Downscaling GRACE data and Validation using Machine learning approaches, application to Morocco.

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Abstract :

The purpose of this study is to enhance the applicability of GRACE satellite data for local water resource management in drought-prone regions. GRACE-derived Total Water Storage (TWS) data, although valuable, is limited by its coarse spatial resolution (100–300 km), which restricts its utility at local scales. This research addresses the challenge by downscaling GRACE TWS data from 100 km to 1 km over Morocco, a country experiencing increasing water stress, for the period 2002 to 2022.

The key problem addressed is the mismatch between the scale of GRACE data and the fine spatial resolution required for effective groundwater monitoring and management. To overcome this limitation, a machine learning approach based on Random Forest regression was applied. The downscaling model utilized multiple high-resolution input variables, including precipitation (10 km), normalized difference vegetation index (1 km), land surface temperature (1 km), evapotranspiration (500 m), elevation (30 m), and snow index (500 m), all covering the same period.

The downscaled TWS data were validated through a three-pronged approach: statistical assessment, comparison with in-situ groundwater level measurements, and consistency with known aquifer dynamics. Statistical validation showed strong model performance, with a Nash-Sutcliffe Efficiency of 0.80, a Root Mean Square Error as low as 0.82 cm, and a Mean Absolute Error of 0.57 cm. Cross-validation confirmed model reliability with R^2 values ranging from 0.56 to 0.89. Throughout the study period, error metrics remained consistently low. Groundwater-level validation showed that the correlation with downscaled TWS improved for 63% of 139 wells, with the highest gains observed in the Marrakech-Safi region and the lowest in Béni Mellal-Khénifra. The enhanced 1 km data captured localized hydrological variations and revealed consistent trends within aquifer systems of similar geological structure.

This work contributes to the congress theme by demonstrating a robust, data-driven approach to improving the spatial resolution of satellite-based water storage estimates. The findings emphasize the potential of downscaled GRACE TWS data for supporting local and regional

groundwater management strategies, particularly in arid and semi-arid environments where water resources are under increasing pressure.

Key words: GRACE data, Total Water Storage, Downscaling, Hydrological validation, Drought, Morocco