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Editorial

Monitoring and modeling of water ecologic security in large river-lake systems

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ABSTRACT

Reliable assessment of the complex natural exchange processes between connected hydrological reservoirs is crucial for estimating hydrological properties, safeguarding ecosystem services, and effectively managing water resources. Although many hydrological or water resource applications require information at a “large scale”, the highly dynamic, seasonal variations of the water discharge and sediment exchange processes between local basins and connected large rivers lead to complex and difficult-to-assess hydrological behaviors in large river-lake systems. This special issue aims to provide the interested reader with some of the latest achievements, experiences gained and challenges addressed related to research in large river-lake systems. Therefore, a diverse group of 15 new articles has been gathered bringing together the cutting-edge research of more than 60 authors on monitoring, modeling, and data science methods for large river-lake systems.

1. Introduction

Reliable assessment of the complex natural exchange processes between connected hydrological reservoirs is crucial for estimating hydrological properties, safeguarding ecosystem services, and effectively managing water resources. Considering the growing concern on climate change and its impact on water resources, the provision of accurate information on exchange fluxes is essential to forecast the future state of hydrological systems. Although many hydrological or water resource applications require information at a “large scale”, the highly dynamic, seasonal variations of the water discharge and sediment exchange processes between local basins and connected large rivers lead to complex and difficult-to-assess hydrological behaviors in large river-lake systems. Contemporary hydrology is faced simultaneously with various challenges such as new model approaches for large hydrological systems (Archfield et al., 2015) as well as adequate and flexible monitoring concepts including event-driven campaigns and coping with the increasing amount of data from both observation and high-resolution modeling (Sun and Scanlon, 2019). Some of these challenges are tackled in the present special issue.

Firstly, despite the significant advances to develop integrated hydrologic and hydrodynamic modeling methods to analyze large river-lake systems having complex interactions and influences, research subjects like conceptual complexity reduction, integration of multi-scale processes as well as sufficient computational performance (e.g. high-performance-computing scalability) remain challenges to the scientific community (Fatichi et al., 2016). New research questions are also emerging as large study areas such as the complex large lake-river systems of Lake Poyang and Lake Dongting in the Yangtze River Basin are taken into intensive investigation (e.g. Hu et al., 2020).

Secondly, from the experimentalist’s perspective, observational data are essential for monitoring and understanding the changing characteristics and principles of basins with complex river-lake interactions which are closely related to improving the quality of water pollution simulation and assessment results. Nevertheless, large river-lake systems often have few stationary monitoring sites and the ability to design both, regular and event-driven measurement campaigns may be limited by the available human and financial resources. Hence, investigating large river-lake systems requires developing novel monitoring and data processing approaches, such as exploiting large-scale and continuous observations (e.g. Li et al., 2020a). Recent advancements in spatial information gathering (e.g. drone monitoring) and intelligent sensing technology (e.g. wireless sensor networks with automatized quality control) provide important tools for the dynamic monitoring of ecological environments with complex river-lake interactions.

Lastly, the rising amount of data drive the development of adapted workflows and platforms for data storing, processing, sharing, analyzing, and visualization (Kolditz et al., 2019). Although data and model integration has been supported by the development of environmental information methods and systems, more novel research should be explored to adequately approach challenges such as big data and open integrated modeling (Lü et al., 2019; Chen et al., 2020).

This special issue aims to provide the interested reader with some of the latest achievements, experiences gained and challenges addressed related to research in large river-lake systems. Therefore, a diverse group of 15 new articles has been gathered bringing together the cutting-edge research of more than 60 authors on monitoring, modeling, and data science methods for large river-lake systems.

2. Overview of research

The contributions have been grouped into four different categories: (i) regional hydrological modeling (Section 2.1), (ii) remote sensing and hydrodynamic modeling of surface waters (Section 2.2), (iii) visualization and data sharing in hydrology (Section 2.3) and (iv) wetland ecohydrology (Section 2.4).

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2.1. Regional hydrological modeling

Contributions addressing this category present research on applying hydrological models to better describe processes on the catchment scale. A focus of the presented work is to extend the Soil and Water Assessment Tool (SWAT) model by either implementing new processes for better describing specific biological and chemical processes or by coupling the model with external forcing.

Meshesha et al. (2020) extend the SWAT model by improving the watershed scale module of water quality for dissolved oxygen, dissolved organic carbon, and fecal coliforms. The modified model examines the spatio-temporal patterns and their impacts on the aquatic ecosystem and water quality processes in the Athabasca River Basin, Alberta, Canada. The improved SWAT model shows good behavior, which can be referenced by similar studies.

Melaku et al. (2020) propose a modified SWAT model to couple snow, soil temperature, and carbon dioxide emission. The practicability and feasibility of the modified model are examined by application on the peatland area in the Athabasca River Basin, Canada. The results confirm that the modified SWAT model performs well in representing the dynamics of snow depth, soil temperature, and CO2 emissions.

Lai et al. (2020) establish a forest growth model featuring variable density and mixed vegetation types to handle the limitation of the SWAT model in estimating accumulated biomass. The modified model is validated with the application to field data on the Meijiang River Basin, China. The modified SWAT model outperforms its original model in terms of simulated flow and nutrient load estimations.

Worku Meshesha et al. (2020) augment the modified SWAT-bacteria module by incorporating a pH factor to evaluate the potential effect of pH on E. coli concentrations. With the results of E. coli observations from four sites of the Athabasca River Basin, the modified SWAT-bacteria module could be a powerful tool for the future regional to global scale model of E. coli concentrations.

2.2. Remote sensing and hydrodynamic modeling of surface waters

Investigating large scale hydrosystems requires advancement of remote sensing data processing and modeling capabilities. Presented research in this section focuses on developing methods in this field using large Chinese water systems such as Poyang Lake and Dongting Lake as case studies. From a methodological point of view, the contributions cover processing time series data from high resolution satellites as well as developing new algorithms and numerical high resolution models to better describe hydrodynamic processes in large river-lake systems.

Liang et al. (2020) approach the hydrological influences on wetland cover distribution and transition in a large complex lake–floodplain system, Poyang Lake (China) using time-series satellite remote sensing observations. The results show that hydrological fluctuations have various degrees of impacts on different types of wetland cover transformation.

Liu et al. (2020b) illustrate the dynamic changes in water quantity in Poyang Lake based on HJ-1A/B and Landsat data from 1989 to 2018, and analyzed the influencing factors and ecological impacts of water quantity changes. The results show that in terms of the water area change trend, on the annual scale, the mean values of water area and volume demonstrate overall decreasing trends.

Liu et al. (2020a) investigate the hydrological connectivity with applications in a complex river-lake floodplain of the Poyang Lake floodplain using geostatistical methods in combination with remote sensing data. The results find the apparent seasonal shifts of the dominant hydrological factors that affect the spatial-temporal changes of the hydrological connectivity.

Li et al. (2020b) apply a 2D floodplain hydrodynamic model to investigate the coupled effects of floodplain vegetation on the hydrodynamic patterns of Poyang Lake (China). The model results indicate the interactions between vegetation and hydrology vary with the floodplain seasonality, which provides important knowledge regarding the role of floodplain vegetation changes to decision-makers for both Poyang Lake and other similar flood pulse systems.

Zhao et al. (2020) utilize Landsat thermal infrared imagery to quantify the long-term (2002–2017) impacts of the Danjiangkou Dam (China) on the thermal regimes of downstream Han River. The findings provide new scientific understandings about the long-term seasonal thermal regimes of dammed rivers, which could be applicable to thermal effect investigations for large dams.

Hu et al. (2020) propose a new 1D hydro-environmental model for free-surface flows and scalar transport in large river-lake systems by solving local linear systems based on domain decomposition. This model further implements the OpenMP parallel technique to improve its efficiency. Achieved increases in model performance will help to run flow and scalar transport schemes for large shallow water systems in the future.

2.3. Visualization and data sharing in hydrology

Contributions to this category underpin the need to share and visualize the fast growing amount of data available in hydrology. Presented research not only provides new ideas to standardize and visualize high-dimensional data sets but also focuses on using open source software to ensure transferability of the developed workflows.

Wang et al. (2020) propose a new data sharing strategy for geographic modeling and simulation. In practice, hydrologists are often faced with the problem of data from numerous sources with different formats. The data sharing method relies on a structured data description model rather than raw data files by processing multisource hydrological data in a unified way. A corresponding data configuration manager for customizing data is implemented using Python-based SDK including data publishing services. A built-in data viewer allows for a shareable visualization of multi-source data.

Rink et al. (2020) present a visualization framework for data exploration, analysis and presentation of complex hydrological systems in large catchments. The case study for demonstration is the Poyang Lake Basin. The Virtual Geographic Environment (VGE) combines a wide range of 2D and 3D observation data sets with simulation results from both an OpenGeoSys groundwater model and a COAST2D hydrodynamic model. Methods of scientific visualization are utilized to illustrate various aspects of multi-variate data in intuitive ways. Moreover, interaction techniques for navigation, animation, and access to linked data sets from external sources, such as time series data or websites, are important features for building environmental information systems. The VGE concept is implemented in a generic way and, therefore, transferable and applicable to other regions of interest.

2.4. Wetland ecohydrology

Advancing knowledge of chemical and ecological responses on changing hydrological conditions is central to better predict the impact of water resources development projects and water management systems. The authors contributing research to this section investigate nutrient and water organism dynamics in the wetlands of large Chinese hydrosystems heavily influenced by human interventions.

Bai et al. (2020) investigate the dynamics of phosphorus fractions in surface soils of different flooding wetlands before and after flow-sediment regulation in the Yellow River Estuary based on different types of soil samples for tidal flooding and freshwater restoration, and freshwater flooding wetlands from April to October of 2012. The findings provide the fundamental data for phosphorus fractions and help for guiding flow-sediment regulations and freshwater restoration.

Xie et al. (2020) conduct in-situ experiments to investigate the groundwater vertical flow direction and rate in four zones of salt marsh macrophytes in the Yellow River Estuarine Nature Reserve. The experiments show that the shallow soil water-salt interactions affect the habitat of macrophytes, which form band-shaped macrophyte zones.

Dai et al. (2020) propose a study of the Water Diversion from the

Yangtze River to Lake Taihu in China, which addresses the challenge of identification and quantification of potential contributions of allochthonous inputs and physicochemical habitat shifts to variations in phytoplankton communities.

3. Summary

Modeling and monitoring the complex hydrological behavior in and between large river-lakes systems continues to be a highly relevant topic of hydrological research. The contributions received for this special issue reflect a set of current themes in the field and demonstrate how hydrology on large scales benefits the relentless growth of computational power and the increasing availability of long high-resolution time series of space-borne geospatial datasets. They further emphasize the demand to develop data-processing and visualization workflows capable of analyzing the growing amount of data available for large coupled hydrosystems. We hope that this small selection of examples provides a broad and diverse view of the state-of-the-art research ideas and methods for other hydrologists to improve insight into "their" data and processes.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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