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Editorial

Monitoring Lakes Water Using Multisource Remote Sensing and Novel Modeling Techniques

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1. Introduction

Inland lakes are indicators of climate change and environmental deterioration [1,2]. As a unique ecosystem unit, an inland lake is one of the basic places for human survival and development. In recent years, with the rapid development of regional societies and economies, the ecological environment of inland lakes has been rapidly degraded by human activities under the influence of large-scale water and soil exploitation activities, leading to massive deterioration of the ecological environment of lakes [3]. Therefore, lake ecological restoration and water quality monitoring under the coupling effect of climate change and human activities are the key to lake protection and management. In recent years, remote sensing has played an increasingly important role in the monitoring of the terrestrial water cycle.

Remote sensing technology has been applied in many fields, such as the monitoring and management of water storage, water quality, water levels, and hydrodynamics [4]. Remote sensing technology has been applied to water bodies since the 1970s [5]. Over time, the technology and theory of lake water color remote sensing monitoring have gradually matured, and an integrated lake remote sensing monitoring system of "Satellite-UAV-Ground" has been developed. In addition, the rapid development of computer and artificial intelligence technology in recent years provides a powerful algorithm support for the intelligent remote sensing observation of lakes. Therefore, the explosive growth of remote sensing data applications is driven by the coupling of multisource remote sensing data and the expansion of new modeling technology.

This Special Issue presents a review and recent advances of general interest in the use of remote sensing (RS) and geographic information systems (GIS) on inland lakes, with a focus on monitoring inland lakes (e.g., water storage, water quality, water levels, and hydrodynamics) and water resource management.

2. Overview of the Contributions

The call for papers was announced in July 2021, and after a rigorous peer-review process, a total of 11 papers were published [6–16]. To gain a better insight into the essence of the Special Issue, we will focus on the summary and analysis of these articles that mainly include four themes: (1) remote sensing monitoring of lake water quality; (2) remote sensing extraction and analysis of water area and water volume based on novel algorithms; and (3) remote sensing simulation and analysis of the watershed water environment.

2.1. Remote Sensing Monitoring of Lake Water Quality in Lakes and Reservoirs

Lakes (including reservoirs) have attracted more and more attention as the main drinking water source for more than 85% of the population in China. Remote sensing, as the only means to achieve large-scale, periodic, and operational monitoring, has played an important role in lake monitoring and research. Lake remote sensing, as a branch and cross-subject of lake science, remote sensing science, and other disciplines, enables researchers to learn from and promote each other. Zhang et al. [6] analyzed the response relationship between the water quality index and water reflectance, and used remote sensing technology to establish a water quality index monitoring model to monitor water quality in the Ebinur Lake watershed, producing a demonstration project for the use of remote sensing technology in lake monitoring in arid areas. Aranha et al. [7] used Sentinel-2 MSI TOA Level 1C reflectance images and analyzed the concentration of chlorophyll-a (Chl-a) in water bodies of five reservoirs located in the semi-arid region of northeastern Brazil. The model has a strong observation ability and high accuracy. Luo et al. [8] developed an online water quality assessment early warning system that integrates a high-frequency monitoring system (HFMS) and data quality control technology, which was applied in the Qiandao Lake region, China. The Early Warning System (EWS) focuses on data availability, quality control methods, statistical analysis methods, and data application, but not on the technical aspects of the detector, wireless data transmission, and interface software development. The development of this system provides a strong support for the automatic monitoring of lake water quality and three-dimensional lake hydrodynamic and ecosystem prediction. Together, these papers contribute to the development of the continuous monitoring of water quality in small and large reservoirs based on remote satellite-based analysis. Such an analysis is a strategic resource for promoting regional water security, and the future goal is to implement large-scale, intelligent remote sensing technology for the observation of water quality in lakes and rivers.

2.2. Remote Sensing Extraction and Analysis of Water Area and Water Volume Based on Novel Algorithms

The observation and monitoring of surface water area is of great significance for water resource management as well as ecological protection in a basin. Using remote sensing or hydrological model estimation methods can quickly obtain long time series of a water area, make up for the lack of data in a scarce-data area, and provide a basis for further research on surface water.

Li et al. [9] based their work on the GEE (Google Earth Engine) cloud platform and studied the effect of nine kinds of water indexes on the surface water extraction in Bosten Lake Basin by adding a slope mask to remove misclassified pixels to find the best extraction method for surface water extraction in the basin by means of accuracy verification and visual discrimination through a continuous iteration of the index threshold and slope mask threshold. The results show that when the threshold value is -0.25 and the slope mask is 8 degrees, the index WI2019 has the best effect on the surface water information extraction of Bosten Lake Basin, effectively eliminating the interference of shadow and snow. The extraction accuracy of surface water by remote sensing is improved, and provides a more accurate and convenient method for the extraction of surface water area under complex terrain. Chen et al. [10] adopted a spatial downscaling model for mapping lake water at a 10 m resolution by integrating Sentinel-2 and Landsat data, which was applied to map the water extent of Qinghai Lake from 1991 to 2020. This was further combined with the Hydroweb water-level dataset to establish an area-level relationship to acquire the 30-year data on water levels and water volumes. Then, the driving factors of the water dynamics were analyzed based on the grey system theory. The results were of great significance for local sustainable development and ecological protection. Zhang et al. [11] used DYRESM to estimate the water volume entering Waihai, part of Lake Dianchi, from 2007 to 2019 without historical hydrological observation data. Then, they combined this information with the monthly monitoring data of water quality to calculate the annual external loading. This method effectively solves the problem of the limited accuracy in the statistical results of lake water volume and external load estimation caused by a lack of data. Salama et al. [12] used remote sensing techniques and a geographic information system to analyze different satellite images, including multi-looking Sentinel-2, Landsat-9, and Sentinel-1 (SAR), to monitor the changes in the volume of water from 21 July 2020 to 28 August 2022. The volume of Nile water during and after the first, second, and third filling was estimated for the Grand Ethiopian Renaissance Dam's (GERD) reservoir lake, with comparisons for future hazards and environmental impacts. There are great challenges in the extraction of fine water based on remote sensing images. Future research will focus on developing water extraction algorithms suitable for multiple complex scenes (including highly heterogeneous urban scenes, cloudy and foggy scenes, and high-altitude mountain scenes), developing artificial intelligence algorithms with high accuracy, and developing fully automated extraction algorithms.

2.3. Remote Sensing Simulation and Analysis of Watershed Water Environment

The combination of the space in which people live in and the water body that can directly or indirectly affect human life and development is called the water environment. This water environment is applied to all kinds of natural factors and related social factors. Increasingly, the global watershed environment is facing more and more destruction, the inherent allocation mechanism of various elements of the natural environment is being maladjusted, and the environmental quality is deteriorating. Therefore, the observation and simulation methods and technologies of the watershed water environment need to be improved urgently, and remote sensing technology fills this gap fittingly. Tripp et al. [13] demonstrated their ability to monitor spatial and temporal changes in the playa water inundation area on sub-monthly time scales in West Texas, USA, using 10 m spatial resolution imagery from the Sentinel-2A/B satellites. The study developed a faster and more accurate method to cover a relatively small area compared with traditional monitoring methods. The methods provide a strong support for identification of small playas and ecological applications. Tang et al. [14] investigated the dynamics of the mid-channel bars (MCBs) in the Three Gorges Reservoir (TGR) using the Gravity Center Shifting Model. The number and area of MCBs changed dramatically with water-level changes, and the changes were dominated by MCBs. The study helped to reveal the mechanisms for the development of MCBs in the TGR. It also offers a scientific basis for the planning, optimal utilization, and ecological restoration of the MCBs in the TGR. Li et al. [15] used the Soil and Water Assessment Tool (SWAT) model in combination with the GCM model to address the separate and combined impacts of changes in climate and land use/land cover on the hydrological processes and sediment yield in the Xin'anjiang Reservoir Basin (XRB). The SWAT model simulation shows that climate change will exert a much larger influence on the sediment yield than land use/land cover (LULC) alteration in the XRB. These studies provide a deeper understanding of the sediment response to climate-driven forces and LULC changes in the XRB, which is beneficial for water quality protection and bloom prevention in the reservoirs in the East Asian monsoonal region. The watershed water environment is the main link to human activities in the basin. Large-scale, real-time remote sensing monitoring and simulation is the theme that needs undivided attention in the future.

3. Conclusions

The 11 papers summarized above contribute to the increasing interest in the study of monitoring lake water based on multisource remote sensing and novel modeling techniques. The Guest Editors hope that readers will be inspired by this Special Issue and will continue to study and innovate in the field of remote sensing observation of lake water color. In particular, the era of "big data" and "artificial intelligence (AI)" has arrived, which will usher in new development opportunities for the remote sensing observation of lake water color. In the future, with remote sensing and AI algorithms as the core methods, this field and others will focus on the miniaturization of spectral sensing devices, ease of use, lake water quality monitoring, and watershed water environment regulation. The dynamic monitoring of the integration of "heaven, earth, air and water" monitoring is a realistic requirement to promote the construction of an ecological civilization. Using space-based, ground-based, buoy-based, hand-held, and other methods to conduct all-weather and multidimensional monitoring and data analysis of water environments with a large spatial scope and long-time span and the ability to upload data analyses and results to online monitoring platforms through 4G/5G networks is anticipated to become the focal research topic in the future.

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