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Estimation of Future Extreme Flood Discharge using d4PDF and POT Analysis

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Introduction

The impact of climate change on floods, especially the problem of how the peaks and inundation situations will change in the same return period, is a long-standing concern. With improving requirements for flood risk management and diversified concerns, a large number of high-resolution hydrodynamic models are required. For limited computational resources, repeated model building will result in waste. Moreover, for higher-level management departments, it is difficult to analyze and utilize the dispersed modeling results.

Therefore, it is necessary to establish a reasonable, fine and consistent hydrodynamic model for estimating flood frequency changes in the future within limited computational resources. Since the data required for Flood Frequency Analysis (FFA) are extremes, the computations of hydrodynamic models can be reduced by only considering extreme precipitation events and the consequently flood processes.

However, due to the spatial and temporal variability of precipitation, the timing, even the event leading to extremes in each basin or sub-basin may not be consistent with the whole region. This study proposes a method to reduce errors in FFA due to such phenomenon, and assesses the reliability.

Method

Database for Policy Decision-Making for Future Climate Change (d4PDF) is a multi-model ensemble dataset for studying climate change impacts and adaptation planning. The data used in this study (SI-CAT DDS5TK) are further downscaled to 5 km including 3 scenarios (current, the sea surface temperature increases by 2k and 4k in the future) with 31 × 12-year-data (years × ensembles), respectively.

This study is conducted on Shikoku Island (contains 8 major river basins) and the Rainfall-Runoff-Inundation (RRI) model is adopted for discharge simulation.

The annual maximum precipitation within 48h (AM-48h) events of entire Shikoku Island and each basin were selected for simulation (hereinafter called regional data and basin data). This procedure is also implemented under 2K and 4K scenarios.

Block Maximum (BM) method and Peak Over Threshold (POT) method are used for implementing FFA with simulated discharge results. Different from those with decades of observations, each scenario of d4PDF can provide 372-year-rainfall series. For datasets with so many year records, the annual maximum may not be a good way to select the extreme values. Because the selected extreme values will grow linearly with the year, and a large amount of data will be concentrated in the low return period. This will result in a poor fit of the FFA model for high return period data. Therefore, as the reference, POT method and the basin results were adopted, using a threshold of the top 10% of the annual maximum discharge. Considering that the extreme discharge of a basin/sub-basin in the same region is still influenced by the same precipitation event if its magnitude is large enough, the top part of AM-48h will be used for FFA, whose selection parameters are shown in Table 1.

Table 1 Parameters of the data selection method

Models	1	2	3	4	5
POT (threshold)	10%	20%	30%	40%	50%
BM (block size)	10 Y	5 Y	4 Y	3 Y	2 Y

The results of the FFA model are evaluated by relative bias (BIAS) and Relative Root Mean Square Error (RRMSE). The equations are shown in Eq.1 and Eq.2. The model results can be regard as excellent if RRMSE ≤ 10%, good if 10< RRMSE ≤ 20%, fair if 20% < RRMSE ≤30%, and poor if RRMSE > 30%.

$$BIAS = \frac{y_e - y_r}{y_r} \times 100\% \qquad \textbf{Eq.1}$$

$$RRMSE = \frac{\sqrt{\frac{1}{n}\sum(y_e - y_r)^2}}{\frac{1}{n}\sum y_r} \qquad \textbf{Eq.2}$$

y_e is the predictions from the model to be evaluated.

y_r is the predictions from the reference model.

Result

Figure 1 shows the ability of the FFA models in each basin (using regional results) with different selection parameters fitting the basin data. The gray line represents the performance of the reference model fitting the basin data. The results show that although there are inevitable errors between regional models and basin data, the RRMSE is limited to a reasonable range using the method proposed in this study. Among them, the optimal threshold for the POT method is 10% and the optimal block size for the BM method is 2 years.

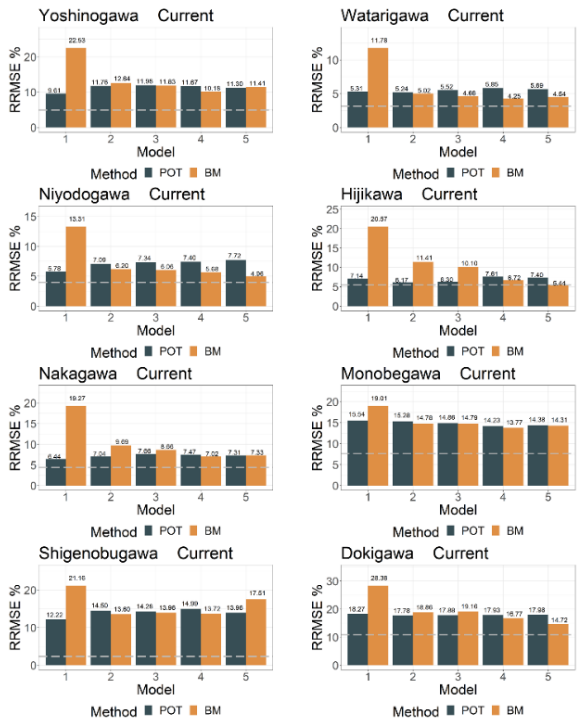

Figure 1 Performances of FFA models with different selection parameters in each basin (Current Scenario)

Table 2 shows the number of basins that meets the criteria under each scenario when adopting optimal models. Most of the models meet the good and above criteria, and no model falls to the poor criteria.

Figure 2 shows the quantile prediction results of the reference model, the optimal POT model, and the optimal BM, as well as the change rate of the future scenarios compared to the current scenario, using Niyodogawa as an example. The results show that although the regional model underestimates slightly compared to the reference model, the trends are consistent and the change rates are quite similar. Thus, the method of this study can effectively utilize regional data and the results obtained are as instructive as those from individual modeling on a basin-by-basin basis.

Table 2 The number of optimal models meeting the RRMSE criteria

Scenarios	Excellent	Good	Fair	Poor
Current	5	3	0	0
2K	3	3	2	0
4K	6	2	0	0

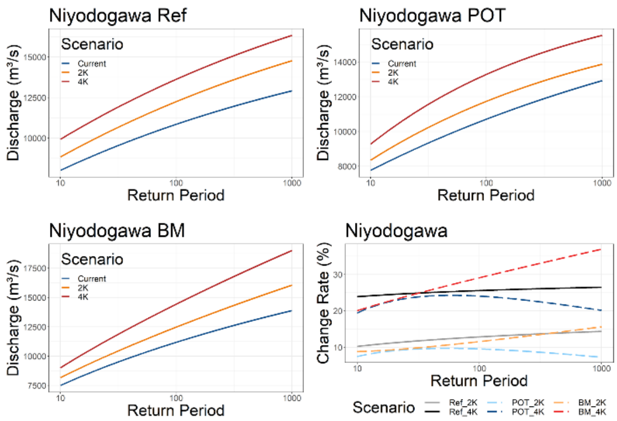

Figure 2 The quantile prediction results under different scenarios and the change rates of future scenarios of FFA models (Niyodogawa)

Conclusion

The conclusions of this study are shown as follows:

1. Using a high threshold can improve the accuracy of FFA when utilizing large GCM ensembles.
2. The optimal threshold for the POT method is 10% of AM-48h, and the optimal block size for the BM method is 2 years.
3. Based on the method of this study, the errors and computations can be reduced. The result has reference value for future flood mitigation.