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ASSESSING CLIMTE CHANGE IMPACT ON FLOOD PEAK DISCHARGES OF ALL THE CLASS-A RIVERS IN JAPAN

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1. Objectives

Climate change is expected to significantly increase flood risk in many parts of the world. In Japan, we have experienced several heavy storm events causing devastating flood damage in this decade. For example, Hagibis, a strong typhoon hit Japan in September 2019. The heavy rainfall resulted in dike break has occurred in major six rivers out of 109 class-A rivers, updating the highest insurance payment for water-related disaster (MLIT, 2019). Because the frequency of such devastating floods is low at the present climate, large ensembles are required to detect its future changes by climate change. In 2017, a large ensemble climate simulation data d4PDF was developed, it has been widely applied to assessing climate change impacts mainly on extreme events (Ishii and Mori, 2020). So far, the authors have addressed future changes of flood peak discharges in all the 109 class-A river basins and its simultaneous occurrence probability using d4PDF (Kobayashi et al., 2020; Tanaka et al., 2020; Tanaka et al., 2021). We present the summary of a series of these research works.

2. Study area and methods

To achieve the impact assessment on flood peak discharge over Japan, we took the following four steps in class-A river basins: 1) bias detection and correction of Annual Maximum Basin Rainfall (AMBR) in d4PDF, 2) rainfall-runoff modelling of each river basin, 3) rainfall-runoff simulations of d4PDF annual maximum storm events and 4) flood frequency analysis of single river basin and statistical test of the number of flooded rivers. River basins in Japan are classified into classes A and B depending on social/economic importance. As class-A river basins covers a large proportion of population (63.5 %) and area (63.7 %) with all major economic zones, this study targeted all 109 class-A river basins. d4PDF is a dataset of large ensemble climate projections under four climate scenarios, i.e. the pre-industrial and the past climates and the climates 2K and 4K warmer than the pre-industrial climate (https://www.miroc-gcm.jp/d4PDF/index_en.html). This study used the past and the 4K warmer climate experiments (hereinafter, historical and 4K experiments). The past experiment consists of 50 ensembles in which the past 60-year climate from 1951 to 2010 was reproduced with different initial and boundary conditions, producing 3000-year samples. The 4K experiment consists of 6 ensembles of future Sea Surface Temperature (SST) patterns in which 60-year stationary climate were simulated with 15 different initial conditions.

The bias of extreme rainfall intensity in d4PDF was identified for AMBR. Observed rainfall was Radar AMeDAS Rainfall (RAR) that is a radar observation rainfall adjusted with gauged rainfall data by Japan Meteorological Agency. The empirical cumulative distributions between RAR (29 samples from 1988 to 2016) and d4PDF were compared using the two sample Kolmogorov-Smirnov test at a 5 % significance level. For the rejected, i.e. largely biased, river basins, mainly in southern Japan, the bias was corrected using a quantile mapping method. To extrapolate the tail of the distribution in RAR, the Generalized Extreme Value (GEV) distribution and Gumbel distribution were fitted. Due to the small number of samples in RAR, the shape parameter of the GEV distribution might be extreme in some river basins; therefore, a typical range of the shape parameter was examined using d4PDF in all the 109 river basins, which was identified to range from -0.043 to 0.222. In the model selection between the GEV and Gumbel distribution, the Gumbel distribution was employed if the shape parameter of the fit GEV distribution was in the outside of the range. Then, the bias correction factor of AMBR was identified as the rate of the quantile between d4PDF and a parametric distribution of RAR and multiplied to hourly rainfall intensity of annual maximum storms. To translate rainfall to flood peak discharge, a kinematic wave-based distributed hydrological model (Tanaka and Tachikawa) was constructed in each basin.

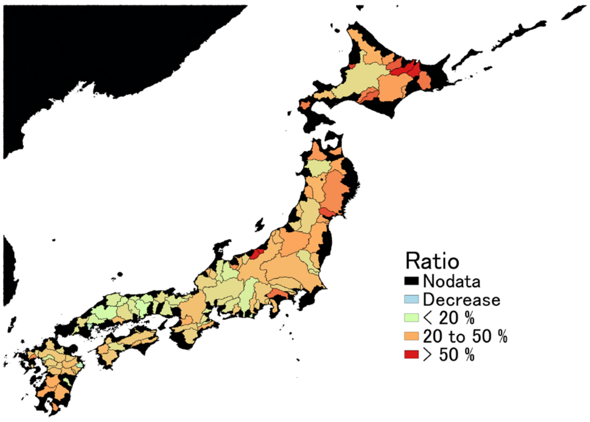

Fig. 1. Increase ratio of 100-year discharge between the past and 4K experiments in all the 109 class-A river system, Japan (Kobayashi et al., 2020). Flood peak discharge in the 4K experiment is the mean value of six SST ensembles.

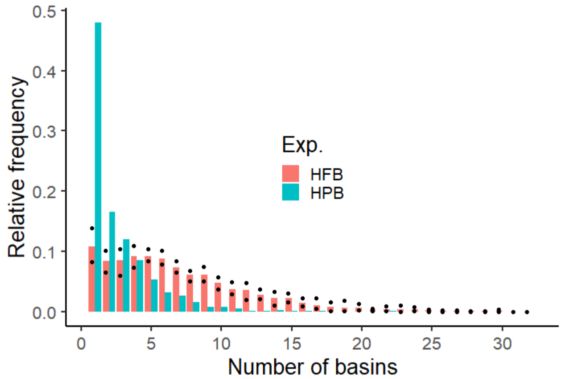

Fig. 2. The number of river systems where annual maximum flood peak discharge exceeded its design level in the same year in the past (HPB) and 4K (HFB) experiment (Tanaka et al., 2021). In this analysis, all the SST ensembles were merged to one sample.

3. Results

The increase ratio of the 100-year discharge (discharge at the non-exceedance probability of 99 %) between the past and 4K experiments of all the river basins are shown as a colored basin map in **Fig. 1**. In the 4K-warmer climate, all the river basins will experience 100-year flood more frequently than the past climate in the end of 20th century. The increase ratio is larger in the Pacific Ocean side, Kyushu and northern Japan. As the result, the return period of the present design flood peak is projected to decrease to 15 to 60 years. **Figure 2.** shows the number of river systems where annual maximum flood peak discharge exceeded the present design level in the same year, indicating the simultaneous floods in a single year. Compared to the past climate (HPB), the 4K-warmer climate (HFB) will increase the number of rivers in the same year, e.g. five river basins may be flooded in the same year at the same frequency as no flooding. The difference of the two histogram is statistically different at 1% significance level according to the one-side binominal distribution test.

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