

Evaluation of GRACE daily gravity solutions for hydrological extremes in selected river basins

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1. Motivation

Water storage anomalies from the Gravity Recovery And Climate Experiment (GRACE) satellite mission (March 2002-present) have been shown to be a unique descriptor of large-scale hydrological extreme events. However, possibly due to its coarse temporal (monthly to weekly) and spatial (> 150.000 km²) resolution, the comprehensive information from GRACE on total water storage variations has rarely been evaluated for flood or drought monitoring or forecasting so far.

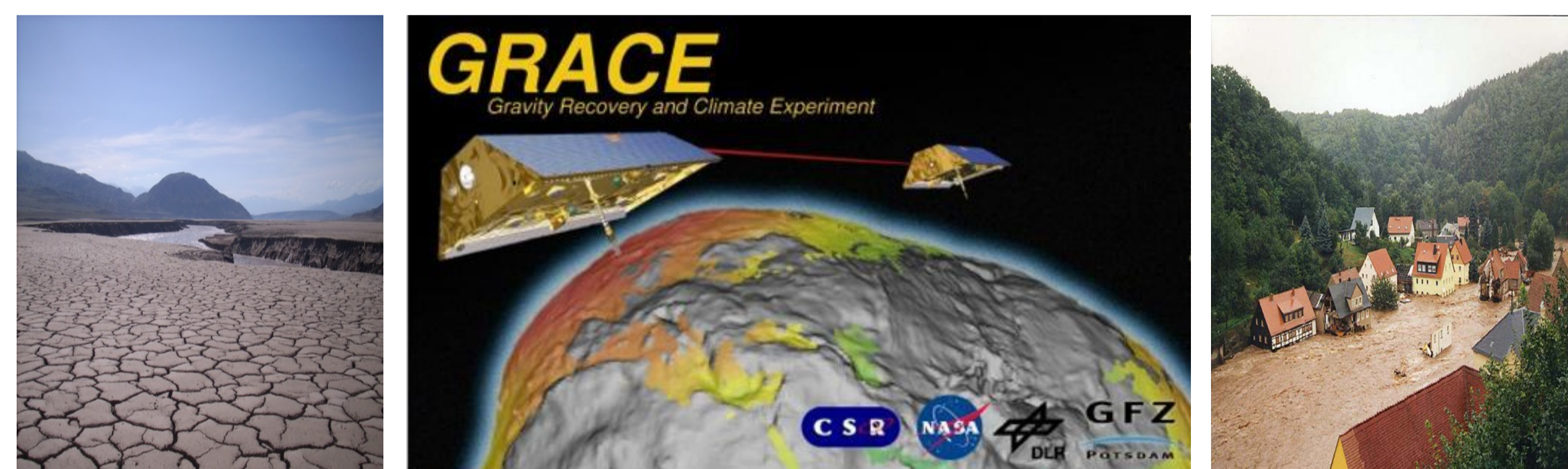


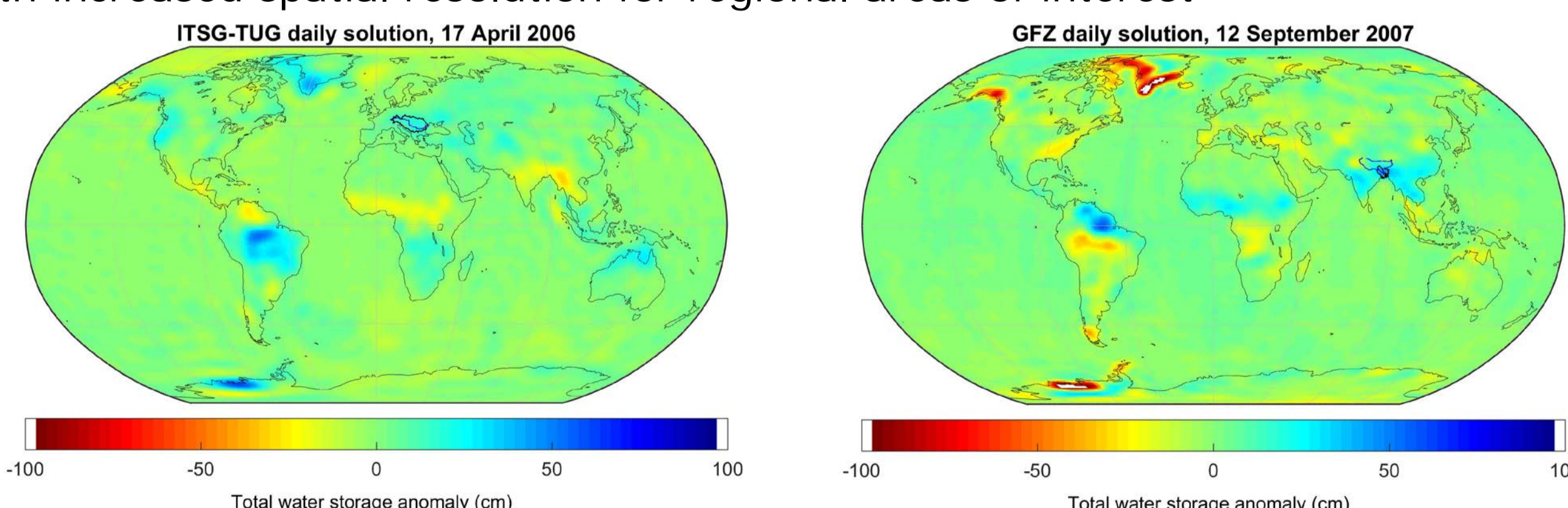
Image source: podaac.jpl.nasa.gov/GRACE

In the context of the Horizon 2020 funded **European Gravity Service for Improved Emergency Management (EGSIEM) project**, we evaluate two approaches to solve spatio-temporal variations of the **Earth's gravity field as daily solutions** for historical extreme events in medium-large river basins.

2. Daily 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**.

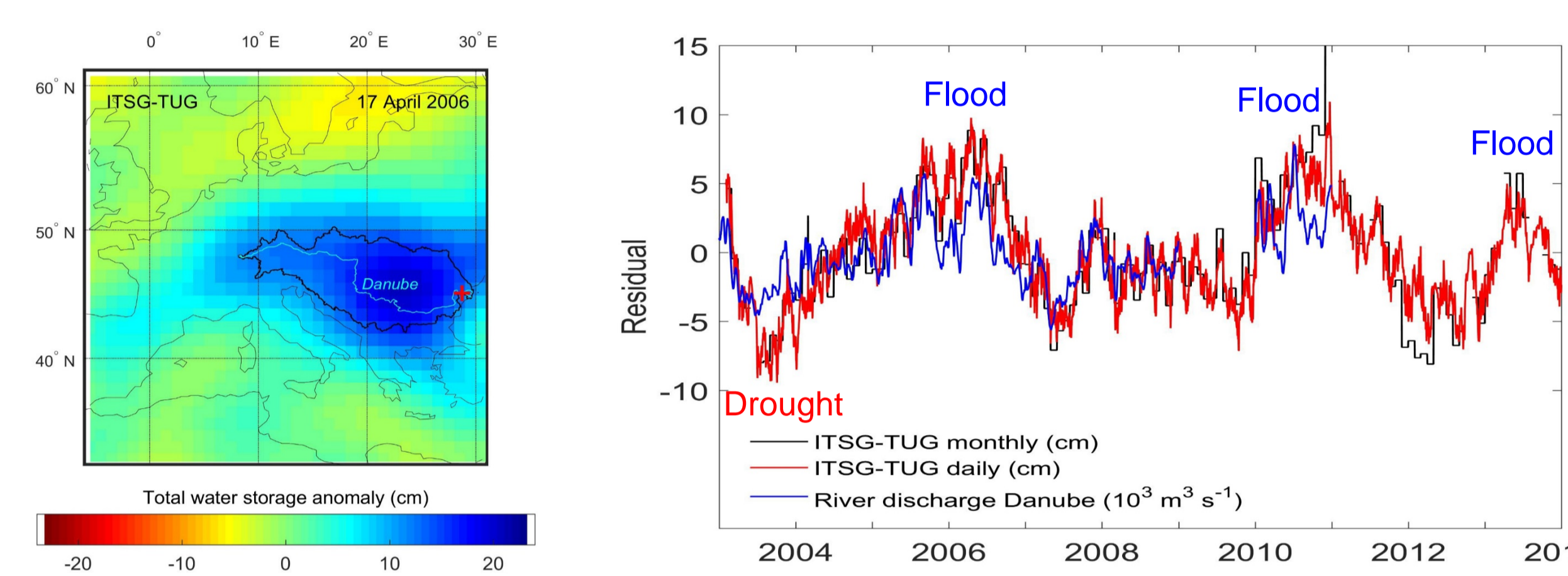
Daily gravity field solutions are made available by the **GFZ German Research Centre for Geosciences and the Graz University of Technology (TUG)**, with each analysis center providing an independent solution. TUG focuses on improving global gravity field solutions, whereas GFZ will implement tailored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



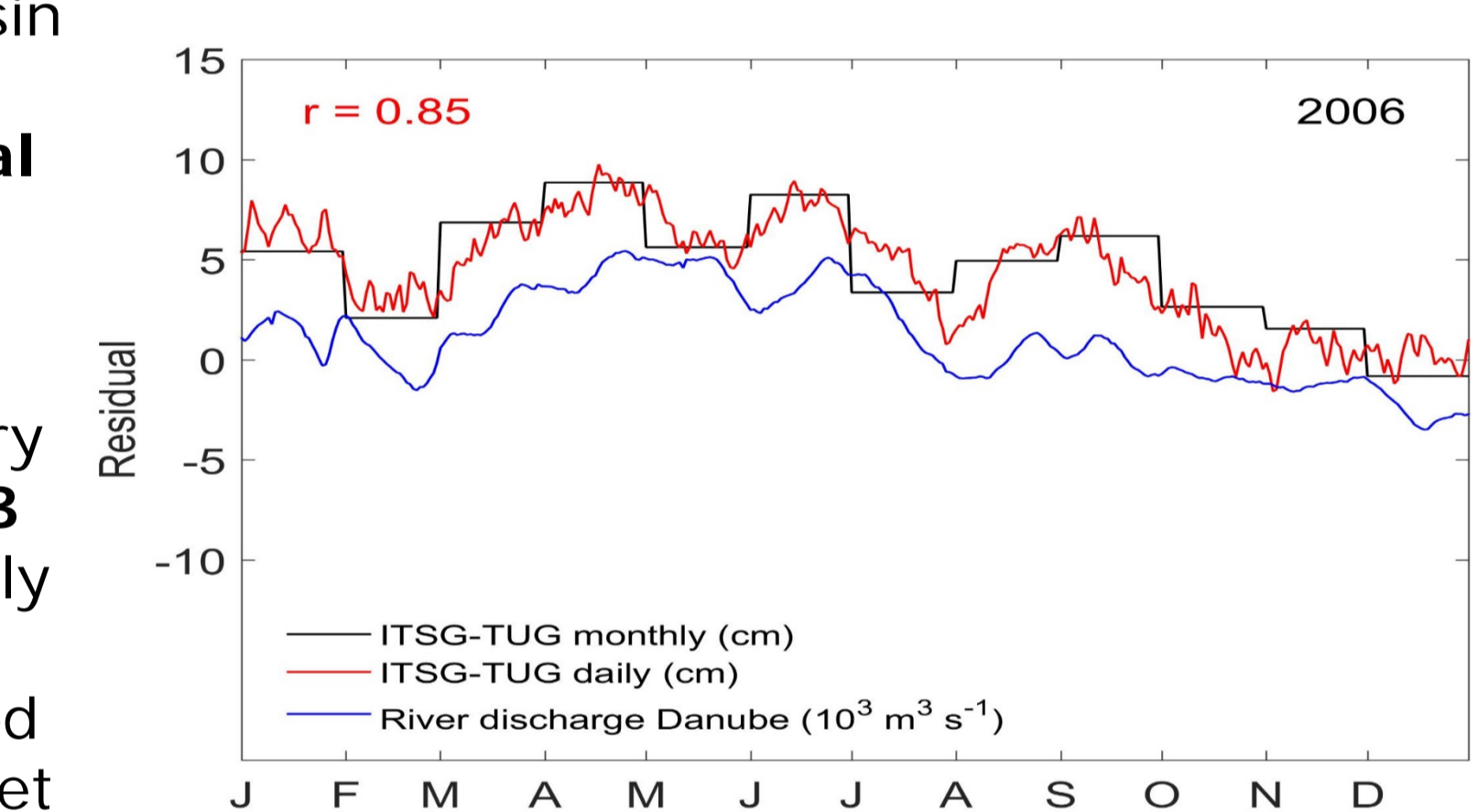
Additional processing converts the resulting gravity field solutions, expressed in terms of spherical harmonics coefficients, into global 1° x 1° **gridded map of total water storage anomaly (TWSA) in equivalent water height (cm)**.

3. Results

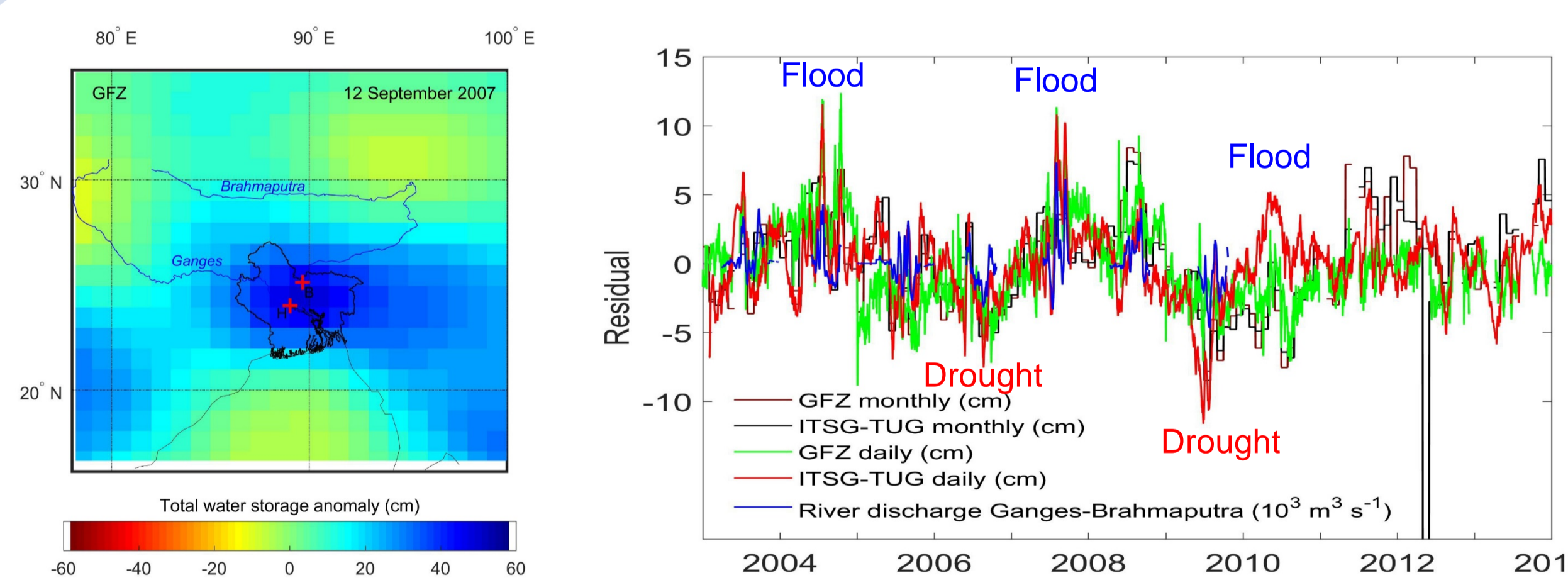
Danube Basin



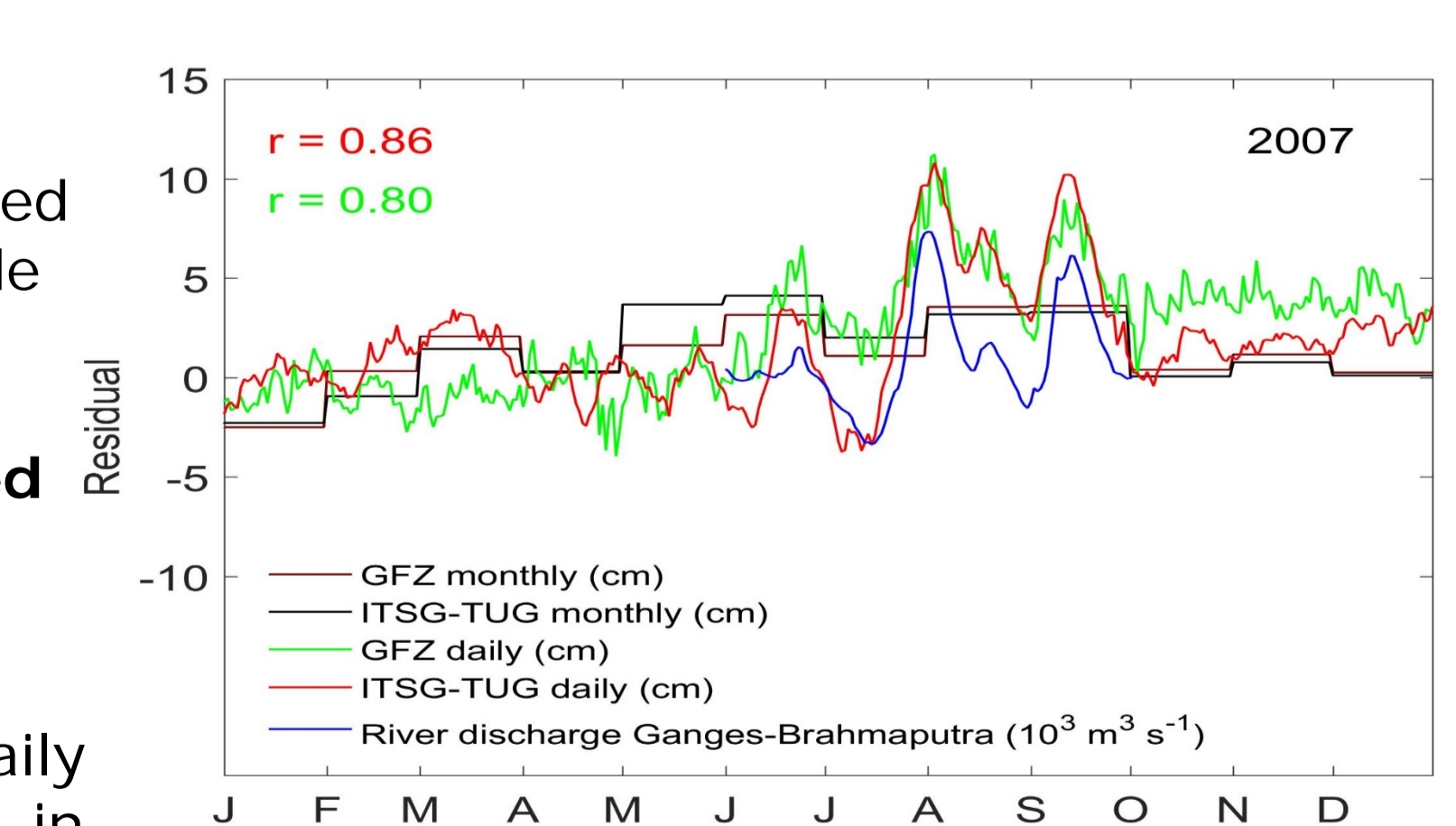
Results for the Danube basin show a **built-up of seasonally adjusted total water storage**, which culminates in flood occurrences in 2006, 2010 and 2013. A low reflects dry conditions during the **2003 European heatwave**. Daily gravity field solutions correlate well with observed discharge at the basin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

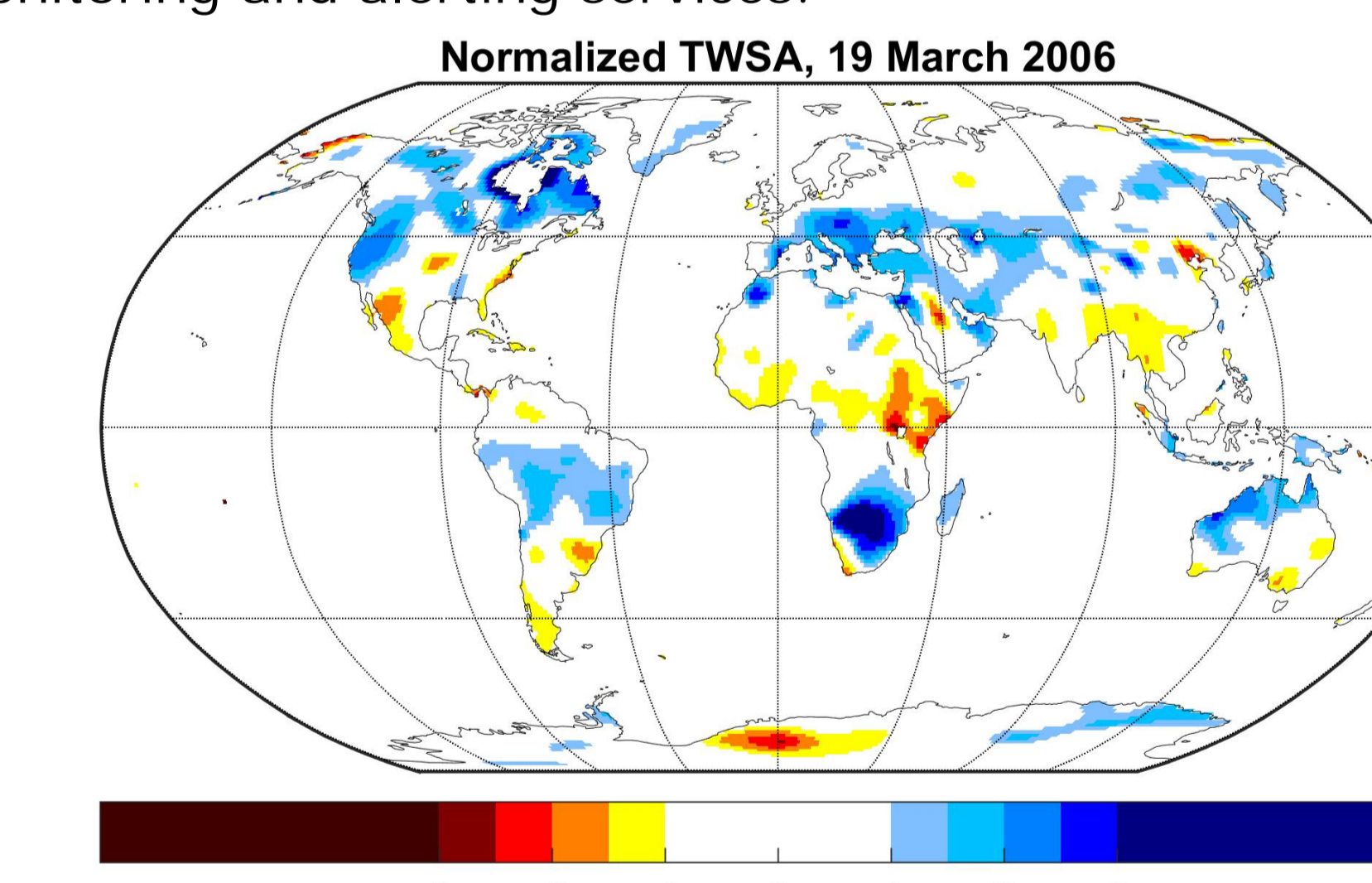
Daily GRACE gravity solutions have been evaluated against daily river discharge data for extreme events in selected medium-large river basins. Compared to monthly gravity field solutions, the **daily solutions are able to reflect high-frequent temporal variations in river discharge during major flood 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. Outlook

EGSIEM will establish a **demonstrator near-real time (NRT) daily gravity field service**. Compared to the official GRACE gravity products, the NRT solutions will not only increase the temporal resolution from one month to one day, but will also **reduce 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 is the current situation.

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.



The example above proposes how such a gravity-based indicator could look like. A simple index expresses the GRACE-derived **total water storage anomaly (TWSA) in units of standard deviation**. Wetter than 'normal' conditions (2.5-3 times the standard deviation) are indicated for the Danube basin, signaling an early warning for widespread flooding during April 2006. Floods in Southern-Africa and Morocco/Algeria have also been recorded around this time. Negative normalized TWSA coincide with documented drought conditions in Tanzania and southern China.

Acknowledgements

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