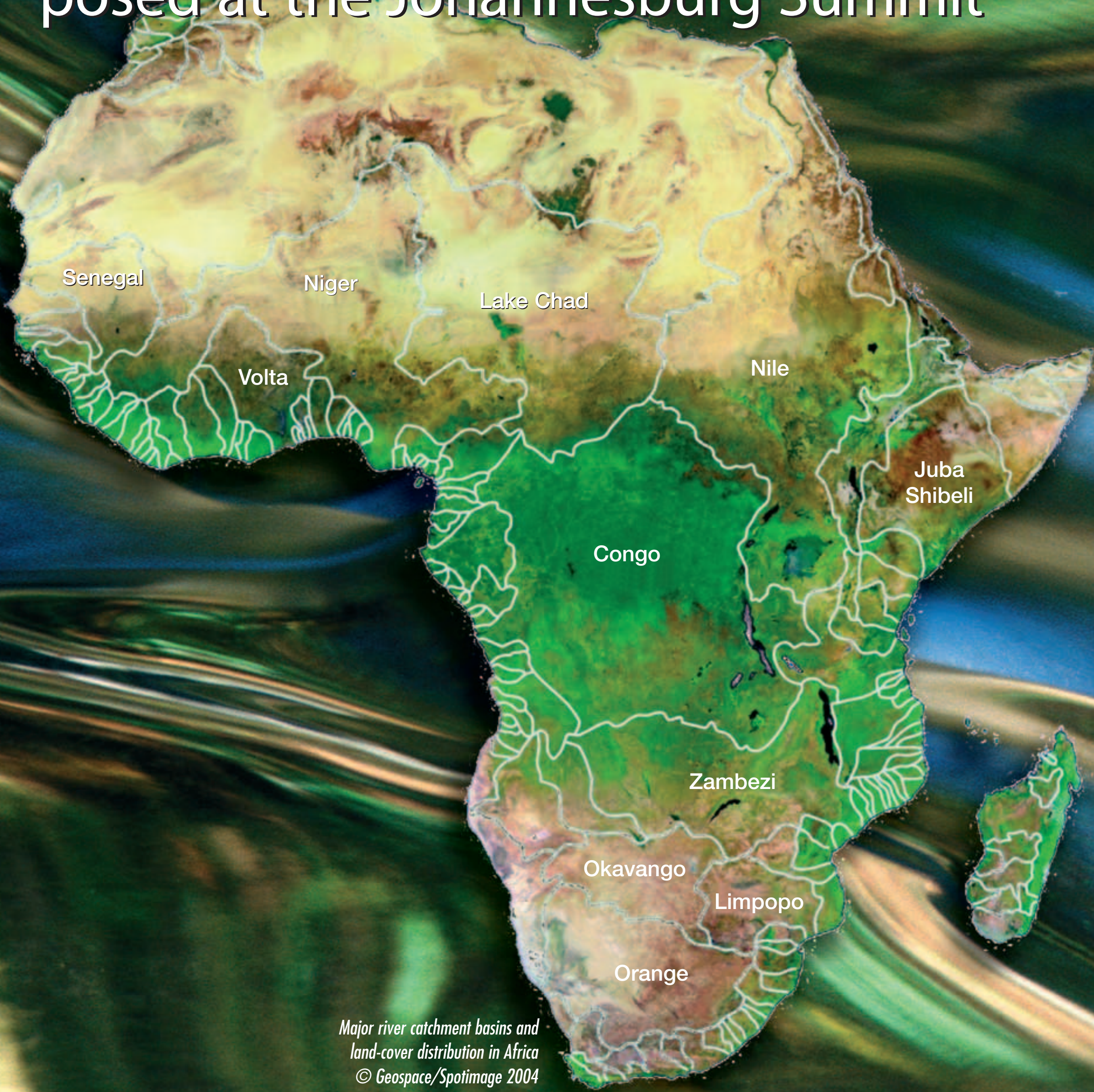
Looking after Water in Africa

– ESA's TIGER Initiative meets the challenges posed at the Johannesburg Summit



Major river catchment basins and land-cover distribution in Africa © Geospace/Spotimage 2004

Water resources, the 'blue gold' of the 21st century, can be successfully monitored from space using Earth-observation technology. Satellites can measure precipitation, atmospheric water content, soil moisture, surface run-off, lake and river levels, groundwater reservoirs, as well as ice and snow cover. Improved sensors, better modelling and a deeper understanding of the underlying science have substantially advanced our knowledge of the global water cycle in recent years.

However, there are still major shortcomings in both the understanding and the observation of key parameters. The estimation of groundwater resources, for example, poses a major challenge, as they are not directly visible from space. Indirect methods based on gravity-field measurements, radar interferometery and altimetric monitoring of rivers need to be applied to gain knowledge of reservoir volumes and flows. In order to improve our capabilities and to offer this technology to people in developing countries, ESA has launched a new programme focusing on the use of space technology for water-resource management in Africa. The initiative, called 'TIGER', is a direct follow-up of ESA's strong engagement in the 2002 Johannesburg World Summit on Sustainable Development, and implements its recommendations through concrete actions.

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All Life Depends on Water

Almost all aspects of the Earth system involve or rely on water. Ours is unique among the planets because its water is maintained in vapour, liquid and ice forms. Water is, in fact, the only known substance that can naturally exist in gas, liquid, and solid form within the relatively small range of air temperatures and pressures found at the Earth's surface. In all, our planet's water content is about 1.39 billion cubic kilometres and the vast bulk of it, about 97%, is in the global oceans. Only about 3% resides as freshwater on the land.

Wetland ecosystems are a principal source of life on Earth

Furthermore, two thirds of this freshwater exists in ice caps, glaciers, permafrost, swamps, and deep aquifers, where it is largely inaccessible. A very small fraction of the total is held in the atmosphere, but it plays a critical role in our climate and in the transport of ocean water that precipitates over land. The latter can be considered as the renewable part of the resource, determining the amount of water that can be used by humans without depleting the water stored in reservoirs or aquifers.

Water and energy are intimately involved in driving atmospheric circulation. Consequently, climate- and weather-prediction systems must consider water as a primary component. Humans affect the water cycle not only indirectly as global warming affects precipitation patterns, but also directly as river control, irrigation and general water-management practices reorganise the patterns of water movement. The drying out and over-salinisation of the Aral Sea and the construction of the Three Gorges dam are prominent examples of humans influencing regional water-resource management. The complexity of these interactions and the range of their space and time scales pose major challenges to hydrologists and decision-makers alike.

To represent these variables adequately, a mix of satellite and in-situ data is required. Remote sensing, especially from space, can provide spatial coverage for rainfall, soil moisture, snow cover, snow water equivalent, and vegetation conditions. Remote sensing does not, however, remove the need for ground-based measurements. Hydrologists use remote sensing as a major, and in many cases essential information source to better understand and monitor the global and regional water cycle. The challenge for space agencies lies in the adequate integration of space-based information into a holistic decision support system, which should lead to better decisions and ultimately to better lives for those who most depend on improved management of water resources.

The Johannesburg World Summit on Sustainable Development

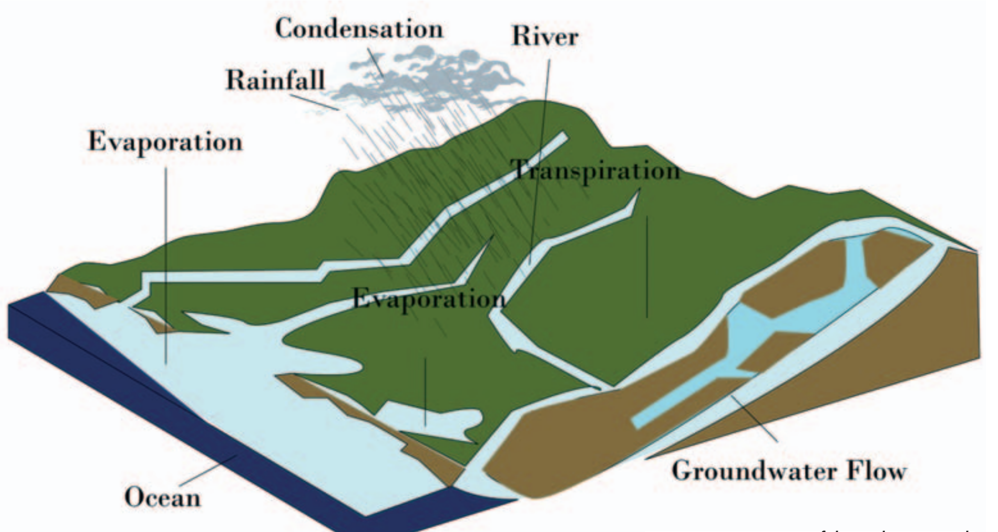
The 2002 Johannesburg World Summit on Sustainable Development recognised the importance of natural resources for development, and hence stability, on our planet. The biggest challenge mankind is facing over the next 50 years is that of coping with a predicted 50% increase in the Earth's population, from 6 billion today to 9 billion by 2050. Heads of State and Governments committed themselves at the Summit to the Johannesburg Plan of Implementation for Agenda 21, integrating the three pillars of sustainable development – economic development, social development and environmental protection – at local, national, regional and global levels.

Water is probably the most crucial among the issues prioritised in Johannesburg, which also include energy, health, agriculture and biodiversity. Freshwater is a finite and vulnerable resource. Over one billion people still do not have access to safe drinking water, and nearly two billion lack safe sanitation. An estimated 10 000 people die every day from water- and sanitation-related diseases, while thousands more suffer from a range of debilitating illnesses.

Humans currently appropriate more than half of the accessible freshwater run-off, and this proportion is expected to increase significantly in the coming decades. A substantial amount, namely 70%, of the water currently withdrawn from all freshwater resources is used for agriculture. With the rapid increase in the world's population, the additional food required to feed future generations will put further enormous pressure on freshwater resources. According to recent global water assessments, around 70% of the future world population will face water shortages, and 16% will have insufficient water to grow their basic food requirements by 2050. The impact of inadequate water and sanitation services falls primarily on the world's poor.

Earth Observation for Water-Resource Management

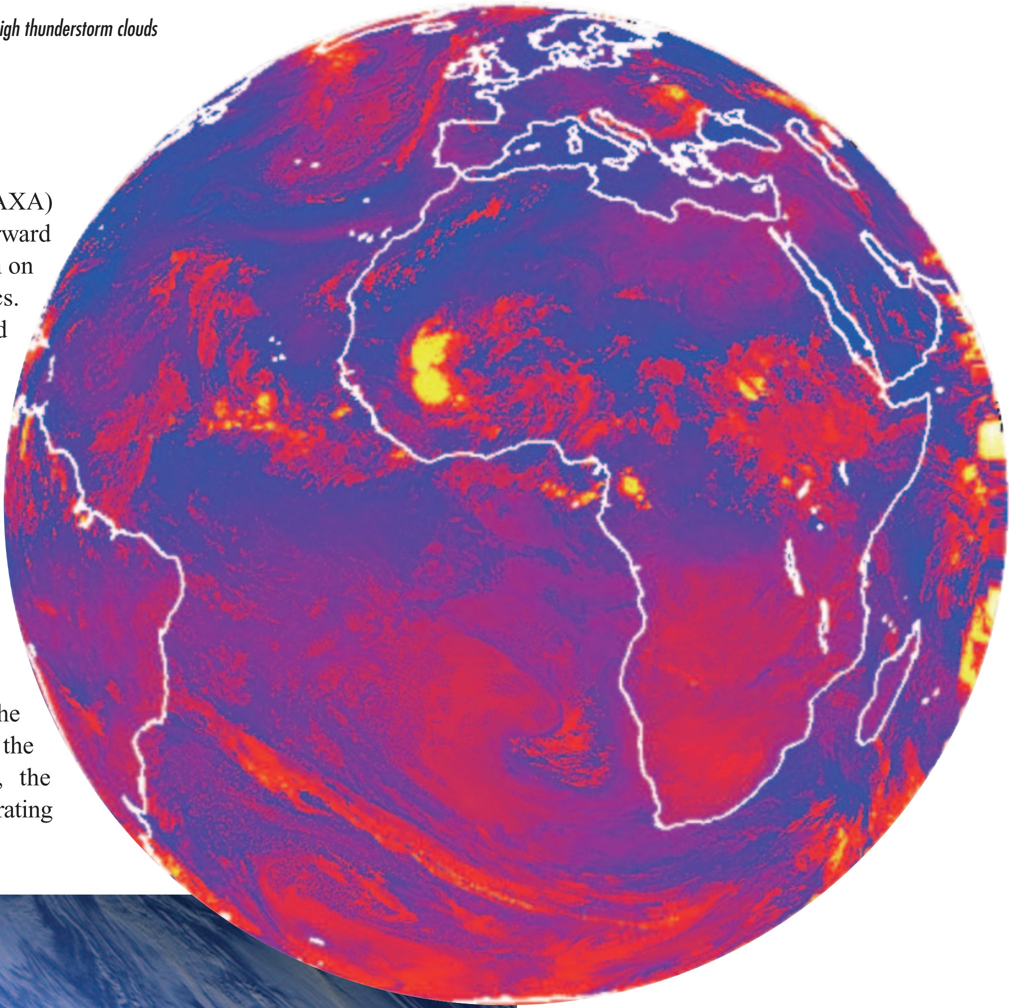
Earth-observation satellites play a major role in the provision of information for the study and monitoring of the water cycle.



Main components of the Earth's water cycle

Atmospheric-temperature, water-vapour and cloud-cover measurements are provided operationally by meteorological satellites such as MSG and MetOp. ERS and Envisat, for example, provide surface temperatures, ocean winds, wave heights, and ice-dynamics data, as well as information on vegetation cover, soil moisture, and geology over land surfaces.

Precipitation is clearly a key parameter, but given its high temporal and spatial variability it is a fundamentally difficult parameter to measure. Until recently, visible/infrared images from geostationary meteorological satellites provided the best source of information from space – with indirect but frequent estimates of rainfall derived from measurements of cloud-top temperature. The advent of the Tropical



Meteosat MSG-1 image taken on 14 July 2003 showing high thunderstorm clouds (yellow) 'overshooting' into the stratosphere
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Rainfall Mapping Mission (NASA/JAXA) in 1997 provided a major step forward with the provision of 3-D information on rainfall structure and characteristics. ESA has joined NASA, JAXA and other partners to continue this collaboration and to develop the Global Precipitation Mission (GPM), due for launch in the second half of this decade. The GPM constellation of satellites will provide global observations of precipitation every three hours to help develop our understanding of the global structure of rainfall and its impact on climate.

Recognising the central role of the water cycle in our understanding of the Earth system and climate change, the world's space agencies are already operating or are currently developing a number of new missions aimed at addressing key scientific objectives. These include the Aqua mission (NASA), Cloudsat (NASA), EarthCare (ESA/JAXA), GRACE (NASA/DLR) and ESA's Cryosat. Altimetric measurements provided by Topex-Poseidon and Jason from CNES and NASA, and ERS and Envisat from ESA, provide continuous monitoring of lakes and rivers with centimetre accuracy. Revolutionary new measurement capabilities will be provided in the future by ESA's Soil Moisture and Ocean Salinity (SMOS) mission scheduled for launch in 2006. Following GRACE, ESA's Global Ocean Circulation Experiment (GOCE) mission will determine the Earth's gravity field and its geoid with high accuracy and will allow the retrieval of water-table height measurements, one of the main parameters of interest to hydrologists.

Artist's impression of ESA's Soil Moisture and Ocean Salinity (SMOS) satellite

To ensure the necessary co-ordination between these many satellite programmes, the IGOS Partnership is developing an Integrated Global Water Cycle Observations (IGWCO) Theme. This Theme provides a framework for guiding international decisions regarding priorities and strategies for the maintenance and enhancement of water-cycle observations so that they will support the most important applications and science goals, including the provision of systematic observations of trends in key hydrological variables.

The first element of IGWCO is a Co-ordinated Enhanced Observing Period (CEOP), which is capitalising on the opportunity of the simultaneous operation of key European, Japanese, and American satellites during the period 2001-2004 to generate new water-cycle data sets.

New technologies for measuring, modelling, and organising data on the Earth's water cycle offer the promise of a deeper understanding of the cycle's processes, and of how different management decisions may affect them. Earth-observation satellites provide synoptic, high-resolution measurement coverage that is unprecedented in the geophysical sciences. The challenges to be faced in exploiting these new capabilities include:

– converting satellite measurements into useful parameters that can be applied in scientific models, and which can be inter-compared and inter-calibrated between the different satellite missions;
– providing consistent and accurate data over many years in order to detect the trends, which is necessary for climate-change studies;
– succeeding in the technology developments aimed at accurately measuring key parameters from space for the first time – including soil moisture and ocean salinity; and, above all,
– mobilising a large scientific community in the developed and developing countries to address this fascinating subject.

To complement the satellite data, existing ground-based measurement networks and systems must continue operating to obtain current data that can be compared meaningfully with past records.

ESA's TIGER Initiative

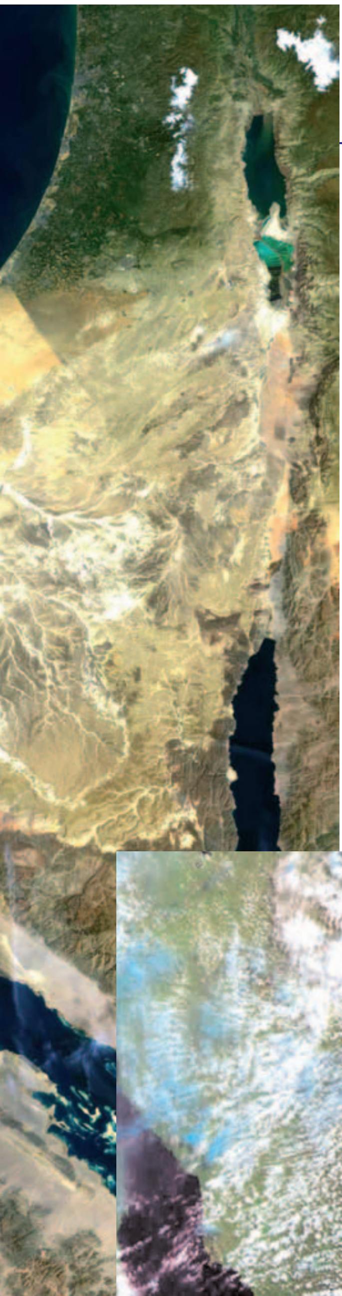
During 2002, under ESA's Chairmanship, the Committee on Earth Observation Satellites (CEOS) invested a considerable amount of effort in its participation at the World Summit on Sustainable Development, in Johannesburg. This Summit acknowledged the important role of Earth-observation satellites in assisting sustainable development. Altogether, 12 specific Articles in the 54-page WSSD Plan of Implementation that was adopted by Heads of State and Governments in Johannesburg refer to the use of Earth observation.

In November 2002, at its 16th Plenary Meeting held at ESA/ESRIN, in Frascati (I), CEOS adopted a WSSD Follow-up Programme. This Programme proposes action in a number of fields, which were identified in the Plan of Implementation as areas where Earth observation plays an important role for sustainable development.

It is within the framework of the WSSD Follow-up Programme that ESA has launched its TIGER initiative, as a direct response to the challenges identified in Johannesburg. TIGER is aimed at improving our scientific understanding of the water cycle and developing sustainable Earth-observation services for integrated water-resource management in developing countries, with a particular focus on Africa. It consists of two major elements:

(i) a set of individual projects with limited geographical coverage and scope, which are 'building blocks' for the

(ii) political process, which aims at developing long-term, large-scale, sustainable information services for better decision making in the water-resource management domain.



The Nile river delta captured by Envisat's MERIS instrument on 1 March 2003
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Lake Tanganyika, the deepest fresh water lake in the world, on the border between Tanzania and Zaire. These images were taken using Envisat's AATSR instrument during the rainy season in April 2002 (left) and during the dry season in July 2002 (right)
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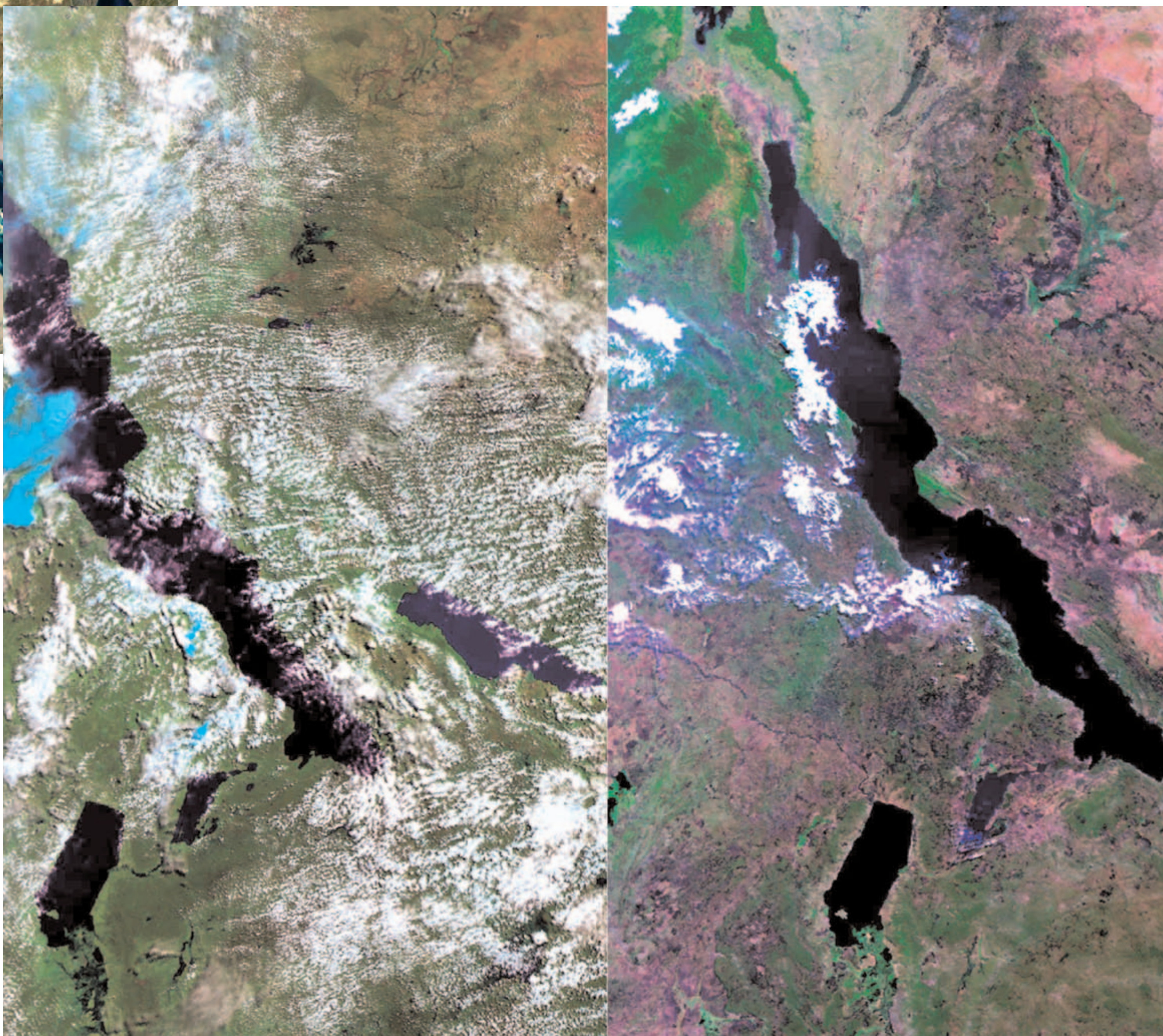
The Committee on Earth Observation Satellites (CEOS)

CEOS was created in 1984 under the auspices of the G7, with the goal of coordinating Earth-observation satellite missions among its Members. The 21 Members include space agencies that have active Earth-observation satellite programmes, while the 23 Associates include organisations that receive, process or use environmental data gathered from space. ESA is a founding member of CEOS and a permanent member of the Secretariat, which carries out the executive work in support of the annually rotating CEOS chairing agency. CEOS was chaired by ESA in 2002, followed by NOAA in 2003, China in 2004 and BNSC in 2005.



To achieve this long-term goal, strategic partners with a development mandate are involved, such as financing institutions or development organisations. Other partners include user organisations in Africa and beyond, as well as providers of space technology and services. Close co-operation with UNESCO has been established, thereby benefiting in particular from its International Hydrology Programme (IHP) and World Water Assessment Programme (WWAP), which provide access to a global network of hydrologists and field officers. UNESCO also supports training activities and develops educational material.

During 2003, the TIGER participants were identified and the organisational structure and work programme defined. Two major consultation meetings with stakeholders were held, one in May in Paris and one in October in Rabat. The topics identified as priorities for the first phase are groundwater resources, wetlands, epidemiology and food security; other topics may be added at a later stage. A two-phase approach was agreed, with Phase-1 (until end-2005) serving to demonstrate the usefulness of Earth observation for integrated water-resource management to African users and decision-makers, while Phase-2 (2006 onwards) will engage major donor and development agencies in order to turn the successful demonstrator projects into major development programmes. The precise content of Phase-2 will be defined in the course of 2005 on the basis of the Phase-1 results, as well as the results of reviews by African local and national authorities and potential international donor agencies. A key criterion will be the prospect of sustainability for selected services.

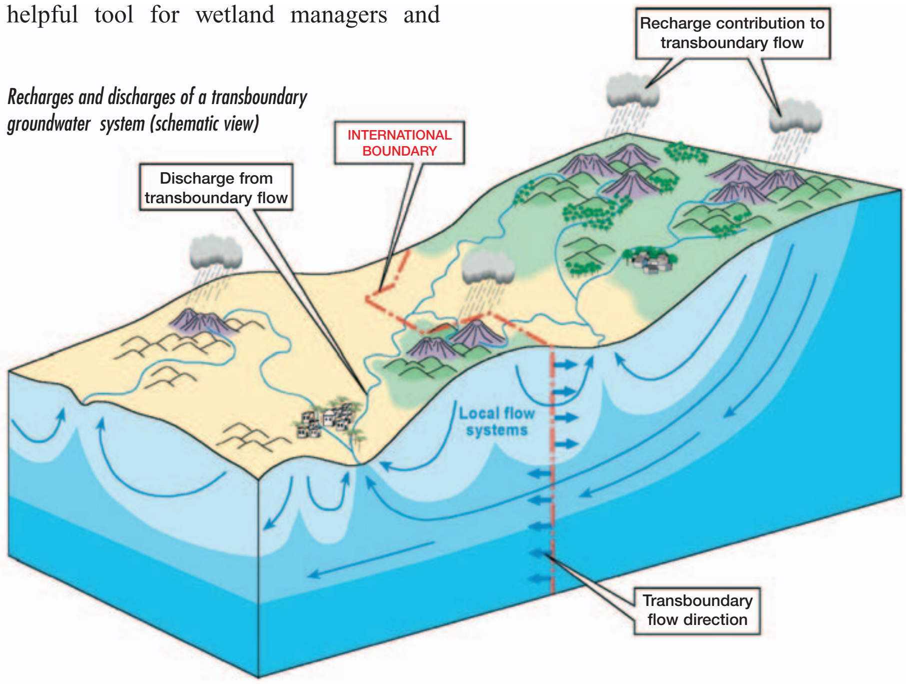
TIGER Demonstration Projects in Africa

As of early 2004, ESA has launched or initiated four projects within the framework of TIGER, focusing on various aspects of water-resource management in Africa. These projects, implemented through the Global Monitoring for Environment and Security (GMES) and Earth Observation Data User Element (DUE) activities at ESRIN in Frascati, are:

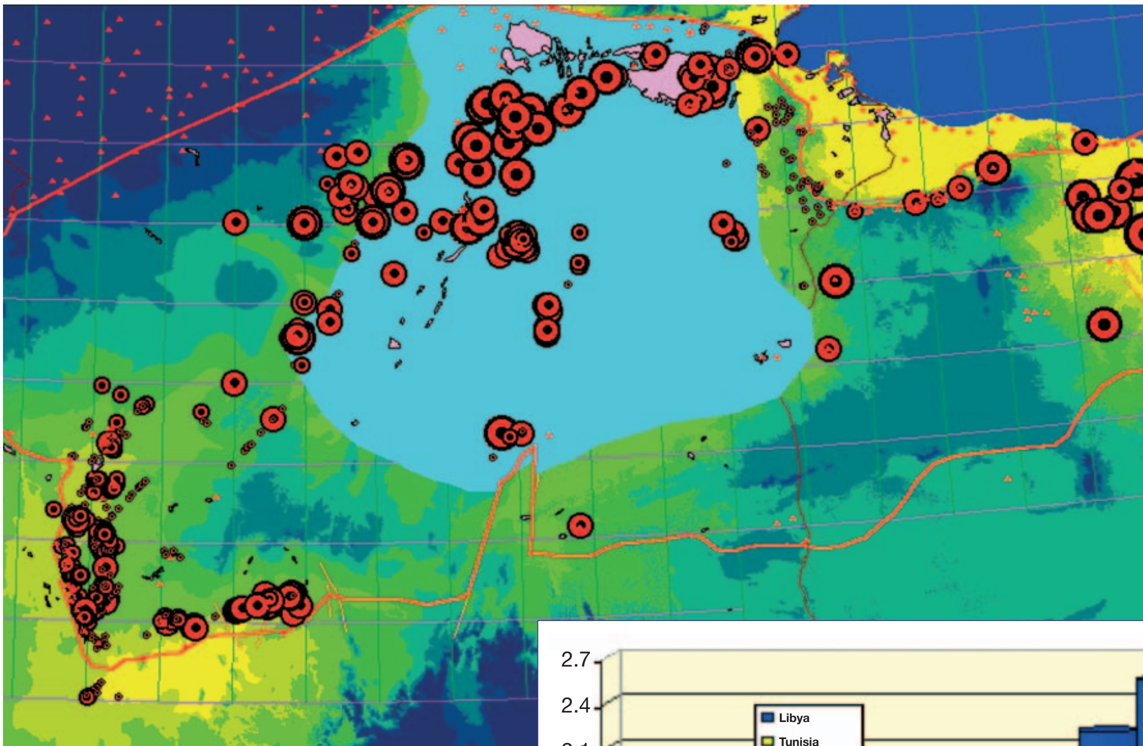
– Global Monitoring for Food Security
– Global Wetland Monitoring
– Epidomiology
– Groundwater Resource Monitoring.

The goal of the *Global Monitoring for Food Security (GMFS)* project is to improve the provision of operational information services to assist food-aid and food-security decision makers. GMFS aims to consolidate, support and complement existing regional-information and early-warning systems on food and agriculture. It will concentrate initially on Sub-Saharan Africa, and will focus on end-users from regional organisations whose mandate is agricultural monitoring for food security and early warning of food crises. The project also aims to meet the needs of users in international organisations such as the UN Food and Agriculture Organization (FAO) and the EuropeAid Cooperation Office (AIDCO).

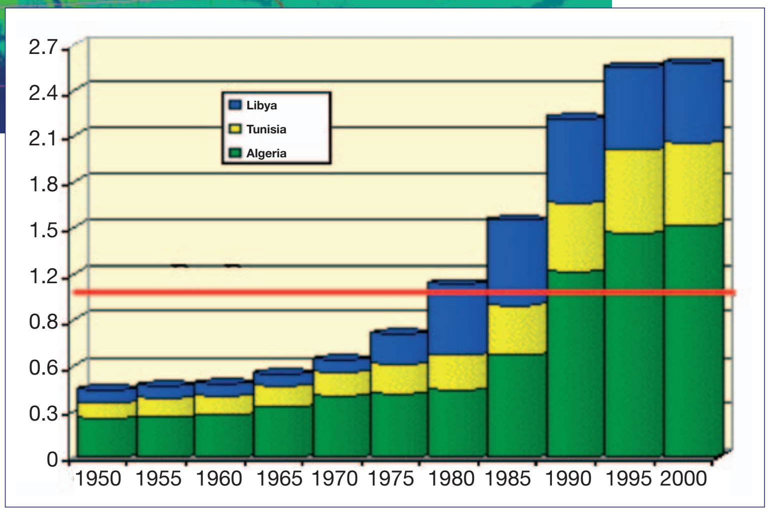
The *Globwetland* project is producing satellite-derived and geo-referenced products, including inventory maps and digital elevation models of wetlands and the surrounding catchment areas. These products will aid local and national authorities in fulfilling their obligations under the Ramsar Convention for wetlands conservation. They should also serve as a helpful tool for wetland managers and scientific researchers. For much of the last century, wetlands have been drained or otherwise degraded, but scientific understanding of their important roles in terms of biology and the water cycle has grown, spurring international efforts to preserve them. An assessment of the monetary value of natural ecosystems published in Nature in 1997 arrived at a figure of 27.7 trillion Euros, with wetland ecosystems making up 12.5 trillion - or 45% - of that total. Most of all, wetlands support life in spectacular variety and numbers: freshwater wetlands alone are home to four in ten of all of the world's species, and one in eight of global animal species. Much of human civilisation has been based around river valleys and flood plains. However, global freshwater consumption rose sixfold during the 20th century - a rate more than double that of population growth. With wetlands often made up of difficult and inaccessible terrain, satellites can help provide information on local topography, the types of wetland vegetation, land cover and use, and the dynamics of the local water cycle. In particular, radar imagery provided by ESA's Envisat mission is able to differentiate between dry and waterlogged surfaces, and so can provide multi-temporal data on how given wetlands change with the seasons.



Recharges and discharges of a transboundary groundwater system (schematic view)



Left: Water-extraction points from the northwest-African aquifer
Below: Water extraction (in billions of cubic metres per year) from 1950 to 2000 for Libya (blue), Tunisia (yellow) and Algeria (green)
© OSS 2003



The *Epidemio* project is aimed developing Earth-observation services for epidemiologists, with a particular focus on malaria and Africa. Malaria affects 300 million people worldwide, and kills up to 1.5 million people annually. The incidence of the disease is influenced by local climate, which can be monitored by satellites to help in forecasting malaria outbreaks. The Epidemio project provides maps of water bodies - updated through the wet and dry seasons - as well as digital elevation models and weekly land-surface-temperature maps. Water mapping is especially useful for malaria risk prediction as mosquitoes begin life as aquatic larvae and the adults rarely travel more than 2 km from their breeding ground during their two- to three-week lifetime.

The above three projects were already started during 2003, but another new project will be initiated in early 2004 which focuses on the use of Earth observation for groundwater monitoring. This project, known as *Aquifer*, is aimed at using SAR interferometry measurements to derive the surface subsidence rates of the terrain above the northwest African aquifer, which is the largest in the world and spans three countries: Algeria, Libya and Tunisia. These subsidence measurements will be coupled with geomorphologic information and in-situ measurements to model water extraction rates from the aquifer. ERS and Envisat SAR data will be the main data sources used in this project.

Conclusion

There is no doubt whatsoever that the management of water resources will pose a major challenge in this century, particularly as the growth in the global population is greatest in regions with dry and semi-dry climates. With its TIGER initiative, ESA is addressing this challenge head-on by fostering a greater understanding of the water cycle, and by providing crucial information to decision makers at local, regional and global levels. Improved information about the use of water resources not only provides a better basis for life and health to local people, but is also a critical factor in supporting peace and stability among countries desperately concerned about the use of shared water resources. Hence, information from satellites is not only a tool for natural-resource management, but also a confidence-building resource by providing transparent information to people in the developing and developed world.