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Earth observations for global water security

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The combined effects of population growth, increasing demands for water to support agriculture, energy security, and industrial expansion, and the challenges of climate change give rise to an urgent need to carefully monitor and assess trends and variations in water resources. Doing so will ensure that sustainable access to adequate quantities of safe and useable water will serve as a foundation for water security. Both satellite and *in situ* observations combined with data assimilation and models are needed for effective, integrated monitoring of the water cycle's trends and variability in terms of both quantity and quality. On the basis of a review of existing observational systems, we argue that a new integrated monitoring capability for water security purposes is urgently needed. Furthermore, the components for this capability exist and could be integrated through the cooperation of national observational programmes. The Group on Earth Observations should play a central role in the design, implementation, management and analysis of this system and its products.

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Introduction

Concerns about the sustained availability of safe water are increasing based on the expansion of water problems around the world. Recent projections reported by the UN Department of Economic and Social Affairs (UNDESA) suggest that up to half of the world's population will be living in areas of high water stress by 2030 [1]. Furthermore, much of the world's population increase will occur in developing countries where water scarcity and water quality concerns are expected to cause tensions among sectors (e.g. agriculture versus urban users) and impediments to co-balancing human needs and ecological requirements. Every year more than one and a half million children and adults without access to safe drinking water and sanitation die or experience severe health problems [2]. In the face of these rising pressures on water resources, monitoring becomes critical on all spatial and temporal scales because it contributes a systematic and transparent approach for resolving water issues.

This article emphasizes the connections between water security, sustainable development, and Earth observations. By way of background, the UN adopted Millennium Development Goals (MDG) at its UN Millennium Summit in 2000 [3,4]. For more than a decade UN nations have regularly reported their progress in achieving these goals. As discussed at the Rio+20 UN Conference on Sustainable Development, new Sustainable Development Goals (SDGs) are being proposed to build upon the MDGs thereby contributing to the sustainability of the world's resources [5,6].

Linked to these goals is the concept of water security. Although some nations interpret water security in terms of water issues that could affect their own national security [7], this article has adopted the UN-Water working definition that describes water security as: 'the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability' [8]. For many of the 31 nations which are poor and currently under chronic water stress [9], it is very difficult to achieve water security without outside help. The first step in obtaining such help for all nations is to utilize better information in the management of the water that is needed by these populations and ecosystems. In addition, as natural variability and extremes are amplified by climate change, there is a need to augment water resource systems to cope with increased variability in the supply. In particular, engineered systems that are optimized based on the assumption of continuity in supply and demand patterns may become vulnerable to trends in light of non-stationarity in the water cycle [10•].

Across many regions, it is not possible for water experts to obtain the data necessary to carry out comprehensive assessments of threats to water security. Earth observations are an essential part of the required knowledge base. They encompass the wide range of information that can be obtained by sensors in the environment and those observing the Earth from satellites or aircraft. Some nations fail to collect adequate observations to document the current state or changes associated with their water resources. Other countries indeed collect the data, but do not distribute them to other nations or experts who could otherwise apply them in conjunction with sophisticated assessment tools. These attitudes towards data exchange and attempts to limit their beneficial use suggest that more proactive initiatives and policies on data exchange and alternative observational systems need to be developed to avert a strategic knowledge gap.

The Group on Earth Observations (GEO), a voluntary organization of 90 member nations and more than 65 international participating organizations, is developing a Global Earth Observation System of Systems (GEOSS) based on interoperability and data sharing [11]. Through its Water Task and its Integrated Global Water Cycle Observations (IGWCO) Community of Practice [12], GEO brings attention to the needs for: better *in situ* water observational networks and new space-based measurement systems, improved data sharing, stronger user engagement, and improved assimilation and modelling capabilities. In addition to regional projects, GEO currently is coordinating the development of global monitoring systems for forestry and agriculture.

We provide here a review of the data required to support water security decisions ('Information needed for addressing water security' section). The ability of observational systems to meet these requirements for each critical variable is then presented in 'Sources of data for improving water security' section, followed in the 'Information Integration and Decision Support' section by an assessment of the information integration needed to fill data gaps and to support applications for decision makers. The article concludes with a summary statement that underlines the need to develop a comprehensive Global Water Security Monitoring System (GWSMS).

Information needed for addressing water security

While one might consider that the data needed to support water security assessments are unique, in practice, they are the same variables used for water management decisions. Unninayar *et al.* [13] documented the data and information needs of water managers with different responsibilities for water data and services. When the information needs of water managers along with the needs of users from several sectors were reviewed, precipitation and soil moisture were the two most frequently requested variables. For water security issues, emphasis must also be placed on river discharge, surface water storage, snow water equivalent, groundwater, and water quality and sediments.

For water security applications, individual water management decisions must be contextualized since these decisions have cumulative impacts and consequences over time and space. For example, the simple approval of a water allocation request for irrigation water often proves to be more complex when assessed within a broader water security framework. Within such a framework, water supply projections, competing priority demands and water quality needs would also need to be evaluated in making assessments. Although the information used would rely on observations and hydrologic models, decision makers would need access to more accurate data with specific error estimates and access to the historical information necessary for contextualizing the decision into a broader regional or global water security framework.

Information for assessing water security needs must be provided to policy makers and politicians who are then able to publically articulate whether the water security situation is improving, remaining constant or deteriorating. This could be done most effectively if quantitative goals were set, supported by information from a monitoring system, such that policy makers could readily determine whether a nation or basin was progressing towards water security. The development of SDGs could be helpful for clarifying which variables and space scales need to be emphasized in a monitoring system. In addition, they could help to develop a more robust monitoring system by relying on fully objective and transparent sources of information based on Earth observations and serve as the recognized basis for decisions by the UN bodies or panels responsible for reviewing progress on the implementation of SDGs. This approach would enhance the more prevalent in-country evaluations and surveys that were commonly used to assess progress on the MDGs.

To address water security issues, decision makers require information on the current state of the system and on future states for assessing progress and problems and to facilitate planning and problem mitigation. These types of information are regularly reviewed by GEO at both the user need definition and the system development levels. With its focus on interoperability, data integration and analysis, and capacity development, GEO is in an excellent position to guide the development of a water strategy monitoring system as part of its post-2015 work programme.

Integration is important for the communication of information related to water security. Policy makers indicate that a few meaningful indicators are more relevant to their needs than large quantities of unprocessed data. They