41ST IAHR WORLD CONGRESS SINGAPORE
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INNOVATIVE WATER ENGINEERING FOR SUSTAINABLE DEVELOPMENT

Estimating rainfall-runoff amounts based on cluster analysis of spatiotemporal rainfall distributions using long-term ensemble climate projection data

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NILIM

Introduction

- In light of concerns that climate change will increase rainfall and cause severe flood damage, the National Institute for Land and Infrastructure Management (NILIM) has used long-term ensemble climate projection data to calculate the ratio of rainfall to current and future climate, which is used to develop the basic river management policy based on climate change in Japan (Kawasaki, 2022 and Maeda et al., 2024).

Table 1: the ratio of rainfall

Area	2℃ rise experiment	4℃ rise experiment
Hokkaido	1.15	1.4
Northwestern Kyushu	1.1	1.4
Others	1.1	1.2

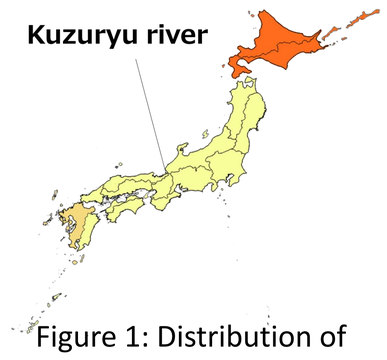

Figure 1: Distribution of the ratio of rainfall

- The ratio of rainfall is an index that focuses on the rainfall values for the present climate and the future climate.
- Even if the rainfall values are the same, cases of short-term and locally concentrated rainfall are assumed.
- In some cases, there is concern that larger river flows may result compared to rainfall experienced in the past.

- By understanding future changes in the spatiotemporal distribution of rainfall, it is expected to set target external forces for flood control planning in the future.

- The pattern classification using Self-Organizing Map (SOM) was conducted in order to understand future changes in the spatiotemporal distribution of rainfall.
- The rainfall-runoff calculations in each cluster were conducted to analyze rainfall-runoff characteristics.

Methodology

- We used the long-term ensemble climate projection data (SICAT_DDS_5kmTK) (Sasai et al., 2019).
- We conducted a cluster analysis of the rainfall spatiotemporal distribution using Self-Organizing Map (SOM).
- The Rainfall-Runoff-Inundation model (RRI model), which is a distributed runoff model, was used in this study (Sayama et al., 2012).

Table 2: SICAT_DDS_5kmTK

Boundary condition	Dynamic downscaling	5kmDS data
d4PDF 20km (historical: 1980-2010) 31years×12member	**NHRCM** Dynamic Downscaling Simulation 20km resolution ↓ 5km resolution	**historical: 1980-2010** 372years
d4PDF 20km (future: +2K) 31years × 12member		**future: +2k** 372years
d4PDF 20km (future: +4K) 31years × 12member		**future: +4k** 372years

Target: Kuzuryu river
Input units:
the largest annual basin-averaged rainfall events
Input data for each input unit:
7 midstream basins x 1-hour rainfall data x 48 hours (336 dimensions of data)
Cluster analysis:
K-means method(silhouette method is applied)

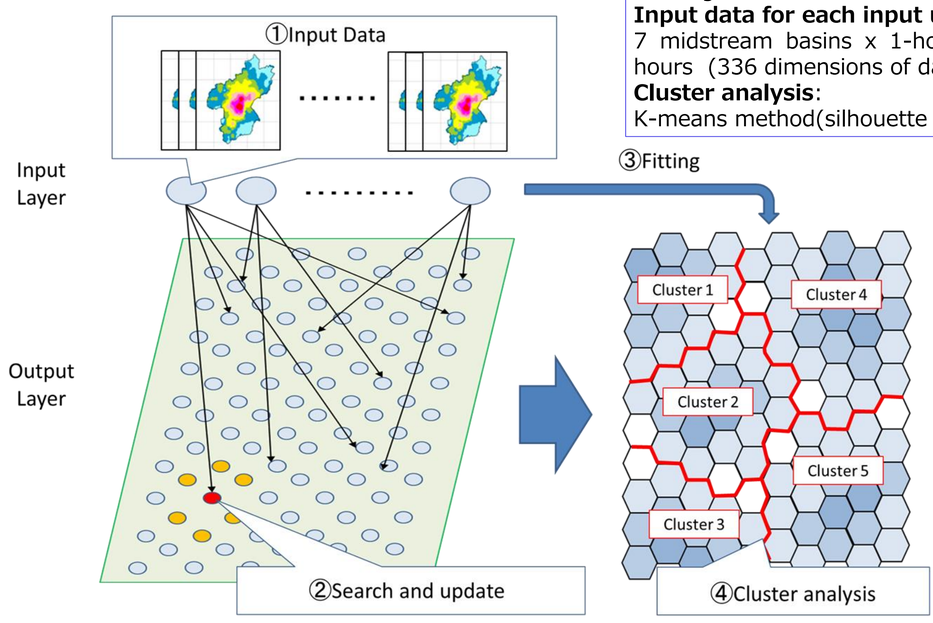

Figure 2: Self-Organizing Map (SOM)

Results & Discussion

①The pattern classification

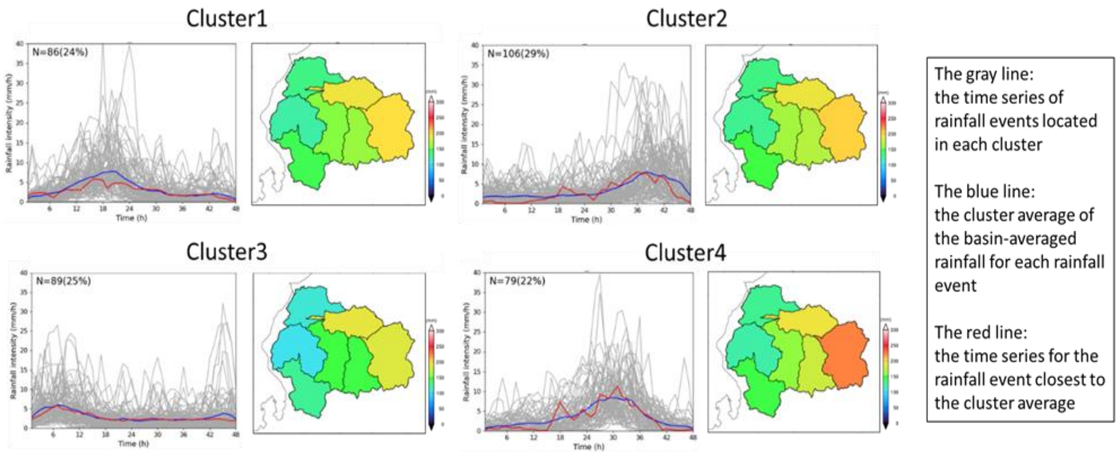

Figure 3: The time series of basin-averaged rainfall and the average of 48-hour accumulated rainfall per subwatershed for each cluster

Table 3: Characteristics of rainfall spatiotemporal distribution for each cluster

Cluster	Characteristics of rainfall spatiotemporal distribution (spatio, temporal)	The number of rainfall events※	The frequency of occurrence
1	Upper and middle Kuzuryu River, Peak in the Middle	86	24%
2	Upper and middle Kuzuryu River, Peak in the Late	106	29%
3	Upper and middle Kuzuryu River, Little change	89	25%
4	Upper Kuzuryu River, Peak in the Middle	79	22%

※This study used the data for a total of 360 years from the 2° C rise experiment.

②The rainfall-runoff calculations for each clusters

Table 4: Rainfall events and the results of rainfall-runoff calculations

Case	Rainfall events				The calculated peak discharge without flood control operations at the Nakatsuno point [m³/s]
	The duration	Cluster	The 48-hour accumulated rainfall [mm]	The stretch rate※	
1	2089/8/2 5:00 ～ 2089/8/4 4:00	1	326.1	1.27	5,118
2	2070/7/30 7:00 ～ 2070/8/1 6:00	1	318.0	1.30	6,418
3	2083/6/22 21:00 ～ 2083/6/24 20:00	2	352.4	1.17	3,766
4	2086/7/6 16:00 ～ 2086/7/8 15:00	2	346.0	1.20	4,854
5	2077/7/30 3:00 ～ 2077/8/1 2:00	3	391.8	1.06	5,041
6	2068/7/17 7:00 ～ 2068/7/19 6:00	3	382.1	1.08	4,807
7	2074/8/3 13:00 ～ 2074/8/5 12:00	4	412.0	1.00	6,932
8	2067/8/5 15:00 ～ 2067/8/7 14:00	4	364.0	1.14	6,518

※The stretch rate is rounded to the third decimal place.

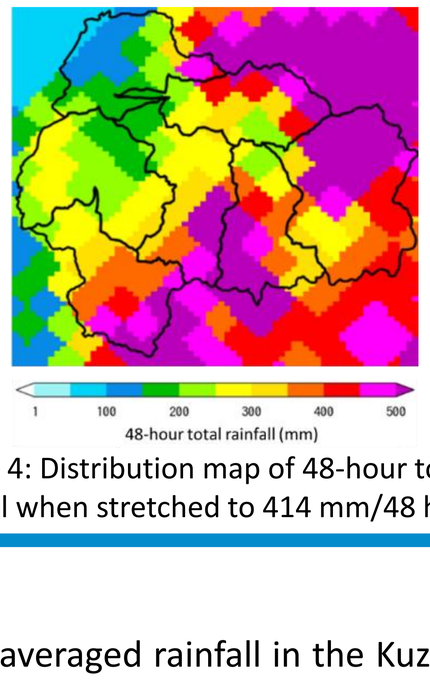

Figure 4: Distribution map of 48-hour total rainfall when stretched to 414 mm/48 h (Case 7)

- Self-Organizing Map can classify rainfall event groups by 4 clusters with similar characteristics of rainfall spatiotemporal distribution.
- The largest rainfall-runoff was observed in Cluster 4 (“Upper Kuzuryu River, Peak in the Middle” type).

Conclusions

- In the 2°C rise experiment, rainfall events that produced the largest annual basin-averaged rainfall in the Kuzuryu River basin were classified into 4 clusters, with the rainfall events in Cluster 2 (“Upper and middle Kuzuryu River, Peak in the Late” type) having the highest frequency of occurrence.
- The rainfall-runoff calculations for each clusters were performed for eight rainfall events with total rainfall equivalent to approximately 1/150 annual exceedance probability of occurring, and the largest rainfall-runoff was observed in Cluster 4 (“Upper Kuzuryu River, Peak in the Middle” type).

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References: Fujita et al. (2019), Kawasaki et al. (2022), Kohonen (1982), Liu and Weisberg (2011), Maeda et al. (2024), Mizuta et al. (2017), Sasai et al. (2019), Sayama et al. (2012)
Acknowledgments: This study utilized the dynamical downscaling data, which are produced from d4PDF using the Earth Simulator, by the Social Implementation Program on Climate Change Adaptation Technology (SI-CAT) sponsored by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

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Introduction

- Flood control planning using ensemble data in japan (MLIT,2021)
- Set target forces for flood control planning by the ratio of rainfall between present and future climate.

The ratio of rainfall

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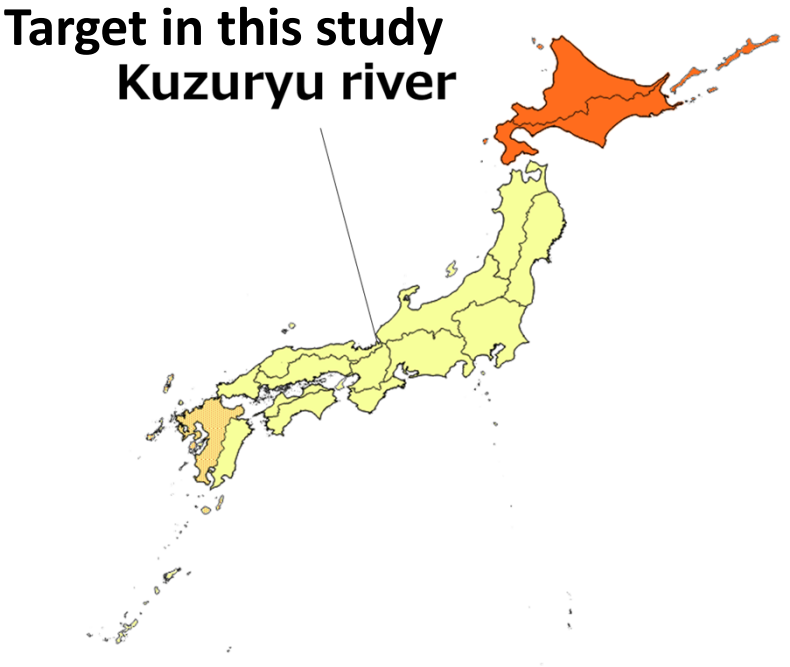

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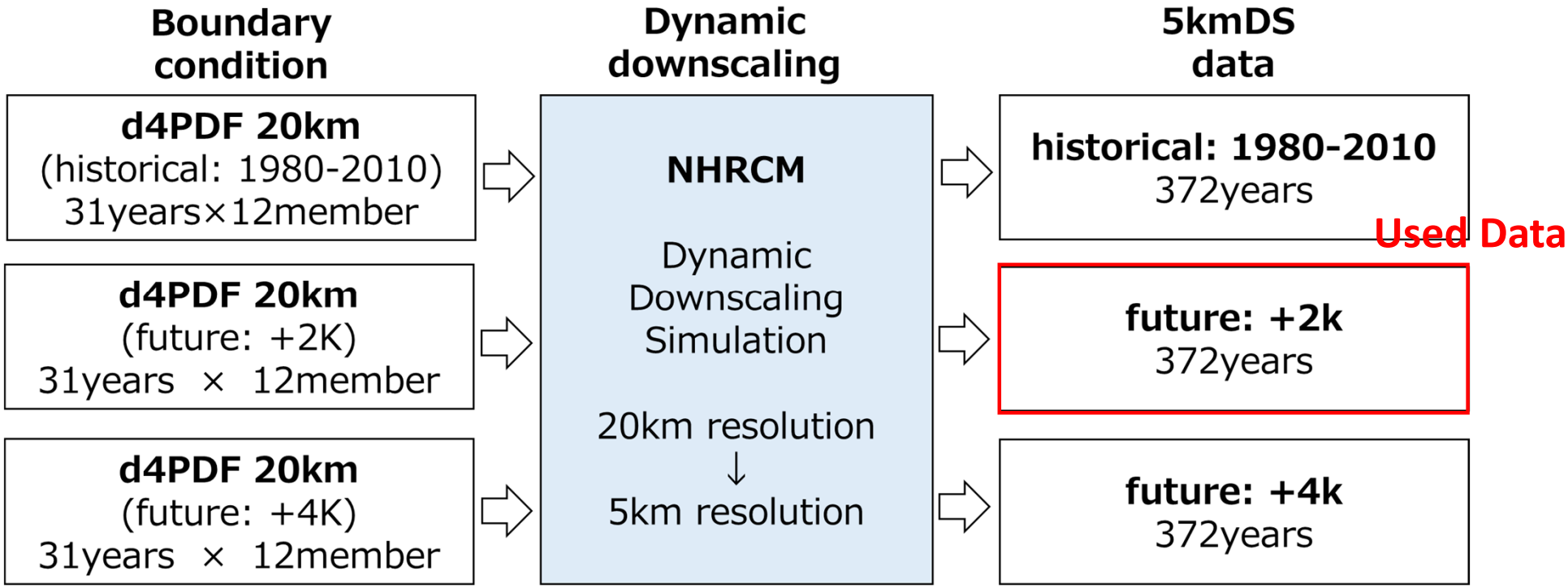

Design of SICAT_DDS_5kmTK (Sasai et al., 2019)

Methodology

- Classify the spatiote mporal rainfall distrib utions by Self-Organiz ing maps(SOM).
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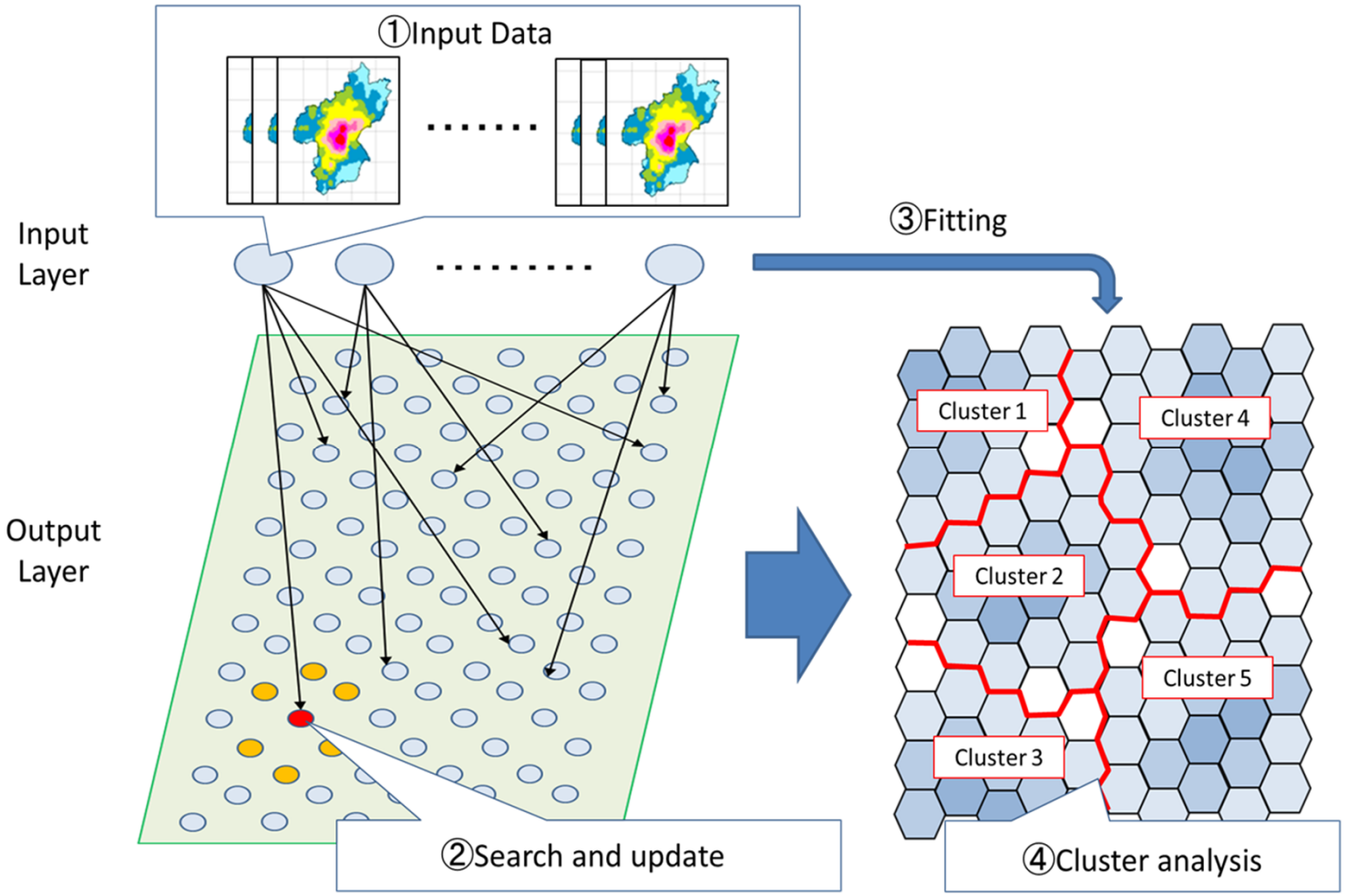
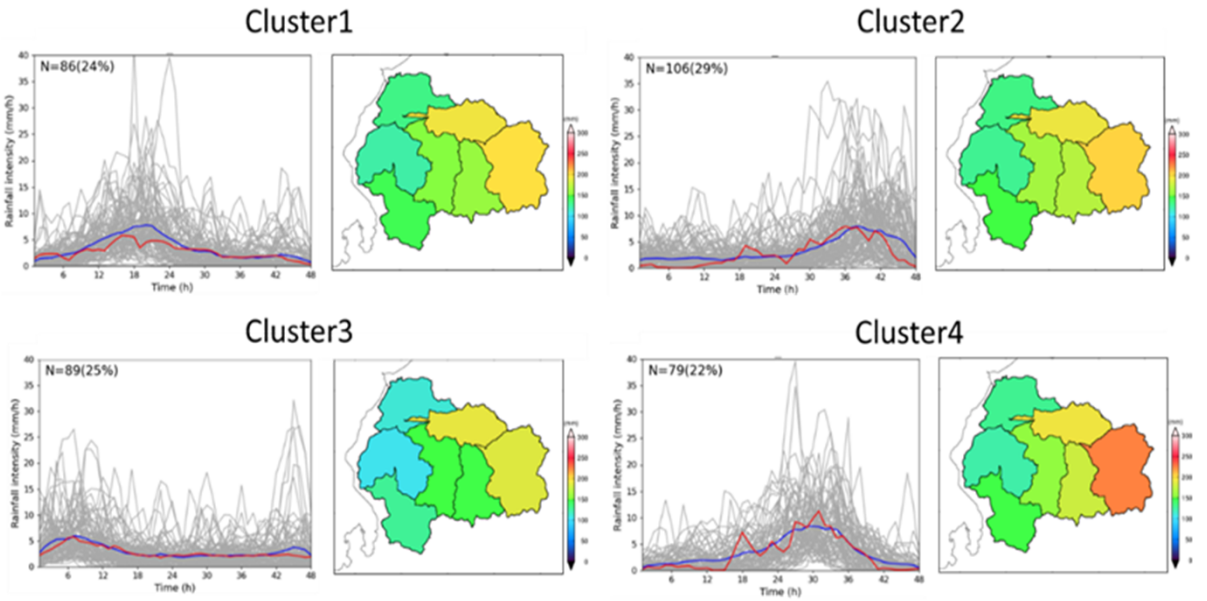


Self-Organizing Maps (SOM)

Results

- Four clusters were obtained for the 2°C rise experiment.
- The rainfall events in Cluster 2 having the highest frequency of occurrence.



The gray line:
the time series of rainfall events located in each cluster

The blue line:
the cluster average of the basin-averaged rainfall for each rainfall event

The red line:
the time series for the rainfall event closest to the cluster average

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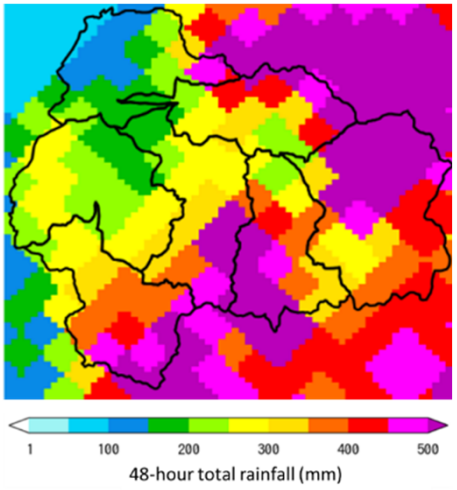

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