remote sensing

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Editorial

Editorial for the Special Issue "Remote Sensing of Large Rivers"

Enner Alcântara [1] and Edward Park [2,*]

1 Department of Environmental Engineering, Sao Paulo State University (UNESP), Sao Jose dos Campos 12245-000, Brazil; enner.alcantara@unesp.br
2 National Institute of Education (NIE) and Asian School of the Environment (ASE), Nanyang Technological University (NTU), Singapore 639798, Singapore
* Correspondence: edward.park@nie.edu.sg; Tel.: +65-6790-3413

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Large rivers play important roles on Earth, such as transporting eroded materials from the continents to the ocean, facilitating the transfer of nutrients through biogeochemical cycles, and sustaining complex ecosystems and high levels of biodiversity [1–3]. They are also essential resources (energy sources, irrigation, food, and transportation) and can even be hazardous for human populations. For this reason, interest in large river research has been continuously increasing across disciplines over the last few decades. Recent advances in field techniques—e.g., to measure discharge, model flow structures, water quality monitoring, or bathymetric surveying, and computational methods—have further accelerated the production of knowledge on large rivers. In addition, the maintenances of hydrologic gauge stations in large river basins by regional/governmental agencies have also been supporting the growing science of large rivers at regional scales.

Despite the efforts and recent advances in technical aspects, a considerable proportion of the large rivers on our planet still remain unexplored, mainly due to their spatiotemporal hydro-sedimentological complexities and vast scales, which make the large rivers difficult to characterize only using traditional in situ methods. Recent unprecedentedly high human impacts on fluvial systems globally are posing additional threats and complexities for large river systems by modifying their hydrogeomorphologic and ecological regimes [4–9].

Remote sensing has become one of the most efficient and relevant means to regularly assess the spatiotemporal dynamics of various riverine environments, including channels, floodplains, lakes, reservoirs, and wetlands, over a large scale [10]. For this reason, applications of remote sensing in the study of large rivers have recently been increasing substantially [11]. This special issue on remote sensing of large rivers is dedicated to contributing to this fast-growing current trend of remote sensing applications in the large river sciences. We invited studies on recent advances in the study of large rivers solidly based on any types (active or passive) and platforms of remote sensing from multidisciplinary points of view.

A total of 18 manuscripts were submitted to our special issue, and after rigorous peer review process by 40 anonymous reviewers, nine papers, those of high-quality content based on their cutting-edge remote sensing techniques, were finally selected for publication by a total of 34 authors. The geographical distribution of the authors' institutions is global, with the highest number from the USA and Brazil (10 each), followed by China (six), Singapore, and Vietnam (two each). Authors were also based in Thailand, South Korea, Italy, and Kenya (one each).

Published papers cover a wide range of topics concerning various characteristics and variables of large rivers, from discharge, sediment budget to bathymetry. Several of them are focused on methodological advancement through developing innovative approaches in studying the river systems. We, therefore, broadly divided the published papers into two groups: remote sensing-oriented methodological development, and case studies applying remote sensing to study river systems. Papers focused on methods are further organized into three sections based on topics: (1) methods concerning applications on water mass, such as discharge and water budget assessment [12–14]; (2) methods concerning water quality, such as Total suspended solids (TSS) and pollutants [15–17]; and (3) contributions in mapping bathymetry [18]. We published two application papers that used existing remote sensing techniques as a tool to better characterize large river systems, both in the Asian continent [19,20].

A paper contributed by Sichangi et al. [12] presents a novel approach of combined river width (from Moderate Resolution Imaging Spectroradiometer (MODIS) data), water level variability (from radar altimetry), channel slope, and estimated velocity through hydraulic geometry [21], which was then validated through two virtual stations along the Yangtze River with reasonable accuracy. Although there is a growing body of applications, estimating discharge solely from optical remote sensing is still nascent, and hence the presented work has the potential to be applied worldwide. Another paper in this issue [13] combined ensemble learning regression to estimate discharge with satellite radar altimetry. Here, multi-mission altimetry showed the premise to overcome the spatial limitation of the gauge station series, by having several virtual stations in the river longitudinally. They validated the new method in the Mekong River, a morphologically complex, and the largest, river in Southeast Asia.

Surface water storage (SWS) is crucial in large rivers because it largely controls hydrophysical and ecological processes in the floodplain. In the case of the Amazon River, seasonal storage of water and sediment is estimated to be around 250 km^3/year [22] and 80 million tons/year [23], respectively, along the lower reach. In this special issue, a contribution by Melo and Getirana [14] presented a new approach combining Gravity Recovery and Climate Experiment (GRACE) and radar altimetry to measure surface water budget in the Amazon Basin. Although radar altimetry has been widely used in the Amazon to estimate SWS by measuring water level at high accuracy [24,25], it can only measure widely-spaced points along tracks, hence not offering spatially distributed information. For the first time, the radar altimetry has been demonstrated to reproduce GRACE-based SWS, which can be used for filling inter-mission gaps of GRACE.

The total suspended matter (SPM) in a river and reservoir primarily controls the underwater light fields affecting the aquatic photosynthesis. A paper contributed by Bernardo et al. [15] developed a new bio-optical model based on a semi-analytical scheme to estimate the SPM in an optically complex water body (where Chl-*a*-driven turbidity is high) in the dam cascade in Brazil. Their results were validated with high accuracy, showing strong promise for application in other optically complex inland waters.

Another study in our special issue [17] developed a semi-automated model to detect water pollution from static optical remote sensing images by systematically detecting outlier signatures from the image. They demonstrated the model performance using case studies throughout different settings of large rivers, through successfully detecting water-related hazards such as pollution/landslides, or oil spills. Sharing a similar objective to monitor contaminants in rivers, Legleiter et al. [16] showed experimental results characterizing dispersion patterns of trace dye in a river using an unmanned aerial vehicle (UAV). One of their key findings is the demonstration of applicability to monitoring dyes of different levels of concentration and water turbidity, which extends the applicability over rivers with different water types.

Remote sensing of river bathymetry is a rapidly growing field that offers a faster and more continuous measurement, compared to conventional methods [26]. The quality of the bathymetry driven by the spectral imaging method, however, is largely subject to water turbidity that obstructs the electromagnetic radiation [27], hence is limited to relatively shallow waters. In the paper contributed by Legleiter et al. [18], multi-beam echosounder and hyperspectral imagery were integrated to show the maximum depth detectable based on spectral images. They showed field-validation results at high accuracy, while highlighting the needs of remote sensing data calibration over a broad range of depths.

The last two contributions in our special issues are application papers where they extensively utilized existing remote sensing methods to advance the understanding of fluvial geomorphology and basin-scale water resources issues. The first paper, by Wang et al. [20], investigated the morphodynamics of a sandy bar in the middle Yangtze River by means of bar sediment budget, particularly in response to an episodic flood event. Their major finding was that extreme events are responsible for major reorganization of the channel geometry, and also during these events, bars become the source of sediment (rather than the sink). They also discuss potential hydro-sedimentologic regime disruption from the Three Gorges Dam.

Another paper, by Yang et al. [19], conducted a large-scale spatiotemporal analysis of lakes in the Hindu Kush-Himalaya-Tibetan (HKHT) region, which is the source region for many large Asian rivers, based on over 40 years of Landsat data. Their analysis revealed dramatic sub-regional surface lake dynamic patterns across the HKHT, which are driven mainly by climate change (especially precipitation) and associated glacier melting. We hope that their findings could have implications for dealing with water-related hazards, controlling glacial outburst floods, and securing water resources in the HKHT region, where the largest Asian rivers are born.

We are grateful to authors for contributing their cutting-edge research to our special issue. We also appreciate the 40 reviewers who selflessly offered rigorous and timely reviews. Without them, our special issue on remote sensing of large rivers would not have been successful. Finally, we would like to thank the editorial manager Ivana Liu, and the MDPI editorial team, for providing huge supports to the guest editors so that we could handle each manuscript efficiently.

Although there is much work to be done on the topic of this special issue, we truly hope that the papers published here can help research communities to better understand complex large river systems around the world, and also inspire them to continue to develop new remote sensing methods.

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