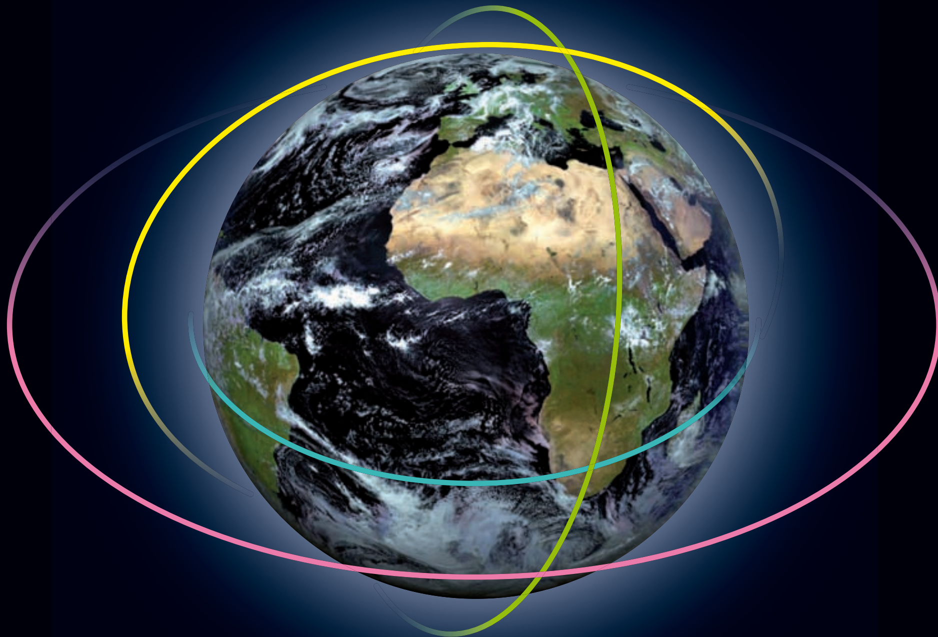
SPACE AND CLIMATE CHANGE



USE OF SPACE-BASED TECHNOLOGIES IN THE UNITED NATIONS SYSTEM

UNOOSA

World Meteorological Organization
Weather • Climate • Water

WMO-No. 1081

Sincere appreciation is extended to Dr Marielle Guirlet (on contract with WMO), Mr Juan-Carlos Villagran (UNOOSA), Ms Azusa Sakamoto (JAXA) and the authors of the individual chapters for their dedicated efforts in preparing this report.

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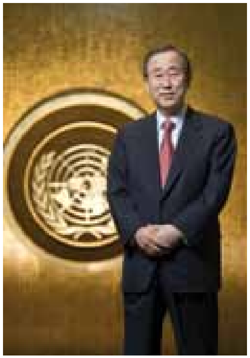
SPACE AND CLIMATE CHANGE:

USE OF SPACE-BASED TECHNOLOGIES IN THE UNITED NATIONS SYSTEM

CONTENTS

FOREWORD

Climate change threatens to have a catastrophic impact on ecosystems and the future prosperity, security and well-being of all humankind. The potential consequences



extend to virtually all aspects of sustainable development – from food, energy and water security to broader economic and political stability.

Global observing systems, including those from space, play an important role in helping to gauge these threats. This publication describes how United Nations organizations use the information provided by space-based technologies to monitor the Earth's climate system and support decision-making about climate change adaptation, prediction and mitigation, including addressing the needs identified under the United Nations Framework Convention on Climate Change. It also provides an overview of the global observing systems co-sponsored by several United Nations organizations and the International Council for Science that coordinate Earth observations on behalf of United Nations Member States.

United Nations organizations are making full use of space-based technologies in our shared quest to build a safer, better world for all. I commend this publication to all who desire a clear understanding of how these technologies are enhancing our ability to manage planet Earth and to address the critical challenges facing the human family.

Ki-Moon Ban

Ban Ki-moon
Secretary-General of the United Nations

BACKGROUND

The United Nations Inter-Agency Meeting (IAM) on Outer Space Activities, coordinated by the United Nations Office for Outer Space Affairs (UNOOSA), has been the focal point for inter-agency coordination and cooperation in space-related activities since 1975. This annual meeting aims to promote inter-agency cooperation and to prevent duplication of effort related to the use of space applications by United Nations organizations.

At the thirtieth session of the IAM, held in Geneva, Switzerland, in 2010, representatives of the organizations agreed to issue a special report[1] and a publication outlining the way in which United Nations organizations use space-based technologies to address climate change. The report and publication outline activities ranging from observations and data collection and dissemination to the development of standards, research and product generation.

The report and the publication have been elaborated under the framework of the United Nations System "Delivering as One" initiative, which was established by the Secretary-General of the United Nations in 2009. Its purpose is "to develop a strategic, coherent, and operational framework to support the intergovernmentally agreed decisions within the UNFCCC [United Nations Framework Convention on Climate Change]".[2] The Framework aims to maximize existing synergies, eliminate duplication of effort and optimize the impact of the collective effort of the United Nations system.

This publication, a synthesis of the longer report, also describes the three global observing systems, which are co-sponsored by several United Nations organizations and the International Council for Science (ICSU), in addition to efforts conducted by United Nations organizations targeting climate change and its impacts through the use of satellite observations.

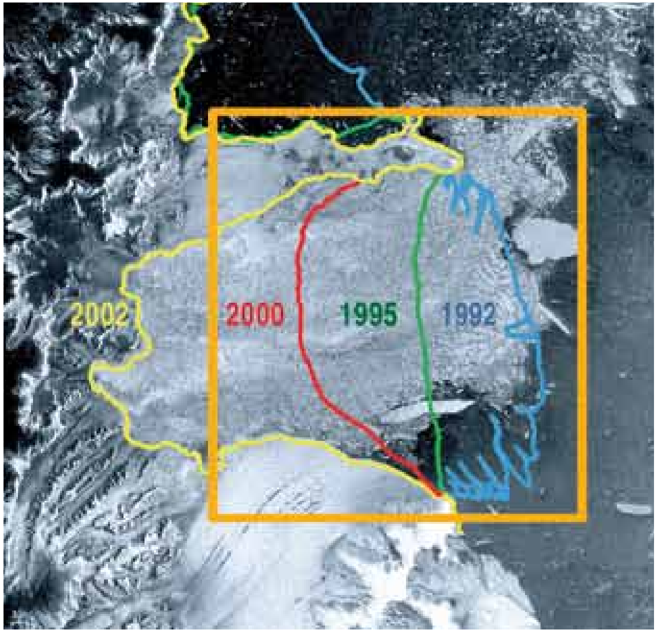
1 *Space and Climate Change: Special Report of the Inter-Agency Meeting on Outer Space Activities on Use of Space Technology within the United Nations System to Address Climate Change Issues* (A/AC.105/991).

2 United Nations System Chief Executives Board for Coordination: *Acting on Climate Change: The United Nations System Delivering as One*; available at: http://www.un.org/climatechange/pdfs/Acting%20on%20Climate%20Change.pdf.

THE UNITED NATIONS SYSTEM ACTING AS ONE

In 2009, Mr Ban Ki-Moon, the Secretary-General of the United Nations, emphasized climate change as the "defining challenge of our time". As highlighted in the *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC),[3] overwhelming scientific evidence indicates that climate change will threaten economic growth and long-term prosperity, as well as the very survival of the most vulnerable populations. Projections by the IPCC indicate serious impacts, including sea level rise, shifts in growing seasons, and increasing frequency and intensity of extreme weather events, such as storms, floods and droughts.

Satellites, as part of the global array of networks for monitoring climate change and its impacts, provide a unique and critical global perspective in terms of Earth observations. As displayed in the insets throughout this publication, satellites are now used to monitor changes in polar sea ice and glaciers, emissions of greenhouse gases related to deforestation and industrial processes, temperature changes, sea level rise, and other parameters.



EUROPEAN SPACE AGENCY

One of the first photos taken by Envisat, an Earth observation satellite operated by the European Space Agency's (ESA), shows the Larsen B ice shelf, observed on 18 March 2002. Over the last decade ESA satellites have been monitoring changes in the region. The break-up of the ice shelf has now reached the rock faces of the Antarctic Peninsula itself.

3 IPCC (2007): *Climate Change 2007: Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change.*

For a complete list of variables that are observable from space and are deemed important for climate observations, see the table below.

Essential Climate Variables to which satellite observations make a significant contribution

Domain	Essential Climate Variables (ECVs)
Atmospheric (over land, sea and ice)	Surface wind speed and direction, precipitation, upper-air temperature, upper-air wind speed and direction, water vapour, cloud properties, Earth radiation budget (including solar irradiance), carbon dioxide, methane, and other long-lived greenhouse gases,[4] ozone and aerosol properties, supported by their precursors[5]
Oceanic	Sea surface temperature, sea surface salinity, sea level, sea state, sea ice, ocean colour
Terrestrial	Lakes, snow cover, glaciers and ice caps, ice sheets, albedo, land cover (including vegetation type), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Leaf Area Index (LAI), above-ground biomass, fire disturbance, soil moisture

4 Including N_20, CFCs, HCFCs, HFCs, SF_6 and PFCs.

5 In particular NO_2, SO_2, HCHO and CO.

(The information in the table is drawn from the draft update of the Satellite Supplement,[6] the satellite-based component of the Global Climate Observing System Implementation Plan,[7] published in 2010.)

Recognizing the usefulness of satellites for these purposes, the Food and Agriculture Organization of the United Nations (FAO), United Nations Educational, Scientific and Cultural Organization Intergovernmental Oceanographic Commission (UNESCO IOC), United Nations Environment Programme (UNEP), World Meteorological Organization (WMO) and ICSU joined efforts to establish three global observing systems for coordinating observations of the Earth's physical domains. These are:

- the Global Climate Observing System (GCOS);
- the Global Ocean Observing System (GOOS);
- the Global Terrestrial Observing System (GTOS).

6 *Systematic Observation Requirements for Satellite-based Products for Climate*, GCOS-107 (WMO/TD-No. 1338), September 2006; available at http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf. Note: an update is currently under way.

7 *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (2010 Update), GCOS-138 (WMO/TD-No. 1523), August 2010; available at http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf.

As a facilitator of intergovernmental negotiations targeting climate change, the UNFCCC spearheads United Nations efforts towards global governance to address the threat of climate change. Within the Conference of Parties (COP) of the UNFCCC, issues relevant to science, research and systematic observation of climate change and its impacts are considered by the Subsidiary Body for Scientific and Technological Advice (SBSTA).

Following the guidelines established by the Secretary-General of the United Nations on the need for organizations in the United Nations system to deliver as one, UNOOSA and WMO have compiled this report on the efforts focused on climate change undertaken by organizations participating in the IAM.

Under the leadership of the Secretary-General of the United Nations, the United Nations System Chief Executives Board for Coordination (CEB) has established a framework for coordinating the response of United Nations organizations to the global and multifaceted challenge of climate change.

Taking into consideration the role of the IAM to enhance coordination and cooperation, the IAM has agreed:

- to promote the establishment and operation of a global repository of satellite-based data and to ensure access to these data by all United Nations entities through inter-agency mechanisms, such as the United Nations Geographic Information Working Group;

- to contribute to the enhanced use of space technology to address relevant needs identified under the UNFCCC and to support actions to implement the Convention, for example, in the context of the Cancun Agreements and work conducted under the SBSTA;

- to facilitate, through existing mechanisms, the exchange of experiences and lessons learned regarding space applications in the context of climate change and the benefits and limitations of emerging technologies;

- to support the needs identified through ongoing initiatives, such as the Global Framework for Climate Services (GFCS), the Advanced Real Time Environmental Monitoring Information System (ARTEMIS), and the Rapid Agricultural Disaster Assessment Routine (RADAR) initiatives, as well as the efforts of other United Nations entities.

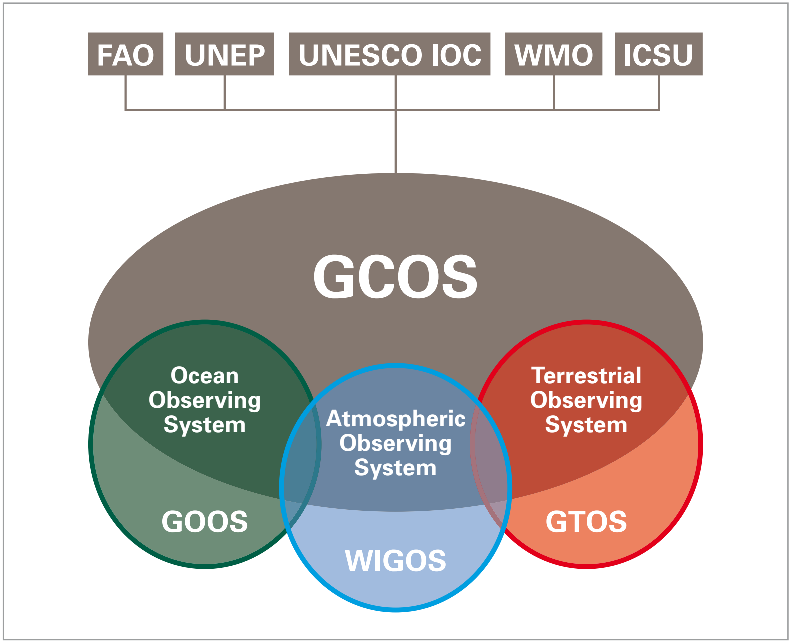

NASA EARTH OBSERVATORY

UNITED NATIONS CO-SPONSORED GLOBAL OBSERVING SYSTEMS

The image on the facing page illustrates the diverse agricultural landscape including areas of centre-pivot irrigation in the western part of Minas Gerais state in Brazil. Though most widely known for its mineral wealth, Minas Gerais is also a large agricultural producer for Brazil.

OVERVIEW

United Nations Organizations, including FAO, UNEP, UNESCO IOC and WMO, and their partner ICSU, co-sponsor several global observing systems that cover selected domains of the Earth's systems – climate, ocean, land and atmosphere. In each instance, one organization is responsible for hosting the Secretariat – FAO for GTOS, UNESCO IOC for GOOS, and WMO for both GCOS and the WMO Integrated Global Observing System (WIGOS).

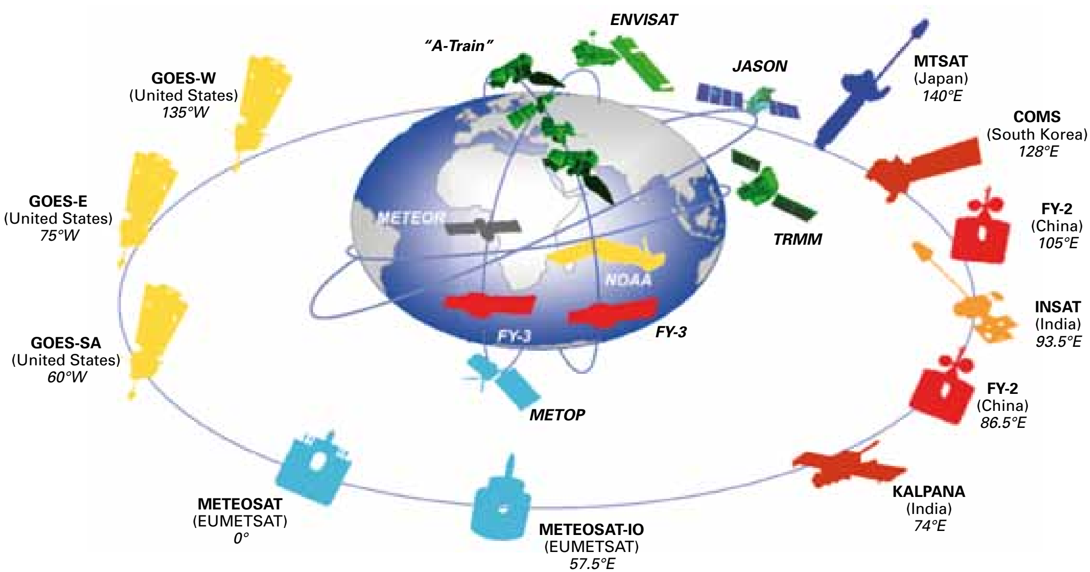


This schematic of United Nations sponsors and the component observing systems, includes the Global Climate Observing System, the Global Ocean Observing System, the Global Terrestrial Observing System and the WMO Integrated Global Observing System.

Each observing system includes space-based, surface and airborne observations, which are shared broadly among the co-sponsors and their Member States.

As an example of the space-based component, the figure below shows satellites that contribute data and information to WIGOS.

Space-Based Component of WMO Integrated Global Observing System



The space-based component of WIGOS includes operational satellites in geostationary and low-Earth orbits, and research and development satellites in low-Earth orbit (Source: GEO Secretariat).

GLOBAL CLIMATE OBSERVING SYSTEM

GCOS
GLOBAL CLIMATE OBSERVING SYSTEM

http://gcos.wmo.int

The Global Climate Observing System (GCOS), established in 1992 and led by WMO, is a joint undertaking of UNEP, UNESCO IOC, WMO and ICSU. Its goal is to provide comprehensive information on the total climate system, involving a multidisciplinary range of physical, chemical and biological properties, and atmospheric, oceanic, hydrological, cryospheric and terrestrial processes.

GCOS is built on the Global Ocean Observing System, the Global Terrestrial Observing System, the WMO Integrated Global Observing System and a number of other domain-based and cross-domain, research and operational observing systems. GCOS includes both in situ and remote-sensing components. Its space-based components are coordinated by the Committee on Earth Observation Satellites (CEOS) and the Coordination Group for Meteorological Satellites (CGMS). GCOS is intended to meet the full range of national and international requirements for climate and climate-related observations. As a system of climate-relevant observing systems, it constitutes, in aggregate, the climate observing component of the Global Earth Observation System of Systems (GEOSS).

GCOS takes advantage of Earth observation satellites as a vital means to observe the climate system from a global perspective. This global perspective allows experts to compare Essential Climate Variables (ECVs) in diverse regions of the globe. Satellite observations differ from ground-based and airborne measurements, which are generally more limited in spatial coverage, but nevertheless are vital to enhance and validate information derived from space. The GCOS satellite requirements were developed in collaboration with the World Climate Research Programme (WCRP), WMO and the climate community at large. Those that were laid down in the 2006 publication *Systematic Observation Requirements for Satellite-Based Products for Climate*[8] consist of detailed specifications on accuracy, stability over time, and the spatial/temporal resolution of satellite data and derived products.

Also included are the ten satellite-specific GCOS Climate Monitoring Principles (GCMPs). Satellite

8 *Systematic Observation Requirements for Satellite-based Products for Climate*, GCOS-107 (WMO/TD-No. 1338), September 2006; available at http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf.

climate data records that meet the GCOS requirements have significantly added value to climate monitoring, studies of trends and variability, assimilation in models, and, ultimately, decision-making in many societal sectors, including agriculture, water resource management, forestry and marine applications.

In responding to the GCOS requirements, space agencies have coordinated their actions, both individually and collectively, through CEOS and CGMS. These actions apply to climate-monitoring operation of satellite systems and to coordinated exploitation of acquired datasets, for example, in the Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) initiative and, in the case of WMO, to the incorporation of GCOS needs in the re-design of its Global Observing System (see figure on p. 13).

In 2010, the GCOS programme published an update of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC, in which it called for sustained observation of the 50 ECVs that are needed in order to make significant progress in generating global climate products and derived information. Currently, about 30 ECVs can be obtained from satellites.

Cross-domain coverage by satellites and in situ reference sites are essential parts of GCOS.

GLOBAL OCEAN OBSERVING SYSTEM

http://www.ioc-goos.org

The Global Ocean Observing System (GOOS), created in 1991, is led by UNESCO IOC and co-sponsored by UNEP, WMO and ICSU. Its establishment was initiated by UNESCO IOC at the request of Member States that recognized the importance of a unified ocean observation system.

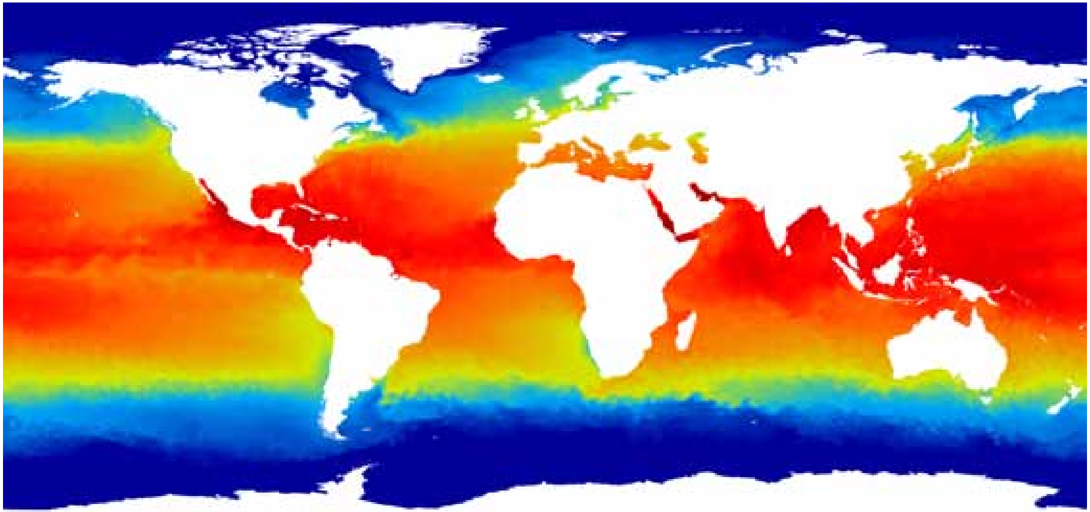
The ocean is an integral part of the global climate system, as it absorbs over 80 per cent of the excess heat caused by global warming, controls weather systems, and adds to decadal climate variations by slowly transporting heat around the world. Therefore, the IPCC has emphasized the need to understand ocean processes as a way of contributing to decision-making about societal responses to climate change.

Through GOOS, the world's oceans are now beginning to be routinely and systematically observed and the collected data processed in a timely fashion and applied in decision-making. The requirements for ocean observations, in relation to climate monitoring, research and forecasting, are set by the Ocean Observations Panel for Climate (OOPC), which reports to GCOS, GOOS and WCRP.

Key parameters linked to climate change include sea level, sea surface temperature, ocean colour and sea-ice extent. Each parameter is being addressed through GOOS. Sea level change has been identified as one of the most obvious results of climate change and has been monitored from space since 1992. Sea level rise is driven by expansion of the upper ocean layers due to increases in subsurface ocean temperature and is slightly modified by the transfer of water between the oceans and land-based reservoirs. The melting of mountain glaciers and polar ice sheets also contributes to global sea level rise. Local sea level is strongly influenced by regional and local processes, including natural earth movements and human-induced land subsidence caused by fresh water extraction. These factors are critically important for densely populated, low-lying coastal regions that are prone to storm flooding, such as Bangladesh or the deltas of the Nile and Mississippi rivers.

In a complementary fashion, sea surface temperature is vital for weather prediction and for understanding coupled ocean–atmosphere dynamics, which are required for climate prediction. Ocean colour is an indicator of biological activity, and ocean life is dependent on the biogeochemical status of the ocean, which is affected by changes in its physical state and circulation. Finally, sea-ice extent is significant as an indicator, and driver, of climate change and for its important role in polar ecosystems and navigation.

Sea surface temperature map for 5 October 2011



GOOS provides a wealth of products and services based on the acquisition of near real-time data from a multitude of sources and data that are stored, served and processed by numerous institutions and governments. A good example of this cooperation is the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) system, which was developed by the UK Met Office as part of the European MyOcean project and contributes to the Group for High-Resolution Sea Surface Temperature (GHRSST). OSTIA uses satellite data together with in situ observations to determine sea surface temperature.

GLOBAL TERRESTRIAL OBSERVING SYSTEM

http://www.fao.org/gtos

The Global Terrestrial Observing System (GTOS), created in 1996 and led by FAO, is an inter-agency programme that is co-sponsored by FAO, UNEP, UNESCO IOC, WMO and ICSU.

Terrestrial ecosystems and natural resources are essential for sustainable development, so assessments regarding how climate change is affecting these ecosystems and resources are extremely important.

GTOS has worked to raise awareness of the utilization of remote-sensing data to support sustainable development. The use of these data, together with in situ data and information, has generated great interest among the Parties to several conventions for both the reporting and monitoring of the sustainable use of natural resources. Particular emphasis has been placed on very fragile ecosystems, such as those in coastal areas and in mangroves, which are rich in biodiversity and highly affected by population pressure.

GTOS promotes the following:

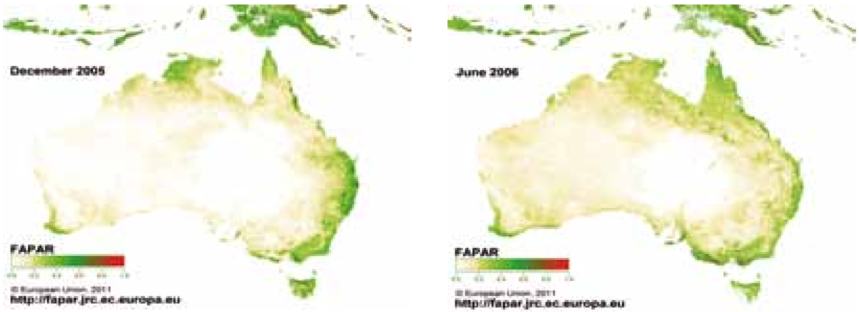
- integration of biophysical and socio-economic, georeferenced data;
- interaction among monitoring networks, research programmes and policymakers;
- data exchange and application;
- quality assurance and harmonization or standardization of measurement methods;
- collaboration to develop regional and global datasets.

GTOS has been playing a leading role in defining the terrestrial ECVs within its overall mandate, which is to improve understanding of the terrestrial components of the climate system, the causes of changes to the system, and the related consequences in terms of impact and adaptation.

Efforts conducted through GTOS led to the elaboration of the report entitled *A Framework for Terrestrial Climate-Related Observations and the Development of Standards for the Terrestrial Essential Climate Variables: Proposed Workplan*. The Workplan consists of two main phases: implementation of the organizational framework and standardization of individual ECVs. Recognizing the usefulness of these phases, the SBSTA encourages GTOS to continue implementing the Workplan.

NASA EARTH OBSERVATORY

The Advanced Land Imager (ALI) on the NASA Earth Observing-1 (EO-1) satellite captured this image of the Orange River at the border between Namibia and the Republic of South Africa on 17 February 2010. A network of bright rectangles of varying shades of green contrasts with surroundings of grey, beige, tan and rust. Immediately south of a large collection of irrigated plots, faint beige circles reveal centre-pivot irrigation fields apparently allowed to go fallow.



Monthly maps showing values of Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), a terrestrial ECV, over Australia in December 2005 and June 2006 (N. Gobron et al. (2008): Uncertainty estimates for the FAPAR operational products derived from MERIS – Impact of top-of-atmosphere radiance uncertainties and validation with field data. Remote Sensing of Environment, *112(4):1871–1883, DOI: 10.1016/j.rse.2007.09.011). The maps are based on MERIS measurements and are available at: http://fapar.jrc.ec.europa.eu.*

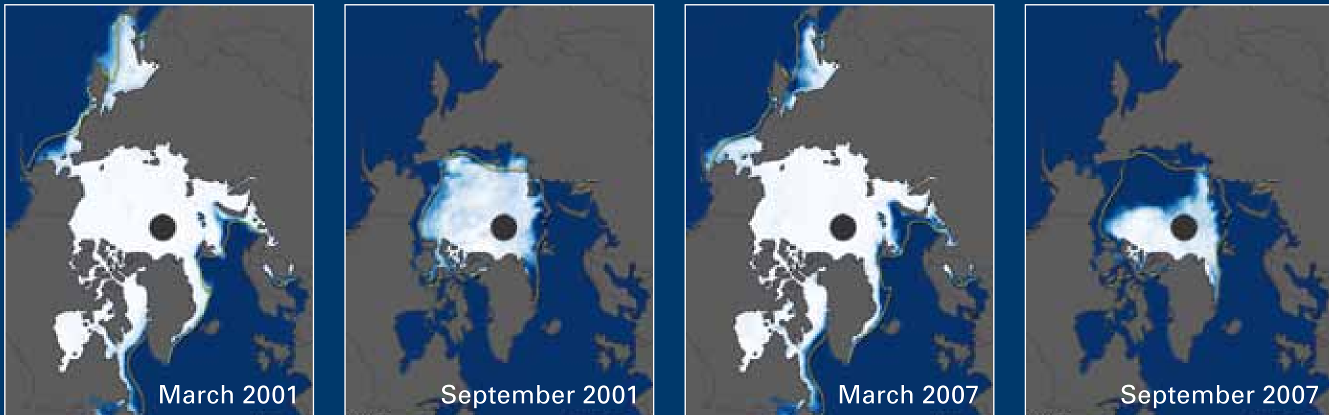
IN FOCUS: SEA ICE IN THE ARCTIC

Layers of frozen seawater, known simply as sea ice, cap the Arctic Ocean. This ice grows dramatically each winter, usually reaching its maximum in March, then melts just as dramatically each summer, generally reaching its minimum in September.

Cycles of natural variability, such as the Arctic Oscillation, are known to play a role in Arctic sea-ice extent, but the sharp decline seen in this decade cannot be explained by natural variability alone. Natural variability and greenhouse gas emissions (and the resulting rise in global temperatures) are likely to have worked together to melt greater amounts of Arctic sea ice. Some models forecast an ice-free Arctic for at least part of the year before the end of the twenty-first century.

Since 1978, satellites have monitored sea-ice growth and retreat, detecting an overall decline in Arctic sea ice. Over the years, satellite sensor capabilities have steadily improved, but some limitations remain, often due to weather and the combination of land and water (along coastlines) in the satellite sensor's field of view. The figures on the next page show Arctic sea-ice concentration in March and the following September in 2001 and 2007. The black circle at the centre of each image is a blind spot north of which satellite sensors are unable to collect data. The sea-ice estimates from the National Snow and Ice Data Center and the NASA archive for sea-ice data, assume that this area is ice-filled. The outline on each image shows the median sea-ice extent observed by satellite sensors in March and September from 1979 through 2000. Some areas in the images, such as places along the Greenland coast or in Hudson Bay, may appear partially ice-covered when they actually were not.

This time series is made from a combination of observations from the Special Sensor Microwave/Imagers (SSM/Is) flown on a series of Defense Meteorological Satellite Program missions and the Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E), a Japanese-built sensor that flies on the NASA Aqua satellite. These sensors measure microwave energy radiated from the Earth's surface. Scientists use the observations to map sea-ice concentrations, as sea ice and open water emit microwaves differently.



NASA EARTH OBSERVATORY

Arctic sea ice images taken in March and September 2001 (figures on the left), and March and September 2007 (figures on the right). These images were extracted from a time series beginning in September 1999 and ending in March 2011. They are available at http://earthobservatory.nasa.gov/Features/WorldOfChange/sea_ice.php.

ACTIVITIES OF UNITED NATIONS ORGANIZATIONS

The one-metre resolution image of the Dolomite Mountains (Dolomiti) on the facing page was collected on 25 October 2000 by Space Imaging's IKONOS satellite. The image features Italy's breathtaking Alps located approximately one hour's drive north of Venice. The Dolomites are comprised of sheer rock walls forming 1 000-metre, needle-like pinnacles, large limestone plateaus, deep verdant valleys, alpine meadows and villages, and the emerald green Lake Misurina, known as the "pearl of the Dolomites".

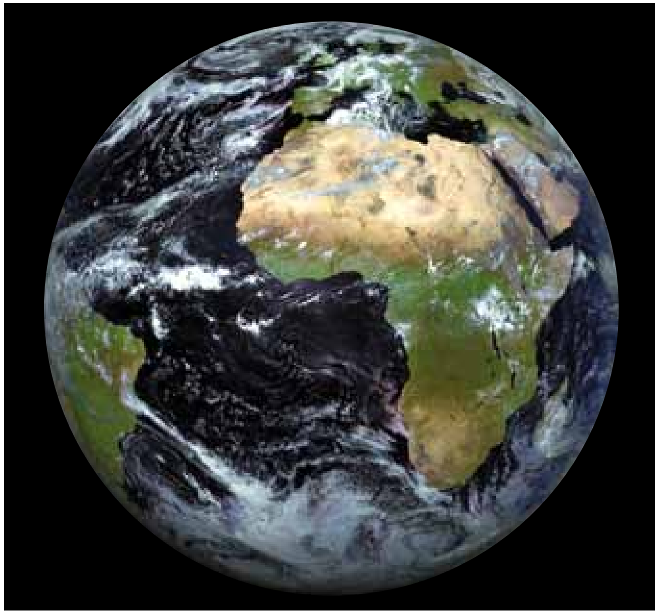
ECONOMIC COMMISSION FOR AFRICA

http://www.uneca.org

The Economic Commission for Africa (ECA), the African Union and the African Development Bank have initiated a programme to ensure that adequate information is available to develop policies on climate issues. The programme includes the establishment of an African climate policy centre at ECA.

The Economic Commission for Africa is implementing a geospatial database, which, in addition to collecting data directly, relies on datasets gathered by other agencies and the national offices of Member States, taking into account a distributed database architecture that provides access to the cooperating databases. ECA Member States endorsed the provision of assistance to African countries and institutions to implement Web-based services to enable the transparent sharing of geospatial data and services on climate change issues.

In cooperation with the Institute for Global Mapping and Research of the European Academy of Sciences and Arts, ECA is developing a pan-African atlas focusing on land- and water-related data in order to address issues such as food security, land degradation, water management, disaster risk management and climate change adaptation. This pan-African atlas, in addition to providing relevant data and information on different sectors, will support research, training and decision-making on the continent, and facilitate risk mapping for

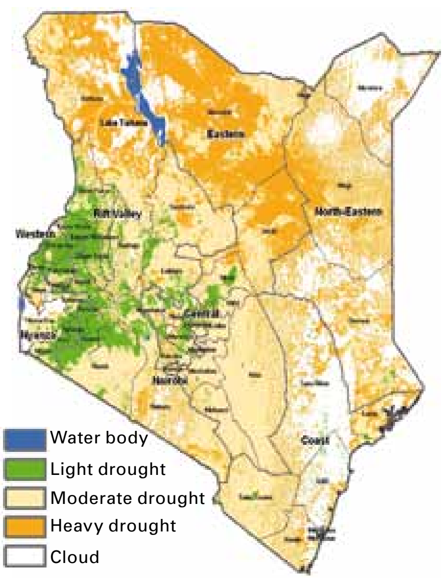


EUMETSAT

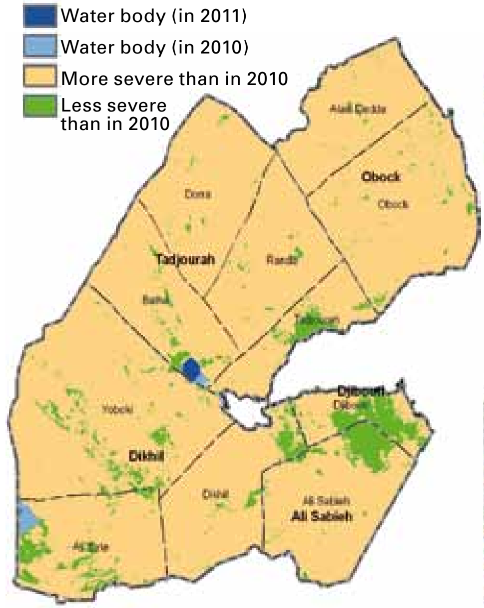
View from space of Africa and the Atlantic Ocean, displaying spectacular cirrus clouds over Algeria.

prevention and preparedness, disaster management, risk reduction, and mitigation of climate change impacts. Efforts include the establishment of a data warehouse and an online atlas accessible continent-wide through nodes in subregions, centres of excellence, national focal points and the academic community.

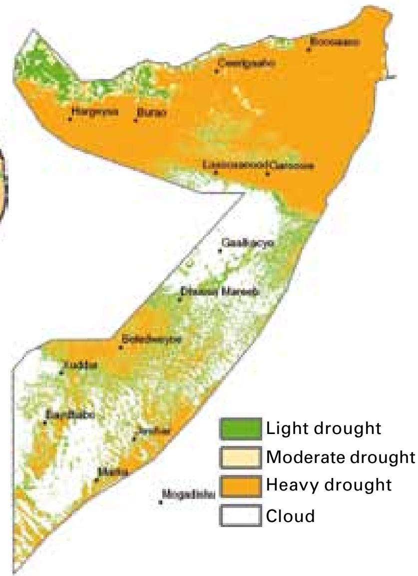
Drought monitoring with MODIS in Kenya



Drought monitoring with MODIS in Djibouti



Drought monitoring with MODIS in Somalia



Satellite imagery has been used to assess drought conditions in the Horn of Africa since July 2011. Based on NDVI analysis, the map of Kenya (left) shows that about 29.4 per cent of the country is in heavy drought (dark orange areas), 37.9 per cent is in moderate drought (light orange areas), and 8.3 per cent is in light drought (green areas). The rest of the country is covered by clouds (white areas). The map of Djibouti (centre) shows that most of the country is severely affected by drought compared to 2010. The water area of Lake Abbe and Lake Asal in 2011 (dark blue areas) has shrunk by 65.2 per cent compared to 2010 (light blue areas). The map of Somalia (right) shows that almost the entire country is in drought, with 49.8 per cent of the country in heavy drought (orange areas), 7.5 per cent in moderate drought (pale yellow areas) and 13.5 per cent in light drought (green areas).

PRODUCED BY THE NATIONAL DISASTER REDUCTION CENTRE OF CHINA, MINISTRY OF CIVIL AFFAIRS, BASED ON MODIS IMAGERY

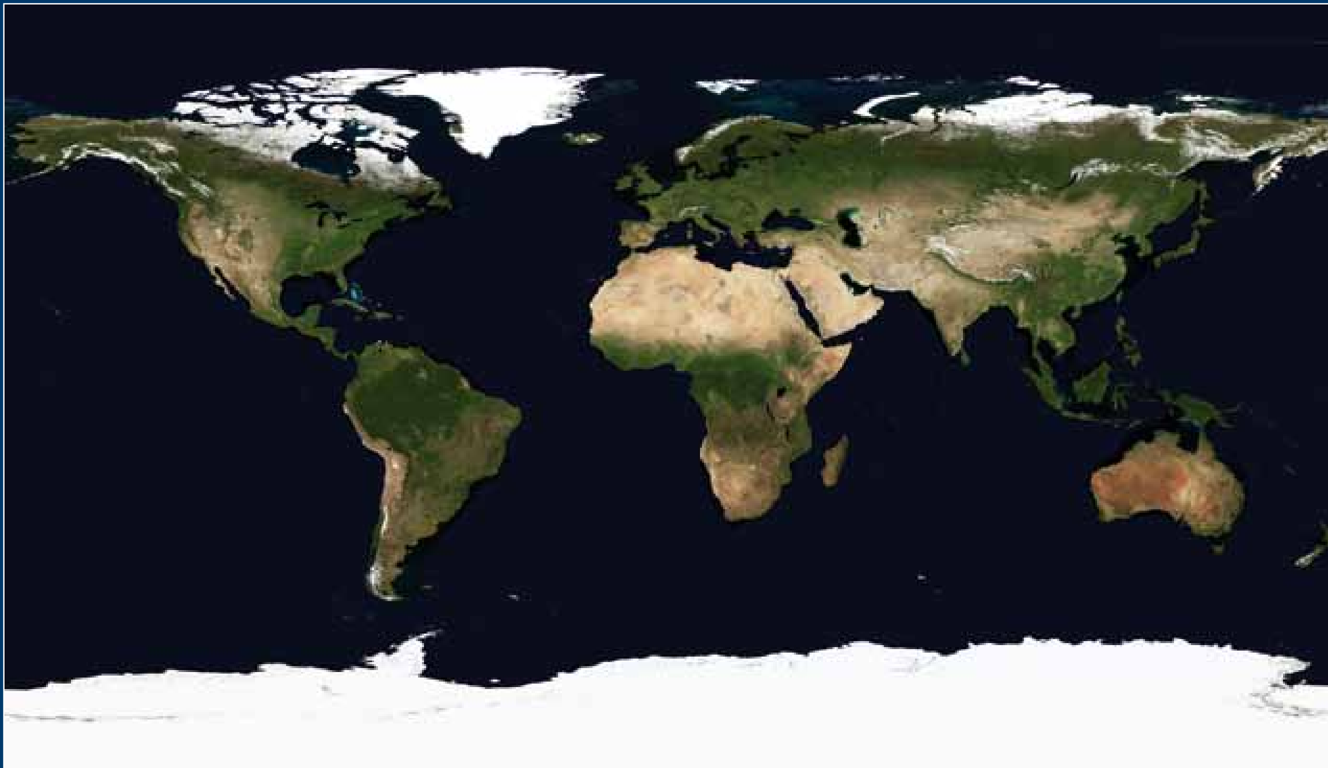
IN FOCUS: SATELLITE FOREST MONITORING

According to the *Fourth Assessment Report* of the IPCC, "the largest growth in Greenhouse Gas (GHG) emissions between 1970 and 2004 has come from energy supply, transport and industry, while [emissions from] residential and commercial buildings, forestry (including deforestation) and agriculture sectors have been growing at a lower rate." The report also states that 17.3 per cent of CO_2 emissions are produced by deforestation and decay of biomass and peat.

Recognizing the need to offer developing countries incentives to reduce emissions from forested lands and to invest in low-carbon paths for sustainable development, FAO, the United Nations Development Programme (UNDP) and UNEP joined forces to launch a mechanism called *Reducing Emissions from Deforestation and Forest Degradation in Developing Countries* (REDD+: www.un-redd.org). Within REDD+, FAO supports countries on technical issues, such as measurement, reporting and verification of carbon emissions and flows, and greenhouse gas inventories. The support includes assisting countries to make use of the Satellite Forest Monitoring System (SFMS) to assess forest extent and change, to elaborate greenhouse gas and forest inventories, and to estimate anthropogenic emissions by sources and removals by sinks.

The strengths of remote-sensing observations stem from their ability to provide spatially explicit information and repeated coverage encompassing large and/or remote areas that are difficult to access otherwise. Archives of remote-sensing data span several decades and therefore can be used to reconstruct past time series of many variables, including land cover and land use. FAO helps countries establish SFMSs, which are based on technology developed by the Brazilian Space Agency (the National Institute for Space Research, or INPE), to support their Amazon monitoring systems. Outputs expected from data acquired through SFMSs are:

- annual rate of gross deforestation at the national level;
- annual rate of forest degradation at the national level;
- a spatially explicit forest database with the identification of annual changes in forest cover;
- bi-weekly georeferenced information on forested area undergoing change (natural or anthropogenic).


NASA EARTH OBSERVATORY

Natural-colour NASA Terra MODIS image for the period from 1 July to 1 August 2004

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

http://www.fao.org

Assessments of land cover and land-cover changes, including land-cover dynamics, are recognized as essential requirements for the sustainable management of natural resources, environmental protection, food security and humanitarian programmes. The Food and Agriculture Organization of the United Nations (FAO) and UNEP have jointly initiated the Global Land Cover Network (GLCN). This network (www.glcn.org) is an international collaboration for developing a fully harmonized approach to create the accessible, reliable and comparable baseline land-cover data that are required by local, national and international initiatives. The GLCN aims to increase the availability of reliable and standardized information on land cover; to promote harmonization and dissemination of methodologies, products and services; and to facilitate the development and implementation of land-cover mapping and monitoring initiatives. Regional collaborative networks have been, and are being, established for East, West and Southern Africa, South and Central America, the Middle East, and South-East and Central Asia.

Data from Earth observation satellites are used by FAO for food security early warning systems. In this regard, FAO established ARTEMIS to provide a routine flow of satellite imagery in near real time indicating the status of the growing season and vegetation development over Africa. The ARTEMIS system is capable of receiving and processing around 100 Mb of satellite data per day, and most ARTEMIS products are generated at a 7.6 km spatial resolution. Since May 1999, these products have been synthesized for the entire terrestrial surface of the globe with SPOT-4 VEGETATION Normalized Difference Vegetation Index (NDVI) data at 1 km resolution. These products are used mainly in the field of early warning for food security, in particular, by the Global Information and Early Warning System (GIEWS) on food and agriculture and for agriculture production forecasts. In past years, the products were also used by the Emergency Centre for Locust Operations (ECLO), the Emergency Prevention System (EMPRES) for Transboundary Animal and Plant Pests and Diseases, and the Programme Against African Trypanosomiasis (PAAT). Current external users of ARTEMIS products are the World Food Programme (WFP) food security analysis service and the Southern African Development Community through its regional remote-sensing unit.

Currently ARTEMIS delivers several products to FAO and external users, as shown in the following table.

Products delivered by ARTEMIS			
Source	Product	Output	Users
EUMETSAT	METEOSAT (MSG) and other weather satellite images from high-rate transmission (HRIT): 1/3 km res, 12 spectral channels (IR, Vis and UV), 15-min repeat cycle, Africa/Europe; and low-rate transmission (LRIT): 5 km res, 5 spectral channels, global composite (every 3 hrs)	Europe/Africa 1 km (HRV)/3 km res images, 15 min cycle; global composite 4 km image, 3 hrs	FAO/NRC
EUMETSAT	FAO rainfall estimate (FAO-RFE), decadal and monthly, for Africa, derived from METEOSAT data (FAO METEOSAT receiving system, IR channel, 3 km) and image processing	FAO-RFE (decadal and monthly)	FAO/NRC
USGS	NOAA Geostationary Operational Environmental Satellites (GOES): Interpolated Estimated Decadal Rainfall (IERF) for Africa	Africa Interpolated Estimate Decadal Rainfall	FAO/EST; FAO/NRC
USGS	NDVI (Global Area Coverage) images from NOAA-AVHRR instrument, NASA/GSFC/USGS. Decadal/monthly for Africa	Decadal/monthly NDVI for Africa (IDA format)	FAO/EST; FAO/NRC
VITO NV	SPOT-4 VEGETATION (1 km) images and derived products		

FAO hosts the Global Fire Information Management System (GFIMS), which integrates remote-sensing and Geographical Information System (GIS) technologies to deliver Moderate Resolution Imaging Spectroradiometer (MODIS) hotspot/fire locations and burned-area information to natural resource managers and other stakeholders around the world.

The FAO Rainfall Estimate Routine (FAO-RFE) is a new, independent method to estimate the rainfall amount, particularly in certain regions where the coverage of weather stations is scarce. FAO-RFE is based on the Meteosat Second-Generation (MSG), infrared channel, combined with data from the global forecast model of the European Centre for Medium-Range Weather Forecasts (ECMWF) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). A local calibration is performed using surface gauges. FAO-RFE offers 10-day and monthly rainfall totals for the whole of Africa and for four other regions (http://geonetwork3.fao.org/climpag/FAO-RFE.php). The methodology is transferred to national meteorological agencies on demand.

Another methodology employed by FAO, which combines information derived from historical disasters with current remote-sensing data, improves the mitigation of tropical cyclone impacts and supports special actions to be taken both during and immediately following an event. The FAO Rapid Agricultural Disaster Assessment Routine (RADAR) has been used, for instance, to assess the impact of Hurricane *Mitch* on the agricultural production system in Honduras (http://www.fao.org/nr/climpag/nat_1_en.asp) as a way to plan response measures quickly. The use of products derived from remote-sensing applications enhances the effectiveness and accuracy of emergency planning operations.

INTERNATIONAL TELECOMMUNICATION UNION

http://www.itu.int

The International Telecommunication Union (ITU) is the specialized United Nations organization responsible for telecommunications/information and communication technologies (ICTs), including space technologies. ITU also focuses on the use of ICTs to target climate change. The goals of ITU are to provide governments and the private sector with ways and means to use ICTs as a vital component in climate monitoring, climate change mitigation and adaptation to climate change.

Radio-based remote sensors (active and passive) are the main tools for climate monitoring and climate change prediction. These satellite-borne sensors obtain information on the environment on a global basis by measuring the levels and parameters of natural and artificial radio waves, as these inherently contain information about the environment with which they have been in contact. Earth observation and meteorological satellite systems form the backbone of the WMO Global Observing System, and other satellite systems (fixed, broadcasting and mobile) are used for information dissemination around the world. The global monitoring of greenhouse gases is also performed by remote sensors on board satellites. Satellites can observe the concentration and distribution of GHGs, and monitor their absorption and emission. One of the first satellites dedicated to monitoring gases in the Earth's atmosphere that contribute to global warming – the GHG Observing Satellite (GOSAT) – was launched in 2009 by the Japan Aerospace Exploration Agency (JAXA). In the future, such satellites could be used to monitor the implementation of international treaties (for example, the Kyoto Protocol).

JAPAN AEROSPACE EXPLORATION AGENCY

GHG Observing Satellite GOSAT (http://jda.jaxa.jp/)

Data and information obtained by climate monitoring and climate change forecasting systems are used to build national and international strategies to mitigate the negative effects of climate change. Often, satellite communications are still able to function immediately following a disaster, when terrestrial systems have been significantly damaged or destroyed. Satellites can serve to assess the extent of damage, help locate survivors, measure the danger for rescue teams and ensure that response crews can communicate.

Satellite communications, accessed through hand-held devices, are increasingly used during disasters.

As the steward of radio-frequency spectrum/satellite orbits, and as the global telecommunication standardization body, ITU creates regulatory and technical bases for the development and effective operation of satellite climate monitoring and data dissemination systems by:

- allocating the necessary radio frequency spectrum/satellite orbit resources;
- analysing compatibility between new and existing satellite systems;
- carrying out studies and developing treaty-status (Radio Regulations) and voluntary (ITU Recommendations) international standards for space-based and other telecommunication systems/networks;
- providing guidance on the use of satellite systems for environmental monitoring and for the prediction and mitigation of negative effects of disasters caused by climate change;
- cooperating with the ITU Member States, United Nations organizations, space agencies and operators, among others.

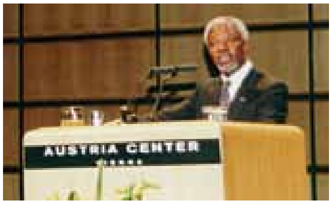
UNITED NATIONS

OFFICE FOR OUTER SPACE AFFAIRS

UNOOSA

http://www.unoosa.org

Efforts on climate change conducted by the United Nations Office for Outer Space Affairs (UNOOSA) are traced to the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in Vienna in 1999, at which Member States recognized the contribution of space science and space applications to the well-being of humanity and development in areas such as disaster management, meteorological forecasting for climate modelling, satellite navigation and communications. Such recognition led to a proposal for the nucleus of a strategy to address global challenges in the future. The proposal highlighted, among other areas, the protection of Earth's environment, the management of its resources, the use of space applications for human security, development and welfare – including natural disaster mitigation, relief and prevention efforts – and the strengthening of the coordination of space activities in the United Nations system.



UNOV

Mr Kofi Annan, then Secretary-General of the United Nations, opening the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) in 1999

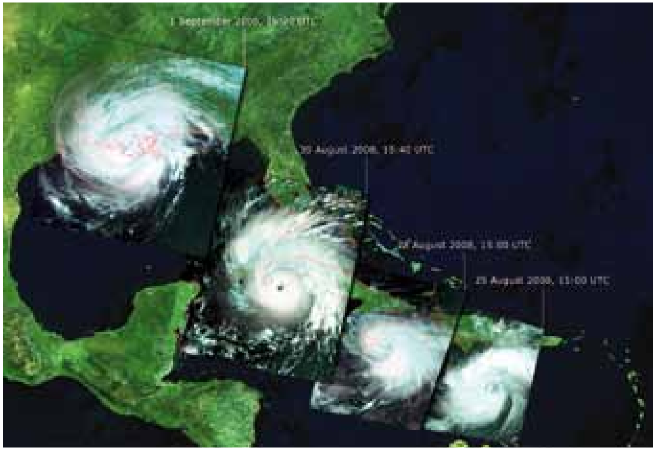
In 2006 the Office launched the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) which promotes the use of space-based information to support activities conducted during all phases of the disaster management cycle.

In recent years, the Office has been conducting a variety of activities to build capacity and raise awareness with regard to a range of topics, including:

- use of space technology for water management;
- integrated space technology applications to monitor climate change impacts on agricultural development and food security;
- integrated space technology applications for environmental protection and disaster vulnerability mitigation;

- integrated space technologies and space-based information for analysis and prediction of climate change.

The Office has also conducted symposiums on topics related to climate change under the Scientific and Technical and Legal Sub-Committees of the Committee on the Peaceful Uses of Outer Space (COPUOS). Climate change is now a regular agenda item in the political negotiations conducted on a yearly basis under COPUOS, and the Office is also contributing extensively to addressing this topic within the IAM on Outer Space Activities.



EUROPEAN SPACE AGENCY

This sequence of Envisat images shows the development and path of Hurricane Gustav *on 25 August, 28 August, 30 August and 1 September 2008 (from right to left). Instruments aboard the ESA satellite allow it to observe various features of hurricanes, including high-atmosphere cloud structure and pressure, wind pattern and currents at sea level, and oceanic warm features that contribute to the intensification of hurricanes.*

The four main directions proposed as part of the UNOOSA climate change strategy are:

- to promote the effective use of space solutions to address the challenges of climate change;
- to enhance international cooperation in space science and technology, and its applications in areas related to climate change;
- to strengthen the capacity of Member States, especially those that are developing countries, to use the results of space research in the context of climate change;
- to provide technical advisory services on space technology applications in climate change-related projects, upon request by Member States.

Activities under this strategy include conducting workshops in different regions of the world, developing tools and methods to make better use of space-based applications in the area of climate change and increasing capacity-building efforts.

IN FOCUS: SEA LEVEL RISE

A large proportion of the world's population lives in coastal areas, including in megacities such as Hong Kong, China, Jakarta and Tokyo. Therefore, it is important to address the way in which sea level rise will affect such areas and their inhabitants.

The IPCC *Fourth Assessment Report*[9] indicates that increases in sea level are consistent with warming. Global average sea level rose at an average rate of 1.8 (1.3 to 2.3) mm per year from 1961 to 2003 and at an average rate of about 3.1 (2.4 to 3.8) mm per year from 1993 to 2003. It is unclear whether the faster of these rates reflects decadal variation or an increase in the longer-term trend. Since 1993, thermal expansion of the oceans has accounted for about 57 per cent of estimated individual contributions to sea level rise, with decreases in glaciers and ice caps contributing about 28 per cent and losses from the polar ice sheets responsible for the remainder. From 1993 to 2003, the sum of these climate contributions is consistent within the context of uncertainties regarding the total sea level rise that is directly observed.

Satellites offer a unique perspective from which to track sea level rise on a global scale using satellite altimetry measurements. Such measurements indicate that the annual rate of sea level rise is not uniform across the globe. In fact, small island developing States in the Pacific, New Zealand, Malaysia, the Philippines, and Eastern Asia appear more affected than the Pacific coasts of North and South America (see facing page, figure on left).

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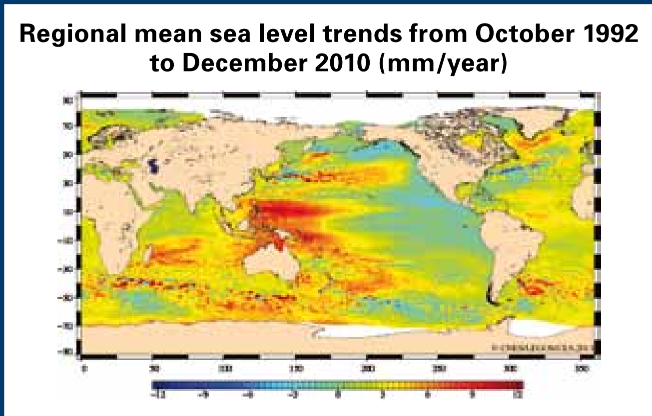
9 IPCC (2007): *Climate Change 2007: Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change*.



CNES/CLS/LEGOS

Although the global trend indicates a rise in the mean level of the oceans, there are marked regional differences that vary between –10 and 10 mm/year. A map of these regional trends can be obtained using gridded, multi-mission Ssalto/Duacs data since 1993, which enable the local slopes to be estimated with a very high resolution (1/3 of a degree on a Mercator projection). Isolated variations are thus revealed, mainly in the major ocean currents. The trends highlighted with this map are due not only to global climate change, but also to local/interannual variations in the sea surface height.

SPACE IMAGING

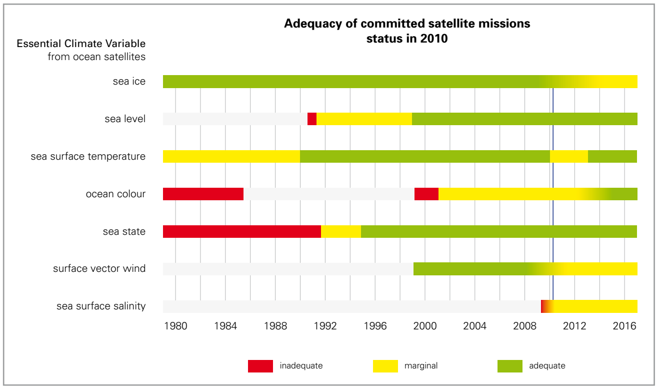
This four-metre resolution image of Bora Bora (meaning "First Born") was collected by Space Imaging's IKONOS satellite on 25 October 2000. The image centres on Bora Bora's main island, referred to as "The Marvelous Island", located 240 kilometres northwest of Tahiti. More than seven million years old, the island is protected by a coral reef with only one navigable inlet, visible on the left side of the image. Other features include Matira beach and its world-famous lagoon, the principal village of Vaitape, across from the inlet, and a 32-kilometre road circling the island.

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

http://ioc-unesco.org

With oceanography advancing from a science that deals mostly with local processes to one that also includes the study of the ocean basin and global processes, researchers and a wide spectrum of users critically depend on access to an international exchange system to provide data and information from all available sources.

The Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO IOC) was established in 1960 to facilitate such an exchange system and to promote international cooperation and coordination of programmes in marine research, services, observation systems, hazard mitigation and capacity development. The role that satellites play in ocean observations has been critical in showing the spatial variability of many of the ocean ECVs, given the difficulty and expense of in situ oceanic observations. In this regard, the adequacy of committed satellite missions from 1980 to 2016 is shown ECV by ECV in the figure below. While the situation has improved since the 1980s, more remains to be done for selected ECVs.

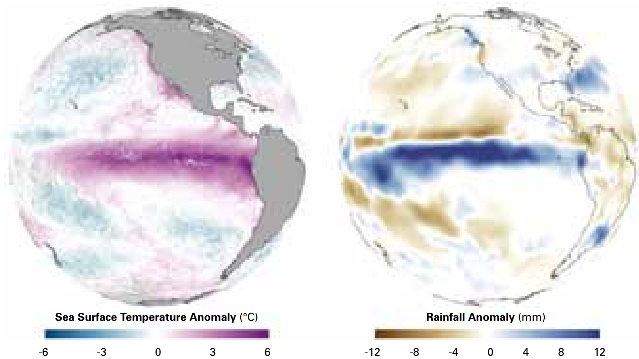


Perhaps nowhere is the intricate relationship between the ocean and the atmosphere more evident than in the eastern Pacific. The ocean's surface cools and warms cyclically in response to the strength of the trade winds. In turn, the changing ocean alters rainfall patterns.

The figures on the following page show images of the sea surface temperature (SST) anomaly and of the rainfall anomaly in December 1997. The SST anomaly image is made from data collected by the Advanced Very High Resolution Radiometer (AVHRR) between 1985 and 2008.

The anomaly is calculated as the difference between the SST average value for December 1997 and the long-term average of SST observed between 1985 and 2008. The rainfall anomaly image is a product from the Global Precipitation Climatology Project (GPCP), which blends rainfall data from a number of satellites. The anomaly is calculated as the difference between the rainfall average value for December 1997 and the long-term average of rainfall for December between 1979 and 2008. Changes in rainfall echo changes in SST. For example, positive anomalies of SST (pink areas) correspond to positive anomalies of rainfall (blue areas), emphasizing the interplay between ocean and atmosphere. The unusually warm waters are dark purple in the sea surface temperature anomaly image, indicating that the waters were as much as 6°C warmer than average. Also, the corresponding streak of dark blue in the rainfall anomaly image reveals that in December 1997, as much as 12 millimetres more than average fell over the warmed eastern Pacific. The unusual rainfall extended into north-western South America (Ecuador and Peru). The disruption in the atmosphere affects rainfall throughout the world. In the United States, the strongest change in rainfall is in the south-eastern part of the country. During El Niño years, such as 1997, the South-east receives more rain than average. Many people recognize the extreme ends of the spectrum, El Niño and La Niña, by the intense rains and severe droughts each brings to different parts of the world.

El Niño, La Niña and rainfall



Sea surface temperature anomaly and rainfall anomaly for December 1997. The anomaly values are calculated from long-term averages inferred from satellite observations (see text). Images for all months of December between 1985 and 2008 are available at: http://earthobservatory.nasa.gov/Features/WorldOfChange/enso.php.

NASA EARTH OBSERVATORY

UNITED NATIONS ENVIRONMENT PROGRAMME

UNEP

http://www.unep.org

In 2005, the United Nations Environment Programme (UNEP) published *One Planet Many People: Atlas of Our Changing Environment*, which presented hundreds of examples of environmental change as annotated "before and after" comparisons of Landsat images over previous decades, some of which relate directly to regional and global climate change. One example is the area spanning the border between Kenya and the United Republic of Tanzania, which is directly dependent on groundwater discharge from Kilimanjaro. Another example of significant change is in the Lake Faguibine area (see figure on next page). In the 1970s, Mali's Lake Faguibine, one of the largest lakes in Africa, was an important source of water for the surrounding area. An extended period of reduced precipitation in the late 1980s led to a complete drying up of the lake in the 1990s. Despite relatively normal rainfall in recent years, Lake Faguibine remains nearly dry. This change has prompted high-level national action to rehabilitate the lake's supply and to ensure its more sustainable use. The success of the UNEP atlas and its proven appeal as a format for communication with policymakers and the general public have spawned numerous follow-on products for Africa, in which satellite images are used

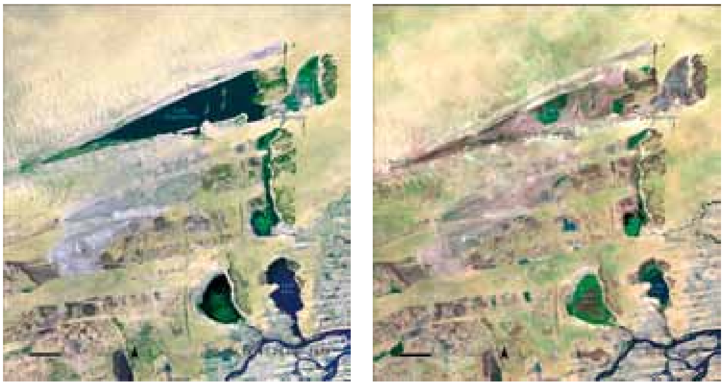
EUROPEAN SPACE AGENCY

The Bahamas as acquired on 24 January 2004 by the Medium Resolution Imaging Spectrometer (MERIS) aboard Envisat. This full-resolution image stretches from the southern tip of the Florida Peninsula and the Florida Keys down to the southern coast of Cuba, with the islands of the Bahamas and the shallow blue waters around them seen to the right.

to highlight environmental change driven by climate-related factors and other causes.

The Nairobi Convention provides a mechanism for regional cooperation, coordination and collaborative actions among the countries sharing the waters of the western Indian Ocean. UNEP is currently supporting national-level planning through analysis of coastal zone impacts of climate change on mangrove distribution and health in Mozambique, Kenya and the United Republic of Tanzania. These studies gauge the extent of the impact and the shifting patterns of exploitation from climate-induced changes. Landsat and Quickbird images are being combined with high-resolution aerial survey photos to provide a longitudinal analysis of how these commercially and environmentally important ecosystems are being affected.

Lake Faguibine in 1978 (left) and 2006 (right)



When Mali's Lake Faguibine is full, it is among the largest lakes in West Africa – it covered an estimated 590 km^2 in 1974 – and it is an important source of water for the surrounding area. The lake is at the end of a series of basins that receive water from the Niger River when it floods. Thus, water levels in Lake Faguibine are closely tied to the flow of the Niger River. A lack of rainfall in the catchments of either the lake or the river can affect water levels in Lake Faguibine. Water levels have fluctuated widely in Lake Faguibine since the beginning of the twentieth century. An extended period of reduced precipitation in the late 1980s, however, led to a complete drying up of the lake in the 1990s, making the traditional livelihoods of fishing, agriculture and pastoralism difficult if not impossible. Despite relatively normal rainfall in recent years, Lake Faguibine remains nearly dry (http://www.unep.org/dewa/africa/africaAtlas/graphics/).

AFRICA: ATLAS OF OUR CHANGING ENVIRONMENT © UNEP

WORLD FOOD PROGRAMME

http://www.wfp.org

The World Food Programme (WFP) uses vegetation indices and rainfall data obtained from moderate- to low-resolution Earth observation satellites to monitor the agricultural season and to identify threats to food security. A key factor for this type of analysis is the availability of medium- to long-term time series of Earth observation data, which allows for the identification of areas with significant interannual variability and trends in key diagnostic factors (biomass productivity proxies, growing-season timing, and so forth). The ongoing monitoring process generates critically important data and information that enable WFP and its partners (governments, national and regional institutions and non-governmental organizations) to implement extensive food security planning.

Analysis performed by WFP also embraces potential food security risks emerging from environmental and socio-economic vulnerability to climate variability and projected climate change impacts at the country and regional levels. Low-resolution Earth observation data (obtained through MODIS, for example) are being used in combination with food security and vulnerability data to monitor and anticipate the potential impacts of climate-related hazards. Operational decision-making and risk management action are improved through the use of such information.

In collaboration with partners, WFP has been introducing important innovations in risk management at the national level. Working with the Government of Ethiopia and partners such as the World Bank, WFP

SE-CONRED, GUATEMALA

This phogograph shows corn crops affected by drought in Guatemala in 2009.

has recently developed a specialized service supporting national risk management. The Livelihood Enhancement, Assessment and Protection (LEAP) service uses ground and satellite rainfall data to monitor the Water Requirement Satisfaction Index and to quantify the risk of drought or excess rainfall in different administrative units of Ethiopia. The information provided through LEAP supports the Government's decision-making and risk management processes, including the activation of national safety net programmes that ensure protection for millions of food-insecure people who may be affected in various parts of the country.

More recently, WFP has been exploring, in partnership with the African Union Commission, a new continental mechanism, Africa RiskView, which, through satellite data, monitors and quantifies weather-related food security risks in Africa. Africa RiskView should provide information about potential crop losses and guide contingency funding allocations to African Union Member States through the use of a common risk pool.

WORLD HEALTH ORGANIZATION

http://www.who.int

The World Health Organization (WHO) has a long-standing programme on health protection related to climate change that is now organized under a specific resolution adopted by the World Health Assembly.

Climate change has important implications for human health. Some of the largest contributors to the global burden of disease – including malnutrition, infectious diseases, such as diarrhoea and malaria, and weather-related disasters – are sensitive to climate variability and change. Therefore, WHO works to strengthen the essential health system functions that can help protect vulnerable populations from climate-sensitive health impacts, drawing on contributions from a wide range of technical programmes administered through its headquarters and regional and country offices.

The World Health Organization works with partners in the developed and developing world to promote the integration of remotely sensed environmental and Earth science data with in situ public health surveillance data for a better understanding of the relation between potential risk factors and public health outcomes. This includes collaboration with the United Nations Institute for Training and Research Operational Satellite Applications Programme (UNOSAT), UNOOSA/UN-SPIDER and WMO.

Space-based technologies are used to support WHO operational work, such as the mapping of the geographical distribution of meteorological hazards to public health and critical public health infrastructure. For example, the Vulnerability and Risk Analysis and Mapping (VRAM) programme uses remotely sensed and other environmental information and combines it with disaggregated vulnerability and capacity indicators to identify population and health services that may be exposed to hazards, such as floods, droughts and heat-waves, and to enhance disaster risk reduction efforts.

Remote-sensing technology is also well suited for monitoring the dynamic nature of outbreaks and epidemics of infectious diseases, which may often be triggered by extreme weather. WHO uses these technologies to improve outbreak awareness, preparedness and response, and works with a diverse community of partners to provide information and develop models to support preparedness response and control strategies.

The use of remote-sensing has significantly advanced the ability of WHO to track and visualize the real-time evolution of local outbreaks and epidemics, providing support to the daily activities of the WHO Centre for Strategic Health Operations.

WHO also uses geospatial information in its programmes for combating specific diseases, such as Rift Valley fever, yellow fever, cholera, plague and leptospirosis. Notably, the Meningitis Environmental Risk Information Technologies (MERIT) project is a collaborative initiative among WHO and other members of the environmental, public health and epidemiological communities. The project is aimed at reducing the burden of epidemic meningococcal meningitis across Africa's "meningitis belt" by integrating knowledge of environmental influences, such as absolute humidity, absorbing aerosols, rainfall and land cover, to develop a decision-support tool and to inform the current vaccination strategies. The project also serves as an example that may facilitate the use of environmental information in public health decision-making.

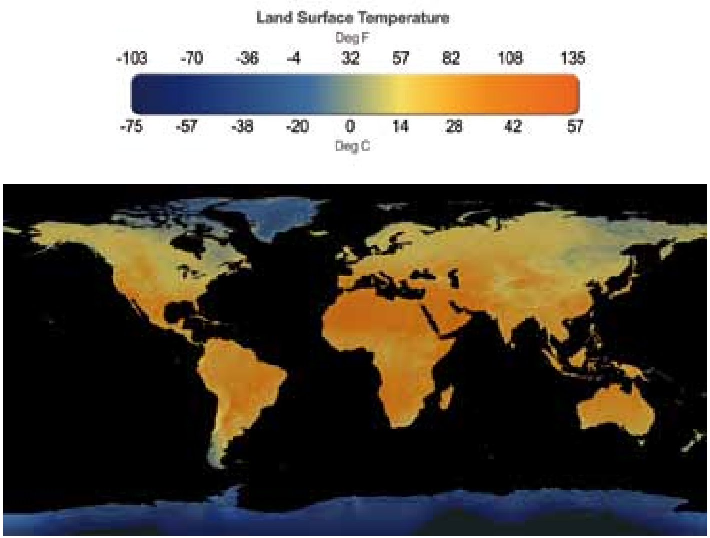

EUROPEAN SPACE AGENCY

Several large smoke plumes originating from burning peat fields and forest fires are visible in this Envisat image, acquired on 29 July 2010, covering the area east of Moscow. The city itself is seen in the bottom left corner of the image. The smoke plumes stretched over several hundred kilometres and, combined with the normal air pollution in the city, caused pollution levels ten times greater than the normal levels for the capital.

IN FOCUS: GLOBAL TEMPERATURE

In 2007, in its *Fourth Assessment Report,*[10] the IPCC stated: "The temperature increase is widespread over the globe and greater at higher northern latitudes. Average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. Land regions have warmed faster than the oceans. Observations since 1961 show that the average temperature of the global ocean

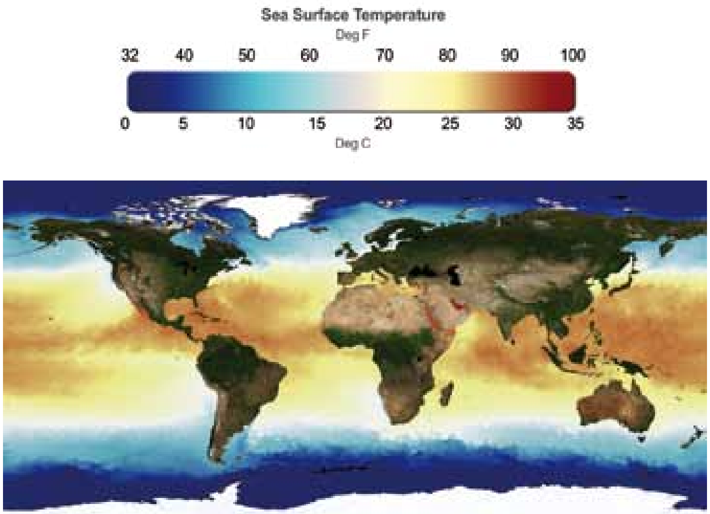
10 IPCC (2007): *Climate Change 2007: Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change.*



NOAA

Land surface temperatures derived from satellite measurements on 18 September 2011. Land surface temperature is greatly influenced by land use and cover: bare or sparsely vegetated lands such as deserts are able to heat up to much greater temperatures than forested areas at the same latitude. These daily data plots are generated by averaging all of the data collected by the NOAA Advanced Microwave Sounding Unit (AMSU) and Defense Meteorological Satellite Program (DMSP) SSM/I microwave sensors from four different polar-orbiting satellites over a 24-hour period. Blue areas are cool and orange areas are warm.

has increased to depths of at least 3 000 metres and that the ocean has been taking up over 80 per cent of the heat being added to the climate system. New analyses of balloon-borne and satellite measurements of lower- and mid-tropospheric temperature show warming rates similar to those observed in surface temperature." Satellites offer an efficient way to monitor the temperature of the oceans, thereby providing data to assess ocean–atmosphere interactions. These assessments are essential in the context of climate change.



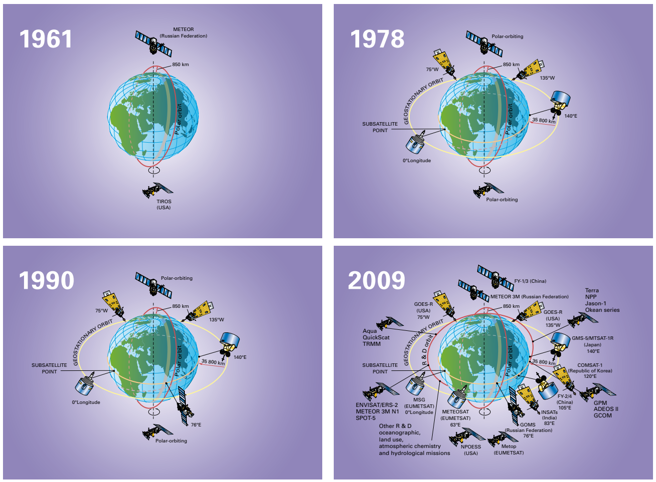
Sea surface temperatures derived from satellite measurements on 18 September 2011. Each day, the ocean absorbs enormous amounts of energy from the Sun. This heat is moved through the ocean via large-scale circulation processes, fast-moving currents, and small whirling eddies. Not only does the heat stored in the ocean affect its inhabitants, but also greatly influences the atmosphere above, including the Earth's weather and climate. Satellites are able to monitor the temperature of the ocean's surface, also known as sea surface temperature. This image is generated on a daily basis using SST data from a variety of polar-orbiting and geostationary satellites.

NOAA

WORLD METEOROLOGICAL ORGANIZATION

http://www.wmo.int

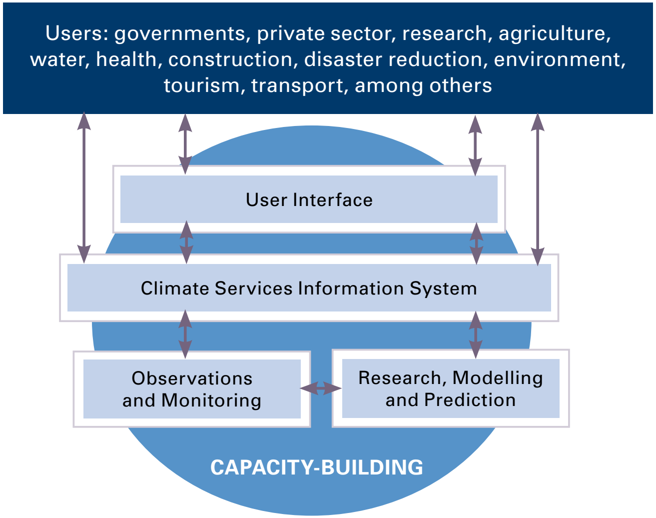
The World Meteorological Organization (WMO) is the specialized agency of the United Nations with a mandate for weather, water, climate and related environmental matters. Through the network of National Meteorological and Hydrological Services (NMHSs) of its 189 Members, WMO plays an important role in weather and climate observation and monitoring, understanding climate processes, the development of information and predictions, and the provision of sector-specific climate services.



This figure shows the evolution of the space-based global observing system.

These observations are underpinned by an international Global Observing System (GOS) that has grown substantially since 1961 and now includes constellations of operational satellites in geostationary and low-Earth orbit, as well as research and development satellites. Since 1993, WMO has issued annual statements on the status of the global climate, which describe climatic conditions, including extreme weather events, and it has provided a historical perspective on the variability and trends that have occurred since the nineteenth century. This information, which is contained in the statements, enhances the scientific understanding of climate variability and the associated impacts that affect the well-being, properties and lives of people around the world.

Between 1979 and 2009, WMO organized three World Climate Conferences, which have influenced the establishment of a number of important scientific initiatives, including the IPCC, which is co-sponsored by UNEP and WMO and received the Nobel Peace Prize in 2007;

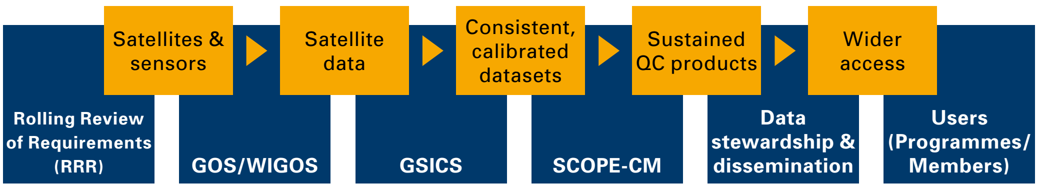


GFCS overview

GCOS, which is co-sponsored by UNEP, UNESCO IOC, WMO and ICSU; the WMO World Climate Programme (WCP); the World Climate Research Programme (WCRP), which is co-sponsored by UNESCO IOC, WMO and ICSU; and, most recently, an agreement to create a Global Framework for Climate Services (GFCS) based on a strong foundation of observations that include surface, airborne and space-based observations.

Of particular relevance to climate monitoring is the Global Space-based Inter-calibration System (GSICS), which ensures consistency of satellite measurements from different satellite operators and different programmes over time through cross-calibration against reference instruments and calibration targets.

The work of WMO includes activities along a continuum, from requirements to users (see figure below). Activities include the gathering and articulation of requirements, which is something that is done by GCOS, among others, as well as the compilation of observations from the contributing space agencies, the intercalibration of these observations, product generation activities, such as SCOPE-CM, data distribution and dissemination efforts, and, finally, training and capacity efforts, such as the WMO-CGMS Virtual Laboratory for Training and Education in Satellite Meteorology (VLab), which ensures that WMO Members and their partners can benefit from these space-based observations.



This illustration shows the continuum from requirements to users.

NASA

ACTIVITIES OF OTHER ORGANIZATIONS

The figure on the facing page shows Maupiti Island, spanning less than 10 kilometres, and located in the South Pacific Ocean, about 46 kilometres west of Bora Bora. The remote island lies 5 800 kilometers from Australia, and about 3 800 kilometres from New Zealand. Maupiti consists of a central island poking 213 metres above the sea surface, framed by low-profile serpentine islands and coral reefs that enclose a lagoon. The image was captured with the Advanced Land Imager (ALI) on the NASA EO-1 satellite.

INTERNATIONAL COUNCIL FOR SCIENCE

http://www.icsu.org

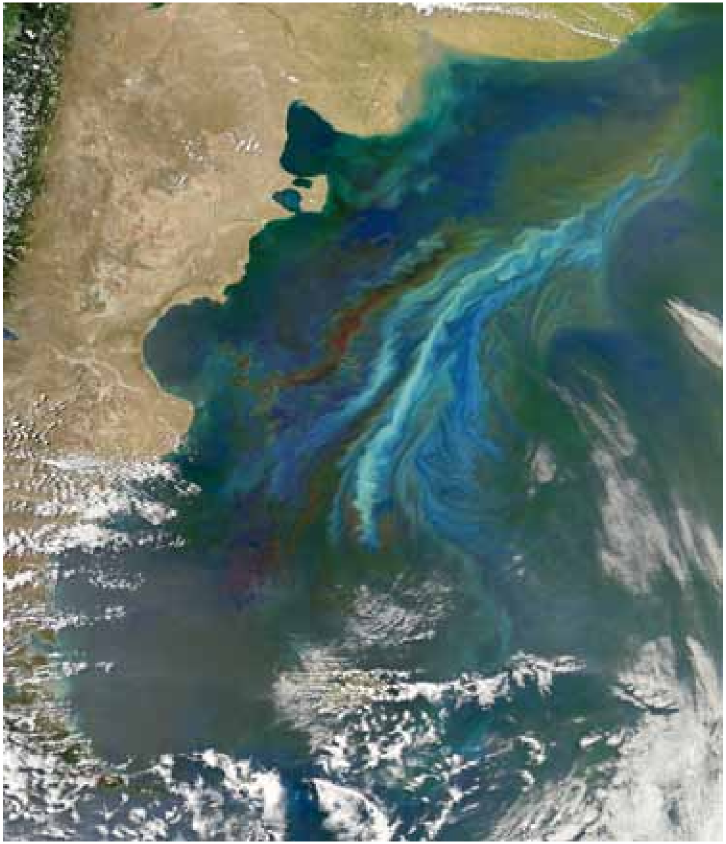
The International Council for Science (ICSU) has a long tradition of cooperation with several United Nations organizations in scientific activities and programmes addressing climate change. Most of these activities and related programmes make full use of available space technologies. ICSU co-sponsors GCOS, GOOS and GTOS, global environmental change research programmes and the following climate-related programmes addressing climate change and/or its impacts:

- WCRP;
- International Geosphere-Biosphere Programme (IGBP);
- DIVERSITAS (international biodiversity research programme);
- International Human Dimension Programme (IHDP) of Global Environmental Change;
- Earth System Science Partnership (ESSP), established by WCRP, IGBP, DIVERSITAS and IHDP;
- Integrated Research on Disaster Risk (IRDR);
- Programme on Ecosystem Change and Society.

The Committee on Space Research (COSPAR) was created by ICSU in 1958. It is the most notable undertaking of its kind in that it encompasses all disciplines of space research, from Earth sciences to astronomy, planetary exploration, solar physics, plasma and magnetosphere studies, life sciences, microgravity and fundamental physics.

The COSPAR scientific assemblies provide an opportunity for the regular exchange of up-to-date scientific information on all disciplines of space research. Issues discussed include space and global change, science and technology in global Earth observation, and solar variability, cosmic rays and climate. Additional information is available on the COSPAR Web page at http://www.cospar-assembly.org/.

NASA EARTH OBSERVATORY



The Moderate Resolution Imaging Spectroradiometer (MODIS) on the NASA Aqua satellite captured this image of a massive phytoplankton bloom off the Atlantic coast of Patagonia on 21 December 2010. Scientists used seven separate spectral bands to highlight the differences in the plankton communities across this swath of ocean.

ACRONYMS AND ABBREVIATIONS

AMSR-E	Advanced Microwave Scanning Radiometer for Earth Observing System
ARTEMIS	Africa Real Time Environmental Monitoring System
AVHRR	Advanced Very High Resolution Radiometer
CEB	United Nations System Chief Executives Board
CEOS	Committee on Earth Observation Satellites
CGMS	Coordination Group for Meteorological Satellites
COP	Conference of the Parties (UNFCCC)
COPUOS	Committee on the Peaceful Uses of Outer Space
COSPAR	Committee on Space Research
ECA	Economic Commission for Africa
ECLO	Emergency Centre for Locust Operations
ECMWF	European Centre for Medium-Range Weather Forecasts
ECVs	Essential Climate Variables
EMPRES	Emergency Prevention System
ESA	European Space Agency
ESSP	Earth System Science Partnership
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAO	Food and Agriculture Organization of the United Nations
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
GCMPs	GCOS Climate Monitoring Principles
GCOS	Global Climate Observing System
GIEWS	Global Information and Early Warning System
GFCS	Global Framework for Climate Services
GIS	Geographical Information System
GLCN	Global Land Cover Network
GOOS	Global Ocean Observing System
GOS	Global Observing System
GOSAT	Greenhouse Gas Observing Satellite
GSFC	Goddard Space Flight Center (NASA)
GSICS	Global Space-based Inter-calibration System
GTOS	Global Terrestrial Observing System
IAM	Inter-Agency Meeting on Outer Space Activities
ICSU	International Council for Science
ICTs	Information and Communication Technologies
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimension Programme
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IRDR	Integrated Research on Disaster Risk
ITU	International Telecommunication Union
JAXA	Japan Aerospace Exploration Agency
LAI	Leaf Area Index
LEAP	Livelihood Enhancement, Assessment and Protection

MERIS	Medium Resolution Imaging Spectrometer
MERIT	Meningitis Environmental Risk Information Technologies
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NMHSs	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
OOPC	Ocean Observations Panel for Climate
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis
PAAT	Programme Against African Trypanosomiasis
RADAR	Rapid Agricultural Disaster Assessment Routine
REDD	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
RFE	Rainfall Estimates
SBSTA	Subsidiary Body for Scientific and Technological Advice
SCOPE-CM	Sustained, Co-Ordinated Processing of Environmental Satellite Data for Climate Monitoring
SFMS	Satellite Forest Monitoring System
SPOT	Système Pour l'Observation de la Terre
SSM/Is	Special Sensor Microwave/Imagers
SST	Sea surface temperature
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNISPACE	United Nations Conference on the Exploration and Peaceful Uses of Outer Space
UNITAR	United Nations Institute for Training and Research
UNOOSA	United Nations Office for Outer Space Affairs
UNOSAT	United Nations Institute for Training and Research Operational Satellite Applications Programme
USGS	United States Geological Survey
VLab	Virtual Laboratory for Training and Education in Satellite Meteorology
VRAM	Vulnerability and Risk Analysis and Mapping
WCP	World Climate Programme
WCRP	World Climate Research Programme
WFP	World Food Programme
WHO	World Health Organization
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization

CONTRIBUTORS

Global observing systems (Global Climate Observing System, Global Ocean Observing System and Global Terrestrial Observing System), the Economic Commission for Africa, the Food and Agriculture Organization of the United Nations, the International Telecommunication Union, the United Nations Office for Outer Space Affairs, the United Nations Educational, Scientific and Cultural Organization Intergovernmental Oceanographic Commission, the United Nations Environment Programme, the World Food Programme, the World Health Organization, the World Meteorological Organization and the International Council for Science.

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