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11TH ANNUAL SPACE GENERATION CONGRESS: EARTH OBSERVATION SESSION REPORT ON SPACE APPLICATIONS FOR WATER MANAGEMENT

Katrina Laygo
Space Generation Advisory Council (SGAC), United States, katrina.laygo@spacegeneration.org

Ms. Noemie Bernede
Space Generation Advisory Council (SGAC), Germany, noemie.bernede@gmail.com
Ms. Natassa Antoniou
Secure World Foundation, Belgium, nantoniou@swfound.org
Mr. Olubunmi Akinwumi
Space Generation Advisory Council (SGAC), Nigeria, yolemi.akins@gmail.com

Water is one of the most fundamental resources, necessary for human consumption, agriculture, safety, and industry. Due to its vitality, the issues and practices of water resource management continue to be a rising challenge for stakeholders and decision makers. Space-based Earth Observations (EO) represent a valuable technology to efficiently monitor the Earth's resources. They are beneficial for assessing the water cycle on local, regional and global levels and in providing information, with peaceful objectives, for events that may span the borders of multiple countries. A great number of space-based technologies such as land and marine observations, along with weather satellites, are available and allow for the precise monitoring and measurement of water resources and factors that can influence the water cycle and inform water management practices. This paper focuses on EO applications for water management related to consumption, agriculture, and safety. Accessing clean water and monitoring water quality and resources are vital to the component of consumption. Improving or enhancing agricultural productivity and benefiting from ecosystem services are vital to the second focus area of agriculture. Enhancing water-related disaster management issues (e.g. floods and landslides) and improving sanitation fall within the third focus area of safety. The goal of this study was to identify concrete connections between EO applications and secure, sustainable access to basic living necessities such as food, water, and shelter. This analysis identifies the importance of utilizing EO for water management by assessing the current global situation and the perspectives of stakeholders, decision makers, international organizations, the public, and commercial sectors. The importance of stakeholder awareness of space capabilities and of stakeholder cooperation in water management is underscored. Finally, this paper presents four main recommendations for improving the applications of EO in water resource management. This study was undertaken during the Space Generation Congress of the Space Generation Advisory Council in September 2012 by the "Earth Observation – Space Resources for Water Management" working group. The final paper represents the ideas and the recommendations of representatives of the young generation from more than ten countries.

I. INTRODUCTION

Water is a fundamental resource for life, necessary for human consumption, agriculture, safety, and industry. Water scarcity and recurrent flooding occur regularly and continue to strongly impact many regions around the world, especially in developing countries. Other phenomena such as glacier melting, erosion, and desertification also pose numerous risks to the environment and affected communities, although sometimes in less obvious ways. As water is a vital component of everyday life, the issues and practices of water management continue to be a rising challenge for stakeholders and decision makers. Space-based Earth Observations (EO) are valuable for water management and the assessment of the water cycle on local, regional and global levels and in providing information (with peaceful objectives) for events that may span the borders of multiple countries. A great number of space technologies such as land and marine observations, along with weather satellites, are available and allow for the precise monitoring and measurement of water resources and factors that influence the water cycle.

The goals of the working group were to:

- Identify the importance and applications of using EO for water management
- Identify the stakeholders in the sector of water management and related issues, such as the lack of or access to data
- Recommend ways to improve or enhance the use of EO in water management

II. WHAT IS WATER MANAGEMENT AND HOW IS IT SPACE RELATED?

In order to identify current space-based technologies that are currently used or have the potential to be used for water management, the group first established the scope and definition of water management. For the purposes of this report, water management in three different but connected areas – *water for consumption, for agriculture, and for safety* – were identified as the main focus areas. Accessing clean water and monitoring water quality and resources are vital to the component of *consumption*. Improving or enhancing agricultural productivity and benefiting from ecosystem services are vital to the second focus area of *agriculture*. Enhancing water-related disaster management issues (e.g. floods, landslides) and improving sanitation fall within the third focus area of *safety*. The group sought to make concrete connections between EO applications and secure, sustainable access to the basic living necessities such as food, water, and shelter.

A. Current Satellite Technologies Utilised for Water Management

Currently, there are a number of satellite technologies being utilised for water management. The satellite technologies discussed in this paper fall into the two categories of active and passive remote sensing. The satellite technologies were also categorised according to the specific measurements and applications to water management.

i. Active Satellite Remote Sensors

Active satellite remote sensors, such as microwave and radar sensors, provide their own form of radiation to highlight a study area, as opposed to passive ones that simply detect radiation. Radar, also known as **RA**dio **D**etection and **R**anging, is the most common form of active microwave sensing. The advantage of radar lies in its wide range of imaging conditions, wherein it is able to penetrate clouds and image an area during day or night. Radar altimeters and scatterometers are also considered active sensors. They can measure the distance to the ground of a spacecraft with the transmission of short microwave pulses or can transmit short microwave pulses to measure the reflected energy.[1] The data from these two instruments can be used to study vegetation, soil moisture, and changes in snow distribution, for example.

ii. Passive Satellite Remote Sensors

Passive remote sensors detect the emitted energy from the imaged area. Passive microwave remote sensing may be utilised in meteorology, hydrology, and oceanography.[2] These physical disciplines are critical for water management practices. Various surface parameters such as salinity, soil moisture, sea ice, precipitation, and the amount of water vapor and liquid water can also be measured. Passive multispectral (MSS) systems sense visible and infrared portions of the electromagnetic spectrum. Blue, green, red, and infrared wavelengths are measured for water discrimination and mapping, soil and vegetation studies, and vegetation discrimination and mapping (such as the assessment of agricultural health and productivity). Thermal infrared sensors measure the surface temperature and thermal properties of a target area.[3] Since water areas are usually very distinguishable from their surrounding areas, analysing infrared images allow for a better understanding of the distribution of water on the surface, the monitoring of evapotranspiration,[4] and the location of possible water sources. Table 1 includes examples of active and passive remote sensor satellites and their specific applications to water management.

Satellite Measurements	Water Management Applications
Soil Moisture	Drought / vegetation health
Rainfall	Global flood and landslide monitoring
Ocean Color	Oil spills, water quality indicators, biological activity
Elevation Data / Interferometry	Flood and wetland mapping, landslide
Sea Surface Height	Ocean tides and circulation
Wind Speed	Weather forecasting near coastlines
Snow Cover / Sea Ice	Snow melt estimation, flood forecasting
Extent of water areas	Mapping of water resources

Table 1: Current Satellite Measurements from Active and Passive Remote Sensor Satellites and their Specific Applications to Water Management.

iii. Examples of Existing Satellite Missions Dedicated to Water Management

Some examples of current satellite missions dedicated to water management include:

- **Tropical Rainfall Measuring Mission (TRMM)**, a joint space mission between the National Aeronautics and Space Administration (NASA) and the Japanese Aerospace Exploration Agency (JAXA) to monitor and study tropical rainfall.
- **JASON-1,** a joint mission between NASA and Centre National d'Etudes Spatiales (CNES) of France to monitor global ocean circulation, improve global climate predictions, and monitor El Niño events.[5]

- **Gravity Recovery and Climate Experiment (GRACE)**, a joint mission between NASA and the German Aerospace Center (DLR), which measures differences in Earth's gravity as an indicator of water. GRACE data is extrapolated to assess changes in global ocean circulation, groundwater, sea levels, and exchanges between ice sheets or glaciers and the ocean.[6]
- **TERRA, AQUA, Landsat 7, Earth Observer 1 (EO-1), and the Advanced Spaceborne Thermal Emission Radiometer (ASTER)** are a part of NASA's **Land-Cover/Land-Use Change Program (LCLUC),** an interdisciplinary science programme consisting of several satellite sensing systems utilised for LCLUC research, which includes studies on water, energy cycle impacts and food security.[7]

III. STAKEHOLDERS IN WATER MANAGEMENT AND THEIR CURRENT ISSUES

A. Stakeholders

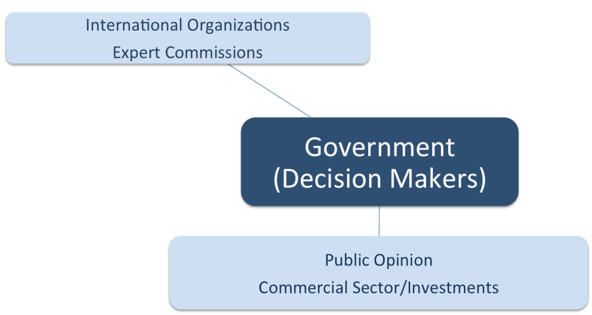

Figure 1: Stakeholder interaction diagram, depicting top-down and bottom-up approaches to governance of water resources.

Water resource management involves many stakeholders, ranging from the general public and local governments to private industry and international multilateral organisations, all of whom have different objectives. It is essential that stakeholders are identified and considered in developing plans to utilize space-based technologies for water management. Stakeholder engagement ensures that the right information is available to the right people at the right time.

Based on the ubiquitous necessity of water, each person is essentially a stakeholder, but not everyone participates in decision making on water resource management. However, current trends towards democratisation, privatisation, and globalisation are beginning to make it possible to include local households, companies, and a multitude of other stakeholders in both the development and implementation of new plans and policies.[8] For example, the government in the United Republic of Tanzania has developed a new policy and legal framework that involves local famers as one the main stakeholders in water resource management.[9]

The high number of stakeholders involved in water management and their diverging interests impact decision making processes (such as budget allocation) and communication strategies regarding the technologies available. Synergies and collaboration are key, in particular for a better implementation of space technologies in water management.

B. Current Issues Faced by Stakeholders

Despite the fact that space-based technologies, especially EO, are recognised worldwide as valuable tools for international development and water management, many issues still exist that limit the accessibility and widespread use of these technologies. The main problems facing developing regions that are most in need of water management assistance are:

1. **Lack of awareness**: Organisations and individuals who could benefit from EO and remote sensing for water management applications are not aware of the available technologies.
2. **Need for capacity building**: The capabilities must be enhanced, mainly in developing countries, to allow for a sustainable use of space technologies.
3. **Lack of infrastructure for collecting and analysing satellite data**: Better organisational processes are of high importance to make the best use of collected data.
4. **Data access, purchase and sharing**: In countries with no national space agencies, there is frequently no organisational framework to access EO data. The role of national government is critical to the success of any initiative in these areas.
5. **Lack of funding**: Financial resources are not consistently available for purchasing EO data. Lacking are organisational or political processes to create a budget for institutions that need space technologies.
6. **Limits of in-situ monitoring:** In-situ monitoring is important and valuable, but can be difficult or impossible to collect in remote areas. Even in areas where in-situ measurements are taken, satellite data may complement findings and provide more comprehensive coverage. This is especially beneficial in areas where it may be physical

difficult or prohibitively expensive to collect in-situ data.

IV. RECOMMENDATIONS

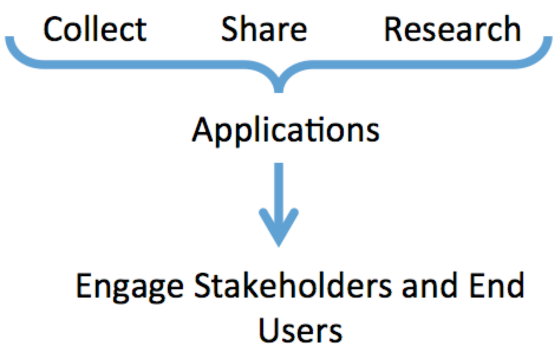

Figure 2: Satellite Water Management Application Workflow.

The EO group put forth four recommendations to better integrate space-based EO into current water resources management approaches. The recommendations take a streamlined and interconnected approach (Figure 2) in collecting and sharing satellite data:

1. **Collection and Sharing of Data and Conducting Applied Research**: The collection and sharing of data must be coordinated among space agencies and data distributors in order to ensure the continuity of data. To allow maximum use by a broad range of stakeholders, the data formatting should be standardised and the accessibility of data must be increased, especially with high-resolution imagery. This can be achieved through lowering costs and minimising restrictions for the peaceful utilisation of data, as well as providing incentives for data use. Such incentives include competitive grants or scholarships for data use applied to water management concerns in the awardee's study area, and competitions following models such as the X Prize Foundation.
2. **Identifying Applications for EO Data:** There are countless examples of where EO data can be applied to water resource management, including the monitoring of groundwater depletion and the mapping of aboveground water sources and flood sites. To ensure the continuity in these application focus areas, stakeholders and end users should take advantage of current programmes that are effectively making use of the data, such as SERVIR, a collaborative project between NASA and the United States Agency for International Development (USAID). SERVIR addresses issues such as drought in Africa with satellite imagery. Stakeholders and end users are encouraged to build onto or model programmes after successfully established regional initiatives, such as the European Space Agency (ESA) TIGER initiative and the Global Earth Observation System of System (GEOSS) Asian Water Cycle Initiative.
3. **Prioritise Local Capacity Building:** International, regional, and local cooperative projects and exchange programmes among university students and the public are recommended in order to expand the EO user base and increase the effectiveness of their applications towards water management. Site demonstrations, in which local community members meet with scientists, engineers, and university students utilising space-based EO for water management would be an effective way to tangibly transition research results and data to the public. For example, a demonstration of how radar and digital elevation model (DEM) data is effective in determining where to build sanitation systems would allow for the practical use of the data, combined with field measurements for validation.
4. **Engage Stakeholders and End Users:** In order to raise public awareness of the benefits of space-based EO, social media outlets such as YouTube, radio, television, Facebook, and Twitter can be integrated with crowdsourcing map tools such as Ushahidi and OpenStreetMap. On a standalone basis, these social media outlets can be key drivers in expanding general public awareness of the tangible connection between spaced-based EO and how it can improve or enhance everyday life, with a focus on the vital resource of water and its management. Remote sensing and Geographic Information Systems (GIS) courses should be further integrated into Science, Technology, Engineering, and Mathematics (STEM) education from an earlier time frame, preferably prior to the university level. Finally, decision makers on the national government level must be made aware of the benefits of space-based EO for water management and their direct impacts on the lives of citizens. This can be achieved through the identification of metrics to quantify the return on investment in integrating EO into

water management. These would include information on resources and money leveraged, knowledge acquisition, and levels of prestige. Applied science researchers, engineers, and university students are highly encouraged to partner with local and regional water resource agencies and conduct research within a specific water resource application of the region. This would build both the capacity of the researcher and the end user to utilise and disseminate space-based EO products for improved decision support, and address near-term (and eventually longer-term) community concerns of water management.

V. CONCLUSIONS

Water is a fundamental resource for life, necessary for human consumption, agriculture, sanitation, and industry. The "Earth Observation – Space Resources for Water Management" working group identified the different applications of Earth observations in water management. They also identified relevant stakeholders. These included international organizations, expert commissions, government (local, regional, national), the commercial sector, and finally, the public.

The current issues faced by stakeholders included the lack of awareness, the need for capacity building, the lack of infrastructure for collecting and analyzing satellite data, data access, purchase, and sharing, the lack of funding, and limits in in-situ monitoring.

Finally, the four recommendations are parallel with research on the potential applications of satellite data for water management. This knowledge can be used to develop and improve water management decision-making. It is essential to engage stakeholders and end users to ensure that these applications are put to use and meet the needs of the community.

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