CaMa-Flood developer/user international meeting 2024

5th and 6th July, 2024 (Friday and Saturday)
at the Institute of Industrial Science, The University of Tokyo.

Presentation Abstracts

<Opening Session>

[O0-1] Dai Yamazaki
Institute of Industrial Science, The University of Tokyo

Recent advances and next challenges in global hydrodynamics modelling

I will provide the overall review of the 15 year history of CaMa-Flood development, summarizing the achievements we have made. The review will include both technical developments and applicational studies. Also, I'd like to discuss the future possible directions for further developments.
https://hydro.iis.u-tokyo.ac.jp/~yamadai/CaMa-Flood_v4/

<Session 1: Flood Risk Assessment>

[O1-1] Tobias CONRADT
Potsdam Institute for Climate Impact Research

Application of CaMa-Flood in the Danube River Basin

The Danube is Europe's second largest river regarding length, basin area, and discharge. Its basin covers approximately 800,000 km^2 and overlaps or intersects with no less than 19 countries. Eleven major languages are spoken within that area which poses a challenge to transnational river management, flood protection, and coordinated disaster response.

The European Commission's research and development project DIRECTED aims to enhance climate change adaptation (CCA) and disaster risk reduction (DRR) activities (https://directedproject.eu). The Danube river basin was chosen as one of the real world labs (RWL) of the project.

Within that framework, the author is tasked with the re-establishment of the “Danube model”, a coupling of the eco-hydrological model SWIM with CaMa-Flood. This combination had already been used five years ago for another project, but model codes and data availability have much improved since which called for a thorough overhaul. The “Danube model” is expected to generate river flood scenarios from climate scenario input data for assessing the hazards of extreme floods in the simulations and possible changes of return intervals. As the favoured climate scenario data – EURO-CORDEX downscaled CMIP6 – will not become availabe before 2025, the presentation focuses on challenges in the set-up and calibration of CaMa-Flood v.4.1 using historical weather (E-OBS) and hydrometric data.

Three main exhibits are animations of (1) a failed attempt to run CaMa-Flood again on the irregular subbasins of the runoff generating model (numerical issues probably caused by inconsistencies in their elevation data produce absurdly high runoff in some places, model rivers dry out, etc.) followed by smoothly simulated flood waves based on the 3-arc minute raster distributed with CaMa-Flood; (2) the simulated 1999 flood in the upper, German part of the Danube River whose downscaling correctly showed a flood lake emerging at the town of Neustadt; and (3) the unprecedented 2014 flood in the Croatian part of the Sava river, a major tributary.

This final example illustrates the problem of levees missing from the simulation in level cultural landscapes: Much larger areas than during the real event are constantly flooded in the model, and flood peaks become heavily curbed by their buffering effect. Fortunately, solutions – the levee module and modified downscaling approaches – are currently being developed; see the contributions by Yuki Kita and Gang Zhao.

https://directedproject.eu

[O1-2] Fang Zhao

East China Normal University

Analyzing the Impact of Precipitation Patterns on Historical Mega-Flood Events in the Yangtze River Basin

Catastrophic flood events often result in significant loss of life and property. However, their rare occurrence makes it difficult to fully understand the impact of rainfall patterns on floods and their extent. Studying the characteristics of historical catastrophic floods can inform adaptation strategies for similar events under future climate change. This research focuses on the catastrophic floods of China's Yangtze River basin in 1931, 1954, and 1998. The GSWP3-W5E5 reanalysis climate data and socio-economic data from the Inter-Sectoral Impact Model Intercomparison Project phase 3 (ISIMIP3) are used as inputs for the CWatM hydrological model, which is calibrated with historical discharge data from the main hydrological stations of the Yangtze River. The simulated daily runoff data then drives the CaMa-Flood model to obtain daily discharge and inundation areas during the flood events. Results closely replicate the inundated areas and affected crop areas recorded in historical documents. The study further analyzes the relationship between the GSWP3-W5E5 precipitation data and model-simulated inundation dynamics during these catastrophic floods. Our study offers scientific insights for adapting to future catastrophic floods in the region.

[O1-3] Masahiro ABE[1,2] and Peter Adriaens[1,3]

[1] University of Michigan

[2] Ministry of Land, Infrastructure, Transport and Tourism, Japan

[3] Equarius Risk Analytics

Model Development to Assess Corporate Financial Flood Risks under Climate Change

This research focuses on integrating flood risk impacts on corporate financial metrics at the facility level using geospatial information under climate change scenarios. The work augments the theoretical framework of current models used to predict corporate financial impacts from flooding, by linking financial disclosures and imputed information to climate risk projections. As part of the approach, we seek to combine facility-level locations and corporate finance metrics from a range of financial databases and Aqueduct Floods, a global water risk database with information on floods based on multiple climate models. We test the financial flood risk model on components in the Nikkei 225 index as a use case since these companies have a global presence across multiple climate regimes. Simulated projections will be compared against disclosed corporate data from public reporting, including TCFD (Task Force on Climate-related Financial Disclosures), Japanese government and insurance-based information, if available. The results will allow for repricing of corporate financial vulnerability to flood exposure resulting from climate change, leading to making risk management decisions that offset impacts on capital investments and operations.

[O1-4] Prakat Modi[1], Yukiko Hirabayashi[1], Kiyoharu Kajiyama[2]

[1] Department of Civil Engineering, Shibaura Institute of Technology, Tokyo

[2] Department of Civil and Environmental Engineering, Tokyo Institute of Technology, Tokyo

Impact of Sea Level Rise on Fluvial Flooding on Coastal Mega Cities

Future climate change will increase the global sea level and impact river hydrodynamics, especially on the downstream side. This will impact the total population exposed to fluvial flooding, particularly in coastal cities. The consideration of the sea level in a large-scale hydrodynamic model is necessary to predict the future realistic exposure for adaptation and mitigation measures.

Here, we simulated the global flooding considering the sea level impact using a large-scale hydrodynamic model (catchment-based macroscale floodplain; CaMa-Flood), accounting expansion of the inundation area of low-lying areas due to backwater effects. We simulated the global fluvial flooding for the SSP3-RCP7.0 scenario and found that the average annual maximum inundated area from 2070 to 2100 increased from 20 million sq. km to 20.1 million sq. km, and 1.27 million sq. km to 1.28 million sq. km for flood depths larger than 5m. We also found a large impact of sea level rise due to the backwater effect for coastal cities, suggesting the great impact of the sea level on global flood exposure. It shows the consideration of sea level rise for future flood hazard mapping for reasonable impact assessment.

<Session 2: Real-time Flood Impact Assessment>

[O2-1] Kei Yoshimura & TE Development team

The University of Tokyo

Development of Today's Earth, a real-time global flood forecasting system, and its applications

In the annual average value of economic damage caused by natural disasters worldwide, floods are estimated to account for about one-third of the total economic damage, about 104 billion US dollars, which is about the same as the amount of damage caused by earthquakes. In Japan, the torrential rains in western Japan in 2018 caused 1.1 trillion yen in damage, and Typhoon No. 19 in 2019 (Hagibis) caused 1.8 trillion yen. There is no debate that mitigating damage caused by floods is an extremely important and urgent issue around the world.

Today's Earth (TE) is a global hydrological forecasting simulation system jointly developed by the University of Tokyo and JAXA. TE uses a land surface physical model (MATSIRO) for rainfall-runoff processes and a catchment-based macro-scale floodplain model (CaMa-Flood) for river runoff processes. Real-time meteorological information based on satellite observations, such as precipitation from GSMaP and radiation from MODIS, is used as much as possible to analyze and predict the current state of terrestrial hydrological quantities such as soil moisture, evapotranspiration, and river discharge. Two versions are available: a slightly lower resolution (1/4 degree) global version (TE-Global) and a higher resolution (1/60 degree) Japanese version (TE-Japan). The Japanese version of the flood forecast information is restricted under the provisions of the Meteorological Service Law.

As part of the demonstration study of flood forecasting using TE-Japan, 62 municipalities have received flood forecast information (as of February 2024) and are generally looking to utilize the information in their respective disaster prevention work. According to a survey conducted in March 2021, many municipalities feel that the biggest challenge is "analyzing and deciphering information" during a flood event, and it is hoped that this will help with such challenges.

The use of TE-Japan's flood forecast information by the private sector is also progressing. Such private companies include insurance companies, public transportation companies, energy companies, construction companies, consulting companies, and media companies. The main applications are disaster prevention-related, such as providing disaster prevention information through so-called "disaster prevention apps," assisting in decision-making for business operations during emergencies, and supporting operational planning for flood protection facilities. Future deregulation of flood forecasting is likely to lead to more diverse uses in Japan.

[O2-2] Fitsum Woldemeskel[1], Christoph Rudiger[1], Dai Yamazaki[2], Huqian Zhang[3], Toby Marthews[4], Siyuan Tian[1], Jiawei Hou[1], Wendy Sharples[1], & Chun-Hsu Su[1]

[1] Bureau of Meteorology

[2] The University of Tokyo

[3] Centre for Climate Research Singapore

[4] UK Centre for Ecology & Hydrology

Implementation of CaMa-Flood for seamless hydrological prediction across Australia: progress and challenges

The Australian Bureau of Meteorology provides hydrological forecasts and projections at discrete spatio-temporal scales. As part of their ongoing research and development Program, the Bureau has set out to develop an improved implementation of the UK Met Office's operational land surface model – Joint UK Land Environment Simulator (JULES) – in a whole-of-earth system modelling approach with a specific focus on Australia's unique hydrology and phenology. This approach will facilitate consistent and seamless hydrological reanalysis and prediction capabilities across a wide range of spatio-temporal scales. This presentation discusses the progress we have made towards implementation of CaMa-Flood coupled with JULES (JULES-CaMaFlood) in Australia and some of the challenges that would be of interest to the developers and users of CaMa-Flood. To this end, CaMa-Flood was implemented and tested at both 3-min and 1-min spatial resolution and the simulated streamflow from JULES-CaMaFlood is evaluated at 460 catchments across Australia. Preliminary results suggest that the JULES-CaMaFlood performs reasonably well for perennial catchments while the metrics are generally lower for intermittent and ephemeral catchments. Assessment of simulated streamflow indicate that high model performance is achieved across northern Australia and along its east coast. However, the performance is relatively poor in the western and south-western parts of Australia, possibly due to the non-perennial nature of some of the catchments located in these regions. In terms of CaMa-Flood ancillary, we have made progress in adapting the Bureau's hydrologically conditioned Geofabric DEM for grid-based unit catchment creation together with sensitivity analysis of the global river geometry datasets for Australian river conditions. Some of the challenges and future work include: better representation of river geometry in low lying flat areas and ephemeral catchments; incorporation of diversions and dam operations, particularly when multiple dams are operated jointly.

[O2-3] Yuki Kita & Dai Yamazaki
Institute of Industrial Science, The University of Tokyo

Flood risk reduction effect of levee in a global riverine inundation model

Levees play a crucial role as important infrastructures to mitigate flood hazards worldwide. Over time, the number and standard of levees have been continuously improving to meet the needs of society. However, macro-scale effects of levee protection have not been evaluated precisely because the macro-scale hydrological model cannot simulate the levee protection effect. The global flood model (GFM) CaMa-Flood has developed the levee calculation scheme as well as downscaling function. Real-time flood impact assessments in the absence of levee will overestimate the flood damage. For decision-making of typhoon control, a more realistic risk assessment that takes into account levee flood protection is required. The research objective is to develop a new scheme in which a global hydrological model reflects levee protections and improve the accuracy of a high-resolution inundation simulation by a GFM.

The CaMa-Flood v4.13 has a levee scheme representing a levee protection effect. We assumed levee parameters such as heights and fractions in Japan using construction standards defined by return period of flood. We have simulated the flood inundation occurred in 2019 October in Japan. In addition to the static levee condition, we have developed a levee break module and assumed time length of levee break. The sensitivity experiment showed that the case in which a levee breaks right after the river water overtops levee heights overestimated the inundation compared to the case in which a levee breaks in several hours after the overtopping.

The flood extent should be calculated considering the distance and relative elevation from river channels. The new parameter of floodplain layer considering distance from channel was calculated by using MERIT-Hydro (Yamazaki et al., 2017). Defining protected and unprotected pixel in a high-resolution unit-catchment allowed the CaMa-Flood to downscale flood extent in higher reproducibility with an airplane observation.
We have shown that a GFM considering levees and its breaks improve the flood inundation simulation and the downscaling method can classify protected and unprotected pixels by levees in a high-resolution.

[O2-4] Menaka Revel[1,2], Abdul Moiz[3], Daiki Ikeshima[4], Shinjiro Kanae[4], & Dai Yamazaki[2]

[1] Department of Civil Engineering, University of Waterloo

[2] Institute of Industrial Science, The University of Tokyo

[3] Arizona State University

[4] Tokyo Institute of Technology

CaMa-DA: Global Data Assimilation Framework for CaMa-Flood

Hydrodynamic modeling serves as an essential instrument for comprehending water resources and managing associated risks. However, the complicated nature of hydrological systems and the scarcity of reliable data pose significant challenges to accurate simulation of surface water. Data assimilation techniques provide a solution by assimilating observations into hydrological models, thereby enhancing model precision and lessening uncertainty. The CaMa-Flood Data Assimilation (CaMa-DA) system is a tailor-made framework designed for the CaMa-Flood hydrodynamic model. The CaMa-Flood is a state-of-the-art simulation tool which is employed to examine global river systems. The CaMa-Flood model can diagnose variables such as discharge, water surface elevation (WSE), and water surface area (WSA). Consequently, most observable variables, such as WSE from satellite altimetry and WSA from optical imagery, can be assimilated into CaMa-Flood. The workflow consists of several stages: preparation of physically based adaptive empirical localization parameters, creating runoff perturbations, pre-processing of observations, and data assimilation. The preparation of localization parameters involves standardizing simulations, deriving localization patches using semi-variogram analysis, and calculating localization parameters. The runoff perturbations can be made using different perturbation methods: simple, normal, and lognormal. Observations such as satellite altimetry needs pre-processing for allocating observation locations into the river network. Data assimilation (DA) enables the implementation of several DA methods, namely direct, anomaly, normalized value, and log-transformed value assimilations. Owing to the computational efficiency of the CaMa-Flood model and the physically based adaptive empirical localization methods, the data assimilation is sufficiently efficient for global-scale applications. Despite the current limitations of the model, normalized-value assimilation has demonstrated effective performance in natural river systems, such as the Amazon basin. For more human-influenced basins, such as the Mississippi, anomaly assimilation appears to be more effective. With the advent of new satellite missions, such as SWOT and NISAR, the CaMa-DA holds promise for a more accurate understanding of surface water dynamics.

https://doi.org/10.5194/hess-27-647-2023,

https://doi.org/10.1029/2020WR027876,

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<Session 3: Earth System Coupling>

[O3-1] Zhongwang Wei
Sun Yat-sen University

Development of a Land-River Bidirectionally Coupled Land Surface Model Considering Re-infiltration and Re-evaporation Processes during Flooding

This study presents the development of a bidirectionally coupled model integrating the CoLM land surface model and the CAMA-FLOOD river routing model. The coupled model aims to improve the simulation of flooding processes by considering the re-infiltration and re-evaporation of floodwater. The bidirectional coupling enables the exchange of information between the two models, allowing for a more realistic representation of the feedback mechanisms between the land surface and the river system. We evaluated the performance of the coupled model in simulating flood inundation extent. The results indicate that the new model significantly improves the spatial distribution and temporal variation of flood inundation extent in most cases. However, the model's performance remains unsatisfactory in regions heavily influenced by human activities. Despite this limitation, our model provides an effective tool for accurate flood simulation and thus has the potential to improve flood forecasting, risk assessment, and water resource management.

[O3-2] Sonja FOLWELL, Christopher TAYLOR, & Doug CLARK
UK Centre for Ecology and Hydrology

Improved modelling of Sudd wetland extents in a CaMa-Flood land surface configuration.

Extreme rainfall is driving a rapid expansion of wetlands in East Africa and with it an increase in methane fluxes to the atmosphere. The largest and most complex of these wetland systems is the Sudd which is situated in South Sudan and supplied with water from the Nile River. Land surface models that include a representation of overbank inundation can simulate these systems, yet they tend to underestimate the interannual variability, which is crucial for capturing the correct sensitivity of wetland methane emissions to extreme rainfall events. Two key reasons for this specifically within the Sudd wetland system is a) the role of Lake Victoria in modulating rivers flows on annual and multi-annual timescales and b) the representation of bifurcating channels within wetland itself which control the maximum possible flood extents in neighboring grid boxes or large multi-grid wetlands.
In this study we apply CaMa-Flood at 0.25-degree horizontal resolution forced with gridded runoff from the JULES (Joint UK Land Environment Simulator) land surface model to simulate historical ad observed inundation. We modified CaMa-Flood enabling Lake Victoria outflows to be input as an upper boundary to the CaMa-Flood model, along with runoff fields from JULES and implement bifurcation pathways within the Sudd wetlands. Furthermore, we introduce a loss term that represents the evaporative and infiltration losses across the wetlands. Whilst the

hydrology of the system is complex, with these changes we have improved the ability of the model to simulate the interannual variability in inundation extent. We evaluated the model against inundated fraction estimates using MODIS land surface temperature and altimetry datasets. While we have improved the simulation of the Sudd wetlands, the results highlight the need to incorporate inland wetland bifurcations more widely in land surface configurations as well as developing methods to optimise these.

[O3-3] Muhammad Hasnain Aslam & Kei Yoshimura
Department of Civil Engineering, The University of Tokyo

Enhanced Dynamic Sediment Transport Model to Simulate Global Riverine Sediment Fluxes Incorporating the Impact of In-line Storage Systems

The sediment dynamics not only substantially influence the riverine ecosystem and geomorphological processes shaping our planet but also play an important role in various aspects of earth system modeling. Human intervention in developing critical infrastructures in the form of the construction of dams and reservoirs for various water management purposes largely alters the sediment transport dynamics by blocking the flow of sediment and disturbing the natural equilibrium state of rivers. This study aimed to extend the findings of previous research on the "Development of a global sediment dynamics model", advancing our understanding of the impacts of inline structure on global sediment transfer from land to ocean. We are designing a module that can explicitly handle sediment transport and sediment retention in the reservoirs at finer temporal resolutions and precisely assess the impact of inline infrastructures on downstream sediment transfer. Additionally, we provide enhanced estimations of erosion from highland regions by adjusting the parameters of the erosion model considering various catchment characteristics and using the precipitation forcing. This soil erosion from the land surface is used as an input for sediment transport simulation.

This study aims to provide a base for future research in mitigating the impact of dams on riverine ecosystems and helps in managing water resources on a global scale. We are examining over a thousand large reservoirs contained in the GRanD database representing a significant portion of the global water storage capacity distributed in more than 100 countries. Sediment retention in the reservoir and outflow downstream of the dam body is determined by the trapping efficiency of reservoirs at the simulation time step of less than daily, accommodating the impacts of extreme-flow events on reservoir sediment trapping. Our preliminary estimated sediment concentrations at dam locations and downstream of dams are in line with the observations in CONUS. Our preliminary global estimate of sediment transfer based on the 10-year simulation from 1981 to 1990 including dams' impact is 16.5 Bt/year. The scatter of our simulated sediment flux at river mouths with the observations for the rivers listed in Milliman and Farnsworth (2011) shows a strong correlation coefficient of 0.84, indicating a high alignment of our simulations with the observations.

<Session 4: Computational Efficiency>

[O4-1] Dai Yamazaki

The University of Tokyo

Making CaMa-Flood faster for more complex applications

I will introduce the recent development related to computational efficiency implemented in CaMa-Flood v4.1. Focusing on OpenMP/MPI hybrid parallelization and the Single Precision Mode.

[O4-2] Michel Wortmann, Cinzia Mazzetti, Jasper Denissen, Souhail Boussetta, Gabriele Arduini, Ervin Zsoter, Maliko Tanguy, Christel Prodhomme

European Centre for Medium-range Weather Forecasts (ECMWF)

CaMa-Flood as part of the ECMWF Integrated Forecasting System

The European Centre for Medium-range Weather Forecasts (ECMWF) employs CaMa-Flood as a river routing and flood inundation model in the land-surface model ECland within its Integrated Forecasting System (IFS). The IFS supports a diverse set of global weather, climate, and environmental forecast and reanalysis applications. The integration of river discharge in such system promises a greater consideration of hydrological processes and hazards in numerical weather prediction and derived products.

This contribution provides an overview of recent and planned advancements of integrating and running CaMa-Flood within the IFS. For example, IFS forecasts including CaMa-Flood are run globally at kilometre-scale resolution within the Destination-Earth project. Early results suggest river routing can scale with forecast resolution, with the necessary computing architecture and optimisations. Alongside the integration of CaMa-Flood into the land-surface model, the model code was also upgraded to better calibrate hydrological processes. This will enable better comparisons to discharge and flood inundation observations as well as continuous performance tracking with future upgrades to the IFS.

https://www.mdpi.com/2073-4433/12/6/723

[O4-3] Shengyu KANG[1], Jiabo YIN[1], & Dai YAMAZAKI[2]

[1] Wuhan University

[2] The University of Tokyo

A Computationally-efficient practice for global river hydrodynamic models

The globally recognized CaMa-Flood model, known for simulating rivers on a continental scale, has been a key tool in hydrodynamic modeling over a decade. By clearly representing the stages of flooding, we are able to assess the damage caused by floods in a more explicit way. However, with the increasing refinement of river network maps and the need to conduct experiments across multiple global climate models (GCMs) and scenarios, enhancing computational efficiency has become a crucial challenge. This study offers a computationally efficient method for simulating global river hydrodynamics, employing linear algebra to improve computational speed and facilitate easier deployment on GPUs. Focusing on foundational processes such as river discharge, water budget, and floodplain inundation, the work proposes a method that sidesteps traditional computational bottlenecks by replacing iterative loops with vector and matrix operations. Initial tests on global maps show significant improvements in efficiency, offering a promising practice for refining hydrodynamic models while accommodating complex river network features and flood stage calculations. Moreover, to enhance the adaptability of the model, we propose several improvements in implementing this model. These include reducing the dependency of the computational process on external inputs, particularly beneficial for handling diverse calendars in different netCDF formats; and increasing the I/O buffer to prevent potential bottlenecks as much as possible. This study is dedicated to lowering the entry barrier for the model and deploying it on user-friendly, modern programming languages to facilitate its dissemination and public understanding.

<Session 5: Benchmark & Calibration>

[O5-1] Xudong Zhou[1], Dai Yamazaki[2], Menaka Revel[3], Gang Zhao[4], & Prakat Modi[5]

[1] Ningbo University

[2] Institute of Industrial Science, The University of Tokyo

[3] Department of Civil Engineering, University of Waterloo

[4] School of Environment and Society, Tokyo Institute of Technology

[5] Shibaura Institute of Technology

Benchmark System of Global River Models

We developed a benchmark system for overall evaluation of global river models, which is especially applicable for assessing the simulations from CaMa-Flood. The system incorporates satellite remote sensing data complementing in-situ discharge, including water surface elevation and inundation extent information, therefore, covering larger geographical area compared to using sorely discharge measurements. A set of evaluation and comparison metrics has been developed, including a quantile-based comparison metric that allows for a comprehensive analysis of multiple simulation outputs. The CaMa-Flood developer/user international meeting is a great opportunity to promote the system and a good time to collect feedback from a wide range of potential users. We expect to show some cases relevant to CaMa-Flood development and are looking forward to discussions about the ways for easily usage by others. We hope we can unify the model evaluations and make it possible that all CaMa-Flood simulations can be easily compared among groups.

[O5-2] Dung Trung VU & Dai Yamazaki

Institute of Industrial Science, The University of Tokyo

Improving the performance of flow simulations in mega river deltas by upgrading bifurcation computational scheme in global hydrodynamic model CaMa-Flood

The representation of bifurcation channels in global hydrodynamic models is crucial and can affect the accuracy of simulated flow dynamics, especially in mega river deltas. Therefore, developing and improving computational schemes that can simulate the flow dynamics in bifurcation channels and the interactions between mainstem and bifurcation channels close to reality is necessary. In this study, we try to improve the performance of CaMa-

Flood (Catchment-based Macro-scale Floodplain) model for mega river deltas by upgrading the computational scheme built in the model. Specifically, we use an empirical equation to estimate the parameters of bifurcation channels from their average annual discharge. We test our new scheme on the Mekong River Basin whose downstream delta is an excellent example of deltas with bifurcation channels.

[O5-3] David GUSTAFSSON, Jude MUSUUZA, René CAPELL, Kristina ISBERG, & Jafet ANDERSSON
Swedish Meteorological and Hydrological Institute

Combination of CaMa-Flood and HYPE hydrological model for simulation of Arctic rivers

The Hydrological Predictions for the Environment (HYPE) model is a semi-distributed catchment model for simulations of the flow of water and substances through different storage compartments on land, lakes and rivers to the sea. Pan-arctic and world-wide applications (Stadnyk et al. 2021; Arheimer et al. 2020) have been developed using the GWD-LR dataset (Yamazaki et al. 2014) as a basis for river basin delineation. The more recent MERIT-Hydro data (Yamazaki et al. 2019) is further used for model updates, but so far only over Europe. In all these cases, the catchment delineation was made using in-house software tool (WHIST available from http://hypeweb.smhi.se) and the river discharge is simulated using the semi-empirical routing scheme in the HYPE model.

In this presentation, we will demonstrate the setup of the HYPE model for an arctic river in Sweden, using the gridded sub-basin delineation provided as part of the CaMa-Flood model, which was generated by the FLOW agorithm, and further use of the simulated runoff as input to the CaMa-flood model. The purpose of this activity is on one hand to simplify the setup of gridded applications of the HYPE model, utilizing the MERIT-Hydro data and the FLOW algorithm, and on the other hand, to assess the use of the CaMa-Flood hydro-dynamic model for improved simulation of streamflow and water level in combination with the HYPE model.

Arheimer et al. 2020. Hydrol. Earth Syst. Sci., 24, 535–559.
Stadnyk et al. 2021. Elementa-Science of the Anthropocene 9.
Yamazaki et al. 2014. Water Resour. Res., vol.50, pp.3467-3480, 2014.
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<Session 6: Baseline Data>

[O6-1] **Haoyu Jin, Moyang Liu, Ruida Zhong, & Xiaohong Chen**
Sun Yat-sen University

Spatiotemporal distribution and influencing factors analysis of extreme precipitation in different climate regions around the world

Affected by climate change and human activities, extreme precipitation events have occurred frequently in many places around the world in recent decades. Extreme precipitation is the main factor inducing floods and geological disasters, so extreme precipitation events have attracted wider attention. In this study, we selected climate prediction center (CPC) daily precipitation data from 1979 to 2022 as the research object. First, we analyzed the spatiotemporal variation characteristics of extreme precipitation through multiple extreme precipitation indices. Further, we analyzed the impact of elevation and climate indices on extreme precipitation. Finally, we analyzed the risk changes of extreme precipitation. The results showed that the extreme precipitation attributes reflected by multiple extreme precipitation indices have an increasing trend in most areas of the world. For areas with small extreme precipitation values, the fitting effect of the distribution function is relatively poor. Elevation has a complex impact on extreme precipitation, and extreme precipitation is more likely to occur at appropriate elevations. Areas with small extreme precipitation values are more likely to be affected by a single climate index, while areas with large extreme precipitation values are often affected by multiple climate indices, making the formation of extreme precipitation more complex in these areas. The risk of extreme precipitation also has an increasing trend in most areas of the world, and as precipitation levels increase, the areas where the risk shows an increasing trend increase. This study can provide an important reference for in-depth understanding of extreme precipitation patterns and responses to extreme precipitation events.

[O6-2] **Orie SASAKI[1], Tomoki SAITO[1] Kazuma SHIRAISHI[1], Daiki AKIMOTO[1], Yukiko HIRABAYASHI[2], & Dai YAMAZAKI[3]**
[1] Tokyo Institute of Technology
[2] Shibaura Institute of Technology
[3] University of Tokyo

Integration of river databases in Japan

The global river hydrodynamics model CaMa-Flood utilizes the J-FlowDir dataset, derived from natural elevation data and water maps provided by the Geospatial Information Authority of Japan (GSI), to represent river networks within the Japanese domain. On the other hand, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) maintains its own river network data with MLIT's river IDs. While MLIT's river network data contains valuable information such as river names and the municipalities responsible for their management, utilizing this information for improving the CaMa-Flood and analyzing its results often requires significant effort to check the corresponding rivers. Therefore, this study aims to integrate information from these disparate data sources to provide users with unified access to the river database. Specifically, we conducted a process to link MLIT's river data to grids within J-FlowDir with a drainage area of over 1 km, facilitating the creation of a comprehensive

database. This database enables the identification of which rivers and municipalities each grid in J-FlowDir belongs to. Additionally, users of MLIT's river network data are provided instant access to information such as flow directions and drainage areas for the rivers represented in J-FlowDir. This database enables the identification of the rivers and municipalities associated with each grid in J-FlowDir. Furthermore, users of MLIT's river network data gain immediate access to information such as flow directions and drainage areas for the rivers represented in J-FlowDir. Further integration with observation databases could make easier the utilization of observational data for the calibration and validation of river models.

[O6-3] Peirong LIN, Zimin YUAN, Jie XU, & Ziyun Yin
Peking University

Variations of river channel hydraulic geometry and its implications to global river modeling

Channel geometry and hydraulics characteristics is fundamental in river modeling. Despite a wide variety of river geomorphologies that exist in nature, representation of channel geometry in river models is often oversimplified, owing to our limited understanding of spatial variability of global river geomorphology. At-a-station hydraulic geometry (AHG) depicts the temporal response of river hydraulic parameters to changing river discharge in the form of power functions, which has been found to be closely related to channel geometry in previous studies. AHG exponents are identified as the key to understanding spatial variability, however, most studies acquired data through field measurements, which confined AHG investigations at limited locations and at cross-sectional scales, leaving variations in the AHG exponent largely unexplained.

To bridge the knowledge gap, this study leverages the frontier of remote sensing to more thoroughly assess the width-discharge AHG relationship at a global scale. By pairing multi-temporal river width data extracted from 1.19 million Landsat images and discharge observations from > 17,000 gauging stations, we first obtain > 1000 samples to assess the spatial distribution of exponent b worldwide. Then, we assess b variations against channel patterns and over 200 hydro-environmental factors to understand what drives variations in b. The results show that the statistical distribution of exponent b has a median value of 0.213, comparable to that obtained from large-sample field-based data. Among the examined factors, soil composition, forest cover extent, and precipitation better explain variations in exponent b. In terms of channel pattern, braided channels have distinctly higher median of b than others, followed by straight, anabranching and meandering channels. Nonetheless, the combined effect of numerous factors makes it difficult to be well predicted at the global scale. This study sets a foundation for AHG studies in ungauged regions using satellite remote sensing, which not only contributes to expanding global hydraulic data inventory but also helps to enhance the understanding of the spatial variability of global river geomorphology in large scale river modeling.

<Session 7: Flood Protection Modelling>

[O7-1] Gang Zhao[1] & Dai Yamazaki[2]
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[2] The University of Tokyo

The newly developed levee module in the CaMa-Flood model

In this research, I will present the newly developed levee module within the CaMa-Flood model and demonstrate how to operate this module to achieve global simulation.

[O7-2] Mizuki FUNATO & Dai Yamazaki
The University of Tokyo

Development of a Modified Reservoir Operation Scheme for Improved Global Flood Modeling

Global river models play a crucial role in simulating and forecasting floods, especially in regions lacking dedicated flood forecasting systems. Reservoir operations significantly influence the simulated flow within these models, impacting forecast accuracy. In this study, we modified a reservoir operation system developed by Hanazaki et al. (Hanazaki, Yamazaki, & Yoshimura, 2022) to integrate into the CaMa-Flood global hydrodynamic model.

The modified system incorporates three key alterations. Firstly, the formula was adjusted to increase pre-flood water release while reducing the number of required parameters. Additionally, modifications were made to ensure smooth discharge transitions before and after normal volume changes, eliminating discontinuities. Furthermore, the normal discharge of each dam was recalibrated based on water use capacity and non-flood period inflow, rather than relying solely on annual mean discharge.

To evaluate the effectiveness of the proposed dam operation scheme, we conducted a case study involving 85 dams along the Mekong River basin. For the case study, there were three separate analyses conducted. Each analysis compared the newly proposed dam operation scheme to one lacking one of the modifications, while the remaining two modifications remained consistent with the proposed scheme.

By increasing the amount of water released prior to a flood event, it was observed to reduce the instances of dams exceeding their normal outflow during non-flood periods. In addition, the modification of the formula to ensure continuity in discharge rates before and after normal volume, has led to enhanced stability in dam discharge, effectively mitigating fluctuations in discharge levels. Furthermore, by altering the normal discharge of each dam to be based on the water use capacity and the inflow of the non-flood period, rather than the annual mean discharge, it has made it possible to better maintain normal outflow during non-flood periods.

Overall, the improved dam operation scheme holds promise for enhancing the accuracy of global flood simulation and forecasting within global river models.

[O7-3] Faizal Immaddudin Wira Rohmat & Arno Adi KUNTORO
Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia

Optimizing Flood Control Reservoir Operations in the Citarum Watershed: A Reinforcement Learning

Approach

The Citarum Watershed, located on the island of Java, Indonesia, is one of the most challenging watersheds in Indonesia. The watershed's average annual discharge is 423 m^3/s, serving the 28 million people in the 6900 km^2 area. In addition to that, the watershed supplies water to the Jakarta Capital Region, an expansive irrigation area in the north flatland of the West Java area, and hydropower for the Java-Bali-Madura electrical grid that serves 150 million of the 270 million Indonesia's population. With its growing population, the watershed faces substantial challenges, including the strain on water quantity availability, water quality issues, and flood challenges. The floods happen throughout the watershed, with more frequent occurrences in the relatively flat Upper Citarum Watershed (UCW) and the Lower Citarum Watershed (LCW) areas. On the other hand, the Middle Citarum Watershed (MCW) does not pose much flood risk for its steeper terrains.

The UCW faces severe flooding exacerbated by rapid urbanization, deforestation, and changing precipitation patterns. The Bandung Metropolitan Area (BMA), initially designed for half a million inhabitants, now accommodates seventeen times that number due to explosive urban growth. This expansion replaced vast forest and agricultural lands with impermeable urban surfaces, altering hydrological dynamics and intensifying flood risks by accelerating surface runoff. Deforestation further exacerbates flooding by disrupting the natural hydrological cycle and reducing the watershed's capacity to regulate water flow. Climate change-driven shifts in precipitation patterns add complexity to flood dynamics, compounding challenges for flood management efforts. Additionally, excessive groundwater extraction, unmanaged land cover change, and inadequate water infrastructure amplify flood vulnerabilities in the UCW.

In response to the flood challenges faced by the UCW, a strategy involving the construction of five upstream flood control reservoirs has been proposed. Of these, four reservoirs have been integrated into the long-term plan for the watershed, indicating a commitment to proactive flood mitigation measures. The decision to incorporate these reservoirs into the plan is informed by comprehensive prior assessments of flood risk and hydrological dynamics within the watershed. Additionally, one additional reservoir has been proposed based on recent findings from a flood control study, highlighting the ongoing efforts to refine and optimize flood management strategies. While the locations of the five proposed reservoirs have been determined, the specifics of their design and operational rules remain open for further refinement. This study focuses on optimizing the dimensions and operational rules of one of the proposed reservoirs with the aim of maximizing its effectiveness in reducing flood extent within the UCW.

This study proposes using a reinforcement learning (RL) approach to learn the optimal reservoir operating rule that minimizes flood extent while adhering to operational constraints and objectives. The RL agent interacts with the coupled reservoir-CaMa-Flood model to dynamically adjust reservoir release decisions based on hydrological conditions, historical data, and predefined performance metrics. The considered design decision factors, such as reservoir storage capacity, inflow variability, downstream flood risk, and environmental considerations, can be included in the RL optimization process. The Q-learning technique can be used for the RL algorithm.

The concept proposed to demonstrate the effectiveness of the RL-based approach in learning adaptive reservoir operating rules that significantly reduce flood extent while maintaining operational efficiency and other constraint considerations. The proposed methodology offers a data-driven and adaptive solution for optimizing single-purpose reservoir operations for flood mitigation in complex river basins, contributing to more resilient and sustainable water resource management practices in flood-prone regions.

[O7-4] Youjiang SHEN & Dai Yamazaki
The University of Tokyo

CaMa-Flood-Dam-Module
We enhanced representation of reservoir managements in Global Flood Model CaMa-Flood.

<Poster Session>

[P-1] Shuping LI & Dai Yamazaki
Department of Civil Engineering, The University of Tokyo

Representing hillslope-scale land surface heterogeneity in land surface model substantially modulates water and energy budget

In the past decade, the process of hillslope water dynamics has been resolved in some land surface models to advance the representation of hydrological cycle. It shows the horizontal transportation of water can largely modulate the terrestrial water and energy budget (e.g., evapotranspiration). Although the hillslope water dynamics is represented, the complex land surface conditions (e.g., land cover type and topography) were less addressed and treated as homogeneous, despite its direct control on the water and energy fluxes. How land surface conditions interfere with hillslope water dynamics, and to what extents it modulates land surface process remain unclear. For this purpose, this study investigates the impact of explicitly representing land surface conditions on water and energy budgets. To resolve the hillslope water dynamics and represent the heterogeneous land surface conditions, a sub-grid approach named catchment-based strategy is implemented into the land surface model MATSIRO. Through a series of experimental settings where different land surface conditions are adopted, the impact of representing land surface heterogeneity is evaluated over the African continent, following a catchment-scale analysis that exemplifies the spatial gradient of water and energy. Results show that, at the catchment scale, using the catchment-based strategy can effectively simulate the gradients of soil moisture, runoff generation, latent and sensible heat flux along hillslope. Compared to the conventional tile scheme, representing land cover heterogeneity by hillslope gradient could reveal the spatial heterogeneity in water and energy. At the continental scale of Africa, in addition to the representation of hillslope water dynamics, addressing land cover and topographic heterogeneities has resulted in greater water and energy gradients, especially near the equatorial part of Africa. Importantly, the resolution of land surface heterogeneity has led to variations in the magnitude of energy and water budget over substantial areas. Overall, this research resolves the land surface heterogeneity in land surface model and underscores its significant impact in modulating the water and energy budgets.

10.1029/2023WR036214

[P-2] **Yang Hu[1], Dai Yamazaki[1], Xudong Zhou[2], & Gang Zhao[3]**
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[2] Ningbo University
[3] School of Environment and Society, Tokyo Institute of Technology

A new perspective of assessing flood impact with daily nighttime light remote sensing data

Flooding leads to disastrous impacts on human society and activities worldwide, including damage to physical assets and interruptions to daily activities. However, evaluation for such impacts remains challenging, particularly beyond inundation zones, due to the difficulties in monitoring human activities on a global scale. Nighttime light (NTL) remote sensing data provides a unique perspective for human activities on a large scale, reflecting variations in light intensity caused by flood impact. Here we show the possibility of using a high-quality NTL dataset to assess flood impact on human society and activities. Indices providing impact severity and duration were generated with NTL as proxies for flood impact on pixel scale. Results show the consistency of NTL-derived and reported impact duration for five selected cases, which confirms the reliability of NTL flood impact. A large portion (> 96%) of NTL-based affected areas did not overlap with the satellite-based inundation area for 99 cases in 2013, indicating the unique value of NTL in assessing flood impact beyond inundation. The NTL flood impact indices were mapped at 15 arc-second spatial resolution for 876 events on a global scale from 2013 to 2021. Then, administrative-level characteristics of NTL flood impact were compared at a global scale. It was found that lower developed regions exhibit higher vulnerability and challenge in recovery and are more likely to experience extremely serious and long-lasting impacts compared to higher developed areas. Overall, using NTL data, in addition to conventional inundation-based methods, offers an innovative perspective on flood impact evaluation.

[P-3] **Kinza Khan & Dai Yamazaki**
Institute of Industrial Science, The University of Tokyo

How Much Flood Impact Can Be Mitigated By Infrastructure (Case Study Pakistan Flood 2022)

Floods are one of the most common recurring disasters which affect a region socially and economically. During recent times, climate change has become crisis all over the world leading to more severe flash floods. Pakistan faced the consequence of this situation as evidenced by the 2022 flood. In order to mitigate the consequences of any future flood similar to 2022 flood, this study investigates the possibilities of implementing effective infrastructure. We will analyze various infrastructure schemes using CaMa flood to check their effectiveness in mitigating flood hazards. We will mainly focus on dams and levees, assessing their impact on flood extent, depth, and duration. Through strategic development of the infrastructure, we aim to quantify the potential reduction in flood severity with the help of comprehensive review of existing literature and data analysis. The findings of this study help the management authorities of Pakistan to make crucial decisions regarding infrastructure development for future flood mitigation Through this research, we will showcase the importance of infrastructure

in reducing the impacts of floods in this region.

[P-4] Riaz Muhammad Shiraz
The University of Tokyo

Flood Zoning Map for Risk Mitigation in Pakistan

In the effort of mitigating the impacts of disastrous floods experienced by Pakistan in the previous years specially in 2010 and 2022, flood zoning mapping plays an important role. In 2010 heavy rainfall caused flash and riverine floods in north and north-western regions of Pakistan that create a moving body of water. In 2022 the flood was fueled by extreme precipitation in Sindh and Baluchistan due to climate change. This study focuses on flood zoning mapping techniques particularly their application to return period analysis in the data limited region for the improvement in the flood risk assessment and strategic disaster management in Pakistan. Different types of methods and their results are assessed through effective literature review which mainly discusses effective flood maps. Furthermore, ongoing research for Sindh, a region of Pakistan is shown where runoff will be estimated with H08 model which includes human withdrawal effect and flood inundation maps will be generated with CaMa-Flood model. With the help of CaMa-flood model the inundation maps are created incorporating different return periods (5, 10, 50, 100 years). This research helps in creating effective flood zoning maps which can be utilized for flood risk mitigation.

[P-5] Dhruv Sehgal & Dai Yamazaki
Institute of Industrial Science, The University of Tokyo

Understanding the Impact of River Sediment Outflow on Coastal Oceans

Rivers serve as vital conduits, transporting sediment and nutrients from terrestrial landscapes to coastal oceans. In global-scale river studies, this process plays a significant role in shaping the hydrodynamics and ecosystems of coastal regions. However, the interactions between river discharge, sediment transport, nutrient flux, and their impacts on coastal oceans remain insufficiently understood. This research aims to address this knowledge gap by investigating the dynamics of sediment and nutrient outflow from rivers in Japan and its broader implications for coastal ocean systems in the world. The primary objective of this project is to estimate the sediment and nutrient outflow from terrestrial areas during periods of heavy discharge. Utilizing advanced numerical modeling techniques, such as the CaMa-Flood model, we aim to quantify the magnitude and spatial distribution of sediment and nutrient transport from rivers to coastal oceans. By integrating data on river discharge, soil erosion, land use patterns, and precipitation, we seek to develop a comprehensive understanding of the dynamics driving sediment and nutrient fluxes in the study area. This will be achieved through a combination of field observations, remote sensing data, and numerical simulations, and ultimately characterize the complex interactions between river discharge, sediment transport, and oceanic processes. In summary, this project seeks to address the following research question: How do large-scale runoff events from terrestrial areas impact the hydrodynamics and ecosystems of coastal oceans through the supply of freshwater, sediment, and nutrient elements? This research aims to advance our scientific knowledge on riverine and coastal sediment management strategies.

[P-6] Kota ISHIDA & Dai Yamazaki
Institute of Industrial Science, The University of Tokyo

Estimating Suspended Sediment Concentration in global river from Satellite Image and Confluence Budget Method

Rivers play an important role in the global circulation of nutrients and transports organic carbon to the ocean. Some of these organic carbon and nutrients are transported attached to suspended sediment. Therefore, it is essential to understand the sediment dynamics of global rivers to elucidate the global carbon cycle.

On the other hand, in-situ suspended sediment concentration (SSC) observations are expensive, and the number of observation points is decreasing. To compensate for the lack of observations, attempts have been made in recent years to estimate SSC using bio-optical models or regression analysis, from satellite-observed reflectance of the water surface. However, it is inappropriate to apply the equations obtained for one river to the entire globe due to the difference of parameters from river to river. For this reason, few previous studies, which are regression analyses based on in-situ observations, have attempted to apply them globally.

In this study, we developed an algorithm to estimate sediment concentration from satellite images without requiring in-situ SSC observations.

First, sediment particle size distribution is assumed for each river as a Junge function, and SSC is determined using Mie scattering theory and a simplified bio-optical model. To reduce the unknown parameters in bio-optical model, the bio-optical model at near-infrared wavelength is approximated to consist only of water and sediment for rivers with high SSC, since sediment backscattering and water absorption are dominant at near-infrared wavelengths compared with other constituents such as colored dissolved organic matter and chlorophyll.

Next, the sediment particle size distribution is estimated from minimizing the difference of upstream sediment flux and the downstream flux at the confluence of the rivers. Assuming that the sediment grain size distribution is stationary in each river, the grain size distribution and SSC is determined.

This method can be used to estimate SSC in rivers with high-SSC without field observations.

[P-7] Cao Vu Quynh Anh & Kei Yoshimura
Institute of Industrial Science, The University of Tokyo

Current status and Challenges in Operating Flood Early Warning Systems at the local level in Japan

Flood early warning systems (FEWS) are crucial in reducing flood loss and damage, especially under increasing flood risks due to climate change. Currently, there are limited literature investigating all components of FEWS, namely Risk knowledge, Monitoring and forecasting, Warning dissemination, and Preparedness and Response Capabilities. There also lacks in-depth understanding of FEWS operation at the local level, where local governments play a crucial role. Hence, this study conducted a nation-wide survey targeting Japanese municipalities (n=350) to investigate the current status and challenges of FEWS operations at the local level, and the relationships between these elements. The results indicated that while progress in FEWS operation varies in municipalities, they are encountering different challenges in each element of the system. These include the lack of human resources, difficulties in risk assessment and data acquisition, the lack of financial resources, limitations of disseminations mean to reach vulnerable, and how to understand and raise public perception. Overall, all key elements of FEWS positively correlated. Path analysis results indicated the significant role of vulnerability assessment that integrate socio-economic changes, and warning dissemination in improving preparedness and response capabilities at the local level. This study is the first to investigate all four key elements of FEWS at the local level and relationships of its key factors, providing detailed insights into various challenges that municipalities in Japan are encountering, which are useful for policy directions to enhance FEWS implementation.

[P-8] Swarup Dangar & Dai Yamazaki
Institute of Industrial Science, The University of Tokyo

Improving CaMa flood model simulations with remote sensing

Hydrodynamic models commonly rely on in situ observations for parameter calibration. However, this approach becomes challenging when such observations are unavailable. Accurate monitoring of river water surface elevation (WSE) is crucial for calibrating hydrodynamic models, especially in regions lacking sufficient gauge data. Moreover, achieving high accuracy in simulation of one variable like water depth does not necessarily ensure the same for other hydrodynamic variables like water slope and flooded area, introducing uncertainties in predictions. To address these limitations, we utilized remote sensing data products to devise parameter calibration schemes across large basins globally.

We retrieved river WSE using ICESat-2 derived model parameters to enhance model calibration. This approach can adjust the channel Manning coefficient, riverbed elevation, and cross-sectional shape in the model. The WSE obtained offers high spatiotemporal resolution, particularly in narrower rivers compared to WSE derived from altimetry measurements. Furthermore, the model calibrated using the retrieved WSE improves simulation performance and flood extent in validation. The study demonstrates the capabilities of ICESat-2 having a wider spatial coverage for retrieving river levels, and to precisely gauge rivers, even just a few meters wide. This research can serve as a performance benchmark for models while also providing valuable insights into limitations and sensitivity of parameters.

[P-9] Daisuke Tokuda[1], Hyungjun Kim[2], Dai Yamazaki[3], & Taikan Oki[3]
[1] George Mason University
[2] Korea Advanced Institute of Science & Technology (KAIST)
[3] The University of Tokyo

Development and validation of a coupled simulation framework representing the hydro- and

thermodynamics in rivers and lakes (TCHOIR)

The water budget is governed by both horizontal riverine inflows and outflows and vertical fluxes (precipitation and evaporation). Evaporation is closely related to the heat balance of the water body. Therefore, it is necessary to solve the (a) hydro- and (b) thermodynamics of (1) rivers and (2) lakes to express the lacustrine water budget. This study proposes a coupled simulation framework of (1) river and (2) lake models representing (a) hydro- and (b) thermodynamics, the Tightly Coupled Framework for Hydrology of Open Water Interactions in River-Lake Networks (TCHOIR). This framework improves the FLOW method, allowing the explicit spatial allocation of river and lake grids by upscaling high-resolution topography and lake datasets. The riverine hydrodynamics (1-a) are solved using CaMa-Flood, while this study newly implements models to represent riverine thermodynamics (1-b) and lacustrine hydro- and thermodynamics (2-a and 2-b). The TCHOIR coupler conserves mass and energy in the entire model system and represents lacustrine inflows and outflows driven by water surface elevation by exchanging the variables between the river and lake models at each timestep. TCHOIR is validated on a global scale for river discharge (1-a), river water temperature (1-b), lake surface elevation (2-a), and lake surface temperature (2-b) using in-situ observation data and satellite-based products. The results indicate that coupling the models to represent the interactions between rivers and lakes improves reproducibility compared with the uncoupled model. Notably, TCHOIR is unprecedented in reproducing the absolute value and seasonal variability of lake surface elevation. Further studies are expected to implement a dam operation model at the lake outlets to evaluate the anthropogenic impacts on water resource quantity and water quality downstream.

[P-10] Isatama Windarto

Institute of Industrial Science, The University of Tokyo

Ensemble Damage Assessment Based on Forecasted Flood Extension and Building Asset Map For Extreme Typhoon Event: Case of Typhoon Hagibis 2019

The severe floods caused by typhoons like Hagibis have damaged homes extensively in Japan. Therefore, it is crucial to improve the damage assessment in flood forecasting systems considering the damage and the impact of global warming. This study focuses on modeling an Ensemble Forecasted Flood Damage Assessment on Buildings using The Integrated Land Simulator (ILS) and a Depth-Damage Curve with a 39-H MEPS dataset and Building Assets Mesh Map: Case of Typhoon Hagibis 2019.

[P-11] Xiaoyang Li[1], Kei Yoshimura[1] & Hironori Fudeyasu[2]

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[2] College of Education, Institute of Advanced Sciences, Yokohama National University

Impact-based forecasting for typhoon Hagibis using the ILS with weather control experiments

Typhoon Hagibis, one of the most powerful storms to strike Japan in recent years, caused widespread flooding and significant damage. Impact-based forecasting is essential for planning effective mitigation measures and improving future responses. This study employs weather control experiments using the Integrated Land

Simulator (ILS) to evaluate the flood damage induced by Typhoon Hagibis. The objective is to assess the flood impact in Japan resulting from different potential tracks of Typhoon Hagibis.

The Weather Research & Forecasting Model (WRF) was utilized to investigate the effect of the early-stage location of Hagibis on its subsequent track. The initial position of Hagibis was shifted 2 and 4 degrees eastward (designated as e020 and e040) and westward (designated as w020 and w040) from the original position (c000), respectively. The ILS, which includes the MATSIRO and CaMa-Flood models, was then used to simulate the flood area and floodplain water depth for these five typhoon tracks. The simulations were conducted from October 10 to 15, 2019, with a horizontal resolution of approximately 2 km (1 minute). The results, combined with household distribution and house asset data from the Census, were used for impact-based forecasting.

The original route (c000) resulted in the greatest flood damage. When Hagibis' route shifted westward, the total damage across Japan decreased, but damage in southwest Japan increased. Conversely, when Hagibis' route shifted eastward, flood damage decreased across Japan and within each sub-region. This study underscores the significance of the initial positioning of typhoons on flood damage outcomes. By simulating different typhoon tracks using the ILS and WRF models, we can enhance our understanding of the potential impacts of such events and improve disaster preparedness and mitigation strategies.

Our results indicated an overestimation of flood damage compared to Census data. This overestimation highlights the need for refinement in our assessment methods. Moving forward, we aim to improve our impact-based forecasting by refining our assessment techniques and integrating additional flood defense mechanisms, such as levee and dam schemes, into the CaMa-Flood model. These enhancements will contribute to the development of more accurate and reliable impact-based forecasts, ultimately aiding in better disaster management and response planning.

[P-12] Yuting Zhu [1,2], Kei Yoshimura [2], Xiaoqing Wang [1]

[1] School of Electronics and Communication Engineering, Sun Yat-sen University

[2] Institute of Industrial Science, The University of Tokyo

Probabilistic Fusion of Satellite Data and Hydrological Simulation for Flood Detection.

Flood detection using Synthetic Aperture Radar (SAR) data provides high spatial resolution monitoring but often suffers from noise and uncertainty. Hydrological simulations, such as those produced by Camaflood, offer comprehensive flood forecasts but may lack real-time accuracy. This study presents a novel probabilistic approach to flood detection by integrating SAR data with hydrological simulations through Bayesian inference. By treating the output of Camaflood as prior probabilities and SAR-derived backscatter values as conditional probabilities, we compute the posterior probabilities of flooding. This method combines the strengths of both datasets, offering improved detection accuracy and robustness. Preliminary results demonstrate the method’s potential in accurately mapping flood extents, highlighting its value for real-time flood monitoring and disaster response. Future work will focus on validating this approach across different geographic regions and refining the model to accommodate varying hydrological conditions.

[P-13] **Yingying LIU & Kei YOSHIMURA**
Institute of Industrial Science, The University of Tokyo

Title: Develop Online Data Assimilation Module in CaMa-Flood Model with in-situ Observations to Improve Stream Forecasts in Japan

Floods are one of the most important natural disasters in Japan, causing considerable economic and human losses annually. Reliable realtime flood forecasting is critical for flood protection in Japan. Here, we plan to develop a real-time online data assimilation (DA) module within the CaMa-Flood model to improve stream forecasts and enhance the accuracy of flood extent and flood timing predictions. First, we performed an observing system simulation experiment (OSSE) to test the data assimilation framework. Then we conducted a case study on Typhoon Hagibis to assess the DA effect. We use 95% in-situ observations from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) dataset for assimilation and 5% for validation. The results showed that the normalized root mean square error (NRMSE) of peak flow extent improved in 57% of the stations. However, the improvement in the timing of peak flow was limited. Future research will explore additional methods to enhance the timing accuracy of peak flow predictions.

[P-14] **Toby R. MARTHEWS[1], Douglas B. CLARK[1], Simon J. DADSON[2], & Dai YAMAZAKI[3]**
[1] UK Centre for Ecology & Hydrology
[2] University of Oxford
[3] University of Tokyo

Inundation in JULES-Camaflood and the CHAMFER project

During 2021-24, the Hydro-JULES project has been working in the UK and internationally to help produce next generation land-surface and hydrological predictions. As part of this process, we have been testing, using and modifying the CaMa-Flood code in order to combine it with the code base of the Land Surface Model JULES (Joint UK Land Environment Simulator). Using tropical wetlands as a regional-scale testbed for hydrological dynamics, we have been testing the performance of JULES-Camaflood (a combination of JULES and CaMa-Flood), seeking ways to improve current estimates of the water balance and water dynamics of these large wetlands. Results show a close, but not perfect, match between predicted dynamics and data drawn from global inundation products. Investigating where the model predictions match - and do not match - to observational datasets, we can give strong indications of where greater developments are required, which we believe will lead to practical improvements in the representation of hydrological dynamics in global distributed models.
https://hydro-jules.org/

[P-15] **Sujeet Desai[1], Yadu Pokhrel[2], Amar Deep Tiwari[2], & Huy Dang[2]**
[1] ICAR-Central Coastal Agricultural Research Institute, Goa, India

[2] Michigan State University, East Lansing, Michigan, United States

Flood susceptibility modelling in the west coast river basins of India using a global hydrodynamic model

Climate change is altering the hydrological cycle of coastal river basins due to changes in monsoon patterns. The agriculture of the west coast region of India is highly vulnerable to flooding due to an increase in extreme rainfall events and coastal inundation. Understanding the distribution of floods geographically and their likelihood of occurrence is extremely important for identifying the vulnerable areas for risk reduction, planning adaptation measures, and management of floods. In this study, we present the application of a global scale hydrodynamic model for analysis of river floodplain dynamics between 1986-2022 (37 years) and for reproducing the flood events that occurred in 2018 and during two cyclonic events 'Kyarr' (Oct-2019) and 'Tauktae' (May-2021) in the west coast river basins of India. The modelling framework consisted of the application of a global scale hydrodynamic CaMa-flood model with ERA5 reanalysis simulated, normal and bias-corrected runoff as input data. Model results were validated using the observed streamflow data of 29 gauging stations of west flowing rivers and high-resolution (30 m) Global Surface Water (GSW) data. The various performance matrices such as NSE, KGE, nRMSE, and PBIAS were used to evaluate the model performance. The results revealed that streamflow simulated by the CaMa-flood model showed good agreement with observed monthly and seasonal streamflow data with the maximum NSE and KGE values of 0.8, 0.82, and 0.84, 0.90 for normal runoff input and 0.87, 0.94 and 0.97, 0.97 for bias-corrected runoff input respectively. The performance of the CaMa-flood model improved further with bias correction of runoff input data. The model could simulate the spatiotemporal variation of floods of 2018, 2019, and 2021 and reproduce the flood and inundation caused by the Kyarr and Tauktae cyclones of Oct 2019 and May 2021 in the west coast region. Further, there is a need for the validation of flood occurrence using high-resolution satellite data and long-term historical flood simulation analysis to understand the flood dynamics in the West Coast region. The validated model could be further used for flood projection in the west coast river basins of India under climate change scenarios.

https://drive.google.com/open?id=1BqlHv7mIUqpyWhhnXBLRJSUZQ_sG33n

[P-16] Ridwan Adebayo BELLO & Wenyu Yang
Technical University of Dresden

Investigating Basin-Scale Flood Risk in Elbe Using the CaMa-Flood Model

The management of flood risk along the Elbe River is crucial for Germany and Europe as a whole. Despite numerous studies focusing on flood risk in various cities and regions along the Elbe, the complexity of interactions among multiple tributaries limits the comprehensive understanding of flood risk across the entire Elbe basin. In this study, we propose the utilisation of the CaMa-Flood model as an effective approach to simulate hydrodynamics in large-scale rivers, striking a balance between model accuracy and computational load.

The main objective of this research is to investigate the spatiotemporal characteristics of flood risk in the Elbe

River within the context of the entire basin. To achieve this, the study aims to develop a basin-scale hydrodynamics model in the Elbe River using the CaMa-Flood model, analyse the temporal trends and spatial distribution of flood inundation under various hydrological patterns, and assess the flood exposure risk based on population distribution along the Elbe.

The methodology involves three major steps. Firstly, relevant datasets, including river networks, elevation data, and gauge observations, will be collected from the CaMa-Flood database and processed accordingly. Secondly, a basin-scale hydrodynamics model will be developed in the CaMa-Flood framework, enabling flood simulations under different hydrological scenarios. Lastly, the study will investigate the temporal trends and spatial distribution of flood inundation, as well as evaluate the flood exposure to the population.

The expected outcomes of this research include schematic representations of basin-scale floods and flood exposure to the population. The findings will contribute to a better understanding of flood risk dynamics in the Elbe River basin, enabling more effective flood risk management strategies.

Keywords: flood risk, Elbe River, CaMa-Flood model, hydrodynamics, spatiotemporal characteristics, flood exposure.

[P-17] Mohamed Saber

Disaster Prevention Research Institute (DPRI), Kyoto University

Machine learning algorithms and physical based models for flood risk mapping

Assessing flood risk is crucial for effective flood management, traditionally achieved through hydrological modeling, relying on physical and empirical relationships. Hydrological models, such as rainfall-runoff and hydraulic models, provide a detailed understanding of hydrological phenomena by incorporating physical processes and historical data but face limitations like dependence on accurate observational input and uncertainties in model parameters, as well as calibration and validation processes. Conversely, machine learning can enhance flood risk assessment by learning complex patterns from historical data, managing nonlinear relationships and uncertainties, and integrating diverse data sources such as remote sensing, and other actual observations. This integration improves flood predictions and vulnerability assessments, enabling timely warnings, effective evacuation plans, identification of flood-prone areas, resource allocation optimization, and designing mitigation measures. Despite its potential, machine learning faces challenges like the need for large high-quality training datasets, and difficulty in interpreting complex systems. The black-box nature of some algorithms may also limit understanding and trust. In summary, combining machine learning with hydrological modeling can revolutionize flood risk assessment, enhancing accuracy, early warning systems, resource allocation. In this work, we have also developed flood hazard mapping with memetic programming algorithm with developing a function that can be used for other cases independently. This can be step forward for developing a global hazard map.

Keywords

Machine learning, hydrological modeling, Flood risk assessment, hydrological processes, black-box techniques.