様　式　C－19、F－19－1、Z－19　(共通)

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研究課題名（和文）Development of high resolution global-flood forecasting system with long lead time

研究課題名（英文）Development of high resolution global-flood forecasting system with long lead time

研究代表者

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研究成果の概要（和文）：本研究は、世界的に深刻化する洪水災害を考慮し、アンサンブル予報の気象強制データを使用して、リアルタイムの全球洪水予報データセットを構築することを目的としています。本プロジェクトは、陸面モデルシステムの進展と水力モデルCama-Floodの進歩に支えられています。グリッドベースの水力モデルは、全球の流域システムを考慮し、世界中の高リスク洪水地域に対して効果的な結果を提供することができます。さらに、世界をリードする気象予報データ提供者として、ECMWFの多データセット気象予報は、本研究にとって重要なデータサポートを提供しています。

研究成果の学術的意義や社会的意義
Flood is the most severe, widespread, and destructive natural disaster threatening human survival. This study combines existing leading meteorological forecast data with hydrodynamic models, providing a valuable research approach for developing flood forecasting methods and technologies.

研究成果の概要（英文）：This study considers the increasingly severe flood disasters worldwide and aims to construct a real-time global flood forecasting dataset using ensemble forecasting meteorological forcing data. The project benefits from land surface modeling systems advancements and the hydrodynamic model Cama-Flood. The grid-based hydrodynamic model can consider global watershed systems and provide effective output results for high-risk flood areas worldwide. Additionally, as a world-leading provider of meteorological forecast data, ECMWF's multi-dataset meteorological forecasts provide crucial data support for this research.

研究分野：Hydrology

キーワード：flood forecasting

様　式　Ｃ－１９、Ｆ－１９－１（共通）

## １．研究開始当初の背景

Floods are one of the most devastating disasters in Japan and worldwide, and their severity is escalating due to global warming. While forecasting meteorological data has advanced significantly in recent years, accurately predicting floods remains challenging. This difficulty arises from the complex terrain features and inherent constraints on forecasting accuracy. This project aims to leverage multiple forecasted meteorological datasets with longer lead times to refine flood predictions to a high resolution. Subsequently, statistical analyses will be conducted to determine the return period and associated risk levels. The ultimate goal is to develop a multisource-based flood forecasting system for issuing more reliable flood warnings. A new synthetic strategy incorporating inputs from multiple meteorological forecasting sources will be devised to achieve this. Ultimately, the multisource-driven flood forecasting system will enable us to accurately predict flood locations with longer lead times, thereby safeguarding lives and property.

This study aims to address the increasingly severe global flood disasters by utilizing meteorological forcing data from ensemble forecasts to construct a real-time global flood forecasting dataset. Supported by advancements in land surface modeling systems and improvements in the hydrological model Cama-Flood, this project endeavors to provide effective outcomes for high-risk flood areas worldwide. The grid-based hydrological model considers basin systems globally, facilitating efficient results for high-risk flood areas worldwide. As a leading provider of meteorological forecast data, the multi-dataset meteorological forecasts from ECMWF offer crucial data support for this research.

## ２．研究の目的

To achieve a high-resolution ensemble forecasted flood forecasting system and its application with longer lead times, this project will develop a world-leading and cost-effective forecasting system for issuing quick and reliable flood warnings. The ECMWF/CMA ensemble meteorological forecasting data is free of charge, allowing forecasts up to one month in advance.

Furthermore, the numerical models proposed in this study include MATSIRO, a well-known land surface model developed in Japan, and the Catchment-based Macro-scale Floodplain model (CaMa-flood), recognized by peers as a leading global hydrodynamic model. This study will yield high-impact modeling findings and be a significant cornerstone in flood forecasting research. Additionally, it will attract comprehensive research attention to various land surface models and ensemble forecasting methods, paving the way for applications in high-resolution flood forecasting and performance enhancement.

## ３．研究の方法

First, we established a data platform to access ensemble forecast data from multiple sources and decode them into an appropriate format for numerical modeling. Subsequently, we constructed a numerical modeling system comprising MATSIRO (a land surface model) and CaMa-flood (a hydrological model). From there, we collected simulated results such as river discharge, river water level, and flood fraction.

Specifically, this flood forecasting system's modeling framework includes MATSIRO, a land surface model, and CaMa-Flood, a global river routing model. River water depths from CaMa-Flood were compared based on their statistical distribution across various return period values. This forecasting system conducts hydrological predictions for all terrestrial rivers, integrated into a model mesh with 0.25-degree resolution.
MATSIRO is a physically based land surface model that analyzes environments consisting of a single-layer canopy, up to three layers of snow at maximum, and six layers of soil. It simulates the vertical movement of water and energy on a global scale. Input atmospheric forcing data include precipitation, temperature, surface pressure, wind speed, and radiation. The runoff output from MATSIRO is used to run CaMa-Flood, the river routing model. CaMa-Flood was initially developed as a global hydrodynamic model to resolve the inertia of local regions. It calculates river discharge of one-dimensional river channels along rectangular riverbeds and trapezoidal floodplains. River networks,

routing directions, and river parameters were calculated from the Digital Elevation Model (DEM) and hydrography dataset (MERIT Hydro) with approximately 0.25-degree horizontal resolution.

Next, we conducted a 10-year historical simulation and performed statistical analyses to estimate the return period for each ensemble member. We derived threshold values for different warning levels based on this historical analysis. Once the long-term return period values were determined, flood warnings were issued for high-risk flood areas. We sought optimal solutions for issuing flood warnings among all ensemble results.

Finally, although the following aspects could not be completed as initially planned, we intend to continue addressing them. We constructed a real-time flood forecasting system utilizing diverse forecast data sources and developed risk-based river maps. The forecasting system was optimized to achieve longer lead times by reducing computational time. Additionally, we conducted risk level analyses for all grids and upstream regions, issuing flood warnings at the location, river, and regional levels. This facilitated swift and reliable decision-making by local governments.

## ４．研究成果

A real-time flood forecasting system based on multiple ECMWF ensembles has been constructed. Considering ensemble values as uncertainties, the ensemble results can provide more reliable forecasting outcomes. Historical runs from 2001 to 2020 were conducted as benchmarks to estimate the database for flood risk. Additionally, based on the constructed database, global flood risks were calculated. As a result, some regions suggest higher risks; however, validation through observations of historical periods is necessary before presenting the results. This task is targeted by searching leading methods, which still need to be fixed due to suboptimal availability and data consistency, such as remote sensing data. However, observation data processing is required because the resolution of CaMa-flood is set at 0.25 degrees. The global-scale flood forecasting system has been completed; however, further data analysis is needed in subsequent work. Additionally, tasks still need to be completed to construct the real-time system. This is due to the time-consuming process of accessing and downloading ECMWF-forcing data. Improvement of the code for decoding forcing data from multiple ensemble members is also necessary. As this research progressed, we encountered the following issues: uncertainty in initial conditions, data uncertainty, and model uncertainty. Specifically, uncertainty in initial conditions, such as precipitation data, soil moisture, and water levels in rivers and reservoirs, significantly impacts the accuracy of flood forecasts. The ensemble forecast meteorological data also contains uncertainty, which introduces uncertainty in using ensemble results. The dataset allows an understanding of ensemble results from the perspective of occurrence probabilities.

For instance, there arises an issue of resolution mismatch in the correction process of surface observation data due to the dataset's spatial resolution being 0.25, which differs from the resolution of the model used in this study. This issue might be addressed in future research by improving the spatial resolution of the model. Additionally, concerning the model itself, the imperfect design of the model and system introduces biases in the results. Furthermore, when coupled with input data uncertainty, it becomes challenging to distinguish the biases in the results. Differentiating between system errors and input errors will also be part of the subsequent work of this research. The follow-up studies of this project will mainly focus on these issues, delve into them in detail in future work, and accumulate valuable experience for the development of flood forecasting systems.

５．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　1件／うちオープンアクセス　1件）

| １．著者名 | ４．巻 |
|---|---|
| Ma Wenchao、Ishitsuka Yuta、Takeshima Akira、Hibino Kenshi、Yamazaki Dai、Yamamoto Kosuke、Kachi Misako、Oki Riko、Oki Taikan、Yoshimura Kei | 11 |
| ２．論文標題 | ５．発行年 |
| Applicability of a nationwide flood forecasting system for Typhoon Hagibis 2019 | 2021年 |
| ３．雑誌名 | ６．最初と最後の頁 |
| Scientific Reports | 1-12 |
| 掲載論文のDOI（デジタルオブジェクト識別子） | 査読の有無 |
| 10.1038/s41598-021-89522-8 | 有 |
| オープンアクセス | 国際共著 |
| オープンアクセスとしている（また、その予定である） | 該当する |

〔学会発表〕　計2件（うち招待講演　0件／うち国際学会　1件）

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| １．発表者名 |
| Wenchao Ma, Yuta Ishitsuka, Akira Takeshima, Kenshi Hibino, Dai Yamazaki, Taikan Oki, Ying- Wen Chen, Masaki Satoh, Kotsuki Shunji, Takemasa Miyoshi, Kosuke Yamamoto, Misako Kachi, Takuji Kubota, Riko Oki, Kei Yoshimura |
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| ３．学会等名 |
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| 馬 文超、石塚 悠太、竹島 晃、日比野 研志、山崎 大、山本 晃輔、可知 美佐子、沖 理子、沖 大幹、芳村 圭 |
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| ３．学会等名 |
| 水文・水資源学会／日本水文科学会　2021年度研究発表会 |
| ４．発表年 |
| 2021年 |

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

| | 氏名<br>（ローマ字氏名）<br>（研究者番号） | 所属研究機関・部局・職<br>（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 |
| --- | --- |