Towards innovative groundwater resources evaluation for water management decisions and policies:

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Background:

Out of the 592 Transboundary Aquifers (TBAs) that have been identified by IGRAC & UNESCO-IHP (<50km² in the Middle East, 129 in Asia and Oceania, 73 in the Americas), only 6 are under a legal agreement for their sustainable management. This is mostly due to the fact that the dynamics of such aquifers are not yet fully understood and monitored (mainly because of the lack of monitoring data). Water decision-makers increasingly require innovative aquifer management tools that address the broad impacts of global change on aquifer storage and depletion trajectory management, land use, groundwater-dependent ecosystems, seawater intrusion, anthropogenic and geogenic contamination, supply vulnerability, and long-term sustainability. In the past years, NASA’s Gravity Recovery and Climate Experiment (GRACE) - first satellite mission able to monitor total water storage changes (including groundwater) remotely – has provided new insights of the dynamics of groundwater resources. However, GRACE observations are only available since 2002. Given that the dynamics of groundwater are strongly related to interannual climate oscillations whose understanding require a longer time frame than the one GRACE observations can provide (e.g. El Niño, Atlantic Oscillation), there is a need to go back to the “past” to better evaluate the current and future evolution of groundwater resources. The scope of this research provides an initial starting point to address complex interactions between groundwater and global change using GRACE observations, global datasets, modeling and groundwater level time-series data.

Evaluation of the dynamics of Transboundary Aquifers (TBAs) over the past 10 years using GRACE observations:

**GRACE mission: Measuring global change with gravity**

- Earth’s gravity is constantly changing because of the redistribution of fluid masses at its surface, including water. Weaker gravity means less water. Higher gravity means more water.
- GRACE mission does not carry remote-sensing instruments. It is made of two satellites chasing each other (also called Tom and Jerry). When gravity increases, the leading satellite accelerates, before being caught up by the second one. Gravity variations induce distance variations between the satellites. Processed data provides monthly solutions of GRACE measurements.
- Spatial resolution is especially limited by the altitude of the satellites. Even if GRACE allows information down to spatial scales equivalent to 300 km, the error estimate increases with increasing resolution. Good estimate is provided for spatial resolution of 1000km (i.e. 10000km² area).

**The total water storage changes can be partitioned into components where S is the total terrestrial water storage anomalies from GRACE, SWS is surface water storage, SWE+ICE is snow ice water equivalent, SMS is soil moisture storage, and GWS is groundwater storage.**

- GRACE observations applied to TBAs

- 49 TBAs > 10000km² (25 in Africa & Middle East, 9 in Southeast Asia, 8 in the Americas and 7 in Central Asia).

Over the past 10 years, most TBAs have had low depletion rates (<5mm/y). However, there are hotspots in the Middle East and Central Asia with depletion rates higher than 20mm/y.

**Evaluation of the impact of interannual climate oscillations in Southern African TBAs using modeling, groundwater level time-series data and GRACE observations**

- Model: Stampriet Transboundary Aquifer System (STAS) shared by Namibia, Botswana and South Africa.
- Karoo Sedimentary Aquifer shared by South Africa and Lesotho.
- Simple model not requiring extensive programming applied at aquifer scale. It is assumed that at the long term, total water storage variations could be considered as groundwater storage variations.

**Conclusions and way forward:**

NASA’s Gravity Recovery and Climate Experiment (GRACE) has proven to be an extremely useful tool to evaluate the evolution of groundwater resources since its launch in 2002. However, the interpretation of GRACE observations trends could be misleading because its time frame is below most of interannual climate oscillations (e.g. El Niño, Atlantic Oscillation). Extending GRACE time range to the past 10 years using global datasets of precipitation, actual evapotranspiration and runoff offers an innovative tool to better understand the dynamics of Transboundary Aquifers (TBAs), and consequently pave the way towards better water management decisions and policies, especially in TBAs which are currently being considered as hotspots. There is a crucial need to consider the impact of interannual climate oscillations when assessing TBAs. Results obtained for Southern African TBAs (Stampriet and Karoo Sedimentary) show that El Niño and La Niña past events have had an important impact on their behaviour. As the 2015-2016 El Niño was being considered to be very strong, below normal recharge and consequently decreasing groundwater storage could be expected for Southern African TBAs.

**Bibliography:**

1. 2015 Map of Transboundary Aquifers, IGRAC & UNESCO-IHP, 2015
2. Global Precipitation Analysis Products of the GPCC, 2015
3. Climatic Research Unit (CRU), University of East Anglia
4. Global Runoff Database (GRDC)

**Study area:** Semi-arid region (Southern Africa)

**Modeling:**

- Model using GPCC precipitation database allows better description of interannual climate oscillations.
- Modeled results are in agreement with the very limited long-term groundwater level time-series data available.
- Model shows that the trend observed by GRACE observations since 2002 has been preceded by strong interannual climate oscillations which has been verified by groundwater level time-series data.
- LA Niña years lead to above normal recharge while very strong El Niño years lead to below normal recharge

**Conclusion:**

- Stampriet Transboundary Aquifer System (STAS) shared by Namibia, Botswana and South Africa.
- Karoo Sedimentary Aquifer shared by South Africa and Lesotho.
- Model shows that the trend observed by GRACE observations since 2002 has been preceded by strong interannual climate oscillations which has been verified by groundwater level time-series data.
- LA Niña years lead to above normal recharge while very strong El Niño years lead to below normal recharge.