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Remote sensing observations for informing hydrological models – a parameter regionalization approach

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Hydrological models are essential tools for water resource management. However, accurately capturing the hydrological regime in a river basin is challenging, especially where data is scarce. Calibration is often a necessary step but is impossible for ungauged basins. A robust parameter regionalization approach, which can transfer parameter values from gauged to ungauged subbasins, is necessary. In this study, we propose a parameter transfer framework using remote sensing observations to characterize river subbasins in order to limit the number of calibration parameters at basin scale. This study is a contribution to the European Space Agency (ESA) project GlobWetland Africa, which focuses on exploiting remote sensing observations for wetland monitoring and assessment in Africa. The GlobWetland Africa river basin hydrology product allows users to characterize hydrological conditions at catchment scale and assess the impact of human activity and climate change on key wetland areas.

The rainfall-runoff model used in this study is based on the Budyko concept of limits. The conceptual model framework is flexible and can be extended when needed, and the limited number of calibration parameters (between six and ten) is attractive for data scarce basins. The modelling tool has been integrated in the freely available, open-source project QGIS toolbox as a plugin with a user friendly graphical interface. The aim is to define a robust and transferrable approach, which can be applied directly by users at catchment scale. Each river basin is subdivided into so-called hydrological response units (HRUs) based on climatic and physiographic characteristics. The basin characteristics used are readily available as part of the model setup (e.g. elevation slope derived from the Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) and rainfall from Tropical Rainfall Measuring Mission (TRMM) v.7 3B42 and Famine Early Warning System rainfall estimation (FEWS-RFE)) or publicly available products derived from remote sensing observations such as the ESA Climate Change Initiative (CCI) Sentinel-2 high-resolution land cover map. The proposed method can be extended to include more basin characteristics than presented here, for instance soil properties and basin geology. Subbasins within each HRU share the same parameters. The number of units is constrained by the number of in-situ stations available. The calibration itself uses historical in-situ records and any publicly available, suitable remote sensing observations. Four African river basins are studied: the Ogooué, the Semliki, the Tana, and the Upper Niger. The basins were chosen based on their importance for strategic wetlands.

The method improved the overall model performance compared to a simpler, closest-neighbor regionalization, particularly in heterogeneous basins such as the Upper Niger. In particular, grouping the basins according to daily precipitation percentiles rather than annual mean precipitation improved model performance during validation, suggesting a more robust calibration and highlighting the importance of appropriate parameter regionalization. The method allows for a wider range of data to be included in the model development, including important information, which cannot be explicitly integrated in the model calibration.