Fourth annual IGCP 565 Workshop: Support for water management through hydrological models and data assimilation

November 21-22, 2011, Johannesburg, South Africa

The fourth annual workshop of the International Geoscience Programme Project 565 "Developing the Global Geodetic Observing System into a Monitoring System for the Global Water Cycle," which was jointly organized by IGCP 565, the Group on Earth Observations (GEO) and the Global Geodetic Observing System (GGOS), was held on November 21-22, 2011 at the Witwatersrand University, Johannesburg, South Africa.

A significant fraction of the global population is currently without access to sufficient clean and healthy drinking water. Although it was recently claimed that the Millennium Development Goal of reducing the number of people without access to sufficient potable water by half has been reached (WHO, 2012), it is also acknowledged that this progress was mainly due to improvements in China, while in other regions such as most of Africa, the situation remains severe or is worsening. Considering the impact of climate change and unsustainable water resource management, it is likely that the number of people without sufficient water will increase dramatically over the next decades. As pointed out repeatedly (e.g., United Nations, 2006), this is not so much a problem of water availability, but rather of insufficient governance. In many regions, the current lack of sufficient observations of surface and subsurface terrestrial water storage is a main obstacle for developing sustainable regional water management, which is essential for water security. Improved observations providing information on all terrestrial water cycle reservoirs on river basin to local scales is needed, if we want to secure access to water and avoid severe human and ecological disasters that may occur otherwise.

The goal of the IGCP 565 Project is to enhance utilization of the global geodetic observing infrastructure for the monitoring of mass transport in the water cycle (Plag et al., 2011). Geodetic observations of the time-variations in the Earth's gravity field, shape, and rotation capture signals of redistribution of water mass on and below the Earth surface. The accuracy of the geodetic techniques has seen a dramatic improvement over the last four decades, which created the potential for measuring water mass as it cycles from one reservoir to another.

The IGCP 565 Project (2008-2012) has been organizing a sequence of annual workshops that have successively addressed scientific questions related to the development of hydrogeodetic products for regional water management. The first workshop held in 2008 in San Francisco, USA identified the open scientific questions related to the water cycle and regional water management and the extent to which geodetic observations could help improve monitoring and address scientific questions based on such observations. Considering the importance of satellite gravity missions, the second workshop organized in Graz, Austria in September 2009, developed a road map for future satellite gravity missions. The third workshop convened in Reno, Nevada, USA in November 2010 focused on the separation of tectonic and hydrological signals in geodetic observations (Plag and Miller, 2011a, 2011b). Thematically, the fourth IGCP 565 workshop, which followed up several of the recommendations of the third workshop, focused on the assimilation of geodetic observations into hydrological land model schemes to better simulate terrestrial water storage and transfer, and had a particular focus on local to regional scales. This event was of particular relevance for water management researchers and applications users, particularly in developing countries.

The Workshop was held in conjunction with the AfricaArray (see http://www.africaarry.org) Workshop, which was held on November 20-21, 2011, and the UNAVCO GPS Short Course held on November 17-19, 2011 (Figure 1). The goals of the Workshop were (1) to advance and inform the potential progress towards low-latency hydrogeodetic products that would efficiently support

Figure 1 Participants of the AfricaArray 2011 and Fourth IGCP 565 Workshops, November 20-23, 2011, University of Witwatersrand, Johannesburg, South Africa.

regional water management applications; (2) to discuss on-going and proposed projects and programs that have the goal to improve information on water resources particularly in Africa and to support their sustainable management; (3) to entrain new users of hydrogeodetic observations and techniques, and to provide training for improved water resource decision-making in Africa.

The first session on Monday, November 21, 2011 was organized as a joint AfricaArray-IGCP session, providing a platform for reaching out to, and exchanging information with African researchers involved in the AfricaArray. A training session on Monday afternoon provided a tutorial in using Gravity Recovery and Climate Experiment (GRACE) data for hydrogeodetic applications. On the second day, the morning session provided an overview of on-going research within the IGCP 565 Project, and the afternoon session focused on the coordination and, where possible, integration of on-going and proposed projects and programs linked to hydrogeodesy. The majority of the attendees came from African countries and showed particular interest in the overview talks and the GRACE training sessions. Follow-up planning for further training is being implemented, with results to be presented at the fifth IGCP 565 Meeting in October 2012 in Johannesburg.

The workshop focused on scientific questions related to the water cycle at regional to basin-scales in Africa and discussed ways in which hydrogeodesy could support a better understanding of basin-scale water budgets in support of regional water management. Water management in Africa faces major challenges due to climate variability and change: among other extremes, one of the largest rainfall deficits on the planet during the last century occurred in Africa. There is a large interannual to decadal variability in rainfall, which is imposed on an already climate-vulnerable environment. The limited water availability impacts all socioeconomic sectors and, among others, causes health issues, urban water shortages, and insufficient hydropower energy production. Such water variability and deficits are a threat to African food security, where more than 80% of agriculture is rain fed. In areas such as inland river deltas (e.g., the Okavango delta) other economic activities, including tourism, access to building material, and the sale of products) depend on sufficient rainfall. Consequently, Africa is a "hot-spot" due to the highly sensitive interaction between climate and the socio-economic systems. At the same time, research to understand the effects of climate variability on key reservoirs, such as groundwater, is limited. In many cases, separating the signals between climate variability and attributing signals of climate change is not possible due to the lack of sufficiently long observed time series for fundamental variables such as groundwater depth variations. Hence, hydrogeodesy represents a new and fundamental approach for understanding the relationship across climate variations and sub-surface water storage changes. A range of predictive terrestrial water storage models applied to Africa have been under development, but the full integration and validation of geodetic observations into these models is still pending. The IGCP 565 Project provides an important contribution with its focus on developing geodetic products that can be assimilated and integrated into terrestrial water storage models.

The meeting also illustrated the synergies between this project and AfricaArray, where recent developments are increasing the value of the AfricaArray network for hydrogeodetic applications. Other relevant projects and recent meetings include the Middle East North Africa Land Data Assimilation System (MENA), TIGER, the African Monsoon Multidisciplinary Analysis (AMMA), and the GEOSS African Water Cycle Symposium. Research carried out in the IGCP 565 Project, AfricaArray and the other projects mentioned above are of relevance for applied programs related to water management and supply, such as WaterNet and the Famine Early Warning Systems Network (FEWS-NET). Key issues to be addressed are: (1) development of spatial data bases; (2) reliable and continuous monitoring systems that enable a better understanding of the societal problems; (3) capacity building with the goal to have trained users of existing Earth observation systems; (4) development of the infrastructure and the political will to implement science- and observation based water management.

GRACE is still a key geodetic input to monitoring subsurface hydrologic variations and is the critical link between geodesy and hydrology communities. There are many standard and non-standard GRACE products that support water cycle research that are potentially of value for regional water management. Products such as GPS observations are now available for individual river basins (a total of 218 basins), and these products provide important constraints for the water cycle on basin to sub-basin scales, particularly if combined with other a priori information. Among others, trends in the GRACE-based terrestrial water storage have helped to identify hot spots in groundwater depletion. Assimilation of GRACE data into the Land Data Assimilation Systems has significantly improved the simulation of seasonal and interannual groundwater variations at subbasin scales. With a follow-on mission for GRACE now being planned, we now have a good perspective for the operational use of GRACE products for regional operational water management. However, in many cases, access to the relevant products is not straightforward and requires expert knowledge and training of local users.

One of the recommendations of the Third IGCP 565 Workshop was the development of a demonstration project in California that merges geodetic information with hydrologic modelling via assimilation, leading to technology transfer to African nations through a similar project in the Nile Basin. The pilot project in California is underway and is producing promising results. The workshop participants discussed the options for a similar pilot project in a major river basin in Africa and agreed to cooperate on the development of such a project. We are currently working to advance this plan through a new NSF proposal to develop an African Research Coordinated Network.

Several on-going projects in Africa, which are carried out within the framework of the IGCP 565 Project were reviewed. These projects underline the importance of hydrogeodesy both for the monitoring of both subsurface water storage and the understanding of subsurface hydrologic properties. The projects are (1) the Gateway Wellfield Project, Hermanus, South Africa; (2) Hydrogeodetic groundwater exploration in Ethiopia; (3) Hydrogeodetic studies of water balance trends in the Okavango Delta in Botswana. In the discussions, the workshop addressed a number of emerging projects and followed up the recommendations of the Third IGCP 565 Workshop. In 2009, GEO issued a Call for Proposals with the intent to facilitate funding for proposals passing the review. GEO received more than 70 proposals, with many of them related to Water issues. Teams from Africa submitted seven of the accepted Water-related proposals. Unfortunately, GEO was not successful in facilitating funding. Therefore, four of the proposals were discussed during the

workshop in an effort to identify potential ways towards funding. These proposals are (1) Space-Geodetic (Earth) Observations in Support of Groundwater Resource Assessment and Drought Management (in South Africa); (2) Ghana Water Management Proposals; (3) Hydrogeodetic evaluation of regional groundwater resources in Southwestern Nigeria; (4) Application of Global Earth Observation System of Systems (GEOSS) to the management if underground water resources in Nigeria. These discussions are currently being continued.

The workshop brought together more than 40 participants with more than 30 from African countries. Particularly the African participants appreciated the tutorial session on the use of GRACE for hydrology. They also emphasized the need for capacity building related to hydrogeodesy. WaterNet is key to capacity building in water management, and the IGCP 565 project cooperates with WaterNet in this effort. The contributions underline the main recommendations of the third workshop, i.e., the need to develop a community of facilities for integrated hydrogeodetic modelling, as well as interfaces enabling the use of hydrogeodetic products for water cycle studies and water management. Access to data and tools was identified as a key issue.

The main findings of the workshop can be summarized as:

- Africa is a "hot spot" in terms of water issues, due to large climate variability and high sensitivity to change, impact of limited water availability on all socioeconomic sectors, health, and food security, and the highly sensitive interaction between climate and the socio-economic systems.
- Research to understand the effects of climate variability on key reservoirs is limited.
- Research is hampered by the lack of long enough observed time series for fundamental variables.
- Hydrogeodesy represents a new and fundamental approach for monitoring changes in terrestrial water storage change.
- Predictive terrestrial water storage models for Africa are under development, but the full integration and validation of geodetic observations into these models is pending due to insufficient ground-based observations.
- Application of hydrogeodesy to regional water management is hampered by data access, challenges in use of products, and the absence of a workbench with a user-friendly graphical user interface (GUI).
- There are many water-related initiatives, but synergies between activities are not fully exploited.

The participants agreed on the following recommendations:

- Improve coordination and exploitation of synergies between on-going activities.
- Improve access to data through cooperation between agencies and researchers.
- Improve access to tools through the development of GUI workbenches.
- Demonstrate the relevance of hydrogeodesy and predictive terrestrial water models through demonstration projects on river basin-scale.

As a result of the Fourth Workshop, the IGCP 565 project continues to carry out the pilot project in California and to develop a similar pilot in Africa. In cooperation with the AfricaArray and other relevant activities, a proposal for an U.S. National Science Foundation Research Coordination Network has been submitted, focusing on the closure of the water cycle budget at the basin scale for major African river basins.

The outcomes of the workshop also highlight the importance of a community-based modeling framework for integrated geodetic and hydrogeodetic modeling. As a result of the workshop, an initiative is advancing for the development of this framework and to integrate it with the hydrogedetic data portal and the decision support tool developed in the frame of the pilot project.

The need for improved cooperation and coordination of the various projects and programs addressing the water cycle and water-management related studies and activities was highlighted as a critical need by many workshop presentations. Discussion contributions will have an impact on the Fifth and final IGCP 565 Project workshop. This workshop will be organized jointly with several related projects on October 29-30, 2012 in Johannesburg in conjunction with the 13th Annual Symposium of WaterNet (http://www.waternetonline.org) in Johannesburg, South Africa, with the goal of bringing together researchers, managers and decision makers in an effort to make progress towards better informed water management in Africa.

For a full documentation of IGCP 565 and the workshop series, see http://www.igcp565.org.

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