様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

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研究課題名（和文）Global inundation area estimation by assimilating multi-sensor satellite observations into a hydrodynamic model

研究課題名（英文）Global inundation area estimation by assimilating multi-sensor satellite observations into a hydrodynamic model

研究代表者

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研究成果の概要（和文）：グローバルな遥感水面分布パターンを分析し、モデルと比較することでその利点と欠点を明らかにしました。植生の高い地域では、遥感データが水面積を低く評価する一方、人間の活動が激しい地域では、モデルが水面のシミュレーションを過大評価しています。遥感データに基づく水力学シミュレーション結果の評価システムを開発しました。流出、遥感水面高度、および遥感水面積を利用し、総合的な評価指標を通じてCaMa-Floodのシミュレーション結果を自動評価しました。遥感データを用いたモデル同化法を開発しました。異なる手法で遥感水面データを同化することで、水力学モデルのシミュレーション精度を改善することができました。

研究成果の学術的意義や社会的意義
Deepening understanding of remote sensing water surfaces and providing new insights into improving models using sensed data. Relevant research is of great significance for improving flood forecasting and defense capabilities, reducing disaster losses, and improving flood prevention measures.

研究成果の概要（英文）：Analyzed the global distribution pattern of remote sensing water surfaces and the advantages and disadvantages by comparing it with models. Results show that in areas with high vegetation coverage, remote sensing data underestimates the water surface area, while in areas with intense human activities, the model overestimates the simulation of water surfaces. Developed an evaluation system for hydrodynamic simulation results based on remote sensing data. By using runoff, remote sensing water surface elevation, and remote sensing water surface area, the system achieves automated evaluation of CaMa-Flood simulation results through comprehensive evaluation metrics. The system can also be extended to compare with results from other models. Preliminarily developed a model assimilation method using remote sensing data. By assimilating remote sensing water surface data in different ways, the simulation accuracy of hydrodynamic models has been improved.

研究分野：水文学

キーワード：Water surface area　Hydrodynamic model　Data assimilation　Model development

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１．研究開始当初の背景

As climate change develops, the frequency of extreme flood events increases, leading to increasing social and economic losses. Flooding, as the most direct cause of disaster, has not been well simulated in model simulations due to the limited ground observation data. Therefore, remote sensing is needed to evaluate the simulated water inundation. However, at the same time, the accuracy and characteristics of remote sensing inundation data have not been fully validated.

２．研究の目的

The aim of the research is to fully understand the characteristics of remote sensing water surface data and to provide support for model validation, calibration, and improvement of simulation results through remote sensing water surface data.

３．研究の方法

The research methods mainly include data comparison and analysis, and the establishment of an automated simulation result evaluation system. In addition, data assimilation methods were applied to leverage the role of remote sensing water surface data.

４．研究成果

1. The study analyzed the global distribution pattern of remote sensing water surfaces and compared it with model simulations, highlighting the advantages and disadvantages of remote sensing data. The analysis found that in areas with high vegetation coverage, remote sensing data tends to underestimate water surface area due to optical sensors' inability to penetrate dense vegetation and detect water surfaces below. In areas with significant human activities, the model tends to overestimate water surface simulation due to human activities' ability to change water bodies' and rivers' morphology and related flood control engineering reducing the possibility of water inundation.

The research has been published as

Zhou, X., Prigent, C., & Yamazaki, D. (2021). Toward Improved Comparisons Between Land-Surface-Water-Area Estimates From a Global River Model and Satellite Observations. *Water Resources Research*, *57*(5), e2020WR029256. https://doi.org/10.1029/2020WR029256

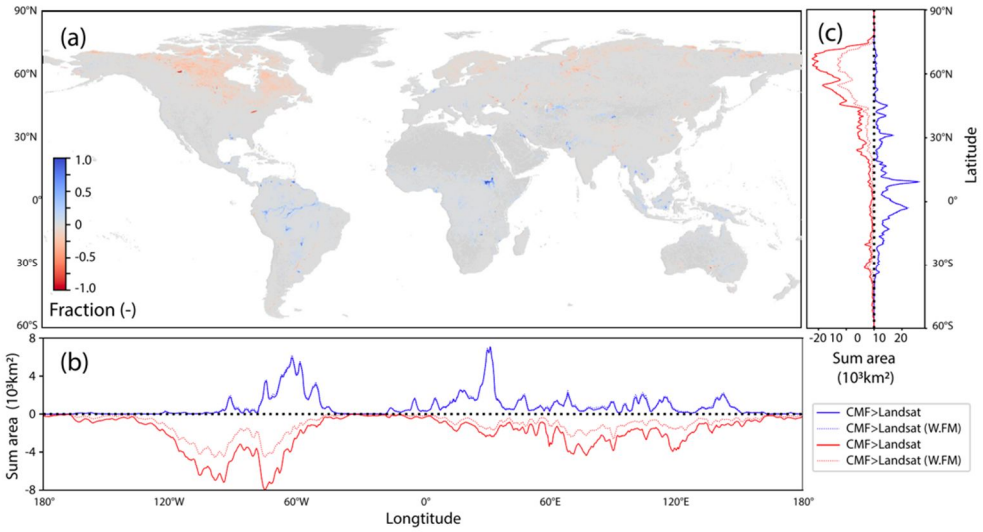

Figure 1. The comparisons between the Landsat remote sensed water surface area and results from CaMa-Flood simulations.

2. The research utilized remote sensing water surface elevation and ground runoff observations, in combination with model calculations and the rating-curve method, to calibrate the river depth parameter of the hydraulic simulation model. This method eliminates the result uncertainty caused by input errors and results in a more robust and reasonable calibration. In the Amazon River basin application, the study found that the rating-curve method reduces uncertainty by 70%, compared to the traditional process line calibration method.

The research has been published as

Zhou, X., Revel, M., Modi, P., Shiozawa, T., & Yamazaki, D. (2022). Correction of River Bathymetry Parameters Using the Stage–Discharge Rating Curve. *Water Resources Research, 58*(4), e2021WR031226. https://doi.org/10.1029/2021WR031226

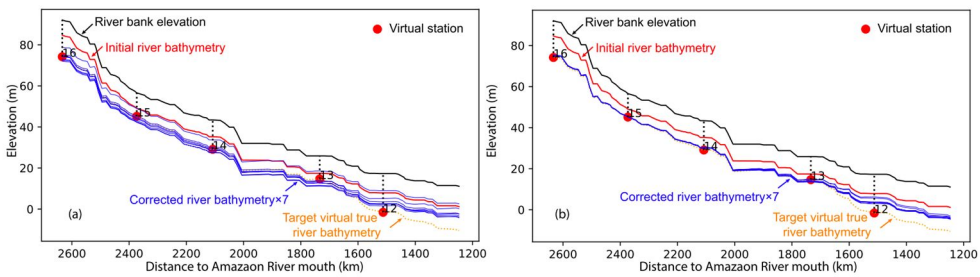

Figure 2. Comparisons of the corrected river bathymetry using the rating-curve method (right) and the conventional method (left)

3. The research developed an evaluation system for hydraulic simulation results based on remote sensing data. By using a comprehensive set of evaluation and comparison indicators that integrate runoff, remote sensing water surface elevation, and water surface area, the system automates the evaluation of CaMa-Flood simulation results and can be extended to compare other model results. This achievement is important in effectively evaluating hydraulic simulation results and provides

strong support for water resource management and hydraulic engineering construction.

The works have been presented in two international conferences:

1. **Zhou, X.,** Revel, M., Modi, P. & Yamazaki, D. A Framework for Benchmarking Global Flood Models, AGU Fall Meeting, 2022 (Oral)
2. **Zhou, X.**, Revel, M., Modi, P. & Yamazaki, D. A framework for benchmarking global flood models. Japanese Association of Hydrological Science (JAHS) Fall meeting. 2022 (Oral)

4. The research also developed preliminary model assimilation methods using remote sensing data. The study improved the accuracy of hydraulic simulation models by assimilating remote sensing water surface data through various methods. The use of remote sensing data for model assimilation can better reflect real-world conditions and enhance model accuracy. This achievement is important in hydraulic engineering construction and water resource management, providing an effective approach to improve hydraulic simulation model accuracy.

The work has been published as

Revel, M., **Zhou, X.,** Yamazaki, D., & Kanae, S. (2023). Assimilation of transformed water surface elevation to improve river discharge estimation in a continental-scale river. *Hydrology and Earth System Sciences*, *27*(3), 647–671. https://doi.org/10.5194/hess-27-647-2023

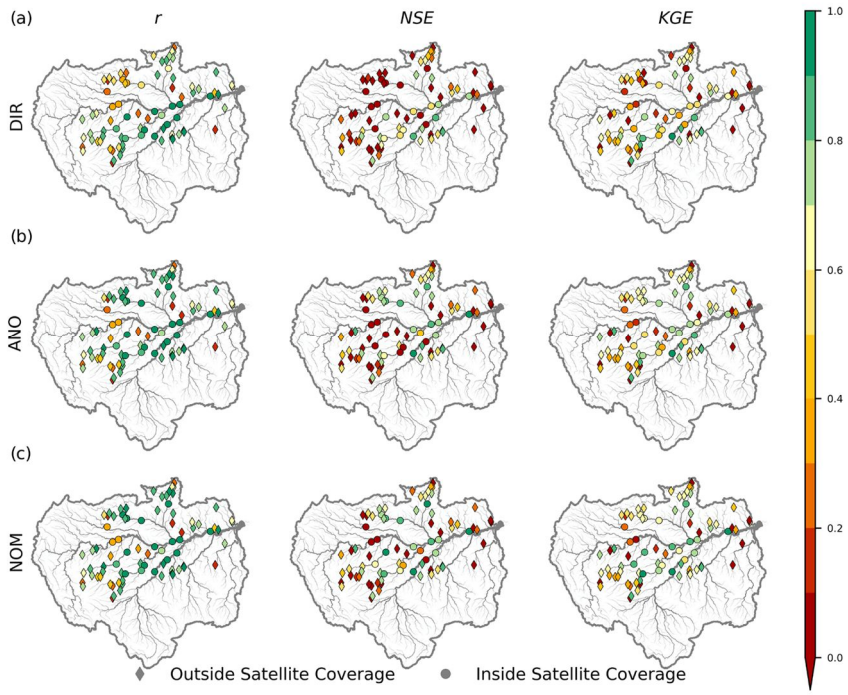

Figure 4. Illustration of model improvement for three groups and different metrics after applying data assimilation

５．主な発表論文等

〔雑誌論文〕　計4件（うち査読付論文　4件／うち国際共著　4件／うちオープンアクセス　4件）

１．著者名 Zhou Xudong、Revel Menaka、Modi Prakat、Shiozawa Takuto、Yamazaki Dai	４．巻 58
２．論文標題 Correction of River Bathymetry Parameters Using the Stage?Discharge Rating Curve	５．発行年 2022年
３．雑誌名 Water Resources Research	６．最初と最後の頁 e2021WR031226
掲載論文のDOI（デジタルオブジェクト識別子） 10.1029/2021WR031226	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Zhou Xudong、Ma Wenchao、Echizenya Wataru、Yamazaki Dai	４．巻 21
２．論文標題 The uncertainty of flood frequency analyses in hydrodynamic model simulations	５．発行年 2021年
３．雑誌名 Natural Hazards and Earth System Sciences	６．最初と最後の頁 1071～1085
掲載論文のDOI（デジタルオブジェクト識別子） 10.5194/nhess-21-1071-2021	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Zhou Xudong、Prigent Catherine、Yamazaki Dai	４．巻 57
２．論文標題 Toward Improved Comparisons Between Land‐Surface‐Water‐Area Estimates From a Global River Model and Satellite Observations	５．発行年 2021年
３．雑誌名 Water Resources Research	６．最初と最後の頁 e2020WR029256
掲載論文のDOI（デジタルオブジェクト識別子） 10.1029/2020WR029256	査読の有無 有
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１．著者名 Revel Menaka、Zhou Xudong、Yamazaki Dai、Kanae Shinjiro	４．巻 27
２．論文標題 Assimilation of transformed water surface elevation to improve river discharge estimation in a continental-scale river	５．発行年 2023年
３．雑誌名 Hydrology and Earth System Sciences	６．最初と最後の頁 647～671
掲載論文のDOI（デジタルオブジェクト識別子） 10.5194/hess-27-647-2023	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

〔学会発表〕　計0件

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関