 µm) wavelength region, where clay minerals have diagnostic absorption features, and five in the thermal infrared (TIR, 8-12 µm) wavelength region, where other silicate minerals like quartz have diagnostic features (Abrams et al., 2015).

ASTER Earth Observation Applications

The Version 1 Australian ASTER geoscience maps were designed to help mineral explorers map specific rock types and the effects of superimposed alteration (footprints to mineralisation) and regolith processes (weathering, erosion and deposition). Thousands of mineral maps have subsequently been downloaded over the web by users from over 40 countries or obtained via external drive (~1 Terrabyte for a complete set of products), which are available through the government geoscience agencies across Australia. This demonstrates how access to new geoscience mapping data can attract interest and investment into a country like Australia, which is reliant on the health of its resources sector.

Geology and mineral exploration

The first gold discovery using the Australian ASTER minerals maps was announced by Kentor Gold Limited on the Australian Stock Exchange soon after the public release of the satellite products. Their discovery at Chukbo in the east Arunta of the Northern Territory (Fig. 1) was based on recognition in the ASTER geoscience maps of coincident phyllic and propyllitic alteration. Similar new targets are also apparent (Fig. 1).

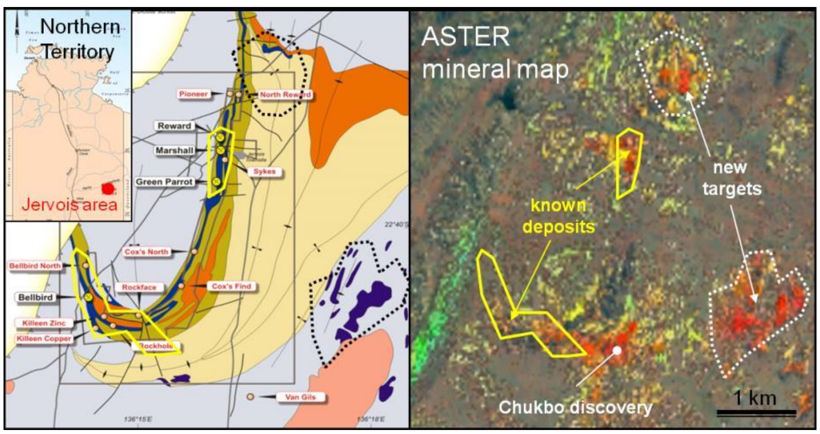


Fig 1: (left) published geology and mineral occurrences in the Jervois area, Northern Territory (from Kentor Gold); and (right) propyllitic alteration (warmer colours) evident in the ASTER "MgOH" product, which was critical in the discovery of Chukbo.

The ASTER mineral maps are easily integrated with other geospatial data allowing for improved understanding of geological processes, including into the 3rd dimension (3D). For example, Figure 2 shows a 3D oblique view of the Australian crust with the ASTER clay composition measured from the surface and the base with the crust (MOHO) measured/modelled using geophysics (Kennet et al., 2011). Thin crust (~20 km) is spatially associated with illite/montmorillonite (warmer colours) while kaolinite (cooler) is developed over thick (up to 40 km) crust. This pattern is interpreted to be related to long-lived depositional (e.g. Lake Eyre basin) versus erosional (e.g. Yilgarn and Gawler Blocks) environments (respectively) with seismic activity related by isostatic re-adjustments to ongoing erosion/deposition along zones of contrasting crustal thickness (Fig. 2).

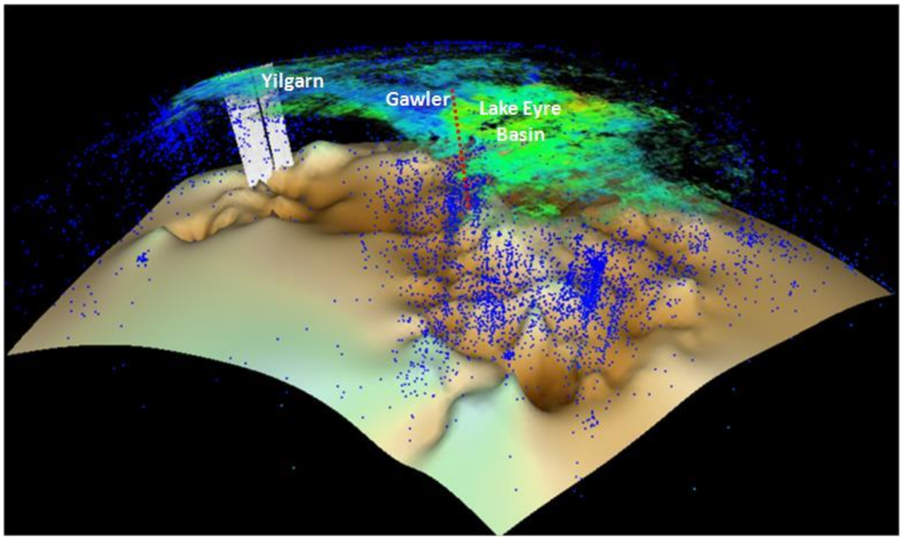
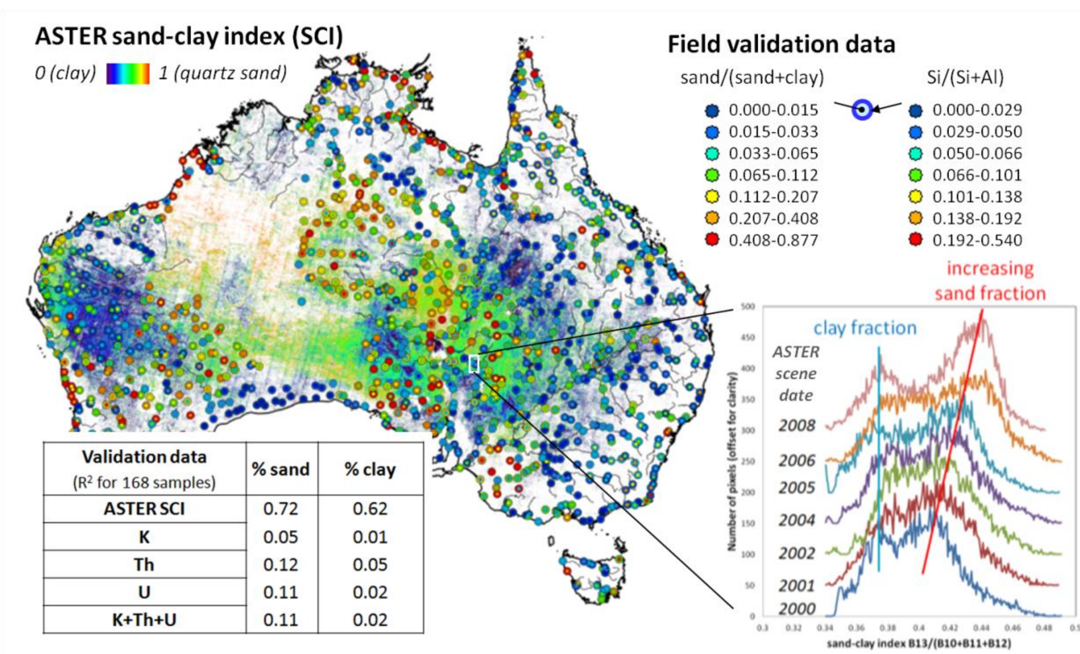


Fig 2: 3D oblique view of the Australian crust that combines the surface clay mineral composition from ASTER (warmer colours are illite-montmorillonite and cooler colours are kaolinite) with the base of crust (MOHO) and seismic activity (blue dots).
http://www.ga.gov.au/data-pubs/interactive-3d-models/world-wind-3d-data-viewer

Environmental monitoring

The ASTER data archive is currently being tested for environmental monitoring, namely, tracking surface clay loss (indicator for the process of desertification) by measuring the proportion of the sand versus clay size fractions. The results to date (Fig. 3) show that ASTER provides superior measurement of this information compared with other standard datasets (e.g. Landsat TM's NDVI, airborne radiometric K, U, Th data) and that there appears to be sufficient resolution with ASTER to track annual changes with a study site in the Lake Eyre basin showing a yearly increase (size and content) of the sand fraction.

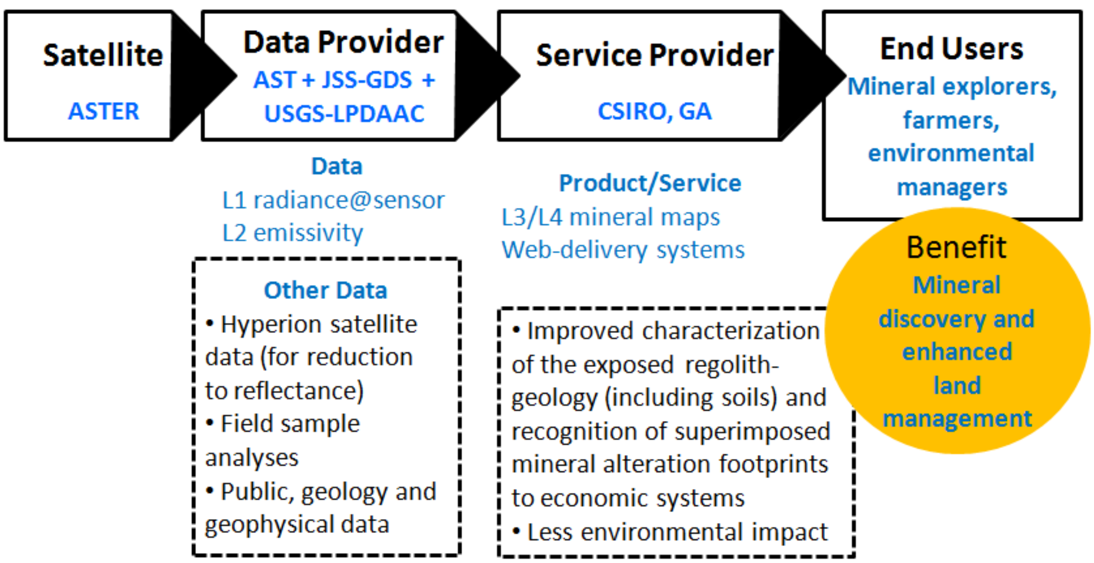


Validation data (R^2 for 168 samples)	% sand	% clay
ASTER SCI	0.72	0.62
K	0.05	0.01
Th	0.12	0.05
U	0.11	0.02
K+Th+U	0.11	0.02

Fig 3: ASTER map of the proportion of sand to clay size material (SCI) validated using field sample analyses of particle size and Si and Al geochemistry. Table (bottom left) provides regression statistics for field sample data. Yearly (2000-2008) histograms (bottom right) of the ASTER SCI for an area near Lake Eyre.

Value Chain

The seventeen Australian ASTER geoscience maps were generated from 3500 Level 1B (radiance@sensor) and Level 2 (emissivity) ASTER images (from an available 2000-2007 Australian image archive of 35,000 scenes) provided by the USGS-LPDAAC with the approval for data access given by the ASTER Science Team (AST) and Japan Space Systems (JSS) and its ground data segment (GDS). CSIRO developed the image processing methodology that transformed the standard Level 1b (and Level 2) image data into cross-calibrated mosaics of reflectance (and emissivity), which also involved the use of Hyperion satellite reflectance imagery (Caccetta et al., 2013). CSIRO also developed the processing methods that generated the Level 3 geoscience information products [1]. CSIRO, Geoscience Australia (GA) and the State and Territory geological surveys across Australia provided the data archiving and related web-portal systems for users to access the digital ASTER Level 3 geoscience products. Users include both resource companies as well as their service companies that interpret the significance of the ASTER geoscience products for mineral exploration often in combination with other spatial geoscience data like geophysics and geochemistry. The public release of these higher level ASTER geoscience products have also attracted other users, including farmers interested in the mineral composition of their soils and government agencies responsible for environmental decision making.



Future

The loss of ASTER's full functionality in 2008 means that any future monitoring of similar mineral information will require the launch of new sensors with mineral-sensitive SWIR-TIR spectral bands (e.g. NASA's proposed HyspIRI). There also exists a global archive of ASTER imagery from 2000-2008 with approximately six complete coverages of the Earth's land surface that has yet to be processed into standard land surface composition products for which three time slices can be generated.

[1] http://c3dmm.csiro.au/Australia_ASTER/Australian%20ASTER%20Geoscience%20Product%20Notes%20FINALx.pdf

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Asia/Oceania – Climate

Enhancing the national carbon accounting and reporting capability using remote sensing data

[2] Shanti Reddy, Elizabeth Farmer, Katherine Green, Zulfiquar Khwaja and Mark Bradley

[3]Peter Caccetta, Suzanne Furby and Drew Devereux

The Department of the Environment developed a fully integrated Carbon Accounting Model (FullCAM) for estimating emissions and sequestration from forest and agricultural systems in Australia. FullCAM is used for tracking greenhouse gas (GHG) emissions and stock changes associated with land use and land management in the Australian national inventory. FullCAM is driven by land cover change data from Landsat series of satellites. In 2014, the land cover change programme has undergone significant improvements to incorporate the Landsat 8 surface reflectance data, extending the forest monitoring capability to support the second commitment period of the Kyoto Protocol. Increased automation, combined with time series data analysis, has led to significant efficiency gains and additional capability to implement new accounting consistent with the Intergovernmental Panel on Climate Change (IPCC) guidelines.

Problem

Estimation of GHG emissions and removals from the land sector is a critical component of the national inventory reporting (NIR) under the United Nations Framework Convention on Climate Change (UNFCCC). The land sector is responsible for about 19 per cent of global carbon dioxide emissions since 1960 (IPCC, 2014). From 2015, most countries will be required to submit biennial update reports to the UNFCCC. International guidance on national greenhouse gas inventories prepared by the IPCC recommends several methods to estimate GHG emissions and removals from the land sector, including use of field measurements, remote sensing techniques, ecosystem models or a combination of these methods.

Integrating models with field measurements and remotely sensed satellite data is a cost effective method to generate the national carbon accounts and also to support domestic climate change policies including project level carbon sequestration activities.

An important consideration in using the satellite data is to ensure time series consistency of national inventory estimates when data from different sensors or satellites is used over a period of time.

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[2] Department of the Environment (DoE), Australian Government

[3] Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Satellite Earth Observation Data Application

Australia has pioneered the application of time series Landsat satellite data to detect land use changes as part of its national inventory system (DoE, 2015). For this purpose, an operational satellite data processing system has been developed to map land cover changes using time series Landsat satellite data starting from 1972 to present (Furby, 2002). A detailed description of the use of satellite data for modelling greenhouse gas emissions and removals from Australia's Land Use, Land Use Change and Forestry (LULUCF) sector can be found in the latest National Inventory Report (NIR, 2013) submitted to the UNFCCC in May 2015 (DoE, 2015)[4].

A significant change in the latest NIR is the use of Landsat 8 surface reflectance data, which is quite different to the previous Landsat 5 and 7 data products used for the national inventory Land Cover Change Programme (LCCP). To ensure time series consistency and compatibility with the existing work programme, a detailed technical assessment was undertaken to assess the geometric and radiometric consistency between the previous and current (Landsat 8) sensor data.

First, the geometric consistency was assessed by matching about 13,300 ground control points (GCP) drawn from the LCCP scenes held in the national inventory data library and the corresponding Landsat 8 reflectance data. This has allowed estimating scene specific transformation coefficients ensuring that the two products are aligned and consistent to within a pixel for the entire country.

The second step in the process was to assess the radiometric consistency between the Landsat 8 reflectance and LCCP products using a total of 339 image pairs. The two products were paired up based on the Landsat path and row, and image acquisition date. For each band, a gain, offset and correlation value was calculated. These values were used to convert LCCP pixels to surface reflectance values (Devereux, et al. 2013).

Following the above steps, the 2014 Landsat 8 surface reflectance data have been classified to identify areas of forest and non-forest, consistent with Australia's definition of a forest, using thresholds applied to a set of linear discriminant functions (Furby, 2002).

The next step is a Conditional Probability Network (CPN) analysis (Kiiveri, et al. 2001) to strengthen confidence in the 'forest' or 'non-forest' classification of a pixel by considering the previous and subsequent images in the time sequence to resolve any uncertainty in the classification of a particular image. This comparative analysis of the same land unit over time was made possible by the accurate and consistent geographic registration and spectral calibration of the image sequences, providing the ability to 'drill' through time on a pixel-by-pixel basis.

The final step in the analysis was to attribute the cause of the forest cover loss either due to (a) permanent change in land use, or (b) temporary loss of forest cover, for example, as a result of harvesting (Figure 2). The attributed land cover change data forms a key input into the FullCAM to estimate emissions and removals for a given change event.

[4] http://www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/national-inventory-report-2013

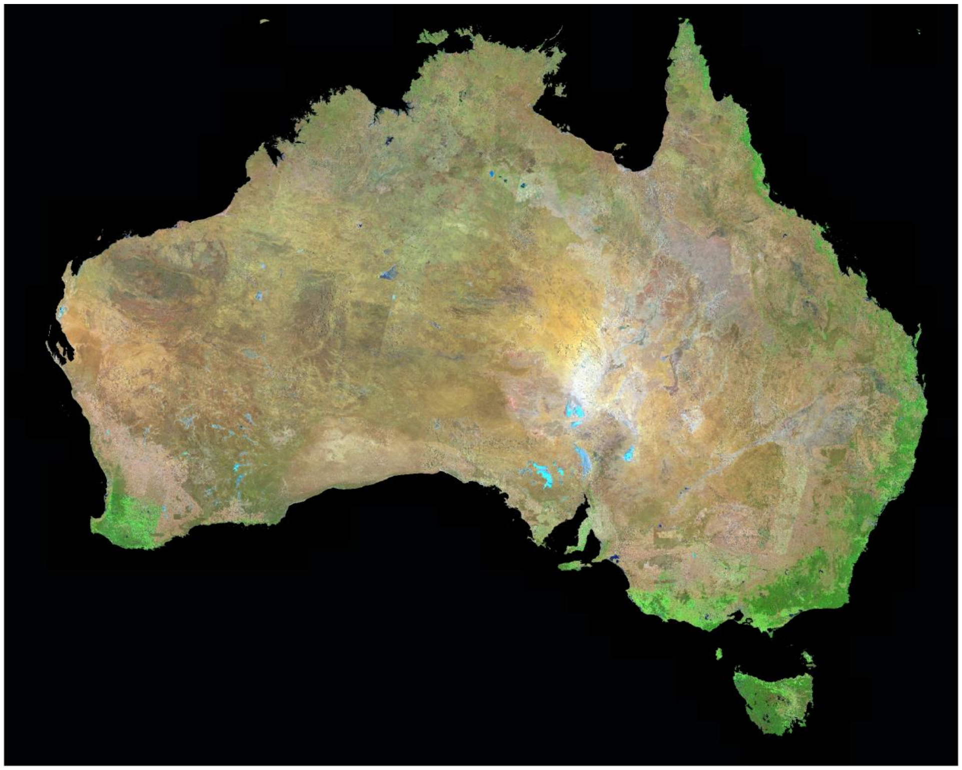

Fig 1: Landsat 8 surface reflectance image of Australia – 2014

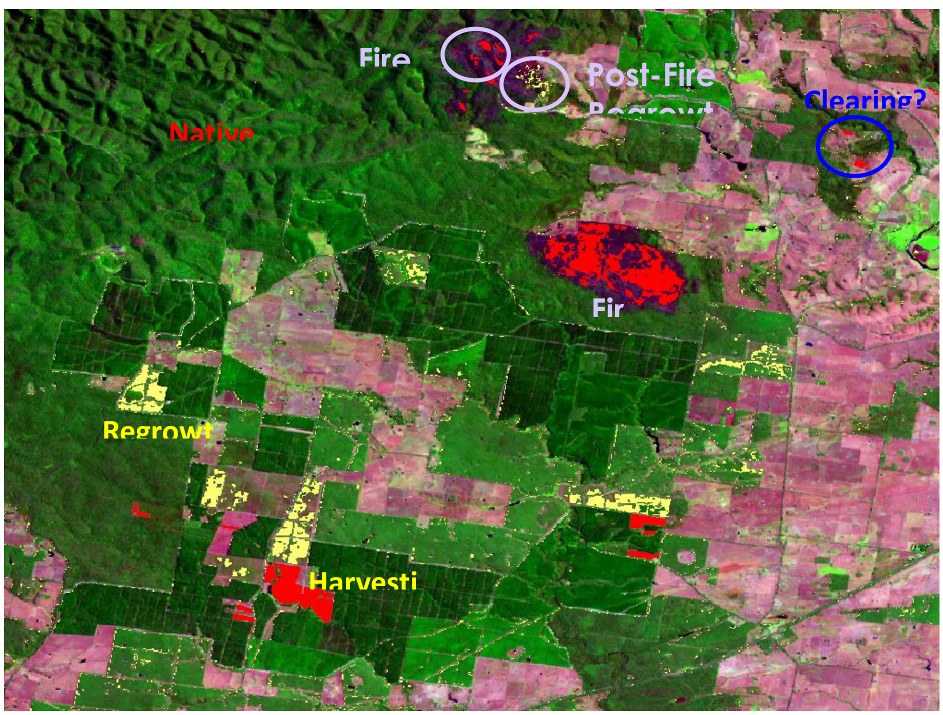

Fig 2: Landsat satellites detect land cover changes such as regrowth (yellow), harvesting (red), forest fires (red), and potential land clearing (blue).

With Australia's land mass of 769 million hectares including approximately 110 million hectares of forest land it is impossible to monitor annual land use changes cost effectively without the use of satellite data. By applying the latest space technology and innovative computations, the Australian government is able to fulfil its international obligation of reporting greenhouse gas accounts to the UNFCCC and the

Kyoto Protocol. The use of satellite data increases transparency and confidence in the greenhouse accounts, which are subject to external scrutiny by technical experts under the UNFCCC review process.

The national inventory information products derived from satellite data are published online to support domestic climate change projects under the Australian Government's Emissions Reduction Fund (ERF) and the Carbon Farming Initiative[5] (CFI). This information is also used more broadly by the science community, non-governmental organisations, state government agencies and the general public.

Value Chain

Fig 3: Key components of the Australian land cover change programme value chain.

More Information

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[5] http://ncat.climatechange.gov.au/cmt/#/Home

Asia/Oceania – Water

Detection and monitoring water resources across a continent

Water is increasingly a significant political issue, at the nexus of food and energy security. Effective management of water is critical to economic development and security. Satellite imagery gives us unique insight into the behaviour of water in the landscape, enabling us to track changes over very large areas over long periods. Decades of imagery from the United States' Landsat series have recently been utilised to analyse surface water dynamics over the entire Australian continent over a 27 year period. This world-first water product has demonstrated application to disaster management, wetland behaviour, river system mapping, groundwater/surface water interaction, and topographic mapping. The ability to conduct such a broad range of studies across a continent helps position societies to have the required discussions about water management.

Problem

Water is a fundamental resource, required for public health, agriculture, industry and the environment. Providing the required water resources across these sectors requires understanding of the historic and ongoing state of total water for a country and even a continent. The issue is especially problematic in a country such as Australia, where the population is extremely sparse, the climate is very dry and rainfall events are episodic. These factors combine to produce a landscape that alternates between drought and flood while still being exploited for regular water supplies.

The standard methods for monitoring water resources involve in-situ measurement of reservoirs and rivers using gauges or visual inspection. To monitor an entire continent in this way is impractical, resulting in insufficient measurements to understand water stores and usage, and poor understanding of what might be impacted by flooding or water diversions.

Satellite Earth Observation Data Application

Satellite imagery provides a method for detecting surface water across large areas. The regular acquisition of imagery and subsequent detection of water provides a history of water at a location. This history is a rich source of information on the location and use of water resources. The detection and monitoring of water over an entire continent can be accomplished by standardising regularly acquired satellite imagery.

The Landsat imagery archive for Australia has been organised into a single, high speed analysis system termed the Australian Geoscience Data Cube (AGDC). It contains data from Landsat 5 and Landsat 7 since 1987, covering all of Australia with approximately 200,000 images. This has enabled the analysis of the presence of surface water for all of Australia for the last 27 years, creating the Water Observations from Space (WOfS) product (www.ga.gov.au/wofs) . WOfS shows the frequency of occurrence of surface water in a 25 m x 25 m grid across Australia for 27 years, providing a unique understanding of surface water resources for the continent. WOfS is a rich information source for water management and is currently being used to help map river networks, water body permanence and where flooding may occur.

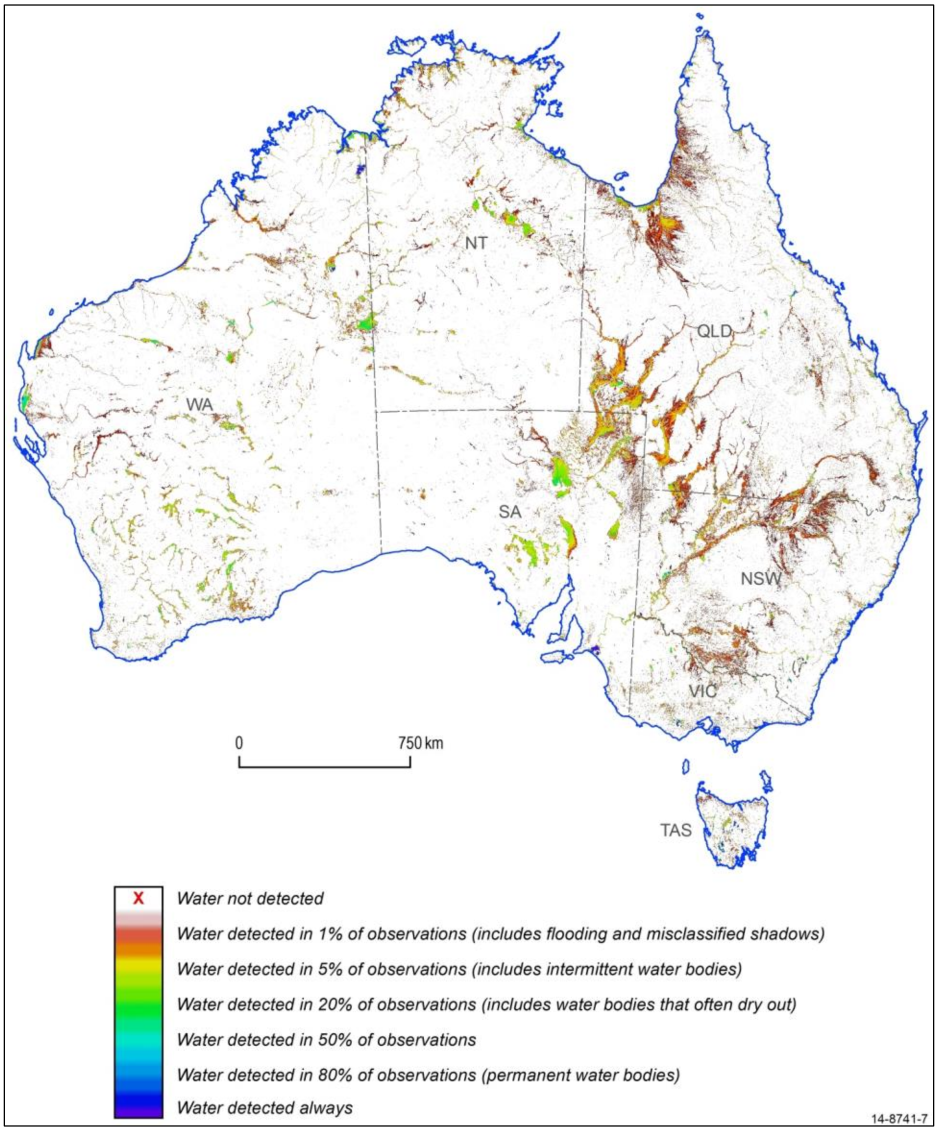


Fig 1: The Water Observations from Space (WOfS) product for all of Australia. The colouring indicates the frequency with which surface water has been observed by the Landsat 5 and Landsat 7 satellites since 1987. Most of the large water areas shown are in red to green colouring, demonstrating that while large areas may become inundated, the frequency of inundation is very low, with most of the continent usually being very dry. Most permanent water bodies, coloured blue, are too small to be visible in the Figure.

Mapping River Networks

Australia has a very large, arid interior, where the presence of surface water usually only occurs after significant rainfall events. This has led to very poor understanding of the location of river networks and the recurrence of water flow within them. The national map of water is the AusHydro developed through collaboration of the Australian Bureau of Meteorology, Australian National University, the CSIRO and Geoscience Australia. While very useful where in-situ observations are frequent, such as along the Australia east coast, the AusHydro is poor at providing information in central Australia where in-situ observations are almost nil. The WOfS product is now providing a means to update the AusHydro with the location and perenniality of rivers along the largest flood plains in Australia. This is a key information source for some of the largest cattle farming establishments in Australia.

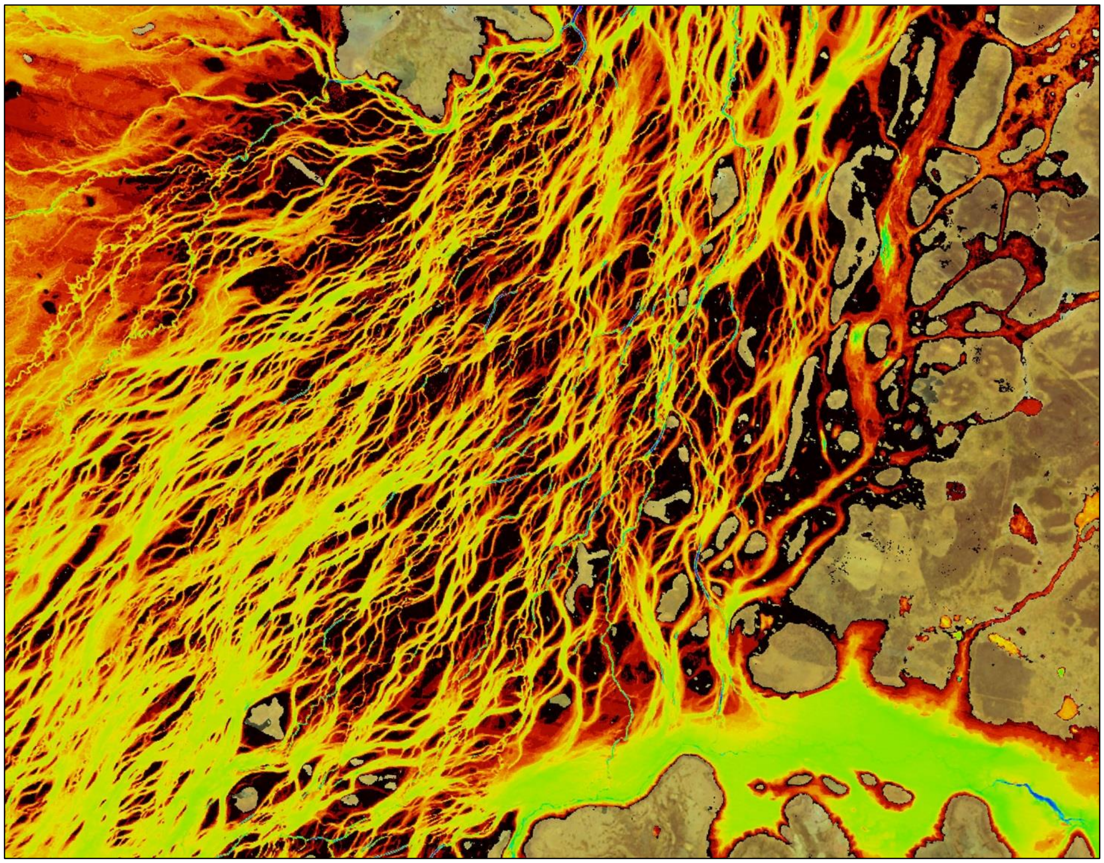


Fig 2: The braided river network of Coopers Creek in south-western Queensland as depicted by WOfS. The colouring indicates the frequency of inundation (see Figure 1 for legend), with blue areas showing permanent water holes in an extremely hot and arid region. These braided river networks are difficult to map by topographic methods.

Water Body Permanence

WOfS detects the presence of water for every observation of every location for the entire 27 year Landsat archive. By combining these water observations into a single summary, the number of times water was observed in any location can be quantified. As a result the perenniality of water bodies can be assessed across Australia, informing the management of water supplies for towns, agriculture and the environment.

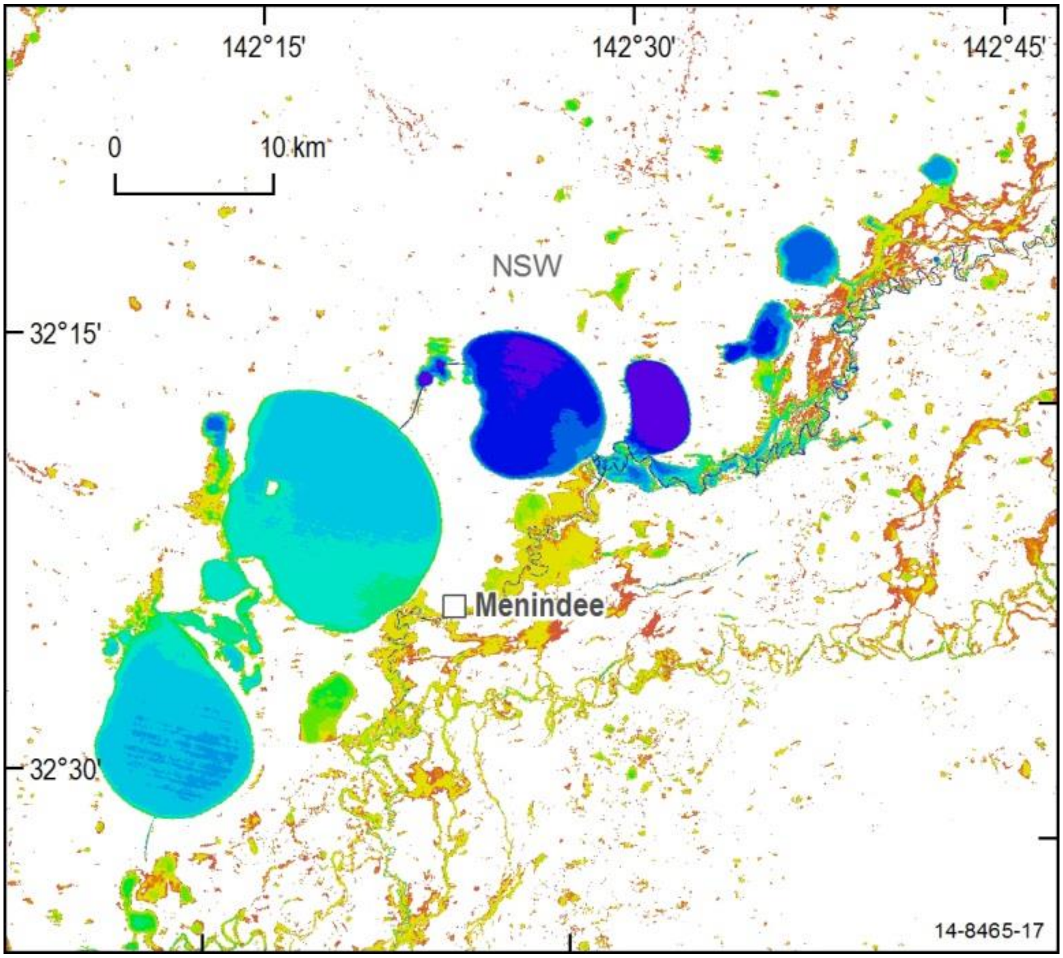


Fig 3: WOfS results for the Menindee Lakes in western New South Wales. These lakes are used to provide water for agriculture and for the town of Broken Hill. The results show that only one of the lakes is actually permanent, and that the others have all become totally dry at some point in the last 27 years (see Figure 1 for legend).

Locations of Potential Flooding

Where surface water has been detected often, it can be inferred that the location contains a regular water feature such as a lake or reservoir. Where surface water is detected infrequently it may indicate flooding. More directly, where a surface water extent is detected impacting a town or road, WOfS can be used to investigate measures for flood mitigation. This information is being used by emergency response agencies to help plan for major flooding.

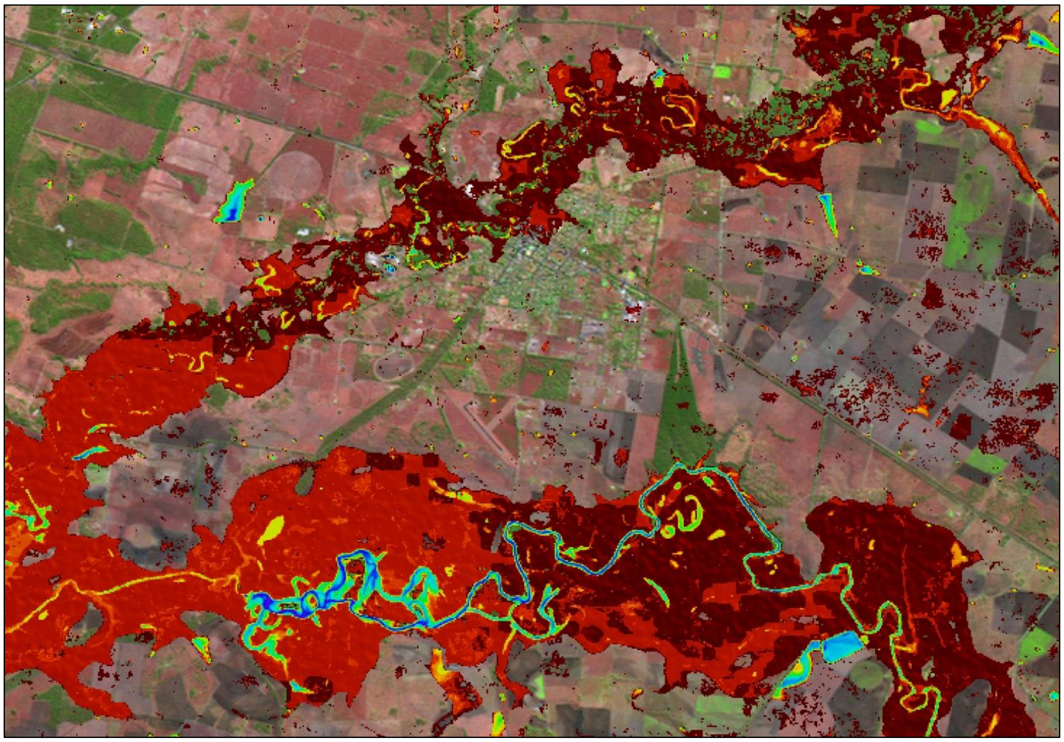
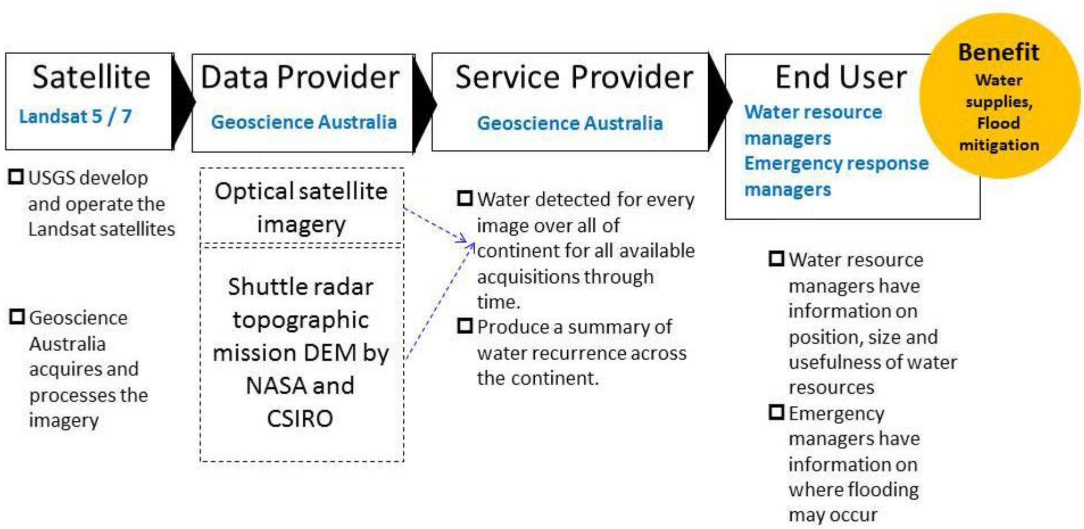


Fig 4: The WOfS product in the area of Chinchilla in southern Queensland. The blue areas indicate where water is a usual occurrence, while the red areas indicate unusual water observations such as caused by flooding. Here the red area spills into the Chinchilla township due to the extreme flood conditions from December 2010 (see Figure 1 for legend).

Value Chain

The WOfS value chain takes imagery from the USGS Landsat satellites, and produces a standard, consistent information product on the location, size and persistence of water resources across the Australian continent, helping water resource and emergency response managers to provide consistent water supplies and flood mitigation.



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Asia/Oceania – Ecology

Collaborative EO Application Development for Understanding and Managing Australia's Environment

Phinn, S.R, Held, A.A., Scarth, P., Gill, T., Paget, M., Nethery, N., Johansen, K. and Ross, J.

Australia's Terrestrial Ecosystem Research Network (www.tern.org.au), and its remote sensing facility AusCover (www.auscover.org.au) have developed and implemented a unique program that has enabled collaboration across multiple levels of state and national government and research institutions to deliver new, continentally consistent, validated time series of satellite EO based biophysical property maps. The spatial data products, image based maps of biophysical properties, along with their supporting field calibration and validation data are used by National, State and Local governments for legislated mapping and monitoring of vegetation cover, vegetation height, composition and condition. Several national and state agencies and research institutions use these data as part of large scale model-data assimilation programs, for meteorological models, regional hydrologic or stream-flow models, or surface energy balance models for crop or forest production. Private agencies, including Insurance, Agriculture and Horticulture and Infrastructure (e.g. power and water supply) use the products in their site selection, monitoring, modelling and management.

The mapping products are all based on a combination of field calibration-validation data and validated algorithms. The mapped products include vegetation structure estimates (cover, height, above-ground biomass, phenology), vegetation indices, burnt area and history, and meteorological parameters. All of the field data, algorithms and time-series are published through the TERN AusCover portal. The data are published with context appropriate and rich meta-data and licensing. The meta-data enables experienced EO data users and other ecosystem scientists to determine if the data are suitable for their purposes and how to process it. The licences are in a slightly modified form of the "Creative Commons By Attribution" license as required under the Australian Government's Data Licensing Legislation. This ensures users of the data are legally bound to cite the data source, so that data producers and their institutions receive formal and measureable recognition of their work output and its use. This enables measurement in the Data-Citation index as well as publishing indexes. This approach enables and promotes the transition of our government, research and academic EO activities to an open-data and open-science culture. All of these agencies in Australia, and the overseas agencies we build EO applications with, benefit from improved access to data, rich meta-data and algorithms, which reduces duplication and enables collaboration and cooperation.

Problem

Development of continental scale biophysical map products, that are derived from EO data and are required on daily, weekly, monthly, seasonal or annual bases require significant and sustained investment in EO data collection, along with continental field data collection, and appropriately skilled personnel and processing, storage and distribution capabilities. In most of the world's continents this is a major challenge due to multiple nations making up continents, and in some cases such as Australia and North America, with multiple states making up continents. Developing and maintaining operational EO programs at these levels is a challenge in itself, let alone having scope for EO research to determine how to build new continental EO based biophysical map products, or to determine how to use new sensors and field data collection technologies and techniques. Australia's Terrestrial Ecosystem Research Network was constructed specifically to address this type of challenge across multiple ecosystem science areas, including EO. AusCover is TERN's EO facility which brings together universities, research institutions, state agencies and national agencies to build and validate continental scale biophysical map products as a research activity – the resultant data sets and programs are described at www.auscover.org.au (Figure 1). The key premise of this activity and other TERN facilities is that it explicitly recognised what has been done previously, and attempts to build on this to develop a continental approach and product, and to improve the process and product where possible so all those contributing will benefit.

Satellite Earth Observation Data Application

The application addressed is public and private use: Supporting an informed and secure society. The lack of collaboration, sharing and cooperation across EO agencies was addressed directly by establishing a three year program, which identified essential biophysical data sets at state and national levels required for environmental monitoring and management, and embarking on a set of activities that would establish what image and field data had been collected across each agency, what algorithms were being used and their applicability and accuracy across jurisdictions. This was used to define how these could be hosted, documented and combined to build more accurate mapping algorithms at a continental scale that all users would benefit from. This was done for vegetation structural properties (cover, height, above round biomass, phenology), vegetation indices, burnt area and history, and meteorological parameters. The algorithm and product development and delivery were only possible due to the multi-jurisdictional "level playing field" approach provided by TERN AusCover, where the agencies could share their data collection infrastructure, staff, data and algorithms. In some cases, e.g. fractional cover and biomass, collaborative new projects, such as with the JAXA's K&C program, were used to help drive research activities. As a result algorithms were built and validated across all major ecosystems, from sandy deserts, through shrubland, savannah, eucalypt woodlands and forests, to dense tropical and temperate rainforests. All of the field data, resultant algorithms and time-series are published through the TERN AusCover portal with context appropriate and rich meta-data and licensing.

As noted in the introduction the image based maps of biophysical properties, along with their supporting field calibration and validation data are used by wide range National, State and Local governments for legislated mapping and monitoring of vegetation cover, vegetation height, composition and condition, from desert to rangelands to rainforest and coral reefs. Large scale model-data assimilation programs have a significant need for near real time meteorological, as well as precise and accurate topographic and biophysical information – which is provided by this Facility. Private – public partnerships are growing, as these consistently collected and freely available become more widely known and understood .

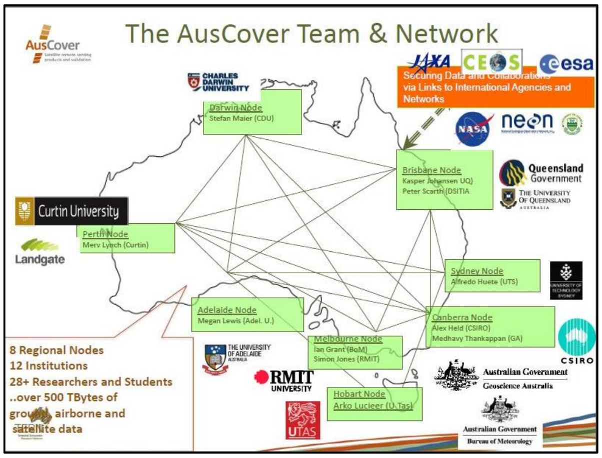


Fig 1: AusCover facility structure

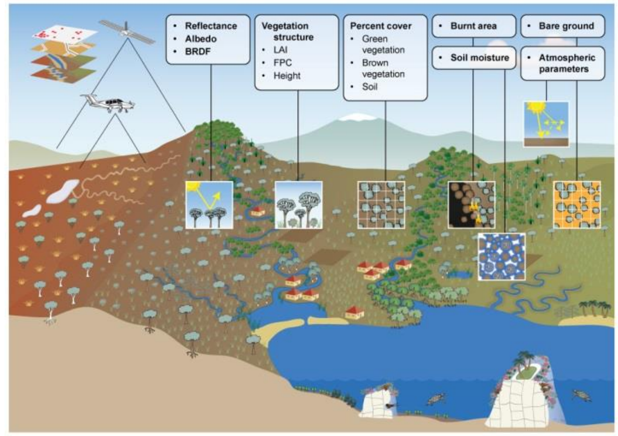
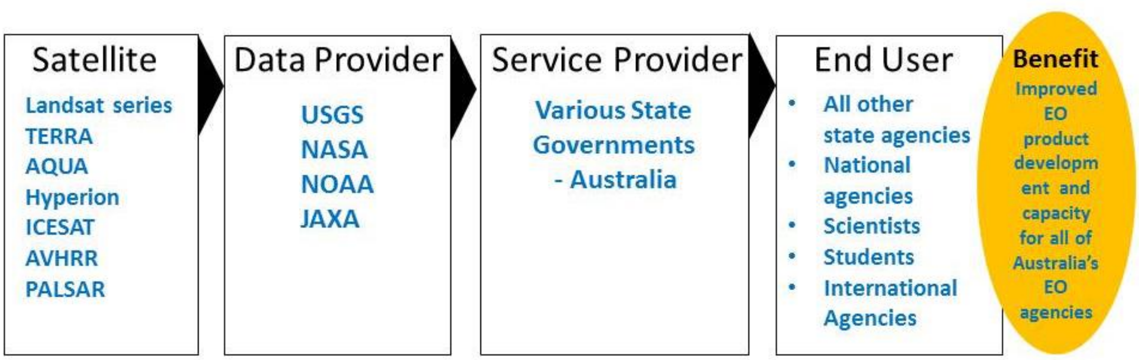


Fig 2: AusCover data products

Value Chain

The data products on the TERN AusCover portal are derived from a range of EO data sources. For satellite image data this includes the USGS Landsat archive, NASA's MODIS, Hyperion and ICESAT archives, NOAA's AVHRR archives, and JAXA's ALOS 2 PALSAR archive. Airborne LiDAR and hyperspectral data are collected and provided by Airborne Research Australia (www.airborneresearch.com.au) and Hyvista Corporation (www.hyvista.com). Field based terrestrial laser scanner data were provided by collaborating state agencies and universities using Riegl instruments. The latter instrument program also enabled an international TLS inter-comparison to occur at several of the AusCover field sites – the data and summaries of this activity are at http://128.197.168.195/?page_id=466.
All of the AusCover products can be freely accessed from http://www.auscover.org.au/data/product-list.



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Asia/Oceania – Ecology

Monitoring changes in Australia's ecosystems to support government monitoring and management

Phinn, S.R, Scarth, P., Witte, CV., Tindall, D., Danaher, T., Hicks, R., Gill, T., Mellor, A. and Johansen, K.

Australia's state governments have Acts of Parliament to enable the protection and sustainable use of our resources, and one of the most important of these Acts across all six States and Territories is the Native Vegetation Act and its variants. These control which areas can and cannot be cleared to ensure we have sufficient vegetation diversity and cover for a broad range of ecosystem services. Each Act has legislation that requires the States and Territories to map on a regular basis, usually every one or five years, the extent of native vegetation and its structural properties (e.g. vegetation cover, height and biomass). They are also required to map changes in these properties for legally binding reports. Satellite image data are the only way to deliver these products. This paper explains the approaches that have developed across Australia to deliver these essential products from EO data. By using the scientifically sound approaches outlined below States and Territories have a widely useable spatial data set to meet legislated mapping requirements from products that are both scientifically and legally defensible. As a result the data are used for a range of compliance monitoring and assessment activities , including detection of illegal clearing and assessing the impacts of changes in grazing and other farming policies, with the net result that Australia's States and Territories are able to better manage our resources strategically.

The legislated monitoring and on-ground management of Australia's environmental resources, atmosphere, vegetation, soils, water bodies and benthos, as noted above, are conducted by state government agencies. State agencies are Australia's largest and longest term users of satellite EO data, as well as our largest employers of EO specialists. This paper outlines a specific range of legislated activities in Australia that are fully supported by EO data, for baseline mapping, monitoring and modelling. Mapping the percentage of a pixel covered by vegetation and its change on an annual basis is a common legislated requirement across Australia's states. The Landsat image archive and extensive field data are used with an established and secure processing system to deliver annually updated maps of vegetation cover and their change at state and national levels. The project driving these applications has been established for over 20 years (see www.qld.gov.au/environment/land/Vegetation/mapping/slats). A slightly different approach has been taken to continental scale vegetation cover mapping, with national research infrastructure used to link state collections of field surveys of vegetation cover, to development of a common method for processing and delivery at national scales.

Problem

Woody vegetation cover mapping is a basis for vegetation mapping and monitoring across several states and nationally. The mapping of woody vegetation cover is linked to several state vegetation management acts and is required on an annual basis (Figure 1). Accurate mapping must work from semi-arid grassland, across savannah woodland, temperate woodlands, to coastal forest and rainforest and cannot be done from field or aerial photography. Landsat Thematic Mapper and field based approaches were developed in 1990s in association with vegetation dependent industries in one state (Queensland), which also paralleled development of national land use maps. As the method and access to Landsat data improved, mapping went from once every five years to annual in 2000, and then moved to use the full Landsat TM/ETM+ archive when it was made available by USGS. The method was initiated in Queensland, and has since been adopted/modified in New South Wales , Northern Territory and Tasmania, and most recently to a more advanced nationally applicable product – persistent green vegetation fraction and fractional cover (Figure 2). These products are used across state governments for a range of applications, including compliance assessment for vegetation clearing permits, recognised as global best practice (Evidence from Earth Observation Satellites. Emerging Legal Issues, December 2012, Brill / Martinus Nijhoff , ISBN 978-9004194434, 498p (Ray Purdy, editor With Denise Leung)).

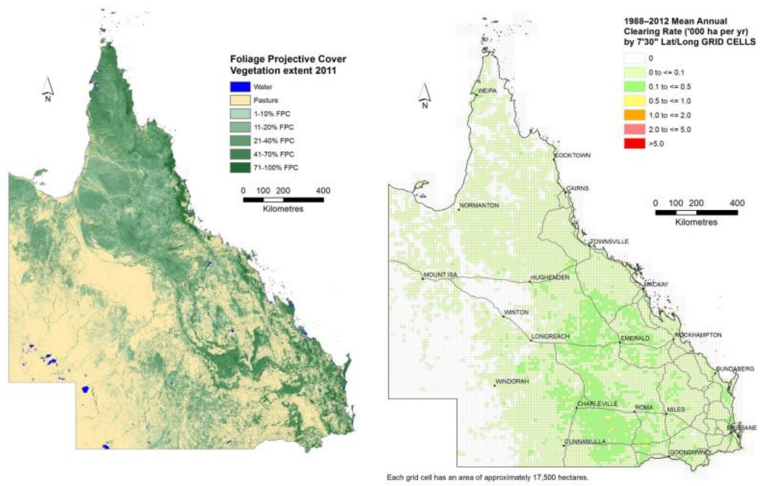


Fig 1: The Statewide Land Cover and Trees Study, woody foliage projective cover mapping results (https://publications.qld.gov.au/storage/f/2014-09-11T02%3A11%3A13.856Z/slats-report-2011-12.pdf)

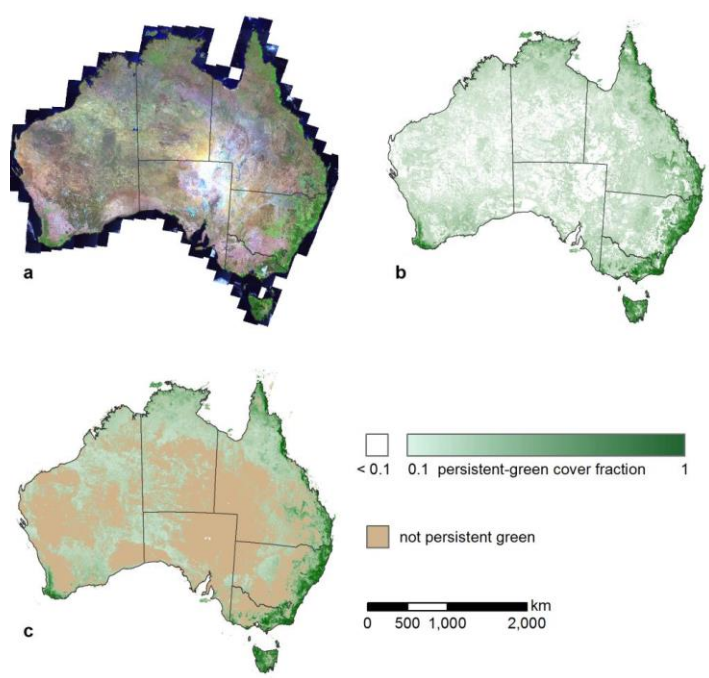


Fig 2: National persistent green vegetation fraction product, base Landsat scenes and product. (www.auscover.org.au/xwiki/bin/view/Product+pages/Persistent+Green-Vegetation+Fraction)

Satellite Earth Observation Data Application

The application addressed is public use: Supporting an informed and secure society

The problems identified here, in mapping vegetation, were addressed by combining extensive field survey programs, with extensively tested satellite image geometric and radiometric correction programs and well supported and maintained project teams to develop programs that accurately map vegetation structural properties. The approaches used are fully documented and published in peer reviewed literature, and the code, approaches and data are available through publicly accessible portals.

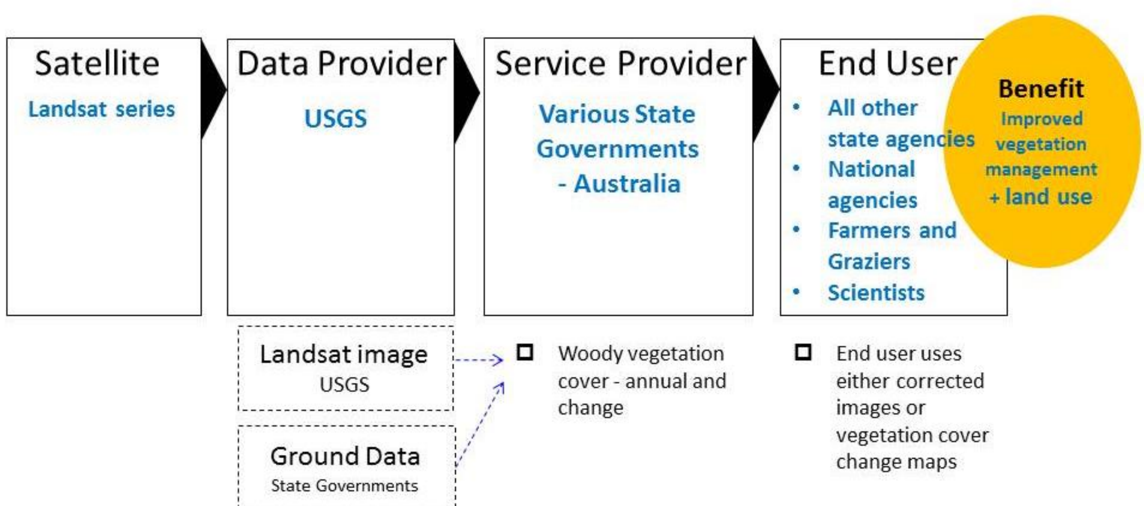
The foliage projective cover data sets are available from:
www.qld.gov.au/environment/land/vegetation/mapping/slats/ and
qldspatial.information.qld.gov.au/catalogue/custom/index.page

The national vegetation fractional cover and persistent green vegetation fraction data, supporting documentation and field calibration data are available from: www.auscover.org.au/data/product-list

Value Chain

The woody fractional cover and other fractional cover products are produced using the USGS Landsat Thematic Mapper, Enhanced Thematic Mapper and Advanced Land Imager archives and SPOT 4 and 5 data. Field data are collected by Queensland, New South Wales, Victorian, Tasmanian and Northern Territory Governments. Data are used by all state agencies, general public, land-holders, research agencies and private companies.

Monitoring changes in Australia's ecosystems to support government monitoring and management



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Asia/Oceania – Agriculture

Sentinel-1 SAR data for operational rice monitoring system

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[1]. Centre d'Etudes Spatiales de la Biosphère, Toulouse, France
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Descriptions

Rice is among the agricultural crops, the most critical staple food for more than half of humanity, with the majority of the world crop grown and consumed in the developing world (90% in Asia). World population, and therefore demand for food, has increased linearly over the last fifty years (+80M/year). In this context of threatened food security, tools to monitor rice production in near real-time are highly needed.

The project goals are to develop products and services for long term exploitation of Sentinel 1 data. The products to be implemented include rice Crop calendar, Rice field mapping, Early warning , Yield estmation, and Damage Assessment. The development is carried out in the frame of Asia-RiCE GEOGLAM initiative, and the R&D phase is currently conducted in an ESA Innovator project led by CESBIO. The demonstration is performed in the Mekong Delta, Vietnam, where the target user is the Ministery of Agriculture and Rural Development.

Challenges

Accurate information is required on the spatial distribution of rice fields, risk occurrence and annual production projections. However, most agricultural surveys rely today on statistics based on limited ground samplings at which data are extrapolated on a national scale. Although the census can provide statistical estimates, slow and unsystematic collection of data can limit the ability to make timely decisions. Currently, MODIS data are the main EO data sources for monthly monitoring of the main crops, which are wheat, maize, soybean and rice (e.g. in GEOGLAM). For rice , the frequent cloud cover over rice growing season limits severely the use of MODIS images (even in 8-day composite) during critical stages of the plant growth, in particular during the onset of the rainy season. Using SAR data, rice mapping and monitoring methods have been developed but operational applications leading to production estimation and forecast have been hampered by the lack of systematic (and cost-effective) SAR data. The launch of Sentinel-1 in April 2014 and the availability of consistent SAR acquisitions (in particular with high resolution and large coverage) represent an unprecedented opportunity for operational rice monitoring applications.

Applications/solutions

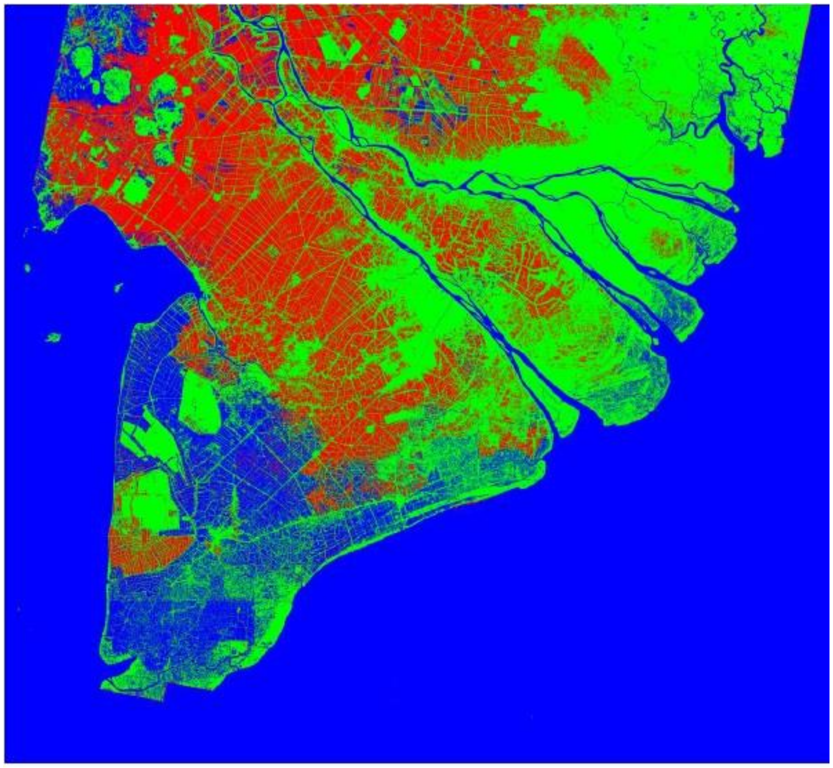
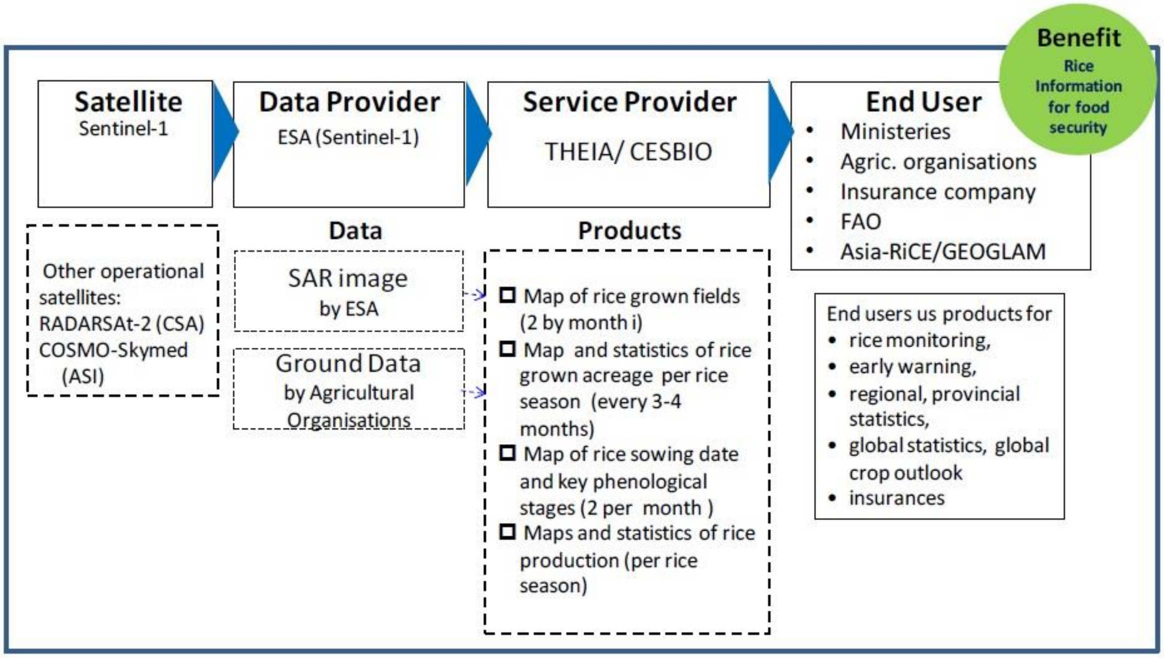


Figure 2: Rice grown area (in Red) for the Winter Spring Rice season (December 2014-March 2015). This is an unprecedented mapping results of a large area (300 x 300 km), at a resolution of 40 m (it is possible to have results at 10 m), and near real time acquisition. The data are available the day after acquisition and processing can be done during the day. A map can be provided every 12 days to show the rice crop growth in the region.

Since August 2014, Sentinel-1 data have been regularly acquired over the Mekong Delta, a super site for the Asia-RiCE/GEOGLAM project. The data have been analysed and rice field mapping has been performed. Figure 2 shows the map of rice grown area in the Mekong Delta (about 300x 300 km) for the rice season from December 2014 to March 2015. Several temporal images have been used to take into account the different crop calendar in this large region. The work on detection of crop calendar and retrieval of crop parameters are on going.

Value chain

The product dissemination can be made through Theia as service provider. The Theia Land Data Centre is a French national inter-agency organization designed to foster the use of images issued from the space observation of land surfaces. Theia is offering scientific communities and public policy actors a broad range of images at different scales, methods and services.



Outcomes/benefits

The improved and timely rice products have a main contribution in terms of supporting countries to manage directly their rice crop . In the GEOGLAM-Asia-RiCE Initiatives, the user community, disseminated in many countries, and coordinated by a well structured programme will take benefit from the methods and techniques developed, and will contribute to the fine tuning of the methods to a diversity of rice crop conditions.

Contact information

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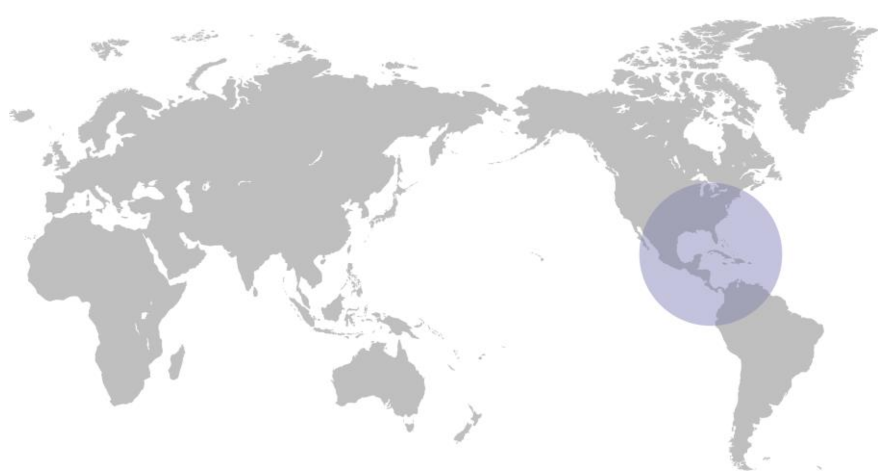
Chapter 2:
APPLICATIONS IN AMERICAS



Americas – Disaster

Disasters and Earth Observation Applications: The Richelieu River Flood Management (Quebec, Canada)

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Descriptions

Reducing loss of life and property from natural and human-induced disasters is a priority in Canada. Disaster losses can be reduced through observations relating to hazards such as floods. The Richelieu River (Quebec, Canada) flood of 2011 was extraordinary, as it lasted for more than one month and caused severe infrastructure and housing damages. Within the framework of the international Committee on Earth Observation Satellite (CEOS), the Canadian Space Agency (CSA) is collaborating with NASA on various projects helping to prevent, manage and respond to natural disasters. This partnership offers the opportunity for CSA and NASA to share satellite data acquired by several Canadian and American satellites for scientific and operational purposes. These include the development of models, systems and procedures geared toward flood forecasting and response. During a recent spring flood along the Richelieu River in Quebec (Canada), multiple governments and non-governmental organizations have worked in partnership on the development of flood information and products derived from RADARSAT-2 and EO-1/ALI data. The ALI images complemented an entire time series of RADARSAT-2 images acquired by the Canadian Government over the affected region, providing additional detail thanks to the multispectral and pan-chromatic imaging capabilities of ALI. The satellite imagery gives the opportunity to monitor the spatial extent of the flooded areas and assist authorities on the ground with their flood response measures. A time series animation of 16 RADARSAT-2 SAR images of the most severely flooded areas along the Richelieu River was also developed and provided to the civil authorities. The information derived from EO data served geospatial information requirements by federal as well as provincial stakeholder organizations, notably Public Safety Canada and the Quebec Ministry of Public Safety. This work was conducted under the CSA's Rapid Information Products and Services (RIPS) and is presently evolving, under the CSA Government Related Initiatives Program (GRIP), into a national operational flood geospatial information system with Natural Resources Canada and other governmental and industrial partners.

Challenges

Disaster losses can be reduced through Earth Observations (EO) relating to hazards such as: floods; wild land fires; volcanic eruptions; earthquakes; tsunamis; subsidence; landslides; avalanches; ice storms; extreme weather; and pollution events. When disaster strikes, a rapid access to data such as: land and ocean conditions; maps of transport links and hospitals; weather forecasts; and information on socio-economic variables can save uncounted lives. Inter-agency initiatives and coordination are now bringing a more timely dissemination of information through better coordinated space systems for monitoring, predicting, risk assessment, early warning, mitigating, and responding to hazards at local, regional, national and global levels (CEOS, GEOSS, 2012).

For a period of around 40 days between April and June 2011, heavy rain and the melting of a thick layer of snow in the area surrounding the Lake Champlain Basin and the Richelieu River caused water levels to rise substantially. In Canada the floods affected approximately 3,000 principal residences in Quebec's Montérégie region. Municipalities primarily affected by the flooding include Venise en Québec, Noyan, Saint-Jean-sur-Richelieu, Henryville, Saint-Paul-de-l'Île-aux-Noix, Sainte-Anne-de-Sabrevois, Saint-Georges-de-Clarenceville and Saint-Armand. According to the Meteorological Service of Canada, the flooding was one of the most important meteorological events in Canada in 2011(PSC, 2012).

Applications/Solutions

Within the framework of the international Committee on Satellite Earth Observation (CEOS), the Canadian Space Agency (CSA) is collaborating with NASA on various projects helping to prevent, manage and respond to natural disasters. This partnership offers the opportunity for CSA and NASA to share satellite data acquired by several Canadian and American satellites for scientific and operational purposes. These include the development of models, systems and procedures geared toward flood forecasting and response. During the spring flood along the Richelieu River, Quebec, in May 2011, CSA asked colleagues from NASA to acquire satellite images with the EO-1/ALI sensor (Earth Observation-1/Advanced Land Imager) in order to capture the flood extent. The ALI images complement an entire time series of RADARSAT-2 images acquired by the Canadian Government over the affected region, providing additional details thanks to the multi-spectral and pan-chromatic imaging capabilities of ALI. The satellite imagery gives the opportunity to monitor the spatial extent of the flooded areas and assist authorities on the ground with their flood response measures.

Emergency Management is a core responsibility of the Government of Canada and a collective responsibility of all federal government institutions (PSC, 2012). This is why Public Safety Canada (PSC) is taking steps to promote a coordinated approach and more uniform structure to the management of emergencies by providing guidance to federal government institutions on how to develop an emergency management plan. A coordinated approach to emergency management planning will strengthen the Government of Canada’s capacity to prevent, protect against, respond to and recover from major disasters and other emergencies.

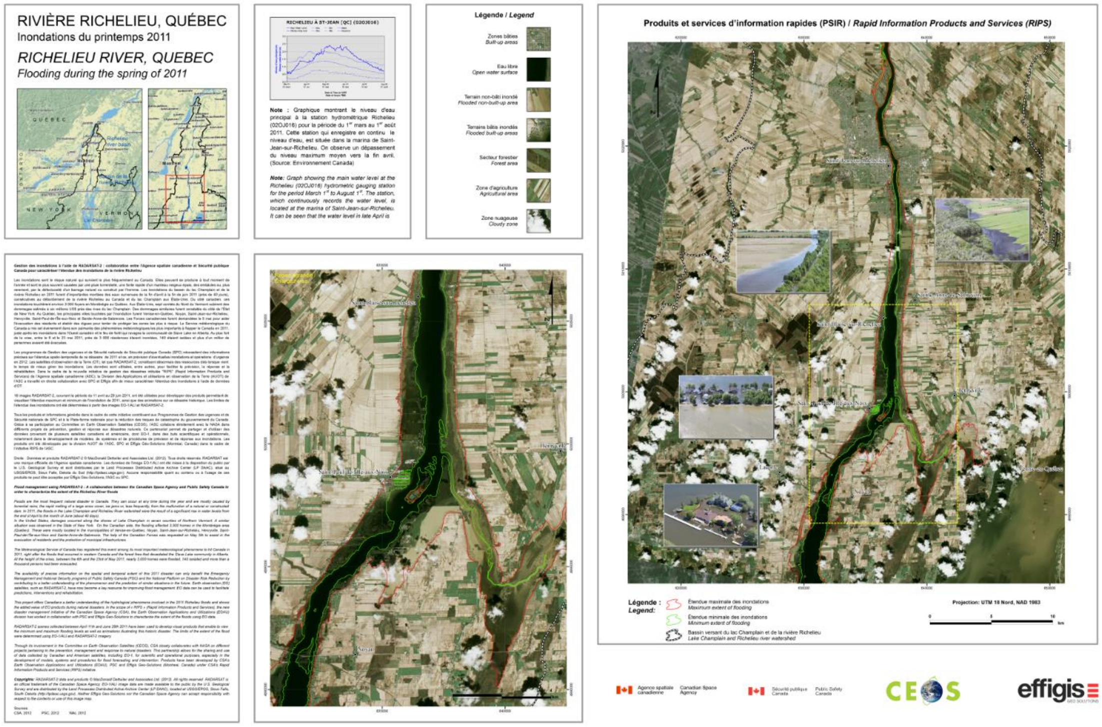
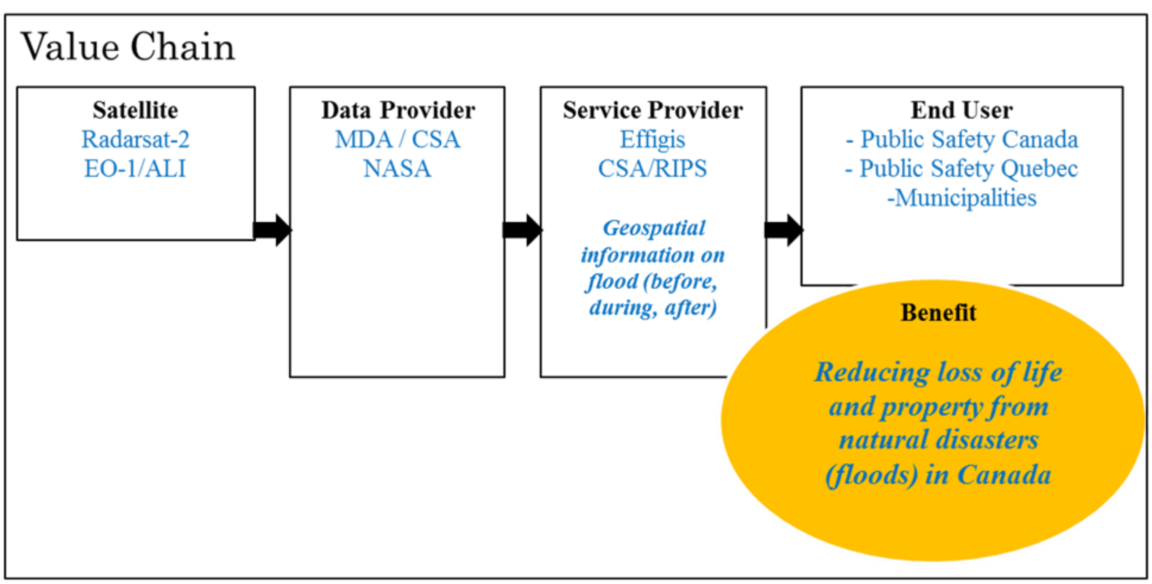


Fig 1: This product reveals the different content of the ALI and RADARSAT-2 (flood extent in red) images taken along the northern portions of Lake Champlain in the United States and the severely flooded banks of the Richelieu River in Quebec, Canada. Credits: CSA, MDA, NASA, USGS, Effigis.

Through the new Rapid Information Products and Services (RIPS) initiative, the CSA's Earth Observation Applications and Utilizations (EOAU) Division, in close cooperation with Public Safety Canada (PSC) and Effigis, developed flood maps and geo-information products derived from RADARSAT-2 and EO-1/ALI data. A time series animation of 16 RADARSAT-2 SAR images of the most severely flooded areas along the Richelieu River was also developed by the project team. Samples of this series of RADARSAT-2 images are shown in Figure 3.2-2.

Value Chain



Outcomes/Benefits: Reducing Loss of Life and Property from Natural Disasters (floods) in Canada

The flood-related information derived from satellite imagery served geospatial information needs and requirements by users (federal, provincial organizations), notably PSC, the Sécurité Civile du Québec and Québec municipalities. Impacts: flood information products are used for federal coordination efforts and the post situation analysis. EO satellites such as RADARSAT-2 have become key resources when the need for more stringent flood management arises. This initiative supports (1) PSC emergency management operations and activities at the regional level; (2) federal institutions in meeting their responsibilities under the Emergency Management Act to prepare and maintain mandate-specific emergency management plans; (3) Canada's National Plateform for Disaster Risk Reduction (DRR) to build multi-stakeholder coordinated leadership in Disaster Risk Reduction; (4) the United Nations International Strategy for Disaster Reduction's Hyogo Framework for Action.

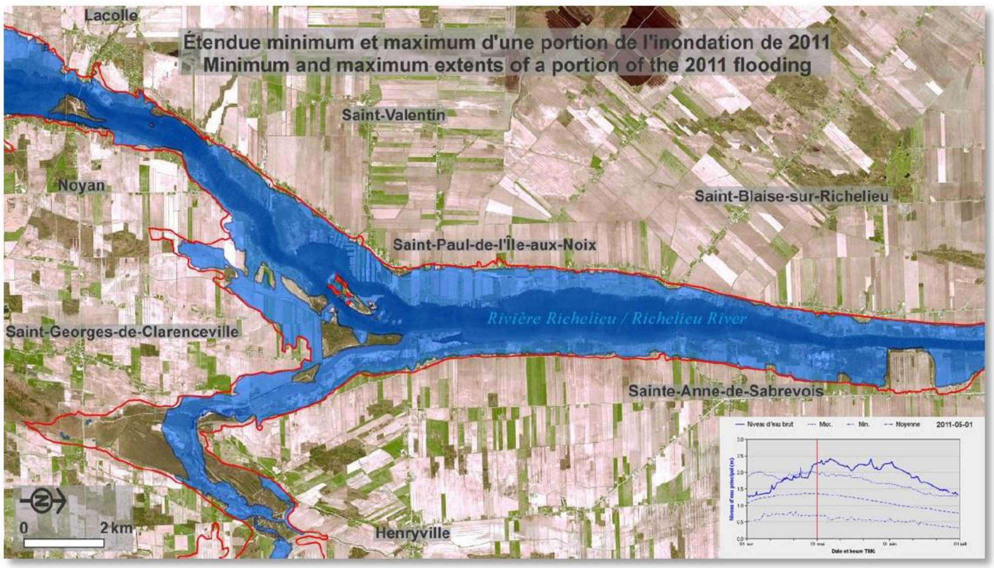


Fig 2: Exemple of the animation made with the EO-1 & 16 RADARSAT-2 images. The maximum flood extent is shown in red. Credits: CSA, MDA, NASA, USGS, Effigis.

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MSP: www.securitepublique.gouv.qc.ca
PS: www.publicsafety.gc.ca/index-eng.aspx
NASA: http://www.nasa.gov/
Effigis: http://effigis.com/
NRCAN: www.nrcan.gc.ca

Reference

CSA (2012) RIPS: Flood Richelieu. Final Report. Saint-Hubert, 7p.

Americas – Disaster

Energy and Earth Observation Applications: Assessment and Mitigation of Geohazard Sites Along Strategic Transportation and Energy Corridors in Canada

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Descriptions

Over the last decade, the Canadian Space Agency (CSA) has been involved in the support of scientific initiatives, demonstration projects and operational implementation activities related to disasters and security management. Through the Government Related Initiatives Program (GRIP), the CSA and its public and private sector partners have fostered the development of Earth Observation (EO) information and services related to geohazards. This article highlights the success of the CSA and its partners from Natural Resources Canada and the Alberta Geological Survey, which developed new InSAR methods and techniques. These techniques demonstrate the potential of RADARSAT-1 and 2 to improve the assessment and mitigation of geohazards, such as ground subsidence and landslides, in Canada. This initiative is directly linked with the Global Earth Observation System of Systems (GEOSS) Implementation Plan and contributes to the GEO Work Plan.

Challenges

The Canadian Space Agency (CSA) understands the tremendous role and value that space-based Earth Observation (EO) systems and information have regarding disaster management, mitigation, response and its environmental and socio-economic impacts and benefits. Security, which includes disaster and geohazard management, is one of the three pillars of the CSA EO strategy. Our vision is for Canada to be an internationally recognized leader in the development and use of EO applications in support of national priorities. We recognize that threats to our environment are a clear danger in the context of climate change and we believe that action is needed now to ensure our quality of life, particularly for those most vulnerable to health threats from environmental and technological disasters. The security area is not only defined by disaster management, but by a wide variety of events that could affect the environment and health of the population. Not being prepared is costly. In the past, Canada has experienced multiple catastrophic events (i.e. Spanish flu pandemic, Tseax river cone eruption, Saint-Jean-Vianney mudslide, Red River floods, Okanagan valley fires, Ocean Ranger oil platform sinking, etc.). In 1998, the ice storm in Quebec cost the country $1.2 billion and the droughts of the last decade in our prairies cost Canada's economy over $3 billion. We now can add glacier and permafrost melting in the Canadian Arctic to the list of hazards which are expected to have a negative impact on our environment and economy. Our need for EO applications to predict severe environmental and man-made disasters has never been greater. As technologies mature, they yield more benefits and applications. Canada's government understands how crucial science, technologies and their applications are to building a strong economy. This article gives an example of one of the Canadian EO success stories in geohazard monitoring using InSAR technologies.

Fig 1: Landslide and soil instability in Alberta Canada. Source: AGS/NRCAN.

This initiative is directly linked with the Global Earth Observation System of System (GEOSS) Implementation Plan (section 4.1.1. Disasters: loss of life and property from natural and human-induced disasters) and contributes to the GEO Work Plans (i.e. DI-06-03: Integration of InSAR Technology). It also supports Canadian government priorities to secure our energy future, preserve Canada's environment, keep Canadians safe, contribute to global security and build stronger institutions. The CSA, through the GRIP Program, has worked with the Canada Center for Remote Sensing (CCRS) on a project involving the application of InSAR technology to map and characterize ground hazards in Western Canada. The project involves characterizing subsidence over abandoned coal mine workings, movements along active faults and slope movement for landslides in the Rocky Mountains, Alberta Plains and in Canada's arctic. All sites chosen for this study are located along strategic transportation and energy corridors. This project is not only meant to demonstrate the application of InSAR monitoring along Canada strategic energy and transportation corridors but also to build InSAR monitoring capacity within NRCAN's Earth sciences sector and the Alberta Geological Survey, part of the Alberta Energy Regulator. InSAR deformation monitoring as a routine hazard assessment method is in its early stage of development in Canada. There is a need to develop convincing case studies at difficult high-risk sites that will be used to establish an InSAR monitoring baseline for continuous integrated monitoring along Canada's strategic transportation and energy corridors.

Applications/Solutions

The project objectives are: (1) to produce InSAR products of active landslide areas along strategic transportation and energy corridors, and of selective seismically active areas in Canada; (2) produce an InSAR image archive of selected active geohazard areas in Canada. The areas selected for this investigation include: large and small active vegetated landslides along strategic energy and transportation corridors (Trans Canada Highway in the Rockies, Mackenzie Valley Pipeline, the Town of Peace River/Highway 2 Corridor, and Highway 49 Crossing of the Little Smoky Highway River, Alberta);

and the seismically active Leach River fault affecting the city of Victoria. Multi-temporal InSAR maps have provided an input for modeling the seasonal motion behaviour and predictability of these hazard sites in order to develop the mitigation strategies for these high-risk areas. As some of these geohazard sites are vegetated and wet, which results in non coherent targets, the installation of corner reflectors as coherent targets is a significant part of this integrated InSAR monitoring development strategy. The results of the project are: the successful integration of field-installed corner reflector technology and InSAR analysis to monitor gradual motion at high risk geohazard sites.

Crowsnest Pass/Highway 3, Alberta

The Crowsnest Pass in Southwestern Alberta is an important trade corridor. Both provincial Highway 3 and CP Rail transport people and goods from eastern Canada into British Columbia and ports on the Pacific Ocean. Much of the settlement in the corridor occurred in the early 1900s when coal mining in the region led to many decades of mining of underground coal seams in the area. Perhaps the most memorable event from this time period was the 1903 Frank Slide, Canada's deadliest landslide which killed over 80 people when it buried a portion of the mining town of Frank. The legacy of the coal mining rush in the region is a series of abandoned underground coal mines that underlay modern-day infrastructure and urban development.

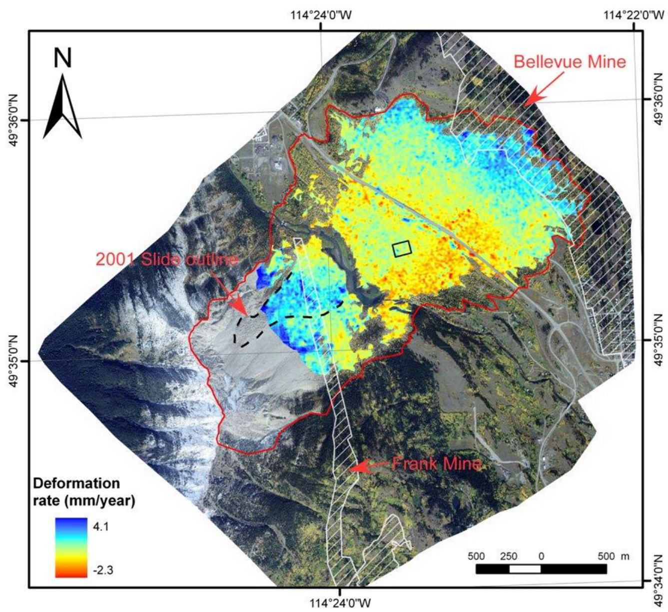


Fig 2: Crowsnest Pass. In conjunction with studies being undertaken by the Alberta Geological Survey (AGS) on unstable slopes on Turtle Mountain, site of the Frank Slide, InSAR technology was utilized to map subsidence of the ground overlying the abandoned coal mine workings. By utilizing Radarsat-1 Fine beam data from fall 2004 to summer 2006, many thousands of coherent targets were identified above the mines and a map was produced showing the rates and patterns of deformations.

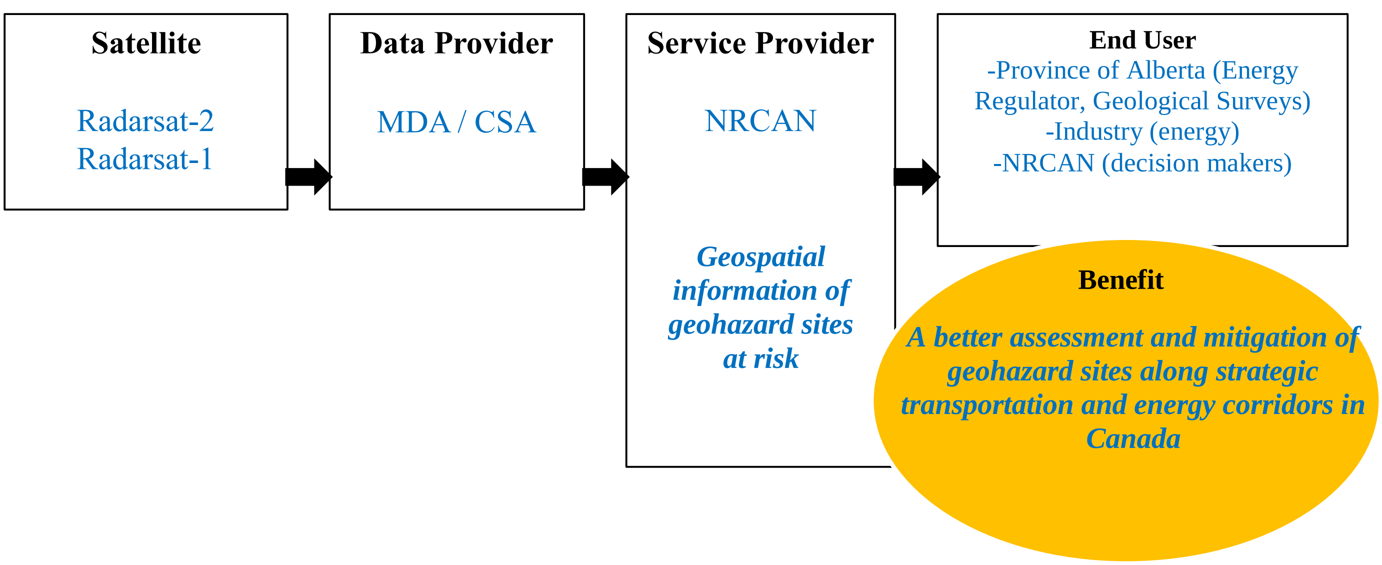
Highway 49/Little Smoky River Crossing, Alberta

The Little Smoky River bridge and approach roads were completed in 1957. Since that time there has been ongoing valley slope instability that has impacted the highway and west bridge abutment, resulting in ongoing costly maintenance issues. As the repairs to the highway, a major trade route for north western Alberta, cost the Alberta government many hundreds of thousands of dollars per year, studies are underway to provide a viable long-term solution to mitigate the impacts of this slope movement on the highway. Options were considered for stabilization of the slide, and for highway realignment away from the area of greatest instability. All options are costly and limited information is available to confirm the viability of each option due to the very deep slide plane. As there are significant decisions to be made by Alberta Transportation (AT) with very little data on the valley walls, the use of InSAR with corner reflectors was considered to be an exciting option for acquiring a wide array of data. In October 2006, an array of eighteen small areas was cleared of vegetation and corner reflectors were installed by personnel from AGS, AT, CCRS and the University of Alberta. Each reflector, in the shape of a four-sided pyramid, was aimed so that the large open end was oriented to be directly perpendicular to the direction of radar pulses emitted from the orbiting Radarsat-1 satellite, which obtains results over the site every 24 days. The reflectors are used to provide an amplified signal back to the satellite, when compared to the heavily vegetated surrounding areas. As of November 2008, a set of 28 readings was obtained for each reflector and the results processed at the CCRS offices in Ottawa. The processed results have been taken by AGS Geological Hazards staff and compared against conventional geotechnical instrumentation on the site (slope inclinometers) and visual interpretations of the complex slope movements on the site. A set of GPS readings was also taken by AGS, AT and CCRS staff during the summer of 2008. Results were passed on to AT to aid in making future decisions as to managing landslide risks along the highway corridor in the future.

Highway 2 Corridor/Town of Peace River, Alberta

The Town of Peace River is located along the floodplain and valley walls of the Peace River in north western Alberta. Although aesthetically pleasing, a large portion of its urban footprint and transportation infrastructure is built either on the flood plain or on the unstable valley walls of the Peace River Valley. Beginning in 2006, a study was initiated to characterize the extent, rates and style of the large scale landslides in and around the municipality and assess their impacts on the highways, gas transmission and distribution pipeline networks, and urban infrastructure. As the glacial history is complex and landslides originate in various settings, the initial components of the study are the development of a three dimensional geological model and completion of an inventory of documented landslides in order to determine logical groupings for landslide types. In order to develop an understanding of the historical movement rates and extents, an InSAR study will review deformation trends between 1992 and 2006 and compare these results to deformations recorded using conventional instrumentation over this time period. This work is currently underway and involves collaboration between AGS, CCRS and the University of Tromsø (Norway). It is expected that the results of the InSAR will be a key component of the hazard analysis and aid in decision making as to mitigation and future land use planning.

Value Chain (including end-users)



Outcomes/Benefits: A better assessment and mitigation of geohazard sites along strategic transportation and energy corridors in Canada

It is clear from these examples and the published results, RADARSAT InSAR monitoring of selected high risk landslide sites affecting transportation routes is providing convincing case studies and guidelines for other users to apply. The Alberta Geological Survey and Natural Resource Canada have increased their uses of InSAR techniques, which have now become routine in monitoring high – risk sites. A large archive of InSAR data for these sites is now available, and is used for future long term integrated monitoring of these unstable slopes that are affecting our transportation routes and energy corridors.

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Americas – Health

Supporting Early Warnings of Infectious Diseases with New Global Risk Maps

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Key Takeaway

Satellite-based risk maps of viral hemorrhagic fevers help health officials anticipate outbreaks and take timely actions for disease control and prevention.

Article

The World Health Organization and nations' health officials can access global risk maps of infectious diseases associated with viral hemorrhagic fevers on a biweekly basis. Applying data on environmental conditions derived from TRMM and other satellites, the risk maps support early warnings of outbreaks and aid health officials' preparedness.

Viral hemorrhagic fevers—such as Rift Valley fever, Marburg hemorrhagic fever, and Ebola—involve bleeding disorders and elevated body temperatures. The diseases affect humans and are especially deadly for livestock. Agents of transmission include types of insects and bats, and inter-annual climate variability and ecological dynamics influence spatial and temporal factors in disease outbreaks. For instance, heavy rainfall can create breeding sites for mass hatchings of mosquitoes that carry the Rift Valley fever virus.

Earth-observing satellites collect data on surface temperature, precipitation, vegetation, and other environmental parameters associated with the diseases' hosts and vectors. A NASA team applied and tested combinations of these data products that correlated with historical records of outbreaks. The risk maps show the probability of environmental patterns related to outbreaks at a given time and place.

Available every two weeks beginning in 2012, the risk maps offer a warning of up to nine weeks prior to an outbreak. Such lead times facilitate timely disease control and prevention, such as collection of surveillance data and preparations to mitigate impact of the diseases. For example, in days preceding outbreaks, public health officials in affected countries can pursue WHO-directed actions such as public education campaigns to mitigate the risks of infection. WHO can coordinate with national institutions to have early warning information, and it can issue international travel guidance.

"WHO supports development of the [viral hemorrhagic fever] forecasting efforts that improve capacities of existing models to increase the period between a forecasting alert and an outbreak onset. The NASA risk maps are an important element towards this end," said Pierre Formenty, lead of the WHO team for emerging and epidemic zoonotic diseases.

Mapping Risks

WHO, the U.S. Department of Defense (DoD), and the USDA Agricultural Research Service actively participated as technical partners and end-user representatives in the project. The team analyzed multiple factors to identify patterns that correlated with outbreaks. The team used TRMM precipitation data, land surface temperature from Terra and Aqua, SRTM topography, and vegetation indices from Terra, Aqua, and NOAA's AVHRR satellite sensor. Web mapping services supported the display of data and maps through Google Maps, Google Earth, Virtual Earth, and other platforms. Overall, the project proved the feasibility of applying satellite observations to create risk maps, leading to routine production of the maps. Global Precipitation Mission products replace TRMM.

The early warnings enabled by the risk maps also aid livestock management. Officials of veterinary services can allocate resources to FAO guidance such as immunization of livestock and spreading of larvicide at breeding grounds prior to outbreaks.

"The [project's] risk map is a good alert forecasting tool of potential outbreaks [of Rift Valley fever]," said Ken Linthicum, director of the USDA Center for Medical, Agricultural, and Veterinary Entomology.

Broadening Applications

The project team expanded its epidemiological model to other regions and diseases with maps in 2012. The team assessed hantavirus with field data from Ukraine as well as Crimean-Congo hemorrhagic fever with field data from Turkey. In both cases, the project modeled the capacity dynamics of the vectors (rodents and ticks, respectively) as a function of temperature, precipitation, and vegetation.

The team also partnered with DoD health officials for advanced awareness of developing infectious disease threats, involving DoD's Global Emerging Infections Surveillance and Response System. Information from the risk maps can inform decisions from the use of tick repellant to the mobilization of medical personnel.

Captain Clara Witt, U.S. Public Health Service Commissioned Corps, and senior scientist, DoD Center for Disaster and Humanitarian Assistance Medicine, said of the risk reporting of the project's maps: "It's the 'next generation' of thinking about how remote sensing technology can be used to identify and detect the pre-factors for conditions that lead to disease emergence."

Increasing Capabilities

The maps represent new capabilities for early warnings of outbreaks, especially in areas like sub-Saharan Africa, allowing action prior to the first symptoms. WHO, FAO, and various countries' ministries of health and agriculture have begun using the risk maps and related predictions to prepare for and mitigate the effects of outbreaks.

Increasing awareness, acceptance, and use of the risk maps are key challenges still in work. In July 2012, maps indicated risks of Rift Valley fever in portions of Africa. They showed higher-risk conditions moving west from Mali to Mauritania over the summer. The first human cases appeared in mid-September, and the Mauritanian Ministry of Health declared an outbreak in early October.

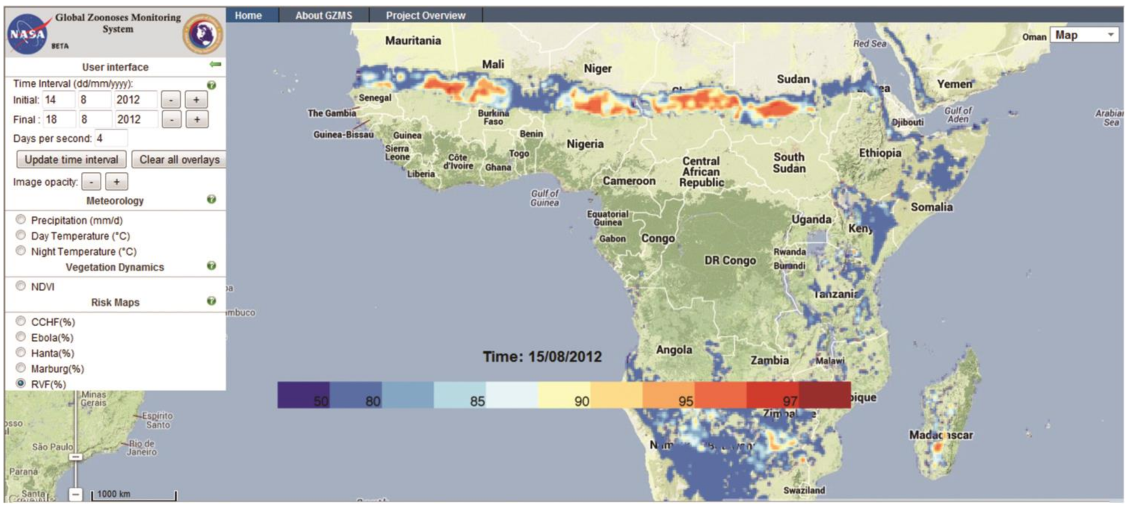
The risk maps are available to health and veterinary officials and for others at http://rs4gzm.org/gzm. NASA is pursuing risk map distribution through the SERVIR project. SERVIR networks raise awareness of the risk maps, supporting surveillance and control activities and efforts to reduce effects on humans and livestock. Among other stakeholders, the team will broaden awareness of its findings and risk maps to more potential end users through journals of zoonotic diseases such as publications of the Centers for Disease Control and Prevention.

To learn more, contact Jorge Pinzon. jorge.e.pinzon@nasa.gov.

Key Quote

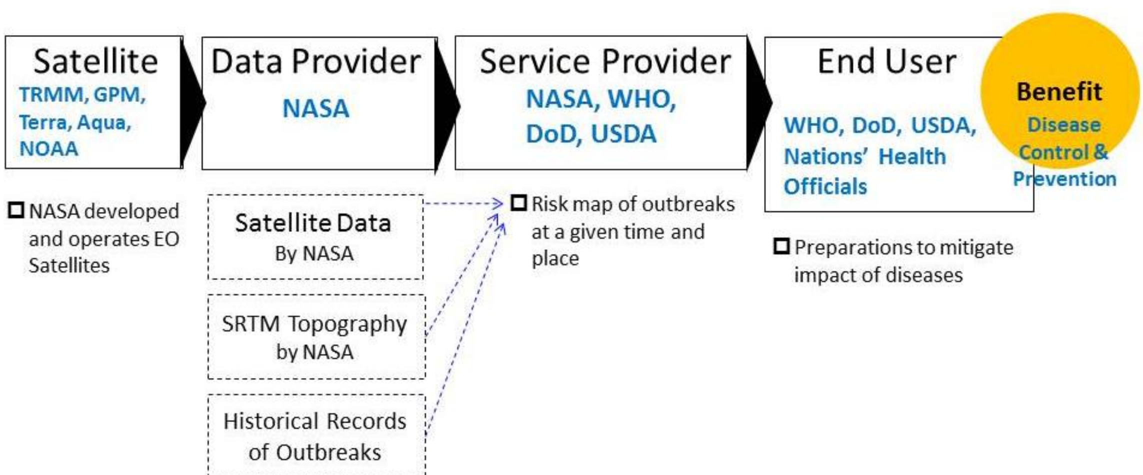
"WHO supports development of the [viral hemorrhagic fever] forecasting efforts that improve capacities of existing models to increase the period between a forecasting alert and an outbreak onset. The NASA risk maps are an important element towards this end."   - Pierre Formenty, World Health Organization

Images



An example of a risk map for Rift Valley fever in Africa from mid-August 2012. Warmer colors indicate higher probability of risk, based on environmental factors related to disease emergence.
Value Chain

Value Chain



Americas – Health

Public Health and Earth Observation Applications: Risk Assessment of Infectious Diseases in Canada

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Descriptions

In the UN resolution entitled "The Space Millennium: Vienna Declaration on Space and Human Development", the participating States recognized the importance of space science and space applications for progress in fundamental knowledge of the universe such as health, environmental monitoring, management of natural resources, disaster management as well as the major contribution that space science and applications make to the well-being of humanity and specifically to economic, social and cultural development. The States also identified an action "to improve public health"[1].

In the context of the prevention and control of various emerging diseases and chronic conditions, the management of key public health issues requires solid evidence-based knowledge. Earth observation (EO) images can provide a contribution by deriving data from population and environmental determinants of health over the large Canadian territory. The Public Health Agency of Canada (PHAC) has recently completed a successful project via the Canadian Space Agency (CSA) Government Related Initiatives Program (GRIP). To assess the average contamination level of recreational beaches in southern Quebec, Earth Observation (EO)-based methodologies and measures were introduced into statistical models. The initiatives allowed the PHAC and their partners to identify farming and urban activities as having a major influence on the microbiological quality of recreational waters in terms of fecal contamination levels and possible foodborne pathogens and were able to identify beaches at high risk of contamination.

Also, risk mapping for vector-borne and emerging infectious diseases, and intelligence synthesis for emergency preparedness were identified by PHAC as areas needing immediate attention. In most of these cases, EO is used to supplement current process and data; in some cases, it is foreseen as being able to replace some of our current requirements for extensive field data sampling. The public health experts in Canada are starting to use EO images in a systematic way.

Challenges

In today's fast changing world, public health is facing many challenges in the prevention and the control of various emerging diseases and chronic conditions. Many of these health conditions arise from a sustained interaction between evolving human populations (change in demography, migrations and travels) and the environment. Zoonotic diseases are infections that can be acquired through contact between animals and humans. According to World Health Organization, at least 61 percent of all human pathogens are zoonotic, and have represented 75 percent of all emerging pathogens during the past decade [2, 3]. The emergence of zoonotic diseases, such as avian influenza (H5N1, H1N1, H7N9), new coronavirus (MERS-Cov), the West Nile virus, Lyme disease, Ebola virus, and malaria, is ranking high among the public health issues that the World Health Organization (WHO), the World Organization for Animal Health (OIE) as well as numerous national organizations, companies and universities are attempting to address. In order to mitigate these types of health risks they are adopting a multi-sectorial approach of collaboration known as the One Health approach [4].

The understanding of inherent mechanisms of infectious diseases transmission is challenged by global and environmental changes. Governments and the public have a need of a better understanding of ecosystems and their health. Also, evidence-based knowledge is required for the management of key public health issues. However, obtaining the necessary data on environmental health determinants constitutes a major challenge because of the large territory to cover. In fact, obtaining those data from field campaigns requires an unreasonable amount of resources. Fortunately, this is where Earth Observation (EO) images can step in and provide a contribution. Data from population or environmental determinants may be derived from EO images, particularly in regard to the impact of natural or anthropogenic ecosystem changes. Operationally, EO images have demonstrated their usefulness in the prevention and control of persistent and new diseases. They provide important wide and near-range geo-spatial information that can fuel research, improve monitoring and risk assessment for public health and guide intervention measures and disease control; they can also be useful in the preparation and response to emergencies; and they can help improve health security by reducing risks concerning the introduction of infectious disease (e.g., new avian influenza). Thus, the EO satellite data and products can be advantageous in several ways, including availability of different scales and wide-spread coverage, monitoring capability and rapid acquisition, costs effectiveness, as well as data quality and data continuity.

In Canada, EO has an opportunity to enhance public health-related knowledge and capacity to investigate diseases across a vast territory of more than 10 million square kilometers, including in the North. In doing so, the Canadian government can rely on access to RADARSAT-2 images through the CSA. Since the 1990s, space-based EO technologies have been integrated into epidemiology and public health domains [5,6]. EO can play an important role in the decision-making process in public health, and the recent methodological approach resulting from this integration is valued by experts working on emerging and re-emerging infectious diseases in Canada. This approach is now known as tele-epidemiology.

Applications/Solutions

Tele-epidemiology is a recent discipline combining epidemiology and space technology applied to human and animal health. It allows the spatial and the temporal study of events affecting the health or disease processes. It involves the monitoring and the assessment of the distribution of animal and human illnesses strongly linked to climatic and environmental variations [5].

Tele-epidemiology is particularly interesting for the study and monitoring of emerging and re-emerging vector-borne diseases, since these involve the transmission of viruses or bacteria by vectors (insects, invertebrates, and mammals) whose population and movements are often influenced by environmental characteristics. Tele-epidemiology is then used to model the spread of disease and map the associated risks from vector-ecology knowledge affected by and following environmental changes (e.g., Lyme, Malaria, Eastern Equine Encephalitis, etc.). The analysis of EO images allows rapid identification of specific sites that can be used for field validation of the presence of a vector infected by a disease and the enhancement of active disease surveillance, as is the case for Lyme disease in Canada [6].

Tele-epidemiology also has recently found usefulness in the study of bacteria contaminating lakes and thus representing a risk to bathers. PHAC has recently completed a project through the CSA Government Related Initiatives Program (GRIP) to assess the benefit and usefulness of satellite data for monitoring and managing foodborne pathogens associated with recreational waters. EO-based methods and measurements were integrated into statistical models to assess the average contamination level of recreational beaches in southern Quebec [10, 12]. Data from various EO satellites, such as RADARSAT-2, Envisat/MERIS, Landsat-5, MODIS, AVHRR, SPOT-5, GeoEye-1 and Worldview-2 were used in order to better characterize the surrounding land use and environmental determinants. The project allowed PHAC to identify farming and urban activities as having the main influence on the microbiological quality of recreational waters in terms of fecal contamination levels and possible foodborne pathogens [7, 8].

Since 2000, the Earth Observation Applications and Utilizations division of the CSA has managed EO-specific programs and projects. Efforts to date have focused on the utilization of radar and optical EO data, and on integrating the satellite data into environmental information systems related to water, agriculture, energy, climate, weather, ecosystems, biodiversity, security, and others. The CSA has worked with other government departments, with industry and with research institutions across Canada to develop and implement a number of health- and environment-related monitoring activities.

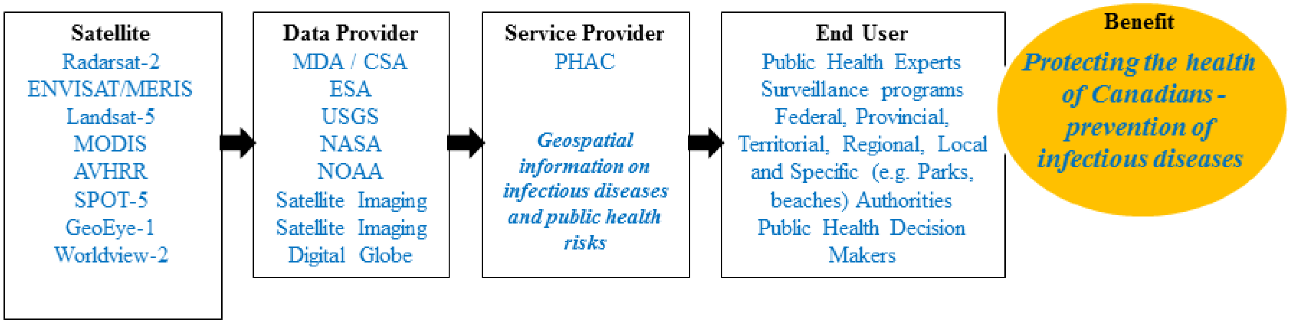
PHAC and the health community are exploring new initiatives with national and international partners, such as the CSA, the World Health Organization (WHO) and the United Nations (UN). These partnerships are advancing the application of EO, monitoring and forecasting systems to health decision-making processes. In particular, they provide a solid base for the (1) development of tele-epidemiology EO applications (i.e., infectious and vector-borne diseases, ecology and behavior, water and air quality); (2) understanding of ecosystems changes that can lead to the emergence of diseases; and (3) integration and fusion of geospatial, medical and socio-economic data for health care decision support systems [9].

Information is at the core of public health, as it can lead to better decision-making in the prevention and control of diseases. Although EO images are widely available, there is further investment required to produce results or spatial information timely, repeatedly and accurately. In Canada, the public health sector is starting to utilize and exploit EO images in a more systematic way. Research and development of tele-epidemiology requires expert training, education, and knowledge transfer from science to operations. In addition, the enhanced development of risk-assessment models and the early warning of infectious diseases by tele-epidemiology could have an impact on current surveillance methods, intervention and controls and will call for adoption of this new approach.

Global and environmental changes challenge our understanding of the inherent mechanisms of zoonotic disease transmission. A better understanding of ecosystems and their health is needed. The EO images offer the opportunity to gather essential information on environmental determinants of health, from coast-to-coast including the Canadian Northern region and other remote communities. Several new EO satellite missions will be launched in the coming years. Satellite systems like the RADARSAT Constellation, the European Sentinels, SMAP, and other future sources of information will increase the benefits for the health sector.

CSA's EO applications programs have focused on user needs and helped facilitate the implementation of tele-epidemiology activities at PHAC, fitting well within a One Health approach promoted internationally. In a world where satellite-based EO play a key role in the stewardship of land, ocean and atmospheric features, it could do the same by helping to manage emerging public health issues at the interface between humans, animals and the environment.

Value Chain (including end-users)



Outcomes/Benefits: Protecting the health of Canadians (prevention of infectious disease)

The prevention and control of persistent and emerging infectious diseases require solid evidence-based knowledge from population and environmental determinants of health. EO offers innovative datasets based on constant evolving geospatial approaches and applications. EO improves our knowledge on diseases by addressing the need for new sources of evidence-based data and intelligence on the determinants of health and their interactions. For example, the use of geospatial technologies and EO images is useful to characterize the spatial and temporal variability of environmental determinants involved in microbial contamination of recreational lakes. Even if bacteria are invisible to the human eye and to satellites, it is possible from space to characterize the sources of contamination and the determinants involved in transport and transmission (agriculture, urban areas, etc.). This risk assessment is feasible with the use of geospatial tools and through the integration of factors involved in microbial contamination, providing the information necessary for decision-making, management of public health surveillance, and control of diseases [8, 10].

EO information provide new benefits and services : (1) enhance current control and prevention programs designed for protecting Canadians against infectious diseases providing up-to-date environmental data and land features pertinent for public health actions such as risk mapping, risk communication and identification of vulnerable populations; (2) EO images contribute to the epidemiological intelligence to support decision by enhancing the current understanding of the spatial progression and speed of distribution of vectors, direction of progression, seasonality, impact on climate change on vector-borne diseases emergence in the coming years; (3) provide wide near-range of geo-spatial information that can guide intervention measures or preparation and response to emergencies; can help improve health security for reducing risk concerning the introduction of human pathogens and toxins in the environment; (4) contributes to public health response mechanisms with early warning detection of transboundary infectious diseases; (5) enhances public health-related knowledge and capacity to investigate diseases across a vast territory of more than 10 millions square kilometers, including the North. It can play a role in decision-making process and the recent methodological approach is valued by experts working on emerging and re-emerging infectious diseases in Canada.

The core benefit of EO is to move one step ahead on an agenda of gaining tactical advantage and efficiency by investing in a useful technology applicable to a whole range of public health issues, both in peace and in peak times. EO is solid, sustainable and innovative avenue enabling better decision making at different authoritative levels and increasing the efficiency of many preventive, preparedness and response actions.

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Agence de la santé publique du Canada   Public Health Agency of Canada

CSA ASC

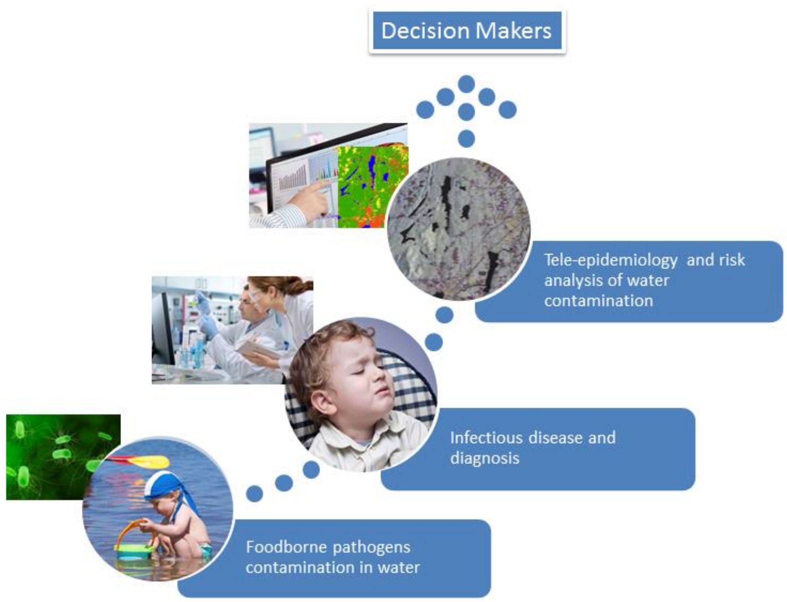

Fig 1: Tracking foodborne pathogens contamination in water from the source with EO images. Source: PHAC.

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Americas – Health

Improving Air Quality Information with Satellite Data

Phil Dickerson, U.S. Environmental Protection Agency
John White, U.S. Environmental Protection Agency
John Haynes, NASA Earth Science
William Corley, Booz Allen Hamilton
Lawrence Friedl, NASA Earth Science

Key Takeaway

The U.S. Environmental Protection Agency integrated Aura, Aqua, and Terra data into the AirNow air-quality decision support system, which health officials use to alert the public about hazardous pollution.
Article

Awareness of local air quality conditions informs choices and actions for many people, from parents of asthmatic children, to athletes and outdoor enthusiasts, to elder care providers, to air quality managers. CDC recommends people take steps to limit breathing air with high levels of particle pollution, as it can contribute to heart problems, asthma symptoms, lung disease, and other health complications. How do people know the conditions in their locality?

The U.S. Environmental Protection Agency (EPA), along with state, local, tribal, and federal agencies, developed the AirNow system to provide nationwide air quality information to the public. AirNow includes real-time maps of air quality as well as air quality forecasts. EPA and Sonoma Technology, Inc., through a NASA-sponsored applications project, integrated data from Aura, Terra, Aqua, and other sources into AirNow, increasing the accuracy of fine particulate matter (PM2.5) information.

The satellite observations can support estimates of surface PM2.5 concentrations. "This [the satellite data] gives you more data than our monitoring network. You can't ever have enough data," noted James Kelly, program manager at the Georgia Environmental Protection Division.

Expanding Data Coverage

The project complements the coverage of the U.S. surface monitoring network, which has most of its monitors near populated areas. As a result, accuracy may be low in areas far from monitors. More than 42 million people reside farther than 40 kilometers from the nearest PM2.5 ground-based monitor and therefore have little or possibly inaccurate information about their near-real-time exposure to PM2.5.

"Right now we've got a grid for the state and we've got . . . 11 monitors in Atlanta," said Kelly. "And they're trying to project [air quality in] 20 counties with 11 data points."

To support broader coverage, the project team created the AirNow Satellite Data Processor (ASDP) to make operational use of satellite data products, including aerosol optical depth data from MODIS on Terra and Aqua and nitrogen dioxide data from Aura/OMI.

The system fuses the satellite-based estimates of surface PM2.5 concentrations with routine, ground-based measurements. This data fusion can fill in the monitoring gaps to improve estimates of surface PM2.5 concentrations in unmonitored areas as well as supplement monitor-dense areas. The project reduced relative errors in estimating surface PM2.5 from satellite data to less than 50 percent for most of North America. In 2013, EPA integrated ASDP into the AirNow framework.

"The [ground] monitors are really, really accurate at the spot that they're at. But then how do you spread that out across a large area? The big wide open spaces get even more pronounced when you go further west," commented Darren Palmer, EPA lead for air monitoring and quality in the southeast U.S. "But even in the middle between Atlanta and Columbus there's a big [gap where] you don't have a great idea of what the actual air quality is. And the satellite can help capture that."

There are many events that create particulate matter, such as wildfires, which often occur in sparsely populated areas yet affect largely populated areas with downwind smoke.

"I see the satellite data as being very useful. I think it's great for forecasting and, to me, looking to try and find are there other areas that we should potentially be monitoring," said Gordon Pierce, technical services program manager at the Colorado Department of Public Health and Environment. "We don't have the resources to monitor everywhere in the state to see if there's an issue, especially as conditions change over time."

Overall, EPA expanded AirNow coverage to reach millions of people not adequately covered by the network of ground-based monitors. EPA improved the information available so people can take protective action to avoid exposure to high PM2.5 levels and reduce health risks.

"What I hope can come from [the satellite products] is the ability to look at more data analysis to allow us to anticipate health impacts, particularly as it relates to emergency room visits, doctor visits, [and] provider visits, related to asthma and upper respiratory illness," said Bert Malone, deputy director of the City of Kansas City, Missouri, Health Department.

Providing Socioeconomic Benefits

An economic impact analysis of the project examined the cost savings of using satellite data instead of installing new monitors to provide air quality information for public health decisions to populations in currently unmonitored locations. The study found that the addition of satellite data could provide daily PM2.5 information to 82 percent of the people living in currently unmonitored locations (approximately 15 million people); the study estimated that the capability represents a value of about $26 million.

The analysis also examined the non-monetary public value and community-level benefits. Interviewees reported reduced adverse health impacts on sensitive populations resulting from more accurate air pollution warnings and health alerts; increased public viewing and understanding of air quality maps on AirNow because of greatly increased spatial coverage; increased media use of AirNow air quality maps resulting from expanded geographic coverage; and better communication with the public about the spatial distribution of air pollution, especially in sparsely monitored areas, resulting in better public understanding of these issues.

The project team included representatives from EPA, NASA, NOAA, Dalhousie University, and Sonoma Technology, Inc.

To learn more about AirNow and the project, visit http://www.airnow.gov and http://asdp.airnowtech.org.

The socioeconomic impact report is available at: http://www.ctg.albany.edu/publications/reports/sti_finalreport .

Key Quote

"This is the best tool I have seen so far that integrates satellite data with information from ground monitors."

- Cassie McMahon, Minnesota Pollution Control Agency

Images

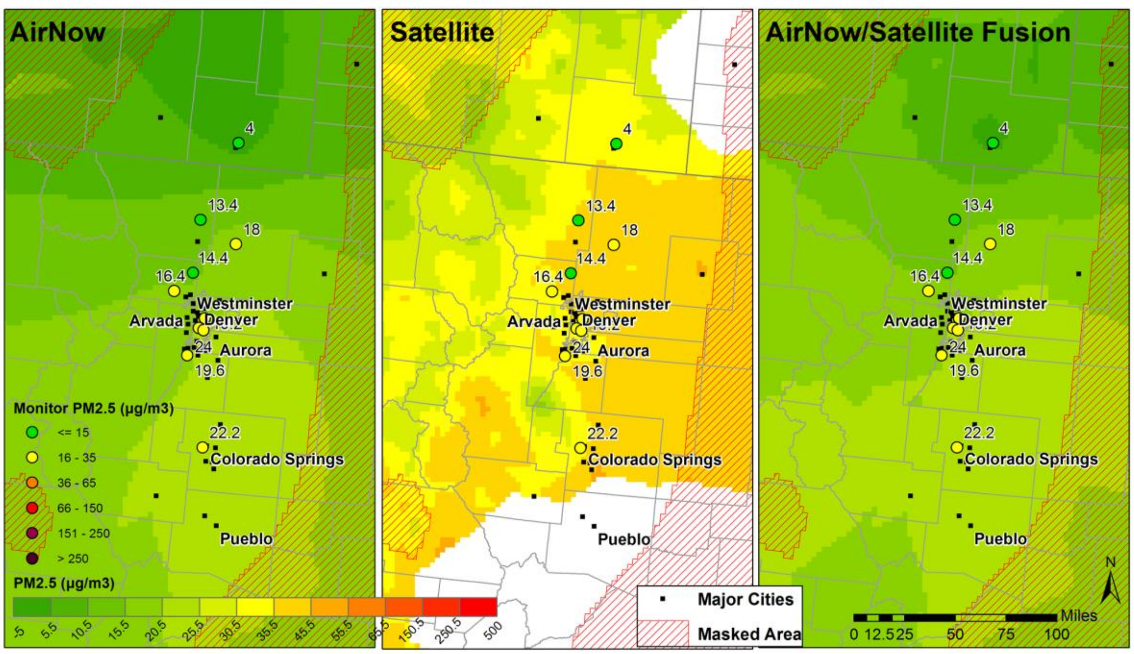
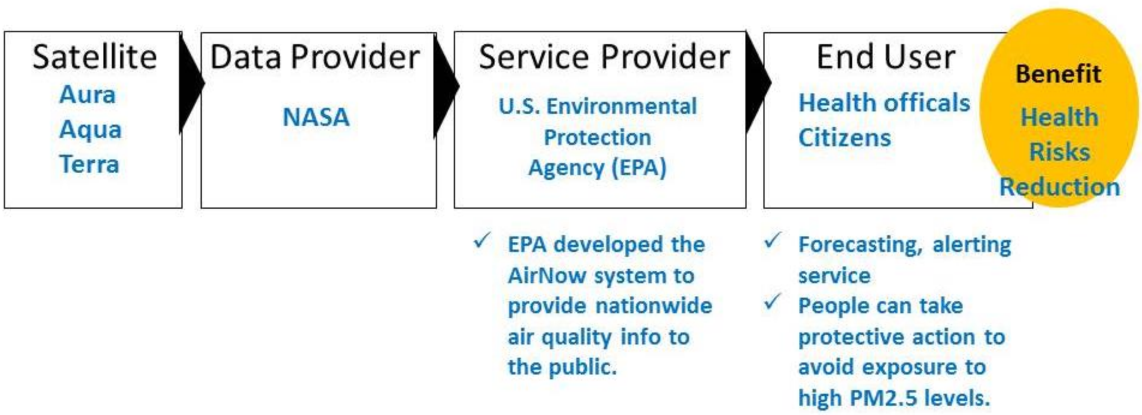


Fig 1: Example of ASDP data fusion product. The image shows 24-hour average PM2.5 ground concentrations from AirNow (left panel), satellite-estimated PM2.5 levels (middle panel), and the fusion of satellite and ground monitor data (right panel). The dots show monitor locations and concentrations. Colors reflect the AQI, and white areas in middle panel indicate areas obscured by clouds. Image credit: ASDP.

Fig 2: AirNow daily peak combined Air Quality Index (AQI) map of San Bernardino and Riverside counties, California, October 24, 2013. Yellow indicates moderate air quality conditions, orange unhealthy for sensitive groups, and red unhealthy. Image credit: AirNow.

Value Chain



Americas – Energy

Use of AW3D within Mineral Exploration

By Greg Madden, Geoimage Pty Ltd and Alex Farrar, First Quantum Minerals Ltd

Abstract

Performing mineral exploration operations within remote, mountainous areas is always difficult, expensive and time consuming. This case study highlights an example where a high quality Digital Elevation Model (DEM), derived from satellite imagery, is an extremely effective tool to use within these operations. The study area is located in the Andes Mountains in Southern Peru. The large elevation range and the remoteness of the area justified the use of a high resolution DEM as part of the exploration process. The 5-metre resolution ALOS World 3D (AW3D) topographic data was identified as a superior solution to off-the-shelf medium resolution DEMs. The use of AW3D within the exploration process has resulted in significant time savings in the crucial interpretation and planning stages, improving the ability of field teams to access the highest priority targets first. This data will continue to add value throughout the exploration stages of the projects including accurate siting of drill pads and 3D modelling of other datasets. This case study provides a good example of how a high quality satellite derived dataset, such as AW3D, can be employed within the mineral exploration phase of a mining operation.

Introduction

Mining operations within remote areas can often provide a number of challenges, requiring innovative ideas or solutions to optimise efficiency. For companies, such as First Quantum Minerals Limited, operating in areas such as the Andes mountains these problems need to be overcome very early on in the exploration phase. The use of remote sensing datasets, such as ALOS World 3D (AW3D) Digital Elevation Model (DEM) within the mineral exploration phase of the mining life-cycle is an example of such innovation. The AW3D dataset, when combined with Very High Resolution satellite imagery can provide a wealth of information for a number of phases, particularly during exploration and planning.

Challenges

The Project Area is 678sqkm in size, located within the Andes Mountain Range in Southern Peru and is mountainous with elevations ranging from 1809m to 4791m and slopes ranging between 0 to 81 degrees. Such steep terrain means that vehicular access within the region is limited, due to a multitude of un-crossable steep sided valleys that cut through the project area. Navigating within these steep sided creek valleys on foot provides the best means to map the project, due to the fact that they incise geology and provide good geologic exposures. However, navigating around the creek valleys is also necessary for accessing the further afield regions of the project, as well as for the purposes of taking gridded samples for analysis and for less detailed surface geologic mapping.

Therefore consultation of 3-dimensional terrain models and imagery is vital before going into the field. Such consultation allows large savings in time and energy that otherwise would have been used in the field walking down dead ends. This is especially important in locations like the Andes, where high altitude walking exacerbates energy and effort spent.

Fig 1: 3D Visualisation WorldView-2 over AW3D DEM (©NTT Data, RESTEC/Included©JAXA and ©DigitalGlobe 2015)

Applications/Solutions

During the early exploration phase of the project, freeware such as Google Earth was sufficient to use for basic navigational mapping purposes. However as it became clear that the project would advance beyond the generative exploration phase, the decision to invest in high resolution satellite imagery and terrain models became compelling.

The large size and remoteness of the project area lent itself to the utilisation of imagery and DEM derived from satellite imagery. Complete imagery coverage over the area was available from DigitalGlobe's extensive, very high resolution imagery archive. However, only monoscopic imagery was available. The lack of archive, stereo data meant that a decision regarding the DEM dataset was required.

The option of acquiring very high resolution, stereo data was considered and was rejected for the following reasons:

- The possibility of cloud, and cloud shadow being present within the fresh capture imagery. Any portions of the stereo data that contains cloud, or cloud shadow, preclude the production of elevation values. The resultant "holes" would require infilling with low resolution datasets such as Shuttle Radar Topography Mission (SRTM) 90m data, or ASTER GDEM 30m data;
- Very High Resolution satellites typically acquire data, including stereo captures, at off-nadir angles that were deemed undesirable over the project area. Given the topography throughout the area, there was a high risk of no stereo data due to occlusion, particularly over the steep creek valleys. Again, these "holes" would require infilling with SRTM or GDEM data; and
- The overall requirement did not necessarily dictate that an expensive 1m DEM dataset was necessary.

Once the decision was made to reject a 1m DEM dataset, AW3D was then considered. When considering suitability for this particular area, AW3D was found to have the following benefits:

- AW3D is generated from the large archive of triplet mode imagery acquired by the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) sensor on the Japanese ALOS satellite. The dataset is produced by using numerous triplet datasets, which serves to either reduce or totally remove cloud and smoke effected areas. In our case, a dataset was available over the area that had no cloud effected area, and therefore fully covered with 5m elevation data;
- The PRISM Triplet dataset involves a forward-looking, backward-looking and nadir sensors. Of further benefit, ALOS typically acquired data with minimal off-nadir capture angles. The triplet configuration, combined with direct overflight of the satellite meant that there was a significant reduction of occlusion holes, caused by slope;
- Because the AW3D is produced as an “off-the-shelf” product, there was minimal delivery time of the product, this combined with a relatively low expense, meant that the data could be quickly incorporated within the exploration operations; and
- The 5m resolution was considered more than adequate to support operations.

Overall, the AW3D solution was considered a suitable option for use within the project. The dataset provided a consistent and complete terrain model which when combined with very high resolution imagery, such as DigitalGlobe's 50cm resolution WorldView-2 imagery, improved efficiency in planning and decision making processes.

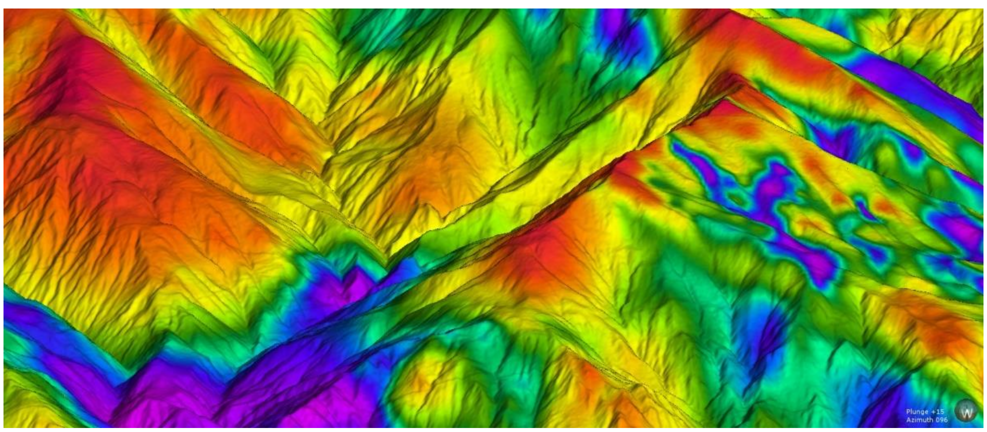
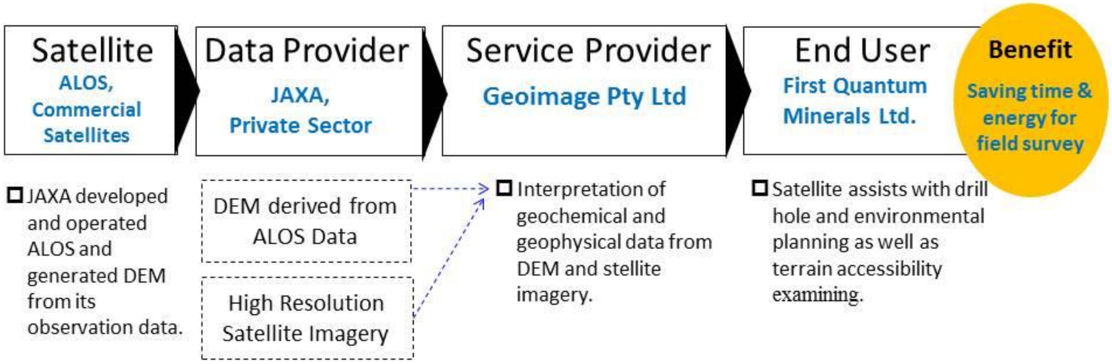


Fig 2: Analytic Signal Vertical Integral (ASVI) Airborne Magnetics draped over AW3D- Shaded Relief (©NTT Data, RESTEC/Included©JAXA)

Outcomes/Benefits

The 5m DEM and high resolution satellite imagery are now vital parts of the 3D geologic model. Interpretation of geochemical and geophysical data using the 3D terrain model is essential in such rugged terrain. The DEM and imagery also assists with drill hole and environmental planning as well as a higher resolution dataset to examine for terrain accessibility. Importantly the satellite imagery is a few years more recent than the Google earth, as such it has more updated roads and infrastructure information. The purchase of the detailed satellite imagery has the added importance of having a dated image showing the environment before any invasive exploration or mining activity has been initiated; therefore providing a baseline of the undisturbed land that can be used as part of any environmental permitting that may take place in the future.

Value Chain



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FIRST QUANTUM
MINERALS LTD.

Americas – Energy

ASTER Data Used to Identify Copper Potential Regions

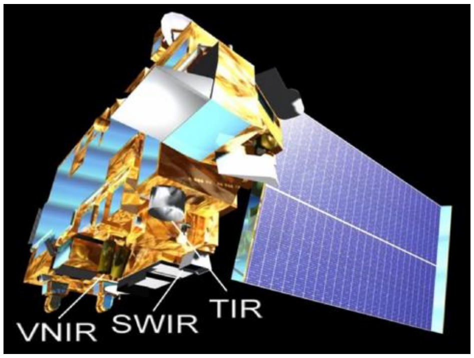
Problem

The mining licenses for large-scale promising areas (alteration zones) and easily accessible small-scale promising areas have been kept maintained by the metal majors in Northern Chile, while chances for Japanese companies were limited in early 1990's.

Basement rocks were covered by Quaternary sediments and volcanic rocks in the area. Even if large-scale alteration zones existed, they were covered by overburdens, and their exposure was limited in small scale. Their potentials were not evaluated sufficiently.

Satellite Earth Observation Data Application

The Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) is a 15-channel imaging instrument operating on NASA's Earth Observing Terra morning orbital platform since 1999 (Yamaguchi et al., 1998). By the joint project between the U.S. National Aeronautics and Space Administration and Japan's Ministry of Economy, Trade, and Industry, ASTER has been acquiring data for 15 years, since March 2000.

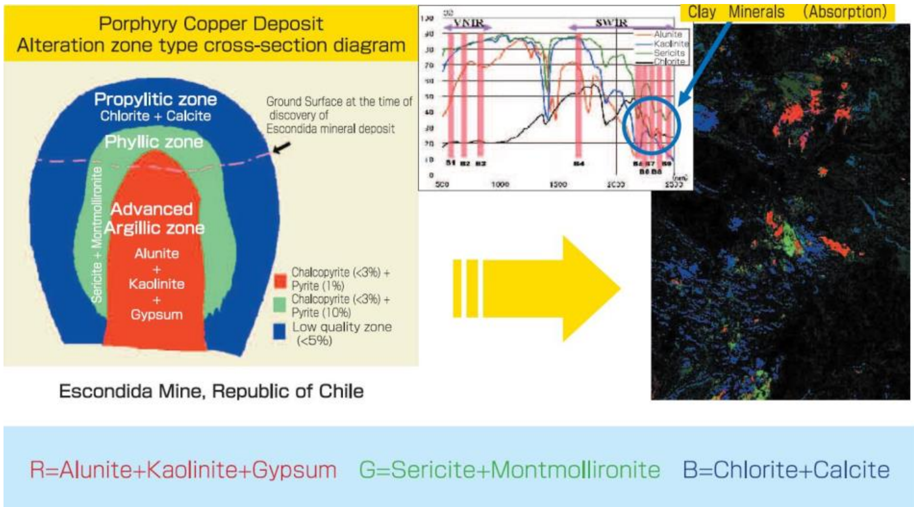


ASTER

Having more excellent spatial and spectral resolution than previous satellite sensors (Landsat Thematic Mapper with 80m of spatial resolution), ASTER can not only extract small-scale alteration zones, but also analyze mineral phase on pixel basis and create alteration zones maps.

These analyses enable to evaluate small-scale promising areas (alteration zones) in mountainous remote areas being hard to access.

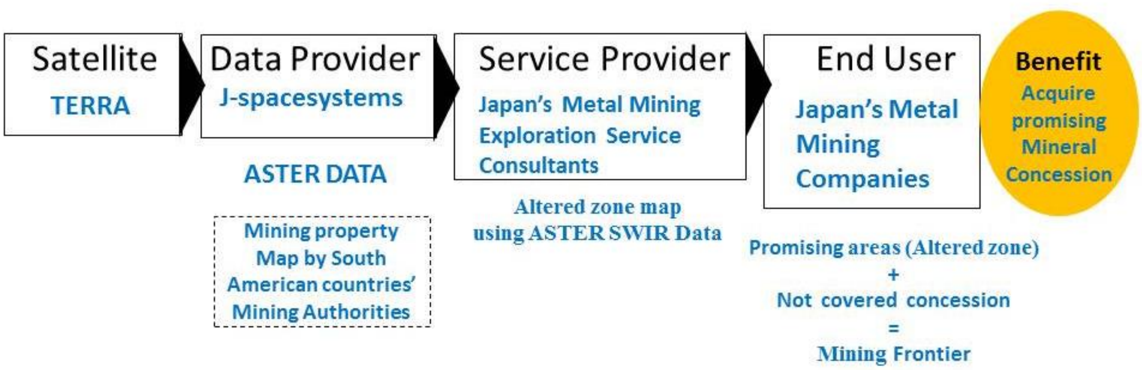
By taking advantage of ASTER sensor's identification capability of mineral phase, sericite alteration zones indicating the center of the porphyry copper mineralization are exposed partially or totally and are extracted as promising areas.

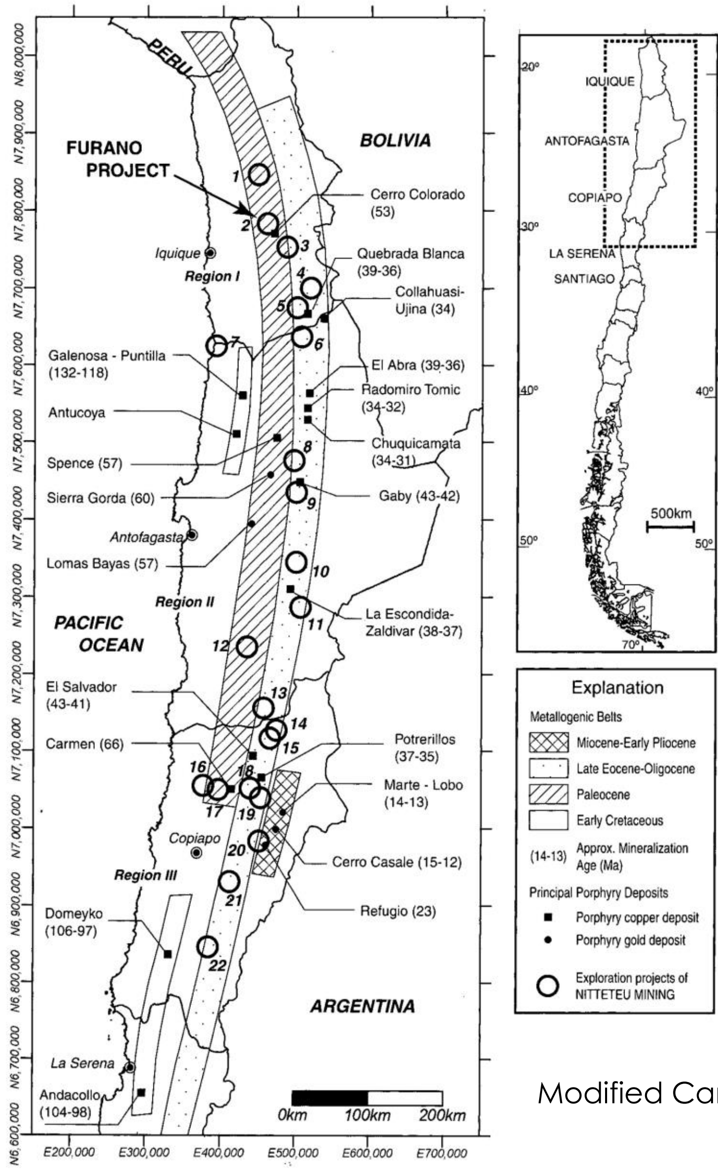


Value Chain

Japanese companies applied for mining licenses in promising areas and acquired them. Those areas had been evaluated as worthless to keep mining license by metal majors.

Japanese company extracted promising areas through the study of mineralization model, taking into consideration mineral deposit types, and the analysis of ASTER data with high resolution multi sensors made it possible to extract altered minerals. Then they reviewed the availability of mining licenses periodically and applied for mining licenses at the time when promising areas were released as open areas for mining licenses, and they carried out development study sequentially.





The numbers 1 to 22 shows project names as below.

1 : Monbetsu,
2 : Furano,
3 : Kitami,
4 : Otaru,
5 : Sapporo-N,
6 : Sapporo-S,
7 : Tokachi,
8 : Esashi,
9 : Tsugaru,
10 : Odate,
11 : Oga,
12 : Kamioka,
13 : Shinyo,
14 : Zaou-N,
15 : Zaou-S,
16 : Tadami-W,
17 : Tadami-E,
18 : Nazu,
19 : Shirracawa,
20 : Iwaki,
21 : Hitachi,
22 : Choushi.

Modified Camus and Dilles, 2001

More Information

They started nationwide project to extract promising areas over the country using ASTER data.

They applied mining licenses for promising areas and started comprehensive survey consisting of geological, geophysical, geochemical and drilling survey steadily, and screened out promising areas. METI, JOGMEC and Japan space systems encouraged researchers and engineers engaged in mining industry to develop the leading technology to extract promising areas using ASTER and other satellite data. Their efforts led to acquisition of their own mining lease or joint mining development projects.

The teamwork among those Japanese companies has helped to secure stable supply of mineral resources for Japan.

End Users

Japanese mining companies, such as JX Holdings Inc., JX Nippon Mining & Metals Corporation, Mitsui Mining & Smelting Co., Ltd., Pan Pacific Copper Co., Ltd. Sumitomo Metal Mining Co., Ltd.

Benefit

The Caserones project is one of metal mining projects owned by Japanese mining company, Pan Pacific Copper Co., Ltd.,(PPC), which is located in the Andes in excess of altitude 4,200m. The field work is always facing severe circumstances and a risk of altitude sickness.

At first, satellite data analysis was carried out in order to reduce workloads and area of field survey, then field survey was efficiently conducted, confirmed mineralized zones.

If satellite data analysis was not available and ASTER's SWIR data was not efficient to extract mineralized zones, PPC would not have started the Caserones project in consideration of hard work and risk of altitude sickness far before feasibility study be done.

In this sense, Satellite data analysis had played an important role in the early stage of the Caserones project to reduce a risk of exploration.

Related Organizations

The Ministry of Economy, Trade and Industry or **METI**, a ministry of the Government of Japan, has jurisdiction over a broad policy area containing Japan's industrial/trade policies, and energy security.

Japan Oil, Gas and Metals National Corporation, JOGMEC is Japanese government-related organization in charge of securing a stable supply of oil and natural gas, mineral resources.

Japan Space Systems, or **J-spacesystems**, one of the general incorporated foundations and a non-profit organization, covers entire space related technical field from the development of satellite systems to their utilization, especially remote sensing technology.

Americas – Water

Monitoring of water quality and water level of rivers and lakes in Brazil: towards a remote sensing-based operational monitoring application at the Brazilian National Water Agency

Jean-Michel Martinez[1], Dhalton Tosetto Ventura[2], Gérard Cochonneau[1], Eurides de Oliveira[2], Rita Cerqueira Piscoya[2], Valdemar Santos Guimarães[2]

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Short Summary

A remote-sensing based application called HIDROSAT is operated by the hydrological department at the Brazilian National Water Agency (ANA) to deliver suspended sediment concentration, chlorophyll-a concentration and water level estimates of rivers and lakes from different satellites. The remote sensing data improves the conventional monitoring capacity by increasing the number of stations and the frequency of data collection.

Problem

The Brazilian Water Agency (ANA) coordinates the national hydrometeorological network, being responsible for approximately 2900 stations distributed all over the Brazil, most of them comprising, at least, water level and rainfall monitoring. Suspended particulate matter (SPM) sampling is run, along with discharge measurement, at 488 stations. Water level is recorded daily or hourly. SPM and water quality data are collected every four months. Considered the country size and the importance of water resources for environmental and economical purposes, both the network's spatial coverage and SPM sampling frequency should be considered as insufficient. Furthermore, water quality monitoring in lakes are under responsibility of other institutions and lacks homogeneity. The improvement of monitoring capacity would necessarily raise significantly the operational cost of the national hydrological network but is seen as crucial. As a result, alternative techniques to conventional monitoring methods based on field measurement must be evaluated.

Satellite Earth Observation Data Application

Recently, ANA and the French Research Institute for the Development (IRD), through a research agreement with the Brazilian Cooperation Agency (ABC), have developed the MEG-HIBAM project that aims at incorporating the spatial remote sensing data into a global monitoring strategy for hydrological processes. The project seeks to integrate both conventional and remote sensing based technics for the improvement of the operational monitoring capacities in the Brazilian largest catchments. A web-based interface operated by the ANA was developed in order to deliver remote sensing-based hydrological data, called Hidrosat.
(www.ana.gov.br/hidrosat)

Optical remote sensing can be efficiently used for the monitoring of the water color, e.g. its spectral behavior. The water color is linked to the presence of optically active components within the water column. Three main components alter the water optical properties in the visible and infrared wavelength range: colored dissolved organic matter (CDOM), surface particulate matter (SPM) (either organic or inorganic) and photosynthetic pigments of microalgae such as the chlorophyll-a (Chl-a). The presence of each optically active component as well as its concentration controls the light absorption and scattering processes, making possible to derive algorithm to infer some water quality parameters from the analysis of the upwelling light emerging from a water body.

Altimetry satellites determine the distance from the satellite to a water body by measuring the transmission/scattering time of a radar pulse. The altimeter emits a radar wave and analyses the return signal that bounces off the surface. To obtain fine water level estimates of river and lakes different complex corrections are calculated to take into account satellite exact orbital position, atmospheric interferences and earth's geoid. The altimeter visits the same point on the globe every 35 to 10 days depending on the satellite configuration.

The Hidrosat application aims at providing hydrological parameters either related to water quantity (water level) or water quality (SPM, Chl-a) in rivers and lakes of some ungauged or poorly gauged basins. The applications consider three main topics / areas ranging from water resources monitoring to health risk assessment and socio-economic impacts:

- Monitoring river water level and sedimentary fluxes in the Amazon River basin. The largest river basin in the world is facing increasing hydrological extremes and modification of sediment fluxes through construction of dams. Remote sensing data allow to complete and to extend the field-based monitoring capacity that is hampered by the ANA network's low density in the Amazon basin and the difficulty to operate in a large transboundary basin.

- Eutrophication pollution in Nordeste semi-arid region. Uncontrolled growth of alga (mostly cyanobacteria) results in a decreasing of oxygen content of the water, and a diffusion of toxins. Those processes raise the cost for water treatment, cause fish mortality and increase disease prevalence in the local population. Hidrosat represent the first monitoring system of the eutrophication level of several reservoirs (through Chl-a proxy) delivering satellite-based estimates within 15 days.

- Sedimentation processes in cascade of dams used for electric power generation. Brazil's economy relies largely over hydroelectricity, which accounts for 85 % of the country electricity generation. However, hydropower efficiency and dam life expectancy is directly impacted by sediment trapping which need to be monitored independently. Hidrosat allows to monitor upstream/downstream water turbidity variations and to analyze the impacts of the different impoundments in the Parana River catchment.

The remote sensing derived data makes possible to increase the number of monitoring stations and the data acquisition frequency. The use of MODIS images makes possible to deliver 8-day estimates of the different water quality parameters while satellite altimetry is delivered every 10 days using Jason-2 data. This delay represents a step forward, especially for the water quality monitoring, where data originating from the conventional network are usually updated every four months.

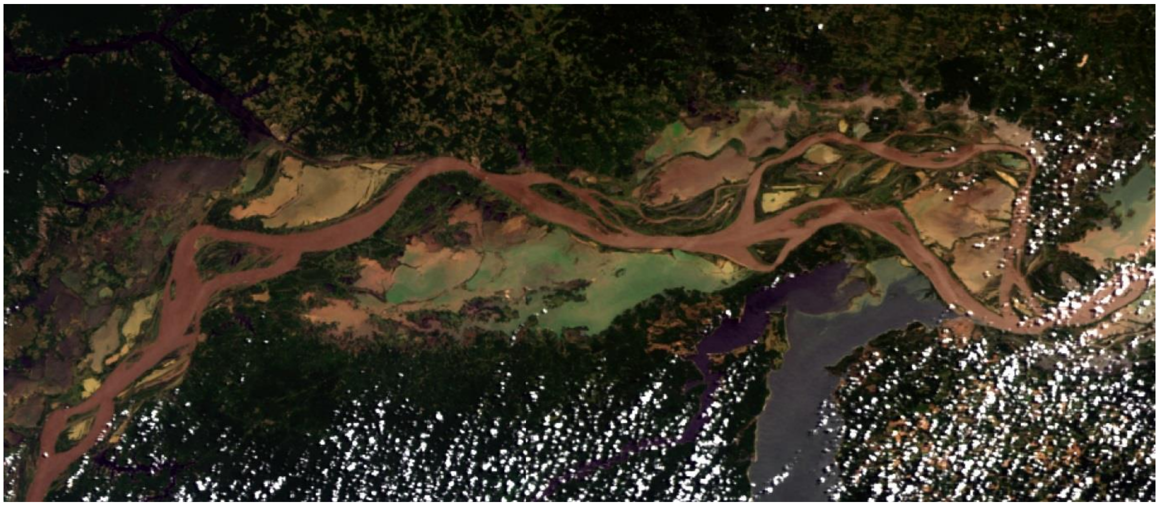


Fig 1: Satellite image of the Amazon River and of its floodplain. The different water colors are related to different biophysical processes that drive water quality and that can be monitored from space.

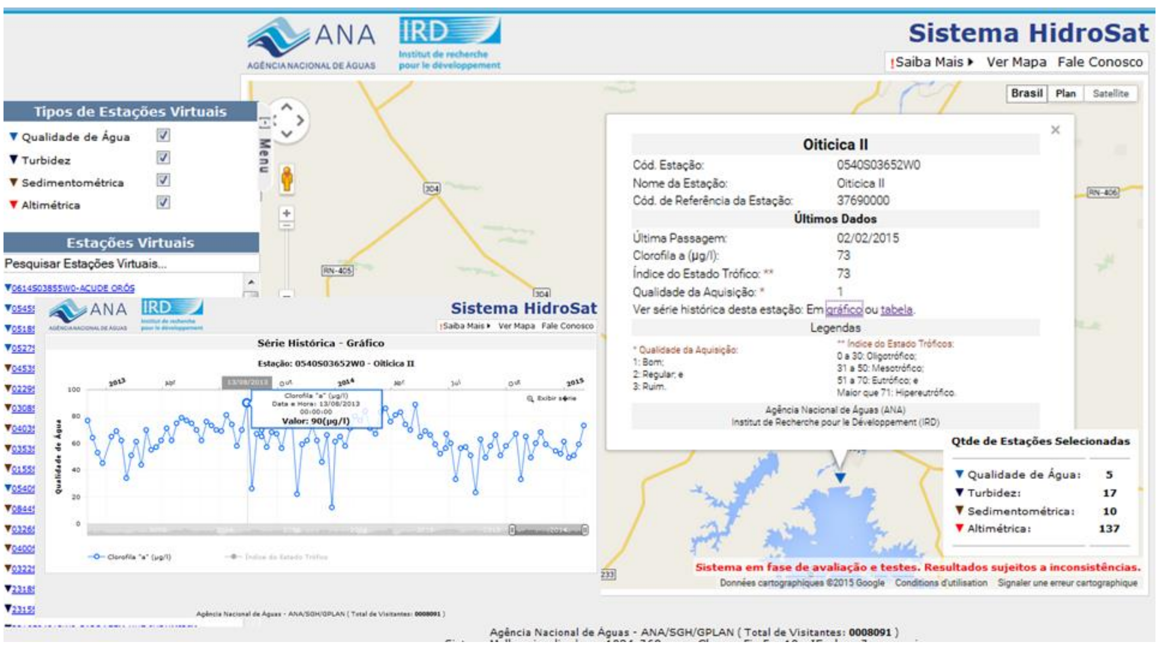
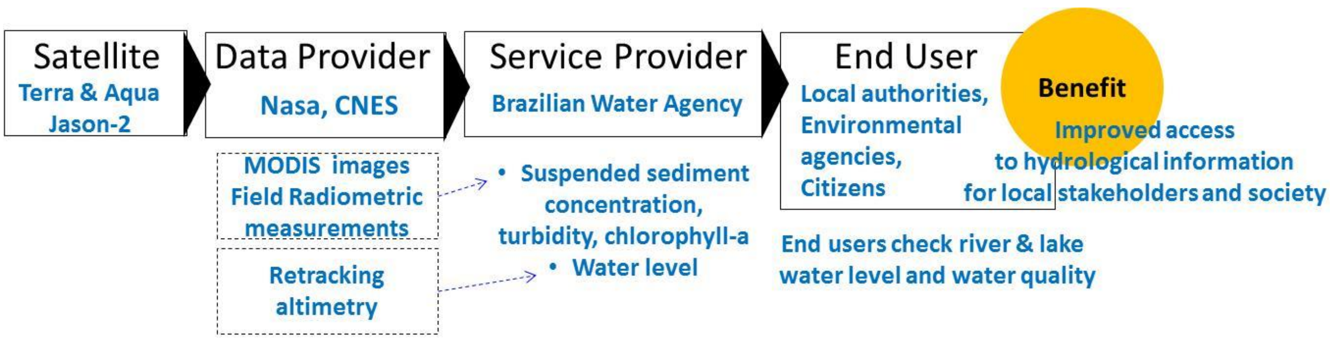


Fig 2: Hidrosat online interface hosted by the Brazilian National Water Agency delivering hydrological parameters assessed from satellite data, including water level and water quality of rivers and lakes in Brazil.

Value Chain

The remote sensing derived data makes possible to increase the number of monitoring stations and the data acquisition frequency. The use of MODIS images makes possible to deliver 8-day estimates of the different water quality parameters while satellite altimetry is delivered every 10 days using Jason-2 data.

This delay represents a step The IRD teams developed the satellite data processing chains for both altimetry and water color. For several years, the end user has been trained to run the different processing softwares and to the different remote sensing techniques. A specific database has been built at ANA that is interconnected to the national hydrologic database maintained by the agency. Jason-2 data are processed automatically using VALS software to deliver water level estimates each 10 days with a 2-day delay. Water quality parameters are assessed from MODIS sensors onboard Terra and Aqua satellites. MODIS products considered are surface reflectance 8-day composites at 250-meter and 500-meter spatial resolution (e.g. MOD/MYD09 Q1/A1 products). Water quality parameter retrieval is based on algorithms calculated from field radiometric measurements realized by ANA and IRD/GET teams. The Hidrosat application delivers, depending on the catchment, time series of either suspended sediment concentration, chlorophyll-a concentration or water turbidity. Those data are used to increase knowledge about water resources, for definition of environmental policies such as aquaculture licensing or for flood forecasting.orward, especially for the water quality monitoring, where data originating from the conventional network are usually updated every four months.



More Information

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Website URL : www.ana.gov.br /hidrosat

IRD Institut de recherche pour le développement

ANA AGÊNCIA NACIONAL DE ÁGUAS

Americas – Ecology

Earth Observations to Advance Wildlife Habitat Conservation and Management

Robert Crabtree, Yellowstone Ecological Research Center
Woody Turner, NASA Earth Science
William Corley, Booz Allen Hamilton
Lawrence Friedl, NASA Earth Science

Key Takeaway

The EAGLES system broadens ways for fish and wildlife managers to apply Earth observations for habitat management and species conservation.

Article

The U.S. Fish and Wildlife Service (USFWS) manages the 150 million-acre National Wildlife Refuge System and funds efforts by states, territories, and tribes for fish and wildlife monitoring and conservation projects. In general, efforts to sustain species populations through habitat management depend on an understanding of the environmental factors that influence these populations.

Together with USFWS, a NASA-sponsored project developed a system of tools supporting applications of Earth observations and ecological forecasting for fish and wildlife management. The project team utilized features of satellite remote sensing to provide environmental information on broad areas and large ecosystems, such as national parks and wildlife refuges, and at finer, species-level spatial and temporal scales. The project team created an adaptable, unifying architecture known as EAGLES—the Ecosystem Assessment, Geospatial analysis, and Landscape Evaluation System.

Enabling Data Access and Use

EAGLES provides a series of linked software applications in ArcGIS and Web-enabled environments, incorporating Earth observations for ecological forecasts. For example, EAGLES includes data products from MODIS (snow, vegetation, others), SRTM (elevation), and AVHRR (solar radiation), among other sources. It also includes geospatial covariates (explanatory variables) from remote sensing data, data products, and ecosystem models using MODIS and Landsat data. The satellite observations complement data from conventional monitoring of large ecosystems through field plots and aerial surveys.

Overall, EAGLES allows biologists and managers direct control and access to powerful data processing and modeling capabilities for landscape planning and management of focal species and their habitats. The system reduces the data storage and computation capabilities needed to create customized environmental covariates.

The EAGLES system incorporates legacy data—data in older formats that state and federal agencies have collected over several decades, largely from ground-based surveys. For instance, the team enabled access to legacy data on focal species populations such as bison and pronghorn sheep. In validating the system, the team merged the legacy species data with the covariates to carry out diagnostic analyses and predictive modeling of habitat distribution and birth and death rates. Such capabilities can help EAGLES users to better understand the impacts of climate and other environmental factors on species populations.

Migrating Bison

Using the EAGLES system, the project created a means to generate estimates of annual forage production using MODIS vegetation data. Applying the forage estimates (along with estimates of the amount of water stored in snow) in models, the team predicted the seasonal migration of bison from Yellowstone National Park.

The team concluded that the significant variables for predicting bison movement were herd size, annual forage biomass, and changing snowpack. Wildlife managers can now better understand how bison decide to leave or stay in the park, depending on how hard it is for the bison to access forage through the snow as well as compete with each other.

P.J. White, chief of wildlife resources at Yellowstone National Park, said: "The forage and snow estimates . . . were useful for predicting seasonal migrations by Yellowstone bison within and outside the park, and in improving collaborative policies with other federal, state, and tribal agencies to manage transboundary movements based on considerations of bison conservation, disease transmission to cattle, human safety, and property damage."

Assessing Alternatives

The team developed tools to forecast species distributions based on habitat and climate projections. Users can devise and analyze "what-if" scenarios (e.g., future climate conditions, land development, and wildfire disturbances) and their associated outcomes. These and other capabilities inform decisions by USFWS and similar entities to, for example, regulate land use, develop climate adaptation strategies, or restore habitats.

"We are using data provided by [the project team] to better determine how waterfowl populations in the North American prairies will respond to system change," said Kathy Fleming, landscape ecologist, USFWS. "Our ability to sustain waterfowl populations through harvest and habitat management depends on an understanding of the environmental factors that influence these populations annually, over continental scales."

Within EAGLES, the Customized Online Aggregation & Summarization Tool for Environmental Rasters (COASTER) system allows users to visualize spatial and temporal patterns in environmental data sets. The system contains data that would take months to compile and weeks to analyze. It can process large data sets and facilitate cost-effective generation of customized environmental covariates for analysis. A test of the system in 2012 showed it reduced the average processing time from six months to six weeks.

COASTER can characterize ecosystem circumstances in a specific area of interest, such as a national park, by using real-time manipulations of 77 geospatial biophysical variables. As the project and partners demonstrated in 2012, such data allow wildlife managers, biologists, and land managers who use COASTER and other EAGLES tools to make their own ecosystem assessments and examine the appropriate explanatory variables in species population models.

Supporting Users

"The design of the COASTER system was based on feedback from a number of federal biologists, including USFWS biologists and managers," said Kurt Johnson, national climate change scientist, USFWS. "We wanted something that was free, on the Internet, in GIS-ready formats, and most importantly, a user friendly analysis tool set that provided access to enormously large data sets on changing environmental and habitat conditions."

The project team also integrated or created needed, enabling data products to assist managers, applied researchers, and other users of the system. For instance, the team loaded temporal and spatial meteorological data on COASTER. The team created a 60-year climate data set at daily, 1-kilometer resolution for the contiguous United States. Derived from MODIS data, the project team also created a fractional surface water product, giving the percent of open surface water. Particularly supportive of continental waterfowl population models, this product covers most of North America at 500-kilometer resolution and provides estimates every eight days.

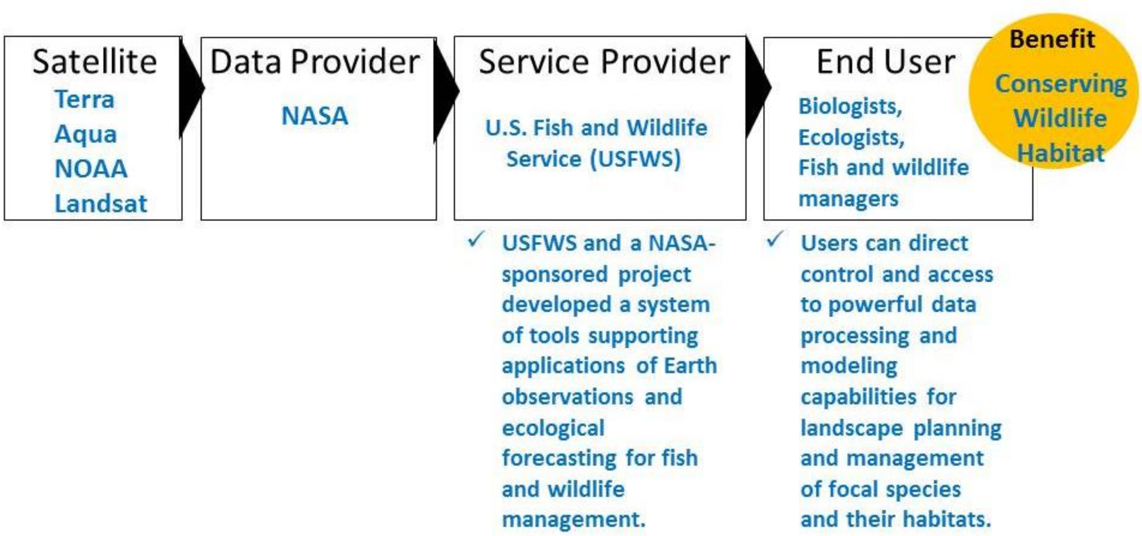
Beyond USFWS, potential end users of the system include the U.S. Forest Service, Bureau of Land Management, National Park Service, state fish and wildlife departments, tribal governments, universities, and nongovernmental organizations focused on conservation. Training sessions by the project team and USFWS help people employ EAGLES, COASTER, and all the tools to inform their decisions.

To learn more about EAGLES tools, visit www.yellowstoneresearch.org/eagles.html.

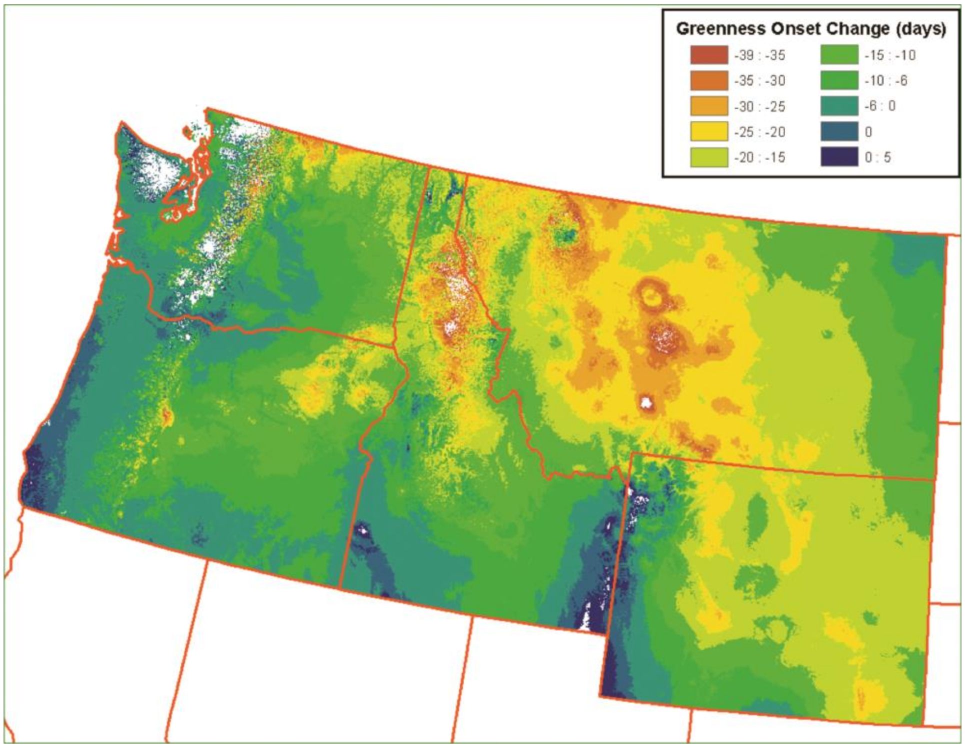
Key Quote

"The Fish and Wildlife Service manages trust resources—endangered species, migratory birds, refuges, certain fishes—at the continental scale that are constantly responding to a changing environment. And COASTER allows you to conduct rapid assessments of environmental effects such as climate change almost anywhere in North America." - Kurt Johnson, U.S. Fish and Wildlife Service

Value Chain



Images



COASTER supports ecosystem assessments. This example shows the 55-year trend (1955–2009) in spring greenness onset in the Pacific Northwest and Northern Rockies.

Americas – Ecology

Advancing Marine Mammal and Protected Species Management Through Earth Observations

Patrick Halpin, Duke University
Woody Turner, NASA Earth Science
William Corley, Booz Allen Hamilton
Lawrence Friedl, NASA Earth Science

Key Takeaway

A multi-agency team applied satellite observations to improve assessments of marine mammal habitats and reduce human impacts on whales, dolphins, and other species.

Article

The U.S. Navy, Bureau of Ocean Energy Management, NOAA, and other entities use a Spatial Decision Support System (SDSS) in assessing the density and distribution of marine mammals, including whales, porpoises, and dolphins. Supporting efforts to reduce impacts on marine species from seismic surveys, naval exercises, oil drilling noise, and other human activities, a NASA-sponsored application project improved SDSS predictive models through new indices using satellite observations. In 2012, the U.S. Navy began actively and consistently using the modeling system for environmental impact compliance.

Developed to support marine mammal conservation, SDSS is a data management and statistical modeling system that allows users to visualize and explore predicted habitats for marine mammals around U.S. waters. Model results yield predictive maps for the likelihood of encounter from parameters such as depth, distance to shore, sea surface temperature, and chlorophyll concentration. SDSS uses observations from the space-based sensors MODIS and AVHRR as well as data from NOAA surveys. As an interactive map server, the system enables examination of model outputs across multiple time scales and usable spatial formats.

The project worked to improve cetacean population density estimates in SDSS. Together with project partners at the U.S. Navy, BOEM, and NOAA, the project team combined remote sensing data from Aqua and other satellites with in situ oceanographic measurements to create indices applicable to protected species in the northeast Pacific Ocean, northwest Atlantic Ocean, and Gulf of Mexico.

The team incorporated these indices into predictive models of species density, abundance, and habitat. SDSS also improved through the team's work to add a near real-time predictive capability based on the indices derived from available Earth observations. The team's habitat-based density models combine remote sensing data and ecologically significant variables.

Overall, the team enhanced the effectiveness of SDSS, increasing both the spatial and temporal perspective of models. That is, SDSS offers improved perspectives on past events and insights on the next month and next season.

"These analyses identify primary variables influencing marine mammal distribution, thereby providing the context for successful accommodation of whales and dolphins in marine spatial planning frameworks," said Tim Cole, aerial survey team lead at the NOAA Northeast Fisheries Science Center.

To conduct training exercises at sea, the U.S. Navy files environmental impact statements (EIS) to obtain permits from the NOAA National Marine Fisheries Service. In 2012, the U.S. Navy began using the team's models for estimating whale and dolphin density in EIS development. The use supports assessments of potential impacts of sonar-related training and testing, ensuring that its activities comply with environmental and conservation legislation. Improvements to density models and predictions in SDSS support the U.S. Navy's submissions of quality EISs, helping reduce revisions and streamlining EIS reviews and permit issuance. The U.S. Navy has benefited from improved data on the density and ranges of Dall's porpoises off the U.S. West Coast.

During this project, the team participated in a working group to map cetacean density and distribution in U.S. waters, particularly to gauge the cumulative effects of sound on cetaceans. The group established a hierarchy of data, identified the best available data, and arranged to make the data available to users via a NOAA website interface. Working group members unanimously agreed that the SDSS and enhancements developed through the NASA project represented the best available estimates of cetacean density.

The Mapping Cetaceans and Sound Symposium in 2012 featured the models and data hierarchy. It involved more than 200 managers, scientists, and decision makers from the oil and gas industry, U.S. Navy, NOAA, and BOEM, among others. This event helped to unify management community and federal agency responses to the assessment and management of ocean noise and potential interactions with protected species. Attendees noted that the accumulation of existing data and density models of cetacean species and ocean noise models in a single repository provides an authoritative baseline source for future protected species management.

"The NASA-funded project . . . has significantly advanced our understanding of how marine mammals are utilizing the ocean," said James Michael Price, marine mammals studies coordinator at BOEM. "With more reliable knowledge of where and when these animals are feeding, breeding, or migrating through, BOEM can better assess possible adverse impacts to them and, hopefully, take administrative action to avoid the impacts or at least mitigate them."

In 2012, NOAA and BOEM integrated data from the project into the Multipurpose Marine Cadastre, an integrated marine information system that provides legal, physical, ecological, and cultural information. Originally created to support offshore renewable energy siting, this tool provides a common geospatial framework for broader coastal and marine spatial planning, supporting people working on regional and state coastal and marine spatial planning efforts. The integration of the project's data in this mapping tool helps improve ocean navigation and lower risks of ship-marine mammal collisions and the associated impacts on the animals.

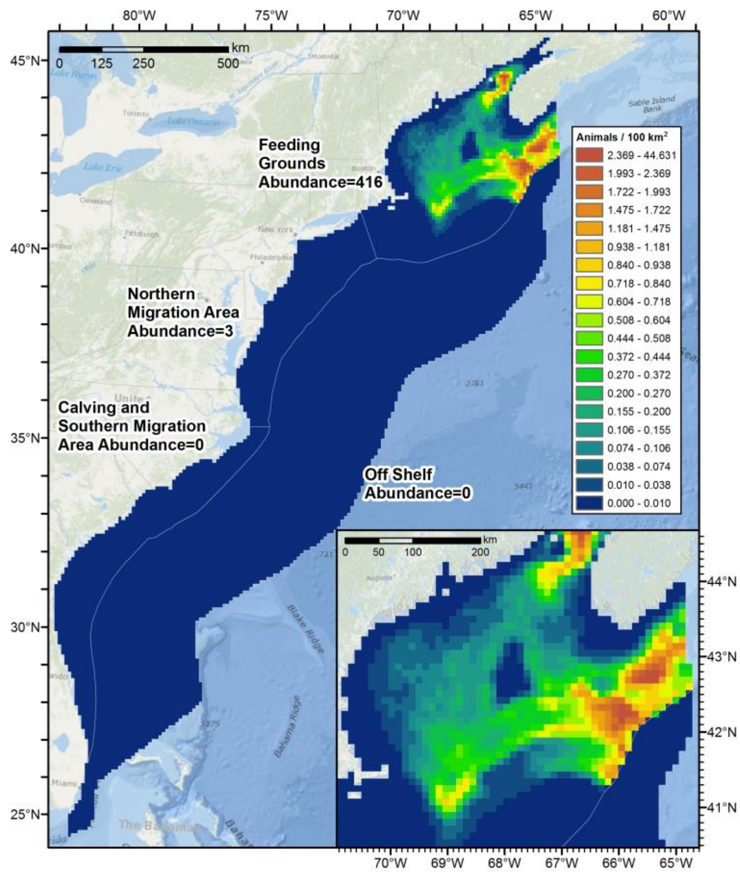
The Strategic Environmental Research and Development Program, a DoD-EPA-DOE partnership, sponsored the development of the Spatial Decision Support System.

To learn more about the system, visit
http://seamap.env.duke.edu/seamap2.5/serdp/serdp_map.php.

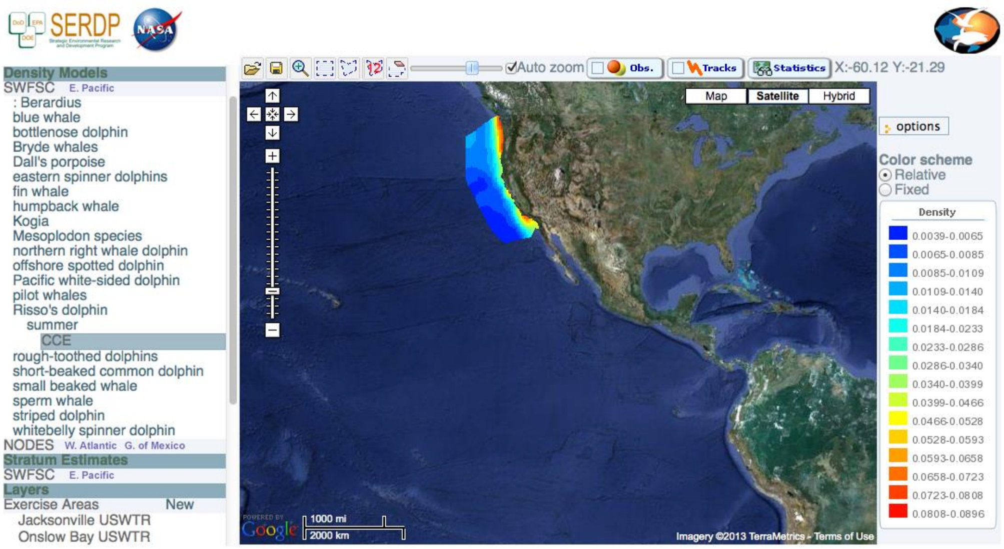
Key Quote

"We see this project as part of an ongoing effort to improve spatial density estimations, and NASA's Earth observations will play an important role in it." - James Michael Price, U.S. Bureau of Ocean Energy Management

Images

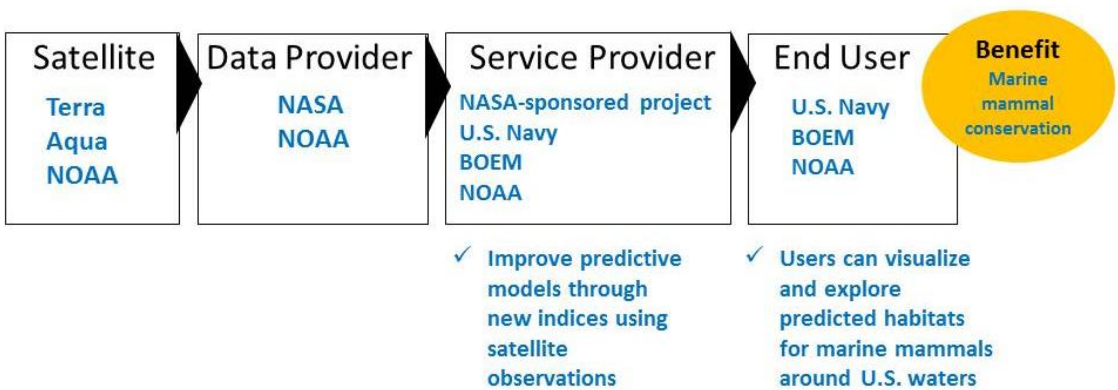


Example of a cetacean density model output for the North Atlantic right whale summer season. This seasonal forecast model uses dynamic oceanographic features (SST fronts, eddies, eddy kinetic energy, etc.) derived from Earth observations.



Example of a cetacean density model output for the North Atlantic right whale summer season. This seasonal forecast model uses dynamic oceanographic features (SST fronts, eddies, eddy kinetic energy, etc.) derived from Earth observations.

Value Chain



Americas – Ecology

Improving Ecosystem Monitoring and Management of Coral Reefs with Satellite Observations

Frank Muller-Karger, University of South Florida
Mark Eakin, NOAA
Woody Turner, NASA Earth Science
William Corley, Booz Allen Hamilton
Lawrence Friedl, NASA Earth Science

Key Takeaway

Applications of Earth observations enhance the Coral Reef Watch decision support system for management of coral reefs, supporting ecosystem health and economic activity.

Article

Coral reef managers use environmental information to monitor conditions and threats to reef ecosystems, taking actions where possible to minimize human impact and support reef health. Increased ocean temperature is an important factor in bleaching, a threat to coral health. Broad-scale temperature data helps reef managers assess regional conditions and trends, and finer-scale data gives them insights for targeted actions, such as redirecting divers and snorkelers to suitable reefs.

"Reef managers can implement various strategies during times of coral bleaching to reduce or mitigate the potential negative impacts additionally caused by human use," said Scott Donahue, science coordinator at the Florida Keys National Marine Sanctuary.

Coral Reef Watch (CRW) is an online tool that provides near-real-time and long-term monitoring, forecasting, and reporting of environmental conditions of coral reef ecosystems. Operated by NOAA, CRW uses satellite data, climate models, and in situ tools to provide bleaching alerts to the public and reef managers.

With coral bleaching, corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease and partial mortality become likely, and the entire colony may die. CRW assesses the intensity of potential bleaching based on a combination of a) instantaneous thermal stress and b) cumulative thermal stress and duration during the most recent 12-week period. CRW introduced its 5-km Bleaching Alert Levels in 2013 with Bleaching Watches, Warnings, and Alert Levels 1 and 2. At Alert Level 1, bleaching is likely; at Alert Level 2, mortality is likely.

Applying Earth Observations

The University of South Florida and CRW staff led a NASA-sponsored project to apply Terra, Aqua, and other satellite data to enhance the spatial and temporal resolution and density of temperature data in the tool. The top need identified in user surveys was higher resolution information, and the project has since achieved 100-times greater spatial resolution.

Water temperatures that exceed thresholds for sustained periods lead to thermal stress in corals, and the CRW system helps pinpoint reefs likely to bleach. "Coral Reef Watch is very informative for what we are trying to do," said Karen Bohnsack, [Southeast Florida] BleachWatch Program coordinator for the Florida Department of Environmental Protection's Coral Reef Conservation Program.

The application uses global, 5-kilometer sea surface temperature (SST) products based on combinations of data from NASA, NOAA, and foreign geostationary and polar-orbiting satellites, including Suomi NPP, GOES-East, GOES-West, NOAA-19, MSG, MTSAT, and Metop-A. The combination helps users better visualize and quantify thermal stress conditions around the world. The project team also created a 1-kilometer product using Aqua/MODIS and AVHRR imagery for the Gulf of Mexico and reefs in the Florida Keys, Caribbean Sea, and off Mexico.

CRW's new products build on the 50-kilometer products it has provided, which allow reef managers to understand conditions of offshore waters around the resources under their jurisdiction. The new products show what is happening closer to shore and within actual reef ecosystems. The new products also provide 25 to 100 times more satellite data per pixel than the old products. The new products also directly cover up to 95 percent of coral reefs around the world.

"The new data products provide observations closer to the scale of coral reefs," explained Mark Eakin, CRW coordinator at NOAA. "Managers want to know as much as we can tell them to help their management of reef resources. . . . Even without bleaching, higher temperatures endanger coral health."

Enhancing Decisions, Public Support, and Research

As a result of the CRW improvements, reef managers can now make more informed decisions, including taking steps to protect coral ecosystems or target monitoring. In the short term, there are actions managers can take for immediate effect, such as reducing allowable pollutant loads or alerting recreational dive vessels to change locations.

"One example would be working with local diving and snorkeling operators to redirect on-water tourist activities away from natural reef areas normally subject to high visitation to artificial reefs and shipwrecks," said Donahue. "This could reduce unintentional physical damage to corals until favorable thermal conditions return."

CRW enables decisions on where to conduct extensive monitoring and ways to engage the public to support reef health and collect information. "In times of severe thermal stress, that higher [5-kilometer] resolution helps us manage where we request researchers and citizen scientists alike to look for potential thermal stress in corals," said Donahue. "Also, over the long term, it may help reef managers refine where they place in situ temperature monitoring devices to help better correlate remotely sensed data with conditions experienced at depth."

The new products mentioned above came online in 2013. Follow-on products involving satellite data are planned based on user input, such as a long-term mean SST climatology product.

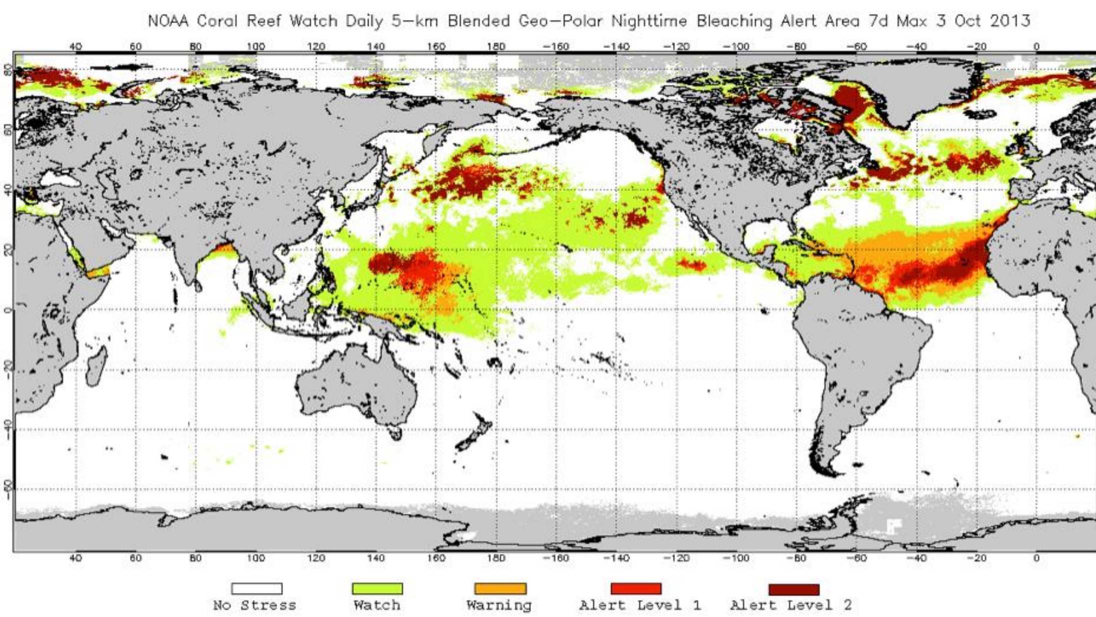
Climate change has contributed to rising ocean temperatures and growing ocean acidification, which affect coral reef health. People are now using space-based information from Coral Reef Watch to reduce further human impacts on the reefs—and the broader ecosystems and local economies they support.

To learn more about Coral Reef Watch, visit http://coralreefwatch.noaa.gov.

Key Quote

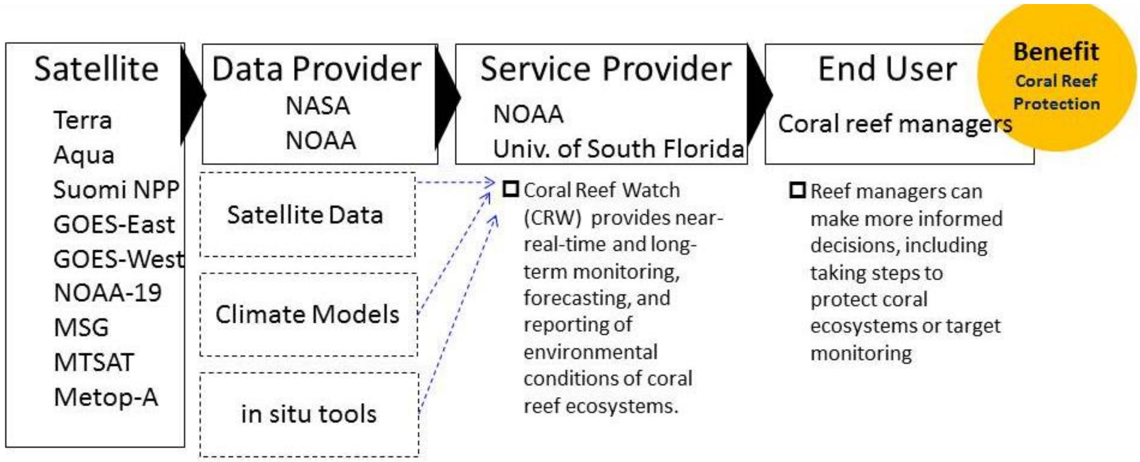
"The new data products provide observations closer to the scale of coral reefs. Managers want to know as much as we can tell them to help their management of reef resources." - Mark Eakin, NOAA Coral Reef Watch

Images



The coral bleaching alert area product shows ocean regions where thermal stress is high enough to impact corals. At this time, coral bleaching was ongoing in the U.S. territories of Guam and the Commonwealth of the Northern Marianas Islands.

Value Chain


Satellite
Terra
Aqua
Suomi NPP
GOES-East
GOES-West
NOAA-19
MSG
MTSAT
Metop-A
Data Provider
NASA
NOAA
Satellite Data
Climate Models
in situ tools
Service Provider
NOAA
Univ. of South Florida
Coral Reef Watch (CRW) provides near-real-time and long-term monitoring, forecasting, and reporting of environmental conditions of coral reef ecosystems.
End User
Coral reef managers
Reef managers can make more informed decisions, including taking steps to protect coral ecosystems or target monitoring
Benefit
Coral Reef Protection

Americas – Agriculture

Enhancing Drought Monitoring in North America through Earth Observations

Matt Rodell, NASA Earth Science
Brad Doorn, NASA Earth Science
William Corley, Booz Allen Hamilton
Lawrence Friedl, NASA Earth Science

Key Takeaway

An innovative application of GRACE satellite observations support and improve the U.S. Drought Monitor and the classification of drought severity.

Article

An Earth observations applications project integrated data from the Gravity Recovery and Climate Experiment (GRACE) satellite mission to improve the U.S. Drought Monitor. Managers and government officials use maps from this important, weekly drought monitoring tool to better manage limited water supplies and distribute drought aid where it is needed most.

Assessing Data from Satellites
The National Drought Mitigation Center (NDMC) produces official drought maps and products on a weekly basis. The NASA-sponsored project developed new drought indicators using Earth observations from GRACE, ground data, and other satellites; these indicators are now part of the NDMC's routine production.

GRACE—a pair of satellites that orbit in tandem about 285 miles above the ground—detects very small variations in the Earth's gravitational field. The variations are used to determine changes in the total amount of water stored both on top of and below the land surface, including snow, surface waters, soil moisture, and groundwater. Having a complete picture of these water types enables better classification of drought severity.

The team combined GRACE data with other observations—including precipitation, temperature, and solar radiation data—and high-resolution numerical modeling to develop a continuous record of soil moisture and groundwater dating back to 1948. The team then used the soil and groundwater record to produce weekly maps of wetness conditions in the soil and aquifers.

This project generated an independent and reliable data set, which augmented the existing data available to assess droughts. Prior to the addition of the GRACE-based drought indicators, the U.S. Drought Monitor lacked information on deep soil moisture and groundwater storage. The officials who produce the Drought Monitor's weekly maps can use this valuable information to gauge the impact of long episodes of wet or dry weather.

The NDMC is located at the University of Nebraska, Lincoln. The U.S. Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA) are the primary federal agencies sponsoring the Drought Monitor.

Facilitating Decisions

The U.S. Drought Monitor authors make routine use of the soil moisture and groundwater data from the project team. "For us, it is another voice in the room to answer questions about soil moisture. It does help greatly to define the long-term and short-term drought situation, as well as provide details for inclusion in the weekly narrative, where the author explains if impacts are hydrologically and/or ecologically devastating, or having more of an impact on agriculture and society," said Matt Rosencrans, a meteorologist at the NOAA Climate Prediction Center.

Drought planning entails drought monitoring, understanding drought impacts, and mitigating the associated risks. Enhanced drought monitoring through additional data could improve drought planning on the national, state, local, and tribal level.

Droughts are significant economically. For example, the USDA Livestock Forage Disaster Program disbursed $479 million for drought-related grazing losses of livestock from 2008 through 2011. The program uses U.S. Drought Monitor ratings of severe and extreme drought by county to determine eligibility for compensation. In 2011, the cost of the Texas drought in livestock and crop losses exceeded $7.6 billion plus more in damages from drought-related wildfires.

The project's data products not only benefit official drought monitoring. Weekly groundwater and soil moisture maps online allow people to tap the data for their own assessments and decisions. The maps are especially useful in helping water resources managers differentiate between short- term and long-term drought.

The GRACE-based data products may ultimately support long-term planning, as decisions on issues such as disaster aid, construction of dams, and water allocation rely on accurate assessments of drought.
The project team included people from the NDMC, NOAA, and the University of California, Irvine.

GRACE is a U.S.-German satellite mission. The GRACE Follow-On mission (GRACE-FO) planned for a 2017 launch will continue these important measurements and the long-term record. A possible GRACE-II mission could improve the accuracy and resolution of the measurements.

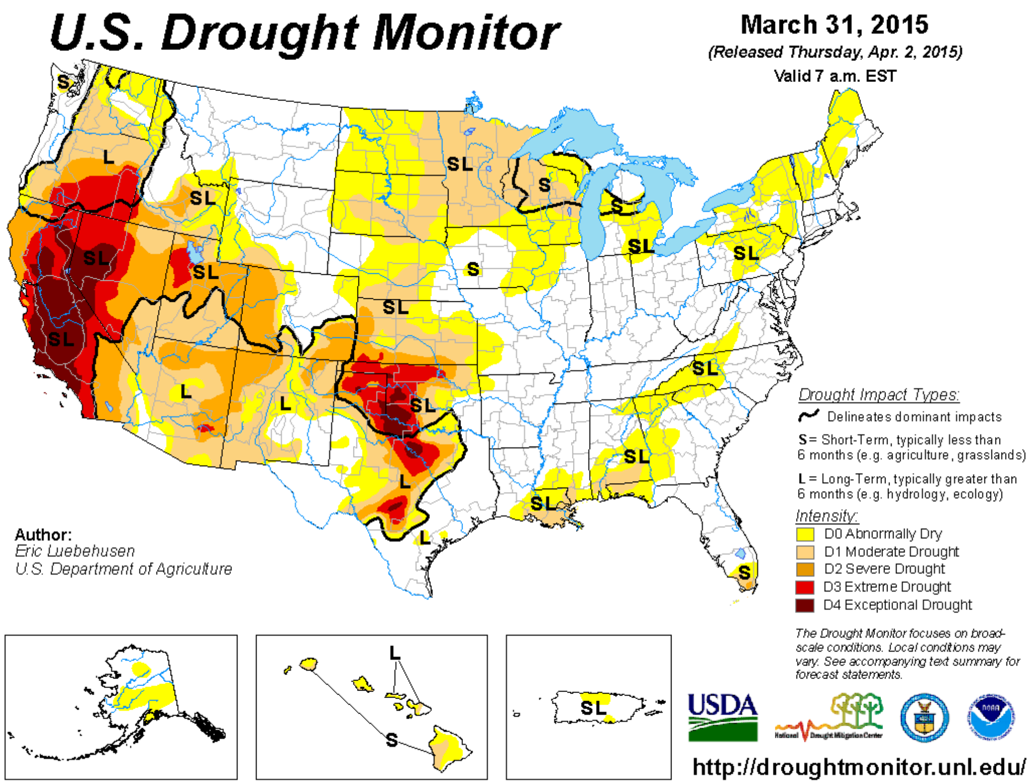
The U.S. Drought Monitor is available on the NDMC website:
http://www.drought.unl.edu.

To view the weekly groundwater and soil moisture condition maps, visit
http://www.drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx.

Key Quote

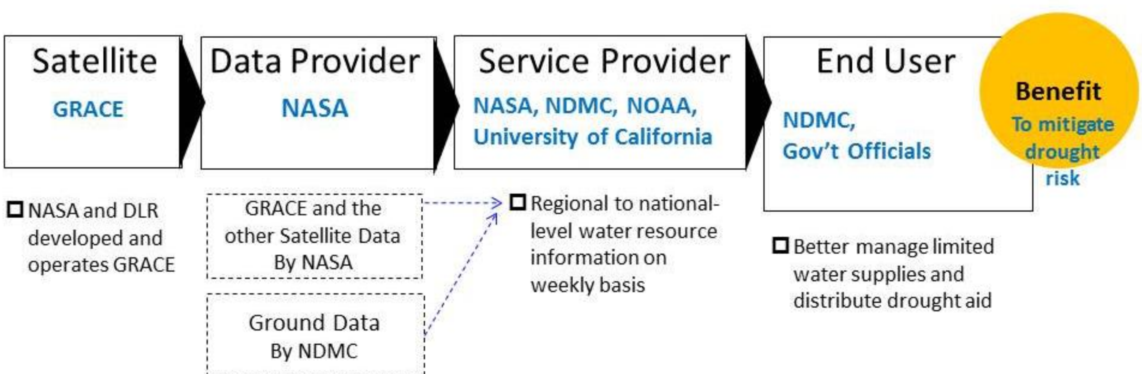
"[These GRACE] maps provide regional to national-level water resource information that was previously unavailable to policy and decision makers. The novel use of satellite-based gravity data in combination with advanced modeling techniques has given us a unique perspective on groundwater that was not resolvable through just ground-based observations." -- Brian Wardlow, National Drought Mitigation Center

Images



U.S. Drought Monitor map, March 31, 2015.

Value Chain



Americas - Forest

Prevention of Illegal Logging in Amazon Forest using ALOS/PALSAR

Problem

Brazil has been struggling with deforestation in the Amazon rainforest since 1970's. As big projects for mining development caused deforestation during 70's and 80's, the main cause of deforestation in the Amazon since 90's is the illegal logging. According to the report[1] from a Brazilian commission, 80% of all logging in the Amazon was illegal during the late 90's.

The Brazilian National Institute for Space Research (INPE) developed and is operating the near real-time forest monitoring system ("DETER") since 2004 to support surveillance and control of deforestation by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA). DETER uses data obtained by MODIS (MODerate resolution Imaging Spectroradiometer) onboard NASA's satellites and can detect deforestation areas over 25 hectares. DETER contributes for prevention of illegal logging, but it cannot monitor deforestation during cloudy weather because MODIS cannot observe the ground under cloud. This is a crucial problem in tropical rainforests like Amazon where cloud cover in rainy season persists for five months per year. Loggers are able to clear-cut hudge areas during the rainy season without any operating satellite-based monitoring system from the government.

Satellite Earth Observation Data Application

The Japan Aerospace Exploration Agency (JAXA) developed and launched the Advanced Land Observing Satellite (ALOS) in 2006 with three sensors on board. One of them was the Phased Array L-band Synthetic Aperture Radar (PALSAR). Radar sensors can monitor ground surface regardless of cloud cover condition because its radiowave penetrates clouds and reaches ground surface. In addition, L-band type radiowave is very sensitive to natural or human-induced changes in forest canopy and PALSAR was one of the most effective satellite tools for monitoring deforestation.

IBAMA´s interest in PALSAR data started when the institution sent an engineer to a remote sensing training course in Japan hosted by the Japan International Cooperation Agency (JICA). In order to have access to the data recorded by PALSAR over the Brazilian Amazon with no cost, IBAMA and JAXA signed a technical agreement in 2007. At that time, Brazil already had a great experience in forest monitoring using optical satellite sensor. However, the knowledge and experience of using radar technology were not mature. Consequently, Brazil sent an official request to the Japanese Government to transfer the technology of Japanese radar satellite to detect deforestation in the Amazon. JICA, right after received the request from Brazil, established a three-year project in 2009 with IBAMA and the Federal Police Department (DPF) and appointed the Remote Sensing Technology Center of Japan (RESTEC) to implement the project.

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[1] Viana, G. 1998. Report of the External Commission of the Chamber of Deputies Destined to Investigate the Acquisition of Wood, Lumber Mills and Extensive Portions of Land in the Amazon by Asian Loggers. Brasilia, Brazil.

JAXA provided PALSAR "ScanSAR" data over the Amazon for IBAMA almost every day during the project. "ScanSAR" is one of PALSAR observation mode which covers a swath of 350-km in the terrain, with 100-m ground resolution. Althoug its spatial resolution is somewhat coarse, it presents the advantage of high temporal resolution, an important issue for law enforcement procedures related to illegal deforestation. Because of the large extension of the Brazilian Amazon, IBAMA was mostly interested in detecting larger deforested areas as quick as possible.

PALSAR images present varying patterns of gray tons and texture, depending on the environmental conditions of ground surface. If a certain area is smooth (e.g., lake, river or paved road), it appears as black or dark gray and with fine texture in the image. On the other hand, if the area is rough (e.g., forestland or grassland), it appears as light gray and coarse texture in the image. As natural forest is compared with deforested areas, the latter will appear darker in PALSAR images. Based on such characteristics, IBAMA, after receiving the ScanSAR images from JAXA, processed multitemporal sets of data to produce color composites to visually detect deforested areas. Deforested areas appears dark in the color composites whereas natural forest appears brighter. Deforested areas larger than 25 ha can be easily detected.

The images can be saved in GeoTIFF format so that interpreters can easily overlay them over the other optical satellite images using some GIS package or even using the Google Earth program. Figure 1 shows the locations of polygons related to the deforestation (clear-cut) found by the RESTEC-trained interpreters of ScanSAR color composites in the time period from July, 2009 to February, 2011. The geographical coordinates of these polygons are sent to IBAMA´s agents in the field to check if the deforestation is illegal (without authorization or against the Forest Code) and to prevent enlargement of deforestation.

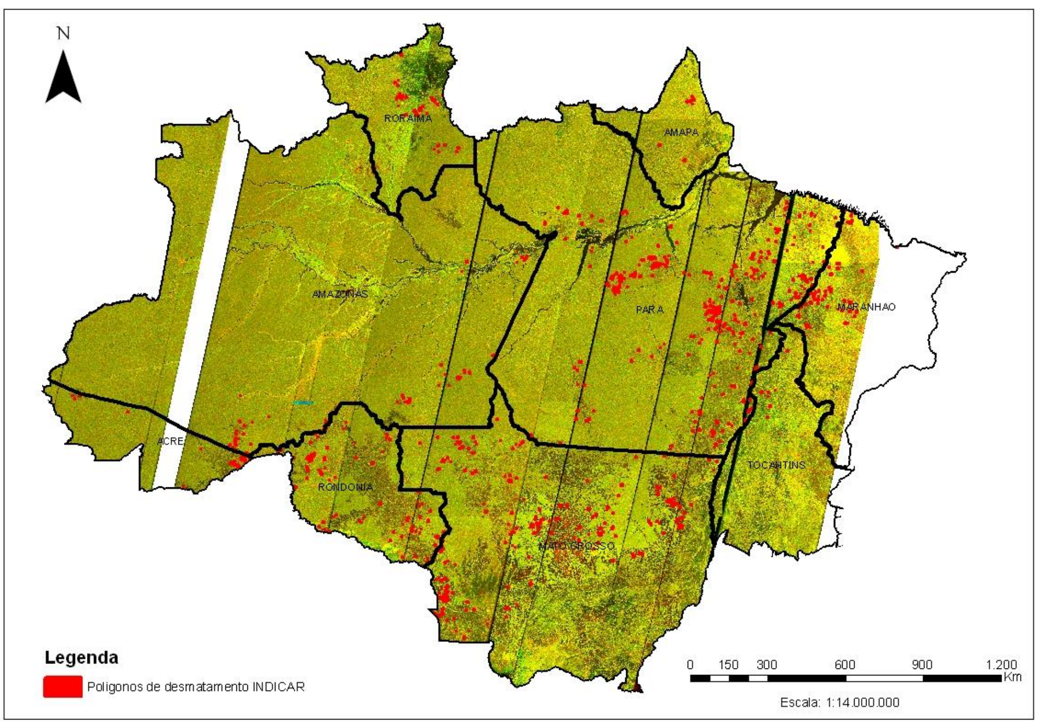


Fig 1: Mosaicked Color Composite Image and Polygons

The rapid delivery of polygons created from PALSAR data is a key issue for preventing illegal logging since the loggers can manage to clear-cut large areas rapidly. RESTEC has developed a software which allows IBAMA´s interpreters to quickly produce color composites for further interpretation. Incorporating the software, IBAMA developed PALSAR based near real-time forest monitoring system ("INDICAR") with the support from RESTEC. INDICAR can detect a deforestation area larger than 4-5 hectares.

The cooperation between RESTEC, JICA, IBAMA and DPF was very successful and indeed efficient, overcoming a real big challenge: monitoring a huge 5.2 million squared kilometers tropical rainfall forested area. PALSAR ScanSAR mode is able to cover a 350-km swath at once which allows to cover the entire Brazilian Amazon every 15 days.

Figure 2 shows the annual rate of deforestation in the Amazon since 2001 (estimation released by INPE every year and available in its website). We can note that the deforestation is decreasing since 2005, right after INPE developed the DETER system. Surely ALOS PALSAR also contributed for such trend in the deforestation rate since 2009.

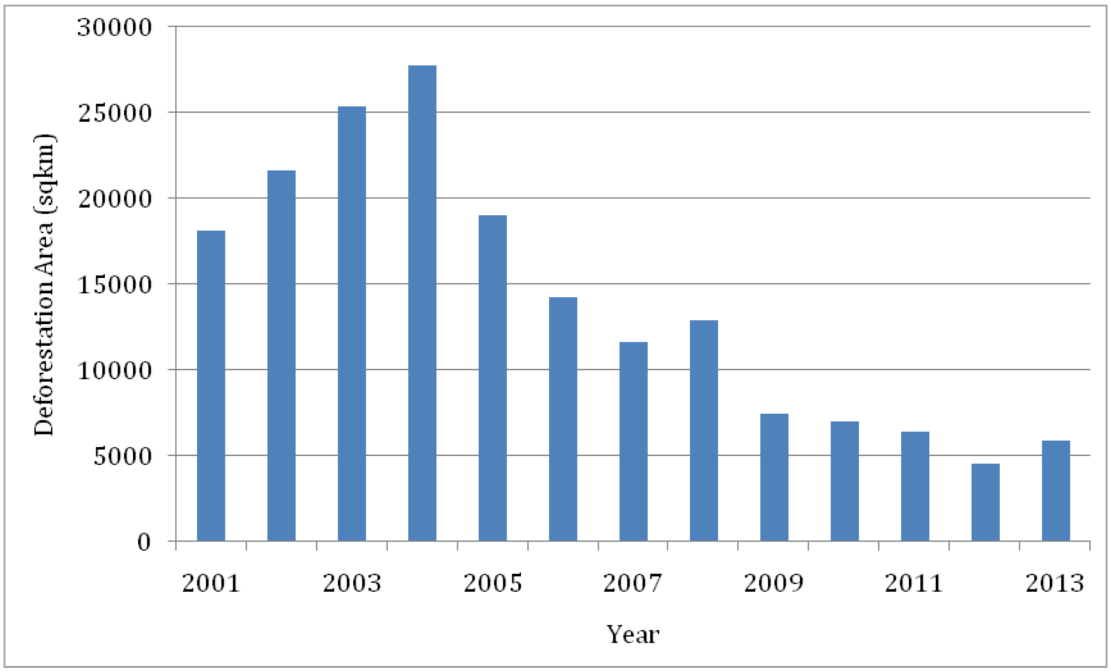
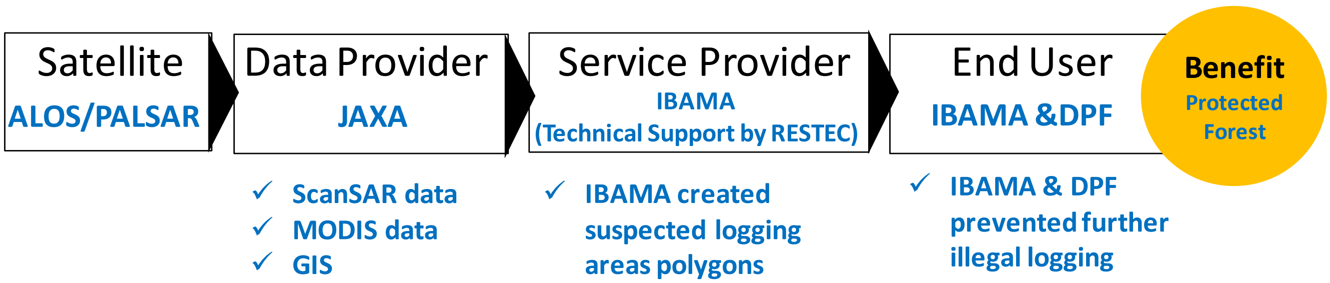


Fig 2: Annual rate of deforestation in the Brazilian Amazon in the time period of 2001-2013.

Since ALOS finished its operation in 2011, INDICAR has also suspended operation. However, JAXA launched ALOS-2 satellite in 2014 and JICA has been considering a next project to upgrade the system with data from ALOS-2. This technology can be transferred to other countries where forest cover is changing in large areas such as 4-5 hectares at minimum each.

Value Chain



JAXA provides PALSAR (ScanSAR mode) data for IBAMA which creates color composites to detect suspicious logging areas. IBAMA agents, with the support from DPF, visit the area in the field for law enforcement procedures, whenever necessary.

More Information

For more information, please feel free to contact:

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Affiliated Agencies: DPF, IBAMA, JAXA, JICA, RESTEC

Chapter 2:
APPLICATIONS IN EUROPE

Europe – Transportation

The Copernicus Sentinels Benefitting Society and Environment: first examples using Sentinel-1A

Europe's Copernicus programme provides key data and information services to improve environment management, help mitigate the effects of climate change and safeguard everyday lives. The Programme is based on a new family of Sentinel satellites that supply accurate data in a sustained, operational way. The first, Sentinel-1, is already routinely providing all-weather, day-and-night radar imagery in support to several applications and notably to those applications requiring continuous monitoring of large areas at sea. Operational supply chains are expected to be progressively integrated with Sentinel-1. Two near real time chains are already up and running, providing ice monitoring services and, since more recently, support to oil spill monitoring. The example featured in this article - ice charts for the Greenland waters - is used by the Greenlandic population (e.g. fishermen, hunters and local authorities) to support safe conduct in the harsh environment.

Problem

Oceans not only represent a key ecosystem influencing life on Earth, but also an enormous reservoir of potential resources. They are theatre to ever increasing exploitation activities and growing marine traffic. In European waters alone, more than 20.000 ships are tracked everyday1, carrying passengers but also oil, gas and other goods. In order to support safe and secure activities while always protecting the environment, enhanced monitoring capabilities are needed. For instance, to support navigation in the Northern seas - which are hazardous in winter due to the presence of ice - or to face spills from vessels, offshore platforms and oil pipelines - which may severely pollute marine and coastal habitats and cause enormous damage to the natural environment and to the economy. Aircrafts could be used to monitor such areas, but over very large surfaces they are time-consuming and expensive, and usually not a feasible option for private companies nor for public authorities.

Satellite Earth Observation Data Application

Earth observing satellites have a demonstrated capability to provide an effective and efficient solution to continuously monitor very large areas at sea. Satellite-borne radar imagers are capable of distinguishing different targets like ships, oil slicks and floating ice. The images can be used, together with other kinds of data, to produce high-resolution ice charts and forecast ice conditions such as motion, concentration, thickness and ridges. The maps and forecasts, continuously updated, are useful for various types of users (e.g. from shipping companies to local authorities) to plan their routes with improved safety of navigation. Examples of satellite maps and of derived ice charts are shown in Figs. 1 and 2 for the case of Greenland waters. Greenland, with its immense coastal areas2, coupled with the remote conditions and the need to reduce the risk of threats to its unique ecosystems, is an area where the use of satellite-based imagery is particularly beneficial.

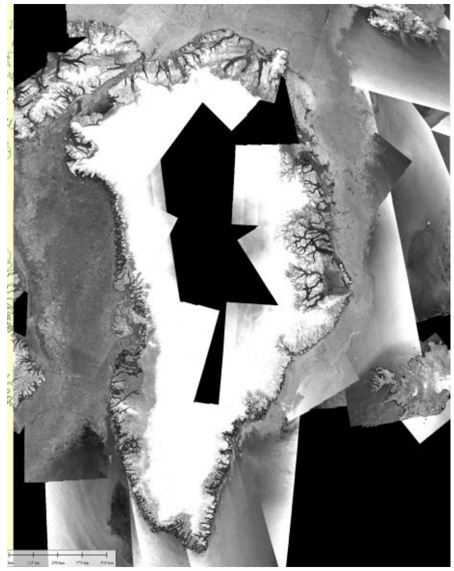

Fig 1: Satellite borne radar images from Sentinel-1 mosaicked by the Copernicus Marine Environment Monitoring Service,. Credits: © Copernicus Sentinel Data (2015)

To support environmental policy applications, satellite images can be screened via semi-automated techniques to quickly detect oil slicks and vessels. If correlated with identification signals emitted by all "regular" vessels, they can help identifying potential polluters and help tracking illegal releases. Thus this application helps to strengthen operational responses to accidental and deliberate discharges, and assist local authorities in their follow-up actions for the areas under their jurisdiction.

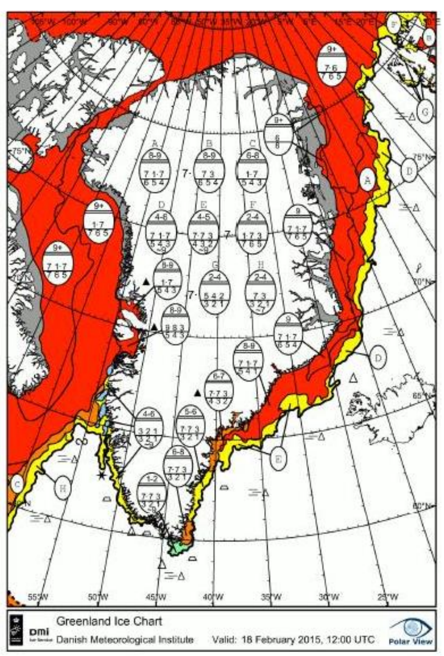

Fig 2: Greenland ice chart, as derived from Sentinel-1 data on Feb. 18, 2015. Credits: DMI, PolarView.

But, for satellite images to be exploited in operational services, a sufficiently frequent coverage must be guaranteed and the information must be made available as quickly as possible. In addition, long-term sustained and reliable data delivery must be ensured. Copernicus Sentinel-1 mission has been designed to meet such requirements and, with its focus on reliability, operational stability, global coverage and quick data delivery, is expected to make a step change in several operational applications. The satellite is capable of imaging up to 4 million sqkm per orbit, ensuring a revisit time in the North pole of up to several times per day. In 2016 a second satellite of the same type, Sentinel 1B, will be launched with a complementary orbit, doubling the coverage performances.

Value Chain

Sentinel-1 acquires in a pre-programmed conflict-free operation mode, imaging global landmasses, coastal zones, sea–ice, polar areas, and shipping routes at high resolution. The data are systematically downlinked, processed and made available to users. The Copernicus Services exploit satellite data and combine them with other types of data (e.g. from other satellites, numerical models and/or in-situ sensors) to derive value-added information for various types of uses. One of these Services, the Copernicus Marine Environment Monitoring Service (CMEMS), provides – among other products - operational forecasts for sea ice, thereby supporting ship routing and search & rescue activities in the Northern seas. In those areas, an average of ~ 15 acquisitions per day are performed by Sentinel-1A, and products are made available via a dedicated dissemination line within 3 hours from acquisition. Based on these data, CMEMS partners produce daily ice charts, iceberg density maps and maps of sea ice drift and deformation. One of the chains, schematically presented in Fig. 3, produces ice maps for the Greenland waters. Such maps are exploited especially from the local population (e.g. public authorities but also fishermen, hunters…) who use it for safe conduct in the harsh environment. Outside from Greenland, shipping companies, fisheries, tourists and scientists worldwide account for almost one third of the user base. Overall, more than 150.000 ice charts and over 200.000 related satellite images are downloaded every year from the DMI access point[1], and the numbers are rising after the availability of Sentinel-1.

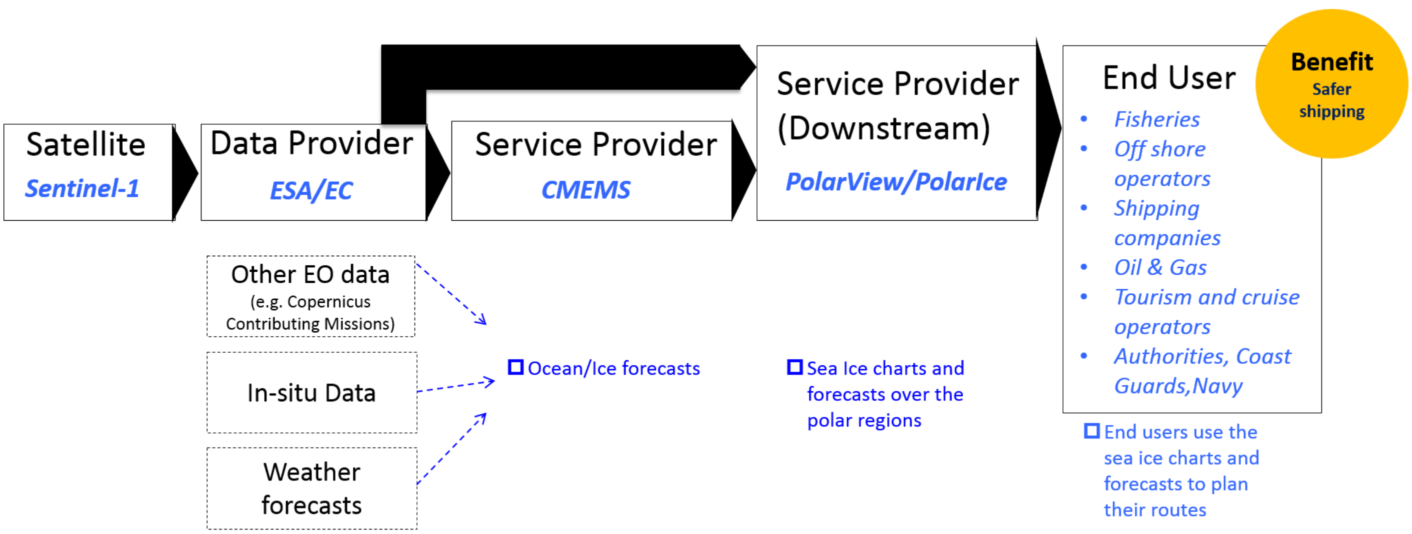

Fig 3: Graphical representation of the ice monitoring value chain, from Sentinel-1 via the Copernicus Marine Environment Monitoring Service (CMEMS) and the downstream service provider PolarView.

Another operational chain is the one to support the maritime surveillance activities within the Copernicus Security Service portfolio. ESA is providing a dedicated interface to incorporate Sentinel-1A

[1] http://ocean.dmi.dk/arctic/satimg.uk.php

data within the EMSA CleanSeaNet oil spill monitoring and vessel detection service. This service is already integrated into European national and regional pollution response chains, whereby national contact points are notified about detected possible oil spills within 30 minutes of the satellite overpass. Today, approximately 2.500 satellite images are processed and analysed by EMSA every year, but it is expected that Sentinel-1A will be capable to boost the service providing a much higher repetition for EU waters.

Sentinel-1 data are available for all users at https://scihub.copernicus.eu under a free and open data policy. Products and alerts from the EMSA CleanSeaNet Service are made available freely to authorized users in Europe at https://portal.emsa.europa.eu. Forecasts and other data from the Copernicus Marine Environment Monitoring Service are freely available at http://marine.copernicus.eu. Free and open access to Copernicus data and information is expected to stimulate the take-up of EO for commercial use and to play an important role in European research, thereby boosting innovation and economic growth.

More Information

Copernicus

For general information about Copernicus, please visit: http://copernicus.eu

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Europe - Transportation

Satellite based maritime surveillance to increase safety, security and efficiency of ship traffic

Authors

Susanne Lehner, Egbert Schwarz, Michael Nyenhuis – German Aerospace Center (DLR)

With 90% of all goods being transported on sea routes, an efficient, internationally competitive maritime industry is of high overall economic significance. The global exchange of goods is rising steadily causing an increase of ship traffic. New fuel efficient and safe routes are being discussed. In addition, tourism plays an increasingly important economic role at sea. To increase safety, security and efficiency of shipping and to protect the oceans, global data that provide reliable information about storms and sea state, sea ice cover, environmental pollution and ship locations are of paramount importance. This article demonstrates the use of the two German high resolution X-band radar satellites TerraSAR-X and TanDEM-X to develop maritime surveillance products, including ship detection and traffic monitoring or wind and sea-state information. The products are generated independently of weather conditions and in near-real-time (NRT) and are delivered to AIRBUS-DS as commercial service provider and users involved in R&D projects.

Problem

The monitoring of ship traffic is currently executed on the basis of data collected from radio communication systems like terrestrial AIS or LRIT and onboard ship or coastal radar. As these systems were originally established to support collision avoidance, their application to generate global maritime domain awareness is limited: Coastal radar and communication systems only provide local shipping information usually at a radius of about 30 nautical miles. Using satellites with radar or AIS sensors may overcome this limitation of range. The quality of AIS data from the communication systems can be affected though by human interference like counterfeiting and negligence as it is a cooperative system. There are further systematic technical limitations like message collisions, which happen for the wide acquisition areas of satellite AIS and thus the need of confirmation by Earth observation data.

Additionally high resolution measurements of wind and sea state fields are essential for maritime domain awareness and frequently requested by shipping and offshore construction and maintenance. The usage of buoy data is restricted to local coverage and weather forecast systems can be improved by better quality of wind field input including frontal development and resolution of underwater topography. Using SAR data is a promising approach to integrate model and in situ data and their use provides the ability to monitor spacious ocean areas in all weather and sunlight illumination conditions.

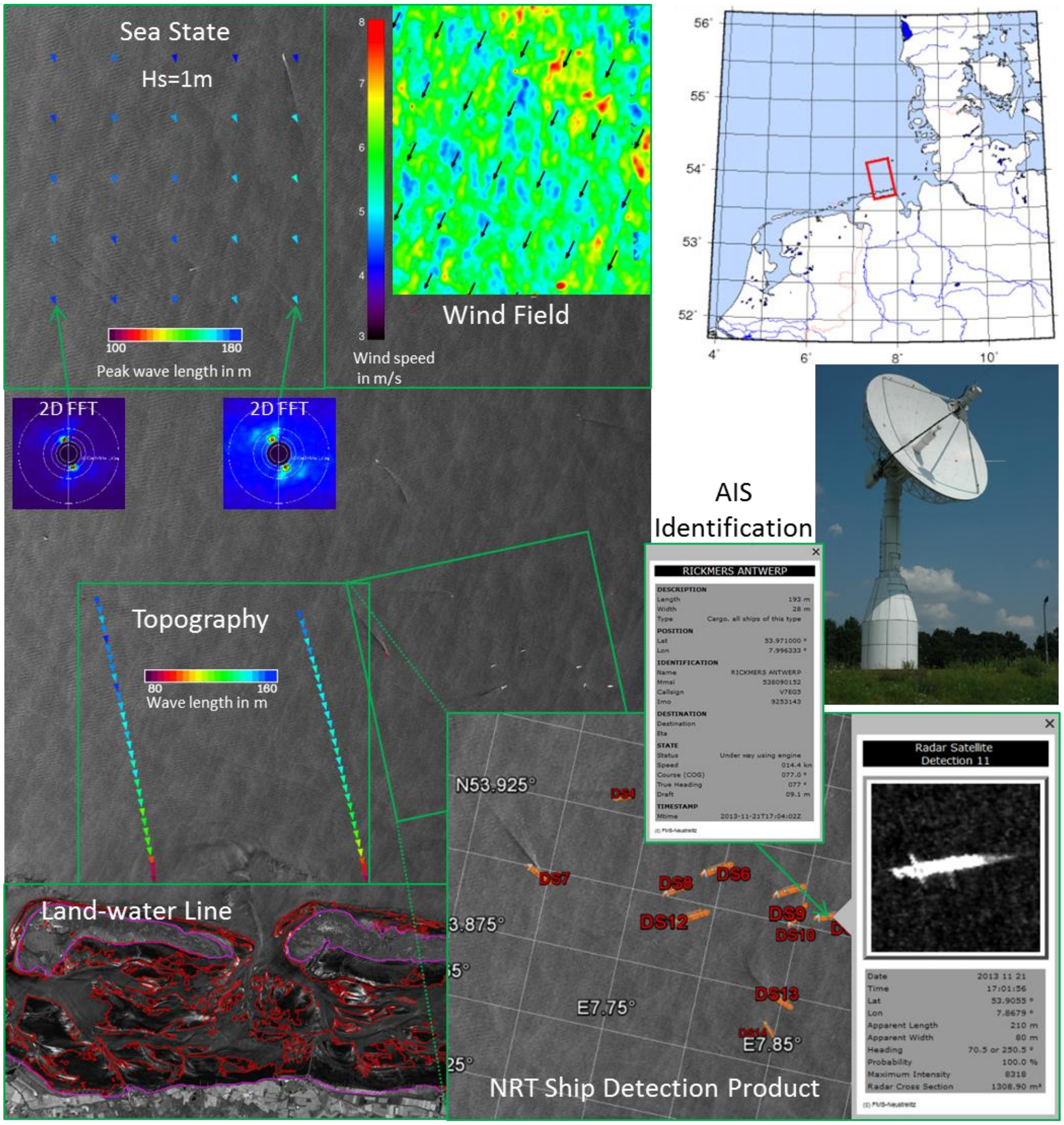

Fig 1: TerraSAR-X Stripmap scene with results provided by maritime NRT-value-adding-processors. Shown are wind field, sea state map (here swell from a different direction to wind), topography retrieval, ship detection results and land-waterlines (date: November 21, 2013) at the German North Sea Coast, © DLR 2013, Visualization of ship detection in Google Earth.

Maritime TerraSAR-X Applications

We investigated how maritime domain awareness can be increased using high resolution X-Band radar data from the TerraSAR-X mission in NRT. The use of large-scale and high-resolution Earth observation data provides the ability to localize, identify and track ships in coastal areas or the open sea. The derivation of wind and sea state parameters supports the planning and maintenance of offshore construction. Radar images and the value-adding products can be delivered to ship bridges and coordination centers within near real time, supporting Search and Rescue missions, Weather Services and pursuit of piracy, smuggling, illegal fishing and environmental crime.

The service is operationally available. AIRBUS-DS, commercial service provider for TerraSAR-X products, added the ship-detection service to the product portfolio and supplies end-users with these products.

The European FP7 project SAGRES demonstrates that by using different satellite resources such services become more reliable and the limitation of image acquisition opportunities can be reduced. DLR currently implements the NRT processing chain for the European mission Sentinel-1. This will increase the service capabilities for NRT products for maritime surveillance.

Value-Adding Chain

DLR developed a near-real-time processing chain for TerraSAR-X ship detection, wind field and sea state derivation, oil spill and iceberg detection within the TerraSAR-X Payload Ground segment. The acquisition circle of the ground station in Neustrelitz using an elevation of five degrees allows a coverage, e.g., towards the South, up to the Mediterranean Sea. Delivery of TerraSAR-X images and value-adding products can be accomplished within 15 minutes. The ship detection products are automatically overlaid by AIS information in order to provide vessel identification and anomaly detection possibilities. Operator interaction is only required for quality assurance.

The wind field and sea state products are delivered to weather centers and used up to now for validation purposes of high resolution coastal models. Assimilation and thus model improvement is a further issue. While a fast delivery is already possible in the framework of campaigns the goal is to achieve a 24/7 service connecting to the technical environment of the individual user at affordable data cost.

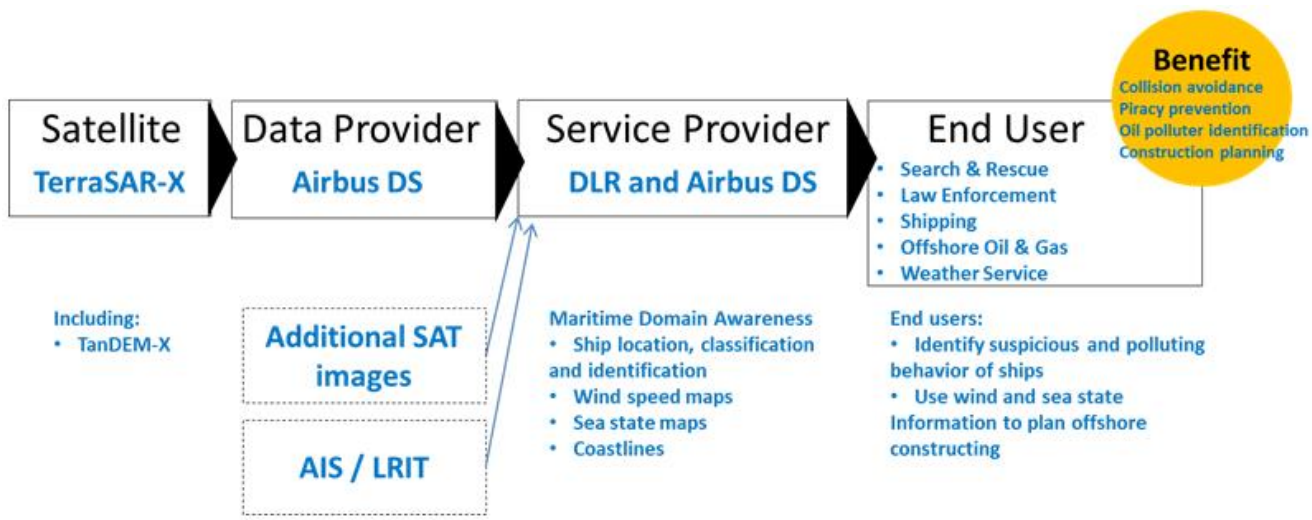

Fig 2: Value-adding chain

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Europe - Transportation

Radar Satellite based sea ice and iceberg monitoring

Authors

Oliver Lang, Roland Christmann, Markus Jochum – Airbus Defence and Space

As a consequence of climate change the sea ice conditions in the Arctic during the summer months become increasingly attractive for commercial shipping. Timely variable ice conditions require continuous and frequent monitoring to ensure safe, ecofriendly and economic routing of vessels. This article describes the use of X-Band synthetic aperture radar (SAR) earth observation data for the derivation of tactical iceberg information. High resolution SAR data can substantially enhance the situational awareness of the local sea-ice conditions and thus is expected contribute to marine safety as well as to the optimized planning of commercial operations in Arctic waters.

Problem

In polar regions pack-ice and iceberg drift show a dynamic nature, with wide deviations in its extent depending on changing oceanographic and meteorological phenomena. Shipping routes in the Arctic north remain therefore affected through ice and icebergs. Increased exploration activities in Arctic waters also increases the demand for maritime domain awareness as offshore operations are conducted within the vast and remote areas towards the poles. Operations involve offshore surveying as well as constructing and maintenance of installation far from terrestrial infrastructure. There is a need for integrated situational awareness services combining large scale ice condition maps with detailed tactical information. Radar remote sensing has the potential to provide the source data for such an integrated service.

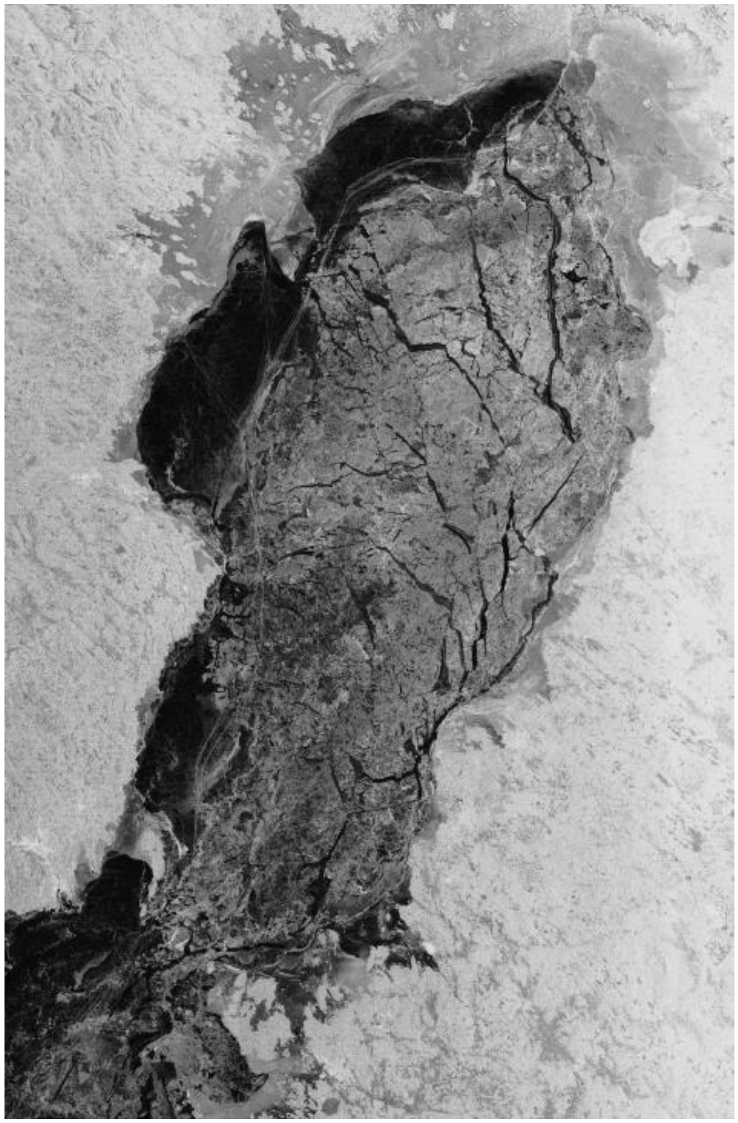

Fig 1: TerraSAR-X Wide ScanSAR scene with heavy sea-ice conditions at Bay of Bothnia (date: March 17, 2013), © DLR e.V. 2013, Distribution Airbus DS

Satellite Earth Observation Data Application

Airbus Defence and Space (Airbus DS) and the German Aerospace Center (DLR) investigated to support tactical ship routing with high resolution X-Band radar data from the TerraSAR-X mission. As a baseline, wide area SAR modes from C-Band missions are used to gather information for strategic ice information. In order to complement the situational awareness, the entities mentioned above were jointly developing and investigating tactical information content from TerraSAR-X imagery. A high level of scene details and provision in a timely manner is a key element for tactical maritime information. The synergistic use of large-scale and high-resolution Earth Observation sensors improves the situational awareness without limiting the observation capacities of a single system.

DLR has developed automatic near-real-time vessel and iceberg detection algorithms for TerraSAR-X imagery. This processing capacity has been evaluated and further complemented by an operator component by Airbus DS. Figure 1 shows an example of an integrated vessel/iceberg detection product.

Earth observation based information layers increase the awareness of the present sea-ice situation beyond the visibility of on-board systems and therefore supports Search & Rescue operations and the avoidance of collisions for vessel operations in maritime areas prone to ice hazards.

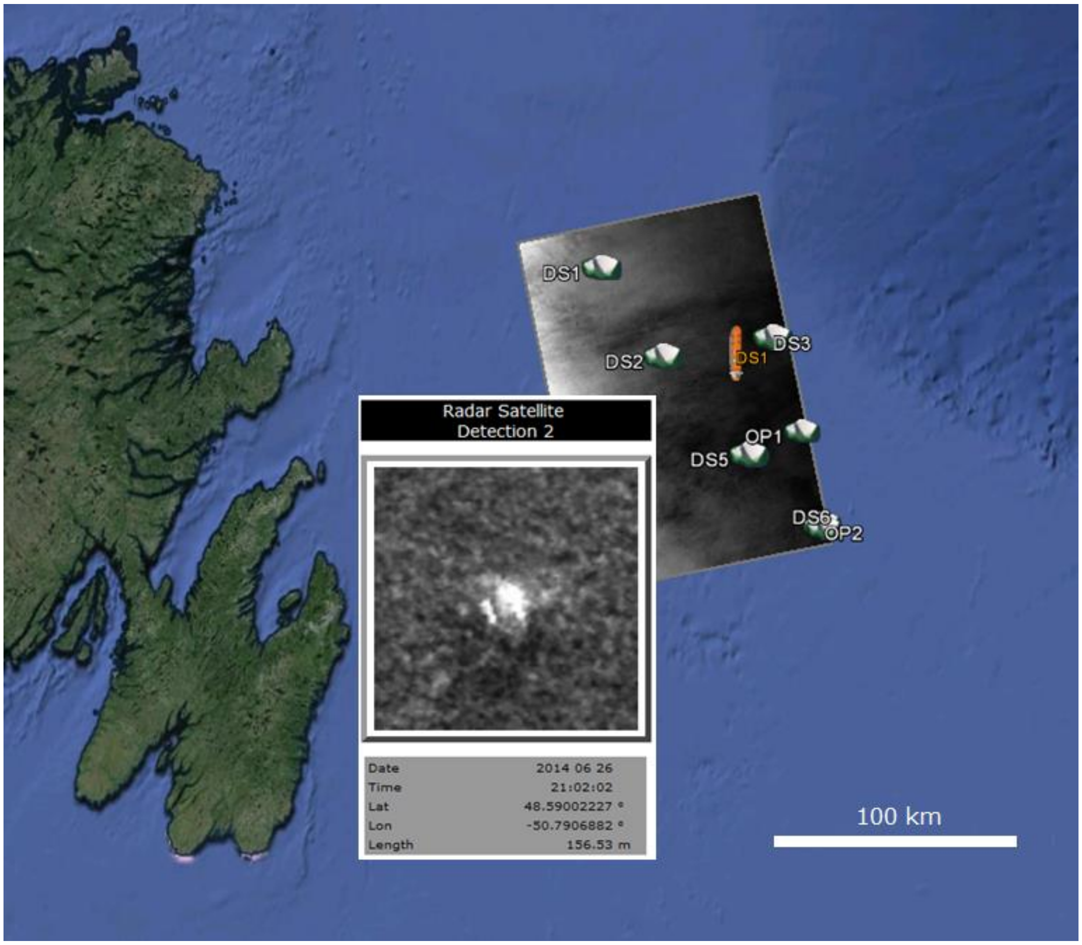

Fig 2: Semi-automatic iceberg/vessel detection report (near Neufoundland, Canada), based on TerraSAR-X (date June 26, 2015), © DLR e.V. 2014, Distribution Airbus DS. Visualization in Google Earth.

Value Chain

X-Band data from the TerraSAR-X mission is well suited for tactical ship routing due to the sensor's high resolution modes its largely independency of cloud cover and sunlight. The Spanish PAZ satellite (owner and operator: Hisdesat) will be launched in 2015 into the same orbit as TerraSAR-X and TanDEM-X. A near-real-time processing chain has been developed for the detection of vessels and icebergs within a scene. DLR is presently preparing a near-real-time production of an ice classification map. In areas where a satellite data reception facility is available, imagery and automated detection products are available within 30 minutes after the acquisition.

A subsequent operator based quality assurance (QA) step ensures reliable detection product and allows for the discrimination between icebergs and vessels by correlation with AIS (Automatic Identification System) information in combination with a visual analysis.

The resulting tactical iceberg / vessel detection product is finally either fused into a more general situation report or alternatively directly used by the end-user.

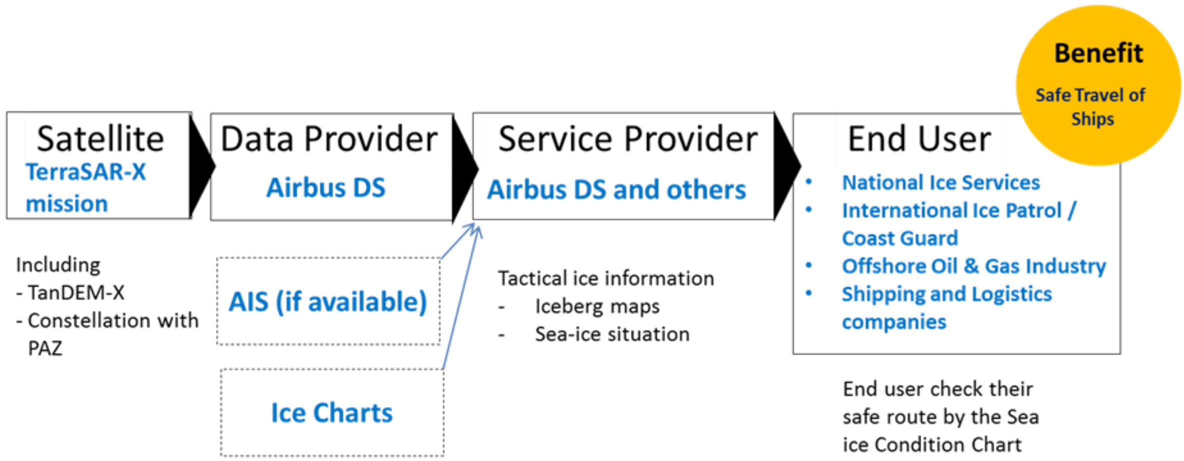

Fig 3: Value Chain for tactical sea-ice information

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AIRBUS DEFENCE & SPACE

Europe - Transportation

Use of Earth Observations satellites for maritime downstream applications

CLS (Collecte Localisation Satellite), France

03-JUN-2015

Since a few years now, ocean-observing satellites entered an operational era and naturally occupy a major place in the development of products and services designed to manage and predict ocean and climate change for the benefit of maritime applications.

Earth-Observation (EO) satellite requires a long experience in the processing, validation, distribution and exploitation of satellite data. Derived from these Earth Observations, remote sensing products are now setup and distributed in real time:

- Sea level heights and ocean currents are derived from altimetric satellites (such as Jason-2, HY-2, Saral/AltiKa and the future generation of Sentinel European satellites).
- Sea surface temperature is derived from optical satellites (such as AVHRR sensors on NOAA satellites, AMSR-E on Aqua, TMI on TRMM...).
- Ocean colour is also derived from optical satellites (such as MODIS sensor on Aqua, VIIRS sensor on Suomi...).
- Sea surface salinity is derived from specific satellites (such as SMOS...)
- Sea state, detection of oil spills, detection of iceberg, and detection of vessels at sea are derived from synthetic aperture radars (such as RadarSat-2, TerraSar-X, CosmoSkyMed, Sentinel-1...).

The development of operational oceanography systems benefits from EO data. These systems integrate composites of remote sensing data with in-situ data and ocean models to provide a real time description and prediction of the ocean state. By broadening the use of EO data to the validation and the calibration of operational oceanography systems, real-time products and services for operational oceanography applications are available for various downstream users.

In this technological context, the use of satellite Earth-Observation (EO) data, provided by up-to-date remote sensing techniques, has been shown to be extremely valuable for different industrial applications at sea. Today, the combination of different remote sensing techniques and operational oceanography systems affords integrated products for downstream maritime applications such as the management of pelagic fisheries and the safety of offshore oil and gas operation at sea.

The distribution of marine resources (fish stocks) in deep ocean is mainly driven by the intrinsic characteristics of oceanic waters. Indeed the presence of fishes is the consequence of the ocean currents, the temperature, the salinity, the phytoplankton content of the oceanic waters. These characteristics are depicted by EO maps on surface and operational oceanographic systems in depth. Making the correlation between ocean characteristics and pelagic fish resources provides relevant information on the presence of fishes. This information is crucial for the protection of marine resources especially in deep ocean where information is sparse. EO satellite and numerical modelling provide operational tools for the integrated management of marine resources in deep ocean. With such tools, authorities in charge of the protection of marine resources regulate or prohibit fisheries in their EEZ

(Exclusive Economic Zone) depending on the estimated fish stocks; fishermen in open ocean (like trawlers, purse seiners, pole liners...) optimize their catches and respect strict quota regulations.

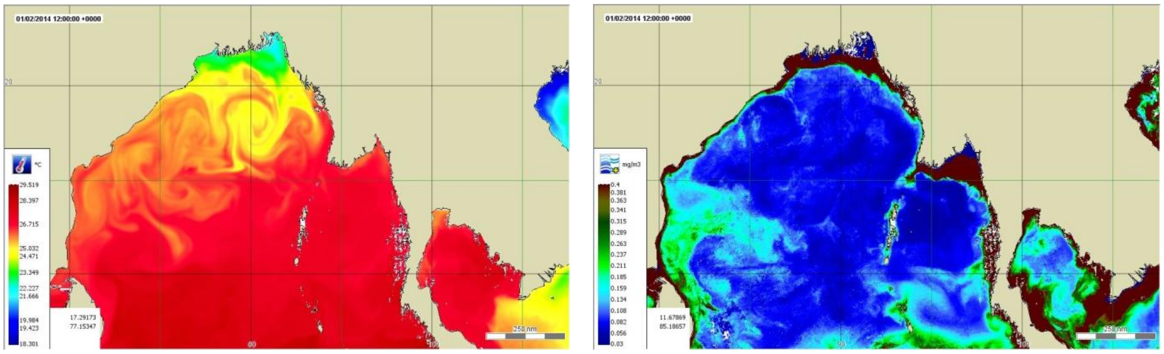


Fig 1: Map of Sea Surface Temperature (left, colours from blue, low temperature, to red, warm temperature) and map of Phytoplankton content (left, colours from blue, low concentration to brown, high concentration). Maps are derived from Earth-Observation data. Information is provided to fish stock managers for fishery regulation.

Recently, the exploration and exploitation of oil and gas industry has moved from coastal to offshore areas where the ocean conditions are extreme: currents are stronger, bathymetry is deeper (more than 1000 meters) and wave and wind environment is rougher. In these conditions, how to design the most robust equipment and ensure the safety of day-to-day operations? The role of EO satellite data became increasingly important for offshore applications especially far away from the coasts. By combining EO data, in situ data, and ocean modelling capabilities, crucial real-time ocean information and environmental studies are provided to the oil and gas industry. They are key-elements to optimize the design of equipment at sea, to support decision makers who are responsible for safety at sea during daily and critical operations and to help the offshore oil and gas community to protect the environment. With such tools, rig designers access inputs to build robust equipment that will resist to harsh conditions at sea; rig managers avoid accident on offshore platforms due to metocean conditions by ensuring safety operation at sea; environmental oil and gas specialists access real-time information to optimize maritime operations in case of oil spill pollutions.

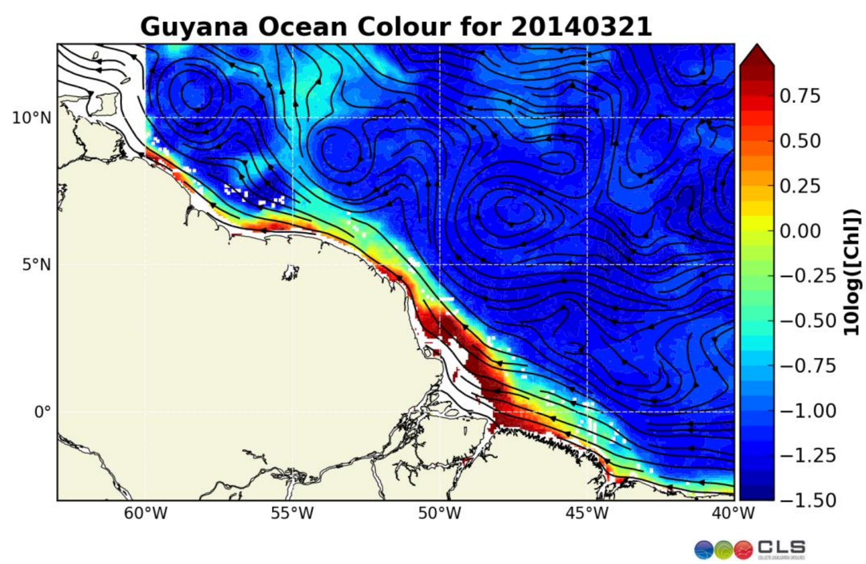
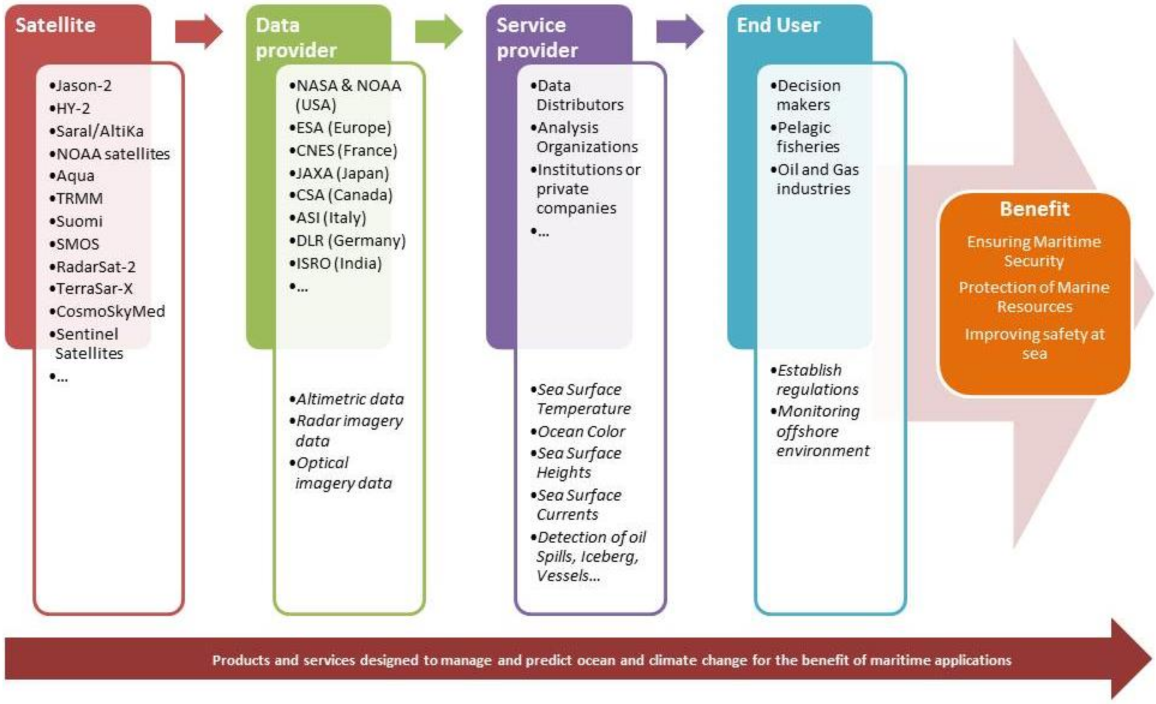


Fig 2: Map of Phytoplankton content (colours from blue to red) and Surface Ocean Currents (curved arrows). Maps are derived from Earth-Observation data and numerical modelling. Information is provided to oil rig safety managers for safety operations at sea.

Value Chain



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Europe - Disaster

The Challenge to Use EO Products for Earthquake-related Civil Protection Activities in Italy

Anna Rita Pisani (ASI), Roberta Giuliani (DPC), Stefano Salvi (INGV), Daniela Di Bucci (DPC), Simona Zoffoli (ASI).

Satellite Earth Observation (EO) products, integrated with ground-based data, can effectively support seismic risk management activities. They contribute in particular to the hazard assessment, by providing important information on ground deformation rates, and to emergency response, by providing information needed to understand the phenomenon and to manage the response actions. This report aims at showing the contribution of EO-based scientific products, generated during the 2009 L'Aquila and 2012 Emilia earthquakes in Italy, to the emergency response managed by the Italian Department of Civil Protection (DPC), which is embedded within the Prime Minister's Office and is the key coordinating body in case of national emergency.

Problem

In Italy, DPC coordinates the response of the National Service of Civil Protection to disasters (e.g., earthquakes, landslides, floods, volcanic eruptions, fires). DPC activities are supported by a number of national Centres of Competence (CC), which are research institutions and academies that integrate technological and scientific advancements in risk prediction (when possible) and prevention, risk mitigation and emergency response. Among the national CC there are also the Italian Space Agency (ASI) and the National Institute of Geophysics and Volcanology (INGV).

Currently, the DPC use of radar satellite data is in a pre-operational phase. Since 2009, during earthquake emergencies, procedures still not formally approved have been tested, and Earth Observation (EO) data contributions have been exploited providing useful results for DPC activities, in particular for event scenarios and situational awareness.

Satellite Earth Observation Data Application

In case of severe earthquakes in Italy, satellite products do contribute to the emergency response. For example geodetic GPS and InSAR imaging data (ERS, ENVISAT, ALOS, COSMO-SkyMed, TerraSAR X, Sentinel-1) are used to generate maps of ground deformation, caused by fault motion, measured in a very precise way (few millimeters) and at high resolution (pixel size up to few square meters). These maps are then employed to generate an accurate estimate of the earthquake source location and parameters, which are essential elements of the event scenario. Other useful information conveyed by the co-seismic ground deformation concerns the (re)activation of large landslides and deep-seated gravitational slope deformations, collapse of sinkholes, shallow caves or mines, passive mobilization of old fault planes, development of soil fractures, occurrence of soil liquefaction episodes. All these phenomena may imply an added hazard for the considered area, and their identification contributes to the situational awareness.

Further important information that can be extracted from the high resolution InSAR images concerns the diffuse effects of the seismic shaking on the built environment. The abrupt change of the surface properties caused, for instance, by building collapses can be detected, and its spatial extent precisely and rapidly mapped.

All these maps can be generated in near real time, being the images availability the limiting factor, since the processing, modeling, and interpretation phases require only few hours, while the first post-event images are generally obtained after 1-4 days.

Since 2009, in a joint effort including ASI, INGV and DPC, applications of satellite EO data during seismic emergencies have been carried out through specific projects.

The SIGRIS project (www.sigris.it), in particular, was mostly focused on exploiting the capacity of the COSMO-SkyMed constellation, a dual-use, 4-satellite X-band system devoted to civilian and defense uses, which is managed by ASI, and which guarantees the shortest possible global revisit time among all EO SAR satellites (down to 1 day for interferometric acquisitions). In this project the role of service providers was played by INGV, IREA-CNR (Institute for Electromagnetic Sensing of the Environment-National Research Council, that is as well a CC) and TRE (Tele-Rilevamento Europa, a spin-off company from the Politecnico di Milano University).

Among the outcomes of SIGRIS project, a first attempt to draw procedures on the activation of the CC that deal with satellite EO data was carried out. These pre-operational procedures were tested in the emergencies following the 2009 and 2012 earthquakes.

The activation of COSMO-SkyMed image acquisition for a seismic emergency in Italy takes place shortly after the occurrence of moderate to large magnitude earthquakes (> 5.0). The Council of Ministers, depending on the severity of the damages and consequences caused by the event, decides whether to declare the national state of emergency, which involves the entire National Service of Civil Protection under the DPC coordination. This prompts the CC activation for the generation, among the others, of EO-based science products. ASI turns COSMO-SkyMed in the state of highest priority, to monitor the crisis area with all available observational resources. Then the archive is examined, and a new acquisition plan is formulated to acquire post-event images matching the pre-event ones (a requirement for InSAR processing). The plan is devised and implemented by ASI, taking into account the requirements (geographic location and timing of acquisition) of the CC scientific teams. These teams process the images provided and generate added-value products: InSAR interferograms, maps of co-seismic ground displacement, maps of the general impact on the built environment, seismic source models, etc. These products are cross-validated by the CC and then provided to the DPC and the National Service of Civil Protection for their institutional use.
Two examples of InSAR-derived products are shown in Figures 1 and 2.

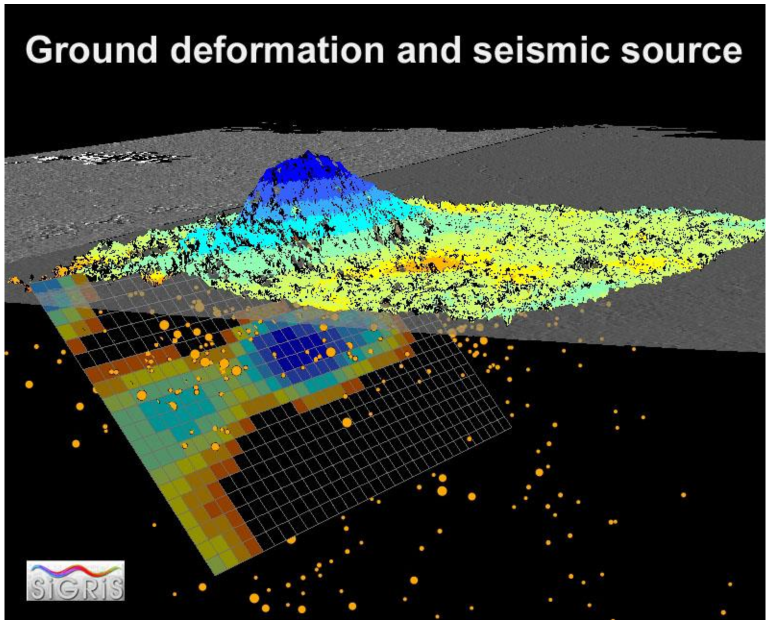


Fig 1: Ground deformation map and earthquake source model generated for a magnitude 5.8 earthquake on May 29th, 2012 in the Emilia region in Northern Italy. The post-event image was acquired 5 days after the earthquake, and the source model was generated in 2 hours and validated using seismological and GPS data. These products can be used to define the event scenario.

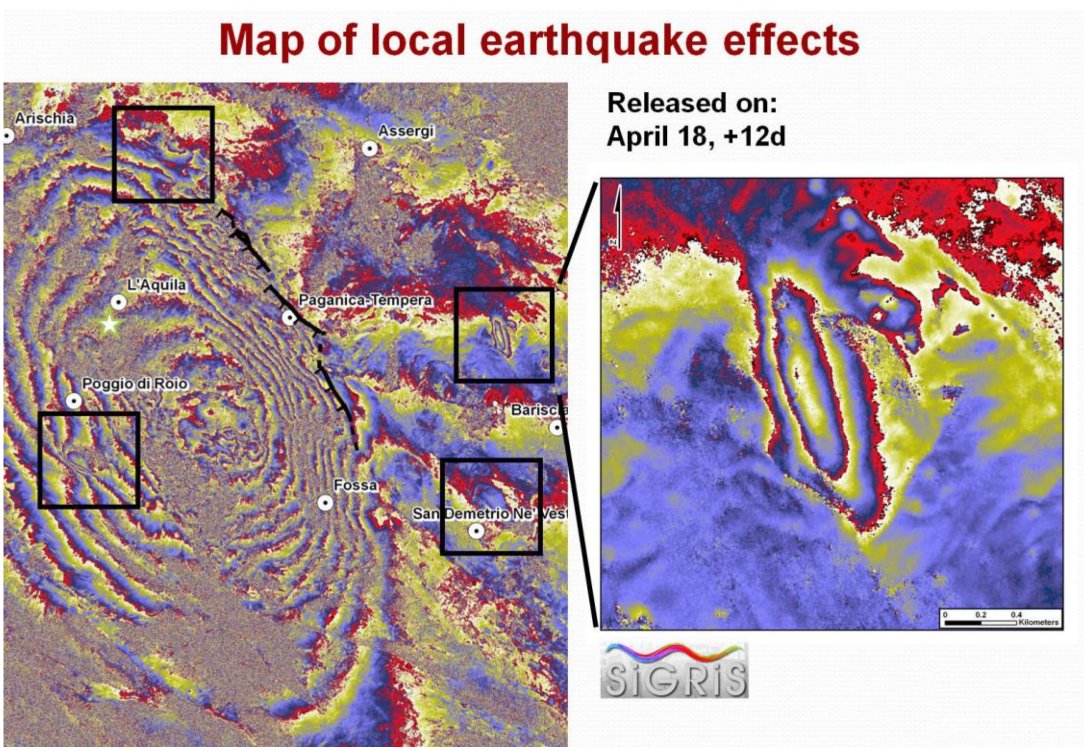
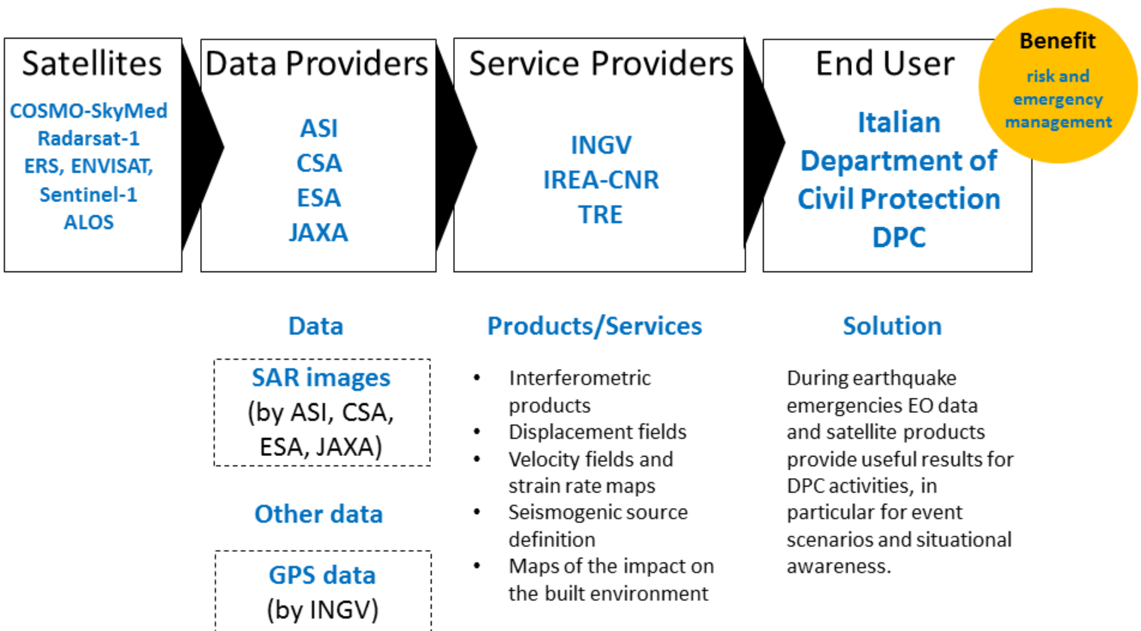


Fig 2: Products generated for the April 6th 2009, Mw 6.3, L'Aquila earthquake (Central Italy). Left image: map of co-seismic ground displacement, where local environmental effects of earthquake are highlighted (reactivated fault scarps and slow moving landslides). Right image: detailed map of ground deformation triggered by the seismic shaking on a preexisting landslide. The first useful COSMO-SkyMed post-event image was acquired 6 days after the earthquake, the first version of the ground deformation map was generated in 4 hours later, and updated versions in the following days. The product here shown was generated several days after the earthquake, since field validation was deemed necessary.

DPC takes benefits from the above-mentioned information in order to achieve a full understanding of the size of the seismic event occurred and, thus, to calibrate the emergency response in a more effective way. As an example, when planning the location of tent camps and provisional housing zones in the epicentral area, one has to take into special account the possibility of further displacements of landslides or the evolution of other geological instabilities that have already shown activation after an earthquake.

In a more general perspective, the National Service of Civil Protection indirectly benefits from the information coming from EO satellite data analysis as this contributes to the seismogenic source characterization, which is part of the scenario and seismic hazard assessment in the risk mitigation policies.

Value Chain



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Europe - Disaster

GDM: the Ground Deformation Monitoring French infrastructure for scientific applications

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As part of a national Solid Earth thematic center deployment, several French institutions are implementing a scientific service dedicated to ground deformation monitoring. This service will be based on a CNES computing infrastructure hosting Sentinels products, and will offer catalogue access, HPC facilities and thematic computation services on InSAR and optical imagery. Computation services will give scientists access to DTM, displacement map time series, quality indicators and processing and modelling tools. GDM is aimed at serving a wide panel of scientific fields, such as earthquake cycle studies, tectonics, volcanism, erosion dynamics, or anthropogenic deformations.

State of the art

The recent and forthcoming Earth observation satellite missions open a new era characterized by both a massive data dump and a need to go beyond the frontiers of the Earth components in order to get the full picture of processes acting in the Earth system at various time and spatial scales. This especially holds for the monitoring of ground deformation, a fundamental information for many processes including earthquake cycle, natural and anthropogenic hazards, and global isostatic adjustments.

Access to satellite and complementary in-situ data is provided by dedicated services. Over the last few years, several notable initiatives have been developed to provide Solid Earth sciences with efficient research e-infrastructures (European Plate Observing System, Virtual Earthquake and Seismology Research Community in Europe -VERCE-, ESA GTEP project -Geohazards Thematic Exploitation Platform- …). French infrastructures for data acquisition and distribution are organized around National Observation Services (in situ data), scientific services participating to International associations data centers and wider research infrastructures such as the Réseau Sismologique et géodésique Français (RESIF) that is the major French contribution to EPOS.

However there is still a need to fill the gap between the raw data and its scientific use, either for technical reasons (big data issues) or due to the need for a better support in term of expertise on the data, of software availability, or of data cost. Therefore the need for thematic cooperative platforms aimed to largely broaden the scientific use of data has been underlined over the last years.

The Sentinel missions launched by ESA will provide a large volume of high quality data. For the first time, it will be possible to access, free of charge, multi scales and high quality multi sensor data. The data volume will represent around 13To/day or around 5 Po/year, which is 50 times the data volume of the ENVISAT satellite. It is thus necessary to implement dedicated structures for archiving, accessing and managing such large data volume and to develop appropriate tools adapted to these new data in order to exploit them for scientific applications.

Sentinel 1 was launched on April 3rd 2014 and S2 and S3 will be launched in 2015. There are urgent needs concerning the access and storage of the Sentinel products, as well as the development and availability of tools for data processing and exploitation. Several complementary initiatives have been thus developed by ESA or national agencies for this purpose.

In France, a national thematic center project named ForM@Ter, interconnected with the CNES infrastructure PEPS (Platform for Exploiting Products from Sentinels), proposes the GDM (Ground Deformation Monitoring) service to facilitate access and exploitation of the Sentinel data for ground deformation monitoring applications.

Satellite Earth Observation Data Application

a) Stakeholders

The GDM service is proposed as one component of the ForM@Ter project.

ForM@Ter is a French Solid Earth thematic data pole project launched in 2012 by the French national space agency (CNES), and the National Centre for Scientific Research (CNRS). It relies on the contributions of scientists from more than 20 French Earth sciences institutions and laboratories. Its goal, designed with the scientific community, focuses on the determination of the shape and movements of the Earth surface with the objective to contribute to a wide variety of scientific areas (earthquake cycle, tectonics, morphogenesis, volcanism, erosion dynamics, geodynamic, geodesy) and to offer many interfaces with other disciplines, such as climatology or glaciology. Tools and products provided by ForM@Ter result from the scientific communities needs and wishes.

The PEPS platform is currently under development supported by CNES and will open its first services for a first test phase during the 1st semester of 2015. The PEPS platform is multi-thematic and is designed to provide to Sentinel data users increased efficient access to high volumes of Sentinel data, as well as:

- processing capacities,
- processing means to reduce the data volume which must be downloaded,
- sharing of tools and pooling ressources,
- validation, awareness and training.

b) Services offered, use and end users

The Ground Deformation Monitoring (GDM) service will mostly use SAR and optical satellite data for quantifying ground displacements for various scientific applications. To this end, it will provide a national cooperative platform with a unified access to relevant space based imagery and products (meta-catalogue accessing) to ease access to data, tools, and qualified products for non-expert users.

GDM will provide:

- storage of Sentinel 1-2-3 data and products,
- catalogue ingestion and facilities (search and retrieval),
- hosted computing and HPC facilities including massive data processing applications, and thematic computational chain hosting.
- displacements data quality evaluation tools

A user interface will be implemented on the ForM@Ter website (www.poleterresolide.fr). It will then be possible to access to the catalog and query remote catalogs such as the PEPS catalog. From this interface, it will be possible to download data, access and use processing tools, make thematic and intermediary products. It will also be possible to use or contribute to web services for data/product visualization and metadata discovering or have possibility to work on Single-Sign-On.

The target audience of this service is:

- Scientists: for research in tectonics; earthquake cycle volcanology (mapping of volcanic deposits and faults, determinations of topography and its evolution, quantification of the deformation…); erosion dynamic; geodynamics etc.

  The service will contribute to the ESFRI EPOS research infrastructure implementation.

- Private sector (local authorities, insurance companies…): for societal needs (land management, risk assessment).

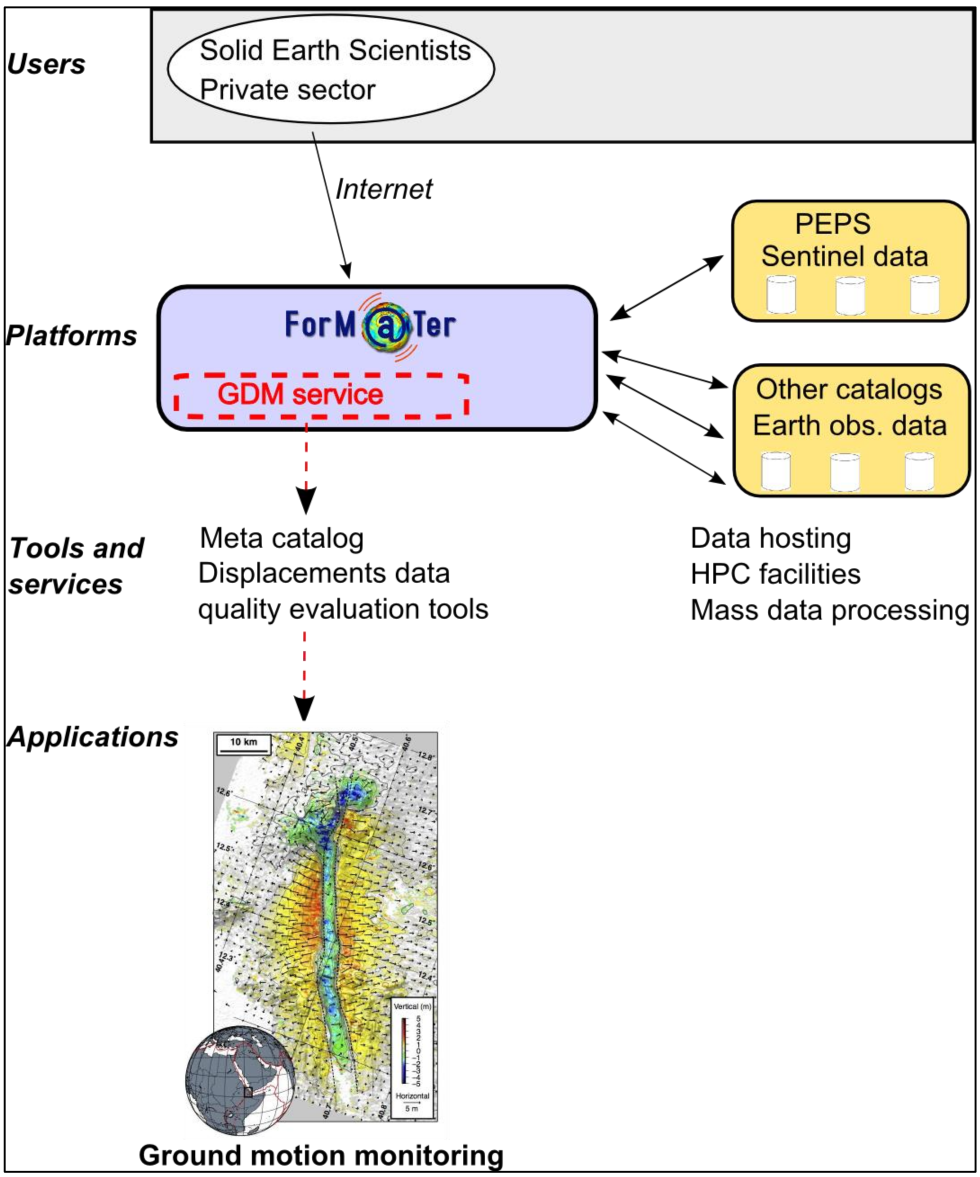
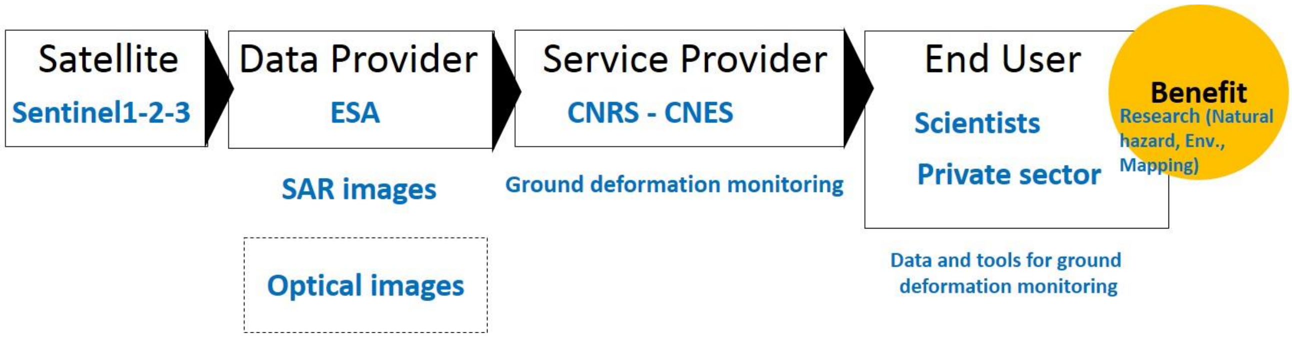


Fig 1: The GDM service, interaction between users and stakeholders, and example of applications.

Value Chain



More Information

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Europe - Disaster

The crucial and unique role of Earth Observation data within the 2014 Cephalonia (Greece) seismic crisis

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Summary

A magnitude 6 earthquake in Jan. 2014, followed a week later by a magnitude 5.9 event, caused extensive damage on the Greek island of Cephalonia. The timely acquisition of satellite radar imagery by the Italian COSMO-SkyMed and the German TerraSAR-X satellite constellations, provided a unique tool to map the 3D surface displacement associated with the second event and model its causative faults. These were located onshore Cephalonia, rather than off its western coast, as expected from seismogenic fault catalogs. This exemplifies the crucial role of Earth Observation data in improving our understanding of regional tectonics and the assessment of seismic hazard.

Problem

The monitoring of tectonic deformation plays a crucial role in improving our understanding of earthquake processes as well as our capability of assessing seismic hazard. To this end, techniques based on satellite remote sensing are particularly cost-effective, and can complement other technologies, which require deployment and maintenance of ground instrumentation (e.g. GPS), particularly in areas of the planet, which are difficult to access for geographical or political reasons. Furthermore, from the numerical modelling of surface deformation measurements, it is possible to infer the causative faults of large earthquakes, and describe their properties (geometric and kinematic). This complements the results based on the analysis of seismological data, especially in regions where the latter are scarce or of difficult interpretation.

Below we discuss the application of satellite Earth Observation data to the study of a magnitude 5.9 earthquake, occurred on Feb. 3, 2014 on the island of Cephalonia, Greece (Fig. 1). This is a plate boundary region with a high density of active faults, where seismological analyses are complicated by an instrumentation gap towards west and south-west, due to a large stretch of sea, and by the varying thickness of the underlying Earth crust. It is also an area where permanent GPS stations are few, and thus can provide only a partial picture of complex surface deformation patterns. For these reasons, Earth Observation data can provide a unique contribution to the understanding of the tectonic activity in this region.

Satellite Earth Observation Data Application

On Jan. 26, 2014 a magnitude 6.0 earthquake struck the island of Cephalonia, Greece, followed by a magnitude 5.9 event on Feb. 3, 2014, causing extensive structural damages and inducing widespread environmental effects. Following the first mainshock, acquisition of satellite imagery was planned from descending passes of the Italian Space Agency (ASI) COSMO-SkyMed satellites in the framework of the CEOS Disaster Risk Management Seismic Pilot and from ascending passes of the German Space Agency (DLR) TanDEM-X satellite. This enabled researchers at the Italian National Geophysics and Vulcanology Institute (INGV) and at the National Observatory of Athens (NOA), funded respectively by the ASI-INGV MUSA project, and by the FP7 EU project BEYOND (GA 316210), to measure the 3D permanent coseismic deformation field of the Feb. 3, 2014 event. The high resolution and timely acquisition of the satellite imagery allowed the application of a combination of advanced processing techniques, namely Differential Synthetic Aperture Radar Interferometry (DInSAR), Intensity cross-correlation and Spectral Diversity (also known as Multi Aperture Interferometry), which in turn allowed the full 3D deformation field to be mapped. Relative deformations as high as 35 cm were observed in the north-south direction, as well as an uplift of about 20 cm of the whole of the Paliki peninsula with respect to the rest of the island (Fig. 2A).

A numerical modelling of the deformation measurements was then carried out (Fig. 2B), which suggests the earthquake was mainly due to the rupture of a 20 km long ~N-S oriented fault, running almost parallel to the east coast of the Paliki peninsula. A second NE-SW oriented structure, ~10 km in length, located in the south of Paliki is also likely to have been activated. These results are somewhat unexpected, since they clearly indicate that sources with a main north-south displacement component (right-lateral mechanism) and a lesser vertical one (reverse component) are also located onshore Cephalonia, and not only off its western coast as previously believed.

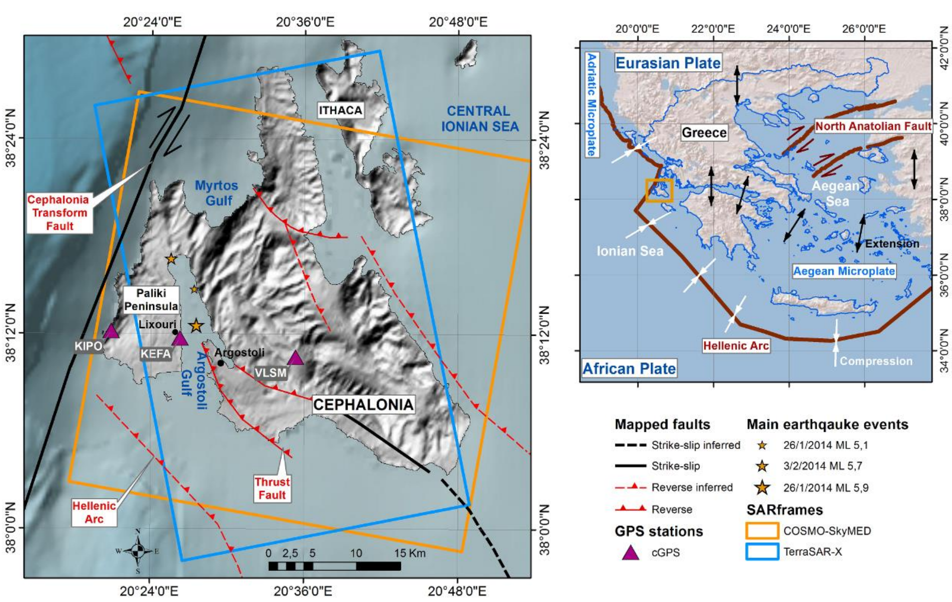

Fig 1: Tectonic context of the Aegean Sea and the main known active faults on the island of Cephalonia. Rectangles indicate the coverage of the satellite radar images. Magenta triangles represent permanent GPS stations. Yellow stars indicate the epicenters of the three largest events of the 2014 sequence.

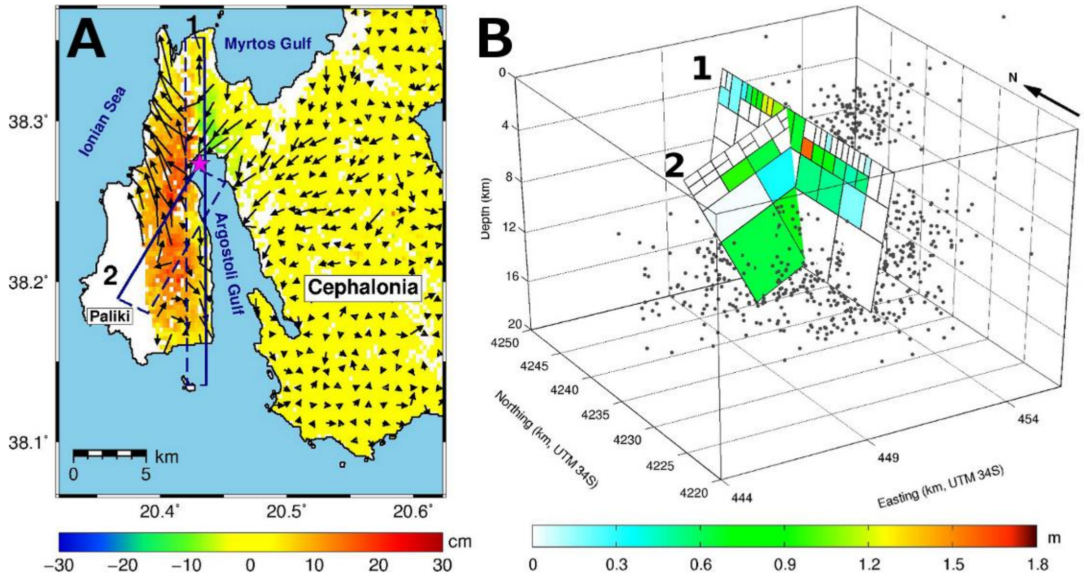

Fig 2: (A) Vertical (colour scale) and horizontal deformation (arrow field) associated with the Feb. 3, 2014 Cephalonia earthquake. Rectangles indicate the surface projection of the causative fault planes with solid lines representing the intersection with the surface. The star represents the relocated earthquake epicentre. (B) 3D view from SW of the estimated motion (slip) on the causative fault planes. The grey dots represent smaller earthquakes (aftershocks) recorded in the month following the main events.

Value Chain

This application used radar imagery from the COSMO-SkyMed and the TerraSAR-X constellations of satellites, operated by the Italian Space Agency (ASI) and by the German Space Agency (DLR) respectively.

The imagery was processed by the National Earthquake Centre department of the Italian Istituto Nazionale di Geofisica e Vulcanologia (INGV), and by two institutes within the National Observatory of Athens (NOA), namely the Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing, and the Istitute of Geodynamics. The output of the processing was a 3D map of the permanent surface deformation associated with the magnitude 5.9 Feb. 3, 2014 earthquake (Fig. 2A) and a numerical model of its causative faults (Fig. 2B).

The end users, which could benefit from this application include Greek national bodies, whose institutional tasks include geological survey and mapping, such as the Institute of Geology and Mineral Exploration (IGME), civil protection, such as the Earthquake Planning and Protection Organisation (EPPO) and research working groups, such as the Greek Database of Seismogenic Sources. (GreDaSS).

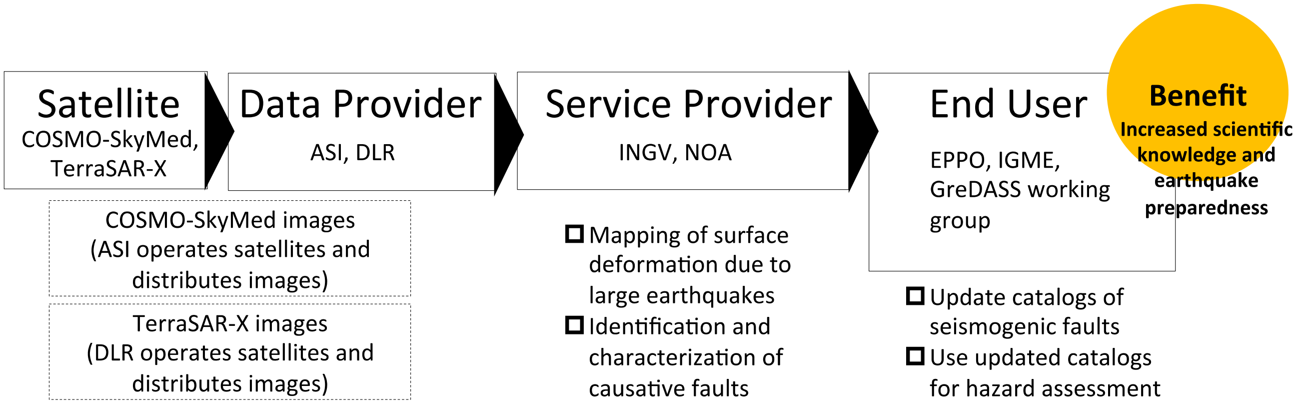

Fig 3: Value chain diagram

More Information

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Further technical information can also be found in the following journal article:
http://srl.geoscienceworld.org/content/86/1/124.full.pdf+html

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Europe - Energy

Using SPOT and Pléiades Data To Plan a Pipeline Settlement

ILF Consulting Engineers provides consulting services to help customers to execute complex infrastructure projects. In the frame of the SCPFX project (South Caspian Pipeline), the company needed a set of geographic information to assess the best routing options for a pipeline corridor in Azerbaijan and Georgia.

Problem

ILF Consulting Engineers needed information to calculate which route would guarantee the fastest and the most cost effective settlement for the pipeline, in two areas in Georgia and Azerbaijan. Leading a survey to assess best routing of a cross border infrastructure settlement can be long and expensive:

- Ground survey suppose the cost and time to send expert people in the fields for a long period – the longer the pipeline, the longer the survey;
- Airborne imagery campaigns also require administrative clearance to get flight authorization from each countries involved by the infrastructure route.

Satellite imagery sounded like a perfect solution for this situation, saving the time and effort associated to organize a ground or an airborne campaign in remote, cross-border locations. However, ILF Consulting Engineers had a double requirement: get data immediately at the start of the project and reach a final accuracy of 1m RMS.

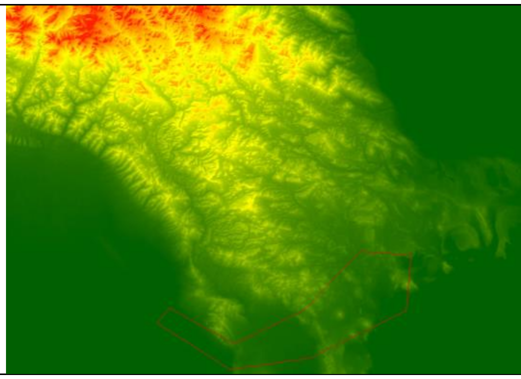
Satellite Earth Observation Data Application

Airbus Defence and Space's constellation capacity contributed to provide a variety of datasets covering a total area of 2,189km² along the pipeline corridor, in order to comply with the customer's double requirements (immediate availability, 1m final accuracy)

1. SPOTMaps and Elevation30 data were delivered promptly, as they are off-the-shelf, ready-to-use data sets derived from SPOT satellites imagery.

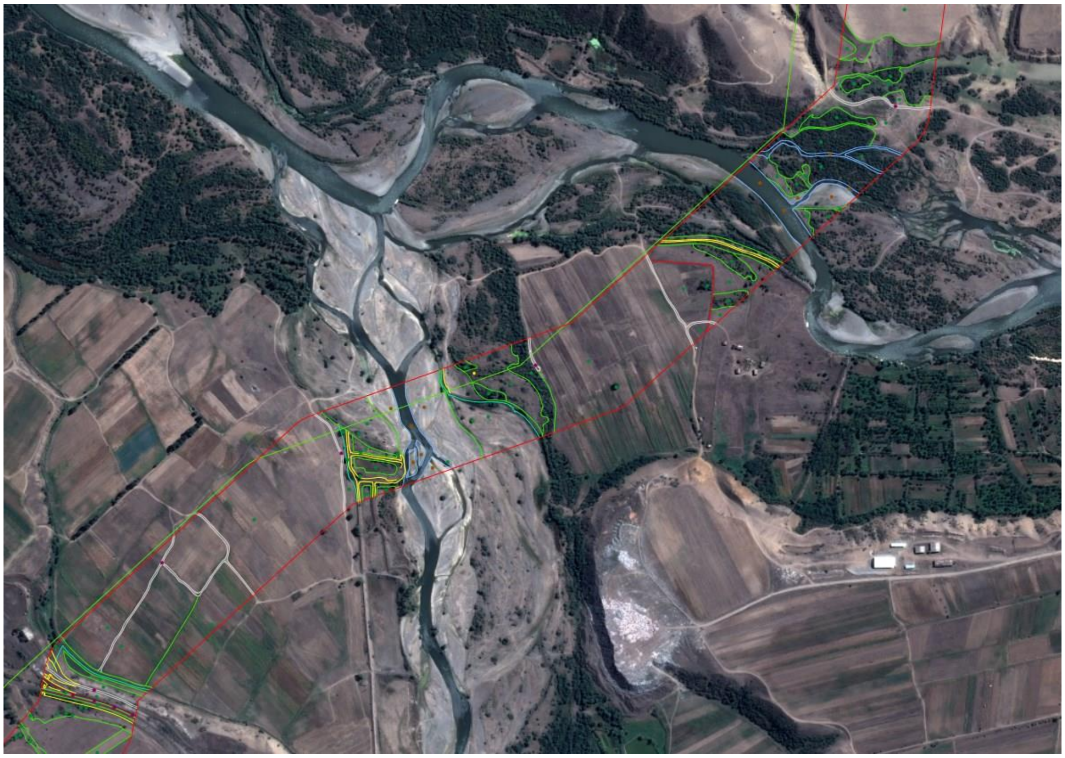
   - SPOTMaps are country-wide mosaics, featuring 1,5 or 2,5m resolution in natural color, available over more than 110 countries to date.
   - Elevation30 is a 3D medium resolution model, available off-the-shelf for more than 75m sq.km.

These 2 datasets supported a rapid preparatory study of the pipeline corridor, to analyse and correct the early routing.

	
▲For Early Morphological Analysis: Elevation30 *30m resolution 3D Model* *6 to 10m LE 90 – Off-the-shelf* *(in red, the customer's area of interest)*	***▲To Adjust Pre-Routing : SPOTMaps*** *Off-the-shelf, seamless, country-wide mosaic*

2. Then, 50cm Orthophotos, as well as 1m Elevation1 Digital Terrain Models were provided for the Area of Interest. Ground Control Points (GCPs) were captured and used to increase absolute accuracy in planimetry and elevation to help define the final plans of the pipeline project. For a subset of the corridor, 3D vector maps of topographic features along the pipeline were extracted in stereo with a scale of 1:5,000. All these datasets were derived from VHR stereo imagery acquired by the Pléiades Constellation.

▲For 3D In-detail Modelling of the Pipeline Route: Elevation 1 DTM
Precise 3D Model representing ground elevation along the final pipeline route

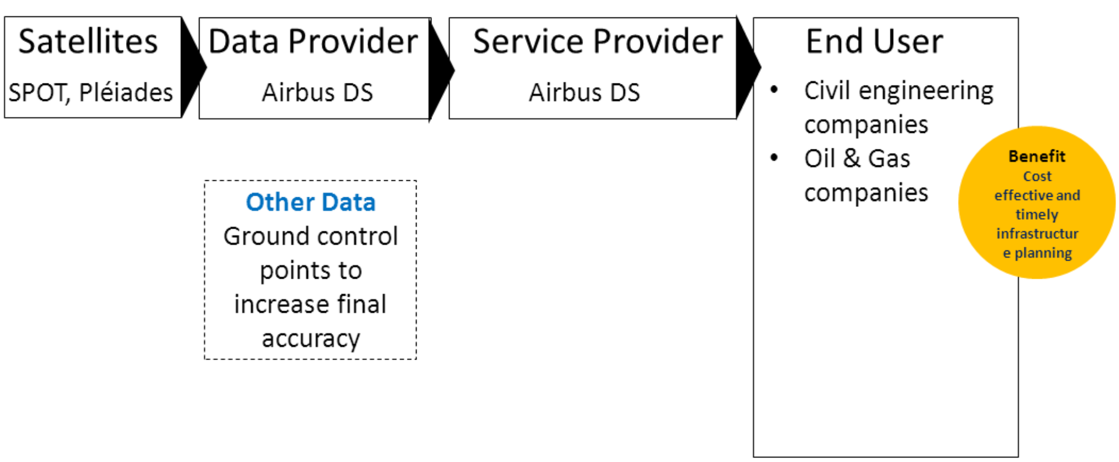


▲3D Vector Map
Topographic feature extraction at 1/5,000 scale

The accuracy of all Airbus Defence and Space products delivered exceeded the customer's specifications and expectations:

"We would like to express our satisfaction concerning the products received from Airbus Defence and Space in the frame of the SCPFX project (South Caspian Pipeline). […] SPOT and Pléiades deliverables were compared with highly precise terrestrial in-situ measurements. For over 80% of the evaluated areas, all products (DTM, Orthophoto and VectorMaps) were far better than the requested specifications, showing an RMS of 50cm to 60cm in the elevation component. Whereas the RMS of the remaining 20% was around 1m, always staying within the project's specifications." ------ ILF Consulting

Value Chain



The key benefits of Airbus Defence and Space's satellite constellation for civil engineering and energy industry are:

- Ideal combination between **coverage** and **resolution**
- From **local insight** (1 / 5,000) to **nation-wide mapping**
- From **detection** up to **identification**
- Cost and time **efficiency**

More Information

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Europe - Energy

Earth Observation for Mine Waste Characterization from Multispectral and Hyperspectral Spaceborne Sensors.

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Earth Observation for mine waste characterization may prove as an important documentation and monitoring tool in the near future for countries with a long mining history such as South Africa. In this rapidly developing country a proof of concept study was carried out to demonstrate the use of data products from multispectral and hyperspectral spaceborne sensors for mapping and monitoring rapidly changing mining landscapes. Here a cost effective monitoring system would have to rely on spaceborne data because of the need for rapid, repetitive and area-wide monitoring. Anticipated end-users of such an application would be state entities (e.g. Department of Mines and Mineral Affairs, Department of Water Affairs, Geological Surveys). Mineral producers with a strong social and environmental responsibility could use such a system to monitor and document their production and disposal activities in order to minimize the environmental footprint of the mining operation. This demonstrates, how the constant development in multispectral and hyperspectral sensor technology facilitates new applications.

Motivation

South Africa is a country with a long mining history due to the historic discoveries of gold and platinum. Figure 1 shows a part of the spatial extent of these areas where the mining for platinum group elements (PGE) and gold is carried out. Gold is mined in the central part from the Witwatersrand "conglomerate reefs", which are coarse-grained clastic sediments. Platinum mining is concentrated along the Bushveld Complex, with its prominent Rustenburg Section shown in the northern part of figure 1. Many large tailings dams and mineral processing sites, which contain the residue from mineral processing (gold and platinum extraction) are located next to densely populated urban areas, such as the Gauteng metropolitan area around Johannesburg and around Rustenburg and its associated towns in the North West Province. Here problems may arise from the dissemination of tailings material into the environment e.g. by dust plumes. The generation of acid mine drainage and the potential of metal dissolution (Cr, Ni, As, Pb, U) is another important factor in an area where fresh water resources for an ever growing population are becoming scarce [1]. Continuous, area-wide monitoring of active and abandoned tailings and mineral processing sites by standard methods, such as field surveying or by airborne data takes, is not cost effective for such a large area.

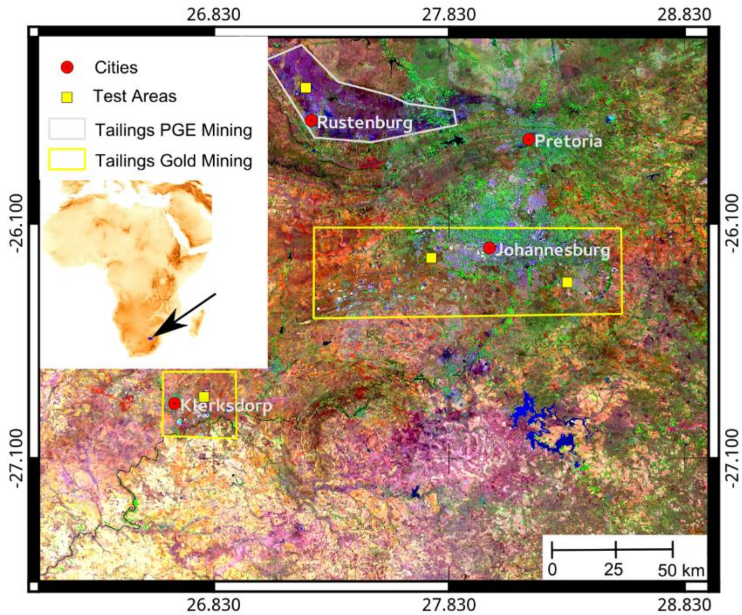

Fig 1: Landsat 8 composite (R: 2200 nm, G: 860 nm, B: 550 nm) of areas affected by gold and platinum mining and associated tailings sites around the greater Johannesburg and Gauteng area, after Mielke et al., 2014. ETOPO-1 inset map (data courtesy NOAA) for reference. Please note that only the future Sentinel-2 will have a swath large enough to cover the whole area in one data acquisition. Whilst the here presented composite is a mosaic of four Landsat-8 scenes.

This cost effectiveness is of major importance for aforementioned governmental entities, which have to maximize the impact of their financial resources that are allocated for monitoring the compliance in the industry sector with the respective laws and regulations.

Spaceborne Monitoring of Mine Waste Sites in South Africa

Only data from multispectral mapping missions can cover the area shown in figure 1 in a rapid, repetitive, effective and continuous way. Landsat-8 OLI [2] is a sensor from such a mission capable of mapping mine waste through the broad iron absorption feature around 900 nm of primary and secondary iron bearing minerals, which are characteristic for mine waste from gold and platinum mining. A robust, area-wide characterization and mapping of mine waste material is only possible via the synergetic use of multispectral data from state of the art, large-scale mapper missions such as Landsat-8 OLI in combination with a hyperspectral spaceborne sensor such as EO-1 Hyperion [3], which offers the potential of material identification via expert systems such as the USGS Tetracorder [4] and the material identification and characterization algorithm (MICA) [5]. This synergetic use is demonstrated in figure 2 at the Impala platinum mines to the north of Rustenburg where the spatial distribution of tailings and mining related material can be seen in the iron feature depth image (right image in figure 2), which matches the spatial distribution of iron bearing pyroxene (left image in figure 2). This absorption feature based relationship could now be exploited to map mine waste material in the larger Rustenburg area [6]. The capacity of Landsat-8 to map iron bearing minerals was greatly enhanced in comparison to Landsat-7 by narrowing the spectral band-width of the near-infrared channel in comparison to the broader near-infrared channel of Landsat-7 ETM+. This new band design was encouraged by the technology demonstrator mission EO-1 with its Advanced Land Imager ALI [3]. Next generation multispectral and hyperspectral sensors have the potential to improve the results shown in figure 2, due to an enhanced spectral and multi-temporal resolution. Such a perfect sensor pairing would be EnMAP [7] and Sentinel-2 [8], which have already shown their potential for the detection of secondary iron bearing minerals from simulated data [9].

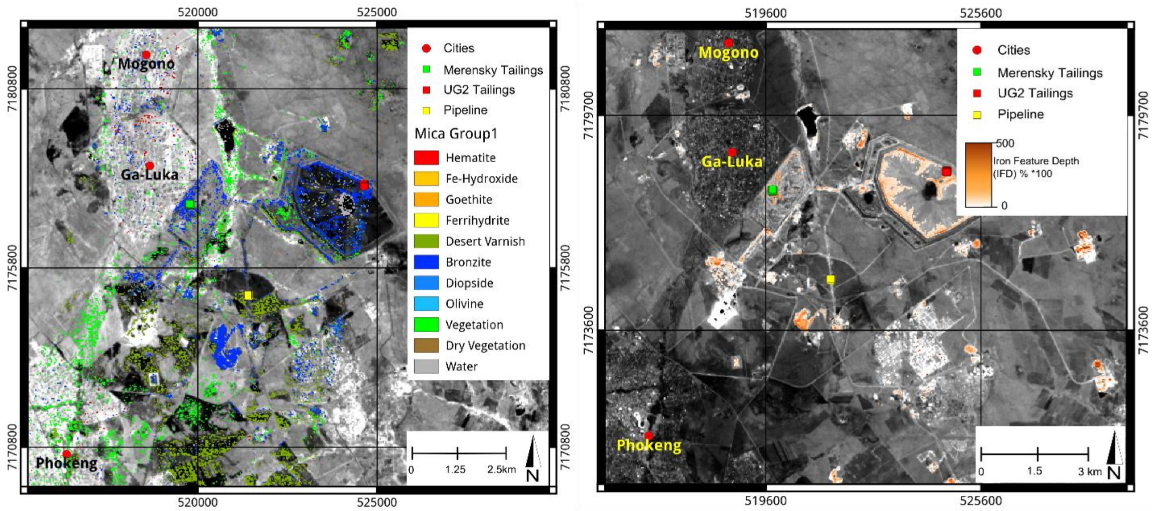

Fig 2: Mineral Analysis from hyperspectral EO-1 Hyperion data (left) using the USGS Material Identification and Characterization Algorithm (MICA) overlain over the near infrared channel of Landsat-8 OLI, from Kokaly 2012 and Iron Feature Depth (IFD) calculated from multispectral Landsat-8 data, after Mielke et al. 2014. With the help of the IFD the mine waste material distribution can be mapped with the large swath of Landsat-8 OLI (right), whilst the narrow swath of EO-1 Hyperion provides the spectral accuracy to calibrate and validate the IFD result from the multispectral OLI sensor.

The here demonstrated technological potential of current and future multispectral (e.g. Sentinel-2) and hyperspectral (e.g. HISUI, EnMAP and HyspIRI) spaceborne instruments could be integrated into an automated mine waste monitoring system for areas, which are affected by large tailings facilities, as shown in figure 1. This is demonstrated in figure 3, which proposes a value chain of such a system. The backbone of such an integrated system would be the level-1 and level-2 data, which are provided by the entities, which are operating the spaceborne sensors, for example by ESA for the Sentinel fleet, by DLR for EnMAP, by JAXA for HISUI and by NASA for EO-1, Landsat-8 and HyspIRI. This data now serves as input for the mine waste monitoring system, which could be designed and operated through a research and development partnership between public research, institutes private companies and state entities (e.g. geological surveys). The here generated level-3 and 4 datasets (e.g. actual maps of the spatial distribution of mine waste material, the change in its spatial distribution over time and derived pollution hazard maps) could then be used by end users such as public legislative and governing bodies and institutions to prevent and mitigate hazards that may arise from a dissemination of mine waste into adjacent areas. The use of an open data principle, which is already implemented for Landsat-8 and for EO-1 by NASA and which is anticipated for ESAs Sentinel-2 and for the German EnMAP mission, will further facilitate the use of multispectral and hyperspectral spaceborne data especially in developing countries such as South Africa. This enables the establishment of a valid and up-to date inventory of active and abandoned mine waste and mining sites in a cost-effective way, ensuring a better protection of local communities in the area by constant, area-wide monitoring. Such methodological development is only possible due to the refinement of the band layout in large-scale mapper missions such as Landsat-8 OLI, which arose from the groundbreaking technology demonstrator mission EO-1 with its multispectral ALI sensor. Furthermore, development of future hyperspectral spaceborne imaging spectrometers (HISUI, HyspIRI and EnMAP) was stimulated by the groundbreaking results of EO-1s Hyperion sensor.

Fig 3: Proposed model for a potential mine waste monitoring value chain that exploits the complementary strengths of multispectral and hyperspectral spaceborne data in a synergetic way. Hyperspectral data can offer a precise material identification (e.g. through a mineral map), whilst multispectral data can deliver an area wide overview on the spatial distribution of mine waste with a high temporal frequency. This synergetic use is based on the physics based absorption feature of iron that can also be resolved by modern multispectral sensors such as Landsat-8 OLI and Sentinel-2.

More Information

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Europe - Climate

Terra Aster data for urban energy efficiency monitoring

Reducing thermal waste, in particular over large areas or in large buildings is vital for global carbon emissions as over a half of the global population are living in urban areas where building stock (domestic and non-domestic use) is the greatest contributing sector of the global carbon emissions. ThermCERT analytical suite developed by Stevenson Astrosat combines and uses space and in-situ derived data to enhance quality and scanning frequency over a lifetime of a thermal investment and provide a suite of tools for targeting, measuring, reporting on, verifying, communicating and promoting thermal efficiency investments.

Problem

Decreasing carbon dioxide emissions is a stated and well defined priority in the European Union and of the global community at large – by reducing thermal waste through greater efficiency, in particular in high numbers of large buildings, a vital and cost effective reduction in global carbon emissions could be achieved.

Current progress on greenhouse gas tackling in most of the EU countries is slow, targeting low targets. In many countries only a fraction of buildings have undertaken an energy audit assessment and recurring assessment (monitoring) does not take place as the process is man power intensive thus not viable. The available information on the progress of the city as a whole is fragmented and people do not identify themselves as contributors to the greenhouse gas emissions and are not active to undertake improvement for their houses.

The environmental and economic benefits of increasing thermal efficiency are well established. The ThermCERT objective is to introduce a reliable and cost effective thermal auditing and evaluation system for wide areas of urban and non-urban environments for such end users including local/national governments, NGOs, businesses/enterprises and other carbon market actors/customers.

Satellite Earth Observation Data Application

Urban environments are extremely complex places with multiples factors that affect both the liveability and vitality of a city for its residence but also a city's environmental impact on the natural world. The main data objectives of the system would be to collate not only thermal data but also important urban 'meta-data' that can be used to make a more rounded decisions –extra data sets may be required to understand why a thermal heat source is behaving in the manner recorded (i.e. the building being looked at maybe historically preserved or serve a special function at a special time which may not show under single data sets but would have a large impact on the decision making process).

Furthermore, for the service to be deemed successful the target end-users (city municipalities and managers of energy utilities) should not require extensive man-power or special training for staff to interact with and understand the data.

Data are delivered into an interactive dashboard (see Figure 1 - Analytical dashboard) to allow for planning and situational awareness in calculating the return on investment and best impact for thermal and energy efficiency progress.

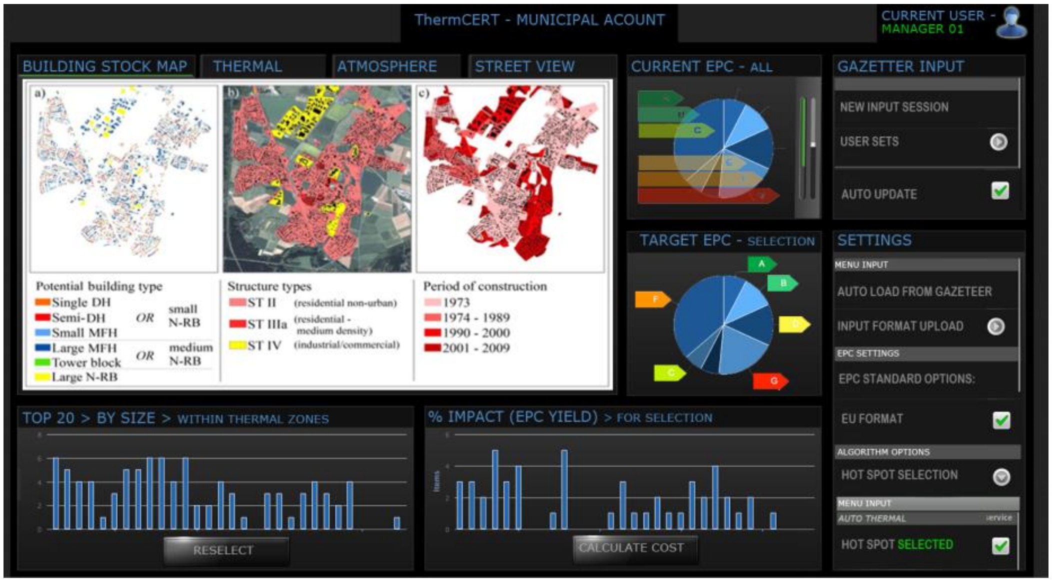


Fig 1: Analytical dashboard

As a part of our proposed integration between Space Data (for wide area planning and base-lining) we will also integrate GNSS[2] tagged in-situ (vehicular) remote sensing systems. Due to the high temporal frequency and ability to collect data in specific higher resolution areas over time, this addition of GNSS will give key measurement, reporting and verification systems for enhanced data and auditing of carbon impact and urban planning projects. Commercial end users will also find value in the access to the data collected and derived from our proposed integrated solution.

Satellite services provide us with a wide area situational understanding that is difficult to beat with other platforms. Specifically when applied to the ThermCERT program, satellite imagery can be used to identify the following key data points:

- 3D digital urban map recreation – effectively a wide area 3D map of the urban environment created on a wide scale for a small number of sensor data.
- Building identification and classification – satellite data can be used to define and understand the purpose of large numbers of buildings, its floor space etc. within the urban environment from a minimal number of scans and thus effort and resources required.
- Wide area emissions within an urban environment – city-wide thermal can be identified from satellite data with a minimal number of scans required.

Satellite systems whilst fantastic at wide 'urban wide' data collection fall down due to the nature of their operations if high resolution or high repeat times are required. To overcome this issue, satellite data needs to be augmented by high resolution/high repeat time in-situ data generated from within the urban environment itself. Data such as the recording of the thermal emissions of buildings within the urban canyon at any specific point provide a highly detailed 'snap-shot' of that particular location and given that these sensors are mounted aboard mobile vehicles the repeat time can be extremely high dependent on the decisions of those running the data collection campaign.

[2] GNSS – a GNSS receiver is an electronic device that receives and digitally processes the signals from a GNSS satellite constellation in order to provide position, velocity and time (of the receiver).

The satellite data, which gives the wide area perspective, can be used to gain a macroscopic view point on the state of the urban environment and also be used to direct the ground based assets to the points of most interest efficiently - satellite data selects "hot-spots" which define the areas where the in-situ sensors then study in detail (see Figure 2 - Satellite and in-situ measurement data integration). Detail through in-situ resolution and improved repeat times (especially if sensors end up on public transport).

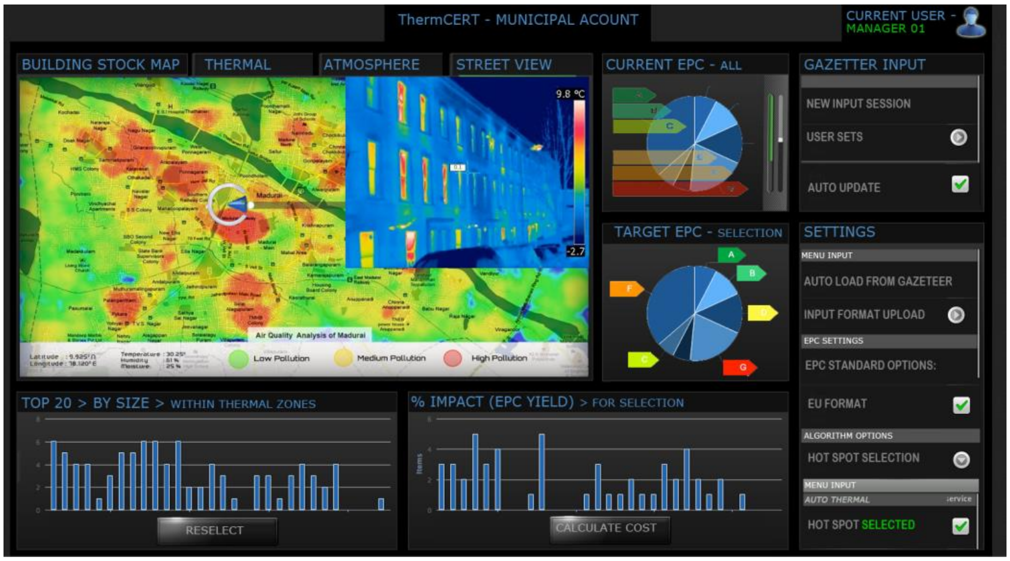
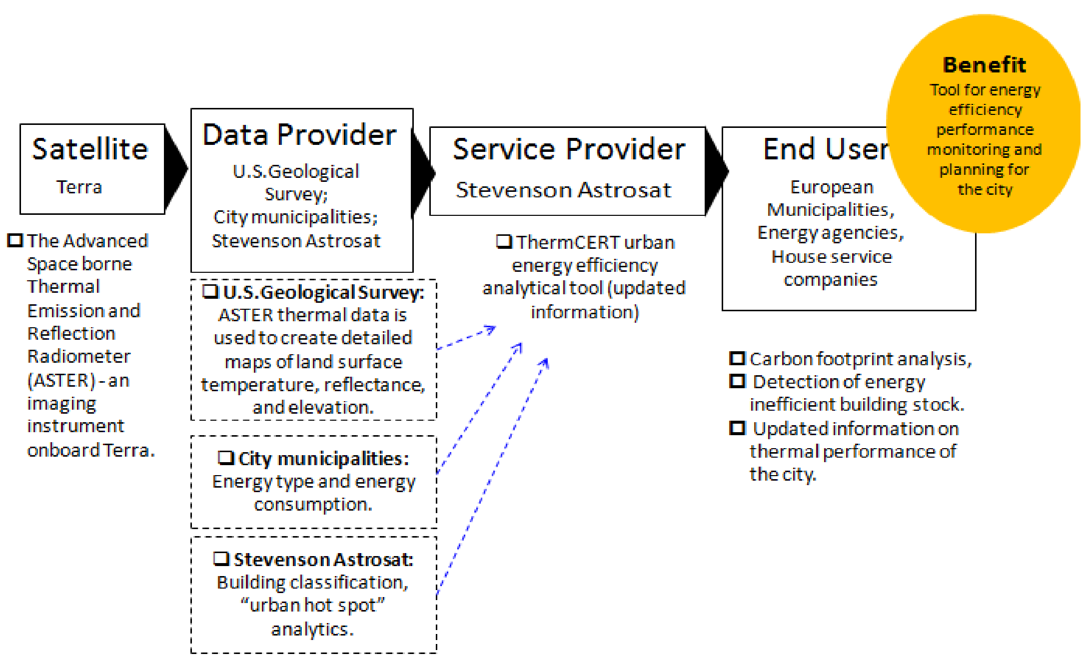


Fig 2: Satellite and in-situ measurement data integration

The ability to collect data that defines the state and health of urban environments is of the highest importance for positive and progressive policy development to ensure prosperity and sustainability. The dynamic nature of urban systems and decision making means that information is required not just as instantaneous or historic snapshots but continuously and on a timely basis – this is what we aim to deliver.

Value Chain



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Europe - Ecology

Ocean fronts helping to define marine protected areas

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Descriptions

A front is the interface between contrasting water masses, often a hotspot for marine animals such as fish, seabirds and basking sharks. Satellite tools for mapping ocean fronts have been developed and applied as a proxy for the abundance and diversity of marine animals, to assist the planning of UK marine protected areas, and delineation of significant areas in the high seas. This has generated impact in the implementation of conservation policy, which will lead to societal benefit; and could also expedite the planning of marine renewable energy installations. These novel algorithms are applied to EO data from NOAA, NASA and ESA.

Challenges

A thermal front is the boundary between water masses that differ in temperature and are often sites of high productivity. Many pelagic biodiversity hotspots are related to fronts and provide important feeding areas for seabirds and a range of iconic species, for example cetaceans and basking sharks around the Isle of Man, Hebrides and Cornwall (Scales et al., 2014a).

The UK policy context of this research was driven by the need to establish an ecologically coherent network of marine conservation zones (MCZs) by 2012. Networks of such marine protected areas are required for conservation of critical marine habitats within Europe, but knowledge of the abundance and diversity of pelagic animals is scarce. All EU countries and more worldwide are required to define MPAs in order to halt the declining environmental status of their seas.

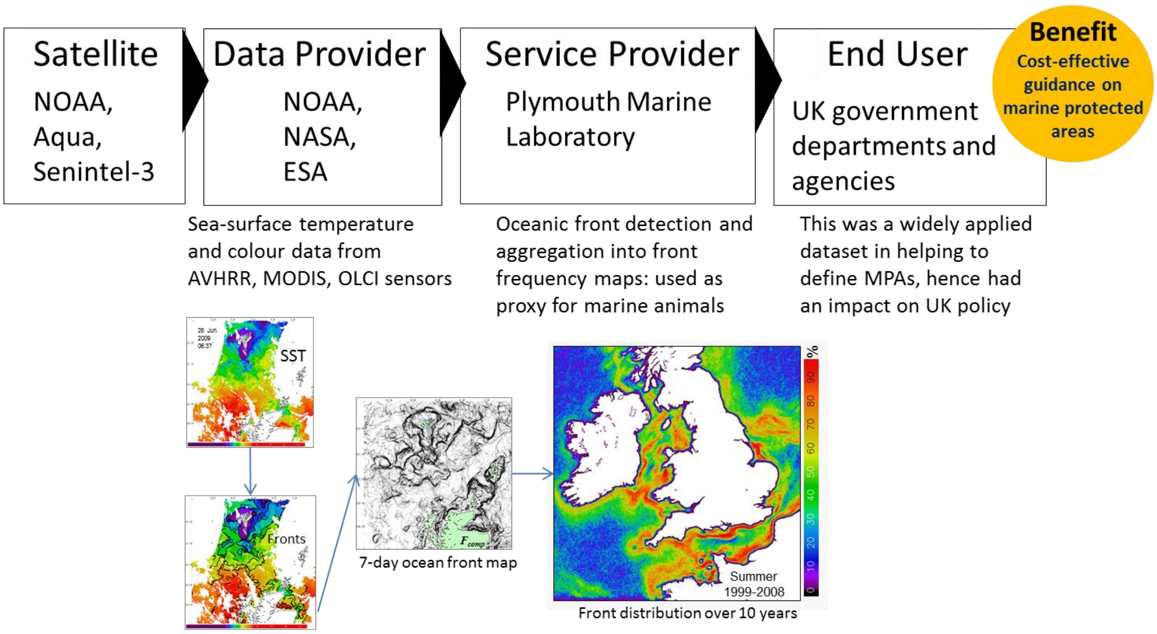
The Convention on Biological Diversity (CBD) has adopted criteria for the identification of Ecologically or Biologically Significant Areas (EBSAs) in the high seas globally, but at present these are based on fixed, benthic features.

Applications/Solutions

Satellite tools for mapping ocean fronts have been developed and applied as a proxy for the abundance and diversity of marine animals, to assist the planning of marine protected areas (MPAs). Frequent locations of thermal fronts in UK shelf seas were identified using an archive of 30,000 satellite images acquired between 1999 and 2008, using techniques developed at PML (Miller and Christodoulou, 2014). We have published many studies on the distribution of different marine animals in relation to fronts, e.g. seabirds (Scales et al., 2014b) and basking sharks (Miller et al., 2015). This increases the evidence-base to underpin applications and impacts.

Value Chain

Current end users include: Defra (UK Gov dept); Scottish Natural Heritage; Marine Conservation Zones regional projects; Wildlife Trusts; Convention on Biological Diversity (CBD); UK National Centre for Earth Observation (NCEO).



Outcomes/benefits

These front frequency maps were applied as a proxy for the abundance and diversity of pelagic marine animals, in a Defra-funded MPA Data Layers project. The front maps were an important factor in recommending at least 11 of the 46 offshore MPAs for UK, indicating that this was among the most widely applied datasets. Hence this research has had an impact on UK policy, and once the MPAs are designated will provide benefit to the environment, society and economy through the conservation of commercial fisheries and charismatic fauna.

The techniques were then applied globally within a US-funded project to identify key habitat areas in the open ocean. The front maps influenced the boundaries of several EBSAs in the Pacific Ocean agreed at a CBD regional workshop in August 2012: *"frontal probability maps were used to help identify a boundary for the Carnegie Ridge and Equatorial front EBSA… Also to pull out how the Humboldt current went offshore in Northern Peru - the boundary mimicked a bird migration route from the Galapagos."*.

A further potential market is to expedite the planning process for offshore marine renewable energy installations by selecting sites to minimise adverse impacts.

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Europe - Ecology

Satellite monitoring of harmful algal blooms (HABs) to protect the aquaculture industry

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Descriptions

Harmful algal blooms (HABs) can cause sudden and considerable losses to fish farms, for example 500,000 salmon during one bloom in Shetland, and also present a threat to human health. Early warning allows the industry to take protective measures. PML's satellite monitoring of HABs is now funded by the Scottish aquaculture industry. The service involves processing EO ocean colour data from NASA and ESA in near-real time, and applying novel techniques for discriminating certain harmful blooms from harmless algae. Within the AQUA-USERS project we are extending this capability to further HAB species within several European countries.

Challenges

In Scotland alone the aquaculture industry (mostly farmed salmon) is worth around £600 million per year; UK wide, shellfish culture contributes a further £33 million per year . Harmful algal blooms (HABs) can cause sudden and considerable losses to fish farms, for example 500,000 salmon during one bloom in Shetland, and 350 tonnes of salmon during a HAB event in Norway, HABs are estimated to cost the US aquaculture industry about £82 million per year. HABs can also present a threat to human health. Early warning of HABs allows the industry to take protective measures.

Applications/Solutions

Earth observation (EO) ocean colour data has been processed in near-real time to provide bulletins to the Scottish aquaculture industry. This service involves novel techniques developed at PML for discriminating certain harmful blooms from harmless algae (Kurekin et al., 2014), and operational processing systems designed to provide timely information on water quality (Shutler et al., 2015). The Linear Discriminant Analysis (LDA) classifier was trained using the full spectrum of water leaving radiances, absorption and backscattering; and false alarms are minimised by labelling as ‘unknown’ any data that cannot be reliably classified (Kurekin et al., 2014). By comparison with in situ measurements, the method has been validated for Karenia mikimotoi and Phaeocystis HAB risk discrimination (Figure 1), though it is only applicable to high-biomass bloom-forming species that cause a characteristic colouring of the ocean.

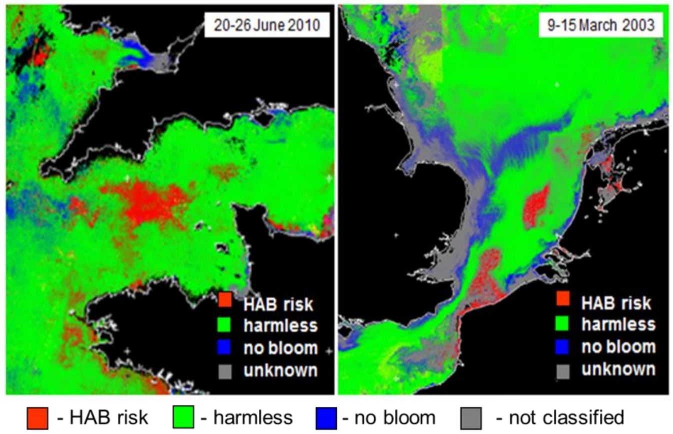
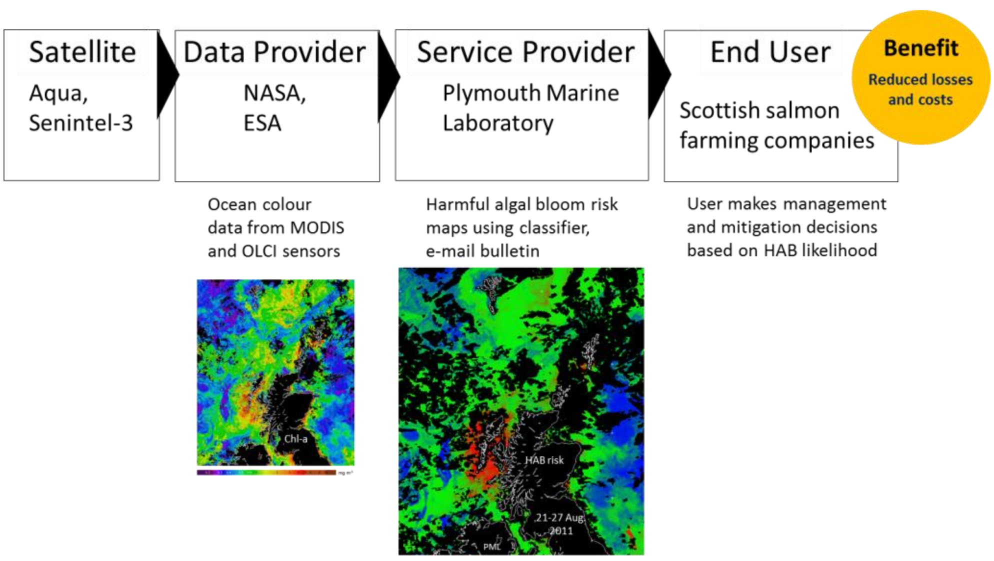


Fig 1: Harmful algal bloom risk maps using EO ocean colour discrimination: Karenia mikimotoi bloom in the Western English Channel in summer 2010, and Phaeocystis globosa bloom in the Southern North Sea in spring 2003

Value Chain

The end users include the Scottish Salmon Producers' Organisation which represents the interests of the individual fish farming companies. Other potential end users include the marine insurance industry, Crown Estate, and fish farming and aquaculture companies in other countries.



Outcomes/Benefits

The service to monitor for HABs has been running successfully for several years funded by the aquaculture industry. Quotes from the industry: *"Allowed us to put the farms on 'alert' a few days before a bloom came…We are convinced that this prevented us from suffering loses." "I would not feel secure enough to go blind in future; we need this information"*.

Within the EC AQUA-USERS project we are further developing the HAB classifiers to improve the capability to discriminate HABs in near-real time, and exploring commercial opportunities for European services.

More Information

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PML | Plymouth Marine Laboratory

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Europe – Agriculture

Earth Observation for Food Security and Sustainable Agriculture

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Earth Observation (EO) through remote sensing from space is the most feasible way to acquire site specific crop properties. The ESA-sponsored and DLR-supported project TalkingFields (www.talkingfields.de) demonstrated how a close combination of agro-ecological crop growth and management models with data from existing and future remote sensing sources (Sentinel, LANDSAT, RapidEye, TerraSAR-X, EnMAP) can be used to support farmers in increasing efficiency of farm management. The TalkingFields services are now commercially offered to farmers in Europe.

Challenge

Global biomass demand for food, energy and biomaterials is expected to roughly double from 2005 to 2050. At the same time most global land suitable for agriculture is already in use. Sustainable efficiency gains and increasing yields on today's cropland are therefore essential to ensure food security even with future demands. Today's crop management is field based and limited in efficiently using fertilizer because it is based on a "one size fits all" approach. 'Precision farming' employs data from space and ground assets to optimize the use of resources for maximum agricultural output. TalkingFields is a valuable service for sustainable and cost-effective agriculture by combining Earth observation and navigation satellites' input with information from ground sensors to help farmers decide how, when and where to allocate resources for the best results (Fig. 1). The service attracted customers from across Europe.

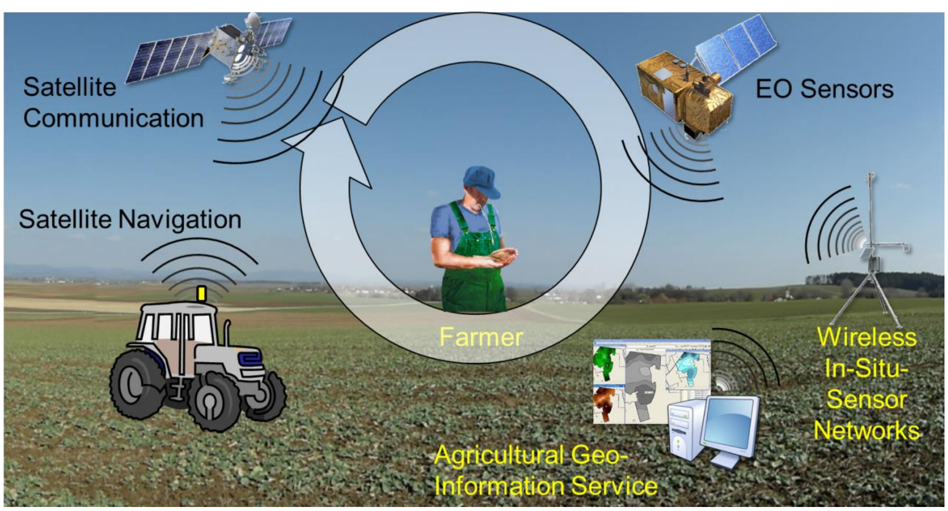

Fig 1: In TalkingFields, the farmer is in the focus. He is assisted by all available technology, including several space components (mainly GNSS and EO).

Satellite Earth Observation Data Application

The TalkingFields service is produced by three German organisations: the satellite remote sensing company VISTA, the agricultural service provider PC Agrar, and the Ludwig-Maximilian-University of Munich, who developed the crop growth model. Combined, their expertise has resulted in an integrated service that can provide farmers with all the elements they need to make educated decisions on how to manage their crops. This combination of services means TalkingFields can use the Earth observation sensors Sentinel-2, LANDSAT, RapidEye, TerraSAR-X and in the future EnMAP to supply data on individual zones' soil fertility and disease risk by analyzing biomass distribution, while its software element calculates the economic returns of different precision farming strategies. Farmers are also supplied with yield reports, covering both past output and future estimates of up to four weeks in advance. Navigation satellites provide accurate geo-location information to enable farmers to apply the advised measures exactly where needed.

TalkingFields (TF) uses remote sensing data of a whole palette of sensors to provide services in the form of TF Yield Maps, TF Yield Forecasts, TF Base Maps for managing site specific fertilizer application or seeding, TF Zone Maps for zoning and probing and TF Biomass Maps e.g. for plant protection. They allow the farmer to more accurately apply seeding, fertilizing, pesticide application and planning of harvest dates. More accuracy means lower production costs, as resources such as water and fertilizer are not wasted. More accurately also means more yield per fertilizer used. This benefits not only farmers, but also agricultural stakeholders such as drinking water protection agencies, resulting in both successful commercial business and as well as environmental gains.

An important characteristic of the TF services is that they are not bound to one specific Earth Observation source. Instead, a multi-mission concept is applied, that allows the use of all optical satellite sensors with a high spatial resolution (resampled to a standard grid size of 20m).

Landsat-8 OLI data has been integrated in the processing and used for growth analyses in 2013 and 2014. The use of Sentinel-2 data is being prepared, so that also this important data source can be used as soon as it becomes available. EnMAP as the expected first imaging spectrometer in space will strongly enhance the TalkingFields services by using the full spectral information to completely derive the TF services from remote sensing data without ground measurements.

The up-to-date services on biomass and yield estimation rely on the fast and reliable availability of EO data. Practical experience about the temporal sampling of EO data shows that 4 optical satellite images per harvest year are necessary for best results.

Improved site characterization is used to quantify the spatial distribution of yield potential within a field by analyzing multi-year satellite observations. Fig. 2 shows one result: the TF Base Map for a farm in Eastern Germany. In opposition to other approaches that usually use the average of different vegetation indices over several years, the approach used by TalkingFields applies a geo-statistical processing that filters out patterns in the field that are observable over multiple years. These patterns are usually bound to site-characteristics, e.g. the water holding capacity of the soils. They do not necessarily show up every year, but they show up persistently.

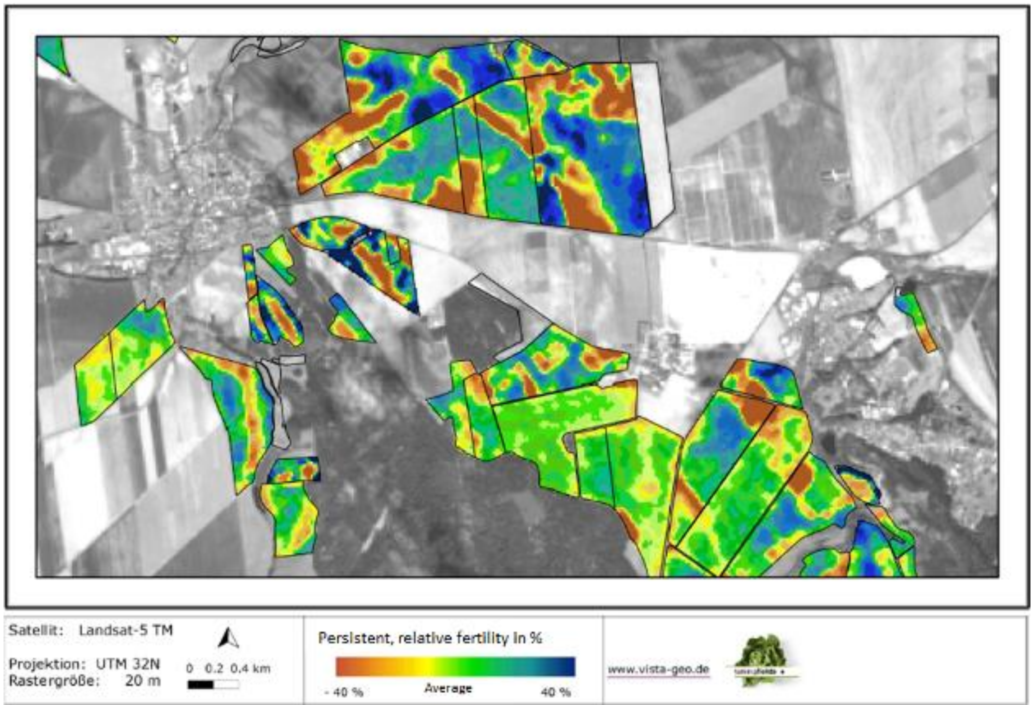

Fig 2: TF Base Map as calculated for a farm in Eastern Germany.

In Fig. 2 elongated features that span several fields and have lower persistent biomass values are visible. These are lime-ridges that have a lower water holding capacity than the soils around them.

At the same time TF Yield Maps deliver yields that are determined by combining a plant growth model with time series of multi-sensor EO data. A comparison between TF Yield Maps and at-harvest measurements is shown in Fig. 3.

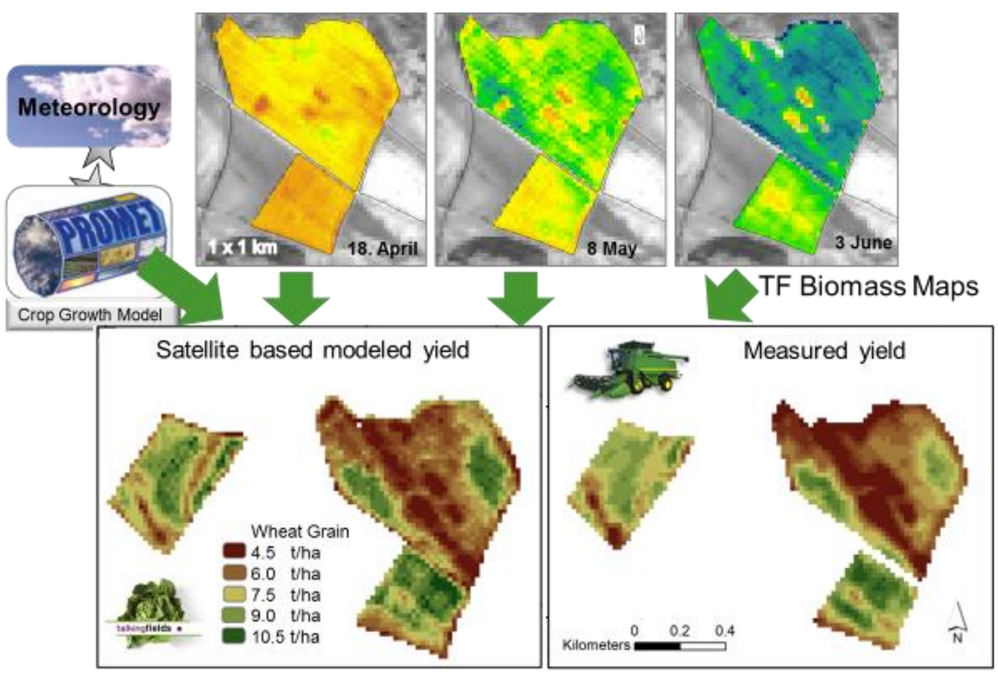

Fig 3: Comparison of the TalkingFields Yield Maps using the PROMET crop growth model and EO data with measured yields during harvests. Satellite data: RapidEye.

Value Chain

The TalkingFields service is one example of the successful integration of EO data from different sources into a value chain addressing the social problem of sustainably optimizing agricultural production (Fig. 4).

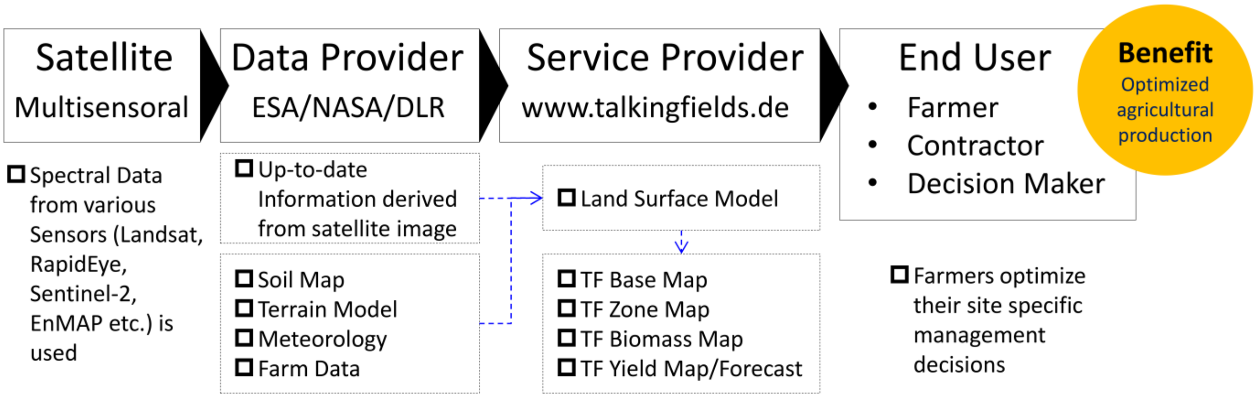

Fig 4: Value chain of the TalkingFields service.

Outcomes

TalkingFields has successfully concluded its Demonstration Phase in April 2014 and is now an operationally running commercial service, which is distributed via the website www.talkingfields.de and by PC-Agrar. Currently, customers from eight European countries are using the service to increase their agricultural production efficiency. The development of the service has been supported through the Integrated Applications Promotion (IAP) programme of ESA's Telecommunications and Integrated Applications Directorate and by DLR within its EnMAP scientific preparation programme.

User Statements

"Everything looks different from above? No, the TF Base Map has confirmed my results from other techniques like soil scanning or the farm soil map. At the same time, the data is available fast and for my whole farm, and the effort I as the farm manager had to put in was low. Especially in regions, for which there is only little information about the site characteristics available, the TF Base Map is a sound and reasonably priced information source. Now I want to take the cooperation a step further and use TalkingFields also for my daily crop management." Rüdiger Klamroth, farmer

"I arranged a field trial with different varieties of winter wheat especially for TalkingFields. Some varieties were developed well after the winter season. Others suffered from winter damages and never caught up. The up-to-date TF Biomass Maps confirmed this without a doubt." Klaus Münchhoff, farmer

"The TalkingFields yield estimation was provided for my sugarbeet fields and it allowed a very accurate yield monitoring that even allowed site-specific yield observations, that was not possible before Talking Fields", Jürgen Schwarzensteiner, farm manager

More Information

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Chapter 2:
APPLICATIONS IN AFRICA

Africa - Disaster

Use of Satellites for Disasters in Southern Africa

The CEOS Working Group on Disasters is working with research partners to develop capabilities for monitoring floods and with end-users to build and sustain the capacity to use these capabilities in real-time disaster management. One of the focus areas of this effort is in southern Africa, where several ongoing projects are being leveraged and coordinated to provide a "one-stop shop" for satellite information pertinent to flood risk.

Problem

Accurate, reliable information is critical for responding to natural disasters, but information from traditional in-situ sources (e.g., rain and streamflow gauges) is typically sparse and often not available to decision-makers in a timely manner, particularly in less developed countries. In addition, those who might be affected by flooding need to be convinced of the threat if they are going to heed the warnings—as an example, in 2008 Namibia endured its worst flooding in decades, but many chose not to heed the warnings given because they had not experienced floods in recent memory. Satellites can address both of these needs by providing real-time information with excellent spatial resolution and coverage as well as analyses of risk based on previous flood events. However, decision-makers are often unable to take advantage of this information because they are unaware of satellite data, do not have immediate access to it, or are not trained in how to use it. To bridge this gap, connections need to be made between these users and the data providers, including making the data available in a format that is easy to use and interpret and providing the training that ensures that the data will be used.

Satellite Earth Observation Data Application

In response to this problem, the CEOS Working Group on Disasters was formed in 2013 to coordinate existing efforts in satellite remote sensing of floods, volcanoes, and earthquakes and connect them with decision-makers in the affected areas. For floods, three pilot areas were selected: the Caribbean (with a focus on Haiti), southern Africa (with a focus on Namibia), and the Mekong Delta, and a global pilot has also been initiated to provide satellite products that are produced on a global rather than a regional scale.

The centerpiece of each pilot project is the "Flood Dashboard": a Web site that allows the user to overlay various relevant satellite products on a map and also to access available in-situ data by clicking on a gauge point (Fig. 1). These satellite products include real-time inundation maps (Fig. 2), flood risk as determined from analyses of previous flood events, current and expected rainfall, and predicted water elevation from flood models that use the satellite data as input. The Dashboard is at http://matsu-namibiaflood.opensciencedatacloud.org/ and is fully open-access. Many of the projects contributing data to this Pilot also have a training component, such as the European Space Agency's TIGER initiative, and the pilot is leveraging this training to the benefit of other Pilot users not directly affiliated with TIGER.

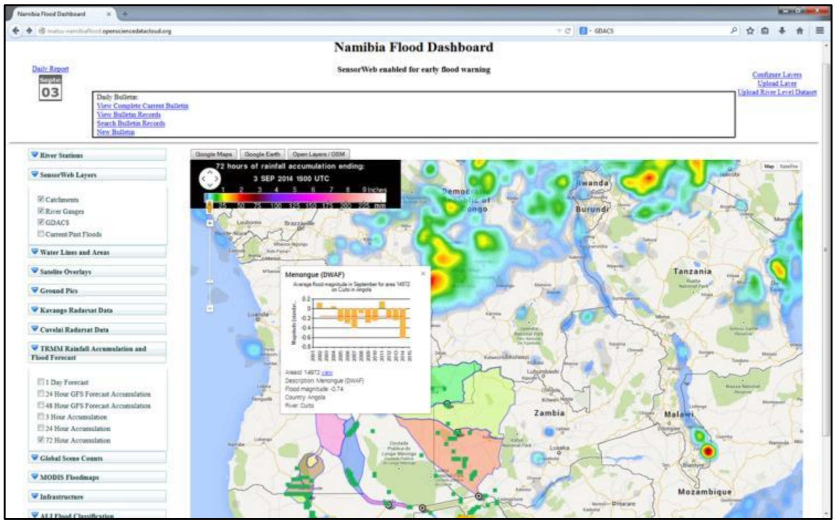


Fig 1: Sample image from the Southern Africa Flood Dashboard, illustrating some of the available imagery overlays and point data.

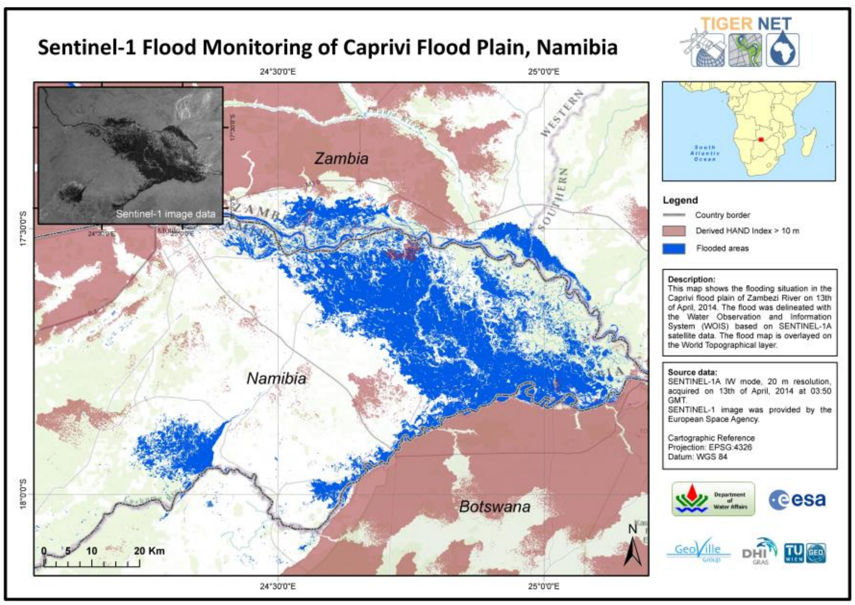
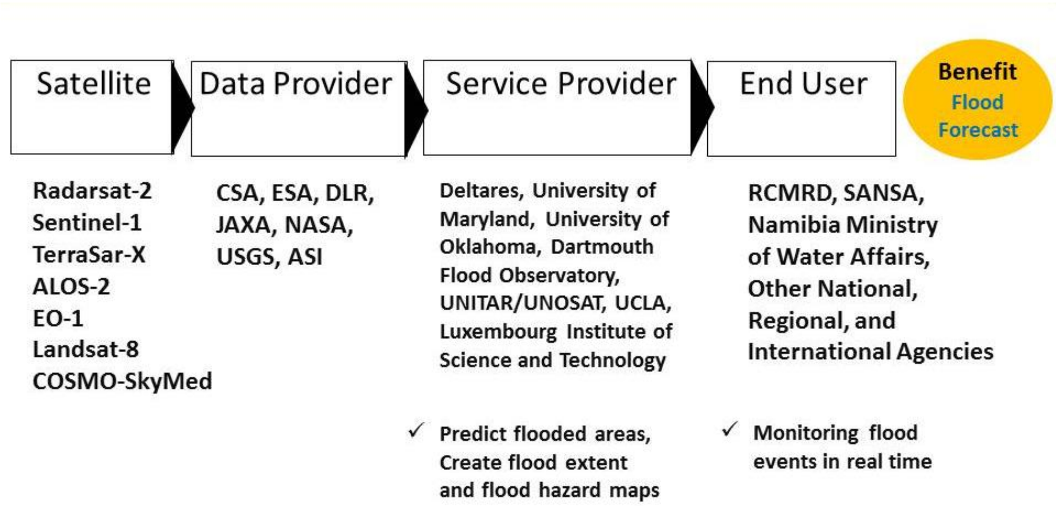


Fig 2: Sample flood image over Namibia from Sentinel-1a on 13 April 2014 created by TIGER-NET. Copyright EAS/TigerNet/Department of Water Affairs/GeoVille/DHI/TU Vienna/GEO. Used by permission.

Value Chain

The pilot project uses data from multiple satellites across many space agencies, such as the Canadian Space Agency's (CSA) Radarsat-2, the European Space Agency's (ESA) Sentinel-1, the German Aerospace Center's (DLR) TerraSar-X (TSX), the Japanese Aerospace Exploration Agency's (JAXA) Advanced Land Observation Satellite (ALOS-2), the National Aeronautics and Space Administration's NASA Earth Observing satellite (EO-1), and the United States Geological Survey's (USGS) Landsat-8. The raw data from these satellites are converted to flood extent and flood hazard maps by value-added partners such as the Lippmann Institute, Deltares, the United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT), and the NASA Jet Propulsion Laboratory (JPL). Many of these data sets are not routinely made available for free, so the Flood Pilot has entered into agreements with the appropriate space agencies to request a limited amount of data whenever flood events occur. This information is then made available by NASA at the Flood Dashboard. Local capacity for processing satellite data is also being developed.

The end users include the Regional Center for Mapping of Resources for Development (RCMRD), who are running satellite data processing programs provided by a Flood Pilot-affiliated project to monitor flood events in real time. The Namibia Ministry of Water Affairs, RCMRD, and the South African National Space Agency (SANSA) are also running a local version of a flood model provided through a Flood Pilot-affiliated effort, having been trained through a workshop in Windhoek, Namibia in February 2014. This model is being used in operational flood forecasting efforts and is benefiting these areas through more accurate flood forecasts and better response.



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Africa – Health

Entomological Rift valley fever risk in Senegal: a high spatio-temporal resolution risk mapping from remote sensing

The results presented here is the outcomes of a franco-senegalese project gathering the Centre de Suivi Ecologique, the Dakar Pasteur Institute, the Direction of Veterinarian Services, Météo-France, and CNES. It addresses the Rift Valley Fever, a viral disease that occurs essentially in Africa, causing very serious economic losses in livestock. A brand new EO satellite-based decision-aid tool for a better management of animal health with the aim of a better adaptive strategy is presented. It is based on SPOT-5 images and designed for local health users. This project was supported and funded by the French Ministry of Ecology (MEDDE) through its GICC program (Gestion et impacts du changement climatique, in French, Management and impacts of climate change in English).

Context

The emergence and re-emergence of infectious diseases with high epidemic potential, such as the Rift Valley Fever, encourage public health actors to adapt their strategy of management concerning human and veterinarian health. This adaptation requires the development of new means of risk prediction. In this context, the study of vector borne infectious diseases requires the knowledge of factors conducive to the emergence and spread of the disease. The first step in risk prediction is to identify areas of vector proliferation. This knowledge enables the identification of areas at risk for human and animal populations. It enables also to model and to prevent the occurrence of diseases by setting up early operational warning systems (SAP). Linkages between infectious diseases, environment and climate variability do not have to be spelled out anymore. Nevertheless, providing users with forecast data and risks maps, at a local scale, on “where and when” a risk for the emergence of given diseases vectors remains quite a challenge. Such risk maps will key contributing elements towards adaptive control strategies of the public heath actors.

Satellite Earth Observation Data Application

Some epidemics (malaria, Rift Valley fever, dengue ...) depend on climatic and / or environmental factors, some of which can be identified by remote sensing and entered in biomathematics models to assess the risk of emergence and propagation of disease vectors. In this context, the Centre National d'Etudes Spatiales (CNES) has developed with its partners a conceptual approach based on the study of climate-environment-health relationships and an original appropriate spatial offer. This multidisciplinary research approach known as tele-epidemiology, combining the physical and biological sciences to define the determinants for the emergence and spread of the disease studied. Earth Observation Satellite data do not provide information directly related to pathogens (viruses, bacteria, parasites) causing the disease, but on their environment (geographical, meteorological, hydrological ...) and in particular on the habitats favorable to the development and proliferation of vectors. Therefore, satellite imagery contributes to the measurement of environmental factors favorable (or not) for the emergence of these diseases vectors. This methodological approach has been successfully applied to Rift Valley fever (RVF) in the Ferlo region of Senegal leading to the development of a dynamic mapping of Zones Potentially Occupied by Mosquitoes (ZPOMs).

The abundance of the main RVF vectors in the Ferlo region (Aedes vexans and Culex poicilipes) is directly linked to ponds' dynamics. The latter is associated with the spatiotemporal variability of rainfall events. Rainfall distribution and its spatial heterogeneity, is thus a key parameter for the emergence of the main vectors of the RVF. The goal of this applied project was to use specific Geographical Information System (GIS) tools and remote-sensing (RS) images and data to detect potential ponds as breeding sites, and evaluate the risk for cattle for being exposed to vectors bites. Subsequently a risk for mosquito's emergence has been modelled and validated using in-situ entomological measurement campaigns. It should be acknowledged that a risk is a result of hazard and vulnerability. If hazard is represented by the mosquitoes presence (entomological risk called also vector hazard), vulnerability is represented by parked animals and migrating livestock.

Three steps have been necessary to achieve the goal:

- Set-up brand-new index for detecting of small and temporary ponds using high-spatial SPOT-5 images. Satellite remote sensing has provided a global view for the dynamics of the ~ 1300 ponds, potential breeding sites for hazards to happen in the Barkédji area
- Modelling dynamic ZPOM combining mechanisms linking rainfall variability, dynamic of ponds and density of aggressive vectors. Remotely-sensed environmental data (Spot-5 images) and meteorological information (from in-situ and satellite data such as TRMM, GSMaP, RFE, CMORPH, PERSIANN) were used to fit a model with hydrological and entomological components, in order to produce dynamic high resolution maps (10-m spatial resolution, daily temporal resolution) to predict the entomological risk for Rift Valley fever in the Ferlo region of Senegal (see figure1)
- Crossing dynamic ZPOM (vector hazard) and cattle park localization (hosts vulnerability) to evaluate the environmental risk (i.e risk for being exposed to vector bites). The integration of dynamic modelling on mosquitoes proliferation and the positioning of the livestock parks into a geographic information system, allows providing every week the Directorate of veterinary services of Senegal with forecasting bulletins of the zones under risks for the following 10 days.

The Directorate of veterinary services is then able to integrate this information into its adaptation strategy of animal health management. This strategy includes:

- park livestock away from zones at risks: warnings in local language have been installed near the ponds to inform breeders to park their animals at least 500m away from the ponds;
- organize anti-larval control: with these bulletins, the Pasteur Institute of Dakar should be able to organize efficient larval and vector control actions;
- organize RVF vaccination: with these bulletins, the Directorate of veterinary services of Senegal could optimize vaccination campaigns in the most risky zones;
- organize the communication strategy: by integrating the forecasted risks bulletins in the National Information System of Surveillance of Epidemics that feeds the Ministry of livestock in Senegal, the headquarters of the Directorate of veterinary services of Senegal and its local representatives in rural districts. It is planned to broadcast advertising messages in local language through local radio stations to facilitate comprehension and acceptance levels

The transfer of all the technologies to the Centre de Suivi Ecologique (service provider), for an operational use, is foreseen by the end of 2015, including the coupled bio-mathematical model and its main output: predicting the emergence of RVF vectors as a function of heterogeneous rainfall amounts.

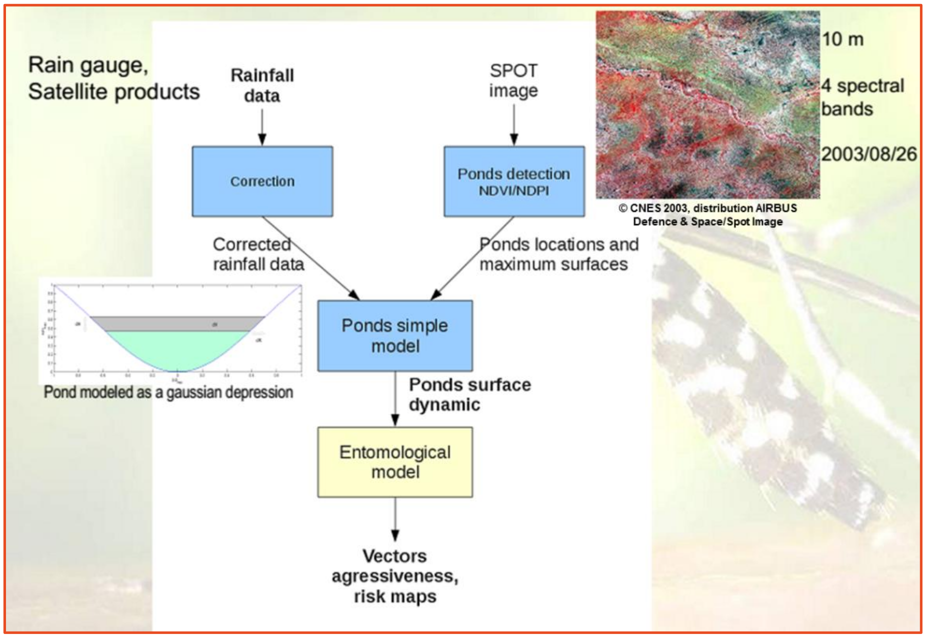
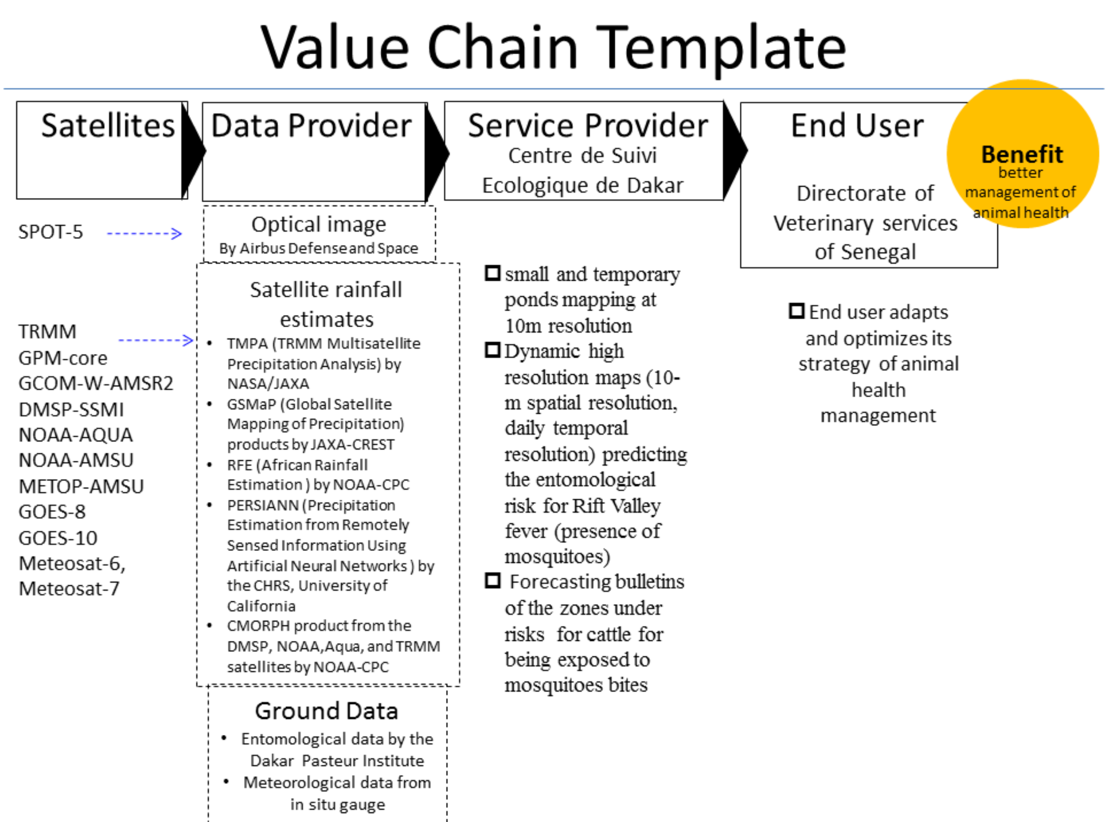


Fig 1: The Rift valley fever entomological risk modelling

Value Chain



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Africa – Agriculture

Mapping and Forecasting Frost in Kenya with Satellite Observations

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Key Takeaway

The Kenya Meteorological Service, Tea Research Foundation of Kenya, and insurance providers utilize maps incorporating MODIS data to improve crop risk management.

Article

In 2013, public and private sector organizations in Kenya began using an automated frost mapping system that incorporates Earth-observing satellite data. The system generates maps to help farmers and businesses manage the risk of frost damage to Kenyan crops such as tea and coffee.

Within a few hours of satellite data collection, the system emails, to the Kenya Meteorological Service (KMS) and other stakeholders, user-friendly maps pinpointing areas with high potential for frost. KMS worked with a NASA-sponsored project team and the Regional Centre for Mapping of Resources for Development (RCMRD), based in Nairobi, to develop the system using land surface temperature data from the Aqua and Terra satellites.

The Meteorological Service use the frost maps to identify areas of potential frost in the highlands of Kenya. In addition, the Tea Research Foundation of Kenya (created by the Ministry of Agriculture) incorporate the maps in efforts to improve crop yields and avoid losses. The maps are also useful to agricultural insurance providers in their assessments of claimed losses.

"The frost maps are excellent tools," said James Kiguru, an accounts manager and agronomist at AON Risk Solutions, a global provider of insurance and risk management services. "[The maps] give us a much stronger basis to conduct our assessments and will boost development of frost insurances. . . . We are able to assist our clients—particularly farmers—when it comes to frost claims which otherwise would be attributed to negligence."

The frost maps are part of KMS activities to respond to requests every winter from farmers and businesses for information regarding where and when frost conditions will occur.

"I shared these maps with colleagues in tea research, and we are excited to have an attempt in this direction," said Ayub Shaka, assistant director, KMS.

Kenya is ranked third in annual world tea production, and it has the highest tea productivity (yield per hectare) worldwide. The industry provides for the livelihoods of an estimated 4 million Kenyans, or about 10 percent of the total population.

In addition to reducing losses to current crops, the project's frost maps can help farmers avoid frost-prone times and locations for future planting. The result is better crop yields, supporting people and livelihoods.

This application of Earth observing satellite data developed through the SERVIR initiative, a NASA–USAID endeavor. In East Africa, SERVIR partners with RCMRD.

SERVIR uses its Wireless Sensor Network (WSN) to more clearly define frost condition thresholds through the collection of temperature, wind speed, and humidity observations in sample locations. (The WSN is a ground-based network of sensors that can be spread over three or four square kilometers to measure environmental conditions.) SERVIR correlates the observations with the forecasts and satellite data products.

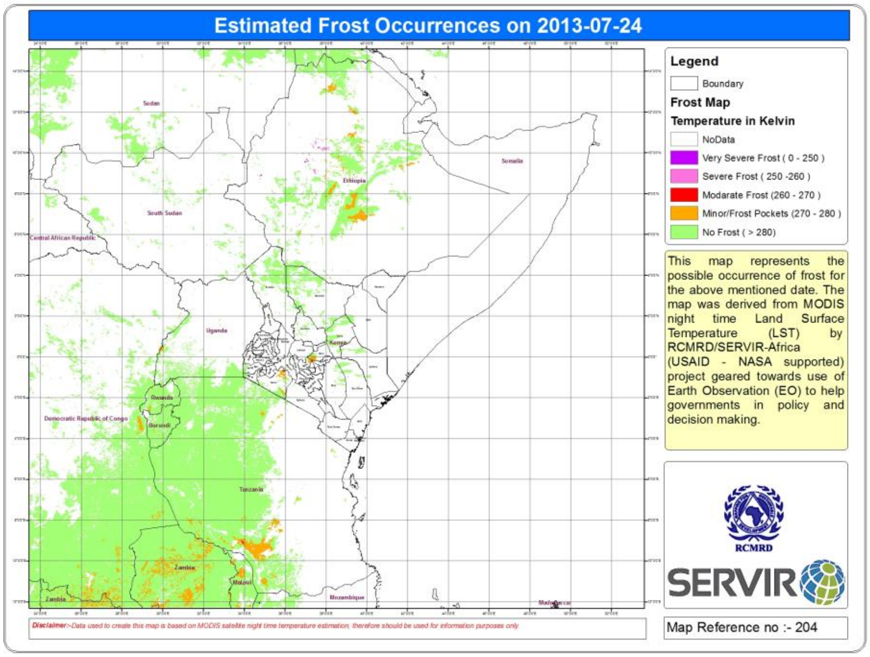
SERVIR has sponsored training workshops and continues to train regional officials in the use of the frost alert system. SERVIR also developed a decision guide for using WSN frost data and satellite frost risk maps. The frost mapping system also uses KMS numerical prediction model forecasts, in addition to the satellite data-derived frost products, to help map areas of potential frost up to three days in advance.

To learn more about the daily frost maps, visit http://41.206.34.124/frostmaps.
To learn more about SERVIR, visit www.SERVIRglobal.net.

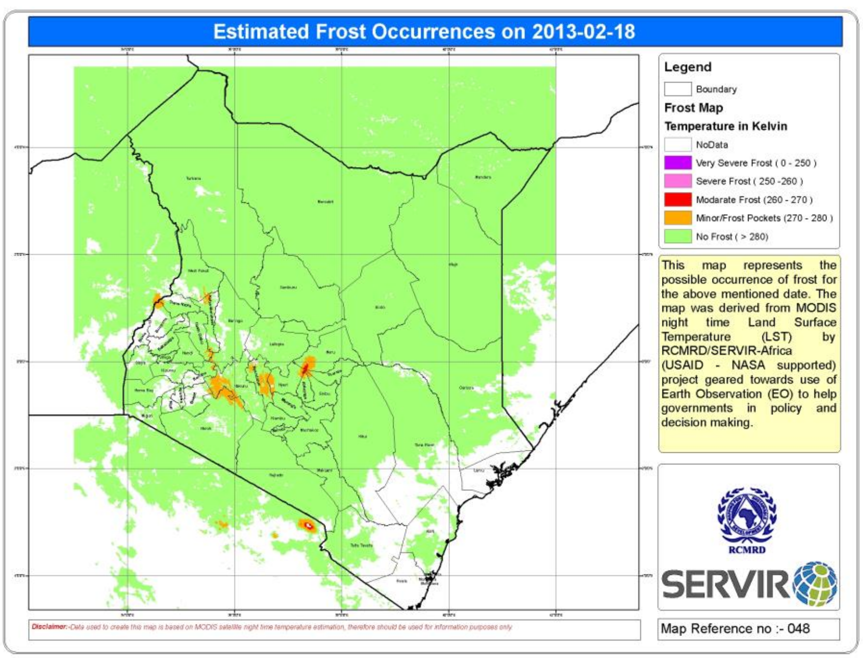
Key Quote

“ [The frost maps] give us a much stronger basis to conduct our assessments and will boost development of frost insurances. . . . We are able to assist our clients—particularly farmers—when it comes to frost claims which otherwise would be attributed to negligence.” - James Kiguru, AON Risk Solutions

Images



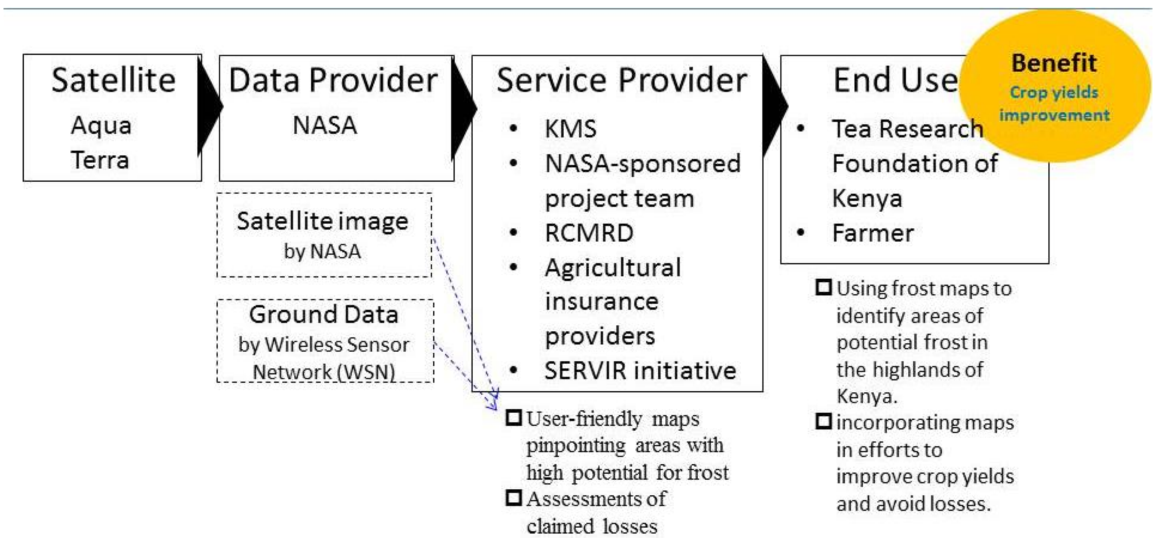
Estimated frost in East Africa, July 24, 2013. The map is based on data from NASA's Terra and Aqua satellites.



Estimated frost in East Africa, Feb. 18, 2013. The map is based on data from NASA's Terra and Aqua satellites.

Tea Farm Visit. Credit: Tea Research Foundation of Kenya

Value Chain



Africa – Other

SPOT monitors the evolution of the Serbian territory

IGIS project is a cooperation between the Serbian Republic Geodetic Authority (RGA) and the French consortium IGN FI - Airbus DS. It is aimed at setting up a National Spatial Data Infrastructure and a Remote Sensing Centre for the Republic of Serbia. SPOT satellites have been triggered to demonstrate their capacity to face this challenge, and provide an in-depth agricultural land cover over the entire country.

Problem

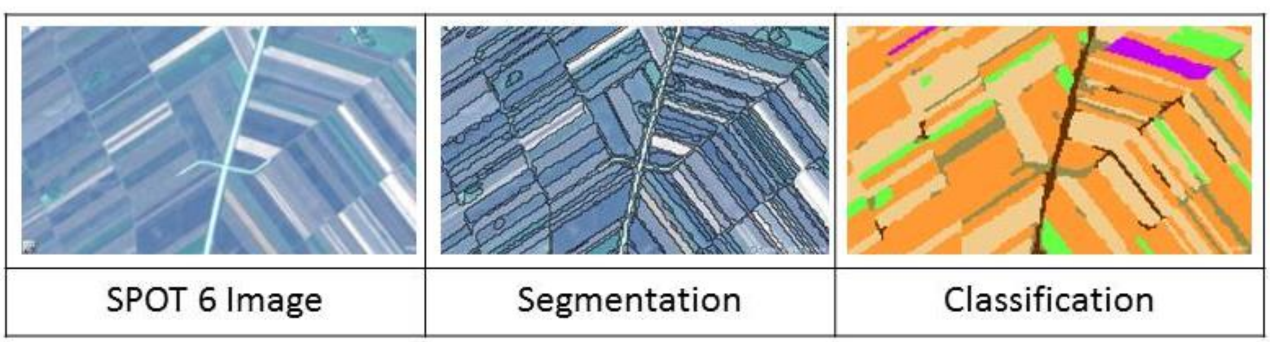
Creating a map of land coverage on a national scale without prior information and ground measurements is a big challenge as it implies access of multitemporal data series to discriminate vegetation types.

To do so, 4 to 6 SPOT complete multispectral coverages are required within a year, each coverage to be collected at relevant periods of the cultural cycles in order to discriminate the various types of crops.

Satellite Earth Observation Data Application

The SPOT 6/7 systems tasking capacity and the efficient management of cloud coverage, thanks to the 6 tasking plans per day, were essential for agriculture monitoring as timeframe for acquisitions are usually very short.

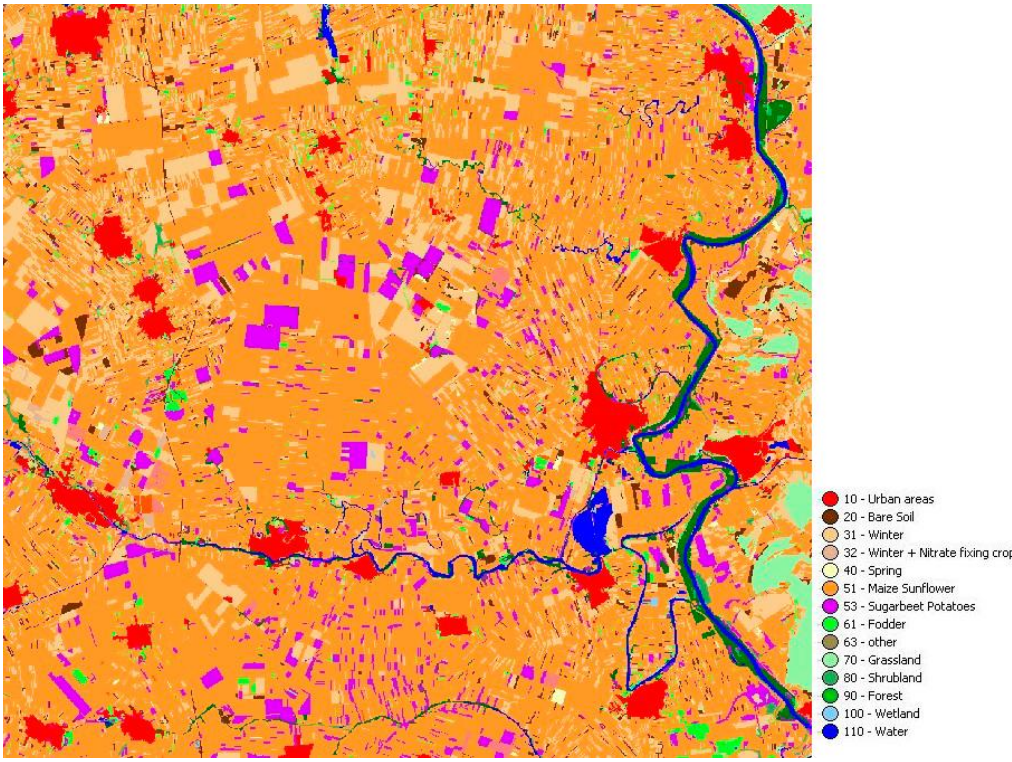
After images collections, a 2-step post-processing is defined as illustrated in the the figure below.



The classification stage provides discrimination of crops variety. It can only be achieved by monitoring plants growth profiles and cycles. We used the OverlandTM processing suite to generate biophysical parameters layers, such as green or brown cover fractions, and canopy shadow factor.

These layers are used as input data for the classification tool, which is based on a decision-tree approach.

The SPOT 6/7 spectral resolution (1.5m Pan-sharpened and 6m Multispectral) and 12-bit image coding are assets to reach a high-level accuracy in a very fragmented agricultural landscape, such as in Serbia, and increase the quality of the segmentation stage.

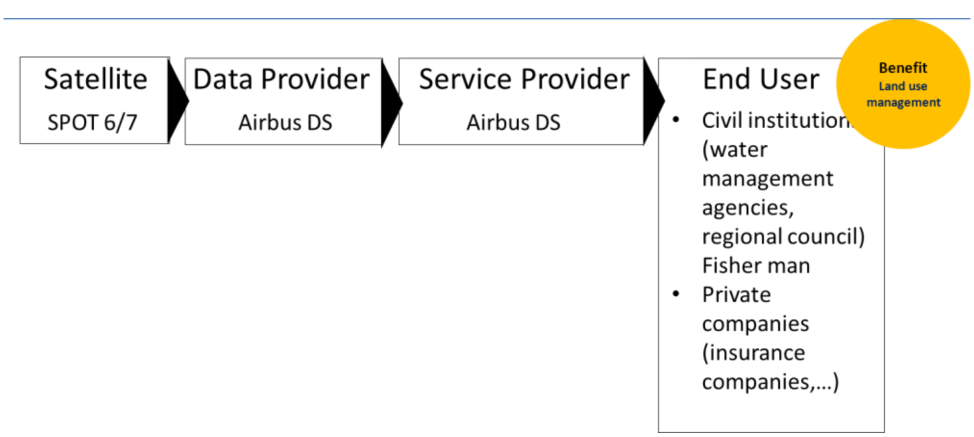


Example of a large scale 14-class land cover map generated over the whole territory of Serbia.

Value Chain

The key benefits of the SPOT solution in the frame of the land cover project are:

- High resolution allows access to intra-field information even for small parcels (<0.05ha)
- The reactive tasking is key for acquisitions at the right period of the cultural cycle
- The blue band of SPOT 6/7 improved discrimination of the crops
- The biophysical parameters extracted from the SPOT 6/7 images allow accurate characterization of the cultural conditions independently from the acquisitions conditions.



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Chapter 2: GLOBAL APPLICATIONS

Global - Climate

GOSAT data since 2009 and its application

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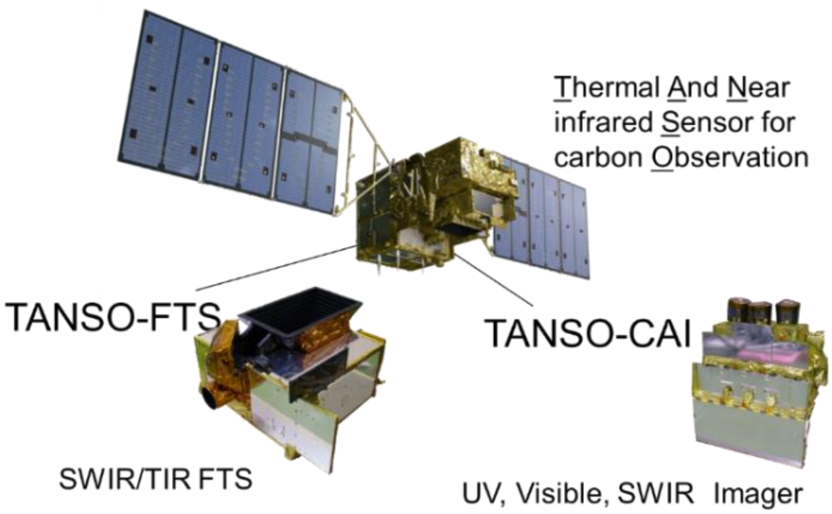
Tatsuya Yokota, the National Institute for Environmental Studies

Description

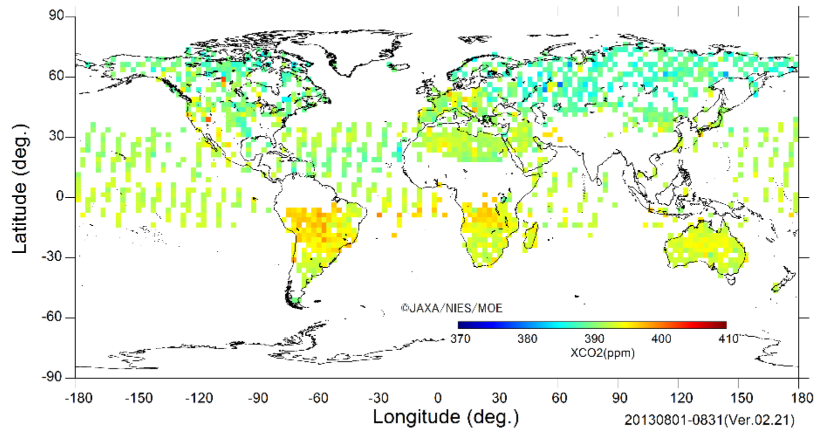
Japan's GOSAT, whose project is promoted by the Japan Aerospace Exploration Agency (JAXA), Ministry of the Environment (MOE) Japan and the National Institute for Environmental Studies (NIES), is the world's first mission to monitor two major greenhouse gases: carbon dioxide (CO2) and methane (CH4).



TANSO-FTS and CAI photos and design view of the GOSAT satellite on-orbit.

Challenges

The high resolution spectra dataset of CO2 and CH4 absorption band has been well-calibrated and distributed to space agencies and research institutes by JAXA since 2009. Multiple teams from more than 10 countries have been working on independent CO2 retrievals with relative errors < 2 ppm over most regions of the globe. These datasets not only reduced uncertainty of regional CO2-fluxes globally, but also demonstrated point-source emission monitoring such as CO2 from mega-cities and CH4 from oil fields and livestock. Furthermore, it has been revealed that the first high resolution GOSAT spectra of vegetation fluorescence presented patterns of gross primary productivity and opened a new viewpoint on the carbon cycle.



Monthly Global Map of Column concentration of CO2. August 2013

Applications/Solutions

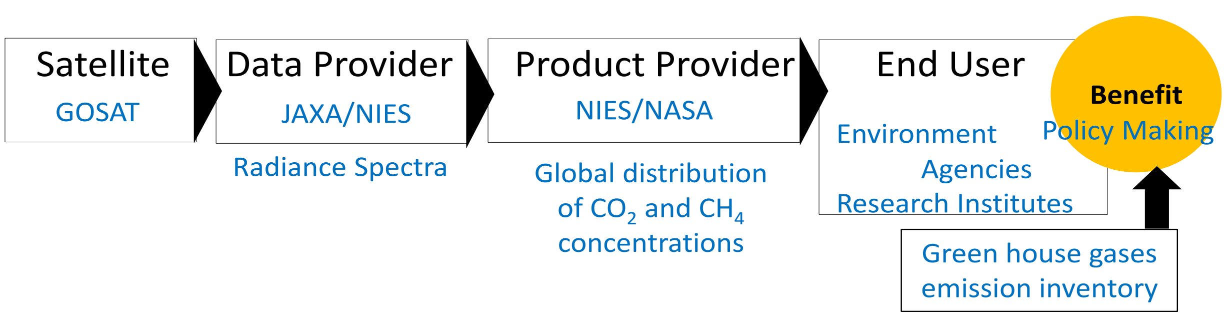
After its 5-year designed life nominal operation, GOSAT has enough propellant for orbit control to extend its operation and no significant degradation has been detected in both the satellite-bus systems and mission instruments. During the first 5-year operation in orbit, GOSAT has demonstrated the effectiveness of satellite greenhouse gas (GHG) observation with precise calibration and validation. The homogeneous GHG spatial scale is relatively large. But the emission source is not equally distributed. GOSAT has an agile pointing system, permitting a large number of custom targets per orbit. Now, in addition to regular grid observation, the pattern has been modified and optimized for monitoring regional emissions qualitatively that are only possible with satellite measurements.

Value Chain

The spectral data acquired by GOSAT are provided from http://data.gosat.nies.go.jp/GosatUserInterfaceGateway (GUIG) to general users.

The gas retrieved results are available also from GUIG and other independent gas retrieved product providers from GOSAT spectral data such as http://mirador.gsfc.nasa.gov/.

Researchers of world-wide institutes and universities have presented outcomes on carbon fluxes and long term trend of GHGs using the GOSAT gas retrieved results.



Outcomes/Benefits

The satellite observation is a very powerful method for monitoring GHGs because a long term and frequent global observations can be done by using a single instrument. GOSAT has made full use of this advantage. The GOSAT data have been constraining the CO2 and CH4 emissions in several existing tracer transport models. Environment agencies could use these results as a reference facts for policy making. Even though the outcomes from GOSAT data are not matured yet, outcomes in near future would useful for policy makers to seek effective reduction method of GHG emissions. The surface observation of GHGs data are limited in developing mega cities. The GOSAT footprint of 10.5 km will cover regions surrounding entire emission sources. GOSAT will demonstrate cost-effective and quantitatively useful GHG monitoring from space. Very recent research results using GOSAT data shows CH4 emissions from oil fields, live stocks, coal plants and waste are larger than the existing inventories by the environment agencies. Policy makers can use such kind of information to make feasible and effective regulations.

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Global – Meteorology

Applications of future EUMETSAT geostationary programme (MTG)

"Meteosat: Observations from geostationary orbit save lives on Earth"

Meteosat weather satellites have been delivering weather and climate data for Europe and beyond, from geostationary orbit 36,000 kilometres above the Earth's surface, since 1977. With the Meteosat Third-Generation (MTG), planned for launch in 2020, EUMETSAT will extend this series of observations until the 2040 timeframe.

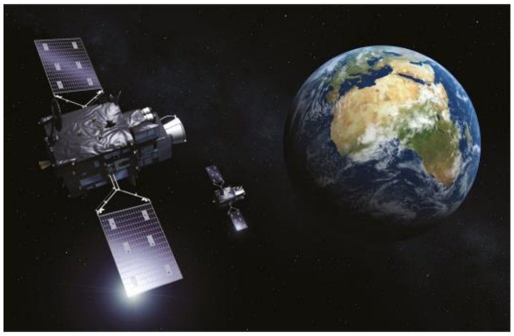
Value of geostationary observations

Changes in weather and climate significantly impact not only our economy and infrastructure - but actually our very lives. Between 1970 and 2012, weather and water-related natural disasters in Europe claimed 149,959 lives and caused over 350 billion EUR in economic damage, according to a study by the World Meteorological Organization.

Meteosat Third Generation

The Meteosat Third Generation satellites will revolutionise weather and environmental monitoring capabilities over Europe and Africa, with an enhanced imaging mission and for the first time, a new infrared sounding mission.

The MTG-I imaging satellites will carry the advanced Flexible Combined Imager (FCI) and the Lightning Imager. The 16 channel FCI will provide increased support to nowcasting and very short-range forecasts of high-impact weather, with more capabilities for measuring cloud and aerosol properties. The new Lightning Imager, another first for Meteosat satellites, will continuously monitor lightning activity in near-real time, supporting nowcasting of severe storms and warnings of lightning strikes.



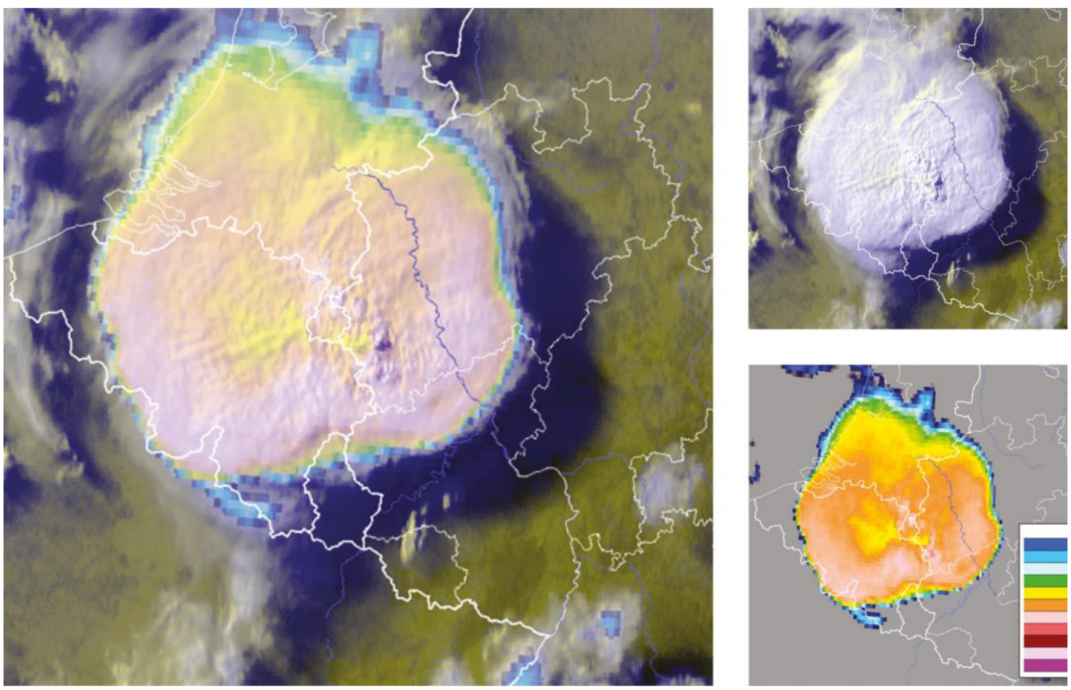
Artist view of MTG-I and MTG-S satellites in orbit (source: ESA)

On the MTG-S satellites, there will be an infrared sounder (IRS) and the Copernicus Sentinel-4 Ultraviolet Visible Near-Infrared spectrometer (UVN). The IRS will provide detailed vertical profiles of atmospheric temperature and moisture - every thirty minutes over Europe – to support nowcasting and short range numerical weather prediction. The instrument will also work together with the Copernicus Sentinel-4 UVN sounder to provide a unique, integrated capability to observe ozone, carbon monoxide, sulphur dioxide and other trace gases in support of air quality monitoring and forecasting, and climate monitoring.

Meteosat Applications

Nowcasting and very short range forecasting

The primary role of the Meteosat satellites is to help detect and forecast rapidly developing high impact weather. Nowcasting and very short range forecasts - up to six hours - are vital for the safety of life, property and infrastructure and rely on very frequent, detailed images of the atmosphere. This supports a large range of nowcasting applications such as detection and detailed monitoring of convection, which can lead to the development of severe thunderstorms, the detection of fog, dust storms or volcanic ash, and the assessment of air mass characteristics.



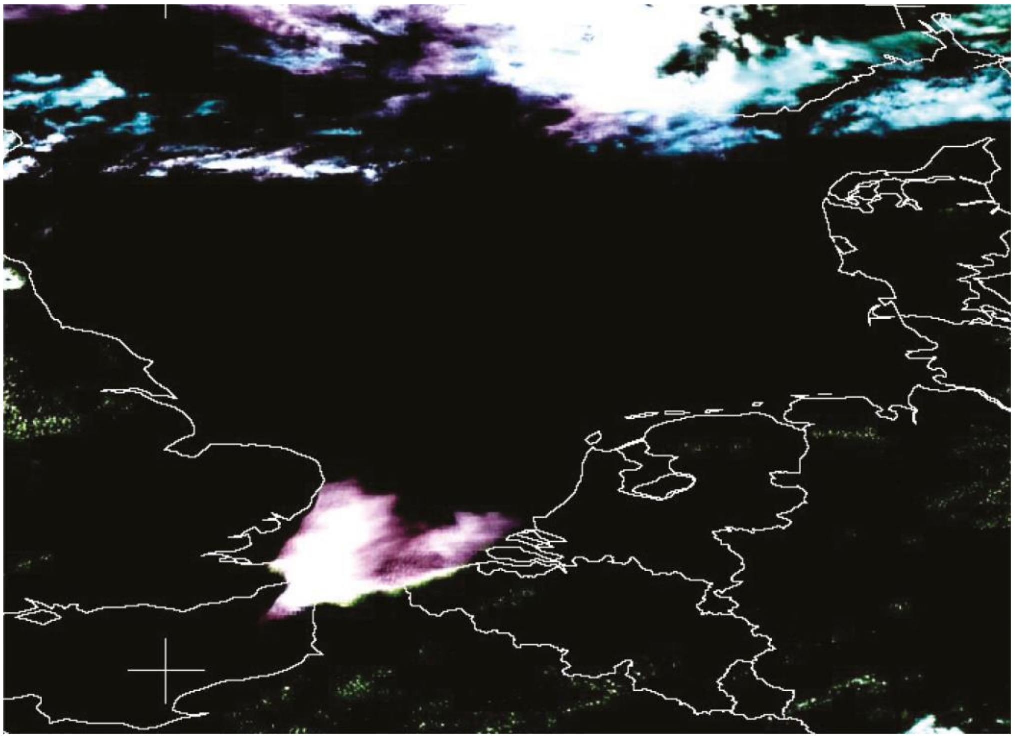
Nowcasting a super cell in Germany: Meteosat visible information (top right) on the texture of clouds and infrared information on cloud temperature (bottom right) are combined in a sandwich product (left) to characterise the intensity and development of cell (source: EUMETSAT)

Convective storms

Severe convective storms, or thunderstorms, are usually accompanied by strong winds, heavy rainfall and hail, and can be a serious threat to life and property in Europe and Africa. Meteosat allows the continuous monitoring of all stages of convection, ranging from the initial instability in the atmosphere indicating the possibility of convection, through to the formation of cumulonimbus clouds, and on to the development and properties of mature thunderstorms. The rapid image updates from MTG satellites (2.5 minutes) are an important tool for meteorologists to monitor the often rapid development of convective storms and help in issuing timely warnings.

Fog

Meteosat imagery allows 24-hour monitoring of the distribution and behaviour of fog and is used, in combination with other techniques, to help detect and monitor fog formation and nowcast its dissipation. This information is particularly important in sensitive localised areas such as around airports, major road networks, and shipping routes and ports.

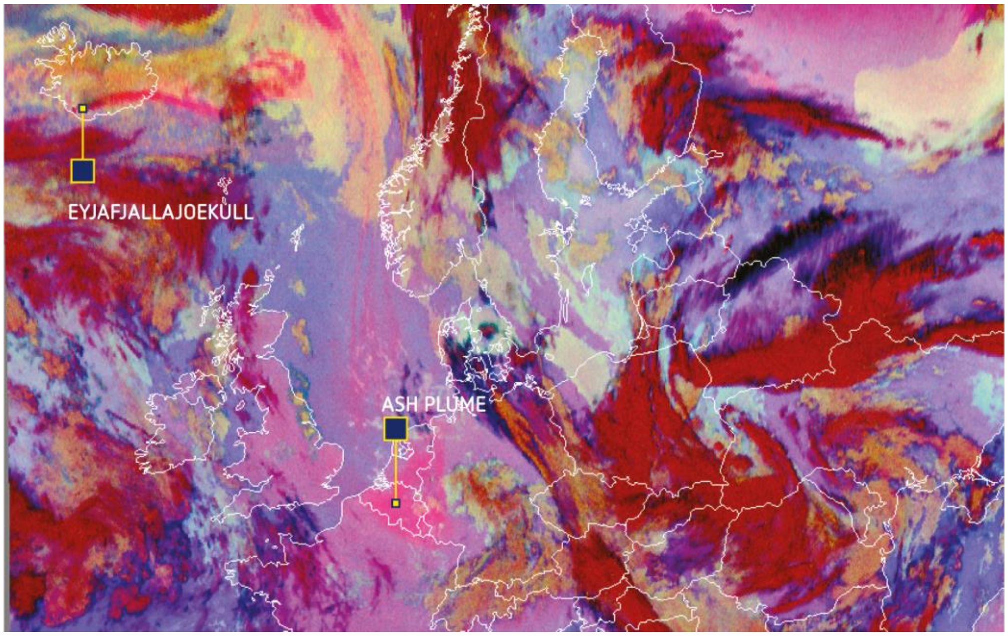


Fog over English channel as seen by Meteosat-10, 18 July 2013 12:00 UTC (High resolution visible channel enhanced with VIS 0.8, NIR 1 and VIS 0.6) showing that London airports are not affected (source: EUMETSAT)

Volcanic Ash

Meteosat satellites can detect volcanic ash in the atmosphere and provide invaluable imagery to follow in near-real time the movement and dispersion of volcanic ash plumes in the European airspace, such as from the Eyjafjallajökull (2010) and Grímsvötn (May 2011) volcanoes. As an example, the ash plumes from the eruption of Iceland's Eyjafjallajökull Volcano in April 2010 grounded hundreds of flights across Europe and cost the airline industry over 1.3 billion (EUR), according to IATA.

Using innovative algorithms and Meteosat imagery it is possible to discriminate ash from clouds and other aerosols, to enable the retrieval of mass loading, height and effective radius of ash. These capabilities make Meteosat imagery one of the primary sources of observations used by the London and Toulouse Volcanic Ash Advisory Centres, operated by the Met Office and Météo-France for monitoring volcanic ash plumes and their transport and dispersion in real time. These organisations are responsible for advisory warnings of volcanic ash in different parts of Europe's air space.



The Eyjafjallajoekull ash plume seen in the night microphysics RGB product as it reaches Belgium, the Netherlands and Germany, 18 May 2010 (source: EUMETSAT)

Inputs to numerical weather prediction models

The fast image repeat cycles of Meteosat imagery allow the derivation of "atmospheric motion vectors", or winds, by tracking clouds and humidity structures between subsequent images. These wind products and also clear sky radiances (water vapour columns) products are ingested in numerical weather forecasting models and provide important information to improve the initial state.

Climate and environmental monitoring

Meteosat satellites have been collecting observations relevant for climate and environmental monitoring since the late seventies, building up in the process one of the longest time-series of climate-relevant data collected by satellite in the world. These observations are primarily related to albedo, water vapour, cloud properties, precipitation associated to convective systems, winds, sea surface temperature, snow cover, vegetation cover and occurrence of fires.

Also, the MSG GERB measurements of the short wave and long wave components of the radiation budget at the top of the atmosphere became available to study the radiation budget, which is an important parameter for climate research.

The most valuable aspects of Meteosat data for climate monitoring are the continuity in spectral channels across the generations of satellites, and that they provide good observation capabilities of daily cycles throughout the seasons.

With the data collected from the existing first generation MVIRI and MSG's SEVIRI and the future MTG-I's Flexible Combined Imager, the duration of the Meteosat climate data record will reach 50 years in 2031 - longer than most other satellite records.

In addition, with the new Infrared Sounder (IRS), observations of the three-dimensional structure of the temperature and moisture fields in the atmosphere will become available from the MTG-S satellites from 2020 onwards. Climate records of atmospheric chemical compounds (O3, etc.) will also start in the same timeframe, as a result of the combination of IRS and the GMES Sentinel 4 Ultra Violet Sounder (UVS) on both MTG-S satellites.

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Global – Meteorology

Applications of future EUMETSAT polar programme (EPS-SG)

The EUMETSAT Polar System (EPS)
Keeping a closer eye on weather and climate

The global economy is also becoming increasingly weather sensitive and in demand of more accurate and timely forecasts. This is particularly true for energy, transportation, construction, tourism and agriculture. For instance, energy providers rely on weather forecasts to anticipate power demand and adapt production during both hot and cold spells. Likewise, forecasts of fog, snow, high winds, thunderstorms and weather-induced dispersion of ash particles are critical to aviation and air traffic management and hence to the global economy.

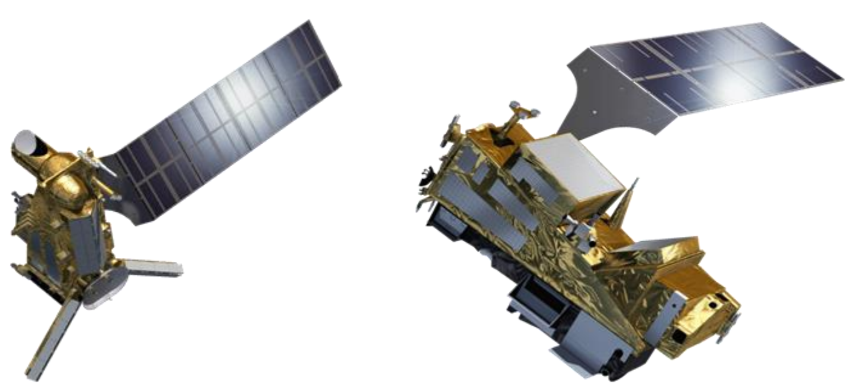
Polar-orbiting weather satellites provide global and accurate observations, essential for weather forecasting up to 10 days and for climate monitoring. In addition, these data are also a key source of real time observations for Nowcasting - severe weather - like the famous "polar lows" - at higher latitudes.

EUMETSAT Polar System – Second Generation (EPS-SG)

The current EUMETSAT Polar System programme (EPS) consists of three Metop satellites. Metop-A, the first satellite of the EUMETSAT Polar System (EPS), was launched on 19 October 2006 and was followed by Metop-B in 2012. Metop-C is planned for launch in October 2018, providing coverage of the polar orbit until at least 2020.

The EPS-SG programme will ensure the continuity of polar observations in the 2020-2040 timeframe. It will consist of two series of three satellites. The Metop-SG A series has the optical imaging, infrared and microwave sounding; aerosol imaging, and radio occultation missions. It also hosts the Copernicus Sentinel-5 mission. The Metop-SG B series is dedicated to microwave and sub-millimetre-wave imaging, scatterometry and radio occultation. It also hosts the ARGOS data collection system.

Both EPS and EPS-SG satellites are deployed as part of a Joint Polar System, shared with the United-States (NOAA).

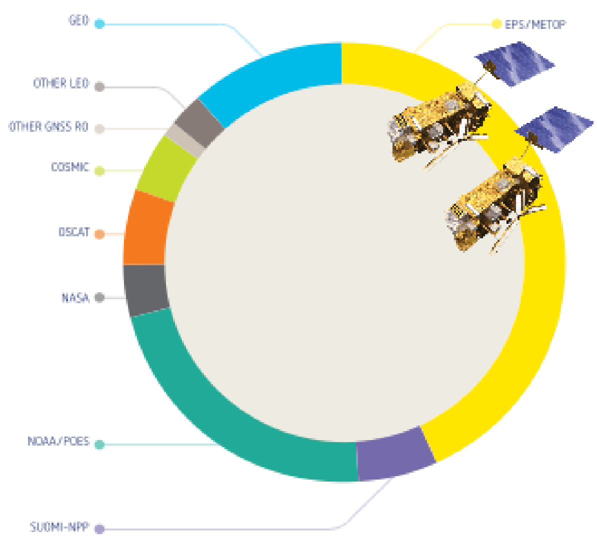


Metop-SG -A et –B satellites (Artist view. Source: ESA)

Benefits of Metop satellites

Forecast information is widely used by many different parts of modern society to better inform decision-makers, to ensure the safety of the population, to protect property, and increase productivity, economic growth and income. Based on a study performed by the World Bank in 2012 and published by the European Space Policy Institute (ESPI)(1), the socio-economic benefits of forecast information in the European Union have been quantitatively assessed for three main benefit areas (Protection of Property and Infrastructure, Added Value to the European Economy and Private Use by European Citizens) and are worth 61.4 billion EUR per year.

The operational polar-orbiting meteorological satellites forming the Initial Joint Polar System shared between EUMETSAT and NOAA (USA) are the most valuable source of input data. The current constellation of 2 Metop and 1 U.S. SNPP satellites accounts for about 72% of the impact of all observations on NWP forecasts, with the Metop-A and –B satellites having a contribution at around 44%.



Relative contributions to the reduction of day-1 forecast errors from all satellite observations ingested in Météo-France's ARPEGE global model. The dual Metop EPS system scores 44% and the full IJPS (Metop, NOAA, NPP) 72%. (Source: Météo-France)

The same study has demonstrated that the benefits of EPS/Metop-SG programme in the 2020-2040 timeframe will generate benefits expected in the order of 61 billion EUR. The cost to benefit ration of such a programme is estimated to 20.

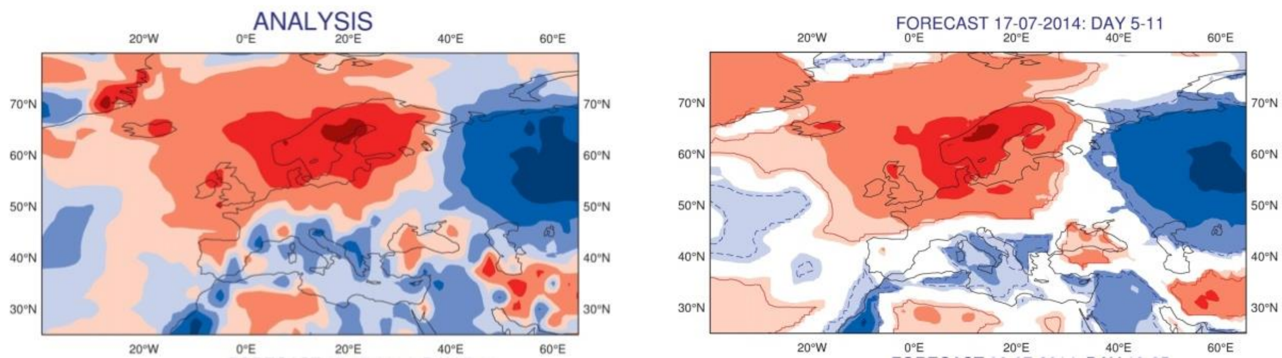
Metop Applications

Input to Numerical Weather Prediction (NWP)

Numerical Weather Prediction (NWP) is the basis of all modern global and regional weather forecasting; the data generated by the instruments carried by Metop satellites are ingested ("assimilated") by NWP models to compute forecasts up to 10 days ahead.

Measurements by infrared and microwave radiometers and sounders on board Metop provide NWP models with global three-dimensional information on the temperature and humidity of the atmosphere with a high vertical resolution. The Infrared Atmospheric Sounding Interferometer (IASI), for example, makes it possible to ascertain temperature and humidity profiles with an unprecedented accuracy of

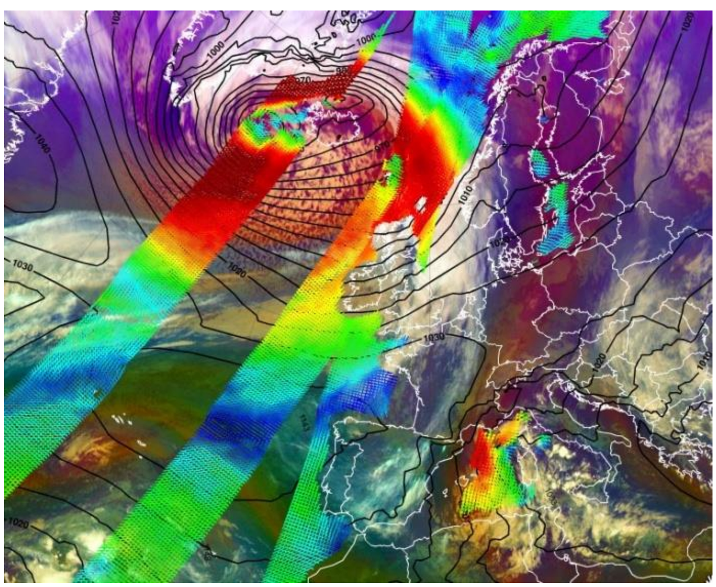
1˚C and 10% respectively, and a vertical resolution of a few kilometres in the lower troposphere, thus significantly increasing the quality and positive impact of the measurements injected into models. The models are further enhanced with the simultaneous measurements provided by the all-weather microwave instruments Advanced Microwave Sounding Unit-A (AMSU-A) and Microwave Humidity Sounder (MHS).



ECMWF probabilistic forecast (right) of temperature anomalies up to 10 degrees one week before a heat wave hit the Nordic countries in July 2014, compared to the conditions actually observed (left). These forecasts involve models coupling ocean and atmosphere and ingesting data from both Metop and Jason-2. (Source: ECMWF)

Early Warning of large scale weather events

Metop data have improved forecasting and early warning of the large scale high impact weather events recorded in 2014, from severe storms in Western and Central Europe to the heat waves in July over Northern Europe which caused record-breaking temperatures in Norway, Denmark and Sweden, with one heat wave lasting from 17 to 30 July.

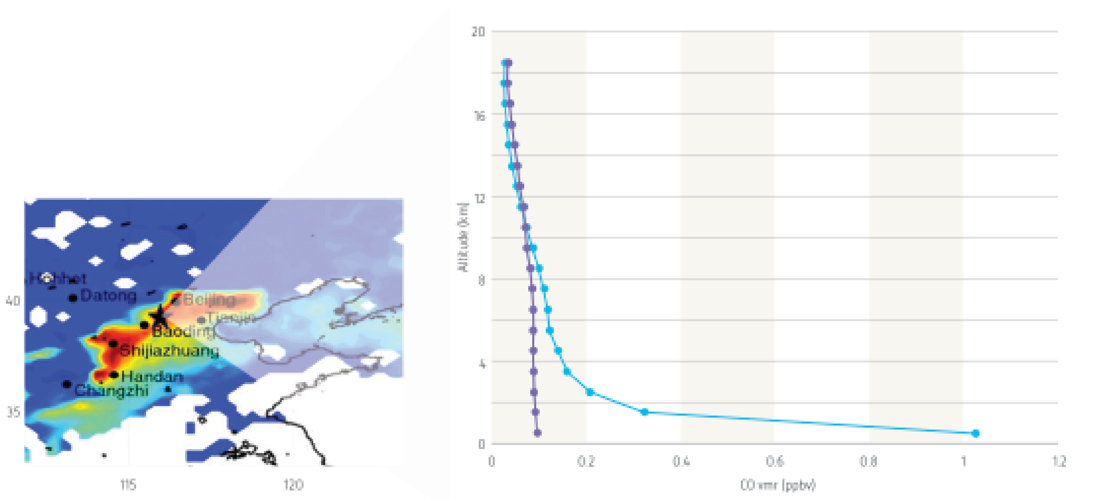


Forecast of winter storm Alexandra overlaid with Meteosat imagery and Metop/ASCAT winds on 9 December 2014. With a central pressure of 950 hPa and winds, Alexandra brought gusts of 129 km/h and ocean waves over 15 m in North-Western Scotland (source: EUMETSAT)

Metop applications – Climate Monitoring

All instruments on board Metop contribute to global climate monitoring models and applications, helping scientists understand the complex interactions between the various factors that influence the Earth's climate system. The satellites support the work of the United Nations Framework Convention on Climate Change (UNFCCC), WMO and Global Climate Observing System (GCOS) by monitoring a range of Essential Climate Variables, such as temperature, greenhouse gases, aerosol properties, sea ice and albedo.

In particular, IASI's ability to detect and measure trace and greenhouse gases has provided capabilities beyond expectations. Trace gases include carbon monoxide (CO), sulphur dioxide (SO2) and ozone, to name a few. A multi-sensor product combining observations from Metop's AVHRR, GOME-2 and IASI instruments was recently introduced to document aerosol optical depth (operational) and type, i.e. fine mode, coarse mode/dust or volcanic ash (demonstration), along with a carbon monoxide (CO) product extracted from IASI data, providing for the first time vertical profiles in highly polluted areas, using an algorithm developed by the O3M SAF.



Total column of carbon monoxide observed by IASI/Metop during a pollution peak in China (location marked by the star), and the corresponding vertical profile (blue) extracted using the algorithm developed by the O3M SAF/ULB/LATMOS (from Boynard et al, 2014, GRL)

The Global Ozone Monitoring Experiment-2 (GOME-2) measures ozone profiles, total columns of ozone and other atmospheric constituents like nitrogen and sulphur dioxide in full synergy with IASI. The observed trace gases are related not only to the depletion of ozone in the stratosphere, but also to other sources like volcanic eruptions and biomass burning. Additionally, the long-term monitoring of the observed trace gases will provide more insight into the impact of man-made sources of pollution on the environment (including air quality) and the climate on both regional and global scales.

More Information

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Reference

The case for the EUMETSAT Polar System (EPS) / Metop Second Generation Programme: Cost Benefit Analysis (Stéphane Hallegatte, John Eyre, Tony McNally, Roland Potthast and Robert Husband) – Yearbook on space policy 2011 / 2012 – Springer 2014.
http://www.springer.com/us/book/9783709116487

Global – Agriculture

Earth Observations Aid Tracking of Global Crop Conditions for Improved Production Assessments

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Inbal Becker-Reshef, University of Maryland-College Park
Brad Doorn, NASA Earth Science
William Corley, Booz Allen Hamilton
Lawrence Friedl, NASA Earth Science

Key Takeaway

Satellite observations of crop anomalies support monitoring of major crop producing regions critical to global food markets to help make more informed estimates of food stocks and food reduce price volatility.

Article

Severe droughts hindered crop production in major portions of the Northern Hemisphere in 2012. Large areas of western and central Eurasia, which account for a quarter of the world's wheat exports, also suffered from extensive drought. The United States, which produces more than a third of the world's corn and soybeans, experienced its worst drought in more than 50 years.

An international team of researchers and applications specialists, with support from NASA, applied satellite-based indices of crop conditions to monitor major crop producing regions, identify anomalies, and inform production forecasts months before harvest. The team includes leaders in international activities to improve global agricultural monitoring, food market transparency, and food security.

Northern Hemisphere, 2012
The project team applied a remote sensing indicator of vegetation rigor known as NDVI (see callout below). The team looked at NDVI anomalies and compared them with the peak NDVI times, pinpointing critical stages in the growing season when crops would be especially sensitive to high temperatures and low precipitation.

Using MODIS data from Terra and Aqua, the project assessed the 2012 growing season in the Northern Hemisphere, computing a time series of daily vegetation images of primary cropland areas. Comparisons of current crop conditions with average conditions for the same date from 2000–2011 showed NDVI anomalies beginning around May. A series of images from May through September 2012 showed the intensification of droughts and impacts on cultivated areas in the United States and parts of Eurasia. (Notably, the images also pointed to generally favorable conditions in the main growing areas in Canada and China.)

The team's analysis indicated widespread crop damage during critical growth stages, especially in the Corn Belt in the United States, and in the wheat growing regions in Russia, Ukraine, and Kazakhstan. Indeed, the production in all these regions was below average. For the United States, corn production in May–June was down about 100 million metric tons.

Comparisons of growing seasons offered insights into the state of current crops relative to prior years with detrimental droughts. For instance, the team compared the NDVI crop anomalies over Eurasia in July 2012 with the NDVI anomalies in July 2010, when large areas suffered severe droughts. The 2012 NDVI anomalies were akin to those from 2010 for Russia and Kazakhstan. Since grain production fell 30 percent in Russia during the 2010 drought and wheat prices rose, officials and markets could anticipate similar, significant disruptions.

Developing Capacity

These efforts were part of broader ones to build global agricultural monitoring capabilities and skill. The team shared its imagery and assessments with an international expert panel formed by the Group on Earth Observations (GEO), including representatives from FAO, main producer countries (Canada, China, Kazakhstan, Ukraine, the United States, and Russia), and the Joint Research Center of the European Commission. The panel examined national, regional, and global crop condition indicators, which complemented the project's, and developed a consensus Northern Hemisphere crop outlook.

The project is part of the GEO Global Agricultural Monitoring initiative, or GEOGLAM. The project directly supports GEOGLAM's efforts to develop a timely, consensus assessment of production for the primary producer countries, with as much lead time as possible in advance of official national statistics. Crop monitoring helps identify areas with likely shortfalls or surpluses in food production. Such information and lead times can help markets reduce price volatility.

"I am confident that this project, combined with the international coordination and harmonization occurring through [GEOGLAM], will deliver to agricultural forecasts the same benefits that have been experienced with improved accuracies of weather forecasts when space-based observations were incorporated into the global weather models," said Barbara Ryan, director, GEO Secretariat. "In the case of agriculture, improved production forecasts will reduce price volatility, which ultimately will create a more food-secure world—something for which we all should strive."

With GEOGLAM and international partners, the project developed efforts to disseminate crop condition outlooks and production forecasts through the Agricultural Market Information System (AMIS). AMIS is a G20 initiative to enhance food market transparency and encourage coordination of policy action in response to market uncertainty. GEOGLAM merges countries' crop condition reports with satellite data organized through CEOS to produce credible, monthly information on crop conditions, supporting the focus of AMIS on wheat, soybeans, rice, and corn as well as its transparency and policy coordination goals.

Information from the AMIS website and the monthly AMIS Market Monitor publication are used by traders, agricultural economists, and policy makers. The monthly reports give in-season information. For example, traders use the information on when and where to buy grain from and when is a good time to sell. Policy makers use the information to determine whether to restrict exports to ensure prices remain low in their country. Agricultural economists and traders use it in assessments of global production and market reactions, such as whether expected decreased production by one producer can be made up by other producers.

In September 2013, AMIS began using the GEOGLAM-produced monthly crop health estimates in the Market Monitor. The Crop Monitor Assessment information appears upfront on pages 2-3 of the AMIS Market Monitor.

Plowing Forward
NDVI applications from the VIIRS sensor on Suomi NPP serve as a continuation and eventual transition from MODIS on Terra and Aqua. The team and international partners provide an online platform to share its findings and identify drought "hot spots." The platform enables users to upload data and provide comments.

GEOGLAM has advanced and continues to advance the use of Earth observations for monitoring major crop producing regions critical to global food markets. Government officials use the information, for example, to make more informed estimates of food stocks, plan emergency reserves, and implement policies to reduce food price volatility.

"The assessments have been able to demonstrate to decision makers the value and utility of remotely sensed derived information for providing timely and actionable information on crop conditions," said Joao Soares in 2012, scientific and technical expert for agriculture, GEO Secretariat.

Overall, GEOGLAM, AMIS, and the Monthly Monitor reports enable consistent, transparent, and in-season estimates of food supply. Produced in an open, international forum, this more objective information means prices are based more closely to supply and demand, reducing perceived risk and speculative pricing (that often leads to high prices) and supporting more efficient markets and commodity distribution.

For more information on AMIS, visit: http://www.amis-outlook.org/home/en/
For more information on GEOGLAM, visit: http://www.geoglam-crop-monitor.org/

Callout/Sidebar

NDVI
Earth-observing environmental satellites can measure outside the visible range of light, observing across multiple wavelengths and seeing more than what is visible to the naked eye. Scientists have identified that some wavelengths are more sensitive and revealing of vegetation than others. For example, healthy vegetation absorbs most of the visible light that reaches it and reflects much of the near-infrared light. Combining those vegetation-sensitive wavelengths in special ways can provide insights on crop health and stress.

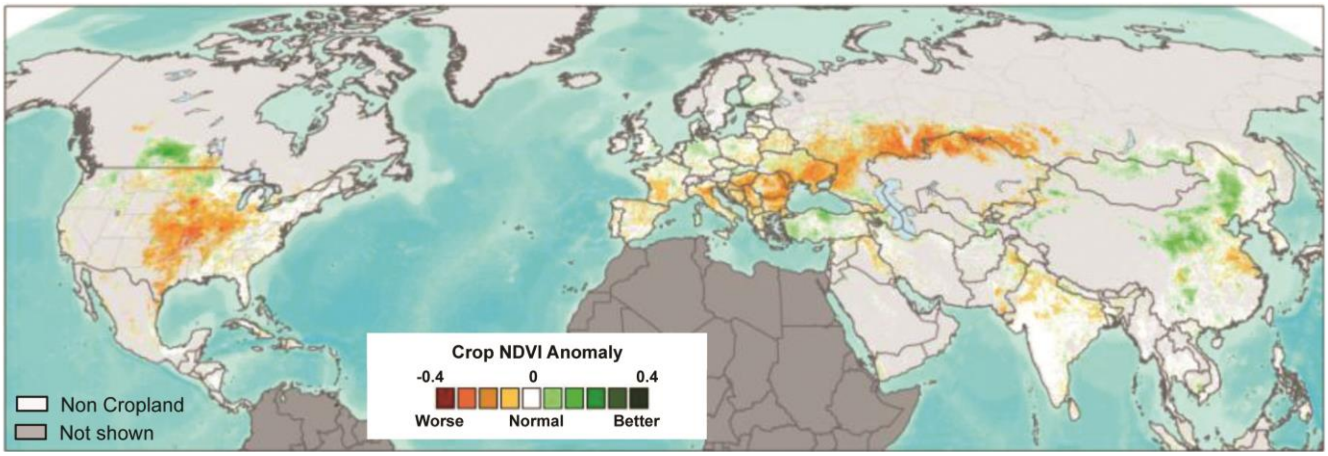
The Normalized Difference Vegetation Index (NDVI) is such a combination. NDVI is an established indicator calculated from differences in the visible and near-infrared light that vegetation reflects. NDVI supports assessments of whether a target being observed contains live green vegetation, and it serves as a measure of the physiological activity of plants.

By assessing the NDVI at particular times in the growing season over many years, managers can assess NDVI anomalies, or departures from average conditions. Peak NDVI varies by crop and region. For instance, peak NDVI for wheat occurs in May in the United States and in July in the Black Sea region.

Key Quote

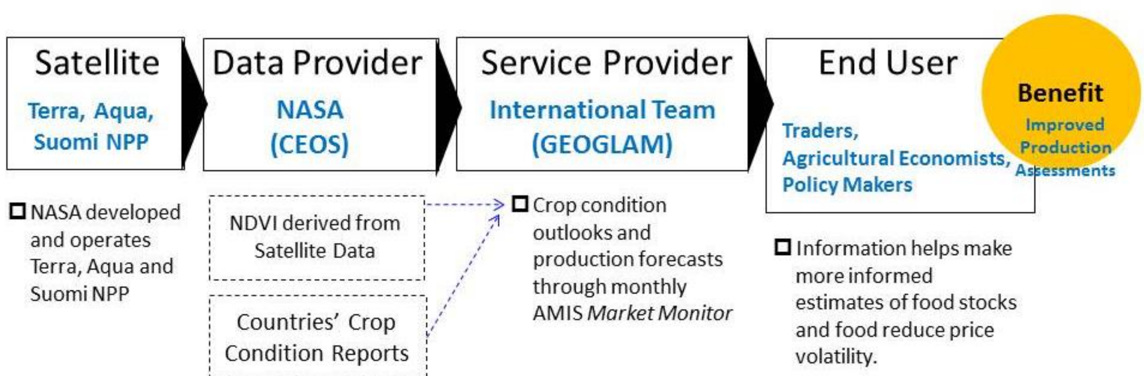
"The assessments have been able to demonstrate to decision makers the value and utility of remotely sensed derived information for providing timely and actionable information on crop conditions." - Joao Soares, GEO Secretariat

Images



This figure shows Northern Hemisphere crop NDVI anomalies in mid-August 2012 compared with average conditions for the same date from 2000–2011. Browns indicate worse than normal conditions, and greens indicate better than normal conditions. Major cultivated areas in the United States, Russia, Ukraine, and Kazakhstan show significant anomalies and impacts to production.

Value Chain



Global – Forest

Forest biomass and change in forest cover using SAR data for forest monitoring systems.

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Centre d'Etudes Spatiales de la Biosphère
Toulouse, France

Descriptions

Efforts to monitor and map changes in the forest using EO has gained momentum in the United Nations Convention on Climate Change (UNFCCC) policy process related to countries reducing emissions from deforestation and degradation (REDD). Data from Synthetic Aperture Radar (SAR) are particularly suitable to measure forest biomass and to monitor changes in forest cover. ALOS-2 data can be used for mapping of forest biomass and Sentinel-1 data for monitoring of changes in forest cover. This is illustrated in 3 examples: 1) near real time detection of forest logging using Sentinel-1 data is being developed in Vietnam and contacts with Vietnamese authorities and Forest Trust are foreseen 2) mapping of change in forest cover and in biomass of woody savanna using ALOS-PALSAR data in Cameroon, the maps have been developed following the requirements of the Ministry of Environment and Nature Protection (MINEP) of the Republic of Cameroon for REDD+ reporting, and 3) a large scale above ground biomass map of Africa has been provided to modellers working on carbon flux models.).

Challenges

Although considerable advances have been made in recent years to develop forest monitoring systems using EO data, significant obstacles still remain in terms of collecting and collating relevant and timely data. Recently, the work led by the University of Maryland (UMD) provides tree cover and cumulative tree cover gains and annual losses. The maps based on 30m resolution Landsat data have the potential to provide countries with annual tree cover change map. However, the tree cover is not sufficient to define forest, and change in tree cover is not necessarily deforestation. For reporting to international agreements, there is also a requirement to retrieve data relating to the carbon budgets which are difficult to obtain. SAR data more directly sensitive to forest biomass, thus an adequate SAR system, with long wavelength, could provide mapping of above ground biomass (AGB) and its change over time to be used for estimating carbon emissions. This is the objective of the ESA BIOMASS mission, to be launched in 2020. Until then, the available long wavelength SARs are at L-band (ALOS-2) which can be used to map the low rage of biomass (< 100 t/ha). At Cband, Sentinel-1, with short repeat frequency(12 days and 6 days with Sentinel-1 a and b) can provide a near real time method to monitor deforestation and forest logging. Both SAR systems, Sentinel-1 and ALOS-2 will thus provide complementary information with optical systems such as Landsat 8 and Sentinel-2 to constitute an EO forest monitoring systems, to be integrated in Global Forest Observations Initiative (GFOI).

Applications/solutions

1. Near real time detection of changes in forest cover:

Changes in forest cover (biomass and structure) due to disturbances in tropical forests are difficult to detect systematically by optical systems because of the cloud cover and the fast vegetation regrowth. Sentinel-1 with dense observation frequency is a very good method to monitor vast regions of forest. Figure 1 shows an example of forest monitoring in Vietnam. It is worth noting that data and results were available one day after the data acquisition, and thus present a near real time monitoring of deforestation or logging operations.

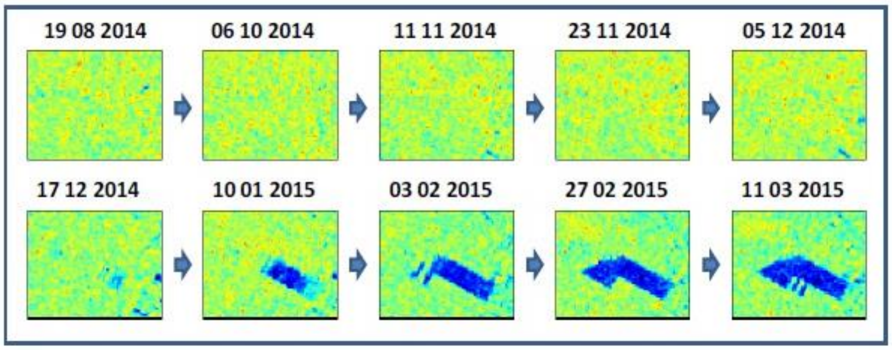


Fig 1: Monitoring forest logging and deforestation with Sentinel-1. The images are in the region of Dau Tieng, Vietnam, where Rubber plantation is currently very active. The illustration show a subset of a 300 km x 400 km region observed regularly by Sentinel-1 .

2. Forest biomass by ALOS-2

Methods for biomass mapping using ALOS-PALSAR data at 25 m resolution have been developed and validated for forest with low biomass (less than 100 tons/ha) such as the savanna forest in Cameroon (Mermoz et al., 2014). forest biomass, needs a small number of reference plots for model calibration.

A similar method has been developed and applied to the low biomass regions of Africa, based on plot data in Cameroon Ugana, Mozambique, Botswana and S. Africa. The biomass map of Africa is currently used by researchers in carbon flux modeling (the LSCE, France) to improve their Global Dynamic Vegetation Model (ORCHIDEE).

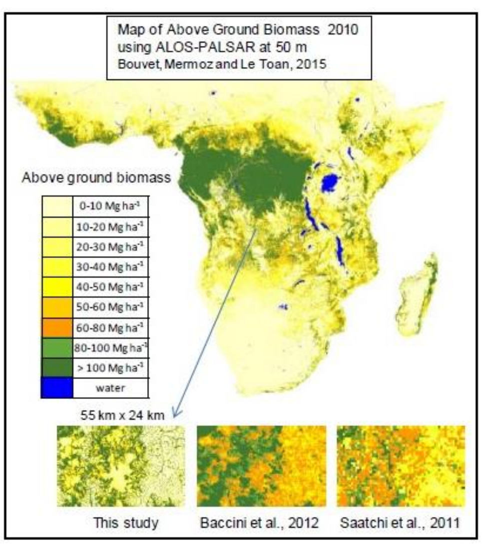
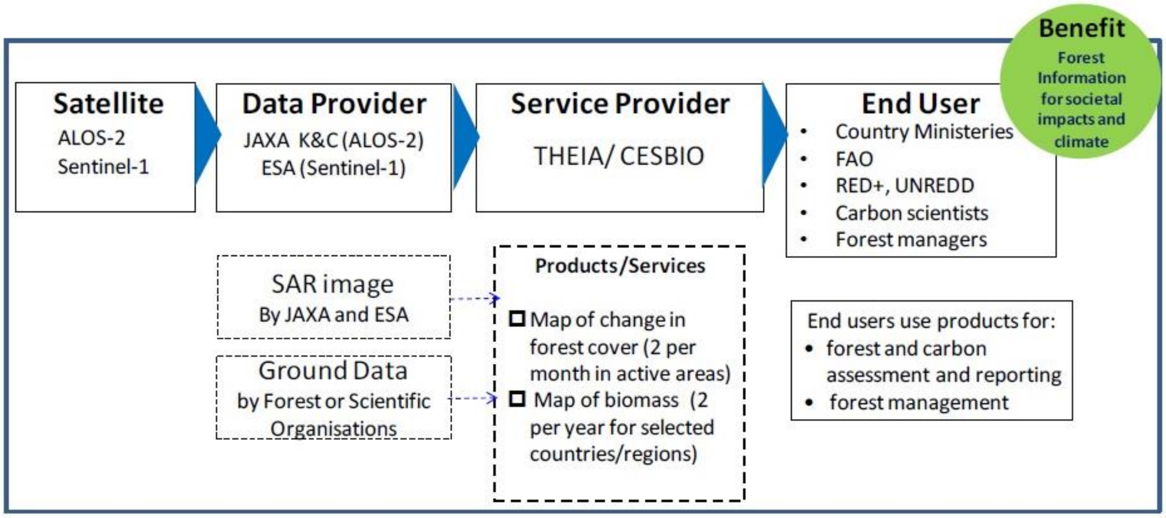


Figure 2 shows the biomass map of Africa up to 100 t/ha. A subset of the map shows more details in the maps as compared to the datasets available in the literature.

Value chain



The product dissemination can be made through Theia as service provider. The Theia Land Data Centre is a French national inter-agency organization designed to foster the use of images issued from the space observation of land surfaces. Theia is offering scientific communities and public policy actors a broad range of images at different scales, methods and services.

Outcomes/benefits

The improved forest monitoring systems has a main contribution in terms of supporting countries to track and manage an important natural resource sustainably. The quantitative data will be used for reporting requirements for organizations suxh as the UN Forum on Forests, the International Tropical Timber Organization, the UNFCCC REDD+ process, and national Forest Strategies and Policies Organization.

The regular large area forest monitoring activities is also particularly suited for the studies on the functioning of the forest ecosystems, and on the related carbon assessment.

Contact information

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http://www.cesbio.ups-tlse.fr/data_all/annuaire/letoan/hp_letoan.html

Global – Other

NEODAAS: Providing satellite data for efficient research

Ben Taylor, Steve Groom, Peter Miller: Plymouth Marine Laboratory
Neil Lonie, Steve Parkes: University of Dundee

The NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS) provides a central point of Earth Observation (EO) satellite data access and expertise for UK researchers. The service is tailored to individual users' requirements to ensure that researchers can focus effort on their science, rather than struggling with correct use of unfamiliar satellite data.

Problem

Satellite EO data are a powerful tool of benefit in many fields of research: many important research and societal questions, such as the rate at which particular areas of the Earth are warming due to climate change, can be answered in no other way because no other mechanism exists for obtaining such wide-scale observations. However, the understanding of EO data is an active research field in itself and, therefore, researchers in fields that may benefit from its use often do not have the requisite training or experience to find, process and critically evaluate available EO data, meaning that it often cannot be applied effectively.

Satellite Earth Observation Data Application

NEODAAS is a facility funded by the UK government to provide a central repository of EO data and expertise to the UK research community. It was formed from the merger of Dundee Satellite Receiving Station (DSRS) with the Remote Sensing Data Analysis Service at Plymouth Marine Laboratory (PML) in 2006. Data are received and disseminated from a number of satellites primarily operated by NASA, NOAA, ESA and EUMETSAT.

NEODAAS differs from the data products disseminated directly by the space agencies in that NEODAAS tailors its outputs to each specific user, as well as providing data products developed in-house, such as thermal front maps. Researchers may request datasets for a particular region and time period of interest from NEODAAS. This means that users require little or no expertise of their own in order to make immediate effective use of the data, since NEODAAS will have provided data selected for their specific application and are available to provide support in use.

NEODAAS frequently provides pro-active near-real time satellite support for field research campaigns, with NEODAAS staff emailing a daily bulletin to the field site (often a ship at sea). Where such support is provided there is often a significant efficiency improvement as satellite data permit targeting of sampling effort on specific features of interest, thereby ensuring either sampling can be completed more quickly or more samples can be collected. The direct reception capability at Dundee allows NEODAAS to make images available more quickly than they would be if data were obtained from other sources.

As an example, Fig. 1 shows a NEODAAS chlorophyll map of the area studied by the 2009 SOLAS-ICON research expedition. SOLAS-ICON was investigating gas exchange between the ocean and atmosphere in the highly variable Mauretanian upwelling zone off West Africa, and followed two transient filaments of water moving off the coast. They relied on NEODAAS satellite data to allow them to find these filaments in order to inform their sampling strategy.

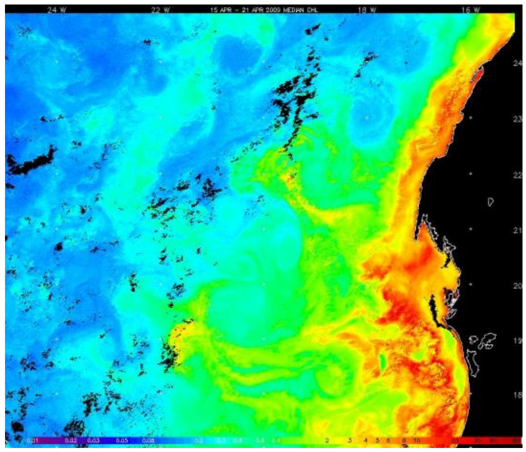


Fig 1: Aqua MODIS Chlorophyll composite for part of SOLAS-ICON cruise

Another example is the Aerosol-Cloud Coupling and Climate Interactions in the Arctic (ACCACIA) project which investigates the processes that control the properties of low-level clouds in the Arctic. The interactions between atmospheric aerosols and clouds in the Arctic are poorly understood, and this is reflected by the poor performance of climate models when modelling Arctic clouds. The Arctic is warming much faster than the rest of the world and this is, therefore, crucial for predictions of climate change.

Two field campaigns were undertaken in 2013 involving both cloud sampling from aircraft and marine investigations from ships. NEODAAS provided near-real-time imagery such as showed in Fig. 2 to inform sampling strategy of the research ships and permit planning of the research aircraft involved so that the science could be accomplished.

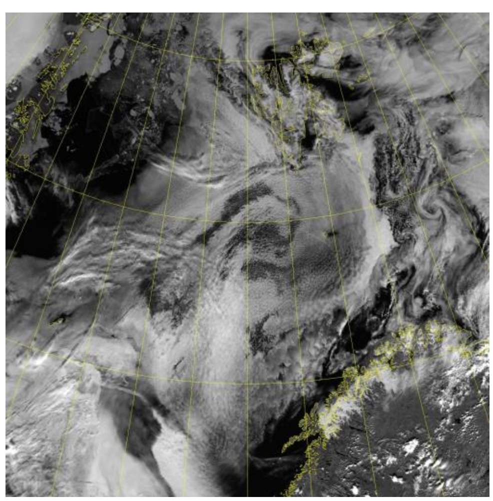
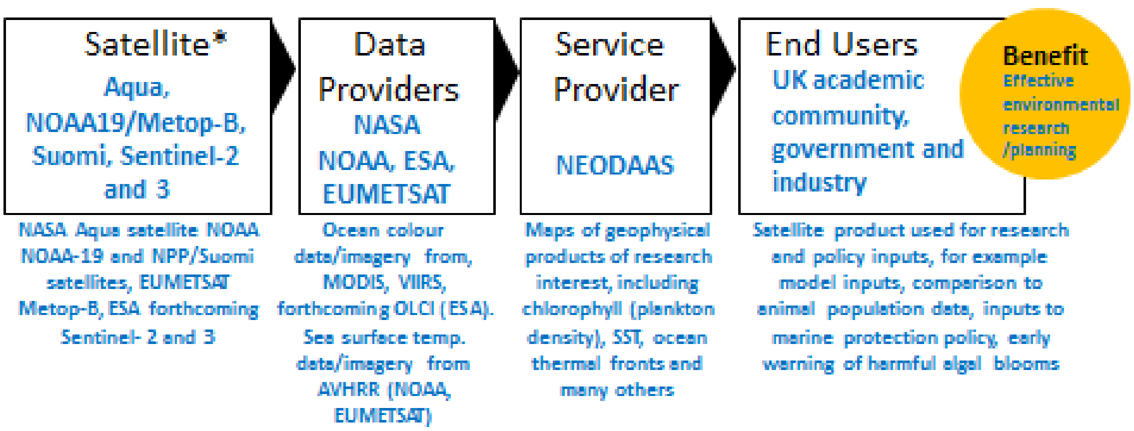


Fig 2: AVHRR channel 2 image received at NEODAAS-Dundee used for ACCACIA project flight planning

NEODAAS provides a direct economic benefit to the UK research sector by permitting researchers to spend their time on their science. It provides a further economic benefit by maximising use of assets such as research ships that are expensive to run – NEODAAS usage costs only a fraction of one day's science time on board a research vessel and, therefore, where NEODAAS data enables effective experimental design it results in a significant cost saving.

NEODAAS can provide assistance for scientific applications: please email info@neodaas.ac.uk to discuss your requirements. Use is likely to be free for UK academic purposes, though a charge may be made for commercial use.

Value Chain



**Historical data from other (now defunct) sensors can be provided to users, examples including the NASA SeaWiFS instrument on Orbview-2, the ESA MERIS instrument on Envisat and the complete NOAA-AVHRR satellite series.*

More Information

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Global – Other

EarthLab Galaxy: towards a worldwide cluster of environment monitoring centers

As first global network of centers dedicated to environment monitoring, the EarthLab program has ambitious goals when it comes to effectiveness and achieving results. The goal is to contribute, through remote sensing and the widespread use of digital tools, to the emergence of a sustainable development model for the planet integrating economic, human and environmental factors.

Unlike the dominant approach on the space applications market, EarthLab aims at designing and implementing solutions based on specific end-users' needs (industries, farmers, oil companies, ship-owners) right from the first phase of defining functions and throughout their exploitation.

Examples of users benefits on thematics are described below:

Agriculture services

Users: Crop producers, Ag. Service companies, Ag Retailers, Insurance companies, Ag. Investors, Traders, Administrations.

Main benefit: Significative improvement of the quality of the final product, reduction of the purchasing of phytosanitary inputs.

Maritime services

Users: Administrations, Navies, Coastguards, Insurance companies, fishing industries, NGO, Oil & Gas companies, Insurance companies

Main benefit: Provision of an optimized global maritime picture of the area.

Forestry

Users: Wood producers, Energy producers, wood & paper Industry, foresters, Insurance, CO2 Investors, Traders, Administrations.

Main benefit: optimization of forestry management practices such as forest inventories, forest dynamics and risks management.

The EarthLab approach goes well beyond providing a product. For our partners and clients, the service is at the heart of a "bundle of values" characterized by ongoing dialogue and exchange. Experts within the community provide users with decision making aids to objectify and secure their technical, strategic, environmental and financial options.

The EarthLab Galaxy will become a worldwide network of some 10 to 15 centers that will in parallel conduct R&D activities and provide operational services, in a partnership spirit to share, at reasonable conditions their innovative outcomes.

Global context

More than 200 satellites are expected to be launched for Earth Observation (EO) by 2020. New technologies associated with aircraft or drones are already complementing satellites to optimize the ability to observe in details all areas of the globe.

The digital revolution, with a growing use of simple and mobile devices to access data (tablets, smartphones, ...), the internet network and the big data phenomena provide solid means to democratize the earth observation satellite services and the global supply of geo-information.

In this context and with increasing needs to monitor the environment on a local and on a global basis, dissemination and adaptation of geo-information services to the greatest number are crucial issues for our societies.

Satellite Earth Observation Data Application

The disruptive program EarthLab, initiated by Telespazio France, is part of this major global dynamics and provides a unique solution for the local release of geo-information end-to-end services.

Based on research units locally incorporating both experts from satellite earth observation and researchers from various environmental fields, the EarthLab network, called EarthLab Galaxy, is organized internationally, driven by a global and local demand using all new technologies in earth observation combined with IT to monitor and preserve the environment. Thus, environmental and economic issues are more effectively addressed simultaneously from both the local and global perspectives.

The creation of the EarthLab Galaxy is based on the implementation of some strategic center, deployed across all continents and to cover the greatest challenges of environmental monitoring.

Each EarthLab center is meant to deal with specific topics. The "original" EarthLab was set up in January 2013 in Bordeaux (France) to work on vine, forestry and costal monitoring issues. A second center is currently being deployed in Libreville (Gabon) and will focus from end 2015 on maritime surveillance and later on land mapping. The next upcoming center will be located in northern Europe and will deal with industrial and environmental risks.

Fig 1: EarthLab galaxy

As of today, the EarthLab applications are organized around four main themes: Land, Ocean, Security and Climate.

Value Chain

The EarthLab Galaxy is supported by a community of partners that provide varied and complementary expertise and/or assets. The collaboration between these stakeholders, coordinated by Telespazio France, leads to tailor-made solutions developed in the different EarthLab centers.

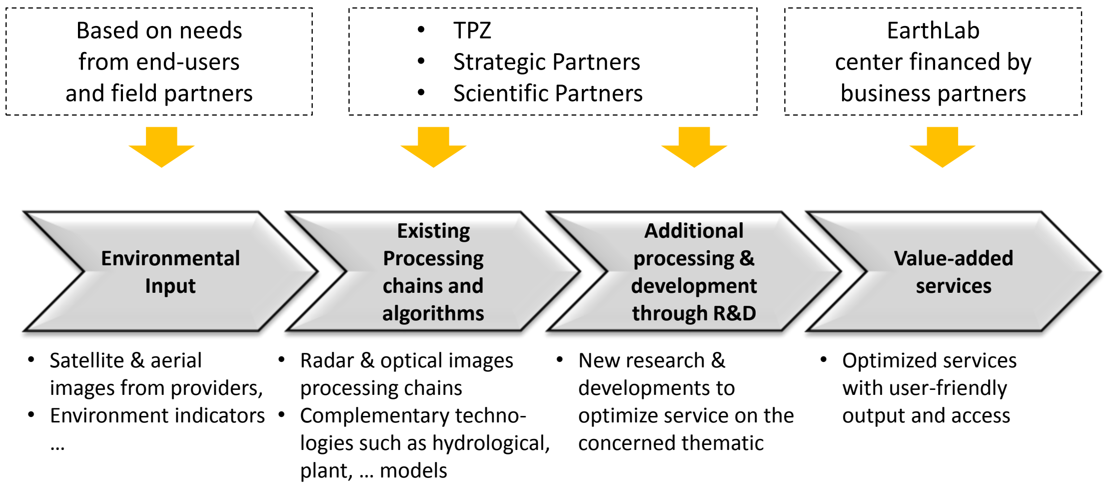


Fig 2: Value Chain of EarthLab

Business partners are private entities or representatives of national and local public authorities. They co-build the EarthLab centers with Telespazio France by providing direct financial support. In addition to this capital engagement for the program, they contribute to EarthLab Galaxy by providing specific, highly accurate knowledge of their territory and the human, economic and environmental issues involved.

Industrial partners are innovative firms that provide technical tools and solutions to complement Telespazio France space expertise. Thanks to these partners, users have access to customized and efficient products and services.

Scientific partners are universities and both public and private research centers that provide the essential knowledge to develop EarthLab products and services. Their fundamental and applied research works feed analysis on each thematic, by identifying problems, putting them into perspective and suggesting concrete solutions.

Field partners or users are full members of the EarthLab community. They express specific field issues on which EarthLab will develop products and services. Users' feedback is essential to the constant evolution and improvement of the program. EarthLab staff will use its expertise to rapidly identify the type of data required and will target the necessary developments based on its acquired experience on operational services.

An EarthLab center is composed of three main components: a data center ingesting multi-source data including satellite images, an operational production services center and a research, development and training area. If the feasibility of a new service is proven after analyzing the service's technical and economic sustainability, it is industrialized and then commercialized by the EarthLab center.

This ecosystem is represented in the figure 3.

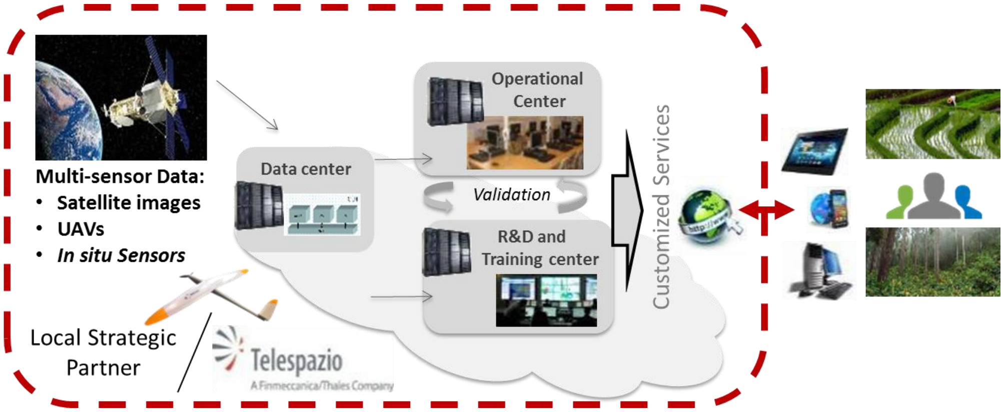


Fig 3: EarthLab global architecture

EarthLab products example

Some examples of services developed and proposed within the existing EarthLab center are presented below.

Agriculture services

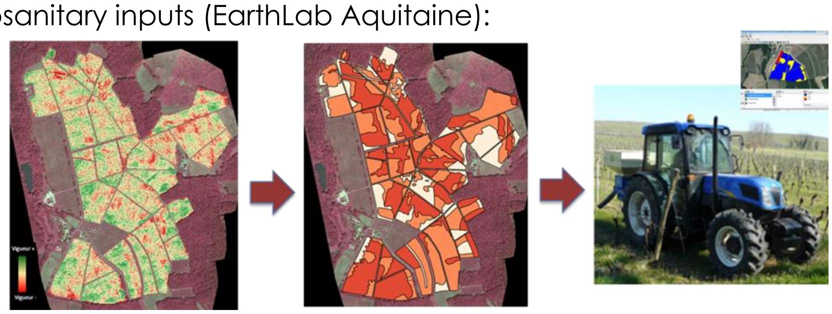
Developed with an EarthLab approach, all services for agriculture are "end to end" services. EarthLab services for agriculture are based on the processing of EO data, the use of integrated local measurement and are compatible with agricultural machines. The selection of EO data depends on the final resolution of the product : HR images are used if the customer requires 5 to 10 meters resolution products and VHR images are used if the customer requiressub-metric resolutionproducts. If necessary, UAV's data could also been integrated. This large flexibility is valuable for the final user.

The service of optimization of phytosanitary inputs allows in average a reduction of 25% of phytosanitary inputs. The two main benefits are: first a significative improvement of the quality and secondly a reduction of the purchasing of phytosanitary inputs.

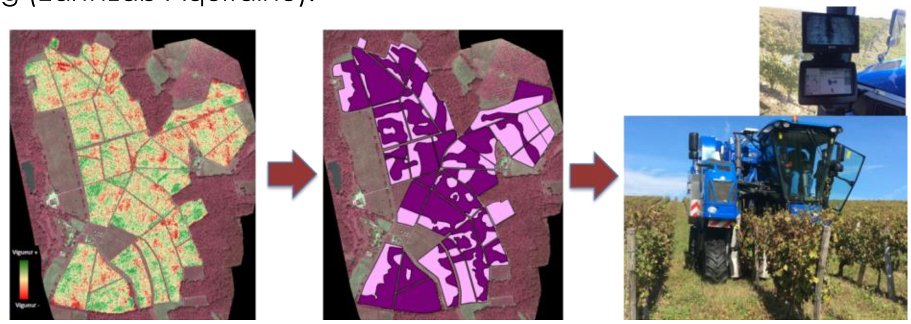
The service of selective harvesting is important for the quality of the final product. It allows to select specific areas having the best parameters to produce higher quality. This service is particularly used on wineyard having different wine quality level.

These two services are available for both perennial and annual crops.

Optimization of phytosanitary inputs (EarthLab Aquitaine):



Selective harvesting (EarthLab Aquitaine):

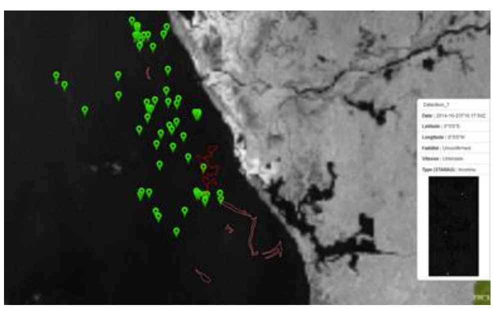


Maritime services

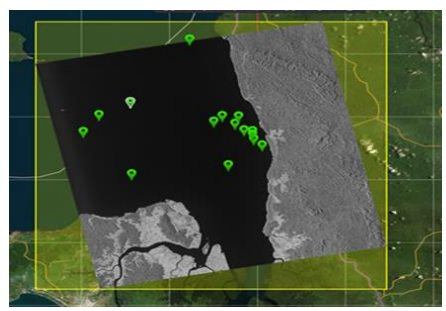
Maritime services rely on the most up-to-date image processing technologies developed within the Telespazio group. They consist in an advanced areas of interest monitoring in order to provide reliable information for decision support.

These means and tools are designed to provide an operational service while ensuring a high level of knowledge of customer's activities on an area. The service integrates localization and identification systems (AIS, VMS...) to provide an optimized global maritime picture of the area. Based on optical and SAR data, the service is available at different scales from medium to very high resolution.

These services are now used by the global oil industry, the Navies, coast guards, by private stakeholders in maritime security and also by environmental agencies and NGOs, to monitor pollution, to monitor illegal activities, or for the preservation of marine protected areas.



Monitoring of Oil & Gas platform over Gabon (EarthLab Gabon)



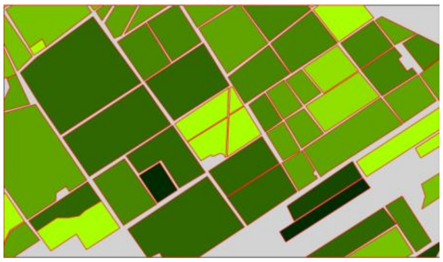
Fisheries' monitoring in Guinea Golf (EarthLab Gabon)

Forestry

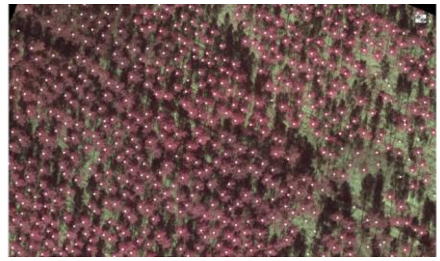
These services ensure effective management of forestry practices, focusing on forest diagnostics, tracking of forest dynamics and risks monitoring. With the use of last-generation image-processing algorithms and highly qualified teams, EarthLab offers comprehensive operational services, focused on forestry real needs.

EarthLab services are adapted to all types of forests (boreal, temperate and tropical forests) and designed to support the user in the optimization of forestry management practices like forest inventories (inventory mapping of forests and their accessibility, estimation of timber volumes and biomass and carbon stocks), forest dynamics (analysis of logging dynamics and yield, retrospective -over more than 30 years- or prospective analysis based on growth models) and risks management (urgent mapping of areas affected by severe weather events or pests, scoping of risks).

Based on optical and SAR data, the service is available at different scales from medium to very high resolution.



Forest density measurement
(EarthLab Aquitaine)



Automatic tree counting
(EarthLab Aquitaine)

More Information

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EARTHLAB

Telespazio
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Appendix:
LIST OF SATELLITES REFERENCED IN THIS REPORT
LIST OF ORGANIZATIONS REFERENCED IN THIS REPORT

List of satellites referenced in this report

Active Microwave

Satellite Names	*Operating Agencies/ Companies*	*Features*
ALOS	JAXA	Phased Array type L-band Synthetic Aperture Radar (PALSAR), Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM)
ALOS-2	JAXA	Phased Array type L-band Synthetic Aperture Radar type 2 (PALSAR-2), Compact InfraRed Camera (CIRC)
COSMO-SkyMed	ASI/MiD	Synthetic Aperture Radar-2000 (SAR-2000)
ERS	ESA	Radar Altimeter (RA), Along Track Scanning Radiometer (ATSR), Global Ozone Monitoring Experiment (GOME), Microwave Radiometer (MWR), Synthetic Aperture Radar (SAR), Wind Scatterometer (WS)
HY-2A	NSOAS/CAST	Microwave Radiometer Imager (MWRI), Radar Altimeter (ALT), Ku-band Rotational Fan-beam Scatterometer (KU-RFSCAT)
ICESat	NASA	Geoscience Laser Altimeter System (GLAS)
Jason-2	NASA/CNES/EUMETSAT/NOAA	Solid-State Radar Altimeter (Poseidon-3), Advanced Microwave Radiometer (AMR)
Radarsat-1	CSA	C-band Synthetic Aperture Radar (SAR)
Radarsat-2	MDA	C-band Synthetic Aperture Radar (SAR)
Saral	CNES/ISRO	Altimeter in Ka-band (AltiKa)
Sentinel-1	ESA/EC	C-band Synthetic Aperture Radar (SAR)
Sentinel-3	EUMETSAT/ESA	Ocean and Land Colour Instrument (OLCI), Sea and Land Surface Temperature Radiometer (SLSTR), Synthetic Aperture Radar Altimeter (SRAL), Microwave Radiometer (MWR), Global Navigation Satellite System (GNSS)
Sentinel-4	ESA	Ultra-violet, Visible and Near-infrared sounder (UVN)
SMAP	NASA/CSA	Soil Moisture Active Passive (SMAP)
SRTM	NASA	C-band transmit/receive, X-band transmit/receive
TanDEM-X	DLR	TanDEM-X SAR instrument (TDX-SAR)
TerraSAR X	DLR	TerraSAR-X SAR instrument (TSX-SAR)

Optical

Satellite Names	*Operating Agencies/ Companies*	*Features*
EnMAP	DLR	Hyperspectral Imager (HIS)
EO-1	NASA	Advanced Land Imager (ALI), Hyperion Hyperspectral Imager, Atmospheric Corrector (LAC)
GeoEye-1	GeoEye	GeoEye Imaging System (GIS)
GOES	NOAA	GOES Imager, GOES Sounder

HyspIRI	NASA	Visible to Short Wave Infrared (VSWIR), Thermal Infrared (TIR)
Landsat 5	USGS/NASA	Thematic Mapper (TM), Multispectral Scanner (MSS)
Landsat 7	USGS/NASA	Enhanced Thematic Mapper Plus (ETM+)
Landsat 8	USGS/NASA	Operational Land Imager (OLI), Thermal Infrared Sensor (TIRS)
Meteosat 6	EUMETSAT/ESA	Meteosat Visible Infra-Red Imager (MVIRI)
Meteosat 7	EUMETSAT/ESA	Meteosat Visible Infra-Red Imager (MVIRI)
Meteosat 10	EUMETSAT/ESA	Spinning Enhanced Visible and Infrared Imager (SEVIRI), Geostationary Earth Radiation Budget (GERB)
MSG	EUMETSAT/ESA	Meteosat Second Generation (MSG): Spinning Enhanced Visible and Infrared Imager (SEVIRI), Geostationary Earth Radiation Budget (GERB)
MTG	EUMETSAT/ESA	Meteosat Third Generation (MTG): Flexible Combined Imager (FCI), Lightning Imager (LI), Infrared Sounder (IRS), Ultra-Violet Near-infrared Sounder (UVS)
MTSAT-2	JMA	MTSAT Imager
Pleiades	CNES	High-Resolution Imager
RapidEye	DLR	RapidEye Earth Imaging System (REIS)
Sentinel-2	ESA/EC	Multispectral Imager (MSI)
SPOT-4	CNES	High-Resolution Visible and Infrared sensor (HRVIR), Vegetation Monitoring Instrument (VMI)
SPOT-5	CNES	High Resolution Geometric (HRG), High Resolution Stereoscopic (HRS), Vegetation-2 instrument (VTG-2)
SPOT-6/7	AIRBUS Defence & Space	New AstroSat Optical Modular Instrument (NAOMI)
Worldview-2	DigitalGlobe	WorldView-110 camera (WV110)

Passive Microwave

Satellite Names	*Operating Agencies/ Companies*	*Features*
Aqua	NASA	Advanced Microwave Scanning Radiometer-EOS (AMSR-E), Moderate Resolution Imaging Spectroradiometer (MODIS) , Advanced Microwave Sounding Unit (AMSU-A), Atmospheric Infrared Sounder (AIRS), Humidity Sounder for Brazil (HSB), Clouds and the Earth's Radiant Energy System (CERES)
Aura	NASA	High-Resolution Dynamics Limb Sounder(HIRDLS), Microwave Limb Sounder(MLS), Ozone Monitoring Instrument(OMI), Tropospheric Emission Spectrometer(TES)
DMSP	NOAA/USAF	Operational Linescan Systerm (OLS), Special Sensor Microwave - Imager/Sounder (SSMIS), SESS / Special Sensor Ultraviolet Spectrographic IMAGER (SESS/SSUSI), SESS / Special Sensor Ultraviolet Limb Imager (SESS/SSULI), SESS / Special Sensor Ionospheric Plasma Drift/Scintillation Monitor - 2 (SESS/SSI/ES-2), SESS / Special Sensor Magnetometer (SESS/SSM), SESS / Special Sensor Precipitating Electron and Ion Spectrometer (SESS/SSJ5)

ENVISAT	ESA	Advanced Synthetic Aperture Radar (ASAR), Medium Resolution Imaging Spectrometer (MERIS), Advanced Along Track Scanning Radiometer (AATSR), Radar Altimeter 2 (RA-2), Microwave Radiometer (MWR), GOMOS, Michelson Interferometer for Passive Atmospheric Sounding (MIPAS), Scanning Imaging Absorption Spectrometer for Atomspheric Chartography (SCIAMACHY), Doppler Orbitography and Radio-positioning Integrated by Satellite instrument (DORIS), Laser Retro-Reflector (LRR)
FY-3	NSMC-CMA/NRSCC	Infrared Atmospheric Sounder (IRAS), Microwave Temperature Sounder (MWTS), Total Ozone Unit (TOU), Solar Backscatter Ultraviolet Sounder (SBUS), Visible and Infrared Radiometer (VIRR), Medium Resolution Spectral Imager (MERSI), Microwave Radiation Imager (MWRI)
GCOM-W	JAXA	Advanced Microwave Scanning Radiometer-2 (AMSR-2)
GPM	NASA/JAXA	Dual-frequency Precipitation Radar (DPR), GPM Microwave Imager (GMI)
MetOp	EUMETSAT/ESA	Advanced Microwave Sounding Unit - A (AMSU-A), Advanced Scatterometer (ASCAT), Advanced Very High Resolution Radiometer / 3 (AVHRR/3), Global Ozone Monitoring Experiment - 2 (GOME-2), GNSS Receiver for Atmospheric Sounding (GRAS), High-resolution Infra Red Sounder / 4 (HIRS/4), Infrared Atmospheric Sounding Interferometer (IASI), Microwave Humidity Sounding (MHS)
NOAA	NOAA	Advanced Microwave Sounding Unit - A (AMSU-A), Advanced Very High Resolution Radiometer / 3 (AVHRR/3), High-resolution Infra Red Sounder / 4 (HIRS/4), Microwave Humidity Sounding (MHS), Solar Backscatter Ultraviolet / 2 (SBUV/2)
Suomi NPP	NASA/NOAA	Advanced Technology Microwave Sounder (ATMS), Visible/Infrared Imager and Radiometer Suite (VIIRS), Cross-Track Infrared Sounder (CrIS), Ozone Mapping and Profiler Suite (OMPS), Clouds and the Earth's Radiant Energy System (CERES)
Terra	NASA	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Clouds and the Earth's Radiant Energy System (CERES), Multi-angle Imaging SpectroRadiometer (MISR), Moderate-Resolution Imaging Spectroradiometer (MODIS), Measurement of Pollution in the Troposphere (MOPITT)
TRMM	NASA/JAXA	Precipitation Radar (PR), Visible Infrared Scanner (VIRS), TRMM Microwave Imager (TMI), Clouds and the Earth's Radiant Energy System (CERES), Lightning Imaging Sensor (LIS)

Other

Satellite Names	*Operating Agencies/ Companies*	*Features*
GOSAT	JAXA	Thermal And Near Infrared Sensor for carbon Observation – Fourier Transform Spectrometer (TANSO-FTS), Thermal And Near Infrared Sensor for carbon Observation – Cloud and Aerosol Imager (TANSO-CAI)
GRACE	NASA/DLR	K-band Ranging System, Satellite Global Positioning System (GPS)

List of organizations referenced in this report

ADB	Asian Development Bank
AGS	Alberta Geological Survey
AMIS	Agricultural Market Information System
ASI	Italian Space Agenc
AST	ASTER Science Team
AT	Alberta Transportation
BOEM	Bureau of Safety and Environmental Enforcement
CCRS	Canada Center for Remote Sensing
CDC	Centers for Disease Control and Prevention
CEOS	international Committee on Earth Observation Satellite
CFI	Carbon Farming Initiative
CMA	China Meterological Administration
CMEMS	Copernicus Marine Environment Monitoring Service
CNES	Centre National d'Etudes Spatiales
CNRS	National Centre for Scientific Research
CSA	Canadian Space Agency
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CVGHM	Center for Volcanology and Geological Hazard Mitigation
DLR	German Aerospace Center
DoD	Department of the Defense
DoE	Department of the Environment
DPC	Italian Department of Civil Protection
DPF	Federal Police Department
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSRS	Dundee Satellite Receiving Station
ECMWF	European Centre for Medium-Range Weather Forecasts
EMSA	European Maritime Safety Agency
EPA	United States Environmental Protection Agency
EPPO	Earthquake Planning and Protection Organisation
ERF	Australian Government's Emissions Reduction Fund
ESA	European Space Agency
ESPI	European Space Policy Institute
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAO	Food and Agriculture Organization
GA	Geoscience Australia
GEO	Group on Earth Observations

GEOGLAM	GEO Global Agricultural Monitoring initiative
GFZ	German Research Centre for Geoscience
GreDaSS	Greek Database of Seismogenic Sources
IATA	International Air Transport Association
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources
IGME	Institute of Geology and Mineral Exploration
IGN FI	French National Institute of Geographic and Forest Information
INGV	National Institute of Geophysics and Volcanology
INPE	Brazilian National Institute for Space Research
IPCC	Intergovernmental Panel on Climate Change
IPGP	Institute of Earth Physics of Paris
IRD	French Research Institute for the Development
IREA-CNR	Institute for Electromagnetic Sensing of the Environment-National Research Council
ISRO	Indian Space Research Organisation
JAXA	Japan Aerospace Exploration Agency
JCG	Japan Coast Guard
JICA	Japan International Cooperation Agency
JOGMEC	Japan Oil, Gas and Metals National Corporation
JPL	NASA Jet Propulsion Laboratory
JSS	Japan Space Systems
LULUCF	Australia's Land Use, Land Use Change and Forestry
MDA	MacDonald Dettwiler and Associates
MEDDE	French Ministry of Ecology
METI	Ministry of Economy, Trade and Industry
MGB	Mines and Geoscience Bureau
MOE	Ministry of the Environment
NASA	National Aeronautics and Space Administration
NDCC	National Disaster Coordinating Council
NDMC	National Drought Mitigation Center
NEODAAS	NERC Earth Observation Data Acquisition and Analysis Service
NIES	National Institute for Environmental Studies
NOA	National Observatory of Athens
NOAA	National Oceanic and Atmospheric Administration
NRCAN	Natural Resources Canada
NSMC	National Satellite Meteorological Center
OIE	World Organization for Animal Health
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PHAC	Public Health Agency of Canada
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PML	Plymouth Marine Laboratory

PPC	Pan Pacific Copper Co., Ltd.
PSC	Public Safety Canada
RCMRD	Regional Center for Mapping of Resources for Development
RESIF	French seismologic and geodetic network
RESTEC	Remote Sensing Technology Center of Japan
RGA	Republic Geodetic Authority
RIPS	Rapid Information Products and Services
SA	Sentinel Asia
SANSA	South African National Space Agency
TERN	Terrestrial Ecosystem Research Network
TRE	Tele-Rilevamento Europa
UCLA	University of California, Los Angeles
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
UNOSAT	Operational Satellite Applications Programme
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WMO	World Meteorological Organization
WHO	World Health Organization

"CEOS"
The Committee on Earth Observation Satellites, coordinates civil spaceborne observations of the Earth. Participating agencies strive to address critical scientific questions and to harmonise satellite mission planning to address gaps and overlaps.

http://ceos.org/

"JAXA"
The Japan Aerospace Exploration Agency,
supports the Japanese government's overall aerospace development and utilization as a core performance agency.
JAXA conduct integrated operations
from basic research and development, to utilization.

http://global.jaxa.jp/

Applications of Satellite Earth Observations:
Serving Society, Science, & Industry

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