

Space-based Earth observations for societal benefit

by Shahid Habib¹, Maryvonne Plessis-Fraissard² and Stephen D. Ambrose³

Introduction

The International Conference on Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services, organized by WMO, took place in Madrid, Spain, from 19 to 22 March 2007. The Conference was held under the gracious patronage of HM Queen Sofía and hosted by the Environment Ministry and National Institute of Meteorology of Spain. Many stakeholders participated, including representatives of National Meteorological and Hydrological Services, international and national agencies, non-governmental organizations, the private sector, policy-makers and researchers.

The purpose of the Conference was to contribute to secure and sustainable living for all peoples of the world by evaluating, demonstrating and ultimately enhancing the social and economic benefits of weather, climate and water services. It sought to assemble authoritative feedback from users and one of the outcomes which emerged is referred to as the Madrid Action Plan. The Plan is aimed at enhancing the value to society of weather, climate and water information and services. Fifteen

specific actions were identified and are available at: http://www.wmo.int/pages/themes/weather/documents/Madrid_Statement_ActionPlan.doc. See also *WMO Bulletin* 56 (1) and (3). The expectation is that a successful implementation of the Plan will go a long way in formulating and implementing an effective response to the critical challenges posed by rapid urbanization, economic globalization, environmental degradation, natural hazards and the threats from climate change.

The Conference called for closer dialogue, partnerships and multi-disciplinary understanding between providers and users of weather, climate and water services as they are essential for improved decision-making and delivery of social and economic benefits. The US National Aeronautics and Space Administration (NASA) and the World Bank were participants in the Conference and consider it necessary to discuss some aspects of their strategies for enabling the practical use of space observations of weather, climate and water resources for societal benefit.

This article therefore highlights relevant areas of both NASA's Earth

science remote-sensing programme and related World Bank's activities. It focuses on possible predictive capability in the areas of water management, agriculture, natural hazards and vulnerability and solid Earth processes to further efforts of the national and international community in solving critical societal problems.

NASA's objectives

NASA is using the vantage point of space to improve knowledge of the Sun-Earth system through global Earth observations. NASA satellite and airborne observations provide measurements that are used in science research to understand the behaviour of our planet as an integrated system and develop capabilities to predict the changes caused by natural and anthropogenic factors. Similarly, the Applied Sciences Programme includes specific areas beneficial to sustainable and societal needs such as: air quality, disaster management, public health, agriculture, water availability, coastal zone management and ecosystems.

NASA has partnerships with federal agencies and with regional and/or national and international organizations having operational responsibilities and mandates to address areas of importance to society and develop mitigation and improvement strategies and scenarios. Disasters affect society in many

1 NASA Goddard Space Flight Center, Science Exploration Directorate, Greenbelt, Md, USA

2 Independent consultant, Vice Chair of the International Activities Committee of the US Research Transport Board; formerly Director, Sustainable Development Network, World Bank, Washington, DC, USA

3 NASA Headquarters, Science Mission Directorate, Washington, DC, USA

ways and to ensure their effective management, the monitoring of risks in real-time, effective preparedness and management of emergencies, it is essential that different stakeholders foster partnerships. In this respect, NASA's partners in the USA include the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency, the Department of Homeland Security, the Federal Aviation Administration, the US Department of Agriculture, the Center for Disease Control and the US Geological Survey. Additionally, NASA collaborates with international organizations and other entities in activities that have the potential to extend science benefits to the international community.

NASA's contribution

The Applied Sciences Programme of NASA is cross-cutting and links to other national application areas such as aviation, invasive species, energy management, ecological forecasting, public health, air quality and water management. The programme responds to the priority requirements of the US administration, including those of the White House Committee on Environment and Natural Resources/Subcommittee on Disaster Reduction, the US Group on Earth Observations, and inter-agency programmes on climate change science and technology. Its Disaster Management Programme collaborates with international entities such as WMO, the United Nations Educational, Scientific and Cultural Organization and the Committee on Earth Observation Satellites, as well as with some national partners.

NASA space missions include research-quality instruments to study the Earth's atmospheric chemistry, biospheric processes, oceanographic processes and productivity and solid Earth variations (see box above). The Shuttle Radar Topography Mission

NASA missions

Some current missions

- Terra (climate and ecosystem variability)
- Aqua (Earth's water cycle)
- Aura (atmospheric chemistry)
- GRACE (Gravity Recovery and Climate Experiment)
- QuickScat (Quick scatterometer) (ocean surface winds derived from the SeaWinds scatterometer)
- ICESAT (ice, cloud and land elevation satellite)
- Jason (ocean surface topography)
- ACRIMSAT (Active Cavity Radiometer Irradiance Monitor) (total solar irradiance monitoring)
- SORCE (Solar Radiation and Climate Experiment)
- TRMM (Tropical Rainfall Measuring Mission)

Some future missions (planned for launch over the next seven years)

- National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) (climate trends and global biological productivity)
- Aquarius (global sea surface salinity)
- Glory (aerosols and total solar irradiance)
- Landsat Data Continuity Mission (global coverage of the Earth's land surface)
- Global Precipitation Mission
- Orbiting Carbon Observatory (OCO) (observations of atmospheric carbon dioxide)

flew on the Space Shuttle in 2000. Interferometric Synthetic Aperture Radar data from that mission enabled the production of elevation maps of the planet's surface with a vertical accuracy better than 10 m.

Most of these missions are developed and implemented with national and international partners. Planned missions will provide information on soil moisture, atmospheric aerosol, precipitation and cloud structure and carbon dioxide. The observations and science data products from these missions are applied in further assessing issues pertaining to floods (Figure 1), landslides, land cover and land use, transboundary pollution and air quality (Figure 2), water-resource issues and fires (Figure 3). Electromagnetic precursor signals provide information related to earthquakes, hurricane physics and track prediction, crop health and

drought prediction and vector-borne diseases such as malaria and Rift Valley Fever.

The project plans associated with the Disaster Management Programme designate specific sensors and models and state specific partnership activities to extend NASA science measurements, environmental data records and geophysical parameters (accessible at <http://aiwgf.gsfc.nasa.gov>). Additionally, the programme is working with NOAA on its Advanced Weather Interactive Processing System, the US Forest Service Remote Sensing and Applications Center and the National Interagency Fire Center on wildfire support. The main activity is to understand the requirements of operational agencies and conduct applied research in transitioning NASA Earth observations and products into decision tools and processes.

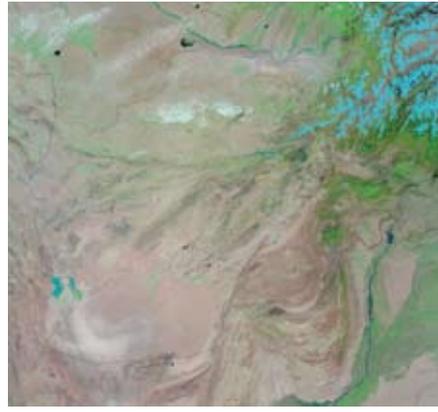
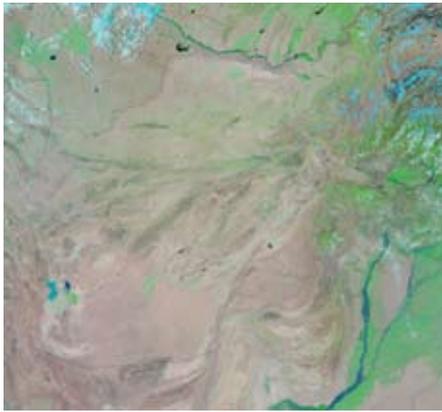


Figure 1 — Flooding of the Indus River basin in 2006

Project on follow-up to the World Summit on Sustainable Development (WSSD)

The WSSD follow-up programme of the Committee on Earth Observation Satellites Module 3 was the driving force for the work NASA is doing today related to sustainable development and disaster management in Africa. NASA participated in Module 3, which eventually came to an end, but continues with disaster-management activities in support of African decision-makers.

The project today seeks to identify current NASA efforts which support WSSD goals and to define the decision-support tools that currently exist for meeting sustainable development needs within Africa, especially as they relate to disaster management, conflict and other application areas. The project subsequently expects to identify the NASA research products having a high potential to contribute to meeting the requirements of these decision-support tools, benchmark the utilities of these products, identify gaps in the capabilities of the decision-support tools to meet the needs of the intended beneficiaries and support transition to operations of the NASA capabilities as agreed upon with NASA's partners. Table I summarizes the current entries in the WSSD Website (<http://aiwv.gsfc.nasa.gov/>) which NASA intends to continue populating.

The World Bank's role as an enabler of Earth observations

The World Bank is a user of spatially referenced information and space observations generated by satellite operators, either directly for its analytical work or through its loans and grants. Although Earth observations

are not used in a standardized manner by the World Bank, they are used more and more frequently at all stages of analytical and operational work. Geographical information has received more attention in recent years as the development agenda seeks to integrate the demands of a rapidly urbanizing world with the challenges of sustainable development, climate change adaptation and vulnerability to natural disasters. Targeting social support to the poorest households, monitoring ecosystems and human activities and planning and managing water resources are a few of the many examples of the use of Earth observations for development with critical social impact.

When addressing development issues, space observations are used in combination with other information. Combining Earth observations of ecological, climate and weather data, for example, with socio-economic and poverty data from household surveys, provides powerful input to improve



Figure 2 — African dust over the Mediterranean Sea, 19 August 2004

Glossary

AMSR	Advanced Microwave Scanning Radiometer	MODIS	Moderate resolution Imaging Spectroradiometer
AMSU	Advanced Microwave Sounding Unit	NASA	National Aeronautics and Space Administration
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer	NPOESS	National Polar-orbiting Operational Environmental Satellite systems (USA)
AVHRR	Advanced Very High Resolution Radiometer	NPP	NPOESS Preparatory Project
CADRE	Crop Condition Data Retrieval and Evaluation (USDA/FAS)	PECAD	Production Estimates and Crop Assessment Division (USDA/FAS)
CARPE	Central African Regional Programme for the Environment (USAID)	SPOT	Satellite pour l'observation de la Terre (Earth observing satellite) (France)
CNES	Centre national d'études spatiales (France)	SRTM	Shuttle Radar Topography Mission
DST(s)	Decision support tool(s)	TRMM	Tropical Rainfall Measuring Mission
ETM	Enhanced Thematic Mapper	USAID	US Agency for International Development
FAS	Foreign Agriculture Service (USDA)	USDA	US Department of Agriculture
FEWS	Famine Early Warning Systems (USAID)	USGS	US Geological Survey
GIS	Geographical Information System	VIIRS	Visible/Infrared Imager/Radiometer Suite
GSFC	Goddard Space Flight Center (NASA)		
MEWS	Malaria Early Warning Systems (USAID)		

the effectiveness of poverty reduction interventions. It is becoming increasingly routine to use remote-sensing as a tool for socio-economic surveys. Through this approach, spatially referenced information can be mapped and integrated with that collected through ground survey. This approach also helps to raise the level of confidentiality on the outcome of such a survey exercise.

Space observations are critical for linking global knowledge with regional, national, local and community information. This is particularly important for climate and meteorological information in poorer and smaller countries, which can benefit from information that they could not generate separately. This is the case, for example, of small African States facing high climate variability with insufficient water-storage infrastructure and incipient water-management systems. In Kenya, appropriate information about rainfall projections has been found to multiply the agricultural output of rural communities. While access to global and space data has improved tremendously, the capacity to integrate local data into global systems emerges now as a challenge.

Earth observations are used in particular where activities and land use need to be monitored. This is the case of the World-Bank-financed Nam Theun 2 dam in Lao People's Democratic Republic. The Government has set aside a large watershed area around the future reservoir as a conservation area, within which no logging is allowed. Monitoring of the compliance is carried out by combining analyses of satellite data with helicopter fly-overs and ground data collection using global positioning satellites. All information is integrated in a comprehensive Geographical Information System. The comprehensive and real-time monitoring and the transparency of the data sources have made it possible for the Government to enforce the logging ban rigorously.

During the last 20 years, the World Bank alone has provided more than US \$26 billion for 550 reconstruction and mitigation projects in its client countries. Increasingly, the disaster recovery projects of the Bank and other multilateral and bilateral agencies either include disaster mitigation elements or are followed by specific projects for disaster mitigation in high-risk countries. Yet, the challenge

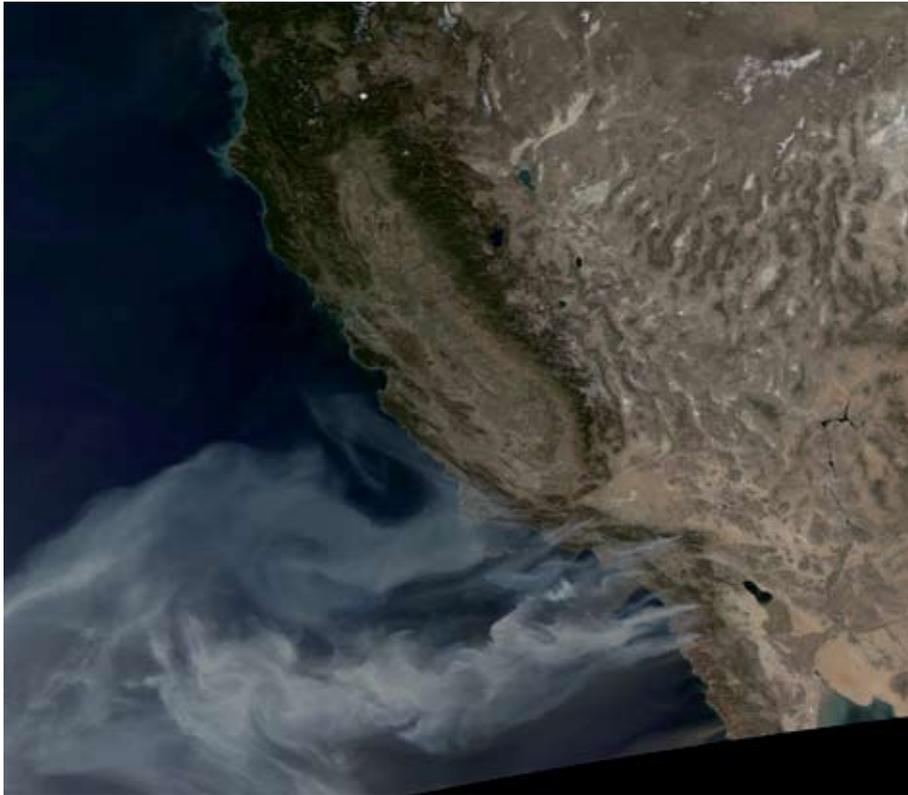
remains daunting: disaster-related risks in developing countries continue to increase rapidly due to unplanned urbanization, environmental degradation, intensification of activities on fragile lands and the corresponding increasing vulnerability of the population. The International System for Disaster Reduction (ISDR) is the umbrella under which UN institutions and international partners share lessons and build coordination and consistency of policies and practices for disaster reduction. In 2006, the Global Facility for Disaster Risk Reduction was launched by the World Bank under the UN/ISDR framework, to bring together public and private sector partners for mainstreaming risk management and preparedness into the poverty reduction strategies of nations. It is expected that, during 2008, about half of the most vulnerable countries in the world will have started to manage disaster risk reduction as a national development priority.

While a high rate of urbanization exposes more and more people to risks associated with natural hazards, a large portion of the population in rural areas remains highly vulnerable, owing to a lack of institutional capacity, communication, transport

Table 1 — NASA projects which have resulted in use of NASA products

<i>Applications area</i>	<i>Project title</i>	<i>Project resources</i>
Agricultural efficiency	PECAD/CADRE -Integrating MODIS and VIIRS NPP observations into the USDA FAS Decision System	Development of a new rapid response version of the MODIS Vegetation Index data, multi-sensor integration with AVHRR and SPOT and new products, including a Vegetation Moisture Stress Index. The data are being evaluated for use in decision-support tools and system employed by the USDA Foreign Agricultural Service to generate production and yield estimates of major, global agricultural commodities
	Agricultural Information System and Multi-Satellite Precipitation Analysis for PECAD/CADRE	Integration of TRMM rainfall data, and MODIS 250-m at 10-day timesteps for the USDA Crop Explorer, a global exploration and analysis tool.
	Near-real-time Lake and Reservoir Monitoring System for FAS PECAD	NASA/CNES TOPEX/POSEIDON (T/P) and Jason-1 satellite missions for use by PECAD/CADRE decision-support tools.
Carbon management	Forest biomass and land-use change in central Africa: reducing regional carbon cycle uncertainty	MODIS, ASTER and Landsat ETM+ data will be incorporated into a land use land cover change map for the central Congo basin.
	Integrating Earth Science Enterprise Results into Protected Area Decision Support for the African Albertine Region - Protected Areas Watch in the Albertine	Landsat 5 and 7 data to provide detailed analyses of the state of tropical ecosystems, the extent and rates of change for effective decision-support systems and conservation policies in the tropical forest basin
Disaster management	Livestock Early Warning System (LEWS)	Use of ASTER, SRTM and TRMM data to characterize and monitor water supply and flood hazards along pastoral migration corridors for protection of pastoral livelihoods and food security
	Flood/landslide modelling	Use of TRMM, SRTM, AMSR-E, and MODIS for input into a global landslide model and flood forecasting system.
	Advanced Fire Information System (South Africa)	Meteosat Second Generation and MODIS fire data to protect power distribution, creating a system to generate automated alarms when active fires are detected in predefined areas in South Africa
Ecological forecasting	Fire Information for Resource Management Information System	Integration of MODIS fire data in a WebGIS with interactive maps and e-mail and text message alerts for cell phones, warning of fires in or around protected areas, will be implemented globally through the United Nations.
	Congo Basin forest monitoring using satellites for CARPE 2	Use of AMSU-A, Landsat 5 and 7, Terra MODIS to enhance decision support, educational and management products of the Central African Forests Commission.
Energy management	Solar and Wind Energy Resource Assessment—renewable energy resource assistance for the United Nations Environment Programme	SRTM, TRMM, and USGS research on drought and flood monitoring to produce stream flow estimates for small hydroelectric projects in Kenya, Ethiopia and Ghana
Public health	MEWS/FEWS NET - USAID famine and malaria early warning	AURA, MODIS, TRMM 3B42 rainfall data into early warning systems that detect food insecurity and malaria outbreaks in semi-arid zones. FEWS NET is a USAID project that integrates remote-sensing an economic information to provide information on food security crises.
Water management	Water and ecosystem resources in regional development	TRMM precipitation and microwave radar for monitoring fluctuations of hydrological and ecosystem variables and likely trends concerning key characteristics of the Okavango River Basin in southern Africa for land-use planning decision support. (Angola, Botswana, Namibia)
Air quality	Aerosol Robotic Network (AERONET)	AERONET provides a long-term, continuous and readily accessible public domain database of aerosol optical, microphysical and radiative properties for aerosol research and characterization, validation of satellite retrievals, and synergism with other databases.

<i>Principal investigator</i>	<i>Name of end user</i>	<i>Location of end user</i>	<i>NASA funding source</i>
Chris Justice University of Maryland	USDA Foreign Agricultural Service and users of its crop explorer service	Southern Africa, East Africa, global	2004 decisions, Cooperative Agreement Notices
Steve Kemplar NASA GSFC	USDA Foreign Agricultural Service and users of its crop explorer service	Southern Africa, East Africa, global	Direct funding from Applied Sciences Programme
Charon Birkett University of Maryland	USDA/FAS	Southern Africa, East Africa, global	NNS06AA15G SAI: 050125-7198 01-5-26221
Nadine Laporte Woods Hole Research Institute	Institut Congolais pour la Conservation de la Nature, Forest Services of Congo, Cameroon, Gabon, Central African Republic	Congo, Democratic Republic of Congo, Cameroon, Gabon, Central African Republic	NNG05GD14G
Nadine Laporte Woods Hole Research Institute	Parks and tourism departments of Congo, Democratic Republic of Congo, Uganda, United Republic of Tanzania	Congo, Democratic Republic of Congo, Uganda, United Republic of Tanzania	05-2-0000-0147
Gabriel Senay US Geological Survey, Sioux Falls	Kenyan National Agricultural Research Systems	Ethiopia and Kenya	NNA06CH75I 2006 ROSES
Robert Adler, NASA GSFC	Global	Available on the Web	Direct funding from Applied Sciences Programme
Diane Davies University of Maryland	Department of Water Affairs & Forestry	Pretoria, South Africa	Direct funding from NASA Applied Sciences Programme
Diane Davies University of Maryland	Tanzania National Parks, SAFNet, Botswana MET, Uganda Wildlife Authority, etc.	Botswana, Madagascar, Mozambique, Namibia, Senegal, South Africa, United Republic of Tanzania	NNS06AA04A 2004 decisions, Cooperative Agreement Notices
Chris Justice University of Maryland	Central Africa Forests Commission (COMIFAC) ERAIFT, Congo Basin Forest Partnership	Central Africa	NNG06GC41G Direct funding from Applied Sciences Programme
Eugene A. Fosnight USGS, Sioux Falls	Consumers, developers, investors and policy makers in the energy sector	United Nations Environment Programme; available on the Web	NNA06CH74I 2006 ROSES
Molly Brown NASA GSFC/ James Verdin USGS Sioux Falls	African Meteorological Services, USAID and United Nations World Food Programme	African countries participating in FEWS NET (25)	2004 decisions, Cooperative Agreement Notices
Dominic Kniveton University of Sussex	Permanent Okavango River Basin Water Commission	Angola, Botswana, Namibia	No support from NASA
Brent Holben NASA GSFC	Kenya Wildlife Service	Kenya	Direct funding from Research & Analysis, Cooperative Agreement Notices/ Request for Proposals



NASA

Figure 3 — Southern California fires, 20 October 2007

and health services. Global warming, coupled with environmentally unsustainable development practices, is exacerbating the vulnerability of communities and infrastructure with greater exposure to more intense and frequent extreme events.

Poverty and disaster vulnerability are intrinsically linked. There is a need to develop a more credible economic rationale for investments in risk-reduction development plans, particularly poverty-alleviation programmes. Mainstreaming risk analysis in country diagnostics and developing country-level high-resolution multi-hazard risk assessment, become priorities. Country risk assessments, including development of hazard and vulnerability maps and other economic diagnostics, identify the underlying causes of vulnerability. Vulnerability reduction is achieved through bringing to bear, in a participatory way, the risk analysis with appropriate social and economic development policies. When accountabilities become clear and citizens can drive the demand, specific case-studies on modelling catastrophic risks into macro-economic

estimates and poverty outcomes are undertaken at country level to inform policy decisions and allocation of resources.

An example of this work can be found with the assessment of farming activities in Ethiopia. Rainfall data are being provided by NOAA's Climate Prediction Center and the Famine Early Warning System-Network, funded by the US Agency for International Development. The programme monitors weather phenomena and helps determine the shape of the rainfall field, while gauge observations determine the intensity and satellite observations are used to fill data gaps.

Summary

Earth observations from space make a significant contribution to our ability to analyse regional situations. Many applications extract geo-located information from global Earth observations to bring focus onto issues of regional importance. In fact, global observations provide accurate, near-real-time boundary

conditions for regional and/or mesoscale models used to analyse and/or predict local conditions. Poor local air quality may not necessarily be due to indigenous conditions, hence it is vitally important that we are able to use Earth observations to help us understand transboundary pollution and its sources. Global precipitation rates are helping us to identify locations more vulnerable to landslides across the world and to develop flood potential maps. All these measurements and the science have great potential for serving humanity.

It is also important to note that Earth observation and mapping are important instruments of transparency, good governance and effectiveness, because they are mostly accessible in real-time. Moreover, mapping allows even people who do not have the technical know-how, to understand project design and decision-making and to relate to impact monitoring and evaluation. Through appropriate dissemination, accountabilities become clear and citizens can drive the demand for evidence-based policies and become empowered in the process.

Funding organizations, such as the World Bank, the US Agency for International Development and others, are beginning to help in implementing this technology for user communities throughout the world. The space revolution has started to impact society in positive and substantial ways but it still has far to go. Our goal is to protect the planet for future generations and mitigate climatic risks to populations around the globe. This is one small facet in the effort to build a secure and sustainable society.