GlobeDrought: Deriving GRACE-based hydrologcial drought indicators

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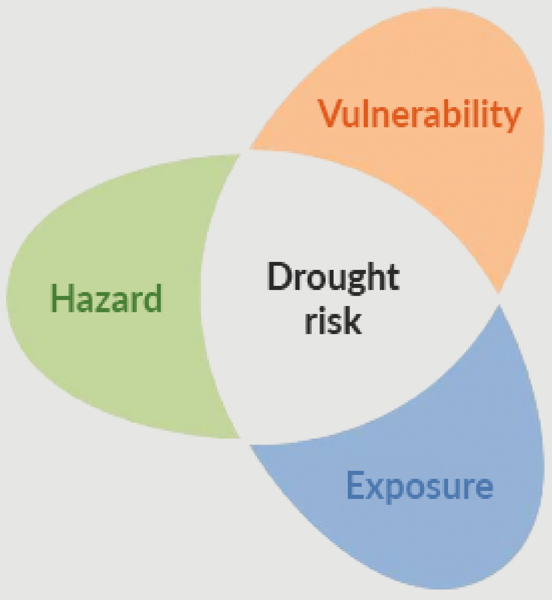
Basic knowledge

The GlobeDrought project

The GlobeDrought project, funded by the German Federal Ministry for Education and Research, aims in developing a web-based drought information system. A major component is the determination of drought risk by considering drought hazard, exposure and vulnerability using model and remote sensing data.



IGG contribution

In most definitions drought is defined as deficit compared to the normal and assigned with four drought types:

- IGG is analyzing meteorological and hydrological droughts, which are part of drought hazard
- Usage of the twin-satellite mission GRACE to determine hydrological droughts
- Integrating of the GRACE data into a hydrological model and automation/parallelization of the processes

The global water cycle and GRACE

- In-situ observations of the hydrological cycle are sparse in time and space and sometimes difficult to derive, for example groundwater
- Analyzing single storage might be insufficient for the drought detection
- GRACE offers a great possibility to observe changes in surface and subsurface storages with global resolution, the **total water storage anomalies (TWSA)**

GRACE TWSA are provided for downloading: `https://www.apmg.uni-bonn.de/daten-und-modelle/grace_level3_monthly_solutions`

Methods and results

Drought indicators

To detect hydrological drought events, drought indicators are used, which help characterizing, monitoring and triggering management plans for droughts and determine **location**, **duration**, **intensity** and **severity** of a drought event. There exist some GRACE-based indicators, however, each has its' advantages and disadvantages. A detailed analysis of different GRACE indicators can be found in Gerdener et al. (2020). One example is the 'Drought Severiy Index' (DSI) by Zhao et. al (2017), which is computed by

$$DSI_{i,j} = \frac{TWSA_{i,j} - \overline{TWSA_j}}{\sigma_j} \tag{1}$$

, where $TWSA_{i,j}$ is the TWSA in month i and year j, $\overline{TWSA_{i,j}}$ is the mean monthly TWSA for the specific months,e.g. for all Januaries, and $\sigma_{i,j}$ is the standard deviation of the corresponding month.

Vertical downscaling

The data assimilation enables to vertically downscale to the model storages. The methodology of the DSI can also be applied to, e.g., surface waters and groundwater (Fig. 2).

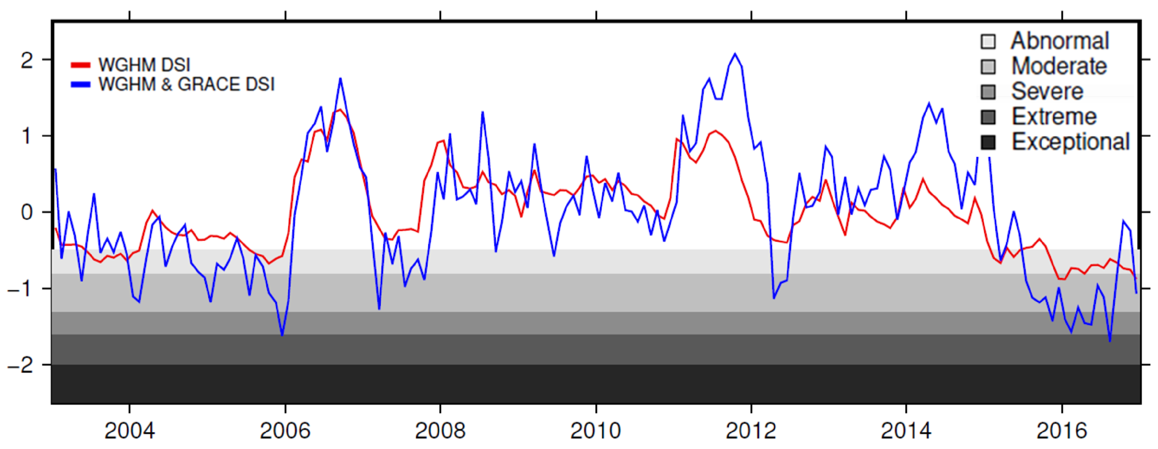


Fig. 2 GPS observation system: The response of the solid Earth as measured by GPS receivers, to surface loading is mainly elastic on weekly to yearly timescales.

- The drought in 2015/2016 is more present in the groundwater storage when assimilating GRACE into the model
- The drought is more present in the groundwater storage than in surface storage
- Assimilation allows new insights into detecting droughts

Challenges and spatial disaggregation

A challenging aspect about GRACE-derived TWSA is the limited spatial resolution (˜300km). Hydrologcial models also provide information about water storages with higher resolution (˜50km), however, due to uncertainties in the forcing data and assumptions the models do not perfectly represent reality. Thus, the GRACE data is assimilated into the global WaterGAP hydrological model(WGHM) to spatially and vertically downscale GRACE while improving the models realism. The DSI in March 2016 identifies a higher severity of drought in the Southern part of South Africa when using the data assimilation (bottom) than using the model only (top left) while spatially downscaling the GRACE data (top right).

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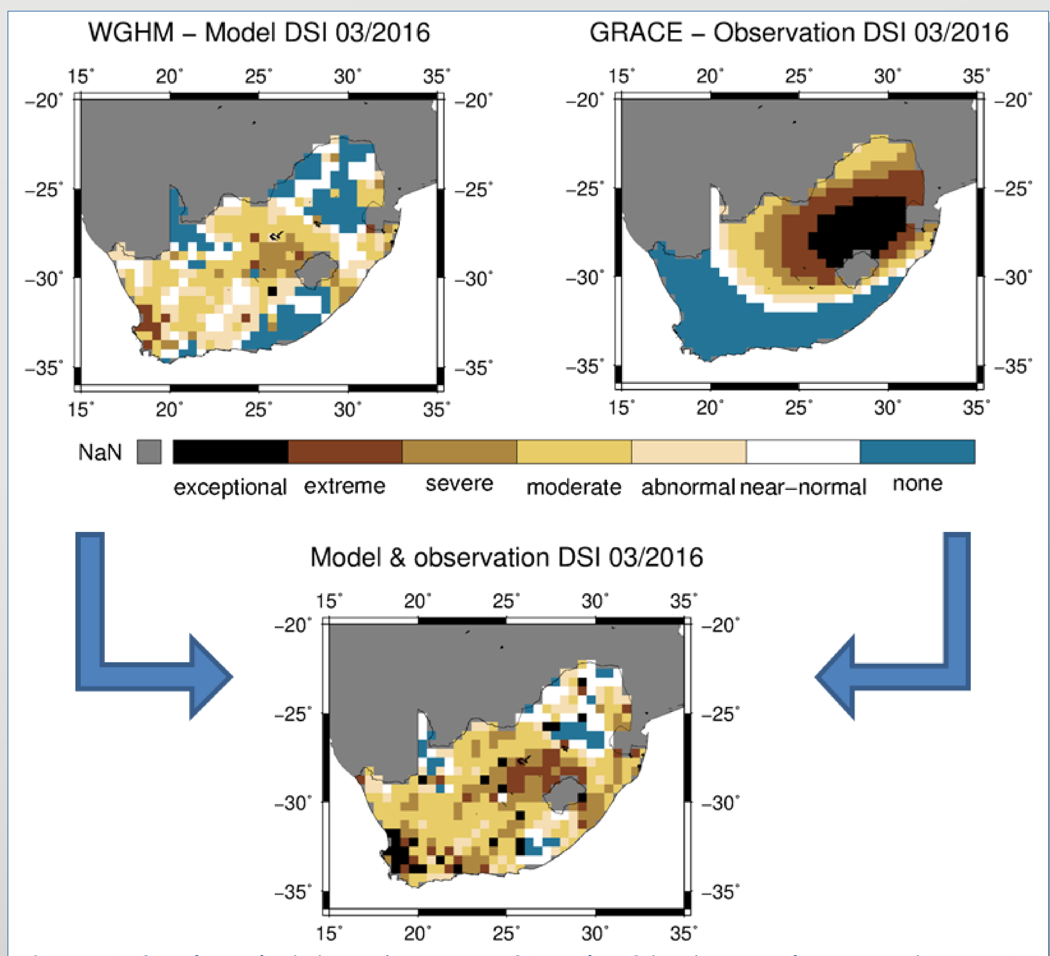


Fig. 1 DSI for the administrative area of South Africa in March 2016 using TWSA derived from the WaterGAP model (top left), GRACE observations (top right), and GRACE assimilated into WGHM (bottom).

The used assimilation filter algorithm is the Ensemble-based Kalman filter (Evensen, 1994), which sequentially for each month computes a model prediction updated by the real observations.

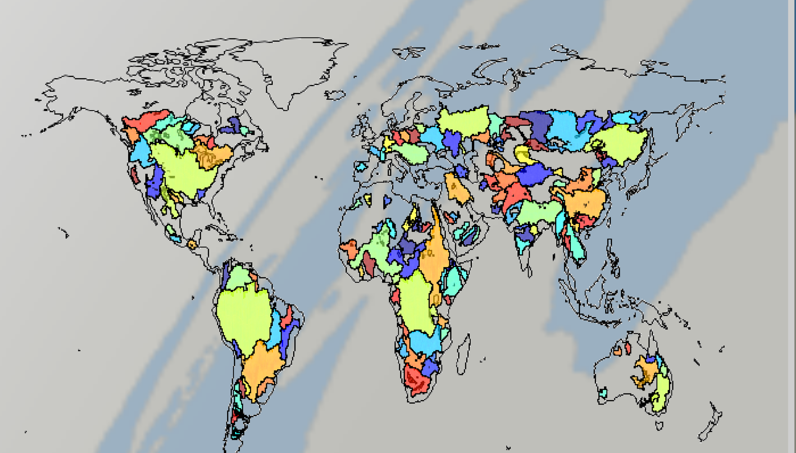
Take home

Key messages

- GRACE TWSA offer the possibility to observe surface and subsurface water storages with global resolution
- The data assimilation enables vertically and spatially downscaling of GRACE, while improving the realism of droughts
- Deeper insights into droughts in South Africa can be gained because, e.g. the 2015/2016 drought was identified as more dominant in the groundwater

Global extension of the framework

Currently, the data assimilation is applied basin-average wise for the 140 largest basins on Earth, which represents ˜ 40% of land surface. Extending the framework to assimilate ˜ 95% (except Greenland and Antarctica) is in progress by using 4° cells to enable the global early warning component.



Want to learn more?

Visit our GlobeDrought website under following link: `https://grow-globedrought.net/`. There, the eLearning platform with online lectures and webinars can be found.

References

[1] H. Gerdener, O. Engels, and J Kusche. A framework for deriving drought indicators from the gravity recovery and climate experiment (grace). *Hydrol. Earth Syst. Sci.*, 24:227–248, 2020.

[2] Meng Zhao, Isabella Velicogna, and John S Kimball. A global gridded dataset of grace drought severity index for 2002–14: Comparison with pdsi and spei and a case study of the australia millennium drought. *Journal of Hydrometeorology*, 18(8):2117–2129, 2017.

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