Research on Future Changes in Rainfall for Flood Control Planning Considering Climate Change

(Study period: FY2016-)

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1. Introduction

As heavy rains are becoming more frequent and more severe due to climate change, it is required that a shift to flood control planning that adapts to climate change . In recent years, an ensemble climate prediction database, in which perturbations are applied to the boundary conditions of climate models to perform a large number of calculations, has been developed. And, with this database, it is possible to evaluate extreme events such as heavy rains in the future probabilistically. For this reason, the NILIM is conducting research on future changes in rainfall by analyzing ensemble climate prediction data from the perspective of developing flood control planning methods that take climate change into account. The following outlines this research.

2. Calculation of rainfall change ratio

In a flood control plan, the river flow rate targeted in development is determined by analyzing runoff at a rainfall equivalent to the target annual exceedance probability (1/100 to 1/200 for Class A rivers) by probability statistical analysis based on past rainfall records. The calculation of the ratio of rainfall between future and past climate ("rainfall change ratio") plays an important role in setting river improvement goals for flood control plans that take climate change into account.

Therefore, the NILIM calculated rainfall change ratios using the "Social Implementation Program for Climate Change Adaptation Technology" (SI-CAT) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the ensemble climate prediction database developed by the Hokkaido University with 5 km resolution.

The following is the procedure for calculating the rainfall change ratio.

1) Japan was divided into 15 regions, considering the possibility that rainfall change ratios may differ from region to region.

2) Among the ensemble climate prediction data, the relationship between accumulated rainfall, rainfall area, and rainfall duration was organized for each year for the data of "past experiments" (corresponding to climate change from 1981 to 2010) and "future experiments" (corresponding to a point in time when the global average temperature rises 2°C or 4°C above the data of the pre-industrialization level [mid-18th century]). The number of years of data varies depending on the type of database used, but is mainly 360 years of past experiments (30 years * 12 perturbations) and 360 years of future experiments (30 years * 6 SST [sea surface temperature] patterns * 2 perturbations).

"6 SST patterns" refer to the six SST patterns (denoted CC, GF, HA, MI, MP, and MR in **Fig. 1**) selected by avoiding them from becoming similar, based on a cluster analysis of 28 models calculated using the RCP8.5 scenario, etc. among the coupled atmosphere-ocean models submitted to the Fifth Coupled Model Intercomparison Project (CMIP5) of the Global Climate Research Program.

3) We conducted a statistical analysis of the maximum annual accumulated rainfall corresponding to the rainfall area and duration obtained in 2) above, and calculated the ratio between the future and past experiments for the rainfall with a 1/100 annual exceedance probability. In organizing the data above, the average values were calculated for a total of nine patterns, including three rainfall area patterns (400, 1600, 3600 km^2) and three rainfall duration patterns (12, 24, 48 hours), assuming a large river basin. **Fig. 1** shows the rainfall change ratios for each of the 6 SST patterns in the case of a 2°C rise. Although there were variations among the regions, the average value for the 15 regions was 1.10 times. For Hokkaido, all values for

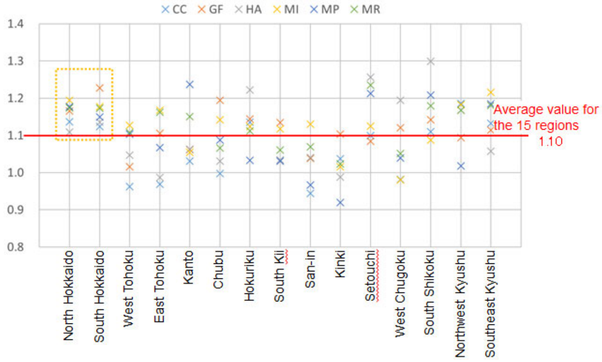

Fig. 1: Rainfall change ratio for each SST (at 2°C increase)

each SST pattern were higher than the national average. In addition, we studied the case of a 4°C rise, the case of small rainfall area, the case of short rainfall duration (between 3 and 12 hours), etc. and reported the results to the "Technical Committee on Flood Control Plans considering Climate Changes," ("Committee") established by the MLIT. As a result, in the Committee's Proposal [1], which was revised in April 2021, rainfall change ratios for flood control planning that take climate change into account, were presented based on the results of studies conducted by the NILIM (**Table**).

In response to this proposal, in the basic improvement policy for the Shingu river system, Gokase river system, and Kuma river system, the design flood was revised based on a rainfall change ratio of 1.1.

Table: Rainfall change ratio (Committee's Proposal) [1]

Region category	2 °C rise	4 °C rise	
			Short time
North Hokkaido, South Hokkaido	1.15	1.4	1.5
Northwest Kyushu	1.1	1.4	1.5
Other (including Okinawa)	1.1	1.2	1.3

3. Study of future changes in the spatiotemporal distribution of rainfall

Even if the accumulated rainfall within a given rainfall duration is the same, cases of short-term concentrated rainfall or locally concentrated rainfall can be assumed, and in some cases, there is a concern that the river flow rate will be larger than the hyetographs experienced in the past. If future changes in such spatiotemporal distribution of rainfall can be grasped, it will be possible to establish cases of spatiotemporal distribution of rainfall that should be considered when formulating a river improvement plan for each river, and it is expected that candidate target flow rates (ranges) for improvement can be estimated based on these cases. However, in order to quantify future changes in this spatiotemporal distribution of rainfall, an appropriate indicator is needed.

Accordingly, the NILIM applies "Gini's coefficient" (an indicator of income inequality where income inequality is smaller when the Gini coefficient is closer to 0 and larger when it is closer to 1), as a method for quantitatively grasping future changes in the spatiotemporal distribution of rainfall, and conducting activities to grasp changes in the spatiotemporal distribution of rainfall in the past and in the future using the indicator of time concentrated rainfall (closer to 0, equal rainfall; closer to 1, short-term concentrated rainfall) and the indicator of space concentrated rainfall (closer to 0, equal rainfall; closer to 1, locally concentrated rainfall).

Fig. 2 is an example of time concentration of rainfall that shows that the time concentration of rainfall, which was previously determined by the shape of the hyetograph, can now be quantified as a value between 0 and 1. A comparative analysis of the ensemble climate prediction data is currently underway to compare the past climate with the future climate using the said indicators.

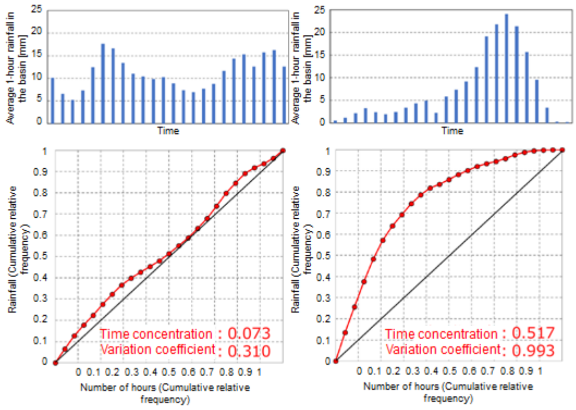

Fig. 2: Example for calculation of time concentrated rainfall
(Area within red and black lines *2 is time concentration.)

4. Future schedule

From FY2022 to FY2023, we plan to "research and develop runoff analysis and flood flow analysis technologies for estimating the flood control effect of runoff control measures" as an commissioned study by "Public Offering for Research and Development of River and Sabo Technology"[2]. In this research, it is expected to develop a model that can accurately analyze changes in the amount of runoff due to changes in the spatiotemporal distribution of rainfall and the effects of runoff control measures such as rain water storage by using rice paddies. Moreover, we intend to reflect such a model together with the results of this research in the technical data for planning river improvement projects that consider climate change.

☞See the following for details.

1) MLIT: Proposal for Flood Control Planning Based on Climate Change, April 2021.
2) MLIT: Public Offering for Research and Development of River and Sabo Technology
https://www.mlit.go.jp/river/gijutsu/kenkyu.html