remote sensing

Editorial

Editorial for the Special Issue "Remote Sensing of the Terrestrial Hydrologic Cycle"

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Received: 16 March 2020; Accepted: 20 March 2020; Published: 23 March 2020

To address global water security issues, it is important to understand the evolving global water system and its natural and anthropogenic influencing factors [1]. The emerging remote sensing technologies enable relatively long-term consistent observations of the key variables of the terrestrial water cycle with unprecedented spatial coverage, providing precious data to broaden our understanding of the causes and consequences of change in the terrestrial water cycle [2]. The data-rich environment largely created by advances in remote sensing has boosted research in global change hydrology [3].

In this Special Issue, most studies used data acquired by various satellite and/or ground-based sensors to characterize the change in the terrestrial water cycle. The key hydrologic variables such as evapotranspiration (ET) and precipitation were derived and evaluated at varying spatial and temporal resolutions. Wang et al. [4] proposed a latent heat flux (LE) algorithm based on a novel microwave vegetation index (EDVI) instead of the optical vegetation index that was commonly used in previous studies. This algorithm was driven by multiple-sensor satellite products of vegetation water content index, solar radiation, and cloud properties, with some aid from a reanalysis dataset. The result showed that the performance of the proposed algorithm was very promising with correlation coefficients of 0.56–0.88 and a mean bias of 16% (23.0 W/m^2) for instantaneous LE estimations, and with correlations of 0.84–0.95 and a mean bias of less than 14.3% for monthly LE estimations based on in situ measurements at three Chinese Terrestrial Ecosystem Flux Research Network (ChinaFLUX) forest sites. Due to the insensitivity of microwave data to clouds, this algorithm shows great potential for estimating ET under both clear and cloudy skies on a global scale. Zhong et al. [5] estimated the ET of major exorheic catchments in China with a water balance method using Gravity Recovery and Climate Experiment (GRACE) data. Although the method has been demonstrated in previous studies [6], the authors addressed a potential approach for understanding the model performance associated with the errors in precipitation input. This study further highlights the unique ability of gravity satellites to capture the response of total water storage changes to both natural and anthropogenic causes, as well as its additional values of closing the water budget. Xu et al. [7] applied various statistical indicators to evaluate the main current satellite-based quantitative precipitation estimate (QPE) products over China. They found that the Chinese Fengyun (FY)-2G QPE and the Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (IMERG) products performed significantly better than FY-2E QPE. The IMERG product agreed well with rain gauge data at the monthly scale, but it performed worse than FY-2G QPE at hourly and daily scales. The FY-2G QPE underestimated precipitation in summer, and the FY-2E QPE and IMERG QPE generally overestimated precipitation. The authors also found both FY and GPM-based products performed worse during 06:00 to 10:00 UTC than other periods. Their findings can provide valuable references for improving satellite-based QPE retrieval algorithms. Qiu et al. [8] evaluated the performance of three "radar-gauge" merging algorithms. Their results show that the radar-gauge integration method performs better than the others. quality of the blending QPE product is not only related to the blending algorithm, but also related to radar QPE and gauge observations. In order to further evaluate the merging QPE product, the authors applied the merging QPE product for flood forecasting and found that a higher quality of the merging products indicates a better agreement between the observed and the simulated runoff. Yang et al. [9] used a machine learning algorithm, K-nearest neighbor (KNN), to classify precipitation types. The authors used six Doppler radar data sources from China as training and classification samples, and used the 2A23 product of the Tropical Precipitation Measurement Mission (TRMM) to obtain the training labels and evaluate the classification performance. Three types of cases, namely the squall line, embedded convective and stratiform cases, were classified by KNN. The results show that the KNN method can accurately classify the location and area of stratiform and convective systems and suggest that the KNN method has great potential for classifying precipitation types.

Some studies used remote sensing techniques to detect anthropogenic impacts on the water cycle, providing valuable knowledge of the interrelations between humans and water. Zhang and Gao [10] combined the water surface area estimated from Moderate Resolution Imaging Spectroradiometer (MODIS) images and the reservoir Area–Elevation (A-H) relationship derived from the Digital Elevation Model (DEM) data collected by the Shuttle Radar Topography Mission (SRTM) to monitor water storage variation. The water storage variation data estimated from the proposed methodology cover reservoirs with 46.6% of the overall reservoir storage capacity in South Asia, providing valuable information for flood monitoring and water resource management in this region. Xu et al. [11] demonstrated an interesting attempt to distinguish irrigated fields from rainfed fields using higher-resolution images (30 m) from Landsat together with hydroclimatic data. It is a challenge to detect the difference in humid and sub-humid areas as these fields have similar land surface characteristics. Efforts have been made to enhance the contrast between neighboring rainfed and irrigated fields, and a machine learning method was adopted to generate maps of irrigated areas in southwestern Michigan. The success of mapping suggested that the subtle difference of land surface characteristics caused by water management practice is detectable from space. The maps also showed that the irrigated area in southwestern Michigan tripled during 2001–2016. Information on the change in irrigated areas would be highly relevant for water and food management. Hao et al. [12] developed a method to detect the irrigation signal (frequency, timing and area) based on multisource time-series data including soil moisture active passive (SMAP), MODIS-normalized difference vegetation index (NDVI) and evapotranspiration (ET), and precipitation from the meteorological stations. The detection result showed that irrigation signals can be effectively detected by removing the precipitation effect and setting the soil moisture change threshold with an overall accuracy of 77.08% in a typical crop-producing region in China. To solve the problem of the coarse resolution of SMAP pixels, a downscaling method was proposed by combing the winter wheat area extracted from MODIS NDVI, and the proposed method can indicate the true winter wheat irrigation timing, area and frequency with an 82.72% growth consistency in the surface water irrigation period. Zou et al. [13] measured the ET rate and quantified the cooling effects of urban hedges using the "three-temperature model and infrared remote sensing (3T+IR)"—a fetch-free and high-spatiotemporal-resolution method—in the urban area of Shenzhen in China. The study discovered that the "3T+IR" technique was a reasonable method for measuring the ET of urban hedges. The hedges could consume 68.44% and 60.81% of the net radiation through the latent heat of ET on a summer day, while their cooling rates for air temperature were 1.29 °C min^{-1} m^{-2} and 1.13 °C min^{-1} m^{-2}, respectively. In addition, urban hedges could also significantly cool the underlying surface, and the surface temperatures of the two hedges were 19 °C lower than that of the asphalt pavement on the summer day. The findings provide new insights in understanding the process of ET in urban hedges and the vegetation cooling effect in the urban environment.

A few studies leveraged remotely sensed hydrologic information to understand the causes and consequences of changes in the terrestrial water cycle. Liu et al. [14] investigated the transition characteristics of the dry–wet regime and vegetation dynamic responses over the Yarlung Zangbo River (YZR) Basin, using NDVI data from the Global Inventory Modeling and Mapping Studies (GIMMS)-NDVI3g dataset together with the Standardized Precipitation Evapotranspiration Index (SPEI) from the Noah land surface model simulations in the Global Land Data Assimilation System (GLDAS). The widely-used remote sensing datasets helped find that the spatiotemporal characteristics of the dry–wet regime exhibited a reversal phenomenon before and after 2000, and the soil water content was an important indicator to identify the dry–wet transition in the YZR basin. This provided another solid demonstration of the value of widely available remote-sensing datasets in helping us to better understand the hydrological responses to global changes in space and time. Yao et al. [15] investigated the impacts of land cover change on the hydrologic regime in Northwestern, Northern, and Northeastern China. The Global Land Surface Satellite (GLASS) leaf area index (LAI) data retrieved from the MODIS reflectance data (MOD-09A1) were used as a primary parameter to reflect land cover change in a hydrological model. The hydrological simulations showed that in relatively humid areas, urbanization increases runoff and the consequent flood risk, whereas in arid and semi-arid regions, the increase of greenness resulting from the Three-North Forest Shelterbelt (TNFS) ecological restoration program increased evapotranspiration and reduced runoff and soil moisture. The study suggested that land cover change would heighten the risk of dryland expansion and flooding more than climate change alone in the future, providing new insights into global change impacts on the terrestrial water cycle. Chen et al. [16] investigated the area dynamics of two closed lakes in the semi-arid areas of the Inner Mongolian Plateau by using Landsat images and found that it expanded in dry seasons and degraded in wet seasons. Such an unexpected phenomenon was believed to be related to the external groundwater recharge from the leakage of the fault zone in this area and provided valuable information for understanding the impact of human activities on lake shrinkage in this area. Although the deep groundwater recharge is being debated, this study provided an easy way of using satellite images to infer interactions between surface water and groundwater.

The articles published in this Special Issue cover a wide range of innovative remote sensing methods to meet the needs of hydrologic practices and remote sensing applications to detect the changes in the terrestrial water cycle and to understand the causes and consequences of the changes. It highlights the potential of remote sensing in addressing global water issues under a changing environment.

Acknowledgments: We would like to thank all the authors and reviewers who contributed to this Special Issue on "Remote Sensing of the Terrestrial Hydrologic Cycle". Q.T. was supported by the National Natural Science Foundation of China (41730645, 41790424), the Strategic Priority Research Program of Chinese Academy of Sciences (XDA20060402), and Newton Advanced Fellowship.

Conflicts of Interest: The authors declare no conflict of interest.

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