WHITE PAPER ON GEO CAPACITY BUILDING AND
WATER RESOURCES IN AFRICA

THE AFRICAN WATER CYCLE COORDINATION INITIATIVE (AFWCCI)

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1. Introduction to Capacity Building and the role of GEO

1.1. Definition of GEO and GEOSS

The Global Earth Observation System of Systems (GEOSS) is a coordinating and integrating network of Earth observing and information systems, contributed on a voluntary basis by Members and Participating Organizations of the intergovernmental Group on Earth Observations (GEO). The vision for GEOSS is to realize a future wherein decisions and actions for the benefit of humankind are informed by Earth observations and information. Thus GEOSS implementation aims to achieve comprehensive, coordinated and sustained observations of the Earth system in order to improve monitoring of the state of the Earth, increase understanding of Earth processes, and enhance prediction of the behaviour of the Earth system.

GEOSS will meet the need for timely, quality long-term global information as a basis for sound decision making and will enhance delivery of benefits to society in the following initial areas:

- Reducing loss of life and property from natural and human-induced disasters;
- Understanding environmental factors affecting human health and well-being;
- Improving management of energy resources;
- Understanding, assessing, predicting, mitigating, and adapting to climate variability and change;
- Improving water-resource management through better understanding of the water cycle;
- Improving weather information, forecasting, and warning;
- Improving the management and protection of terrestrial, coastal, and marine ecosystems;
- Supporting sustainable agriculture and combating desertification;
- Understanding, monitoring, and conserving biodiversity.

GEOSS is a step towards addressing the challenges articulated by the United Nations Millennium Declaration and the 2002 World Summit on Sustainable Development, including the achievement of the Millennium Development Goals. GEOSS will also further the implementation of international environmental treaty obligations.

1.2. Strategic Goals of GEO in Support of GEOSS:

- Sustain operation of comprehensive and coordinated Earth observation networks that meet user requirements in support of informed decision-making;
- Sustain operations of the shared architectural GEOSS components and related information infrastructure;
- Address the need for timely, global and open data sharing across borders and disciplines, within the framework of national policies and international obligations, to maximize the value and benefit of Earth observation investments;
- Implement interoperability among observational, modeling, data assimilation and prediction systems;
- Foster research and development activities and coherent planning for future observation and information systems;
- Catalyze national, regional and global investments in scientific and technological advances and innovative approaches for upgrading and expanding Earth observations;
- Build the capacity of individuals, institutions and infrastructures to benefit from and contribute to GEOSS, particularly in developing countries.

1.3. Capacity Building and GEO

GEO’s use of the term “capacity building” is based on the definition established at the 1992 United Nations Conference on Environment and Development (UNCED) which encompasses human, scientific, technological, organizational and institutional resources and capabilities. UNCED recognized that a fundamental goal of capacity building is to enhance the abilities of stakeholders to evaluate and address crucial questions related to policy choices and different options for development. The GEO definition of capacity building embraces UNCED’s aspirations and focuses on three elements of clearest relevance to Earth observations: individual, institutional and infrastructure capacity.

- **Individual capacity building** refers to the education and training of individuals to be aware of, access, use and develop Earth observation data and products.

- **Institutional capacity building** focuses on developing and fostering an environment for the use of Earth observations to enhance decision-making. This includes building policies, programs and organizational structures in governments and organizations aimed at enhancing the understanding of the value of Earth observation data and products.

- **Infrastructure capacity building** relates to the hardware, software and other technology required to access, use and develop Earth observation data and products for decision-making purposes.

1.4. Current Status of Earth Observation Capacity Building Initiatives

The GEOSS 10-Year Implementation Plan noted that the current availability of Earth observation data and products, especially in developing countries, is not sufficient to support environmental decision-making. Gaps in satellite, aerial and *in situ* observations are being addressed through existing capacity building efforts being pursued by member and non-member GEO institutions.

Using a preliminary survey and analyses of existing documentation related to Earth observation capacity building needs, GEO’s findings indicate that there are many opportunities to build Earth observation capacity, especially in developing countries. For example, initial research revealed the following issues for Africa:

- Limited access to capacity building resources;
- Lack of e-science infrastructure for Earth observation education and training;
- Need for criteria and standards for Earth observation capacity building;
- Gaps between Earth observation research and operational application;
- Connectivity inefficiency between providers and users of Earth observation systems;
- Need for cooperation within and between developed and developing countries and regions;
- Lack of awareness about the value of Earth observations among decision-makers; and
- Duplication of Earth observation capacity building efforts.

1.5. The GEO Approach to Capacity Building

Rather than creating new Earth observation capacity building efforts, GEO seeks to coordinate and build upon existing efforts worldwide to increase the efficient use of limited resources. Such coordination can bring additional institutions into the GEO community and can help fill gaps in current Earth observation capacity.

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2 GMES and Africa: African Global Monitoring for Environment and Security
The establishment of GEOSS by the year 2015 calls for development of a Capacity Building Strategy based on existing efforts and best practices. The strategic target for Capacity Building within GEOSS implementation reads:

Before 2015, GEO aims to enhance the coordination of efforts to strengthen individual, institutional and infrastructure capacities, particularly in developing countries, to produce and use Earth observations and derived information products.

This will be achieved through:

- working with and building on the capacity building efforts of GEO Members and Participating Organizations to further increase the synergies and effectiveness of national and international capacity building programs;
- ensuring the engagement and committed involvement of resource providers in the GEO capacity building process;
- enhancing capacity building efforts to ensure the integration of mature Earth observation-based information systems into day-by-day end-user practices including decision-making, management processes and planning for all Societal Benefit Areas.

This will be demonstrated by:

- Networking activities that specifically build individual, institutional and infrastructure capacity.
- Leveraging resources for Earth observation capacity building efforts.
- Increased use of Earth observation in policy and decision-making.
- Enhanced participation of developing countries in GEO and GEOSS.

1.6. Capacity Building in the Water SBA of the GEO 2009-2011 Work Plan

The GEO 2009-2011 Work Plan serves as the compendium of tasks dedicated to GEOSS implementation in each of the cross-cutting and Societal Benefit Areas of GEO, subject to approval by the GEO Plenary. As such, the Work Plan provides the blueprint of activities and demonstrables leading to achievement of the strategic targets. Within the Water SBA, over-arching task WA-06-07 (“Capacity Building for Water Resource Management”) is defined as developing a plan for a capacity building program focused on the use of Earth observation data for water resources management (surface waters, groundwater), to help: (i) Identify data and general support from space agencies; (ii) Identify a coordinating agency to organize calls for proposals and securing reviews and monitoring of the proposals; (iii) Identify further funding sources; and (iv) Issue a call for participation to the research and development community. Activities within WA-06-07 are then subdivided into three regions: Asia, Latin America & the Caribbean, and Africa.

Asia

In order to address common water-related problems across Asia and promote integrated water resources management by making information usable through GEOSS, the Asian Water Cycle Initiative (AWCI) has greatly strengthened regional cooperation on water monitoring through joint cooperation in river basin pilot projects. Twenty member countries are collaborating on demonstration projects representing 18 river basins to address issues related to observational convergence, interoperability and data integration through the web-based Data Integration and Analysis System (DIAS), and capacity building/training modules in cooperation with the Integrated Flood Alert System (IFAS)/International Centre for Water Hazard and Risk Management (ICHARM), JAXA, Asian Institute of Technology (AIT), United Nations University (UNU) Institute for Sustainability and Peace (ISP) and University of Tokyo. Promotion of GEOSS Data Sharing Principles is also a major component.
Latin America & Caribbean

The Latin America & Caribbean Community aims to develop a plan for a capacity building program focused on the use of Earth observation data for water resources management (surface waters, groundwater). NASA’s SERVIR for Central American (visualization and monitoring using Earth science data) has been particularly successful in this regard.

Africa

Earth Observations and products can be a major source of information for dealing with the water resources challenges facing the African continent. In this context, the GEO framework is being used to coordinate international capacity building efforts to support the development of sustainable African Water Observation Systems, making the best use of Earth observations and products to improve the collection of water information, to enhance knowledge of water cycle and to improve monitoring of water resources for effective adaptation and mitigation measures against impacts of climate change. Activities do not start from scratch but are based on the successful results of the CEOS TIGER initiative obtained during its first implementing period 2005-2008. In the scope of Phase II of the TIGER initiative (focusing on the use of space technology for water resource management in Africa), TIGER will assist African countries to overcome problems faced in the collection, analysis and dissemination of water-related geo-information. In general, TIGER exploits the advantages of Earth Observation (EO) technology to build the basis for an independent African capacity and set up sustainable water observation systems. In addition, plans are being made to build and extend SERVIR (mentioned above) for hydrologic applications (e.g., flood warning) from Central America to East Africa and possibly other parts of the world.

Stepping back to the wider perspective, the African Water Cycle Coordination Initiative (AfWCCI) was launched in Tunisia, January 2009 to bring convergence and harmonization of existing observational activities, techniques, interoperability arrangements, and effective and comprehensive data management as the most fundamental elements that can be addressed under the GEOSS framework, including activities, programs and guidelines under both UN and non-UN agencies.

2. Introduction to Capacity Building Needs for African Water Resources

2.1. African Water Cycle Capacity Building – Scope of the Problem

The nature of water problems vary across the African continent. Although Africa is generally marked by aridity, the continent does experience a wide range of climate conditions, especially in those areas where the Intertropical Convergence Zone (ICTZ) provides rain. In the past, the rivers and lakes of Africa have been able to supply the needs of human societies and wildlife. However, in more recent years changing precipitation patterns accompanied by higher water use have led to the drying up of many of the ponds, wetlands and even lakes. Some of these changes are also related to land use change and/or to the population changes that lead to higher water requirements for human needs.

Issues related to water and health are the result of poor sanitation and indicative of poverty levels. Water-related health issues are common throughout West Africa and Central Africa. According to projections of climate change, the frequency of dry days is expected to increase in North Africa and South Africa, while incidents of heavy rain events are expected to increase in east Africa.\(^3\) Floods and droughts have distinct patterns. For

\(^3\) IPCC 4\(^{th}\) Assessment Report
example, in Central Africa there is a high risk of mortality associated with droughts, but this risk is lower in North and South Africa. In areas where drying is occurring, wetlands and freshwater ecosystems are under continuing threat. Groundwater is another issue in many parts of Africa. In North Africa, groundwater is being withdrawn at unsustainable rates and there is a danger that this resource is being depleted. Given that groundwater is a critical resource for many parts of Africa where surface waters are either non-existent or polluted, its use should be pursued as the development option of last resort. Finally, many of the basins in Africa are transboundary in nature – leading to the important role being played by River Basin Authorities in maintaining appropriate relationships between upstream and downstream countries. For example, the 17 West African countries share 25 transboundary watercourses. Even with these authorities in place there are still tensions between countries in some areas.  

The following references have been used to describe the scope of water issues and challenges in Africa.  

With its 5400 km³ of renewable resources (10% of the world), water represents one of the major development drivers in Africa. It includes over 40 million ha of irrigation potential and 1.4 million GWh of hydro power potential. Today, major river systems suitable for navigation represent a major infrastructure for inland transport. In addition, water bodies, rivers, lakes and wetlands represent a harbor of biodiversity, fisheries and an ecology attraction for tourists. In spite of this economic potential, Africa still faces significant challenges to ensure effective use and efficient management of its water resources:

- The multiplicity of transboundary water resources (more than 60 trans-boundary basins) significantly increases water governance and risk;
- There is low level of development and water utilization. For instance, only approximately 4% of the available water is used in the whole continent. In the case of irrigated areas, the actual use amounts to less than 10% of potential, while only 6% of the hydropower potential has been developed. Concerning water supply and sanitation, the figures are dramatic: over 300 million Africans lack access to safe water supplies and adequate sanitation.
- It is estimated that by 2025 about 600 million people will be exposed to water scarcity situation (<1000 m³/capita/yr).
- Huge infrastructure gaps with less than 50 m³/person storage capacity compared to over 3000 m³/person in Europe and 5000 m³/person in USA.

In a similar vein, the summary report from the first GEO African Water Cycle Symposium identified a number of key challenges currently faced by hydrology researchers and resource managers in Africa:

- Floods and droughts, resulting from large variabilities of atmospheric systems and climate change over the fragile desert and tropic zones, are leading to large human and socio-economic losses, pollution and environmental degradation. These impacts challenge scientists to urgently improve our understanding of these phenomena and capability to predict their onset, intensity and termination.
- Improved management of rivers is needed, particularly for trans-boundary rivers during floods or drought conditions.
- Water scarcity, water pollution and environmental (ecosystem, biodiversity) degradation, including desertification, are increasingly serious in Africa, a continent which has one of the highest population growth rates in the world.

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4 Climate-Induced Water Conflict Risks in West-Africa: Recognizing and Coping with Increasing Climate Impacts on Shared Watercourses  
6 Africa Water Vision for 2025  
8 United Nations Economic Commission for Africa (UNECA); www.uneca.org/awich
• The changing climate is affecting water resources and their use in ways that are only now being recognized. A better understanding of the effects of climate change on the water cycle is therefore needed. In particular, participants pointed out that the increased frequency of climate extreme events in Africa is taking the form of heavy rains in some regions and prolonged drought conditions in others. Many countries are concerned about the potentially significant impacts of global climate change on critical yet vulnerable water resources in Africa.

• Many countries are becoming increasingly reliant on groundwater resources. Over-exploitation of this resource is responsible for lowering water tables in many countries. Furthermore, in many coastal areas groundwater is becoming saline from marine water intrusion.

• Many countries are experiencing difficulties in proper management of water resources and have expressed interest in capacity building programs to correct this problem.

• Observational systems, modeling capabilities and understanding of precipitation processes are needed to support operational forecast services, especially for the complex precipitation systems that produce rainfall over Africa.

• Although many water projects exist in Africa and many international agencies support water programs there, the coordination of these activities is inadequate and leads to inefficiencies.

• Many areas of Africa that are experiencing water problems, especially specific areas (or hot spots) where these issues are critical (e.g., Lake Chad, North Africa groundwater).

• Many African countries need to improve their limited capabilities and infrastructure to address these issues in a systematic way.

In this complex and challenging context, water information systems are fundamental for improving water governance and implementing Integrated Water Resource Management (IWRM) successfully. Today, in many African countries, policies and management decisions are based on sparse and unreliable information. This water information gap is thought to significantly hinder the attainment of water-related Millennium Development Goals (MDGs) as well as delay putting in practice IWRM plans to face the current and coming challenges of the African water sector. New infrastructure and delivery systems are needed to bring appropriate and timely information on the above issues to those who must make decisions about water development. To cope with these issues there must be improvements to the data sets that are available to decision makers and to the systems whereby these data are distributed and displayed.

2.2. Impacts from Climate Change

To gain a more focused understanding of the regional/national challenges being encountered on the African continent with respect to climate change and its impacts on water resources, a detailed questionnaire was distributed to participants in the first Task Team meeting. Based on responses received, the following national/regional water-related impacts and adaptation measures in the context of climate change were identified:

**ACMAD:**

• Mean yearly precipitation is decreasing in large parts of the northern and southern Africa.

• Lake surfaces in many countries diminish, cutting some of the water used food production (for fisheries or irrigation).

• Rivers are not any more “navigable” in some parts.

• Other areas experience more frequent flash floods.

• Drought is more widespread.

**Cameroon:**

• A decrease in the annual precipitation has been reported (an estimated 15.02% decrease from 1961 to
Rainfall has become scant, highly variable and unevenly distributed, leading to the abandonment of the cultivation of tubers like cassava and sweet potatoes.

- Rivers and waterholes for cattle dry out faster than in the past, leading to water scarcity in the region.
- The River Benue is now hardly navigable.

Ghana:
- The rainfall pattern has changed. The rainfall season appears to be shorter than before and the intensities seem to be higher.
- The higher intensities result in floods that are causing pollution and degradation to water bodies that feed dams used by the water supply company.
- Scientific studies in Ghana indicate that rainfall and water resources are declining due to climate change (mean annual total rainfall is projected to decrease by about 9-27% by 2100)
- Surface water and groundwater recharge are projected to decrease anywhere from 10% to 50% by 2050.
- Raising awareness of impacts on the country in terms of water supply, health, food security, etc., is needed. Possible adaptation measures such as rainwater harvesting and utilization of small reservoirs should be considered.

Ivory Coast:
- In the past decades there have been more heavy rains (especially since 2004) while in the north it has become drier.

Lake Chad Basin: Four transboundary areas where impacts associated with climate change is a major issue:
- Variability of hydrological regime and freshwater availability
- Decreased viability of biological resources
- Loss of biodiversity
- Loss and modification of ecosystems

Somalia:
- Due to lack of baseline and recent information for comparison purposes, it was not possible to assess the impact of climate change on the Somali water resources and environment in general.
- Somalia is highly vulnerable to climatic changes given that two thirds of the country is arid and semi-arid.
- There is evidence of increases in extremes, e.g., river flooding, flash floods in the northern part and droughts.
- SWALIM natural resources studies indicate that there is serious environmental degradation and loss of vegetation cover due to absence of legislation and institutions to manage natural resources.

Togo:
- increase of rain
- increase of the flooding frequency
- erosion of the coast
- increase of temperatures

Volta Basin:
- Temporal and spatial distribution of rainfall and hence water availability is changing, adversely affecting crop growing patterns and therefore food security in the region.
- Some areas are becoming drier and floods are occurring more frequently during the rainy season.
- In the dry season, droughts also become common as the floods subside very quickly.
2.3. Climate Change Adaptation

Benin:

- The way in which Climate Change is affecting water resources is typified by significant reductions in the mean annual precipitations; consequently, a global decreasing flow tendency has been observed in the mean annual discharge on major rivers in Benin (Ouémé River, Mono River, Niger at Malanville, etc.).
- However, climate change affects water resources. This is evidence not only by the observed changes in the hydrologic cycle, but also by the increase of uncertainty in projecting hydrologic conditions. For example, increases in the intensity and frequency of extreme weather events (i.e., flash floods, droughts) are among the frequently observed outcomes of climate change in West Africa.
- More generally, most impacts associated with climate change in West Africa occur because the climate changes will have a major impact on water supply and demand.
- By altering the water cycle, climate change is exacerbating the water challenges facing this region and particularly jeopardizing the Millennium Development Goal plans.
- Therefore, most of the actions which are being elaborated for adaptation to climate change in Benin are related to water sector. They include:
  - The Ministry in charge of environment has elaborated the Natural Adaptation Program of Action (NAPA) focusing on water-related issues.
  - Some NGOs (i.e., Benin-Water Partnership – PNE-Benin) have initiated actions oriented toward advocating the necessity of political interest in and financial support of weather and data monitoring.
  - Placing the NHS within the “Direction Générale de l’Eau (DGÉau)” of the Ministry of Energy and Water. This will orient its activities toward reversing the retrogression of data collection system as well as promoting the maintenance and operation of networks and field stations.
  - The Ministry in charge of Education and Research has initiated the process of educating and training a new generation of climate-water risk management specialists.

Volta Basin

- Introduction of new crop varieties adapted to the changes, e.g., early maturing and drought-resistant species;
- Land management to improve water soil moisture needed for optimal crop growth, e.g., rain harvesting
- There are efforts to predict the onset of the rainy season through the use of empirical models.
- The creation of artificial water storage structures for use in the dry season.

2.4. Earth Observations and Africa

According to GMES Action Plan, obstacles and constraints that hinder Earth Observation capacity building efforts include:

- Limited access to CB resources and lack of knowledge transfer for EO applications;
- Lack of infrastructure for EO education and training (Internet access, e-science and e-learning);
- Need for criteria and standards for EO CB;
- Gaps between EO research and operational application;
- Connectivity inefficiency between providers and users of EO systems;
- Need for cooperation within and between developed and developing countries and regions (the very reason of the GMES partnership);
- Lack of awareness about the value of EO among decision makers; and
• Duplication of EO CB efforts.

The summary report from the First GEOSS African Water Cycle Symposium revealed the commonality and regionality of water-related issues and socio-economic impacts caused by water-related disasters in Africa, such as floods, droughts and landslides, water scarcity, river and water environment degradation, and the effects of climate change overall. It was agreed that well-coordinated scientific research initiatives along with a combination of global Earth observations and models using physical, chemical, biological and socio-economic information are essential to adequately address these issues. Furthermore, these efforts must benefit planning and operational services and programs by improving their efficiency and effectiveness.

3. Specific Information and Decision-support Needs (Requirements, Gap Analysis, New Opportunities, Recommended Actions)

3.1. Requirements – water resource management
[actual impacts and consequences of water problems on local populations and how lives are affected; e.g. what is needed from EO to make agriculture strategy more effective in semi-arid areas increasingly vulnerable to droughts.]

Water Management is a complex task that requires a broad spectrum of data products. These in turn require a similarly broad spectrum of data, ranging from remotely-sensed data at coarse to fine resolutions to in-situ data, in some cases at high density. In order to provide useful information to responsible decision makers and actors, not only do we require the data, we require the technological understanding to draw appropriate conclusions and to understand the likely consequences of various possible actions. As one participant from Morocco in the AfWCCI has observed:

- The conventional methods used in agricultural irrigation (surface irrigation, sprinkler irrigation) are causing an enormous waste of water resources (network efficiency to 40% on average for surface irrigation and 60% for sprinkler irrigation), which causes a large waste in the stored water.
- The management of water depends directly or indirectly on a variety of departments, public institutions, and semi-public institutions with an inadequate sharing of responsibilities.

This section lays out the useful information needed for the task. Much of the data are not available. Making the requisite data available may require merely establishing or improving the distribution mechanisms. It may require reducing the price or eliminating charges for the data altogether. In some cases the sensing systems do not exist. In other cases, existing systems may provide data but the scientific understanding of the connection between data and information may be incomplete. An important consideration is the presentation of the data in forms and formats useful to the particular user. In most cases the users have little appreciation of the technical details of the data, so the Science and Technology Community faces the task of presenting appropriate visualizations that will enlighten the user. Clearly, these presentations vary depending on the particular user’s needs. We need to be particularly concerned about building the human capacities within the various countries in Africa. Part of our Capacity Building Task it to ensure that training and education are available to all potential users. This may involve endeavours ranging from short workshops to the commitment to developing a broad education system for the whole population.

Respondents to the above-mentioned 1st Task Team questionnaire identified a large number of needs related to
the use of Earth Observations in water management. These needs included trained experts and other human resources and capacity, infrastructure for data management and services, data processing, simulation models, software customization, institution capacity modernization of observational equipment, national-level training programs, better high-speed internet connections and more data harmonization to promote data exchange between countries. One respondent articulated the impact of war on networks and on the loss of skilled manpower to collect quality control and use data.

Table 1: Summary of the water management needs identified in the survey of African countries (B=Benin; BF=Burkina Faso; Ca=Cameroon; Ch=Chad; G=Ghana; IC=Ivory Coast; So=Somalia; To=Togo; Tu=Tunisia; VB=Volta Basin; Zm=Zambia).

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</tr>
</tbody>
</table>
3.2. Requirements – remote sensing

[completing the information chain, from data providers and processors, through information and services, to decision-makers].

Respondents to the questionnaire distributed at the 1st Task Team meeting were asked to indicate their level of usage of satellite data. Landsat and Meteosat data products proved to be the most widely used. SPOT and NOAA imagery also are used. The EUMETCAST system is also used as a data delivery system. In terms of in–situ measurements most countries and river basin authorities reported significant surface networks although very few countries have radisonde stations. Other gaps in the data collection programs relate to water level measurements (as opposed to streamflow), soil moisture, groundwater and water quality measurements. There is a substantial amount of satellite data available to countries in Africa, although some countries do not have the receiving facilities and other countries are not aware of the data and how to access it and to use it.

Table 2: Summary of the types of satellite data that are currently used in Africa (B=Benin; BF=Burkina Faso; Ca=Cameroon; Ch=Chad; G=Ghana; IC=Ivory Coast; So=Somalia; To=Togo; Tu=Tunisia; VB=Volta Basin; Zm=Zambia).

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<th>G1</th>
<th>G2</th>
<th>IC</th>
<th>So</th>
<th>To N</th>
<th>Tu</th>
<th>VB</th>
<th>Zm</th>
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</tbody>
</table>

Water pollution | X | X |
3.3. Requirements – *in-situ* networks

In terms of *in-situ* data networks, some countries have developed their observational networks better than others. In some cases it is evident from the data submitted where there are limitations in the networks.

**Table 3**: Summary of *in-situ* instrumentation and observing sites reported by each country (B=Benin; BF=Burkina Faso; Ca=Cameroon; Ch=Chad; G=Ghana; IC=Ivory Coast; So=Somalia; To=Togo; Tu=Tunisia; VB=Volta Basin; Zm=Zambia).

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<th>Ga1</th>
<th>Ga2</th>
<th>To</th>
<th>So</th>
<th>Tu</th>
<th>Ch</th>
<th>Zm</th>
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<td>73</td>
<td>138</td>
<td>9</td>
<td>26</td>
<td>64*</td>
<td>120</td>
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<td>80</td>
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<tr>
<td>Humidity</td>
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<td>12</td>
<td>51</td>
<td>73</td>
<td>138</td>
<td>8</td>
<td>9</td>
<td>26</td>
<td>60</td>
<td>30</td>
<td>80</td>
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<tr>
<td>Wind</td>
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<td>12</td>
<td>51</td>
<td>73</td>
<td>22</td>
<td>8</td>
<td>9</td>
<td>26</td>
<td>60</td>
<td>28</td>
<td>80</td>
</tr>
<tr>
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<td>73</td>
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<td>26</td>
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<td>25</td>
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<tr>
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<td>8</td>
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<td>26</td>
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**HYDROLOGICAL**

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<th>44</th>
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<th>80</th>
<th>35</th>
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<tbody>
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<td>Reservoir (Water level, Outflow)</td>
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<td>44</td>
<td>2</td>
<td>0</td>
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<td>80</td>
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**Water Quality**

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<td>Groundwater quality indicators</td>
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<td></td>
</tr>
<tr>
<td>Surface water quality indicators</td>
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<td>1</td>
<td>30</td>
<td>6</td>
<td>33</td>
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</table>

This list of needs was seen as pointing out directions for GEO efforts in Africa’s water sector. They need to focus on data infrastructure and promote a more collective approach to the planning and implementation of data collection activities. At the global level GEO could serve as an advocate for ways and resources to address these problems in Africa. It could also help with the implementation of capacity building and training programs. Respondents noted that on the African continent, GEO will be most effective if it works with regional organizations including River Basin Authorities in Africa.

### 3.4. Requirements - data products, infrastructure, and services

Extensive use is made of the data that are collected. According to the respondents, the most common use involves water management, with flood protection ranking second. Agricultural applications and hydropower planning and operations were other application areas of interest to multiple countries. In terms of data access, it seems that the most effective data programs are those that are managed by international organizations (FAO in
Somalia) or where agreements exist between countries that share a common river basin managed through a regional authority. Some nations maintain their own data services while others rely on regional services. While a number of counties are making extensive use of the internet as a way of distributing data, other countries have not reached this level of sophistication. In some cases national data sets and data products are free while in other cases countries charge for these services. Issues such as slow internet service and limited processing and storage capabilities combined with the lack of trained manpower hinder the advances of national data providers.

Table 4: Summary of status of national/regional data access as determined from the 1st Task Team meeting questionnaire. The detailed responses are included in the Annex (B=Benin; BF=Burkina Faso; Ca=Cameroon; Ch=Chad; G=Ghana; IC=Ivory Coast; So=Somalia; To=Togo; Tu=Tunisia; VB=Volta Basin; Zm=Zambia).

<table>
<thead>
<tr>
<th>Country</th>
<th>CB</th>
<th>BF</th>
<th>CA</th>
<th>CH</th>
<th>G1</th>
<th>G2</th>
<th>IC</th>
<th>So</th>
<th>To</th>
<th>Tu</th>
<th>VB</th>
<th>ZM</th>
<th>ACMAD</th>
<th>CELISS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open data for members of the River Basins - others must request approval</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data managed by intl UN bodies and by their rules</td>
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<td>X</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Nationally open data sets accessible by internet</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some satellite products free - rest of data products must be requested and purchased</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Data made available by request to national service</td>
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<td>X</td>
<td>X</td>
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<td></td>
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</tr>
<tr>
<td>Data made available freely for research and applications</td>
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</table>

3.5. Gap analysis

There are a great number of African scientists specialized in hydrology, informatics, georesources, GIS, descriptive climatology and meteorology but few are concerned with addressing questions of remote sensing of water resources and of downscaling climate scenario. Effectively, as outlined in a TIGER report, the use of EO techniques in Africa is still far from being considered operational. Moreover, research programs and
demonstration projects are still infrequent. One reason is the difficulty of accessing to remote sensing data. As a solution, for example, TIGER projects have benefited from the provision of a privileged access to EO data (ENVISAT, ERS, RADARSAT, Landsat, SPOT-4, ALOS), as well as dedicated training and software tools.

In terms of the requirements for improved information capabilities, African nations identified a number of issues in addition to those raised specifically in the African water cycle survey needs. These are summarized in Table 5.

**Table 5:** Summary of gaps identified by countries in the 1st Task Team meeting questionnaire. The detailed responses are included in the Annex (B=Benin; BF=Burkina Faso; Ca=Cameroon; Ch=Chad; G=Ghana; IC=Ivory Coast; So=Somalia; To=Togo; Tu=Tunisia; VB=Volta Basin; Zm=Zambia).

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<th>Gh</th>
<th>IC</th>
<th>So</th>
<th>To</th>
<th>Tu</th>
<th>VB</th>
<th>ZM</th>
<th>ACMAD</th>
<th>CELISS</th>
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<tbody>
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<td>Security for instruments in the field</td>
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<td>X</td>
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<tr>
<td>Improved networks and instrumentation</td>
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<td>X</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>Improved data processing</td>
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<td>Improved data communications (internet)</td>
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</tr>
</tbody>
</table>
Based on this observation, and given the fact that African universities have structures that are well established, there is an opportunity to build programs in remote sensing for georesources and dynamic climatology and particularly downscaling sciences, at the doctoral level, that will produce scientists capable of tackling the global water issues research. In order to ensure impacts on the economic and private sector, specific programs of Professional Master Science-level would also be implemented.

**Table 6:** In the light of the 1st Task Team questionnaire responses, the analysis of the available support tools suggests the following gaps.

<table>
<thead>
<tr>
<th>Decision support tool</th>
<th>AGRHYMET</th>
<th>Coast-Ivory</th>
<th>Togo</th>
<th>Ghana</th>
<th>ACMAD</th>
<th>RCMRD</th>
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<tbody>
<tr>
<td>Ground-based system monitoring with appropriate spatial density</td>
<td>*</td>
<td>?</td>
<td>?</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Hydrological parameterization software (ILWIS and ARCGIS)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Data management supports</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Decision based on dynamic hydrological models</td>
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<td></td>
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<td></td>
<td></td>
<td>?</td>
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<td>Decision based on risk analysis</td>
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<td></td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>Decision based on the adoption of Moderate resolution Remote sensing products</td>
<td>EUMETCAST MODIS CORONA LANDSAT</td>
<td>SPOT - LANDSAT</td>
<td>Landsat Spot METEOSAT</td>
<td>MeteoSat (PUMA project)</td>
<td>AMESD receiving stations (EU METSAT, WMO, JRC)</td>
<td>* receive data and derived products from the Advanced Synthetic Aperture Radar (ASAR) MEdium</td>
</tr>
</tbody>
</table>
3.6. Dissemination and Service Delivery Needs

For meteorological information, it is worth noting that a large use of remote sensing is adopted by African meteorological institutes (mainly meteosat products). Conversely, the use of remote sensing for hydrological analysis is not of wide use. A reason may be that the linkage between hydrological services and water agencies with WMO is not so important as for meteorological services. On the other hand, the remote sensing information is not so crucial for day-to-day hydrological analysis. Actually, ground observations constitute the core of decision-making. However, it is clear that this situation is changing especially under the consideration of transboundary basins, environmental risk assessment at large scales as well as climate change risk.

Dissemination of capacity building tools may be achieved through the web or by using teletraining (as with, for example, Resolution Imaging Specrometer (MERIS) sensors, and plans are underway to install a GEONETCast antenna).
example, the francophone university program Formation à distance, and the UNU program). On the other hand, training sessions and research programs may be proposed to achieve this goal.

Other dissemination and service delivery issues that need to be addressed:

- Land use information:
- Landsat data are a source for the land-use information highlighted needs
- Improve Archiving facilities

3.7. Additional Issues

Somalia:
Financial resources:

- Resources are needed to meet the millennium development goals
- Somalia is in emergency situation and all donors and interagency efforts are focused on emergency response, with donors stretched to their limits, essential water resources management issues are not addressed and are not priority (e.g., the country has no hydrogeological map and no survey conducted to guide drilling and GW resources development).
- Lack of functioning administration in the country impedes implementation of UN transboundary water agreements and conventions. Support is needed by mandated UN and other bilateral organizations to defend the rights of the Somalia people in the management of transboundary water resources.

- From SW ALIM side:
  1. Support SW ALIM information management activities and efforts through provision of Earth Observation data and infrastructure for its handling available satellite and radar data that will assist SW ALIM to carry out surface and GW water resources assessments (support hydrogeological survey through satellite and radar),
  2. Improve weather information and data needed to develop sound drought and flood forecasting and monitoring systems and,
  3. joint research activities.

SWALIM is struggling to collect all lost water-related data and information, including publication, for Somalia. There are many archives worldwide, e.g., in Italy, the U.K., etc., that need to be recovered and made available to SWALIM.

3.8. Summary of decision supports needs

According to Su (2005)⁹, two issues need to be achieved:

- Earth Observation of the water cycle: The aim of this theme is to contribute to quantify water cycle components (water fluxes and storages) by using Earth Observation data, including precipitation and evapotranspiration fluxes and groundwater recharge.
- Modelling hydrological processes by using Earth Observation and data assimilation: The aim of this theme is to increase ability to model hydrological processes using Earth Observation data and data assimilation techniques.

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⁹ Su, ITC (2005)
Moreover, to achieve both purposes, it is important to develop the efficiency of existing monitoring systems as well as to implement (where it seems necessary) new field observation sites. Effectively as outlined by Su (2005) these observation sites are suitable for (i) basic water cycle process studies, (ii) for Earth Observation methodology calibration and validation, and (iii) for educational purposes.

These decision supports will help develop regional integrated studies. After Desanker and Justice (2001), some key issues related both to the global climate change and to the water cycle coordination initiative involve three questions: (i) climate variability, (ii) hydrological impacts of extremes (droughts and floods), as well as (iii) the management of frontier water resources. Effectively, by region, they are delineated as follows:

- Sahel region: climate variability and conflicts
- East and Horn of Africa: climate variability and droughts and floods
- Southern Africa: climate variability and droughts and floods
- Central Africa: climate variability and change in land use effects
- Maghreb region: droughts and desertification
- Coastal zones: flooding

To address these issues, the decision support is mainly based on the following scientific topics:

- Rainfall remote sensing estimates (NOAA, TRMM)
- Hydrological parameterization using software (such as ILWIS and ARCGIS)
- Data management supports (inventory Databases, ArcView, ArcGis)
- Dynamic hydrological models (or software) including groundwater modeling and recharge (FEFlow, Modflow, SMS HEC Geo RAS, HEC-HMS, …)
- Software for remote sensed water balance (AVHRR Hydrological Analysis System, …)
- Ground monitoring system with appropriate spatial density (rainfall, runoff, groundwater levels, air temperature, …).
- Moderate-resolution remote sensing products (for Input - Outputs)
- Downscaling means
- Forecasting tools
- Risk analysis and assessment
- Data exchange (with other water services)
- Data storage and archiving capacity (National infrastructure to manage, catalogue, archive space data)

Thus, the proposed activities centere on developing a comprehensive climatological-hydrological model that would couple climate scenario projections at the local scale and hydrological responses for decision-making purposes. However, because of water and energy fluxes are well related in the water cycle process, a broader recommendation is to help construct few local research programs on the larger thematic of Energy and Water Cycle fluxes and remote sensing (see for example the NASA-NEWS Energy and Water Cycle Study program [http://www.nasa-news.org/funded_projects/docs/news_0809_selections.pdf]).

4. Institutional Capacities

At the Executive Seminar on using Earth Observations for Improving Water Management in Africa, hosted by the Faculty of Geo-Information Science and Earth Observation (ITC) on 23-25 September 2008 in Enschede, the Netherlands, the question was posed generally to the participants: “What are the blocking points today from the perspective of basin initiatives to make use of Earth observations for improving water resources management?” One response was that there are problems on two levels: first, a critical mass of people who can use Earth observation technologies in governmental capacities has not yet been reached; and second, access to tools is
limited. Another participant added that it is not a question of institutional reticence: governments are keen on participating and Earth observation technology is available throughout Africa, but there are not enough people having the skills to apply it. A third response noted that leveraging of existing infrastructure across Africa is generally lacking.

These responses underscore the relevance of the GEO Capacity Building Strategy which focuses on the three elements of clearest relevance to Earth observations: institutional, infrastructure, and individual capacity (“3 I’s” strategy)\(^{10}\):

- **Institutional capacity building** is focused on developing and fostering an environment for the use of Earth observations to enhance decision making. This includes building policies, programs and organizational structures in governments and organizations aimed at enhancing the understanding of the value of Earth observation data and products.
- **Infrastructure capacity building** is related to the hardware, software and other technology required to access, use and develop Earth observation data and products for decision making.
- **Individual capacity building** refers to the education and training of individuals to be aware of, access, use and develop Earth observation data and products.

It is from this perspective that the next 3 Sections will outline existing capacities in Africa, with Section 4 reviewing institutional capacity, both African and international in scope; Section 5 reviewing current infrastructure capacities; and Section 6 looking at present efforts to build individual capacities.

### 4.1. Existing African Institutional Capacity

The Task Team has noted that coordination already exists at both regional and sub-regional levels across Africa. As examples, the African Centre of Meteorological Applications for Development (ACMAD) serves a coordinating role for climate issues, as well as the African Monsoon Multidisciplinary Analysis (AMMA) that is attempting to interface science with socio-economic issues across the monsoon region. At the same time, the level of knowledge of international programs that could be of assistance to regional activities is often limited. The WMO WHYCOS program was the best known according to the survey, with more recent activities including TIGER, AMMA, AMCOW and UNESCO IHP also receiving recognition by at least three of the respondents. Any capacity building efforts under the GEO framework should therefore be established with both African and international components, building on the already successful efforts of institutions and programs such as these.

While not exhaustive, the following review outlines large scale projects in linkage with African water cycle assessment and Earth observations.

**ACMAD**

The African Centre of Meteorological Application for Development (ACMAD) is an inter-governmental institution under the Aegis of UNECA and WMO with a continental mandate. Its main mission is to assist the African Nations to achieve sustainable development through efficient use of meteorological and climate information.

Hence, ACMAD provides and disseminates, via various means, information for the implementation of policies for vulnerability reduction and adaptation to climate variability and climate change.

ACMAD has contributed to creation and enhancement of critical mass of trained officers in Africa in weather

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\(^{10}\) GEO Capacity Building Strategy document.
and climate. This has been achieved through several workshops and seminars the centre has been organizing

ACMAD has provided regional capacity building and training on high impact weather forecasting, development and applications of climate prediction tools (CPTs) in seasonal climate forecasting and Information Technology (IT) for meteorologists and climatologists from NMHSs in Africa.

ACMAD has a long experience in forecasting extreme weather and climate events, such as severe storms, droughts and floods among other. The seasonal climate consensus forecast issued during regional climate outlook forum (RCOF) has become a major tool in planning and management of climate risk in key socio economic sectors including development adaptation strategies to cope with increasing vulnerability and impacts associated with climate change.

A noteworthy achievement in mainstreaming of climate information into rural systems, is the RANET (Radio internet) system. ACMAD in collaboration with NOAA/CIMMS and other partners started in 1999 the RANET system for agro – hydro - meteorological, climate and environmental information dissemination down to the rural communities. A number of training workshops with media specialists have also been organized.

Some relevant experience in weather & climate applications

1. Weather forecasting & assistance to Community of Practice

ACMAD has implemented an operational procedure to produces & disseminate weather predictions focusing on high weather impact (high rate of precipitations, high winds, heat waves) to countries & regional users.

2. Seasonal Forecasting:

ACMAD has launched the PRESA process in Africa and since 1998 It has has conducted several Regional Climate Outlook Fora in three subregion of Africa. These forums are: eleven (11) PRESAO events for 18 countries (16 West Africa countries, Chad and Cameroon), three (3) PRESAC events for central Africa countries and one (1) PRESA-NOR for North Africa countries.

ACMAD collaborate with most of Global Producing Centers (GPCs) such as ECMWF, Meteo France, UKMO, IRI, NOAA and the Regional Organisation for improved climate services in Africa. ACMAD has contributed to AMMA forecasting component and has been involved in the WMO RCOF review held in Pretoria (2002) and in ARUSHA (2008) and recent WMO 3rd World Climate Conference (WCC-3) held on 31st August to 4th September, 2009.

3. Climate Change & Climate Risk Management:

i. ACMAD uses since 2003 the UKMO Precis model to generate climate change scenarios and has been providing capacity building and training in climate models downscaling, modeling and generation of climate change scenarios.

ii. ACMAD has conducted Climate Scenarios generation for Niger Basin Authority and is presently carrying out similar activity in the Nakambe-Wayne together with Ouranos (Canada) and 2iE (Burkina Faso) to assess climate change impacts on water resources within the basin as part of its collaborative consultation effort for other international institutions

iii. It has contributed to the AU head of State (2007) on climate change and it is one of the main potential actors in CLIMDEV Project and one of the four institutions coordinating the ACTION
PLAN FOR VULNERABILITY REDUCTION in West Africa for ECOWAS

4. Climate & Health:

Its strong collaboration with international climate institution such as IRI in climate risk management has resulted in building strong partnership between health and climate communities. A very relevant experiment was jointly conducted by ACMAD and WHO during January and June 2010, SAHEL dry season, in support of the WHO contingency planning for Meningitis. Continuous monitoring of dust loads and other weather/climate parameters which may be conducive for human diseases outbreak is being undertaken and alert given out on 10 day and monthly basis. Linkages between the North Atlantic Oscillation and diseases outbreak (dust loads) are being further investigated and be in cooperated in the PRESA_Second Generation activities.

ACMAD has for the last 3 years built up a strong network of with many stakeholders

Africa Water Week
Africa Water week is a forum for African water sector professionals, stakeholders and partners in the regional water and sanitation domain. An estimated USD 45-60 billion is required annually to meet Africa’s water infrastructure requirements, of which drinking water supply and sanitation represents some USD 11 billion.

The first African Water week (AWW-1) hold in Tunis from 26-28 March, 2008, hosted by the African Ministers’ Council on Water (AMCOW) and the African Development Bank (AfDB). The theme was "Accelerating the Water Security for Socio-Economic Development of Africa". Among its objectives we find “Investing in water information and knowledge in Africa” which converge with GEO Capacity Building programs. One of the main outcomes was a Ministerial Declaration on Accelerating Water Security for Africa’s Socio-Economic Development. The 2nd African Water Week was hosted by South Africa in Johannesburg in November 2009, where the AfDB lead the thematic session on “Financing Water and Sanitation Infrastructure”. The 3rd Africa Water Week hold in Addis Ababa 26-28 November 2010 on the theme “Implementing the Africa Water Vision and the MDG target: Challenges and opportunities in water and sanitation”. This third meeting called for more innovative sources of funding.

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AGRHYMET
The Agrhymet regional centre (ARC) is a specialized institute of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS). CILSS an intergovental organization created 12th September 1973 is composed of nine countries. The countries are Burkina Faso, Cape Verde, Chad, The Gambia, Guinea Bissau, Mali, Mauritania, Niger and Senegal.

The ARC was created on December 20th 1974 with a mandate to seek to assure food security and to combat the effects of drought and desertification for a new ecological balance in the Sahel. This is done through:

- Data collection, processing and information dissemination on food security, natural resource management, water control and management and desertification control across the Sahel;
- Development of decision support tools to meet the Sahelian populations development needs.
• Technical capacity building through training and transfer of tools, methods and know-how adapted to the Sahelian countries in the fields of climatology, agrometeorology, hydrology, crop protection, geomatics and remote sensing.

Scientists from the three departments covering the different fields of the ARC mandate execute the specified activities. The departments are:

• Training and research Department
• Information and Research Department
• Technical Support Department

Training and Research Department
The long-term training consists of a degree courses in Crop protection, Hydrology, Agrometeorology and Instrumentation and microcomputing sciences. A Master’s degree course in Natural Resource Management was started in 2008.

The ARC also runs short-term continuous education programs on many themes. The themes include Sustainable agriculture, Crop protection, Natural resource management, Water control and management, Utilization of new and renewable energy sources, natural resource conservation and food security, Crop protection and pesticide management, Maintenance of hydro and agro meteorological instruments, geographic Information Systems, Database management, remote sensing among others.

Other training programs offered by the centre includes

• Personalized individual training programs
• Group training programs : ARC offers training modules to potential users (public services, private sector)
• Attachments

Information and Research Department
This department provides information on food security, desertification control and water resources management.

The scientific and technical information is obtained from ground and satellite (NOAA, MODIS, SPOT Vegetation and METEOSAT) data analysis and processing. The information is normally in the form of maps, bulletins and thematic databases.

The main Products and services are the following:
- Maps: normalized Difference Vegetation Index (greenness); monitoring of lakes and water bodies; rainfall estimates; estimated crop yields; successful sowing dates; administrative divisions; areas at risk of food insecurity; assessment and monitoring of the vegetation
- Bulletins: monthly bulletin on seasonal crop monitoring and food situation; special decision makers’ bulletin; regional synthesis; special desert locust bulletin
- Services: attachment in the fields of remote sensing, geographic information systems (GIS), studies and advisory services on ecological and environmental issues; consultancies on the ground and phytosanitary analyses
- Monitoring and Analytical Tools: crop, pastoral and phytosanitary monitoring; climatic and hydrological data management, vulnerability assessment at local and regional levels.

Technical Support Department
The technical information, produced from tabular and spatial data is disseminated among the CILSS member countries and the international community in real time via modern telecommunication equipment managed by the Technical Support Department.
AMCEN
Under the leadership of the African Ministerial Conference on Environment (AMCEN) a consultative and participatory process has generated the Action Plan of the Environment initiative which provides an appropriate framework for the establishment of a strong partnership for the protection of the environment between Africa and its partners based on the commitments contained in the UN Millennium Declaration.

AMCOST
The first African Ministerial conference on Science and Technology (AMCOST), held in Johannesburg in 2003, recognized water Science and Technology as a main program of NEPAD (see below). The Commission of Human Resources, Science and Technology of the Africa Union, Addis Ababa serves as the secretariat and executive organ of AMCOST, with the NEPAD’s Office of Science and Technology in Pretoria as its technical arm. It is worth noting that NEPAD contributes to capacity building in ICT sector. Consequently, the development of both water and ICT sectors under NEPAD framework (http://www.ccafrica.ca/2007/mg/NEPAD-IPPF-Infrastructure.pdf) and the involvement of the private sector under AWF to insure this development objectively constitute important supports of EO CB initiative.


The two Commissions, i.e., Africa Union Commission and European Union Commission, have been working together towards the implementation of the 8th Partnership by establishing the Joint Taskforce (JTF), and the Joint Expert Group (JEG). The JEG brings together experts from the two Commissions and both AU and EU Member States is comprised of two subgroups: The African Expert Group is chaired by Tunisia and has Senegal, South Africa and Kenya (AMCOST Chair) as African country representatives. The European Experts Group; Chaired by France. A list of priority projects, dubbed “Book of Lighthouse Projects” has been prepared. including 6 Early Deliverables were endorsed by the AMCOST Bureau in Lagos December 2008.

AMCOW
The African Ministers’ Council on Water (AMCOW) was formed in 2002 in Abuja Nigeria and has become a Specialised committee for water and sanitation in the African Union. It aims to contribute to promoting social and economic development and poverty eradication among member states through the management of water resources and provision of water supply services. http://www.amcow.net/. Among the mission of AMCOW the task of the management of water resources for sustainable social and economic development and maintenance of African ecosystems needs a lot of information and data exchange systems and need potentially Geoinformation resources.

AMESD
The African Monitoring of the Environment for Sustainable Development (AMESD) project aims “to provide real time and accurate satellite data information in decision making process in the field of environment for poverty alleviation and sustainable development”. Under AMESD, 10 Years Operational Global VEGETATION Monitoring (1998-2008). ECOWAS region (1 km, 10 days resolution) followed by THEMAS project (2009-
The AMMA project

The AMMA project is an international project to improve knowledge and understanding of the West African monsoon (WAM) and its variability with an emphasis on daily-to-interannual timescales. The motivation originates from interest in fundamental scientific issues and by societal need for improved prediction of the WAM and its impacts on West African nations.

In addition to the international structure that has been setup, a network of African scientists linked to AMMA also exists. The African network was originally called AMMANET network of African scientists (AMMANET) but is now called AMMA Africa and it is to help consolidate existing collaborations in Africa and to federate initiatives through a pan-African partnership.

AMMA is endorsed by the World Climate Research Programme (WCRP) and continues to develop with Climate Variability and Predictability (CLIVAR) and Global Energy and water Cycle Experiment (GEWEX). AMMA has also been endorsed by two projects within the International Geosphere-Biosphere Programme (IGBP): International Global Atmospheric Chemistry (IGAC) and Integrated Land Ecosystem-Atmosphere Processes Study (ILEAPS). AMMA also works with international projects and programs to achieve its aims including Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS) and The Observing System Research and Predictability Experiment (THORPEX) (ISP, 2005).

The first phase of the AMMA project was from 2002-2010. This first phase was organized around five themes as follows:
- West African Monsoon and Global Climate
- Water Cycle
- Land Surface-Atmosphere feedbacks
- Prediction of climate impacts
- High impact weather prediction and predictability

The AMMA project had a field program with three components as follows:
- The Long term observing Period (LOP) (2002-2010)
- The Special Observing Period (SOP) during the summer of 2006.

In order to monitor the human dimension of the West African monsoon variability crop yields, water resources and health were to be monitored with the same strategy.

The AMMA extension (AMMA-TTC)

The initial AMMA project focused on geophysical research. The original project was augmented with what is called The AMMA extension (AMMA-TTC). The aim of the extension of AMMA is

1. Assist in the achievement of the UN Millenium Development Goals in Africa and the implementation of the EU Strategy for Africa, which includes “action to counter the effects of climate change” and “the development of local capabilities to generate reliable information on the location, condition and evolution of environmental resources, food availability and crisis situations”;
2. Add to the African participation and ownership of AMMA research activities, and strengthen the linkages between European research institutions and West African research community;
3. Ensure that the further development of national expertise is maintained beyond the AMMA project.
These high level objectives are to be met through specific objectives that can be found in the AMMA-TTC Annex (2006). The strategy for the implementation of the extension of the project have been to define a complementary partnership with universities, research institutions and operational centers that constitute a long term knowledge base to feed expertise, methods and tools to operational centers. The AMMA-TTC implementation is through the use of work packages (WP). The work packages are broadly categorized as follows:

1. Process integration
2. Process studies
3. Impact studies
4. Tools and Methods
5. Demonstration
6. Training and education
7. Management of activities

(AMMA DOW, 2005)

The current status of AMMA project
The phase 2 of the project (2010-2020) is to refocus its work to prioritize climate change and to benefit local people. The proposed work for this phase, AMMA 2 is contained in the International Science Plan 2010-2020.

AWICH
The Africa Water Information Clearing House (AWICH) is one of the products of the UN-Water/Africa group of Agencies, secretariat of which is hosted by NEPAD and Regional Integration Division of UNECA. The UN-Water/Africa group coordinates and harmonizes water activities in Africa by various UN agencies and other sub-regional IGOs. It represents an example of how the UN “delivers as one”. The UN Water/Africa Work Plans are geared towards cohesion and improved effectiveness of all these Agencies in their water activities in Africa.

UNECA plays a key role by hosting the Secretariat of UN-Water Africa from where all the group’s activities and products are coordinated. UNECA also plays a lead role as Task Team Leader to all the other agencies on transboundary waters management. The overall strategy of promoting international cooperation in transboundary water resources and pre-empting potential conflicts is based on the provision of timely, comprehensive and accurate information to decision-makers at all levels from technical experts to policy managers and ultimately political leaders. The focus of the African Water Information Clearing House is on Transboundary water resources information. The group’s work covers all aspects of freshwater in Africa, including both surface and groundwater, the interface between fresh and sea water, water resources quality and quantity assessment, development, use, management, conservation and protection. The group’s work also includes access to and use of sanitation by Africa’s population, and interaction between sanitation and freshwater, water-related disasters, emergencies and water-related extreme events and their impacts on human security.

AWICH was developed in collaboration with UNECA’s Geo-information project with the objective of integrating Africa’s water information into ECA’s policy analysis by providing easy and transparent access to water and geo-information tools, techniques and data products, to enable the Commission tap into national, regional and global data resources for its work. AWICH was also conceived to serve as a one stop shop for water resources-related information for comprehensive African water resources information. Stakeholders of AWICH include governments, local authorities, river basin organizations, water utilities and regulators, local and international consulting firms, research institutions, NGOs, etc.

In 2000, a clear division of labour in the water sector was agreed between the AfDB, OAU and the UN system (with ECA as the focal point). As part of the agreement, AU is envisaged to set policies, the UN System to provide technical and analytical support and the AfDB to mobilize financial resources. It is on the basis of this agreement that most of the activities of the water sub-cluster, of the UN system, in support of NEPAD, have
functioned. Another aspect to this agreement has been the institutionalization of the African Minister's Council on Water (AMCOW). With AMCOW as the Political Leader, River Basin Organizations are also organized into a network (The African Network of Basin Organizations – ANBO) to ensure cohesion and effective coordination. AMCOW has been organized on sub-regional basis with each sub-region represented by two member States on the Executive Committee.

CRASTE-E (Ife-Ife, Nigeria) & F (Rabat, Morocco).
The UNOOSA centres.

ECOWAS
The Economic Community Of West African States (ECOWAS) is a regional group of fifteen countries, founded in 1975. Its mission is to promote economic integration in "all fields of economic activity, particularly industry, transport, telecommunications, energy, agriculture, natural resources, commerce, monetary and financial questions, social and cultural matters ....." The Institutions of the Economic Community Of West African States (ECOWAS) are as follows: the Commission, the Community Parliament, the Community Court of Justice, and the ECOWAS Bank for Investment and Development (EBID). ECOWAS (or CEDEAU in French) contains a Water Resources Coordination Unit (WRCU), based in Ouagadougo, Burkina Faso.

The ECOWAS Commission and the ECOWAS Bank for Investment and Development, more often called The Fund are its two main institutions designed to implement policies, pursue a number of programs and carry out development projects in Member States. Such projects include intra-community road construction and telecommunications; and agricultural, energy and water resources development.

NEPAD
Also, it is worth noting that New Partnership for Africa’s Development (NEPAD) program adopted in 2003 by African heads of States and Governments is addressed to enhance access to water and to water sanitation. Either, the African Water Facility (AWF) is an initiative led by the African Ministers’ Council on Water (AMCOW) to mobilize and apply resources for the financing of water infrastructure and water investment facilitating activities in Africa. (AfDB is managing the African water facility program aimed to help achieving the millennium development goals). In order to provide increased quality and sustainability of investments due to the provision of comprehensive information, AWF also presents assistance to support monitoring, evaluation and management capabilities of the African water sector systems at national and regional levels. http://www.africanwaterfacility.org/en/areas-of-intervention/improving-water-knowledge. These objectives perfectly meet those of Geo. Moreover AWF objectives of fostering M&E standards and methodologies match the first element (HCB) of Geo CB program while the strengthening of national monitoring systems meets the third element (ICB).
NEPAD Water Centers of Excellence: http://www.nepadwatercoe.org

RCMRD
The Regional Centre for Mapping of Resources & Development, located in Nairobi, was established in 1975 under the auspices of UNECA and the then African Unity (now African Union). The goal of the Centre is to be a premier Centre of Excellence in Geo-information science and Remote Sensing for Africa and beyond. It’s also host for the Servir ground station and also GEONETCast data reception facility and a location for training and capacity building in joint course cooperation with organizations such as ITC and others.

RECTAS
The Regional Centre for Training in Aerospace Surveys, located at the Obafemi Awalowo University Campus, Ife-Ife, Osun state, Nigeria, was established in 1972 under the auspices of UNECA, with the mandate in training, research and advisory services in geoinformatics. The centre is a joint project of several African countries: Benin, Burkina, Cameroon, Ghana, Mali, Niger, Nigeria and Senegal. The centre has a long term cooperation
with ITC for conducting professional courses in digital cartography and resource mapping.

SADC
The Southern Africa Development Community (SADC) is a Regional Economic Community (REC) established in 1992 with economic and social development objectives that, among others, include:

• Promotion of sustainable and equitable economic growth and socio-economic development for poverty alleviation and eventual eradication; and
• Achieving sustainable utilization of natural resources and effective protection of the environment
• Creation of appropriate institutions and mechanisms for the mobilization of requisite resources for the implementation of programmes and operations; and
• Securing of international understanding, cooperation and support, and mobilizing the inflow of public and private resources into the region.

SADC currently comprises fourteen member States including Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

4.2. Existing International Institutional Capacity

In environmental modeling significant contributions in the fields of forest cover, vegetation monitoring, marine and coastal management as well as crop management and land and habitat management have benefit from many international programs.

AWC
Arab Water Council Arab LDAS project (2009- )
(http://wmp.gsfc.nasa.gov/projects/LinkedProj_Rodell_Bolten_ArabLDAS.pdf) aims to “providing a LDAS designed specifically for the Arab region using NASA satellite data, surface observations from Arab countries, and publicly-available meteorological analyses to drive a suite of advanced land surface models”. The Arab LDAS will be developed in collaboration with the Arab Water Council (AWC), and/or with national water agencies in Arab countries.

ClimDevAfrica
WMO-GCOS- Climate for Development in Africa Program (ClimDevAfrica), spearheaded by the African Union Commission. The Climate for Development in Africa Programme is an integrated, multi-partner program addressing climate observations, climate services, climate risk management, and climate policy needs in Africa. The user-driven program will support efforts to achieve the Millennium Development Goals. In addition to GCOS, principal partners are the UN Economic Commission for Africa, the African Union, the African Development Bank, the World Meteorological Organization, and potential donors including the UK Department for International Development.

CLIVAR-Africa
CLIVAR is the World Climate Research Programme (WCRP) project that addresses Climate Variability and Predictability, with a particular focus on the role of ocean-atmosphere interactions in climate. It works closely with its companion WCRP projects on issues such as the role of the land surface, snow and ice and the role of stratospheric processes in climate.

CLIVAR-Africa has a major aim of promoting the development of a sustained observing system for regional Africa. This is a major undertaking requiring substantial new investment for improving routine observations over
the continent and adjacent Atlantic and Indian Oceans. There are three major questions that CLIVAR-Africa addresses:

- What are the causes of African Climate variability and how is this related to other parts of the globe?
- How well do current dynamical models simulate African Climate variability and its relationship with the global climate?
- Which deficiencies do dynamical models have that can account for known inadequacies in the simulation of African Climate variability and its relationship with the global climate?

The Programme has been designed from the perspective that there is a substantial need for fundamental understanding of African Climate variability and its relationship with the global climate that has not been done before. This underpinning research must be done before we are justified in promoting more specific projects on predictability. Four projects are therefore focussed on different time-scales annual, inter-annual, intraseasonal and decadal. For each project, the three questions asked in the background will be addressed. It is envisaged that more specific sub-projects will be promoted as the CLIVAR-Africa programme develops.

The CLIVAR-Africa implementation plan provides the rationale for a CLIVAR-Africa Programme and recommends the starting points for implementing such a programme. It is recognised that the community of scientists working on African climate, particularly from a modelling perspective, is much smaller that the corresponding communities contributing to the other monsoon panels in CLIVAR. The programme promoted here allows for this by recommending an achievable set of projects often making use of datasets that already exist or are planned, but have not always been examined from an African climate perspective. It should also be stressed that, due to the smaller scientific community and limited resources, CLIVAR has a major role to play in utilising and organising the available expertise and resources as efficiently as possible. The projects proposed are necessary to address the three questions raised here and are a realistic starting point for the CLIVAR-Africa panel. Through the research carried out in the four proposed projects, CLIVAR-Africa will be in a more authoritative position to make recommendations for improvements.

**FEWSNET**

The FEWS-NET (Famine Early Warning Systems Network), was setup by the USGS, in order to provide local water resources, agricultural and environmental authorities, with satellite-based evaluation tools for drought and flood warning in several large river basins and regions of Africa and the world. FEWS NET was designed to monitor (and forecast when possible) incidence of drought and flooding in Africa in order to identify problems in the food supply system that could potentially lead to famine or other food-insecure conditions. The purpose of FEWS NET is to collect, analyze, and distribute information to decision makers regarding potential or current famine/flood situations, allowing them to authorize timely measures to prevent food-insecure conditions. FEWS NET supports data collection and analysis in 17 African countries. Since 1987, USGS/EDC has provided timely access to satellite data/products in order to identify potential and current problems related to crop conditions and/or flood risk throughout Africa, the Middle east and the west Asian region.

**PUMA**

The PUMA project, and acronym for “Preparation for the Use of Meteosat Second Generation in Africa is the predecessor of the now on-going AMESD joint project of the AU and EU. It aimed at developing the ground infrastructures and facilities for reception of weather satellite data (EUMETCast reception stations), within the African national Meteorological Services as clients and main users. The general objectives are to “give access to the National Meteorological Centres to new generation of satellite meteorological data”. 49 stations were installed in 47 different African countries during the period 2004-2006. http://www.spot-vegetation.com/VGT10YR/PresentationsPDF/1209_17u05_FCazaban_AMESD.pdf

**SERVIR**
NASA’s Regional Visualization and Monitoring System for environmental management and disaster response with the objective of “Enable the use of Earth observations and predictive models for timely decision making to benefit society.” SERVIR took place from December 2005 in Meso America through “improved access to satellite data, models, online maps, visualization and decision support tools, as well as training and strategic partnerships”. Beginning from 2008 SERVIR extended to Africa with the Regional Center for Mapping of Resources for Development (RCMRD) in Nairobi, Kenya. This center was functioning since 1975. It is actually under Africa Union framework within 15 contracting member states from East-Africa: Botswana, Comoros, Ethiopia, Kenya, Lesotho, Malawi, Mauritius, Namibia, Somalia, South Africa, Sudan, Swaziland, Tanzania, Uganda, and Zambia). “The SERVIR-Africa facility will initially focus on establishing a geospatial portal to provide searchable and viewable earth observation data, as well as improved products to address flood forecasting and Rift Valley Fever using unique NASA space-based assets”.


UNESCO-ARSIMEWA project
An Intra-regional Partnerships and Cooperation with African specialised centres in Space Sciences, Mapping and Survey and regional institutions (12 African countries). Its mission is to use Remote Sensing, Communication and Information Systems for Integrated Management of Ecosystems and Water Resources (fresh water and coastal resources) for promotion of Biodiversity Conservation. The project is based on the UNESCO Chairs and UNITWIN Networks.


UNESCO-IHP

UN-Water
UN-Water is a mechanism to strengthen coordination and coherence among all United Nations (UN) bodies dealing with a variety of water-related issues, such as health, farming, environment, energy, food, climate, sanitation and disasters. UN-Water was set up in 2003. UN-Water adds value to existing UN programs and projects and fosters more cooperation and information sharing among UN agencies and their partners.

UN-Water web site: http://www.unwater.org

WADE
ESA's WADE (Water resources Assessment using SAR in Desert and arid lands in West African Ecosystems) project, funded by the Data User Element (DUE), uses ERS and Envisat Synthetic Aperture Radar (SAR) imagery to map and monitor the location and extent of surface water bodies and to identify potential areas for water infiltration. In November 2008, WADE software and data were installed in AGRHYMET’s facilities in Niamey, Niger’s capital city. Following extensive training sessions, AGRHYMET employees are now using the system to carry out their monitoring.

http://www.esa.int/esaEO/SEMRA6VPXP_F_index_0.html

WMO - WHYCOS
The World Hydrological Cycle Observing System (WHYCOS) program was launched by the World Meteorological Organization (WMO) in 1993. This program was launched following the recognition of the critical need for adequate hydrological data, of good quality and available at appropriate time; to develop information products suitable for the needs of water managers and decision makers; the requirement for hydrological and climate research; and to promote regional cooperation on transboundary water resources. The program consists of a number of regional components known as HYCOS. Each HYCOS project, while following common guidelines and standards, is tailored to meet the needs of the participating countries.

The overall objective of WHYCOS is: “To strengthen the technical and institutional capabilities of NHSs and of
regional water institutions in order to collect and transmit, in real or near real time, hydro-meteorological data and information of a consistent quality and thereby enhance the availability and quality of water resources data, information and products and their dissemination through the development of appropriate national and regional hydrological information systems."

Though global in its scope, WHYCOS is implemented following a demand driven approach by supporting regional and river basin-level HYCOS components which are implemented in partnership with basin authorities or regional development agencies. The components are tailored to meet national, regional and global objectives and are designed to fit the regional constraints and respond to the demands emerging in the region, in areas such as water resources management, flood forecasting and warning, monitoring of surface and groundwater resources, and development of water information systems.

WMO, through its WHYCOS program and its regional and basin-wide HYCOS components has been spearheading the efforts to ensure that the African continent’s water resources are adequately managed and their variability in time and space properly monitored. Since the inception of the program, six HYCOS projects have been implemented in Africa. These are MED-HYCOS in Northern Africa, AOC-HYCOS in Western and Central Africa, Niger-HYCOS and Volta-HYCOS in the respective river basins, and SADC-HYCOS phases I and II in Southern Africa. Thirty six African countries have participated in and benefited from the implementation of these projects, with financial support totaling more than 21 million US dollars having been kindly contributed by various donors including the World Bank, the European Commission, and the governments of France and the Netherlands. Five other components in the planning stage are IGAD-HYCOS in the Horn of Africa, Senegal-HYCOS and Congo-HYCOS in the respective basins, the second phase of Niger-HYCOS and the third phase of SADC-HYCOS.

Improving the status of hydrological activities in Africa requires a considerable effort in capacity building, ranging from reconstructing the basic observation capabilities, to improving data archiving and management practices, to training staff in the use of new technologies. It also requires an institutional reinforcement, increasing the awareness of policy makers on the value of hydrological data and information for development, so that the long term operability, in terms of funding and staffing, of NHS can be secured.

Training is therefore one of the fundamental elements of each HYCOS component. Training courses at both regional and national level, organized for experts from the National Hydrological Services, are specially tailored to the specific project and country needs. They also include on-the-job training of individual experts seconded to regional centres, and training of trainers. To date more than 300 experts have been trained through participating in different courses.

Through the HYCOS components a significant contribution has been made to the rehabilitation of the observing networks throughout the continent. The obsolete and silent hydro-meteorological stations are refurbished and upgraded in the framework of the project by installing new gauges and automatic sensors and data loggers, while a subset of the regional stations is also equipped with data collection platforms (DCPs) with near-real time satellite transmission facilities.

4.3. New opportunities

"African Early Warning and Advisory Climate Services in Africa“ (ViGIRisC Africa).
It is an ACMAD project. ACMAD is an African institution under the UNECA and WMO. This project aims to support the development of products and pilot services of vigilance related to climate risk in different areas where vulnerability is high.
4.4. Recommended Actions

A broad recommendation is to increase the number of geoinformation users in Africa, in linkage with water cycle prediction and forecasting. To achieve this objective, a master way is the augmentation of the number of hydrologists and physicians who use remote sensing observations to solve their engineering problems. It seems that African geologists have already achieved this step. In effect, the Journal of African Earthsciences, Elsevier which is an international reports a great number of research and case studies using remote sensing applied to geology and environment. On the other hand, environmentalists make a large use of remote sensing data to monitor ecosystems and especially lakes for sustainable management decision making.

It would be helpful to develop actions with the African Network for Earth System Science (AfricanNESS). http://www.igbp.kva.se/page.php?pid=412. Its science plan and implementation strategy focuses on four top-level issues: food and nutritional security; water resources (Rainfall, land cover, water cycle as part of the Earth system, Land ecosystem atmosphere interaction, water systems); health; and ecosystem integrity. The questions that are addressed are described in http://www.igbp.net/documents/AfricanNess-2008.pdf

On the other hand, in order to augment the number of hydrologists and physician using remote sensing, Tutorials, Professional masters, and research actions including GEO, WMO, Space agencies, water basin authorities, African universities and universities from the developed countries may be undertaken.

A recent example of such networking of efforts is the program DEVELOPING RENEWABLE GROUND WATER RESOURCES IN ARID LANDS PILOT CASE: THE EASTERN DESERT OF EGYPT http://gis.mwri.gov.eg/gis/pdf/Generation%20of%20the%20Arc%20GIS%20Server%20Web%20Application%2001.pdf

Moreover, the actual ITC research partnerships with Ethiopia, Ghana, Kenya, Nigeria, South Africa, Burkina Faso (http://www.itc.nl/Pub/partners/Research-partnerships) may be extended to other countries as well as strengthened by including African universities in the professorial teams.

5. Infrastructure Capacities

5.1. Existing Infrastructure

The available remote sensing resources in relation with Water cycle in Africa are:

- **GEONETCast** is a near real time, global network of satellite-based data dissemination systems designed to distribute space-based, air-borne and in situ data, metadata and products to diverse communities. It is led by EUMETSAT, the United States, China, and the World Meteorological Organization (WMO). Many GEO Members and Participating Organizations contribute to this Task.
The following products and services are being made available to the GEONETCast user community:

- Meteosat image data
- GOES East and West image data
- Land and Ocean Sea Ice Satellite Application Facility (SAF) products
- EUMETSAT meteorological products
- NOAA-NESDIS meteorological products
- NOAA-NESDIS Ocean colour and sea surface temperature products
- VEGETATION products from VITO
- MODIS Ocean colour products
- CMA FY2C satellite images
- CMA FY2C meteorological products

**DevCoCast**
The GEONETCast for and by Developing Countries (DevCoCast) project involves Developing Countries more closely in the GEONETCast initiative. The DevCoCast project:
- builds on existing infrastructure and experiences to reliably and timely disseminate over 50 Earth Observation (EO) products at low cost for the user
- uses and extends the EUMETCast and GEONETCast satellite broadcasting infrastructure supports and trains a broad range of user communities.
- embeds the provided products in research and environmental monitoring and reporting applications to improve planning & decision making processes.
- For and by: Africa, Latin America, China

**GEO Portal**
The GEO portal provides an entry point to access Earth Observation information and services. It connects to a system of existing portals, addressing the GEO Societal Benefit Areas globally while also providing national and regional information to enhance understanding. Derived from ESA's Earth Observation Community Portal www.eoportal.org, this contribution to GEO puts the accent on remote sensing, geospatial-static and in-situ data, information and services.
The GEO portal allows users to:
- Discover data, information and services available in the GEOSS
- Access the GEO Clearinghouse to search data catalogues and datasets
o Access maps, forecasts and other decision support tools, derived from satellite imagery and in situ observations
o Visualize geographical information, maps and imagery from various sources, e.g. from different GEO Societal Benefit Areas through WMS services
o Browse through a comprehensive directory of services providers
o Retrieve Earth observation education, training and capacity building resources and services of many types e.g. tutorials on Earth observation techniques, data analysis, interpretation, or use
o Access information from GEONetcast

• 52 North: Open source and freely accessible satellite data and geo-information processing tools for use in water cycle research and application studies can e.g. be found at http://52north.org. The new Earth Observation (EO) user community portal contains all information to set-up low cost GEONETCast data reception stations together with geospatial software tools for EO data analysis, ILWIS Open. Training opportunities and open access materials are also available.

• AVHRR
The Advanced Very High Resolution Radiometer (AVHRR), operated by the US National Oceanic and Atmospheric Administration (NOAA), is a radiation-detection imager that can be used for remotely determining cloud cover and the surface temperature. Processing permits multi spectral analysis for more precisely defining hydrologic, oceanographic, and meteorological parameters. The experimental African drought monitor is operated by the Land Surface Hydrology Group at Princeton University uses AVHRR data to provides near real-time monitoring of land surface hydrological conditions. Available outputs include water budget components (precipitation, evapotranspiration, runoff, snow and soil moisture) and derived products such as current drought conditions.

• CEOS
Committee on Earth Observation Satellites (CEOS) has available for download the “Remote Sensing Tutorial - Meteorological, Oceanographic and Hydrologic Applications.”

• GLDAS
The goal of the Global Land Data Assimilation System (GLDAS) is to ingest satellite- and ground-based observational data products, using advanced land surface modeling and data assimilation techniques, in order to generate optimal fields of land surface states and fluxes. Data assimilation techniques for incorporating satellite based hydrological products, including snow cover and water equivalent, soil moisture, surface temperature, and leaf area index, are now being implemented as part of a follow-on project funded by the NASA Energy and Water Cycle Study (NEWS) Initiative. The high-quality, global land surface fields provided by GLDAS support several current and proposed weather and climate prediction, water resources applications, and water cycle investigations. The project has resulted in a massive archive of modeled and observed, global, surface meteorological data, parameter maps, and output which includes 1-degree and 0.25-degree resolution 1979-present simulations of the Noah, CLM, VIC, and Mosaic land surface models.

• GRACE
The Gravity Recovery and Climate Experiment (GRACE), twin satellites launched in March 2002, are making detailed measurements of Earth's gravity field, leading to discoveries about gravity and Earth's natural systems. These discoveries could have far-reaching benefits to society and the world's population. Research is showing that GRACE may be used for analysis of terrestrial and ice sheet water mass changes, and new applications in groundwater remote sensing, land surface modeling and data assimilation, freshwater discharge, and decomposition of the storage change signal into its surface water, soil moisture and groundwater components.
• **HydroWeb**
  The Laboratoire d’Etudes en Géophysique et Océanographie Spatiale (LEGOS) /GOHS team has recently developed a water level database on major rivers, lakes and wetlands. This database can be accessed through the LEGOS website (Products/Observation and Archives Services/Hydrology). The water level time series are based on altimetry measurements from Topex/Poseidon, Jason-1, ERS-2, ENVISAT and GFO satellites. At present, water level time series of about 100 lakes (in Europe, Asia, Africa, North and South America) are available. About 250 sites (called virtual stations) on large rivers are also available. Users of the data base can visualize the water level time series as well as Landsat images showing the geographic location of the site. Users can download the numerical values of the time series as well as associated errors. Most river water level time series are based on Topex/Poseidon observations and start in January 1993. The lake water level time series are multi-satellite data combinations. They also start in January 1993. The time series are regularly updated and the number of sites increases regularly.

• **Landsat archives**
  On December 8, 2008, the USGS made the entire 36-year long Landsat archive (dating back to 1972) available to anyone via the Internet for free and with unrestricted access to full Landsat Archive.

• **MODIS** views the entire surface of the Earth every one to two days. Three spatial resolutions -- 250m, 500m, and 1,000m. Moderate Resolution Imaging Spectroradiometer (MODIS) albedo, land cover type and extent, snow cover extent, surface temperature, leaf area index, and fire occurrence.

• **NASA**
  The US National Aeronautics and Space Administration (NASA) has made a Remote Sensing Tutorial available for free download, for learning the role of Remote Sensing - that aspect of space science and technology that relies mainly on sensors on satellites and mounted in telescopes to monitor Earth, other planetary bodies and distant stars and galaxies.

• **SMAP**
  The NASA Soil Moisture Active-Passive (SMAP) mission will use a combined radiometer and high-resolution radar to measure surface soil moisture and freeze-thaw state, providing for scientific advances and societal benefits. Direct measurements of soil moisture and freeze/thaw state are needed to improve our understanding of regional water cycles, ecosystem productivity, and processes that link the water, energy, and carbon cycles. Soil moisture information at high resolution enables improvements in weather forecasts, flood and drought forecasts, and predictions of agricultural productivity and climate change.

• **SMOS**
  THE ESA Soil Moisture and Ocean Salinity mission (SMOS) will provide a global images of surface-soil moisture every three days. This information, along with numerical modelling techniques, will result in a better estimation of the water content in soil down to a depth of 1-2 m, which is referred to as the ‘root zone’. SMOS will provide:
  - Global maps of soil moisture every three days within an accuracy of 4% at a spatial resolution of 50 km – comparable to detecting one teaspoon of water mixed into a handful of soil.
  - Global maps of sea-surface salinity down to 0.1 practical salinity units for a 30-day average over an area of 200×200 km – comparable to detecting 0.1 g of salt in a litre of water.

• **SPOT-Vegetation** data acquisition and product dissemination for Africa by VITO (Belgium) as ground segment processing and data portal at [http://www.vgt4africa.org/](http://www.vgt4africa.org/). A large array of data and land cover products for use in agricultural forecasting, environmental monitoring and water resources assessment.
• TRMM: a joint mission between NASA and the Japanese space agency JAXA. “TRMM radar/radiometer system provided an anchor for rainfall estimates by passive microwave sensors in the tropics and subtropics”. (Hou and Oki, *Earth Observation and Water Cycle*, ESRIN, 18-20 November 2009)

• UNESCO Bilko
The UNESCO Bilko virtual global faculty for remote sensing, freely available to registered users, provides learning and teaching of remote sensing image analysis skills. Current lessons teach the application of remote sensing to oceanography and coastal management, but Bilko routines may be applied to the analysis of any image in an appropriate format, and include a wide range of standard image processing functions.

5.2. New Opportunities

• GMES Africa
The “GMES and Africa” process was launched by the Maputo Declaration, signed on 15 October 2006. The initiative aims to strengthen and further develop infrastructure for a more coherent exploitation of Earth Observation data (space and in-situ), technologies and services in support of the environmental policies for sustainable development in Africa. The GMES Africa consists:
  o In developing the necessary capacity (institutional, human and technical, ) in Africa to adapt and exploit, on an operational basis, the technology, data, product and services developed in the frame of GMES Europe and, which are relevant to the African needs;
  o In developing the techniques, products and services to better serve the African interests and requirements in term of environmental monitoring by adapting them, when necessary, to the institutional African context.

• Princeton Experimental African Drought Monitor
The system provides near realtime monitoring of land surface hydrological conditions. The hydrologic cycle is modeled using the VIC model which is forced by a combined model/observation dataset of meteorological forcings (precipitation, temperature, etc). Precipitation is currently taken from the PERSIANN and TRMM datasets. Temperature and windspeed are taken from GTS gauge reports. The monitor is updated every day at 2 days behind realtime. Available outputs include water budget components (precipitation, evapotranspiration, runoff, snow and soil moisture) and derived products such as current drought conditions.

• DEWFORA: FP7 project for Improved Drought Early Warning and FORecasting to preparedness and adaptation to droughts in Africa.
The principal aim of the DEWFORA proposal is to develop a framework for the provision of early warning and response through drought impact mitigation for Africa. This framework will cover the whole chain from monitoring and vulnerability assessment, to forecasting, warning, response, and knowledge dissemination. DEWFORA will address existing capabilities for drought monitoring in Africa and develop improved drought indicators that consider the wider domain of water use and water users, and their dependence on variable water resources.
The proposal has been built to achieve three key targets:
  o Improved monitoring: DEWFORA will improve the knowledge on drought forecasting, warning and mitigation, and advance the understanding of climate related vulnerability to drought – both in the current and in the projected future climate.
  o Prototype operational forecasting: DEWFORA will focus on the operational implementation of advances made, bringing these to the pre-operational stage through development of prototype systems and piloting methods in operational drought monitoring and forecasting agencies.
Knowledge dissemination: DEWFORA will target dissemination of the advances made (i) through a stakeholders platform that includes national and regional drought monitoring and forecasting agencies, as well as NGO's and IGO’s such as the International Committee of the Red Cross, the Food and Agricultural Organisation (FAO), and the Southern African Development Community (SADC), and (ii) through capacity building programs to help embed the knowledge gained in the community of African practitioners and researchers.

**Deltares: Ecosystem services African Lakes**

In concert with several knowledge institutes from Africa, the UK and Italy Deltares launched the EAGLO-net (the East African Great Lakes Observatory network). The network will focus on developing instruments to support national, regional and international efforts to sustainably manage the ecosystem services provided by the African Lakes for the benefit of the populations in Burundi, Kenya, Uganda, Tanzania, Malawi, Rwanda, DR Congo, Mozambique, and Ethiopia. These instruments will be specifically addressed to providing stakeholders with the tools necessary to manage and adapt to future scenarios of climate change, evolving socio-economic conditions and cultural legacy.

The specific scientific objectives are:

- to create regionally based protocols for the sustained monitoring of resource quality and ecosystem functioning, combining in situ and earth observation technologies in a coherent and constructive manner;
- to initiate a comparative analysis of the African Great Lakes through an improved access to ecological and socio-economic data; and
- to develop lake models to examine future scenarios in relation to perceived regional climate and socio-economic variations.

### 6. Individual Capacities

#### 6.1. Existing Individual Capacities

**ITC**

The Faculty of Geo-information Sciences & Earth Observation (ITC), through its International Water Resources and Environmental Management program, provides MSc and PhD level training and research, focussing on earth observation of the water cycle and integration of EO data in IWRM, with course work at the Enschede campus (NL) and field research in several African countries. In close cooperation with capacity building partners in Africa, it also designs curricula, research programs and conducts decentralized education programs in the following regions:

- Applications of Earth Observation & GIS in Integrated Water Resources Management: a 12-weeks training conducted in Kenya (Nairobi) with scientific staff of joint education partners RCMRD (Nairobi), Egerton University (Kenya) and Addis Ababa University (Ethiopia), focussing on capacity building for the east African region and IGAD countries.
- Capacity Building for IWRM in South Africa: curriculum and course development for earth observation data integration and use in IWRM, including education and research infrastructure building i.e., a Geonetcast reception facility and Remote sensing - GIS laboratory for education and research at the UWC and CPUT universities in Cape Town (SA).
- Distance education course development and delivery for several large earth observation initiatives in Africa, for example the AMESD project (SADC and IGAD regions);
- Distance (on-line) and direct *in situ* support for setting up and use of low cost Geonetcast data reception infrastructure and open source-based data analysis systems, using the Ilwis Open Geonetcast Toolbox in
African universities, training centres and other professional organizations. Operational data reception and training facilities have been installed in higher education institutions in Rwanda, Uganda, Kenya, Ethiopia, Tunisia, Benin, Nigeria, and South Africa.

TIGER II (2009-2011)
ESA’s TIGER II project is based on the results and achievements of its precursor TIGER I (launched in 2002), which sought to help African countries overcome water problems and to bridge Africa's water information gap using Earth-observation (EO) technology”. TIGER I has supported African institutions with access to space-borne data and products, by offering specific training on EO applications for water management, by funding North-South collaborative projects aimed at developing tailored EO-based water information systems, and by favoring take-off, operationalisation and technology transfer of those demonstrated systems (up to 15 projects) to African water authorities.

According to TIGER report 2005-2008 in the period (2005-2007) more than 150 African institutions (water authorities, universities, technical centers) has participated to TIGER projects development and training activities. Almost 100 African experts participating to the activities of the TIGER Capacity Building Facility (TCBF); Projects are distributed all around the African continent, and focus on study-areas located in some 27 different African countries.

A major component of TIGER II is devoted to supporting African scientists, technical centres and water authorities to develop the scientific skills and the technical capacity to make the best use of EO technology to understand better, assess and monitor the status of the water resources in Africa. The TIGER Capacity Building Facility (TCBF), launched in 2006, is based on a long-term vision about developing human, technical and institutional capacity in Africa. It supports up to 20 TIGER projects, which will receive specific technical assistance, training and scientific support to access and use EO datasets to achieve their projects’ objectives. The International Institute for Geo-Information Science and Earth Observation (ITC) of the University of Twente in the Netherlands coordinates all TCBF activities and maintains direct contact with TIGER project institutions. A consortium of scientific and technical experts, including the University of Delft, the University of Lisbon and the Belgium-based company VITO, will assist ITC in supporting the selected projects.

United Nations University
The UN University is dedicated to the generation and transfer of knowledge, and the strengthening of individual and institutional capacities in furtherance of the purposes and principles of the Charter of the United Nations. The UN University fosters intellectual cooperation among scholars, scientists, and practitioners worldwide — especially those in the developing world — and functions as:

- an international community of scholars
- a bridge between the United Nations and the international academic community
- a think-tank for the United Nations system
- a builder of capacity, particularly in developing countries
- a platform for dialogue and new and creative ideas.

The UN University undertakes cross-cultural and problem-oriented research. UN University academic researchers develop targeted foresight and policy studies which feed into decision-making processes (from global to local levels). Through its worldwide knowledge networks of academics from the five continents (with backgrounds both in social and natural sciences) the University imbues its work with a truly global perspective.

WaterNet
WaterNet.org has been established as a network with the mission to build the regional institutional and human capacity in Integrated Water Resources Management (IWRM) through training, education, research and outreach by harnessing the complementary strengths of member institutions in the Southern African region. WaterNet’s
flagship programme is the Regional Masters degree in Integrated Water Resources Management, offered by the core host institutions of the University of Dar-es-Salaam, Tanzania, and the University of Zimbabwe, with specialisations offered by these two universities, as well as the University of Botswana, the University of Malawi, the Polytechnic of Namibia and the University of the Western Cape, South Africa. International scientific support and cooperation is done by UNESCO-IHE (NL) and the ITC-UT (NL) for the newly established Remote Sensing and GIS for IWRM specialization.

The Water Resources and Environmental Management program of ITC-UT provides MSc level training and PhD program, focussing on earth observation of the water cycle components and use of EO data in IWRM.

6.2. Gap Analysis

GEONETCab
The GEONETCab project (EU FP7) is working towards gap and needs analysis in the EO sector and end-user.

6.3. New Opportunities

There is a need for strong and ongoing collaborations between African and non-African universities.

Examples:

DRAGON Program
ESA, together with the National Remote Sensing Centre of China (NRSCC) under the Ministry of Science and Technology of the P.R. China, have cooperated in the field of Earth observation application development for the last thirteen years. This cooperation has been furthered by the creation of a dedicated three-year Earth Observation exploitation program called Dragon. In Dragon 1 program, a series of thematic training courses have been successfully held in Chinese Universities, annually since 2004, jointly organized by ESA and NRSCC, with support from ITC for the local technical logistics. This series of training courses is being continued on an annual basis in the Dragon 2 Program, starting with an advanced training course in land remote sensing in October 2008 and followed by training courses in atmosphere remote sensing and ocean remote sensing in 2009 and 2010 respectively.

The objectives of the Dragon 2 training courses are:
- To enhance the academic exchange and cooperation between Chinese and European remote sensing scientists;
- To contribute to the development of remote sensing research and applications in China;
- To stimulate and support the exploitation of ESA and Chinese EO and TPM remote sensing data for land, atmosphere and ocean applications;
- To introduce available software tools and methods for the exploitation of ERS, Envisat, TPM, Explorer and Chinese mission satellite data.

WISDOM information system (Water-related Information System for the Sustainable Development of the Mekong Delta in Vietnam).
WISDOM was created as a joint initiative of the Ministry of Science and Technology of the Socialist Republic of Vietnam (MOST) and the German Federal Ministry of Education and Research (Bundesministeriums fur Bildung und Forschung; BMBF). From the German side, the project receives 4.5 million euro in funding.
• The data for the WISDOM system comes from Earth observation satellites - including the TerraSAR-X radar satellite which is operated by DLR - as well as from extensive on-site research and measurements conducted by DLR and its partners.
• 60 scientists and 15 doctoral students from several German and Vietnamese institutes, research centres and universities are working on this project, which is scheduled to extend over six years. WISDOM should be fully operation by 2011.

6.4. Recommended Actions

Build a project with a critical mass of collaborating scientists (African, European, Japanese, US) using the examples of DRAGON and/or WISDOM as at template. A Capacity Building component should be integral to any effort. Capacity building in the actual GEO-AfWCCI framework should be composed of the following training modules, at a minimum:
• water cycle modelling course (50h)
• GIS course (30h)
• remote sensing course (30h)
• statistical analysis course (30h)
• mathematical classification and downscaling methods course (30h)
• remote sensing products for water cycle (30h)
• supervised independent work (200h)
• GEONETCAST trainings may be considered as starting point to achieve this planning.
7. What Can GEO offer in terms of Capacity Building in the water sector?

GEO’s aim in terms of capacity building is to enhance the coordination of efforts to strengthen individual, institutional, and infrastructure capacities, particularly in developing countries, to produce and use Earth observations and derived information products. This will be achieved by building on the existing capacity building efforts of GEO Members and PO, increasing and fostering synergies, ensuring engagement of resource providers and enhancing efforts to facilitate integration of mature Earth observation based information systems into day by day end-user practices. Networking activities that specifically build individual, institutional and infrastructure capacity, leveraging dedicated resources for Earth observation capacity building efforts, encouraging the uptake of Earth observation in policy and decision making and enhanced participation of Developing countries in GEO and GEOSS are some mechanisms to achieve GEO’s capacity building aim. For the water related SBA this is achieved through a variety of tasks within the GEO Work Plan.

According to participants at the 1st Task Team meeting, data, data infrastructure, and data collection are in very poor state across Africa. Data needs are known; the problems lie in the collection and availability, and lack of infrastructure. Also, lack of interoperability and integrated satellite products aimed at user needs were mentioned as recurring problems. Steps towards resolving these issues include identifying existing collaborative efforts, and at what levels. The next step is defining a process to enhance organization and coordination of these efforts across the continent.

Another observation was that the G8 had pledged support (Evian, Glen-Eagles, Heiligendamm) to African countries on climate-related issues. Under GEO, these issues of accessibility, standardization, quality assurance, interoperability framework, data quality, and capacity building should be addressed in such a way that they harmonize with G8 objectives to provide climate-change support to Africa.

More specifically, the GEO framework can be used to:

- enhance coordination among and between the various institutions, agencies, and projects, both African and international, as detailed in the previous sections;
- provide a platform for river/river basin authorities to cooperate within and across nations;
- support coordination among regional centers, with those which already have ties to GEO (such as ACMAD), leading the way;
- assist with the transition from research to applications/operations through regional coordination, where countries develop proposals and the GEO Secretariat plays a brokering role to link the proposals with development partners.

From the 1st Task Team questionnaire, AGRHYMET suggested:

- “GEO can help solving these problems by facilitating high resolution satellite data reception and enhancing the capacity of technical Institutions to processing, field data collection for calibration and validation of satellite products”

and Ghana noted:

- “GEO can help in providing alterative sources of data, e.g. satellite images from which rainfall estimates can be made for areas that are not gauged.”
- “GEO can offer to build human capacity through tailor made training workshops, provision of software for flood forecasting etc.”
8. Towards an Implementation Plan for Capacity Building in Africa

To be completed at Symposium

9. Next Steps

To be completed at Symposium

10. Additional References


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Brown M. E. (2008). The Famine Early warning systems and remote sensing data. Springer. Use NOAA estimate rainfall products and Global telecommunication system (GTS) gauge data (where nearly 600-800 raingage stations report daily observations) through meteorological communication centers (one Center for Africa ??). It also use Meteosat GOES precipitation index (30 min intervals) and Meteosat infrared top clouds temperature (every 30 min) to derive rainfall patterns with a scale of 4 km.

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11. ANNEX

Detailed responses to the questions on status of national/regional access to data products, infrastructure, and services as determined from the 1st Task Team meeting questionnaire:

ACMAD
- Need to consolidate national data banks for each country from the data that exists in other data archives around the world.
- Encourage African governments and their development partners to apply some bi-lateral and multi-lateral funds to Earth observation activities at countries and sub-regional levels.

Benin:
- Human resources and capacity are highly needed.
- Although Benin has been actively involved in various initiatives the country suffers from retrogression of data collection systems.
- GEO group can help reversing the retrogression of data collection system.
- The Regional UNESCO IHP National Committees meeting in preparation and scheduled for February or March 2010 in Benin is a good opportunity that can be used for the Second GEOSS African Water Cycle Symposium. This first Task Team meeting might consider the participation of GEOSS to this important African water event.
- Meteorological data is made available easily and freely for students and science community by special request to National Meteorological Direction (NMD).
- Metadata is available for professionals.
- Water related data is available from National Hydrological Service of the Direction Générale de l’Eau (DGEau).
- Acquisition of processing/simulation models/software.

Cameroon:
- The country does not restrict internet access and an optic fiber supported network now exists for easy download of mostly open access data.
- Inadequate in-situ measurements.

CILSS:
- All the satellite data products are free. They can be accessed via internet by FTP (but the most frequent problem is low internet connection) or by sending CD.
- Field data (rain gauge, river discharge) are not free, but can be obtained within a collaboration framework.

Lake Chad Basin:
- There exists policy of free and unlimited access to the satellite and in-situ data to the entire six member States as well as few stakeholders. The policy is binding on all that signed the legal document known as “Agreement on Exchange of Data among the Member States”. The legal document indicates open data and metadata (description) access to entire member States, but to any 3rd party (particularly non member or International Organizations), spatial data can be made available by special request to LCBC.
- As stated data is made available by special request to LCBC in most cases on burn DVD and/or CDs as via internet is close to impossible/difficult.
- Human resources and capacity are highly needed. In-country training institutions need to be strengthened.
• Basins urgently needed an Monitoring and Early Warning System, such as receiving, retrieving and interpreting MSG data or similar to GMES
• Acquisition of modern data measuring equipment
• Improve Data quality and resolution
• Data issue: Access to data transfer via internet has low capacity (LCBC Database and University of Maiduguri Regional Database;
• Upgrading of existing LCBC VSAT;
• Upgrading of existing University of Maiduguri Regional Database;

Ghana, Volta Basin
• Human resources and institutional capacity are highly needed.
• Acquisition of modern data storage equipment
• Better internet connections:
• Data available by official request
• Harmonize data formats between institutions:
• Update maps and baseline data with most up-to-date information:
• Assign one expert and an assistant in Data Base Management System to better support African Meteorological agencies and built in a comprehensive Meta data bank.
• Copies of published reports could be acquired as needed.
• Poor/old data measuring equipment
• Poor/old data storage equipment (low capacity)
• Difficulty in accessing data from even national institutions
• Lack of processing/simulation models/software
• Outdated water related data/maps. Also the resolution of the data is too coarse for most applications.
• Ensuring data from different institutions (Meteorological, Hydrological, etc) have a common format. For example, all data could be stored in netcdf format.
• GEO can help with capacity building with regards to data management, post processing data to update maps, etc

Ivory Coast:
• Human resources and capacity are highly needed.
• To get access to satellite imagery an precipitation data in real time.
• To have more automated stations for hydroclimate measurements.
• Data are recorded at regional climate stations and sent to the central agency (SODEXAM).
• Data are not available on the internet. To access the data it is necessary to request and pay for it.
• Acquisition of processing/simulation models/software.

Somalia:
• Human resources and capacity are highly needed to make up for losses during the 20 year war.
• FAO is the custodian and repository of the Somali data generated under SW ALIM project and other FAO managed projects in Somalia.
• Data access is governed by the organization policies.
• The Somali hydrometeorlogical data recovered so far, and that are collected by FAO SWALIM are available for public download from web site: http://www.faoswalim.org.

Togo:
• Human resources and capacity are highly needed.
• Data available by special request to a national service.
• Tailored made training in water related information extraction from EO: Evaporation, Transpiration, Soil moisture content and Soil classification, etc;
• Acquisition of processing/simulation models/software.
• GEO could help with:
  o Refurbish current hydrometric networks (and stations)
  o Educate and retrain Hydrologists
  o Improve the collection quality control and distribution of data.

Volta Basin:
• The VBA is in the process of developing MoUs with the Volta basin countries who are the primary producers of the data. It is envisaged that data requested from VBA for research purposes will be given free.
• The same will be true of organizations that request for the data to develop decision support tools for water resources managers.
• The conventional data collection system is very expensive and the countries and VBA are not able to raise sufficient funds to meet the data collection budget.
• Data collection, storage, analysis and dissemination are still not well developed in the basin as well and in the Volta basin countries.
• The possibility of acquiring hydrological data, using Earth Observation information has been demonstrated and the application of this to the Volta basin could help resolve the issues of expensive data collection, once the Earth Observation information is already available.
• Training in the methods of extraction and processing of the information and the acquisition of the necessary soft and hardware are essential.
• Any support in the area of data storage, dissemination including standards, etc is welcome.

Zambezi Basin:
• Data Collection networks and their maintenance.
• Data processing capacities (hardware, software and human in some cases) need to be strengthened. GEO can offer to build human capacity through tailor made training workshops, provision of software for flood forecasting, etc.
• Some areas not covered by the network and maintenance of the network faces a lot of challenges.
• Vandalism of equipment used in collecting data. GEO can help in providing alternative sources of data, e.g. satellite images from which rainfall estimates can be made for areas that are not gauged.
• Products derived from METEOSAT are free and available to those on the mailing list (special request).
• ZRA’s policy is to sell products or data it generates. Products derived from satellite data are available at a fee.
• Acquisition of processing/simulation models/software.