A daily Wetness Index from GRACE satellite gravity data for near-real time global monitoring of hydrological extremes

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1. Motivation

Since April 2002, the **Gravity Recovery And Climate Experiment (GRACE)** satellite mission has been churning out **water storage anomaly data**, which have been shown to be a unique descriptor of large-scale hydrological extreme events, i.e. **floods and droughts**. Nonetheless, efforts to assess the comprehensive information from GRACE on total water storage variations **for near-real time (NRT)** flood or drought monitoring or forecasting have been limited so far, primarily due to the coarse temporal (monthly to weekly) and spatial (> 150.000 km²) resolution, and the latency of standard products of about 2 months.

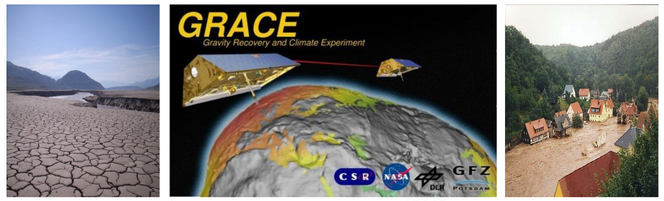


Image source: podaac.jpl.nasa.gov/GRACE

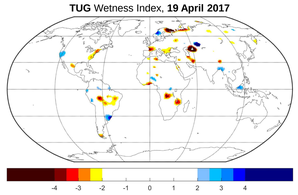
Last April 1, the Horizon 2020 funded **European Gravity Service for Improved Emergency Management (EGSIEM) project** launched into a **6 month duration NRT test run** of GRACE gravity field data, providing daily gridded data with a **latency of 5 days**. This fast availability allows the monitoring of total water storage variations related to floods and droughts, **as they occur**, as opposed to a 'confirmation after the fact', which has been the situation up till only recently.

2. Daily global solutions

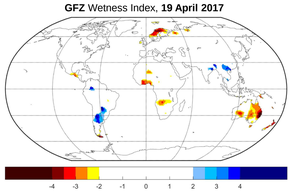
Because the satellite data coverage within one day does not allow for a gravity field solution based on GRACE data alone, the computation of daily gravity maps employs **a prediction – correction principle**. Information obtained from geophysical models on the temporal behavior of the gravity field are used to predict the following day, which is subsequently improved with the available GRACE observations in a **Kalman filter approach**.

Daily gravity field solutions are made available by the **GFZ German Research Centre for Geosciences and the Graz University of Technology (TUG)**, with each analysis center providing an independent solution. TUG focuses on improving global gravity field solutions, whereas GFZ will implement tailored regional representations of the gravity field. Both approaches complement each other, providing global coverage, with increased spatial resolution for regional areas of interest

TUG Wetness Index, **19 April 2017**



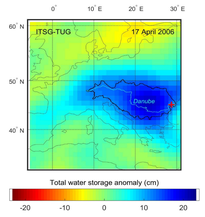
GFZ Wetness Index, **19 April 2017**

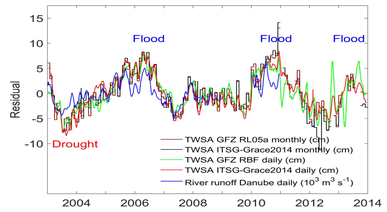


Additional processing converts the resulting gravity field solutions, expressed in terms of spherical harmonics coefficients, into **global 1º x 1º gridded map** of total water storage anomaly (TWSA) in equivalent water height (cm). A **Wetness Index** expresses the deviation from the mean seasonal cycle in units of standard deviation.

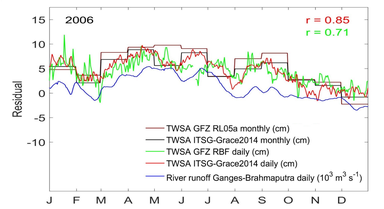
3. Individual river basins

Danube Basin

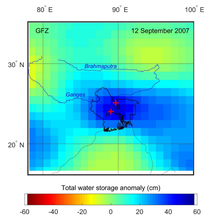


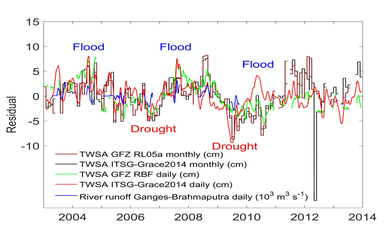


Results for the Danube basin show a **built-up of seasonally adjusted total water storage**, which culminates in flood occurrences in 2006, 2010 and 2013. A low reflects dry conditions during the **2003 European heatwave**. Daily gravity field solutions correlate well with observed discharge at the basin outlet in the **flood year of 2006**.

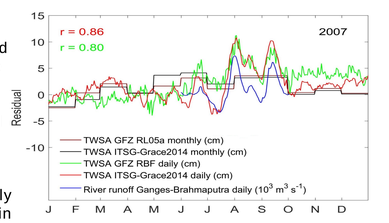


Ganges-Brahmaputra Delta





Results for the Ganges-Brahmaputra Delta show peaks in seasonally adjusted total water storage coincide with floods, while lows correspond with droughts. **High-volume, short-lived floods, triggered by monsoonal rain, are clearly reflected** as high frequency signals in the daily gravity field solutions, e.g. in 2007.



4. River basin results

Daily GRACE gravity solutions have been evaluated against daily river discharge data for extreme events in selected medium-large river basins. Compared to monthly gravity field solutions, the **daily solutions are able to reflect high-frequent temporal variations in river discharge during major flood events**. This is especially true for short-lived, high-volume floods, e.g. as they occur triggered by monsoonal rain in the Ganges-Brahmaputra Delta.

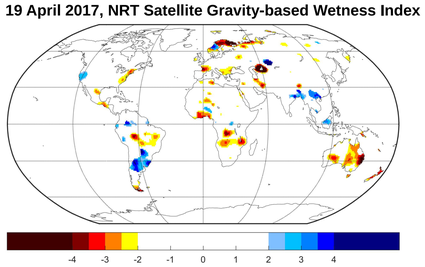
Peaks of (seasonally adjusted) total water storage anomaly (TWSA) reflect flood events, while TWSA lows coincide with dry conditions. TWSA extremes may occur at the end of a long-term (multiple month) period of water storage increase or depletion, indicating its **potential as an early indicator of hydrological extreme events**.

5. NRT global test run

As of April 1 2017 EGSIEM launched into a **demonstrator near-real time (NRT) daily gravity field service**. Compared to the official GRACE gravity products, the NRT solutions not only increases the temporal resolution from one month to one day, but also **reduces the current latency from two months to five days**. Thus, the NRT service allows for the monitoring of extremes in total water storage variations as they occur, as opposed to a 'confirmation after occurrence', which has been the situation up to only recently.

Contrary to other earth observation data, gravity represents **total water storage variations** (i.e., variations of all surface and subsurface water storage compartments). As such, it provides **unique information on the wetness state of a river basin with regard to its actual flood generation potential or its susceptibility to a drought**. For the development and testing of indicators of such hydrological extreme events, we take advantage of the integrative nature of the gravity data and evaluate how large-scale water storage anomalies derived by NRT, daily and regional GRACE products can be used as early warning indicators in flood and drought monitoring and alerting services.

19 April 2017, NRT Satellite Gravity-based Wetness Index



The example above shows the satellite gravity-based Wetness Indicator **in near-real time** for 19 April 2017. The index expresses the deviation of the GRACE-derived **total water storage anomaly (TWSA)** from the mean seasonal cycle **in units of standard deviation**. Wetter than 'normal' conditions (2.5-3 times the standard deviation) are indicated for parts in Latin America, signaling 'El Niño`conditions, prompting **flooding conditions** in southern **Columbia**. Hot-spots indicate ongoing drought-related humanitarian crises in **Africa** (Nigeria, Zambia, Angola, Sudan).

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