Next-Generation Gravity Missions for Drought Monitoring

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1. Introduction

The past GRACE (Gravity Recovery And Climate Experiment) mission has clearly demonstrated its capability to monitor global mass redistribution over its 15 years mission lifetime. In particular, GRACE has quantified the mass variations due to the hydrological cycle at the planetary scale. An on-going ESA-funded study (ADDCON: Additional Constellation & Scientific Analysis Studies of the Next Generation Gravity Mission Concept) investigates multi-pair GRACE-like satellite constellations and their potential applications in the Earth sciences. Among several other goals, the project aims to make the step towards near-real-time products, with a special focus on hydrological services and applications. In particular, it aims to contribute to gravimetric drought monitoring and the characterization of flood potential.

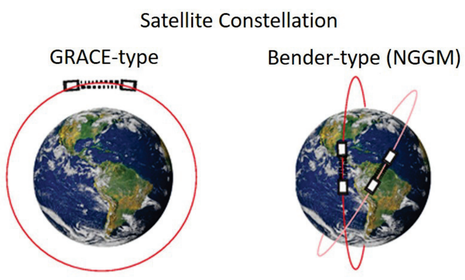

Figure 1: *Schematic view of satellite constellation in one polar pair (GRACE-type) and a polar and an inclined pair (NGGM-type).*

2. Motivation and Objectives

Motivation

- Limitaitions in GRACE producs by their relatively low spatial (300 km) and temporal resolutions (30 days)
- The tight relation between observability of drought events to their spatial-temporal behaviour and their signal amplitude

Objectives

- Analysis of the impact of the next-generation gravity mission (NGGM) for hydrological applications (drought characterization)
- Develope a new method for characterizing *gravimetric drought*, i.e. a deficit in total water storage.

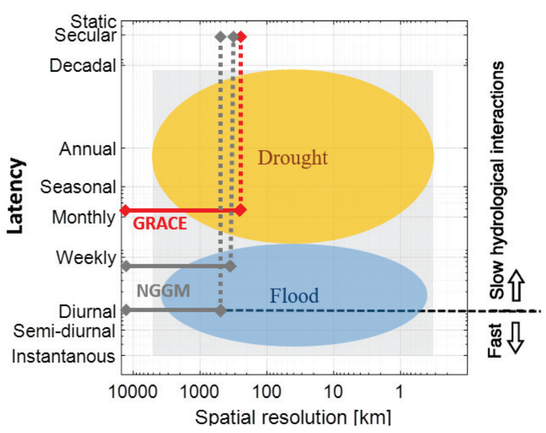

Figure 2: *Spatial and latency of hydrological cycle (gray box) together with bubbles for drought (yellow) and flood (blue). Courtesy: M.J. Tourian*

3. Methodology

Datasets

- The ESA Earth System Model (ESM) of the time-variable gravity field, given as spherical harmonics up to d/o 180, within 1995–2006 with a time sampling of 6 hours.
- The global WaterGAP Global Hydrology Model (WGHM) at a spatial resolution of 0.5°and within 1960–2009.

Method: One of the key challenges is to identify the climatology (long-term mean) reflecting the *normal* behaviour of the system over climatically relevant time-scales, e.g. a minimum of 30 years of data. Due to short record of ESM, we used WGHM.

$$EWH_i \xrightarrow[\text{climatology}]{\text{remove}} \delta EWH_i \xrightarrow[\text{normalization}]{\text{3-month accumulation}} SBDI_i = \frac{1}{3}\frac{1}{\sigma_i}\sum_{n=0}^{N} \delta EWH_{i-n}$$

Figure 3: *Gravimetric (storage-based) drought index*

- external source of EWH (hydro-model)
- no trend removal
- no soil/surface storage removal

The SBDI is a dimensionless quantity that detects drought. We characterized drought using the empirical cumulative distribution function (CDF) of long-term SBDI and U.S. Drought Monitor percentile values: less than 22.0 is an exceptional drought, from 21.99 to 21.60 is an extreme drought, from 21.59 to 21.30 is a severe drought, from 21.29 to 20.80 is a moderate drought, from 20.79 to 20.50 is abnormally dry.

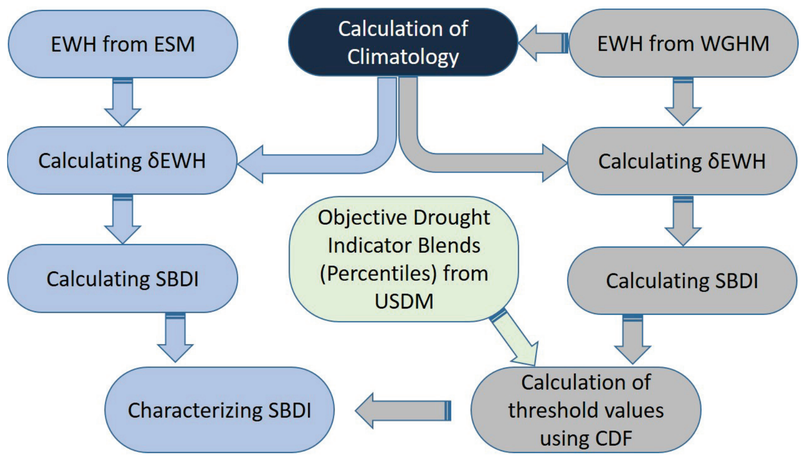

Figure 4: *Flowchart of the SBDI calculation*

4. Validation

Validation with USDM

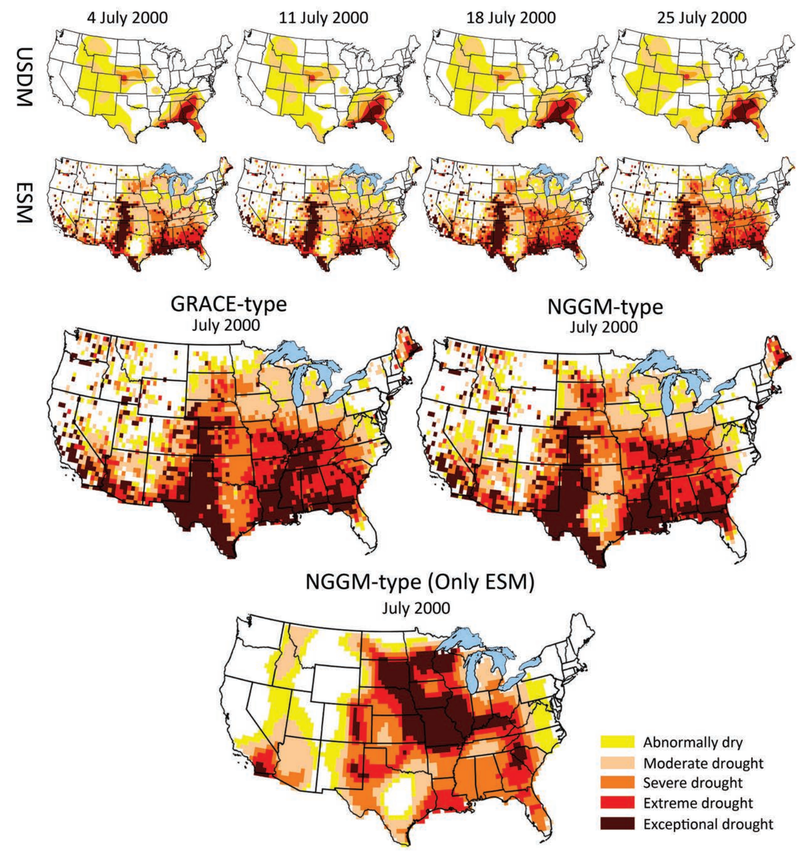

Figure 5: *First two row: comparison of the weekly drought maps from* SBDI *with the* USDM *during July 2000. Middle: comparison of the* SBDI *using GRACE-type and NGGM-type results. Bottom: Misclassification of drought using climatology and threshold values from short record of water storage (here ESM within 1995–2006).*

Validation during extreme hydrological events

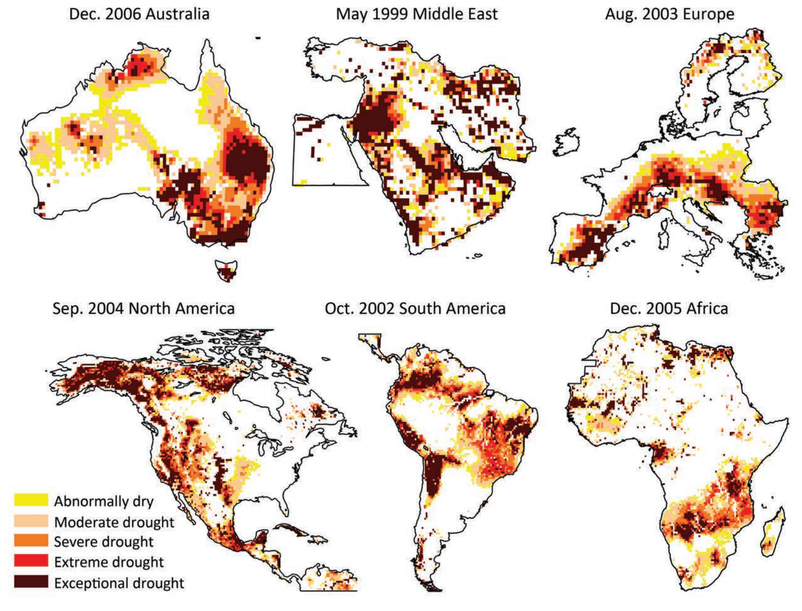

Figure 6: *Performance of the* SBDI *results during some reported drought events during 1995–2006.*

5. Result

B. Time Evolution Drought is a creeping phenomenon and evolves over time. We investigated the evolution of drought for major basins within the time period of ESM (cf. figure 7)

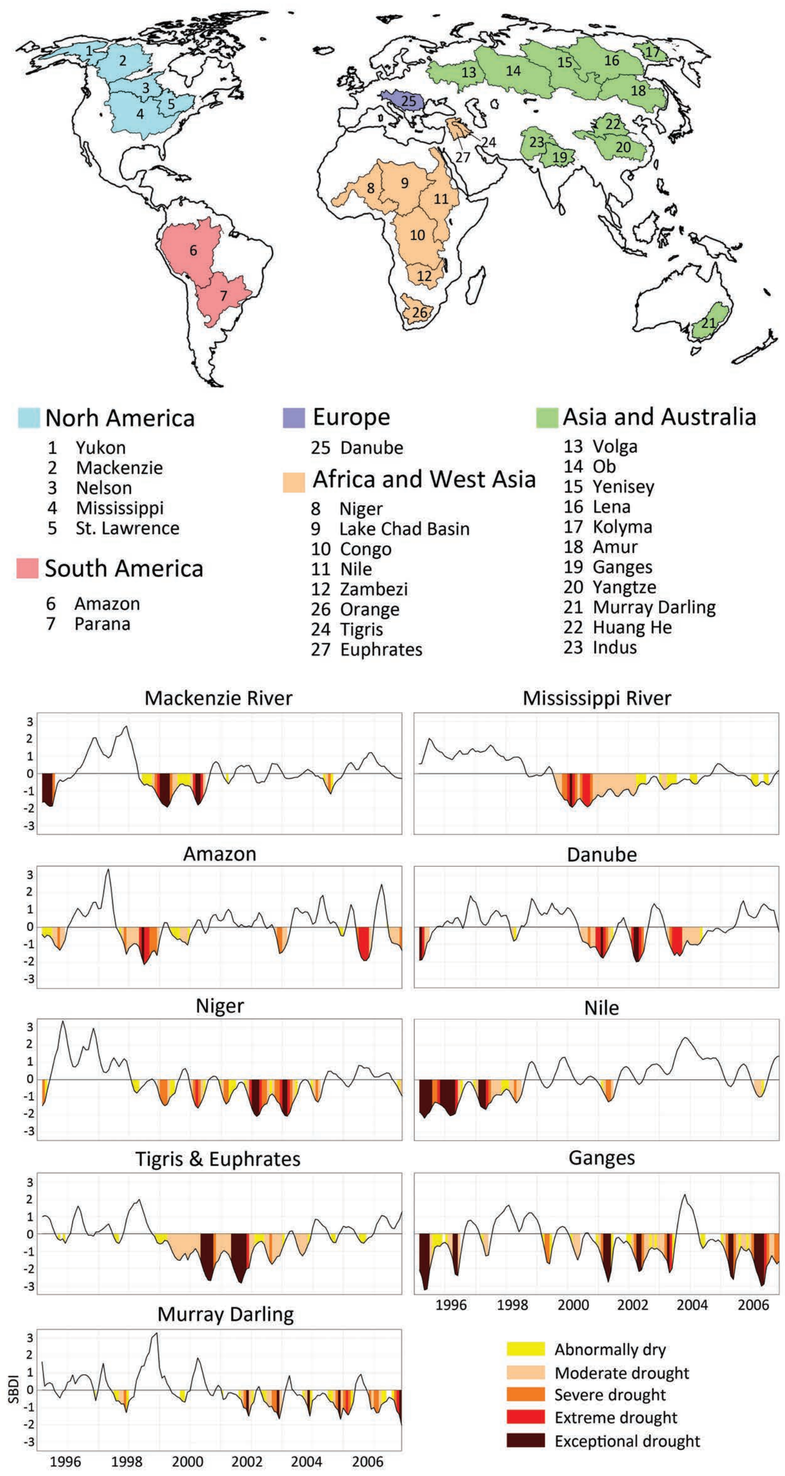

Figure 7: *Time evolution of drought in selected basins.*

A. Spatial Distribution

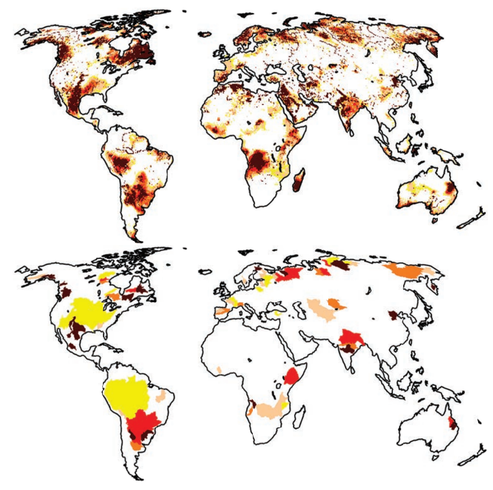

Figure 8: *The global map of* SBDI*, excluding Antarctica and Greenland for July 2006, a month in which major drought conditions occurred worldwide, top: grid, bottom: basin-wise*

6. Conclusion

- In the frame of ADDCON, a new method to identify drought events has been developed, resulting in the definition of a new drought index.
- The new Storage Based Drought Index (SBDI) identified and classified drought events well with respespect to extreme hydrological events and USDM drought maps.
- We were able to demonstrate the sensitivity of both NGGM performance and the developed indices in a closed-loop world.

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