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Analysis on spatial return period of extreme rainfall in different regions

So KAZAMA[1], and Hajime YANAGISAWA[2]

[1] Department of Civil and Environmental Engineering, Tohoku University, Japan
so.kazama.d3@tohouk.ac.jp

[2] Penta-ocean Construction Co., Ltd, Japan
hajime.yanagisawa@mail.penta-ocean.co.jp

ABSTRACT

Spatial return period of extreme precipitation events is analyzed. Spatial return period is the recurrent period during which extreme precipitation occurs even once within a certain spatial area. For the precipitation data, we used d4PDF's large-scale ensemble data and divided Japan into five regions based on climate classification to consider the differences in spatial return periods in each region. The spatial return period with 100-year extreme precipitation is 3.82 years in Hokkaido and 2.34 years in the Pacific side of western Japan, showing regional differences. Additionally, as a result of comparing the spatial return periods of past experiments, 2℃ increase experiments, and 4℃ increase experiments, the rate of increase in the frequency of extreme precipitation is higher in northern Japan, and the frequency may especially increase approximately three times in the Hokkaido region.

1. Methodology

The target area is all of Japan. The precipitation data used is the database for policy decision-making for future climate change (d4PDF) (Mizuta, et al., 2017). We used a high-resolution regional atmospheric model with a horizontal resolution of 20 km that was downscaled for the Japanese region. There are model experiment outputs for 3000 years of past experiments (60 years x 50 members), 3240 years of 2℃ rise experiments (60 years x 54 members), and 5400 years of past experiments (60 years x 90 members). From a total of 13,560 cells that cover all of Japan, 1,038 cells (approximately 410,000 km^2) including land areas are selected as the target area. Furthermore, based on climate classification, the entire Japan was divided into five regions (Hokkaido, East Japan Pacific side, East Japan Japan Sea side, West Japan Pacific side, and West Japan Japan Sea side) so that the number of cells was as equal as possible. Daily precipitation is used for analysis.

Return period (RP) is used as an index to express the frequency. Extreme precipitation that occurs once every 100 years is called RP100-year extreme precipitation. Firstly, the probability precipitation amount for each cell is calculated and this is the standard for RP100-year extreme precipitation. A nonparametric method is used to calculate the probability precipitation amount. This analysis to obtain the spatial probability followed Yanagisawa et al.(2022).

The probability precipitation amount for RP100-year extreme precipitation is calculated for each cell, so the return period for RP100-year extreme precipitation to occur at a certain point is 100 years. However, when the target area is expanded, the frequency of RP100-year extreme precipitation spatially increases within the target area. This frequency is called the spatial return period. Here, the spatial return period is defined as "the period from when extreme precipitation occurs once until it occurs again within a target area consisting of multiple cells." The target area in this study is each region based on climate classification. Therefore, the spatial return period indicates the frequency at which RP100-year extreme precipitation occurs within each region. In addition, the frequency increase rate is calculated as an indicator of future changes in the spatial return period.

The frequency increase rate is the ratio of the spatial return period of future experiments (2°C increase experiment, 4°C increase experiment) to the spatial return period of past experiments.

2. Results and discussion

Table 1 shows the spatial return period (past experiment, 2°C increase experiment, 4°C increase experiment) and frequency increase rate of RP100-year extreme precipitation in five regions based on climate classification. From the results of past experiments, the region with the longest spatial return period (lowest frequency) is Hokkaido (3.82 years). On the other hand, the region with the shortest spatial return period (highest frequency) is the Pacific side of western Japan (2.34 years), where the frequency is 1.6 times higher than in Hokkaido. Regarding the difference in spatial return period between the Pacific Ocean side and the Japan Sea side, almost no difference can be seen in eastern Japan. On the other hand, a difference is seen in western Japan, with the frequency on the Pacific side being 1.27 times higher than on the Japan Sea side. Here, the total number of extreme precipitation occurrences in each cell is equal in each region. In other words, a short spatial return period (high frequency) suggests that extreme precipitation occurs frequently in a narrow range. Conversely, a long spatial return period (low frequency) suggests that extreme precipitation occurs over a wide range and rarely. This is thought to be due to the difference in precipitation type that causes extreme precipitation.

Table 1. Future change (the unit is year) and increase rate of frequency (in parentheses) of spatial return period in different climate area

	Past experiment	2°C Increase	4°C Increase
Hokkaido	3.82	2.08 (1.83)	1.27 (3.00)
East: Pacific side	2.74	1.74 (1.58)	1.29 (2.12)
East: Japan Sea side	2.67	1.78 (1.51)	1.26 (2.21)
West: Pacific side	2.34	1.67 (1.40)	1.33 (1.75)
West: Japan Sea side	2.99	2.07 (1.45)	1.59 (1.88)

The 2°C increase experiment has a long spatial return period in Hokkaido and western Japan on the Japan Sea side (2.08 years, 2.07 years). Additionally, the spatial return period on the Pacific side of western Japan was the shortest (1.67 years). The rate of increase in the frequency of RP100-year extreme precipitation compared to past experiments is highest in Hokkaido, which is 1.83 times. The rate of increase in frequency tends to be lower in southern regions with lower latitudes, with the rate of increase in frequency on the Pacific side of western Japan being the lowest at 1.40 times. There are no areas where the frequency decreases.

The 4°C increase experiment has a long spatial return period (1.59 years) on the Japan Sea side of western Japan. The spatial return period in other areas is almost the same (approximately 1.3 years). The rate of increase in the frequency of RP100-year extreme precipitation compared to the spatial return period of past experiments is highest in Hokkaido, 3.00 times. The frequency increase rate is lower in southern regions with lower latitudes, and the frequency increase rate on the Pacific side of western Japan is 1.75 times.

There are two ways to interpret the frequency increase. The first is that the amount of precipitation in future experiments has increased compared to past experiments, and the occurrence of extreme precipitation has also increased. Second, the spatial return period has become shorter due to changes in precipitation patterns and an increase in local extreme precipitation. It is predicted that the degree of influence of both will differ depending on the region. The future challenge is to elucidate the factors increasing the spatial return period.

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References

Mizuta, R., et al. (2017) Over 5,000 years of ensemble future climate simulations by 60- km global and 20-km regional atmospheric models. Bulletin of the American Meteorological Society 98(7), 1383–1398.

Yanagisawa, H. and Kazama S., Touge, Y.(2022) Spatial frequency analysis of annual extreme daily precipitation across Japan, Journal of Hydrology: Regional Studies, 42, 101131, 2022. DOI: 10.1016/j.ejrh.2022.101131