SaWaM

Project Highlights

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GRoW
WATER AS A GLOBAL RESOURCE

Introduction

Increasing frequencies of droughts and heat extremes, as well as increasing precipitation variabilities in semi-arid regions fuel conflicts of water use and call for mitigation of impacts of climate change. Proactive and sustainable water management is required, which can benefit from hydro-meteorological seasonal forecasts and high-resolution, near-real-time measurements. For comprehensive water management, all sources and sinks of freshwater resources need to be known, including not only the full hydrology, but also ecosystems regarding the food-energy-water nexus. With semi-arid regions being hot spots of erosion, further sediment input, transport and deposition are key for sustainable reservoir operations. The SaWaM project addresses the question whether regional water management and in particular dam operation in semi-arid regions can be improved by the use of global, publicly available information with a focus on near-real-time and seasonal timescales.

Development of a regional operational hydro-meteorological seasonal forecasting system

A fully-integrated model chain produces seasonal forecasts on regional hydro-meteorology at 0.1° horizontal resolution and with forecast horizons up to seven months ahead. Comprehensive forecasts were achieved via bias correction and regionalization (BSCD) of publicly available global seasonal forecasts.

Our forecasts (Fig. 1) predicted high probabilities of extreme wet conditions across large parts of Ethiopia in 2020. During these three months, heavy rainfall particularly in Ethiopia led to record water levels and flooding downstream.

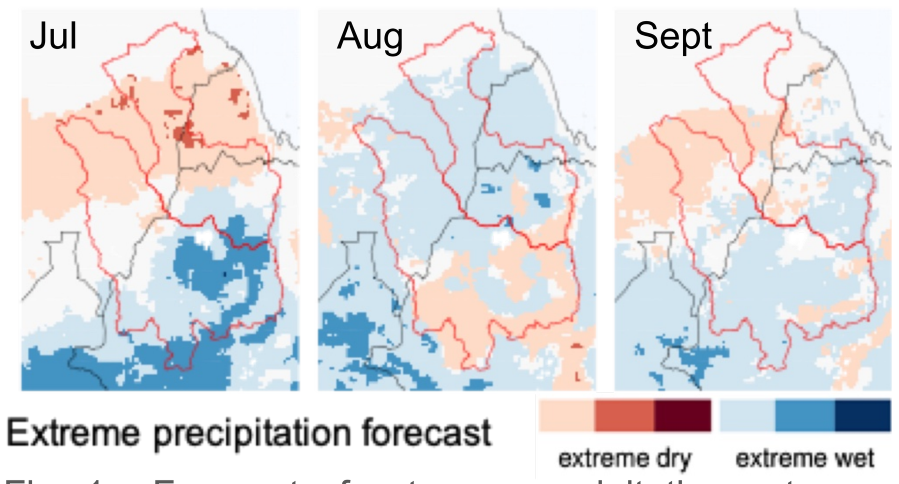


Fig. 1: Forecast of extreme precipitation category issued on 01.07.2020 for Jul, Aug, and Sept 2020 over the transboundary Tekeze-Atbara and Blue Nile basins.

Statistical seasonal forecasting

Apart from BSCD, regionalized seasonal predictions were achieved via statistical downscaling (XDS) using local station data. Techniques of ensemble calibration were used to remove remaining biases. For predicting (upper, medium, lower) precipitation terciles, the Karun basin is better forecasted by the BCSD and the São Francisco basin better by the XDS system (Fig. 2).

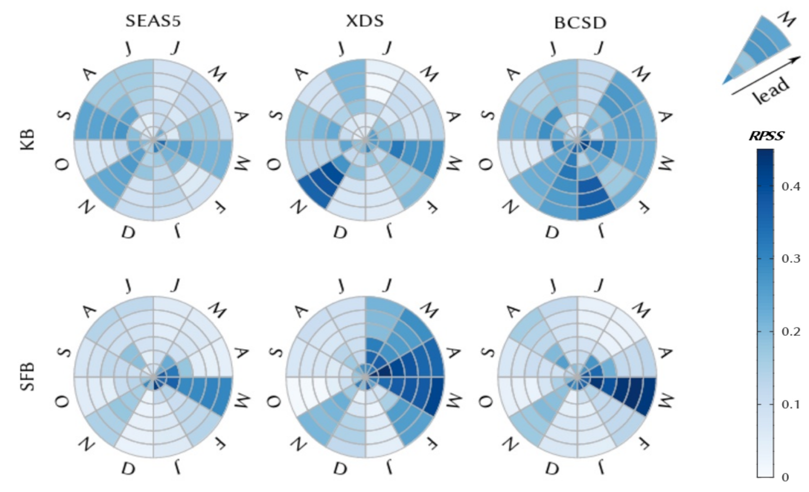


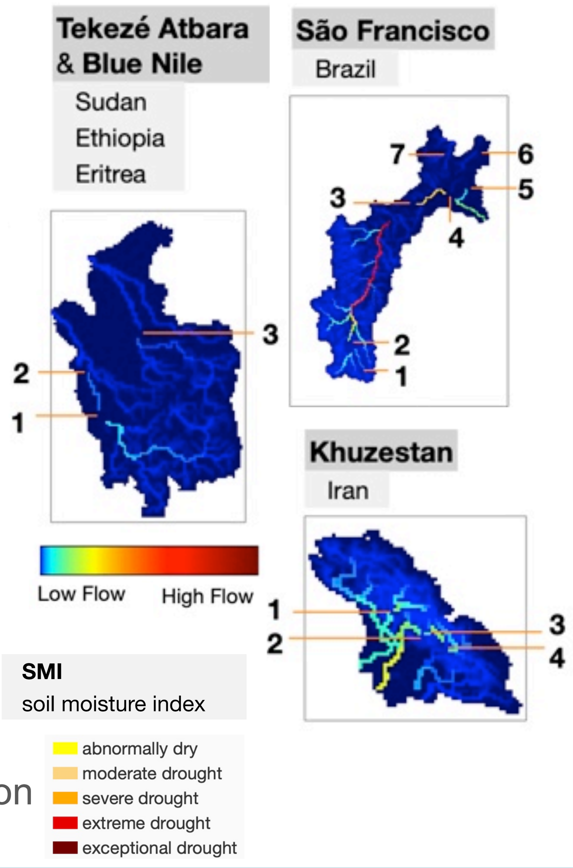
Fig. 2: Comparison of raw forecasts (SEAS5), XDS and BCSD performance for tercile precipitation forecasts with the ranked probability skill score (RPSS) for the Karun (KB) and São Francisco (SFB) basins.

Hydrological seasonal forecasting

Using a distributed, scalable hydrological model incorporating major reservoirs (mHM, Fig. 3), seasonal hydrological forecasting was enabled producing monthly indicators of, e.g., soil moisture, streamflow, and reservoir inflow up to six months in advance.

For the Sudan region in 2015 (Fig. 4), indications of drought are already forecasted 6 months ahead (L5) and intensify with lower forecast horizons (L1 and L0).

Fig. 3: Streamflow forecasting incorporating major reservoirs (numbers) in the target basins.



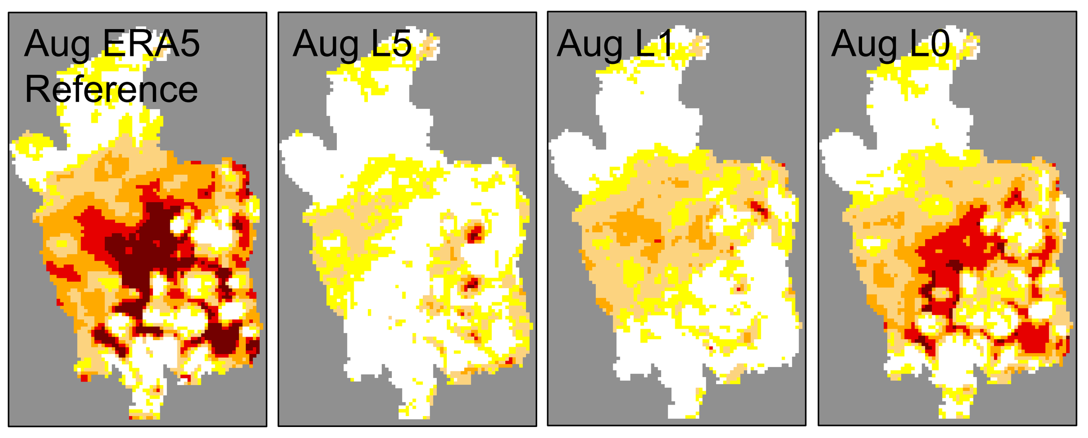


Fig. 4: Seasonal forecasting (L5, L1, L0) and reference simulation of the Sudan drought 2015 shown with the soil moisture index.

User-oriented online application for hydrological decision support

With the provision of a tailor-made information system of supportive regionalized information for each of our semi-arid study basins in Iran (Karun), Brazil (São Francisco), Ethiopia-Sudan (Tekeze-Atbara and Blue Nile), and Ecuador-Peru (Catamayo-Chira), we target the local water managers and emphazize the use of near-real-time information and seasonal forecasts in hydrological decision-making.

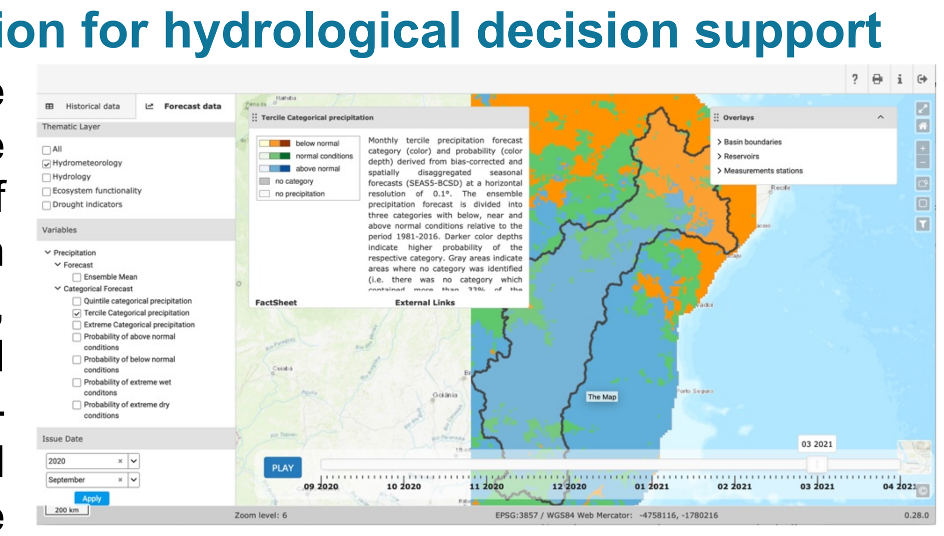


Fig. 5: Decision-support online tool designed for the example of the São Francisco basin in Brazil, including historical and seasonal forecast data relevant for decision-making in water management.

Erosion hotspot analysis and hydro-sedimentological modelling

Reservoir sedimentation is a high, but still underrated risk for water security. A hotspot analysis tool identifies areas that particularly contribute to the sedimentation of water reservoirs. It further reveals leverage areas, where preventative land management has the largest impact on reservoir sedimentation (Fig. 6 a,b).

Novel model results for sediment delivery in sub-catchment areas are possible, given reliable rainfall information (Fig. 6c).

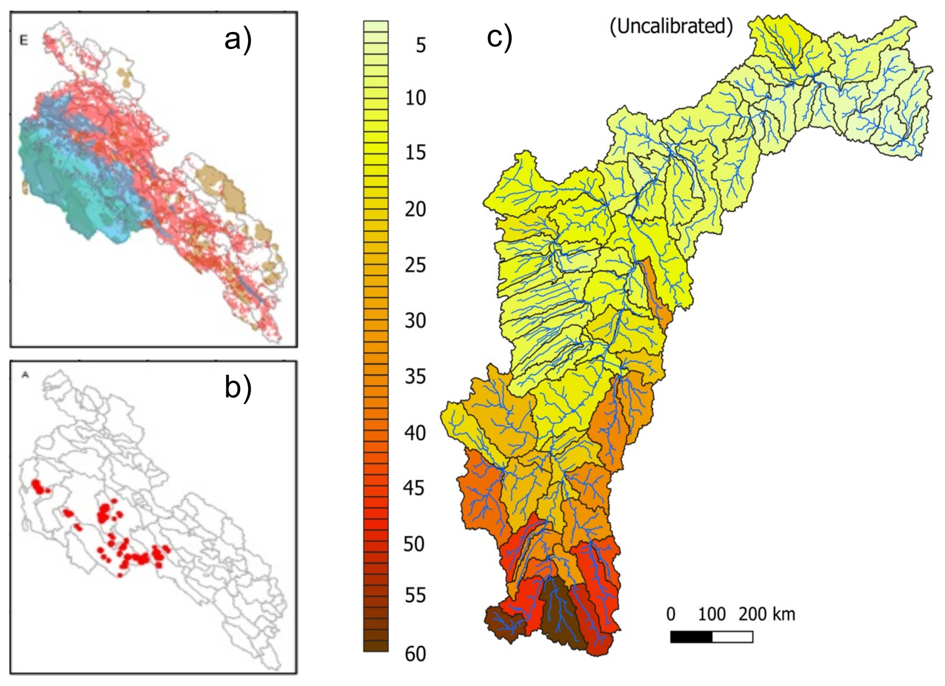


Fig. 6: a) Erosion hotspots and b) resulting leverage areas for the Karun basin at the beginning of the rainy season. c) Modelled average annual (1981-2019) sediment delivery (Mg/ha) for the São Francisco basin.

Vegetation and water dynamics from satellite remote sensing and ecosystem modelling

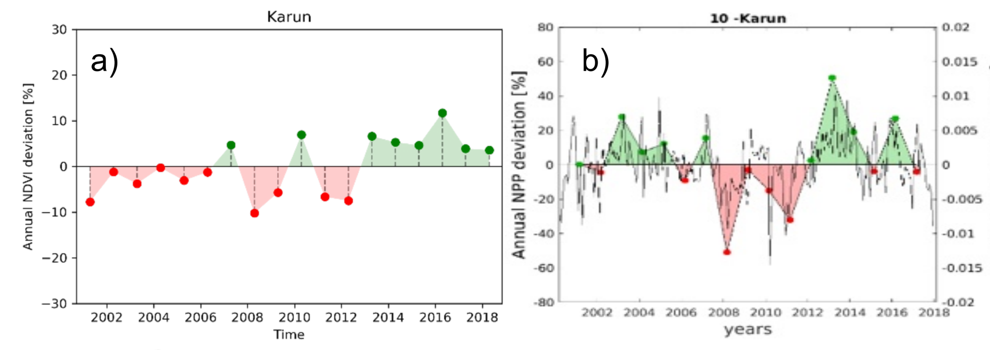


Fig. 7: a) Annual normalized difference vegetation index (NDVI) variations from remote sensing (MODIS) and b) annual modelled net primary productivity (NPP) for 2001-2018.

SaWaM allows the comparison of vegetation dynamics of ecosystems models (LPJ-GUESS) with observations from remote sensing (Fig. 7). Monitored and modelled trends show an overall increase in vegetation-related variables. 2008 is both modelled and observed as the driest year in the Karun basin.

With satellite observations a detailed mapping and monitoring of flooded areas in terms of extent and flood duration is possible, as for the example of the Karun extreme flood event in 2019 (Fig. 8B).

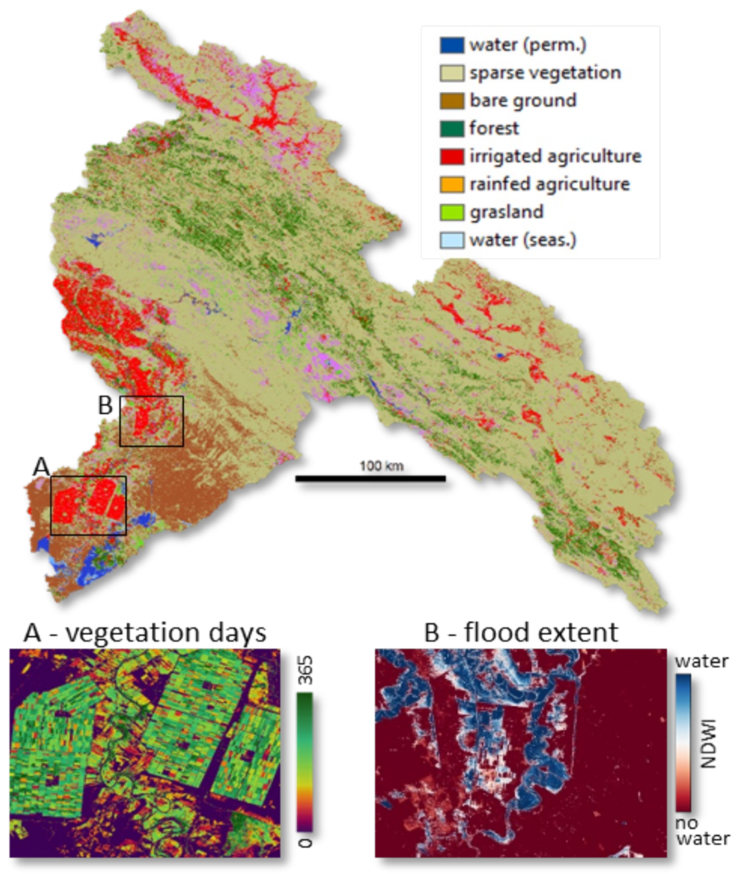


Fig. 8: Sentinel-2 based parameter derivation in Karun for land cover, days with vegetation cover and 2019 flood extent.

Satellite altimetry

Satellite altimetry poses an asset in transboundary water interactions. Virtual gauging stations allow the monitoring of water levels at different altimetry ground tracks along transboundary rivers. As Ethiopia fills the Grand Ethiopian Renaissance Dam (GERD) on the border to Sudan, Sentinel-3B will start to measure the water level of the reservoir (#3 in Fig. 9). The first filling of the reservoir during the rainy season, between June 2020 and September 2020, is well observed by Sentinel-3A.

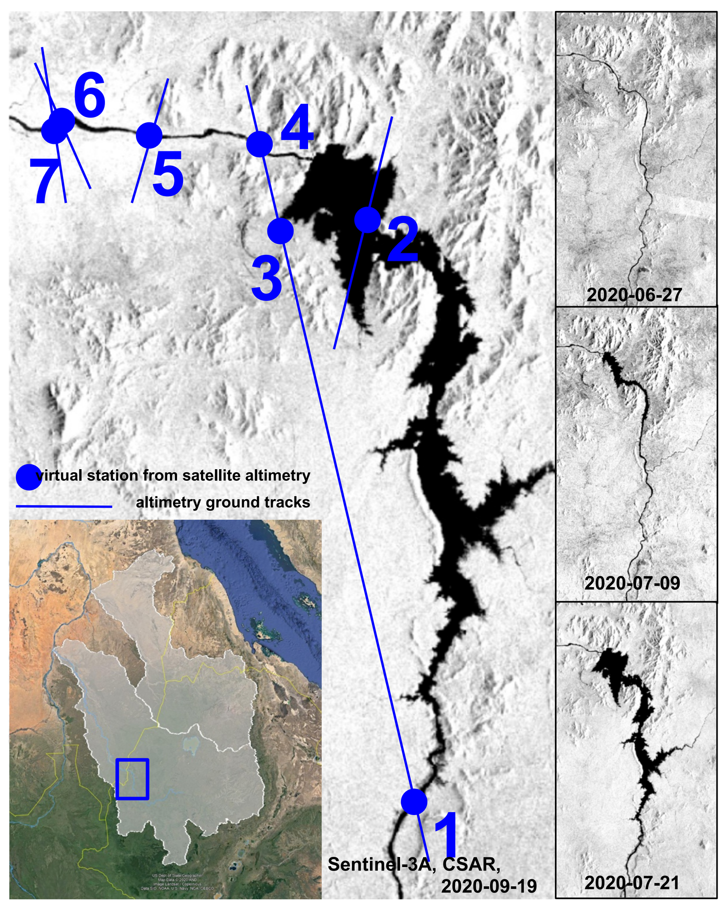


Fig. 9: Remote-sensing based monitoring of the filling of the GERD in Ethiopia on the border to Sudan including virtual satellite altimetry gauging stations around the reservoir.

High resolution near-real time precipitation

Our combination of high resolution geostationary (GEO) IR data and microwave based GPM precipitation data using Random Forest (Fig. 10) for semi-arid areas achieves near-real time precipitation data in high spatial (2-3 km) and temporal (10-15 km) resolution with higher quality than single IR channel GEO algorithms. This method is applicable to different GEO systems in various research areas.

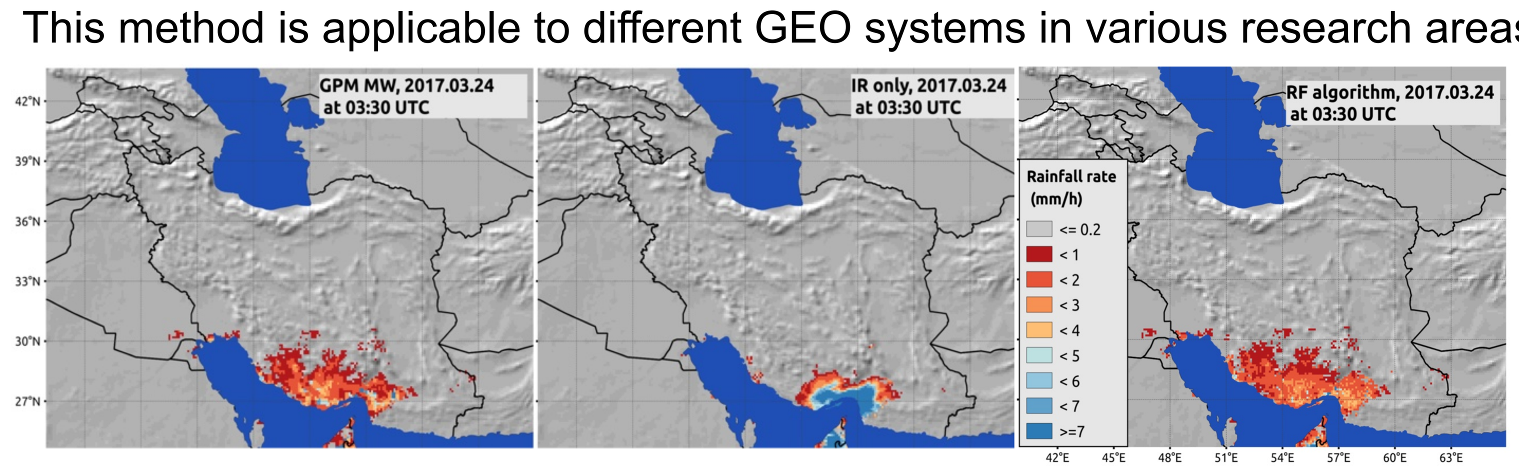


Fig. 10: Precipitation from remote sensing a) of the microwave based Global Precipitation Measurement Mission (GPM), b) of single infrared channel precipitation retrieval (IR only) and b) with the developed random forest (RF) algorithm over Iran on 24 March 2017.

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