【Grant-in-Aid for Scientific Research (S)】

Broad Section C

Title of Project： Study on global terrestrial hydrodynamics with satellite earth observations

OKI Taikan
The University of Tokyo, School of Engineering, Professor

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Keyword：Hydrology, Satellite observation, Land surface model, Data assimilation, Terrestrial hydrodynamics

【Purpose and Background of the Research】

This project aims to transform the studies on global hydrological cycles, which has been primarily based on numerical modeling in recent years, toward an extensive monitoring of global terrestrial hydrodynamics, by fully integrating emerging earth observations from space. It will reveal detailed spatio-temporal dynamics of the global water cycles and contribute to recognize and mitigate the water-related issues occurring throughout the world.

【Research Methods】

To achieve this goal, we will establish a set of methodologies and combine them as a framework to assimilate the latest satellite observations of terrestrial water bodies and flows into the next-generation global terrestrial model, developed by this research team, to represent complex interactions among terrestrial processes explicitly including anthropogenic interventions. This framework, upon the success of the development, is expected to produce a high-resolution digital space of time-varying water dynamics such as river discharge and surface water topography, by interpolating the coverage of satellite measurements by data assimilation, and to infer water management such as reservoir operations and water consumption that are unmeasurable from space. The system will reproduce global terrestrial hydrodynamics from the past 10 years to near-real-time, with unprecedented accuracy.

Data assimilation method for river and lake models will be developed to generate spatially and temporally continuous river discharge estimates. The CaMa-Flood global river model (Yamazaki et al., 2011, 2014) will be used as a dynamics core, and a novel method recently developed by this research team employing the Ensemble Kalman Filter technique for water level assimilation (Revel et al., 2021), will be extended for water topography and river discharge integration.

Data assimilation method for land and water use model will be developed to estimate variables related to human water uses that are not directly observable from satellite observations. By improving existing modeling components developed by this research team (e.g. H08, Hanasaki et al., 2018) and combining assimilated river discharge together with satellite soil-moisture and gravity anomaly observations, a newly developed inverse algorithm will produce further reliable estimations for reservoir operations, human water intake and consumption.

【Expected Research Achievements and Scientific Significance】

Terrestrial hydrodynamics monitoring information are to be created in this project. “Standard Product” for recent 10 years will be developed as a baseline product of this project. Multiple satellite datasets of surface waters available in the period 2011-2020 (e.g. water extent by Landsat, Sentinel, ALOS; water level by ICESat-2, Jason-1/2) will be assimilated to the river-lake model to develop spatially and temporally continuous river discharge dataset. Further, “Advanced Product” using latest satellite information will be developed. Satellite river discharge data based on SWOT, which is expected to be available around the middle of this project period, will be integrated to the monitoring framework to represent water loss along the river network. Then, the assimilated river discharge as well as soil moisture by AMSR and gravity anomaly by GRACE will be integrated to the land-water use model to estimate hydrological variables that are not directly observed by satellite, such as human water use and reservoir operation.

This project is a pioneering aspirational to establish “hydrodynamics in the Human Geosphere” which reveals various terrestrial hydrodynamics components including human water interventions, by integrating satellite observation and state-of-the-art terrestrial hydrologic models. The global terrestrial water monitoring system to be developed in this project will provide a new benchmark information on hydrology and water resources to establish a dynamic and efficient water resources management strategy instead of a conventional static-decision-based approach. This effort is essential to satisfy the basic demands on water-energy-food nexus, and to achieve “sustainable management of water (SDG6).”

【Publications Relevant to the Project】

・ N Hanasaki, S Yoshikawa, Y Pokhrel, S Kanae: A global hydrological simulation to specify the sources of water used by humans, Hydrology and Earth System Sciences 22 (1), 789-817, 2018
・ M. Revel, D. Ikeshima, D. Yamazaki, S. Kanae: A Framework for Estimating Global-Scale River Discharge by Assimilating Satellite Altimetry, Water Resources Research, 57(1), e2020WR027876, 2021

【Homepage Address and Other Contact Information】

http://hydro.iis.u-tokyo.ac.jp/