

Applications of  
**SATELLITE EARTH OBSERVATIONS:**  
Serving Society, Science, & Industry

.....  
*2015 edition*

CEOS: Committee on Earth Observation Satellites  
JAXA: 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 more than 100 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 recognize 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*



## Chapter 1

# About CEOS

A Brief History of CEOS

Evolution in Capabilities

Earth Observation Data Policy

Coordination Framework

Future Possibilities via New Technologies and Services



## Chapter 1 A Brief History of CEOS

## About CEOS 01

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 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 1992, British National Space Centre (BNSC) produced a CEOS Dossier for distribution at the Rio Earth Summit (United Nations Conference on Environment Development) with detailed mission and instrument tables. This publication served as a prototype for the current online CEOS Missions, Instruments, and Measurements Database. CEOS created a permanent Secretariat at its 1992 Plenary that carried on the work of CEOS in monthly telecons under the leadership of the current CEOS Chair Agency.

The 1996 CEOS Plenary approved the creation of a Strategic Implementation Team (SIT) that would meet at the 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). CEOS Associate Members (many of them UN or Science and Technology organizations) participated to help structure IGOS, which was formally established in June, 1998 with 13 founding partners including CEOS. CEOS 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 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 was a “Participating Organization,” in the convening of the 2003 Earth Observation Summit in Washington, DC that established an ad hoc intergovernmental Group on Earth Observation (GEO) and in the 2005 formal creation of GEO in Brussels with environment by Ministers of a Global Earth Observation System of Systems (GEOSS) 10 years 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; and to provide critical datasets for key GEO-related initiatives such as Global Forest Carbon, Global Agricultural Monitoring, and GEO Supersites.

CEOS has likewise connected with the Global Climate Observing System (GCOS) to address satellite-related requirements regarding GCOS-identified Essential Climate Variables (ECVs) in connection with GCOS Implementation Plans and plays a role in the “systematic research and observations” area of focus of the UNFCCC. CEOS received a direct charge from the UNFCCC’s Subsidiary Body for Scientific and Technological Advice (SBSTA) in 2009.

At its 2010 Plenary, CEOS approved the creation of a Working Group on Climate that later became a Joint Working Group also reporting to CGMS. In 2011, the WGEdu was reconstituted as the Working Group on Capacity Building and Data Democracy, seeking 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 the operation of more than 100 orbiting satellites.



CEOS SIT 2015 (CNES)

## About CEOS 02

# Evolution in Capabilities

## Chapter 1

### Number of Countries and Missions

In 1995, only a handful of countries had the capability to develop and operate an Earth Observation (EO) satellite, amounting to around 28 CEOS Agency missions or series of missions active at that time.

Today, the CEOS Database shows that dozens of countries now have active civil EO missions. More than 100 individual missions of CEOS Agencies are estimated to be active in mid-2015. Greater technical capacity worldwide, improved international co-operation, and reduced size and costs of EO satellites have all contributed to the number and diversity of countries with active EO space infrastructure.

### Diversity

The vast majority of the 36 case studies in the 1995 report "CEOS Special Report on Successful Applications of EO Satellite Data" used multi-spectral optical imaging sensors or synthetic aperture radar with only a few variations. Our 2015 examples utilise almost all of the 16 categories of instruments specified in the Earth Observation Handbook, such as atmospheric chemistry instruments, cloud profile and rain radars, and scatterometers. This significant diversity is indicative of the extremely wide range of Satellite Earth observations technologies and capabilities that are now in service of society in 2015.

### Resolution and Performance

EO payloads have evolved significantly over the last two decades. In 1995, the SPOT-3 spacecraft of Le Centre National d'études Spatiales(CNES) was considered to be the gold standard for civil imaging of the land surface, with its commercially available 10-m panchromatic and 20-m multispectral imagery. These days, the Sentinel-2 satellite of the European Space Agency/the European Commission (ESA/EC) provides 10-m multispectral data on a free and open basis. Commercial systems provide extremely high-resolution data – 0.3-m panchromatic or 1.24-m multispectral – as well as rapid global coverage using multiple satellites. Sensor technology is such that payloads being flown in geostationary orbit (35,786km above the Earth's surface) are approaching the resolutions previously only possible in low-Earth orbit (typically hundreds of kilometres up). 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 providing multispectral imagery of the full disk of the Earth from its view every 10 minutes.

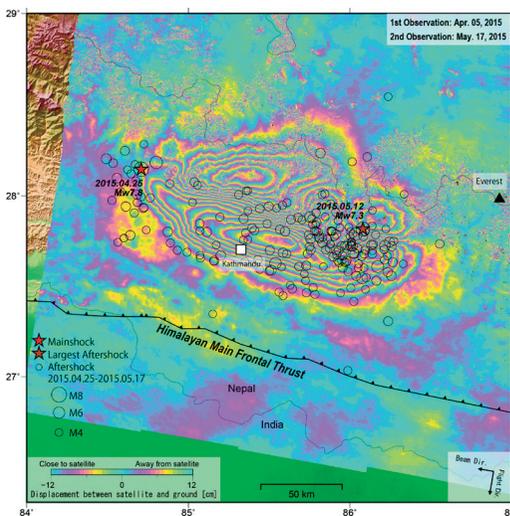
### Accessibility and Data Handling

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 is 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. Small business, NGOs, developing country governments, even individual citizens have the means to access, download, process and extract vital information from EO datasets.

### GPS Integrated Applications

Widespread availability of GPS signals in vehicle navigation units and smartphones has opened up a new world of geospatial applications that 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. 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



## About CEOS 03

# Earth Observation Data Policy

## Chapter 1

The issue of managing data derived from EO satellites, in terms of access, pricing, data rights and other aspects, is commonly referred to as EO data policy. The topic covers a range of issues including: international and national laws and regulations; intellectual property rights; security; socioeconomic benefits of free and open data; public-private partnership; and pricing policy. Data policy is a combination of various concerns and interests of the operators and users.

### National and Regional Policies

The major civil EO programmes globally follow the rules of the UN Remote Sensing Principles, while fostering 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 a 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.

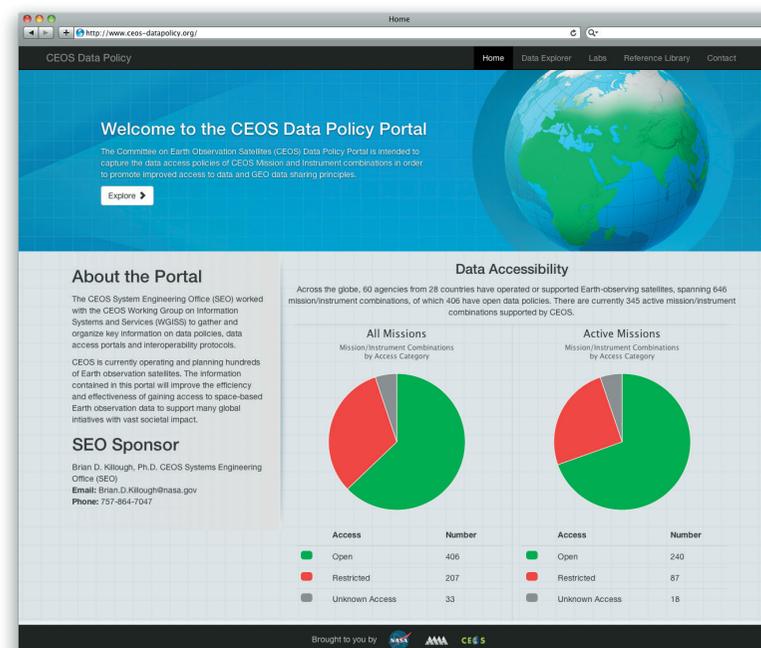
### Open Data

In the 1990s, CEOS had established two sets of Data Exchange Principles that called for facilitating access to Earth observation data for environmental use and global change research. A notable recent event in the international coordination of EO 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 Future

Data policy ideally should optimise the balances of different interests as described above, taking into account the socioeconomic needs, development of the private market, security concerns, as well as the technological changes. Public global data infrastructures such as that of GEOSS could be utilized 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 EO 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 EO.



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

About CEOS 04

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 these data, but no single 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, more than 100 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.

Satellite data requirements are identified through relationships established with CEOS by key user groups. These stakeholders consist of national governments, the intergovernmental GEO, and organizations participating in treaties and global programs affiliated with the UN. These treaties, international organizations and international programs include the UNFCCC, the UN Office for Disaster Risk Reduction (UNISDR), the UN Convention to Combat Desertification (UNCCD), and the Convention on Biological Diversity (CBD).

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

CEOS is committed to maintaining and strengthening its engagement in GEO as it moves into its second decade and looks to the GEO 2016–2025 Strategic Plan 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 will continue to support major GEO initiatives related to agriculture and forestry where it has built close relations with the Food and Agriculture Organization of the United Nations (FAO).



Space data to monitor our climate

The challenge of global climate change brings together nations and international coordinating bodies. In 2005, the UNFCCC requested GCOS 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 CGMS - coordinates the work of space agencies on climate to respond to space-related needs of the GCOS Implementation Plan communicated via the ECVs. CEOS looks forward to an even greater 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.

About CEOS 05

New technologies and trends are presenting new opportunities and possibilities for EO satellite data to support human society:

Dual-use

Dual-use indicates the potential of satellite data to be applied to both civilian and defense applications. As sensor resolutions become increasingly fine and the regulations regarding the release of the data for non-defense purposes are relaxed, we are seeing more countries with satellites that might be regarded as dual-use. In the US, the two commercial data providers – DigitalGlobe Inc. and GeoEye Inc. – were merged in 2013 and continue to be supported by their anchor tenancy agreements with the US Department of Defense. In Europe, we have seen military and civil organisations collaborate and combine budgets to achieve national dual-use systems, such as the Italian COSMO-SkyMed radar satellite constellation and the French Pléiades high-resolution optical satellite constellation. The revenue stability provided by large defense customers supports the development of capabilities for civil use that might otherwise be unviable.

Big Data

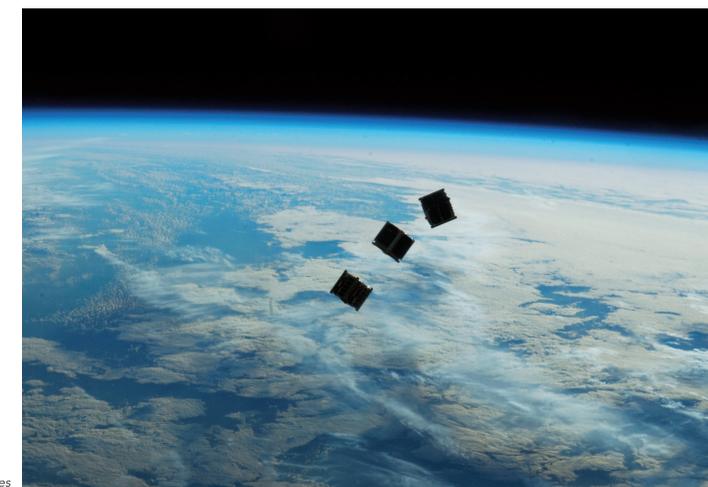
Wikipedia defines Big Data as “an all-encompassing term for any collection of data sets so large and complex that it becomes difficult to process using traditional data processing applications.” Space agencies are convinced as to the potential of satellite EO as an information source in support of many sectors of government and industry. The agencies would concede, however, that they have yet to fully address the major obstacles faced by potential users of the data. Significant, specialised and expensive technologies and skills are needed before satellite data can be used, but most users do not have the financial or technical capacity required to undertake the data handling, calibration and processing involved in extracting the information they require from the data. CEOS member agencies specialise in these skills. It makes sense for space agencies to bring their data to the maturity level needed to make satellite data ‘analysis ready’ and to properly harness the multiple technologies and initiatives behind ‘Big Data’ to allow real-time analysis and data mining to produce better science.

‘Analysis Ready Data’ are data that have been pre-processed and organised so that 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.

The CEOS Chair for 2016 has proposed to study the issues around next-generation EO data system architectures, and the opportunities offered by approaches such as the CEOS Data Cube and commercial cloud storage and processing solutions.

Small satellites

Constellations of multiple small satellites, developed more quickly and more cheaply than the conventional spacecraft, offer the promise of high frequency repeat observations. Specialized companies focused on such constellations – such as Skybox Imaging and Planet Labs – are emerging to take advantage of this technology.



Small satellites

## Chapter 2

# APPLICATIONS

### Analysis of Data Applications Articles

[Sea-Ice Monitoring Using Radar](#)

[Monitoring Canada's Geohazard Risks](#)

[Early Warning of Infectious Diseases via Global Risk Maps](#)

[Public Health and Earth Observation: Risk Assessment of Infectious Diseases in Canada](#)

[Planning Pipeline Routes](#)

[Enhancing National Carbon Accounting and Reporting Using Remote Sensing Data](#)

[Improving Forecasts of Agricultural Crop Yields](#)

[Earth Observation for Food Security and Sustainable Agriculture](#)

[Enhancing Drought Monitoring in North America](#)

[Prevention of Illegal Logging in the Amazon Rainforest](#)

[Protecting the Aquaculture Industry from Harmful Algal Blooms](#)



Transport



Disaster



Health



Energy



Climate Change



Agriculture



Forest



Environment

## Analysis of Data Applications Articles

### Chapter 2

## APPLICATIONS

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 multi-satellite 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<sub>2</sub>. Thanks to international cooperation, GOSAT has achieved unprecedented measurement accuracy of 0.5% in measurements of CO<sub>2</sub> 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.



Source: Ice Information Center, Japan

## Chapter 2: Transport

# Sea-Ice Monitoring Using Radar

Variable sea-ice conditions require continuous and frequent monitoring to ensure safe and economic routing of ships in ice-infested waters. Radar-imaging EO satellites have a demonstrated capability to provide an effective and efficient solution to continuously monitor very large areas at sea, day or night and in all weather conditions.



### Value Chain



## Problem

Pack ice and icebergs demonstrate a dynamic nature, due to changing oceanographic and meteorological phenomena. To increase the safety and efficiency of shipping and to protect the oceans, systematic, frequent and reliable information about sea ice cover is of paramount importance. While in-situ and aircraft-based measurements could be used to monitor sea ice, they are not practical or economic over very large areas. Additionally in winter, when ice is most common, poor weather and light conditions will hamper these observations.

## Satellite Earth Observation Data Application

A number of authorities around the world are now using satellite-based Synthetic Aperture Radar (SAR) instruments to monitor sea ice (in addition to shipping traffic, sea state, and environmental pollution). Satellite-based SAR has the specific advantage of being able to provide data at any time of day, regardless of cloud cover, in a consistent, regular manner over very large areas. Four case studies are presented here to demonstrate the application of satellite-based SAR to sea ice monitoring.

**<Ice Information Center of Japan>** In 1970, there was a large maritime accident caused by drift ice in Hitokappu Bay, Etorofu Island. This accident triggered the establishment of the Ice Information Center of Japan, operated by the Japan Coast Guard (JCG). The Ice Information Center produces and distributes sea ice condition charts during the winter months. The charts indicate the distribution of sea ice around Hokkaido and are effectively utilized for safe navigation of vessels, including fishing boats, merchant vessels and tourist ships. The Ice Information Center cooperates with Japan Aerospace Exploration Agency (JAXA) to produce accurate sea ice condition charts using ALOS/ALOS-2 SAR data, regardless of daily weather conditions. ALOS-2 greatly improved coverage near the center of the Sea of Okhotsk due to its variable incidence angle.

**<Sentinel-1 contribution to Copernicus sea ice monitoring>** Europe's Copernicus programme provides key observation data and information services to improve environmental management, help mitigate the effects of climate change and to safeguard lives. One of the Copernicus Services, the Copernicus Marine Environment Monitoring Service (CMEMS), provides – among other products – operational forecasts for sea ice to support ship routing and search & rescue activities in the Northern seas. In these regions, the wide swath of the Sentinel-1A satellite allows a very frequent revisit (currently, from daily to once every 2–3 days depending on the latitudes), with the objective of ensuring daily coverage once the twin satellite Sentinel-1B is in orbit and the full operations capacity is deployed. The satellite products are made available, within 3 hours from acquisition, to the CMEMS operators who produce daily ice charts, iceberg density maps and maps of sea ice drift and deformation. One of the production chains, run by the Danish Meteorological Institute, generates ice maps for the vast waters of Greenland. These maps are used by local public authorities, shipping companies, fishermen and hunters for safe operations in the harsh ocean environment. Overall, more than 150,000 of these ice charts and over 200,000 related satellite images are downloaded every year, and the numbers are rising following the availability of Sentinel-1A data.

**<TerraSAR-X Maritime Surveillance Products>** DLR has developed a near-real-time processing chain for TerraSAR-X ship detection, wind field and sea state derivation, and oil spill and iceberg detection within the TerraSAR-X Payload Ground segment. Radar images and the value-added products can be delivered to ship control rooms and coordination centers within near-real time, supporting the safe passage of vessels. Wind field and sea state products are delivered to weather centres and used for validation of high-resolution coastal models. The products are generated independently of weather conditions and in near-real time (NRT) and are delivered to Airbus Defence and Space (Airbus DS) as the commercial service provider, as well as to users involved in R&D projects.

### <X-band SAR Tactical Iceberg Information>

Airbus DS and the German Aerospace Center (DLR) have worked to establish a NRT processing chain for the detection of vessels and icebergs using TerraSAR-X imagery. As a baseline, wide-area SAR modes from C-Band missions are used to gather information for strategic ice information. The synergistic use of large-scale and high-resolution EO sensors improves situational awareness without limiting the observation capacities of a single system. In areas where a satellite data reception facility is available, imagery and automated detection products are available within 30 minutes of acquisition. A subsequent operator-based quality assurance step ensures reliable products and allows for discrimination between icebergs and vessels by correlation with Automatic Identification System (AIS) information in combination with a visual analysis. Finally, the resulting tactical iceberg/vessel detection product is either fused into a more general situation report or directly used by the end-user.



### More Information

- Ice Information Center of Japan  
Masuo Takahashi, JAXA Email: takahashi.masuo@jaxa.jp
- Sentinel-1 and Copernicus Copernicus Sentinel satellites:  
<https://sentinels.copernicus.eu>  
Copernicus Marine Environment Monitoring Service:  
<http://marine.copernicus.eu>
- TerraSAR-X Maritime Surveillance Products  
Susanne Lehner, German Aerospace Center  
Email: Susanne.Lehner@dlr.de
- X-band SAR Tactical Iceberg Information  
[www.geo-airbusds.com](http://www.geo-airbusds.com)  
Oliver Lang, Airbus Defence and Space  
Email: oliver.ol.lang@airbus.com



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

Chapter 2: Disaster

# Monitoring Canada's Geohazard Risks

This project demonstrates the application of InSAR monitoring along strategic energy and transportation corridors in Canada. 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.



## Value Chain



## Problem

Geohazards present significant risk to Canadian's quality of life and economy. Two examples from the study sites presented below are the 1903 Frank Slide, Canada's deadliest landslide, which killed over 80 people when it buried a portion of the mining town of Frank, and the Little Smoky River bridge, which has been subject to ongoing valley slope instabilities that have impacted the highway and west bridge abutment, resulting in ongoing costly maintenance.

## Satellite Earth Observation Data Application

The Canadian Space Agency (CSA) has worked with the Canada Center for Remote Sensing (CCRS) on a project involving the application of Interferometric SAR (InSAR) technology to map and characterise ground hazards in three Western Canadian regions. InSAR is a geodetic technique that uses satellite radar to identify movements of the Earth's surface and thereby detect, measure and monitor ground subsidence and crustal changes associated with geophysical processes such as tectonic activity and volcanic eruptions. 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 and (2) to produce an InSAR image archive of selected active geohazard areas in Canada.

1) The Crowsnest Pass in Southwestern Alberta is an important trade corridor. Abandoned underground coalmines underlay modern-day infrastructure and urban development. InSAR technology was utilized to map subsidence of the ground overlying the abandoned coalmine workings. Using 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.

2) The Little Smoky River bridge and approach roads were completed in 1957. Since then, there has been ongoing valley slope instability that has impacted the highway and west bridge abutment, resulting in costly maintenance issues. 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. Corner reflectors were installed to provide an amplified signal back to RADARSAT-1. By November 2008, a set of 28 readings had been obtained for each reflector and the results were processed by CCRS and passed to AT to aid future decision-making on managing landslide risks along the highway corridor.

3) The town of Peace River is located along the floodplain and valley walls of the Peace River in northwestern Alberta. In 2006, a study was initiated to characterise 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. 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. 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.

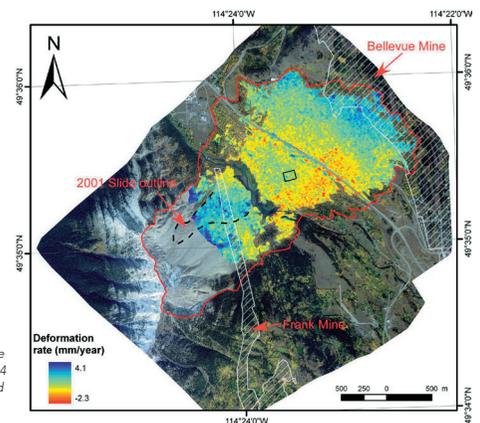


Figure 1. Crowsnest Pass. In conjunction with studies being undertaken by the Alberta Geological Survey (AGS) on unstable slopes on Turtle Mountain, site of the Frank Slide, InSAR technology was utilized to map subsidence of the ground overlying the abandoned coalmine workings. By utilizing Radarsat-1 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. Source: NRCAN.

## User's VOICE

Satellite EO monitoring proved valuable in supplementing our understanding of mountains rock slope failure, without putting people and equipment at risk.

Corey Froese, Alberta Energy Regulator



## More Information

CSA: [www.asc-csa.gc.ca/fra/observation/applications.asp](http://www.asc-csa.gc.ca/fra/observation/applications.asp)  
 NRCAN: [www.nrcan.gc.ca](http://www.nrcan.gc.ca) AER: [www.aer.ca](http://www.aer.ca)

Guy Aubé, Canadian Space Agency  
 Email: [guy.aube@asc-csa.gc.ca](mailto:guy.aube@asc-csa.gc.ca)





Source: WHO/S.Hawkey

Chapter 2: Health

# Early Warning of Infectious Diseases via Global Risk Maps

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



## Value Chain



### Benefit

Early Warning of Infectious Disease Outbreaks, Enhanced Preparedness

## Problem

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

## Satellite Earth Observation Data Application

Earth Observation (EO) satellites collect data on surface temperature, precipitation, vegetation, and other environmental parameters that are associated with hosts and vectors of diseases. A National Aeronautics and Space Administration (NASA) team analyzed combinations of these data products that correlated with historical records of disease outbreaks. Applying data on environmental conditions derived from TRMM, Aqua and other satellites, risk maps can be generated to show the probability of environmental patterns related to outbreaks at a given time and place.

Available every two weeks since 2012, NASA's risk maps offer the World Health Organization (WHO) and nations' health officials warning of outbreaks of infectious diseases associated with viral hemorrhagic fevers up to nine weeks in advance. Such lead times facilitate timely disease control and prevention activities. 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. The WHO can coordinate with national institutions to issue early warnings and provide international travel guidance.

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 early warnings enabled by the risk maps also aid livestock management. Officials of veterinary services can allocate resources to Food and Agriculture Organization of the United Nations (FAO) recommended mitigation strategies such as the immunization of livestock and the spreading of larvicide at vector breeding grounds.

The project team expanded its epidemiological model to other regions and diseases in 2012. The team used field data to inform assessments of Hantavirus in Ukraine as well as Crimean-Congo hemorrhagic fever in 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 has also partnered with United States Department of Defense (US DoD) health officials to provide advanced awareness of developing infectious disease threats, involving DoD's Global Emerging Infections Surveillance and Response System.

The maps present new capabilities for early warning 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 started using the risk maps and related predictions to prepare for and mitigate the effects of outbreaks.

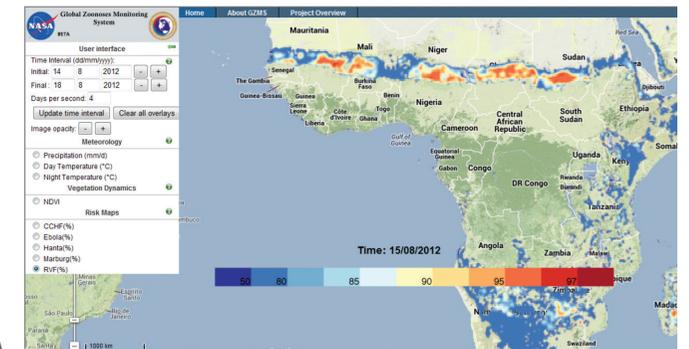


Figure 1. An example of a risk map for Rift Valley fever in Africa from mid-August 2012. Warmer colors indicate higher probability of risk, based on environmental factors related to disease emergence. ©NASA

## User's VOICE

WHO supports development of the 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

## More Information

The risk maps are available at: <http://rs4gzm.org/gzm>

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Chapter 2: Health

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

Evidence-based knowledge is required for the management of key public health issues. However, obtaining the necessary data on environmental health determinants can constitute a major challenge due to the potentially large territory to cover. Data from population or environmental determinants may be derived from EO images, particularly in regard to the impact of natural or man-made ecosystem changes. Operationally, EO images have demonstrated their usefulness in the prevention and control of persistent and new diseases.



## Value Chain



## Problem

Public health is facing many challenges related to the prevention and control of various emerging diseases and chronic conditions. Many of these health conditions arise from a sustained interaction between evolving human populations (changes in demography, migration and travels) and the environment. Zoonotic diseases are infections that can be acquired through contact between animals and humans. 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, are serious public health issues.

## Satellite Earth Observation Data Application

The prevention and control of various emerging diseases and chronic conditions requires solid evidence-based knowledge. EO can provide a contribution by deriving data from population and environmental determinants of health over very large areas. EO provides important geospatial information that can fuel research, improve monitoring and risk assessment for public health, and guide intervention measures and disease control in a cost-effective, rapid and consistent manner.

The field of tele-epidemiology is a new discipline that combines epidemiology and space technology. It involves the monitoring and assessment of the distribution of animal and human illnesses strongly linked to climatic and environmental variations.

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 whose population and movements are often influenced by environmental characteristics. The spread of disease can be modelled and mapped using knowledge of the associated risks from vectorecology. 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.

Tele-epidemiology has recently been applied to the study of bacteria-contaminated lakes in Canada. Public Health Agency of Canada (PHAC) completed a project through CSA's 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. Data from various EO satellites, such as RADARSAT-2, Envisat/MERIS, Landsat-5, MODIS, AVHRR, SPOT-5, GeoEye-1 and Worldview-2, were used to better characterise 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 faecal contamination levels and possible foodborne pathogens.



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

## User's VOICE

Tele-epidemiology provides information on the emergence and transmission of infectious diseases in the vast Canadian territory that is key to decision-making on effective public health responses.

Matthew W. Gilmour, Public Health Agency of Canada

## More Information

PHAC: [www.phac-aspc.gc.ca/index-eng.php](http://www.phac-aspc.gc.ca/index-eng.php)  
CSA: [www.asc-csa.gc.ca/fra/observation/applications.asp](http://www.asc-csa.gc.ca/fra/observation/applications.asp)

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Chapter 2: Energy

# Planning Pipeline Routes

Datasets derived from SPOT and Pléiades imagery were an effective alternative to costly ground and aerial surveys for the assessment of the best routing options for the South Caspian Pipeline through Azerbaijan and Georgia.



## Value Chain



## Problem

Surveys to assess the best routing of a cross-border pipeline settlement can be time-consuming and costly. Ground surveys require a large time and financial investment and the longer the pipeline, the longer the survey. Airborne imagery campaigns also require administrative clearance from each country crossed by the infrastructure route. Satellite imagery is a perfect solution for this situation, saving the time and effort required to organise a ground or airborne campaign in remote, cross-border locations.

## Satellite Earth Observation Data Application

ILF Consulting Engineers provides consulting services to help customers 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.

The SPOT satellite series has operated since 1986, providing high-resolution (20m down to 1.5m), wide-coverage optical imagery – more than 30 million images in total. In addition, the Pléiades constellation consists of two twin satellites in a shared orbit, phased 180° apart. Pléiades offers 50cm resolution optical data products, with a capacity to access daily any point on Earth - an ideal configuration for rapid data acquisition. Airbus Defence and Space's active constellations and substantial archive capacity provided a variety of datasets covering a total area of 2,189km<sup>2</sup> along the pipeline corridor, complying with the customer's requirement of data being both immediately available and resulting in a final location accuracy of 1m RMS.

SPOTMaps and Elevation30 products were delivered promptly, as they are off-the-shelf, ready-to-use datasets derived from SPOT satellite imagery. SPOTMaps are country-wide mosaics, featuring 1.5m or 2.5m resolution in natural color and are available over more than 110 countries to date. Elevation30 is a 3D medium-resolution model, available for more than 80 million km<sup>2</sup> of the Earth's surface. These two datasets supported a rapid preparatory study of the pipeline corridor, to analyse and correct early routing estimations.

In addition, 50cm ortho products and 1m Elevation1 Digital Terrain Models were provided for the detailed 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 at a scale of 1:5,000. All of these datasets were derived from VHR stereo imagery acquired by the Pléiades Constellation.



Figure 1. 3D vector map at 1/5,000 derived from Pléiades imagery ©Airbus DS

## User's VOICE

SPOT and Pléiades deliverables were compared with highly precise terrestrial *in-situ* measurements. For over 80% of the evaluated areas, all products were far better than the requested specifications, showing an RMS of 50–60cm in the elevation component, whereas the RMS of the remaining 20% was around 1m, always staying within the project's specifications.

Georg Schlägi, ILF Consulting

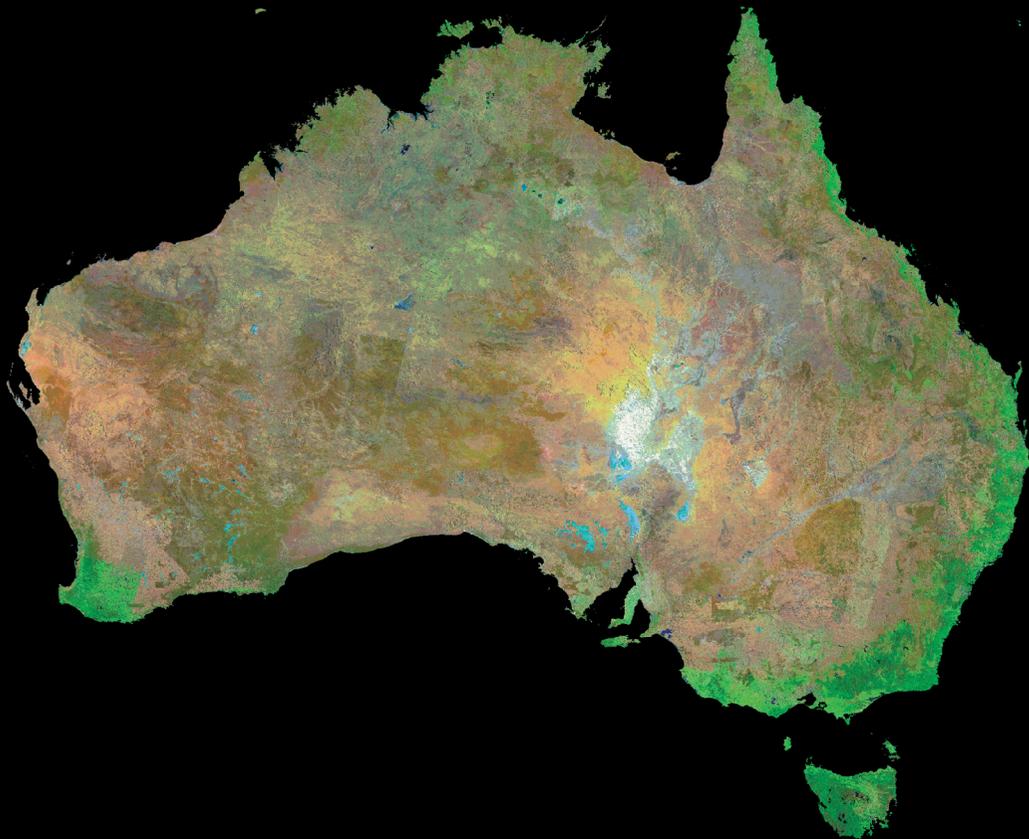


## More Information

<http://www.geo-airbusds.com>

Charlotte Gabriel-Robez  
Airbus Defence and Space  
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Landsat 8 surface reflectance image of Australia - 2014 (last quarter)  
©Commonwealth of Australia (Geoscience Australia), 2015

## Chapter 2: Climate Change

# Enhancing National Carbon Accounting and Reporting Using Remote Sensing Data

The Australian Department of the Environment developed a fully integrated Carbon Accounting Model (FullCAM) for estimating emissions and sequestration from forest and agricultural systems in Australia using land cover change data from the Landsat series of satellites.



### Value Chain



## Problem

Estimating greenhouse gas emissions and removals from the land sector is a critical component of National Inventory Reporting (NIR) under the United Nations Framework Convention on Climate Change (UNFCCC), and from 2015 most countries will be required to submit biennial update reports.

With Australia's landmass of 769 million hectares (including approximately 107 million hectares of forest), it is impossible to monitor annual land use changes cost-effectively without the use of satellite data.

## 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. An operational satellite data processing system has been developed to map land cover changes using time-series Landsat data from 1972 to the present day. 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 NIR submitted to the UNFCCC in May 2015.

A significant change in the latest NIR is the use of Landsat 8 surface reflectance data, which is quite different to the 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 ensure geometric and radiometric consistency between the previous and current data.

Following the steps to ensure geometric and radiometric consistency with previous data, the 2014 Landsat 8 surface reflectance data have been classified to identify areas of forest and non-forest, consistent with Australia's definition. A Conditional Probability Network (CPN) analysis is then performed to strengthen confidence in the 'forest' or 'non-forest' classification of a pixel by considering the previous and subsequent images in the time sequence.

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

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 (CFI). This information is also used more broadly by the scientific community, non-governmental organisations, state government agencies and the general public.



Figure 1. Landsat satellites detect land cover changes such as regrowth (blue), harvesting (red), forest fires (red), and potential land clearing (red).  
©Commonwealth of Australia (Department of the Environment), 2015

### User's VOICE

Space technology provides robust and credible data that is fit for purpose for monitoring and reporting net emissions from the land sector in a cost effective manner. It's a model that is widely applicable and appropriate for many countries to consider when making decisions about national MRV systems.

Rob Sturgiss, member of the IPCC Task Force on National Greenhouse Gas Inventories (TFN)

### More Information

<http://www.environment.gov.au>

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Chapter 2: Agriculture

# Improving Forecasts of Agricultural Crop Yields

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



## Value Chain



## Problem

Severe droughts hindered crop production in key agricultural regions 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 US, which produces more than a third of the world's corn and soybeans, experienced its worst drought in more than 50 years.

## Satellite Earth Observation Data Application

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.

Scientists have identified that some wavelengths of light are more sensitive and revealing of vegetation than others. 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. 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 US and parts of Eurasia. (Notably, the images also pointed to generally favourable 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 US and in the wheat-growing regions in Russia, Ukraine, and Kazakhstan. Indeed, the production in all these regions was below average. For the US, corn production in May–June was down about 100 million metric tons. The 2012 NDVI anomalies were akin to those from 2010 for Russia and Kazakhstan. Since grain production fell 30% in Russia during the 2010 drought and wheat prices rose, officials and markets could anticipate similar, significant disruptions.

This project is part of the GEO Global Agricultural Monitoring initiative, 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. Such information and lead times can help markets reduce price volatility. With GEOGLAM and international partners, the project developed systems 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.

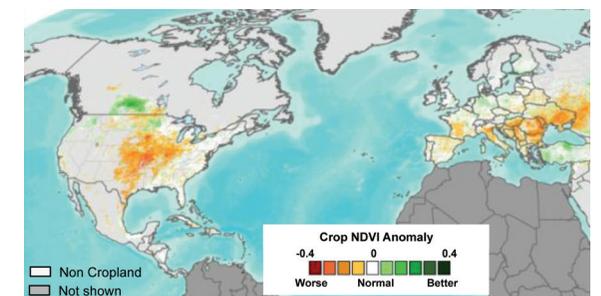


Figure 1. This figure shows Northern Hemisphere crop NDVI anomalies in mid-August 2012 compared with average conditions for the same date from 2000-2011. Browns indicate worse than normal conditions, and greens indicate better than normal conditions. Major cultivated areas in the United States, Russia, Ukraine, and Kazakhstan show significant anomalies and impacts to production. ©NASA

## User's VOICE

Improved production forecasts will reduce price volatility, which ultimately will create a more food-secure world—something for which we all should strive.

Barbara Ryan, Director, GEO Secretariat

## More Information

AMIS: <http://www.amis-outlook.org/home/en/>  
 GEOGLAM: <http://www.geoglam-crop-monitor.org/>

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Chapter 2: Agriculture

# Earth Observation for Food Security and Sustainable Agriculture

Satellite Earth Observation (EO) is the most feasible way to acquire site-specific crop properties over broad areas. In combination with agro-ecological crop growth and management models, EO data can increase the efficiency of farms.



## Value Chain



**Benefit**  
Optimised agricultural production through higher yield and lower environmental impact

## Problem

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 despite significant future demand. Today's crop management is field-based and of limited efficiency, e.g. as fertilizer is used in a "one size fits all" manner.

## Satellite Earth Observation Data Application

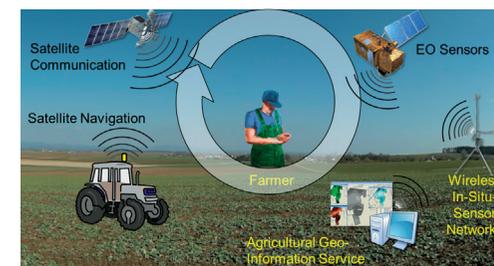


Figure 1. In TalkingFields, the farmer is the focus. He is assisted by all available technology, including several space components (mainly GNSS and EO).

TalkingFields is an integrated Precision Farming service produced by three German organisations: VISTA, PC Agrar and the Ludwig-Maximilians-University of Munich. It combines EO and navigation satellite input with information from ground sensors to help farmers decide how, when and where to allocate resources for maximum agricultural output and minimum environmental impact.

TalkingFields employs a multi-mission approach, using Sentinel-2, Landsat, RapidEye, Sentinel-1, TerraSAR-X (and in the future, EnMAP) to supply data on individual zone soil fertility and disease risk by analysing biomass distribution, while the software element calculates the economic returns of

different precision farming strategies using plant growth models. Farmers are also supplied with yield maps and reports, covering both past output and future estimates up to four weeks in advance. The navigation satellites provide accurate geo-location information to enable farmers to apply the advised measures exactly where needed.

EO based products allow farmers to more accurately apply seeds, fertilizer and pesticides, and to better plan harvest dates. Higher accuracy means lower production costs, as resources such as water and fertilizer are not wasted. Higher accuracy also means more yield per unit of fertilizer, which benefits not only farmers, but also other stakeholders such as drinking water protection agencies, resulting in both successful commercial business and environmental gains.

A multi-mission approach is advantageous as up-to-date services on biomass and yield estimation rely on the fast and reliable availability of EO data. Practical experience has found that four or five cloudfree optical satellite images per harvest year are necessary for best results.

Landsat-8 OLI data has been integrated in the processing chain and used for growth analyses in 2013 and 2014. Preparations are underway for the use of Sentinel-2 data, so that this important source can be used as soon as it becomes available. EnMAP, as a civil imaging spectrometer in space, will strongly enhance the TalkingFields services by providing the necessary spectral information to completely derive services without ground measurements.

TalkingFields successfully concluded its Demonstration Phase in April 2014 and is now an operational commercial service, which is distributed via the website [www.talkingfields.de](http://www.talkingfields.de) and by PC-Agrar. Customers from eight European countries are currently 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.

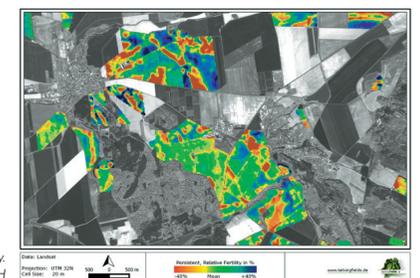


Figure 2. TF Base Map as calculated for a farm in Eastern Germany. ©VISTA GmbH

## User's VOICE

The TalkingFields yield estimation was provided for my sugar beet fields and it provided very accurate yield monitoring that even allowed site-specific yield observations, which was not possible before TalkingFields

Jürgen Schwarzensteiner, Farm Manager

## More Information

[www.talkingfields.de](http://www.talkingfields.de)

Dr. Heike Bach, VISTA GmbH  
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©Tim Benson

Chapter 2: Agriculture

# Enhancing Drought Monitoring in North America

Unique measurements of groundwater from the Gravity Recovery and Climate Experiment (GRACE) satellite mission are used to improve the US Drought Monitor system.



## Value Chain



## Benefit

Water supply management, drought aid distribution

## Problem

Prior to the addition of GRACE-based drought indicators, the US 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.

Droughts are significant economically. For example, the United States Department of Agriculture (USDA) Livestock Forage Disaster Program disbursed \$479 million for drought-related grazing losses of livestock from 2008 through 2011. 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.

## Satellite Earth Observation Data Application

The National Drought Mitigation Center (NDMC) produces official drought maps and products on a weekly basis. A NASA-sponsored project developed new drought indicators using satellite EO from the GRACE mission.

GRACE is a US-German satellite mission consisting of a pair of satellites orbiting in tandem about 450km above the ground, which can detect 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.

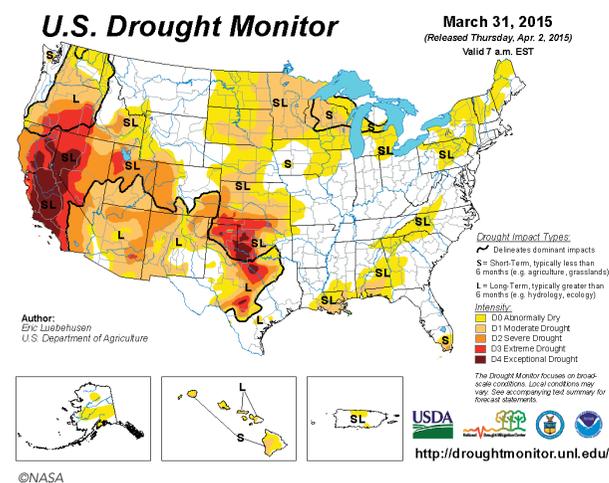
These independent and reliable indicators of deep soil moisture and groundwater storage are now part of the NDMC's routine production, augmenting existing data available to assess droughts.

Drought planning entails drought monitoring, understanding drought impacts, and mitigating the associated risks. GRACE-based data products may ultimately support long-term planning on the national, state, local, and tribal

level, as decisions on issues such as disaster aid, construction of dams, and water allocation rely on accurate assessments of drought.

The project's data products provide benefits beyond official drought monitoring. The online weekly groundwater and soil moisture maps allow open access for users of all kinds to tap the data for their own assessments and decisions. The maps are especially useful in helping water resource managers to differentiate between short-term and long-term drought.

The GRACE Follow-On satellite 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.



## User's VOICE

[These GRACE] maps provide regional to national-level water resource information that was previously unavailable to policy 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 Wardlaw, National Drought Mitigation Center

## More Information

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Chapter 2: Forest

# Prevention of Illegal Logging in the Amazon Rainforest

JAXA, JICA and RESTEC implemented a project to supply radar data from the ALOS mission to complement the optical imagery already in use in Brazil's near real-time forest monitoring system.



## Value Chain



## Problem

Brazil has been struggling with deforestation in the Amazon rainforest since the 1970s. While large mining projects were the major cause of deforestation in the 1970s and 1980s, the main cause of deforestation in the Amazon since the 1990s has been illegal logging. According to a report from the Brazilian commission, 80% of all logging in the Amazon was illegal during the late 1990s.

## Satellite Earth Observation Data Application

The Brazilian National Institute for Space Research (INPE) has developed and operated a near real-time forest monitoring system (DETER) since 2004 in support of the surveillance and deforestation control efforts by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA).

DETER uses MODIS data to detect deforestation areas greater than 25 hectares. However, this optical sensor cannot observe the ground in cloudy conditions – a persistent problem during the approximately 5-month long rainy season. Loggers are able to clear-cut huge areas during the rainy season without detection by the satellite monitoring system that relies entirely on optical imagery.

The Japan Aerospace Exploration Agency (JAXA) developed and launched the Advanced Land Observing Satellite (ALOS) in 2006, carrying the Phased Array L-band Synthetic Aperture Radar (PALSAR). Radar sensors can monitor ground surface regardless of cloud cover because clouds are transparent to the electromagnetic frequencies used. In addition, L-band radar is particularly sensitive to natural or human-induced changes in forest canopy, making PALSAR one of the most effective satellite tools for monitoring deforestation.

In 2007, IBAMA and JAXA signed a technical agreement for daily supply of PALSAR ScanSAR data at no cost. In 2009, the Japan International Cooperation Agency (JICA) also established a three-year project with RESTEC, IBAMA and the Brazilian Federal Police Department (DPF) to build Brazilian capacity for monitoring deforestation using satellite-based SAR.

The ScanSAR observation mode, while somewhat coarse in resolution (100m), has a large 350km swath that can cover the entire Amazon (5.2 million km<sup>2</sup>) every 15 days and ensures a high temporal resolution – a high priority for law enforcement agencies. As a result, deforested areas larger than 25 hectares have been easily detected on very short time-scales.

RESTEC also developed software that allowed IBAMA staff to quickly produce color composites for further interpretation. IBAMA further developed this software to create the PALSAR-based near real-time forest monitoring system, INDICAR, which can be used to detect areas of deforestation larger than 4–5 hectares.

Since ALOS ceased operations in 2011, INDICAR has also been suspended. However, JICA has been considering an extension of the project using JAXA's ALOS-2 mission, which was launched in 2014.

Some analyses suggest that the implementation of DETER was the main driver of the Amazon deforestation slowdown in the 2000s, and that DETER-based environmental monitoring and law enforcement policies prevented the clearing of over 59,500km<sup>2</sup> of Amazon forest area over a five-year period. The daily supply of reliable radar data from ALOS PALSAR undoubtedly contributed to this significant achievement.

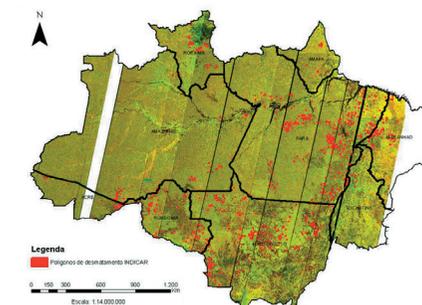


Figure 1. Mosaicked Color Composite Image and Polygons ©JAXA, METI, analyzed by RESTEC

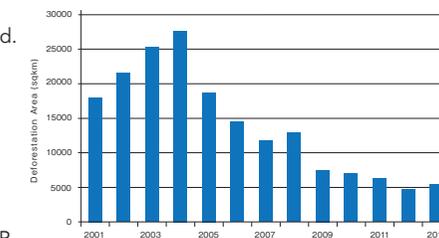


Figure 2. Annual rate of deforestation in the Brazilian Amazon in the time period of 2001-2013.

## User's VOICE

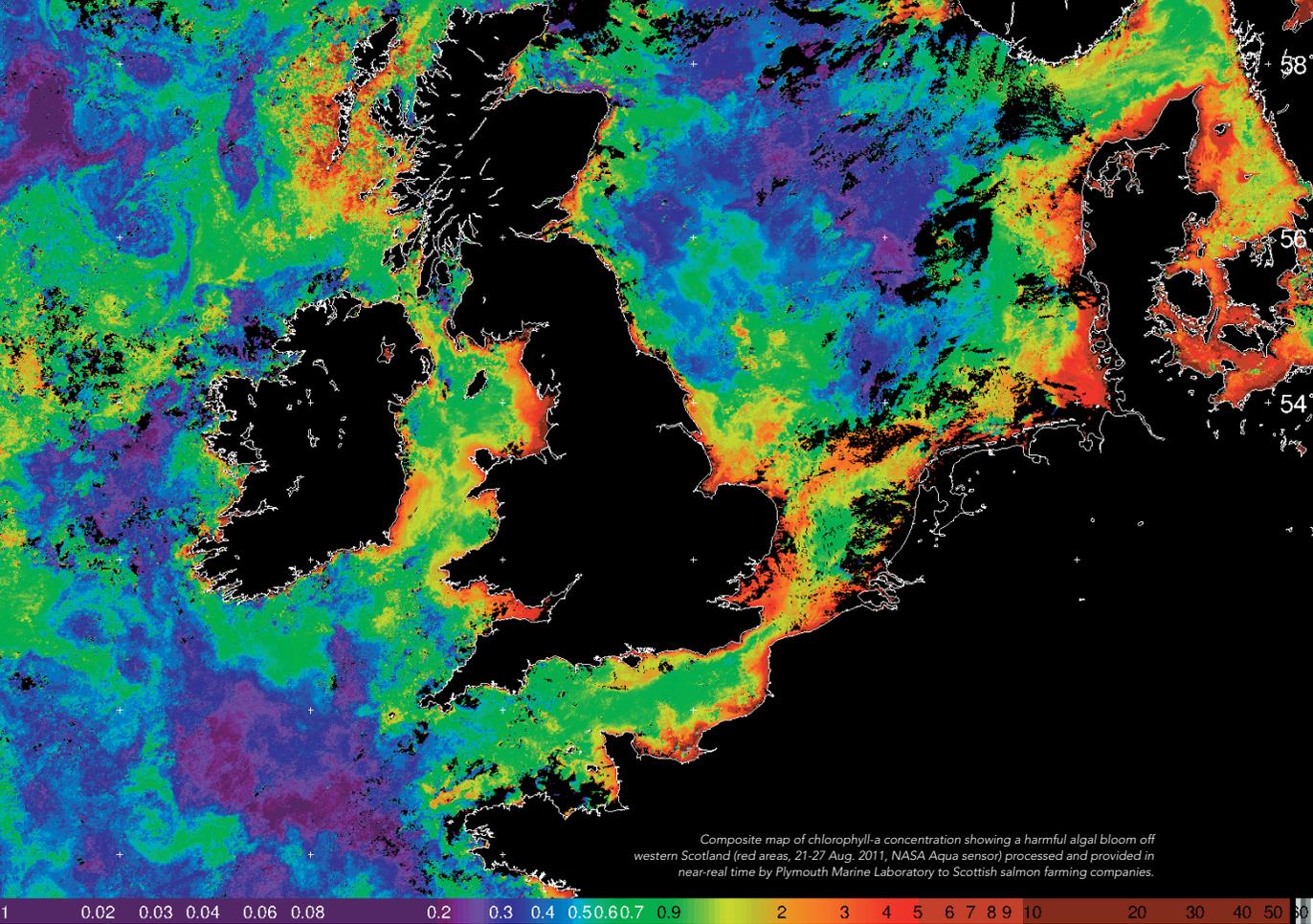
This project was very successful to monitor Amazon deforestation during the rainy season. We thank JAXA, JICA and RESTEC for providing us with such important remote-sensing data.

Edson Sano, IBAMA

## More Information

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Chapter 2: Environment

# Protecting the Aquaculture Industry from Harmful Algal Blooms

Plymouth Marine Laboratory's satellite monitoring of Harmful Algal Blooms (HABs) is funded by the Scottish aquaculture industry and involves processing Earth Observation (EO) Ocean Color data from MODIS and OLCI sensors in near-real time and applying novel techniques for discriminating certain harmful blooms from harmless algae. Early warning of HABs allows the industry to take protective measures to minimise stock losses. Within the AQUA-USERS project, this capability is being extended to further HAB species within several European countries.



## Value Chain



## Problem

In Scotland alone, the aquaculture industry (mostly farmed salmon) is worth around £600 million per year; shellfish culture contributes a further £33 million per year across the UK. HABs can cause sudden and considerable losses to fish farms. Examples include 500,000 salmon lost during one bloom in Shetland and 350 tonnes of salmon lost during a HAB event in Norway. HABs have been estimated to cost the US aquaculture industry about £82 million per year. HABs can also present a threat to human health.

## Satellite Earth Observation Data Application

EO ocean colour data are 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 and operational processing systems designed to provide timely information on water quality. Detection and classifier algorithms are 'trained' using the full spectrum of water-leaving light radiances, absorption and backscattering, while false alarms are minimised by labelling as 'unknown' any data that cannot be reliably classified. By comparison with in situ measurements, the method has been validated for *Karenia mikimotoi* and *Phaeocystis* HAB risk discrimination (see figure), though it is only applicable to high-biomass bloom-forming species that cause a characteristic colouring of the ocean.

Within the EC AQUA-USERS project, the HAB classifiers are being developed further to improve the capability to discriminate HABs in near-real time and the UK ShellEye project is targeting toxin-producing algal species that impact shellfish farms. Commercial opportunities for European services are being explored.

The HAB-monitoring service has been running successfully for several years, funded by the aquaculture industry. The end users include the Scottish Salmon Producers' Organisation and the three largest fish-farming companies in Scotland. Other potential end users include the marine insurance industry, the UK's Crown Estate and fish farming and aquaculture companies in other countries.

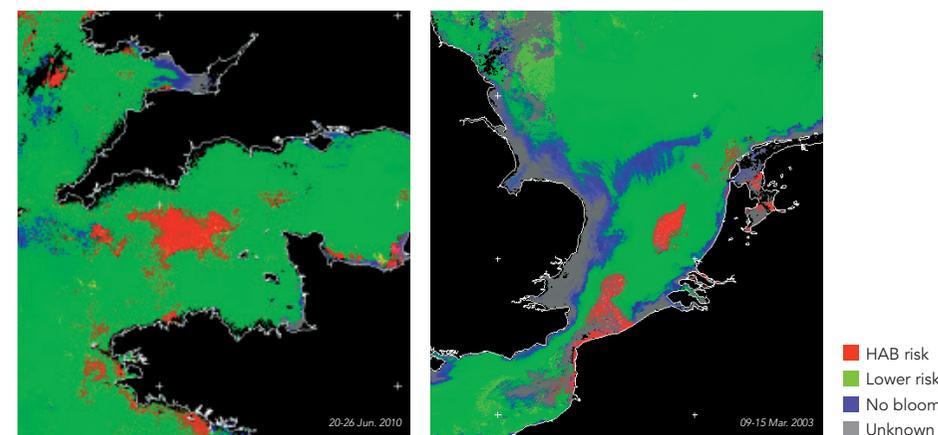


Figure 1. Harmful algal bloom risk maps using EO ocean colour discrimination: (Left) Weekly HAB risk maps of *Karenia mikimotoi* algal bloom in the Western English Channel in summer 2010 (Right) *Phaeocystis globosa* bloom in the Southern North Sea in spring 2003 ©PML

### User's VOICE

Allowed us to put the farms on 'alert' a few days before a bloom came...we are convinced that this prevented us from suffering losses.  
**Rachel Hope, Shetland Products Ltd.**  
 I would not feel secure enough to go blind in future - we need this information.  
**Chris Wallace, Marine Harvest (Scotland) Ltd.**

### More Information

[http://www.pml-applications.co.uk/Services/Remote\\_Sensing](http://www.pml-applications.co.uk/Services/Remote_Sensing)

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**PML** Plymouth Marine Laboratory

# CEOS Data Application Report

No. Summary Sentence

- 02 **Use of SAR data to map and quantify eruptive deposits for lahar assessment:** CVGHM developed a supervised classification method applied to dual-polarization ALOS data to map and quantify eruptive deposit for safe evacuation of population threatened by lahars in Indonesia.
- 03 **Applying remote sensing technology in river basin management in Asia:** ADB and JAXA implemented a project to improve monitoring and warning systems by applying space-based technology and ICT for flood risk management in Bangladesh, the Philippines and Vietnam at a reasonable cost.
- 04 **Sentinel Asia success story:** JAXA has been implementing SASS in the Philippines to provide disaster information and assist disaster management with remote sensing and Web-GIS technologies.
- 05 **Living in a land prone to fire across a continent:** GA, Australian Geospatial Intelligence Organisation and CSIRO developed the Sentinel Hotspots monitoring system to monitor hotspots nationally and provide timely hotspots information to government and private agencies managing fires in Australia.
- 06 **Great flood monitoring with Fengyun 3A satellite data:** In summer 2013, a great flood occurred in Northeast China and neighboring Russian area. Chinese central and local governments made scientific decisions to manage the flood and relief people based on information from Fengyun satellite.
- 07 **Global mapping of the earth's land surface composition:** Australia's geoscience agencies create and provide mineral maps from ASTER data for mining and mineral exploration companies as well as farmers and environmental managers.
- 09 **Detection and monitoring water resources across a continent:** GA developed the Australian Geoscience Data Cube containing Landsat data since 1987 and created the Water Observations from Space product which shows the frequency of occurrence of surface water for 27 years.
- 10 **Collaborative EO application development for Australia's environment:** A program to deliver new, continentally consistent, validated time series of satellite EO based biophysical property maps for national, state and local governments in Australia.
- 11 **Monitoring changes in Australia's ecosystems:** Legislative activities to deliver the vegetation related products from EO data for Australia's state governments according to the Native Vegetation Act.
- 12 **Sentinel-1 SAR data for operational rice monitoring system:** ESA, THEIA and CESBIO implemented a project in the frame of Asia-RICE GEOGLAM initiative to provide Rice Information for food security by using SAR and ground data in the Mekong Delta, Vietnam.
- 13 **The Richelieu river flood management (Quebec, Canada):** CSA is collaborating with NASA on various projects helping to prevent, manage and respond to natural disasters and is making effort to reduce loss of life and property from natural and human-induced disasters in Canada, within the framework of CEOS.
- 17 **Improving air quality information with satellite data:** 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.
- 18 **Using AW3D within mineral exploration operations:** The use of AW3D within the mineral 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.
- 19 **ASTER data used to identify copper potential regions:** Japanese mining companies used the observation data from ASTER to identify copper potential regions with minimum workloads in the initial phase of the project in Andes.
- 20 **Monitoring of water quality and water level of rivers and lakes in Brazil:** ANA and IRD have developed the MEG-HIBAM project that aims at incorporating the spatial satellite remote sensing data into a global monitoring strategy to monitor water quality and water level of rivers and lakes in Brazil.
- 21 **EO to advance wildlife habitat conservation and management:** The Ecosystem Assessment, Geospatial analysis, and Landscape Evaluation Systems (EAGLES) broadens ways for fish and wildlife managers to apply Earth observations for habitat management and species conservation.
- 22 **Advancing marine mammal and protected species management:** A multi-agency team applied satellite observations to improve assessments of marine mammal habitats and reduce human impacts on whales, dolphins, and other species.
- 23 **Improving ecosystem monitoring and management of coral reefs:** Applications of Earth observations enhance the Coral Reef Watch decision support system for management of coral reefs, supporting ecosystem health and economic activity.

No. Summary Sentence

- 29 **Use of EO satellites for maritime downstream applications:** 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.
- 30 **Challenge to use EO products for earthquake-related civil protection in Italy:** DPC, ASI and INGV made a challenge to integrate and use satellite products and ground-based data to understanding phenomenon and support seismic risk management activities in Italy.
- 31 **Ground deformation monitoring French infrastructure for scientific applications:** A proposal of the Ground Deformation Monitoring service, as a part of French Solid Earth thematic data pole project, which will facilitate access to the observation data from Sentinel satellite for ground deformation monitoring applications.
- 32 **Crucial and unique role of EO data within the 2014 Cephalonia seismic crisis:** Italian COSMO-SkyMed and the German TerraSAR-X satellite constellations provided the observation data right after the 2014 Cephalonia (Greece) seismic crisis to understand regional tectonics and assess the seismic hazard.
- 34 **EO for mine waste characterization from multispectral and hyperspectral sensors:** The synergetic use of multispectral data from large-scale mapper missions such as Landsat-8 in combination with a hyperspectral space-borne sensors demonstrated characterization and mapping of mine waste material in very wide areas in South Africa.
- 35 **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. ThermCERT analytical suite combines and uses space and in-situ derived data to enhance quality and scanning frequency over a lifetime of a thermal investment.
- 36 **Ocean fronts helping to define marine protected areas:** PML developed ocean fronts maps from EO satellite data, which were applied as a proxy for the abundance and diversity of pelagic marine animals, for cost-effective guidance on UK marine protected areas.
- 39 **Use of satellites for disasters in Southern Africa:** CEOS WG Disasters implemented a pilot project "Flood Dashboard", which allows the user to overlay various relevant satellite products on a map and also to access real-time inundation maps, flood risk forecast, rainfall, and predicted water elevation.
- 40 **Entomological Rift valley fever risk in Senegal:** The Centre de Suivi Ecologique, the Dakar Pasteur Institute, the Direction of Veterinarian Services, Météo-France, and CNES implemented a project to develop an EO satellite-based decision-aid tool based on SPOT-5 for better management of animal health in Africa.
- 41 **Mapping and forecasting frost in Kenya with satellite observations:** The Kenya Meteorological Service, Tea Research Foundation of Kenya, and insurance providers utilize maps incorporating MODIS data to improve crop risk management.
- 42 **SPOT monitors evolution of the Serbian territory:** Introduction of a project to set up a National Spatial Data Infrastructure and a Remote Sensing Centre for the Republic of Serbia. SPOT satellites demonstrate their capacity to face this challenge, and provide an in-depth agricultural land cover over the entire country.
- 43 **GOSAT data since 2009 and its application:** The world's first mission to monitor two major greenhouse gases – carbon dioxide and methane – GOSAT has been providing the high resolution spectra dataset for space agencies and research institutes since 2009.
- 44 **EUMETSAT Geostationary System - Meteosat Third Generation (MTG):** EUMETSAT is developing Meteosat weather satellites and will extend the series of observations until the 2040 timeframe under its geostationary programme.
- 45 **EUMETSAT Polar System - Second Generation (EPS-SG):** EUMETSAT is developing the polar system that provides global and accurate observations, essential for weather forecasting up to 10 days and for climate monitoring.
- 47 **Forest biomass and change in forest cover using SAR data:** THEIA and CESBIO developed systems to monitor deforestation and forest logging in Vietnam using Sentinel-1 SAR data and biomass of wood savanna in Cameroon using ALOS SAR data.
- 48 **NEODAAS: Providing satellite data for efficient research:** NEODAAS provides EO satellite data access 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 unfamiliar satellite data.
- 49 **EarthLab Galaxy: Worldwide cluster of environment monitoring centers:** Introduction of the EarthLab program – global network of centers dedicated to environment monitoring – to ingest multi-source data, conduct R&D activities and provide operational services for various clients.

Above items of report are included in the Full Report, except 11 articles in this book. Please download the full report from CEOS web site. <http://www.ceos.org/dar2015>

# List of satellites referenced in this report

Types	Satellite Names	Operating Agencies/ Companies	Features
Active Microwave	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)
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	ALOS-2	JAXA	Phased Array type L-band Synthetic Aperture Radar type 2 (PALSAR-2), Compact InfraRed Camera (CIRC)
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	RADARSAT-1	CSA	C-band Synthetic Aperture Radar
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	RADARSAT-2	MDA	C-band Synthetic Aperture Radar
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	Sentinel-1	ESA/EC	C-band Synthetic Aperture Radar
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Sentinel-3	EUMETSAT/ESA	Imaging multi-spectral radiometer, SAR radar altimeter, Sea and land surface temperature radiometer	
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TanDEM-X	DLR	X-band Synthetic Aperture Radar	
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TerraSAR-X	DLR	X-band Synthetic Aperture Radar	
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SRTM	NASA	C-band Synthetic Aperture Radar	
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Optical	GeoEye-1	DigitalGlobe	Panchromatic, Multispectral
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	WorldView-2	DigitalGlobe	8 spectral bands
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	SPOT-5	CNES	Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), High Resolution Stereoscope (HRS), High Resolution Optical Imager
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	Pleiades	CNES/Airbus DS	High-Resolution Imager
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Landsat-5	USGS/NASA	Thematic Mapper, Multispectral Scanner	
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Landsat-7	USGS/NASA	Enhanced Thematic Mapper Plus	
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Landsat-8	USGS/NASA	Operational Land Imager, Thermal Infrared Sensor	
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Sentinel-2	ESA/EC	Multispectral Imager	
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Passive Microwave	Aqua/ MODIS	NASA	Atmospheric Infrared Sounder, Advanced Microwave Scanning Radiometer-EOS (AMSR-E), Advanced Microwave Sounding Unit-A (AMSU-A), Cloud and the Earth's Radiant Energy System (CERES), Humidity Sounder for Brazil, High Resolution Dynamics Limb Sounder (HIRDLS), Moderate-Resolution Imaging Spectroradiometer (MODIS).
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Terra/ MODIS	NASA	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Cloud and the Earth's Radiant Energy System (CERES), Multi-angle Imaging Spectro Radiometer, Moderate Resolution Imaging Spectroradiometer (MODIS), Measurements Of Pollution In The Troposphere (MOPITT)	
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Other	TRMM	NASA/JAXA	Cloud and the Earth's Radiant Energy System (CERES), Lightning Imaging Sensor (LIS), Precipitation Radar (PR), TRMM Microwave Imager, Visible Infrared Scanner (VIRS)
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	ENVISAT	ESA	Advanced Along-Track Scanning Radiometer (AATSR), Advanced C-band Synthetic Aperture Radar (ASAR), Global Ozone Monitoring by Occultation of Stars (GOMOS), Medium-Resolution Imaging Spectrometer (MERIS), Michelson Interferometric Passive Atmospheric Sounding (MIPAS), Microwave Radiometer (MWR), Radar Altimeter-2 (RS-2), Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY)
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GRACE	NASA/DLR	K-band Ranging System, Satellite Global Positioning System (GPS)	

“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://www.ceos.org

“JAXA”

The Japan Aerospace Exploration Agency (JAXA) conducts integrated operations on overall aerospace activities from advanced research and development to utilization as a core performance agency of Japanese government.

http://global.jaxa.jp

**Applications of SATELLITE EARTH OBSERVATIONS: Serving Society, Science, & Industry**

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Sony Music Communications Inc.

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Image on the cover

The image geometrically shows both summer and winter of “Shirakawa-go” (World Heritage / Japan), which is precisely combined with two images taken by JAXA’s satellite “ALOS” at approx. 690 km altitude.

