remote sensing

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Editorial

Editorial for Special Issue: "Remote Sensing of Hydrological Processes: Modelling and Applications"

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1. Introduction

Improvements in satellite remote sensing techniques have allowed the development of several platforms that are able to capture multitemporal data with a wide range of spatial and temporal resolutions. Satellite remote sensing enables monitoring and detecting spatiotemporal changes in natural water cycle phenomena (e.g., precipitation and soil moisture), as well as the assessment of natural and human-induced changes on Earth. In fact, earth observation data provide information for decision making in the water science field at different spatiotemporal scales. Remote sensing in water science is related to the observation, understanding, and prediction of the spatial and temporal distribution of hydrological processes.

Usually, hydrological models are calibrated in specific sites, such as stream gauge stations located at river basin outlets. However, on one hand, assessing runoff in a point of the basin provides an aggregated and limited response of the hydrological system without accounting for spatial variations in hydrological parameters. On the other hand, in the case of ungauged basins, other alternatives to evaluate hydrological model performance are needed. Remote sensing data have become a true alternative for the spatial calibration and validation of hydrological models, considering the spatiotemporal variations in parameters and state variables.

This Special Issue "Remote Sensing of Hydrological Processes: Modelling and Applications" has collected cutting-edge approaches using remote sensing data for improving hydrological variable estimation (e.g., soil moisture and precipitation) [1,2], monitoring vegetation indexes and ENSO [3], the calibration and validation of rainfall-runoff models [4–6], and the monitoring of land uses changes and long-term variation in hydrological variables [7,8]. The proposed methods fall into three main categories depending on the use of the input data sources: improving remote hydrological variable retrieval and monitoring indexes; the calibration and validation of hydrological models; and the monitoring of land use changes and long-term variation in terrestrial water storage.

2. Improving Remote Sensing Hydrological Variable Retrieval and Monitoring Indexes

Several hydrological variables can be tracked using remote sensing technology. One of the most critical variables for hydrological models is soil moisture. The work of Ming et al. 2022 [1] presented a hybrid approach (triple collocation + long short-term memory neural networks) to generate a soil moisture database with high spatial resolution and monthly temporal coverage. In this work, the analysis relied not only on data obtained from models (e.g., soil moisture fields from ERA5-Land), but also on data exclusively obtained with remote sensors (e.g., soil moisture from SMAP, surface albedo, land surface temperature, NDVI, land cover type, etc., from MODIS sensors).

Moreover, the intra-annual variability in soil moisture was studied in detail in Álvarez and Poveda (2022) [3]. This paper presents the joint dynamics of soil moisture (data obtained from SMOS), NDVI (data from the AAVHRR sensor), and the ENSO (El Niño–Southern Oscillation) phenomenon for six regions of tropical South America, applying linear and non-linear methods.

The two previous papers presented the potential of remote sensing techniques to gather relatively coarse-resolution data for hydrological and climatological analysis. Nevertheless, Shi et al. (2023) [2] demonstrated how some weather phenomena could be monitored at both high temporal and fine spatial resolutions using remote sensing technology. They implemented a multidimensional monitoring system for several scales. Then, they could track the precipitation life cycle within a stratiform cloud system in a remote region of China (the Yellow River basin's headwater). Through the analysis of the data obtained from remote sensing, the authors were able to observe characteristics of the macro- and microphysics of clouds and precipitation for one storm event. Finally, they were able to analyze the relevant spatial variations at the ground level of the process of precipitation acoustic interference.

3. Calibration and Validation of Hydrological Models

In the case of ungauged or poorly gauged basins, the use of remote sensing products, such as estimates of precipitation or actual evapotranspiration, could be essential. However, in addition, developing new approaches to calibrate spatially distributed models based on remote sensing hydrometeorological variable retrieval is a challenge. Hydrological models forced by remote sensing meteorological variable retrieval have been successfully used to understand the hydrological system in data-scarce basins [4–6]. The developed methods were applied both in pluvial regime basins [4,5] and in basins where glacier melting constitutes a relevant contribution to runoff [6].

In this sense, Bennour et al. (2022) [4] have been applying several techniques for the calibration and validation of the soil and water assessment tool (SWAT) model at the monthly scale, based on remote sensing hydrometeorological data retrieval, in data-scarce basins (sub-basins of the Lake Chad Basin, Africa). Specifically, these authors have considered remote sensing ETa datasets (ETMonitor, GLEAM, SSEBop, and WaPOR) for calibration purposes, and three types of variables retrieved from remote sensing (ETa, total water storage, and soil moisture) for validation. It is relevant, then, to highlight the limited time period (only one year) considered to calibrate the model, applying the SWAT-CUP tool kit. As a result of their assessments, the best performance was achieved by using the Hargreaves equation for ETp estimation and the ETmonitor ETa dataset retrieved from remote sensing. Four performance metrics, Nash–Sutcliffe efficiency (NSE), Kling–Gupta Efficiency (KGE), percent bias (PBIAS) and determination coefficient (R^2), were applied to calibrate and validate the model, with satisfactory results.

Senent-Aparicio et al. (2022) [5] assessed the potential of several reanalysis datasets, both discharge datasets (GloFAS product of the European Centre for Medium-Range Weather Forecast) and climatological datasets (CHIRPS-CHIRTS and CFSR), to calibrate the SWAT hydrological model at the monthly scale for an ungauged basin of Central America (Grande San Miguel River basin, El Salvador). Considering several statistical indicators and efficiency coefficients, the authors demonstrated the potential and usefulness of these datasets for poorly gauged or ungauged basins.

Haq et al. (2023) [6] considered long-term satellite data (snow cover from MODIS images) to force the snowmelt runoff model (SRM) to assess the trends in melt runoff components of glaciers of the study area (Karakoram Mountains, Pakistan), with good results. The usefulness of this methodology as a good alternative to detect changes in melting glaciers of data-scarce areas was highlighted.

4. Monitoring of Land Use Changes and Long-Term Variation in Terrestrial Water Storage

The world's population inhabiting urban areas has increased by over 50 % in a short period of time (United Nations Statistics). Demographic projections indicate that this proportion will continue to increase in the coming years. Soil impermeabilization caused by urbanization has affected the hydrological cycle of urban areas, increasing surface runoff and flood risk. In Kabeja et al.'s study (2022) [7], the influence of urban land cover change on spatiotemporal changes in flood peak discharge and flood volume within a rapidly urbanizing catchment located in Beijing was investigated. They used Landsat satellite imagery from 1986 to 2017 to quantify urban growth in their study area. They also employed a hydrological model (HEC-HMS) forced by meteorological data to assess the impact of urban sprawl on the basin's hydrological response. This work found that increases in urbanized area are mainly due to the conversion of agricultural land. These changes in land use have led to an increase in the vulnerability of the watershed to flood risk. A positive and consistent trend was observed between the proportion of urban land use change and flood volume and flood peak discharge in the sub-basins into which the study area was divided.

Terrestrial water storage change (TWSC) is a critical indicator of the impact of climate change on the hydrological system. Many works have revealed that the TWSC plays an irreplaceable role in the detection of the recession of glaciers and snowy areas, with it also being a good source of information to describe changes in soil moisture and in the water content of aquifers. In Wang et al.'s study (2021) [8], the characteristics of the spatiotemporal variations in the TWSC were investigated in the Yarlung Zangbo River Basin, which is located in the southeast of the Qinghai–Tibet Plateau. Gravity recovery and climate experiment (GRACE) data from 2003 to 2017, combined with a re-analysis product of the European Centre for Medium-Range Weather Forecasts (ERA5) data and Global Land Data Assimilation System (GLDAS) data, were adopted for evaluating the performance of TWSC estimation. The terrestrial water balance method and the summation method were used to estimate terrestrial water storage, obtaining four sets of TWSC, which were compared with TWSC derived from GRACE. The paper by Wang et al. (2021) shows how from 1948 to 2017, variations in soil moisture played a major role in the change, especially after 2002. From that year onwards, there was a change in the trend in the estimated values of the TWSC. The outcome of this research should be an outstanding reference for researchers in the field of ecohydrology and will be crucial for the evaluation of water resources in mountainous areas of the planet.

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