GlobeDrought: A global-scale tool for characterising droughts and quantifying their impact on water resources

GlobeDrought – towards improved drought risk analysis and projection at global and regional scales

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Keywords: *Integrated risk assessment, vulnerability, agricultural systems, water supply, drought*

ABSTRACT

In times of drought, water resources are insufficient. These water shortages often have negative effects on agricultural productivity and on associated socioeconomic factors, causing reduced income, food shortages and even famines. The overall objective of GlobeDrought is to develop an integrated drought risk information system which will adequately describe causal links in the formation and development of droughts, connections between the various types of drought hazards (meteorological, hydrological and soil moisture), and associated vulnerabilities. With its planned monitoring and experimental early warning system, the project aims to reduce the time between satellite-based data collection, identification of a drought risk and the implementation of potential countermeasures by political decision-makers and those involved in international humanitarian aid. The global-scale analyses focusing on drought impacts on agricultural systems will be supplemented by detailed analyses for regions heavily affected by droughts such as Southern Africa (South Africa and Zimbabwe), Eastern Brazil, Western India, and the Missouri River Basin of the United States. The results of literature reviews and expert consultations show that it is very important how drought risk analyses are conceptualized and that there is no consolidated, commonly shared framework and methodology for drought risk assessments at the moment. GlobeDrought is therefore also going to contribute to methodological improvements and more precise terminology in drought risk and impact assessments. First outcomes of the global and regional studies show that the modeling tools and sensor data used in GlobeDrought provide a consistent picture of drought development across the domains meteorology, hydrology, agronomy and economy.

INTRODUCTION

Drought is considered a major determinant of variability in crop yields and crop production worldwide. In particular regions that are less integrated into the world market face challenges to ensure sufficient food supply when exposed to drought. Historically, one adaptation to aridity or frequent drought events was the development of irrigation infrastructure to protect crops and farms against missing rainfall. The global area equipped for irrigation increased from about 63 million hectares in year 1900 to more than 306 million hectares in year 2005. It is estimated that about 90% of the global consumptive freshwater use is for irrigation (Döll et al., 2012). In particular during droughts irrigation water requirement is high so that meteorological droughts caused by missing rainfall can translate faster into hydrological droughts characterized by declining water storage in surface water bodies and aquifers. Shortage in water supply for irrigation schemes can then transfer a hydrological drought into a soil moisture drought, characterized by low soil moisture and low crop yields. It is therefore essential to monitor the drought situation and to propose useful countermeasures when critical thresh-

olds are surpassed. Operational early warning systems for droughts try to address the problem. However, they are mostly only capable of characterizing the status quo, or offer limited forecasts for droughts in the near future – e.g. the next three to six months. These early warning systems generally do not sufficiently integrate variables and drought indicators. In particular, they do not adequately describe causal links in the formation and development of droughts, connections between the various types of droughts (meteorological, hydrological and soil moisture), and socioeconomic and ecological factors as key drivers of exposure and vulnerability. The project intends to fill this gap by developing an integrated drought risk information system, including a monitoring and experimental early warning system. The overall objective is to gain a better understanding of the development of droughts and the links between different drought types, including the role of the socio-economic setup affecting the vulnerability and exposure to drought. Existing drought risk analyses and impact frameworks will be evaluated and an improved drought risk analysis framework will be implemented into the new drought risk information system. The drought information system will provide general information at global scale and more detailed region specific information for project regions with a distinct socio-economic setup and distinct environmental and climatic conditions. Consequently, target groups differ and comprise organizations with the mandate to inform policy makers such as the Global Drought Observatory (GDO) of the European Union, organizations involved in international humanitarian aid, regional and national water management organizations or farmers in the project regions.

METHODS

To analyze drought risks and drought impacts, an improved drought risk analysis framework is being developed and used, comprising of indicators for drought hazard, exposure and vulnerability which together determine drought risk and related impacts (Figure 1). Indicators for drought hazard, exposure and vulnerability are specific to the impacts to be analyzed.
The drought risk information system will comprise of both, a global component and regional components, providing more specific analyses for the regions Southern Africa (South Africa and Zimbabwe), Western India (Maharashtra), Eastern Brazil (Ceará) and the Missouri River Basin in the United States. The information system will be developed and tested using historical data for climate, satellite based water storage anomalies, land use, crop yields, water use, trade and socio-economic indicators complemented with vegetation health analyses, using remote sensing. The experimental early warning system will provide data, maps and tools for near real time drought monitoring. In addition, a projection of the development of droughts within the next year will be provided, based on ensembles of historical climate data as a replacement of climatic data for the future. Probabilities will be calculated to quantify how likely it is that a drought becomes more severe, remains similar, becomes less severe or disappears within the projected time period. The drought hazard analysis will be complemented by an indicator-based assessment of present-day vulnerabilities as a major determinant of sectoral drought impacts.

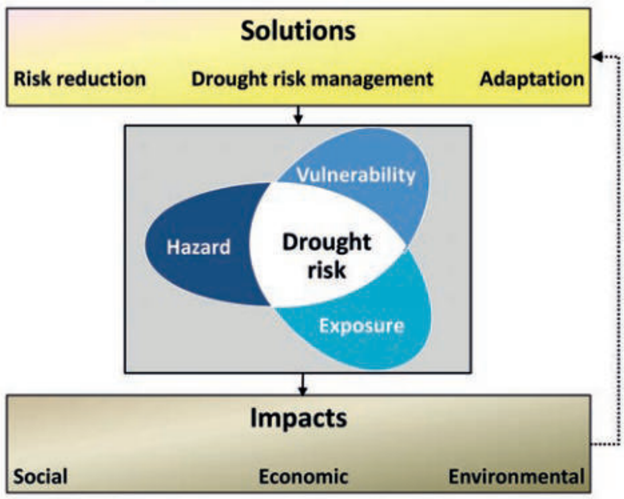

Figure 1: The conceptual framework used in the GlobeDrought project to analyze drought risk and drought impacts at global and regional scale.

The regional drought assessments will be adapted in a co-design process to the requirements of partners and stakeholders in the project regions. Therefore, the regional drought information systems will be more precise and of higher spatial resolution while the indicators used and the impacts studied will vary for the specific regions. In contrast, the global information system will facilitate comparisons of drought impacts, drought risks and drought conditions across the globe.
To quantify drought hazard and drought impacts, a set of hydrological and crop models will be combined with advanced methods to generate drought related information from remote sensing. Total water storage anomalies detected from the gravity satellite mission GRACE are used to improve trends in water storages simulated by the hydrological model WaterGAP. Further, we also compute hydrological indicators by using total water storage changes from GRACE directly. Spatial patterns and interannual variability in sowing and

harvest dates for major crops determined by MODIS satellite data are used to inform the crop model solution SIMPLACE <LINTUL5,SLIMWater,SLIMRoots> to improve the simulation of drought impacts on crop productivity and irrigation water requirement.

INTERIM RESULTS AND DISCUSSION

Indicators to be considered for drought hazard, exposure, and vulnerability analysis and hence for characterizing the risk of specific drought impacts, were selected based on a comprehensive literature review (Hagenlocher et al., submitted), internal discussions during an indicator workshop held at the University of Bonn on 16 Feb 2018, and expert consultations during the first stakeholder workshop (03/04 May 2018) at United Nations University in Bonn, Germany. The specific relevance of each indicator was evaluated using an online survey which was designed in collaboration with the Global Drought Observatory (GDO) of the European Commission, and sent to 124 international drought experts. A set of more than 50 indicators was defined and out of this indicator set specific indicators are selected, depending on the drought impact to be studied, the project region and the relevance identified by the experts. Based on the response of the regional and global experts it was decided that drought impacts on agricultural systems (irrigated agriculture, rainfed agriculture, agro-pastoral

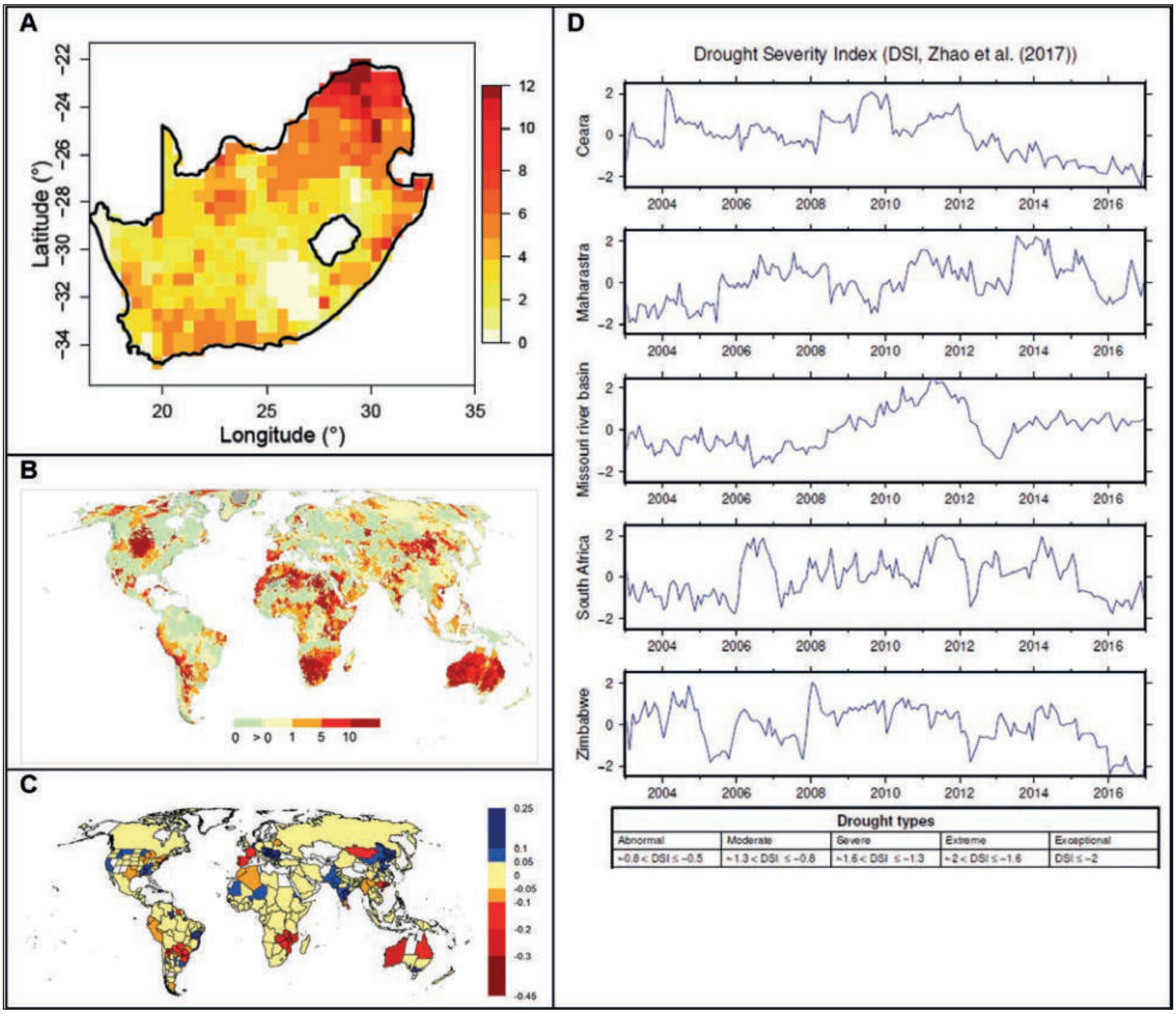

Figure 2: Accumulated drought months per year from 3–Month–SPEI in RSA (A), accumulated water storage deficit volume calculated with the model WaterGAP (B), deviation of AET/PET ratio from long-term mean for maize calculated with GCWM (C) for year 2005. Drought Severity Index (Zhao et al., 2017) for the project regions using total water storage changes from GRACE gravity measurements (D) for period 2003-2017.

systems) and drought impacts on water supply will be studied at the global scale. In addition, depending on the relevance and local user needs, more specific impacts will be studied at the regional level. A publication, describing the novel drought risk analysis framework and the indicators selected so far, is under preparation.

By analysing remote sensing based indicators and the output of the global hydrological and crop models, we found that the different, independent data sources provide consistent information on the development of different types of drought (Figure 2). There is also a good agreement to survey data for agricultural production. For example, crop production in Zimbabwe and South Africa was extremely low in year 2005, identified as severe drought for Southern Africa (Figure 2). The results of the crop model applied at global scale showed that the severity of drought impacts differs between the specific crops, for example between crop cultivated in the winter or summer season or those cultivated in the wet or dry season, so that crop specific information needs to be considered in drought impact assessments (Eyshi Rezaei & Siebert, 2018).

The GlobeDrought teams could also make considerable progress with the coupling of models and the assimilation of remote sensing data into hydrological and crop models. This is of major importance for the more detailed analyses to be performed at regional level. Results were presented so far at four international conferences and in four journal articles. Additional publications in journals are under preparation. The project received considerable attention in the media, for example it was featured in WaterSolutions (issue 03/18).

The indicator data obtained from analyses at global scale are currently being categorized and implemented into the web-based drought information system hosted by Remote Sensing Solutions. Metadata descriptions have already been collected, the data itself are now being structured according to the conceptual framework shown in Figure 1.

CONCLUSIONS & OUTLOOK

The results of the global drought risk analysis and first regional results are promising. The indicator data are now being transferred to the web-based information system to be presented and discussed at the second stakeholder workshop of the project which will take place in autumn 2019.

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BMBF Project ID: 02WGR1457A-F

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