275 *ANNUAL VARIATION IN HEAVY RAINFALL FREQUENCY IN KYUSHU, JAPAN, LINKING TO A SYNOPTIC FIELD PATTERN CLASSIFIED BY SELF-ORGANIZING MAP*

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1. INTRODUCTION

Climate change has affected human life, food production, and many ecosystems, etc in the world, and may give serious damages to them accompanying future anticipated global warming. This issue is one of the most important concerns in Japan. Therefore, it is important to diagnose climate change and associated weather situation.

However, in spite of serious issue that significant signals obtained from such situations cannot be easily recognized because of too many and complicated meteorological information, there are few systematic reports that what kind of synoptic patterns have affected temporal variability of heavy rainfall for decade in Japan. Many studies focused on a case study relating to individual storm, the statistical analysis of rainfall only (Fujibe and Kobayashi, 2007).[1]

Therefore, the aim of this study is to investigate decadal variation of heavy rainfall frequency in Kyushu area (target area) located in the west of Japan and, subsequently, to visually demonstrate significant relationships between decadal variation of heavy rainfall and synoptic field patterns recognized by using the Self-Organizing Map (SOM) developed by Kohonen (1995).

The SOM is a kind of unsupervised artificial neural networks (ANNs) technique in the field of information science. The SOM provides useful information for helping the interpretation of non-linear complicated features by classifying a set of high-dimensional data into the units (patterns) arranged regularly on a two-dimensional space that can be *easily* and *visually* recognized by '*human eye*'. The SOM has been widely applied to many fields that requires pattern recognition. For the analysis of synoptic meteorology, Nishiyama et al. (2007), Crimins (2006), Hope et al. (2006), Cassano (2006), etc. were applied.

2. METHODOROGY

The main task of this study is to construct synoptic field patterns corresponding to decadal variation (30 years: 1979-2008) of heavy rainfall by applying the SOM. The methodology available for the analysis of synoptic meteorology is summarized by Hewitson and Crane (2002). According to their suggestion, the first step of the methodology is to conduct the pattern recognition of high-dimensional synoptic situations (e.g. spatial distribution of geo-potential height, wind, temperature, moisture). The next step is to construct visualized-relationships on the two-dimensional SOM space between formed patterns and independent local variables (e.g. extreme high and low temperature, strong wind, heavy rainfall frequency) observed in a specific target area. The final step is to investigate the frequency of synoptic patterns linking to the frequency of independent local variable per each synoptic pattern, temporal variability in the frequency per each synoptic pattern, and so on.

2.1 Training data

In this study, synoptic fields related to heavy rainfall in Kyushu, Japan, are represented by the spatial distribution of wind components at the 850 hPa level and Precipitable Water (PW) using NCAR-NCEP reanalysis data (4 times per a day). A data sample characterizing the pattern consists of 48 dimensions (16 grid points, 3 variables).

On the other hand, for detecting heavy rainfall features, this study uses rainfall data recorded in Kyushu located in the west of Japan. The rainfall observation system is called as the Automated Meteorological Data Acquisition System (AMeDAS), which has been maintained

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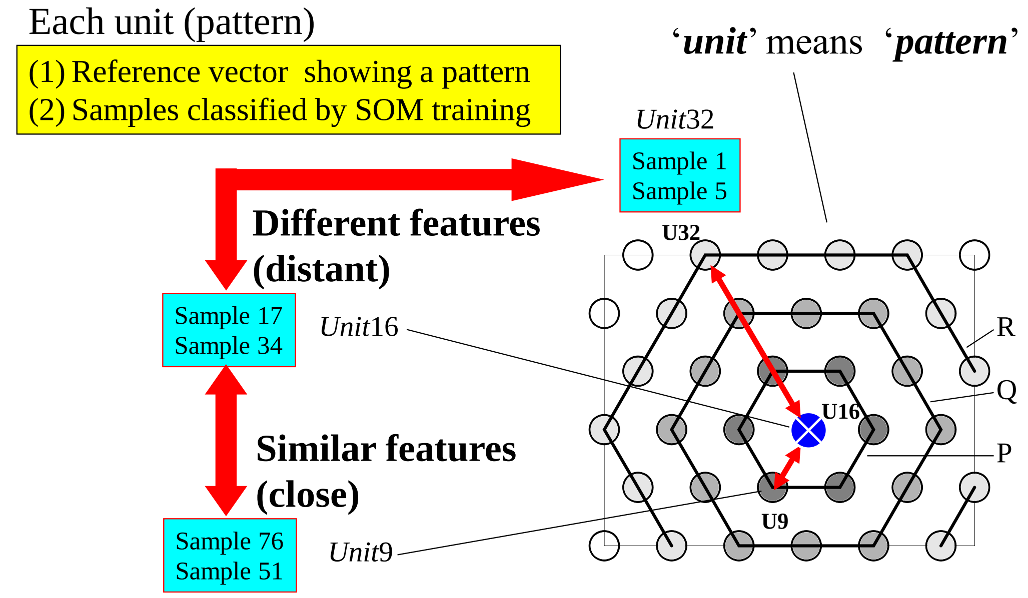


Fig.1 Interpretation of the SOM

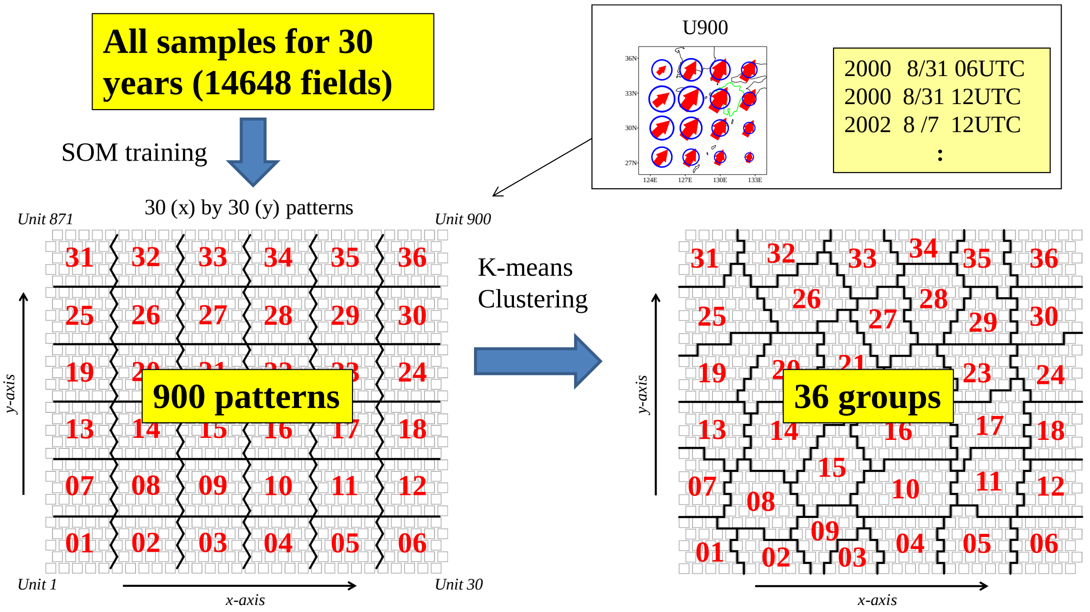


Fig.2 SOM classification and subsequent K-means clustering

by the Japan Meteorological Agency (JMA). The observational items of AMeDAS consist of rainfall, temperature, wind, and sun duration. Rainfall only is observed at all the locations. Its resolution is very fine and equivalent to about 17 km, covering all areas in Japan. These data are recorded per 10 minutes and 1 hour.

This study relates synoptic field synoptic field at T (=0, 6, 12, 18UTC) to heavy rainfall frequency during 6 hours between T-3 and T+3. The heavy rainfall frequency is calculated by summing up AMeDAS hourly rainfalls (>=50

Table. 1 frequency of synoptic field patterns and heavy rainfall in each group
Gray rows show the top ten groups of heavy rainfall frequency >=50mm/h.

group	pattern freq	freq (50mm/h)	group	pattern freq	freq (50mm/h)	group	pattern freq	freq (50mm/h)
1	378	84	13	408	20	25	617	206
2	270	35	14	586	14	26	487	76
3	164	85	15	391	7	27	274	34
4	445	46	16	582	19	28	449	135
5	536	2	17	438	3	29	280	55
6	555	0	18	324	0	30	414	8
7	310	24	19	443	22	31	400	181
8	448	22	20	458	74	32	544	328
9	218	13	21	363	25	33	439	70
10	559	30	22	281	104	34	212	169
11	355	0	23	296	30	35	334	79
12	382	1	24	431	1	36	569	18

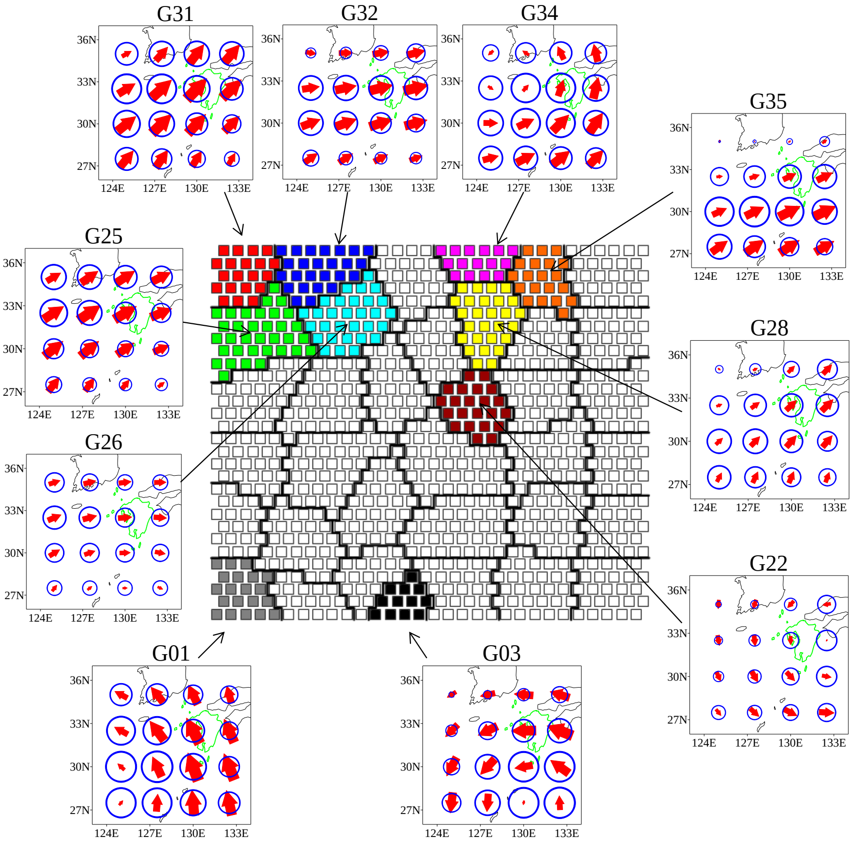
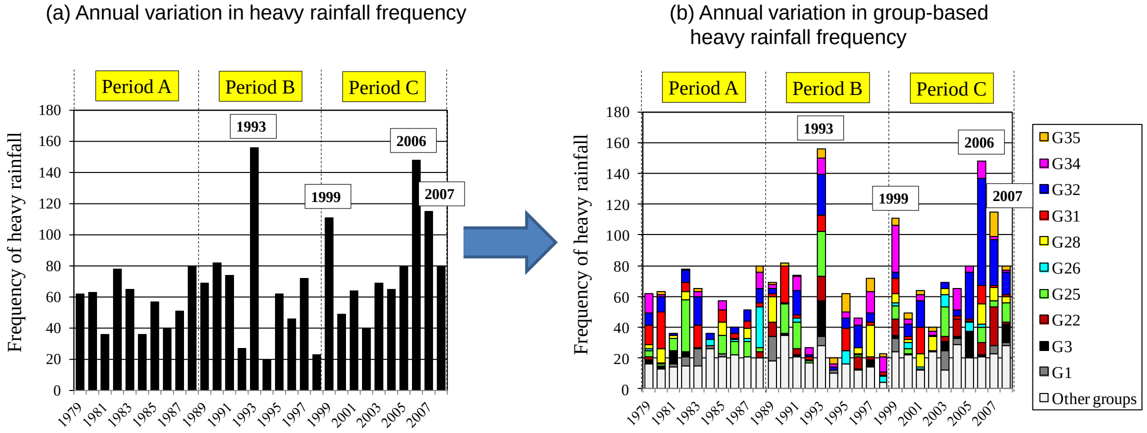


Fig. 3 Synoptic field patterns constructed by the SOM (heavy rainfall groups: 10 groups)

mm/h) recorded during 6 hours in the target area (Kyushu area in Japan).

2.2 SOM Training

The SOM is represented by two-dimensionally-arranged units shown in Fig.1. Each unit corresponds to a pattern. After the SOM training, similar input samples are classified into an identical unit on the map. In


(a) Annual variation in heavy rainfall frequency

(b) Annual variation in group-based heavy rainfall frequency

Fig.4 Temporal variation in heavy rainfall frequency (>=50mm/h) and group-based heavy rainfall frequency

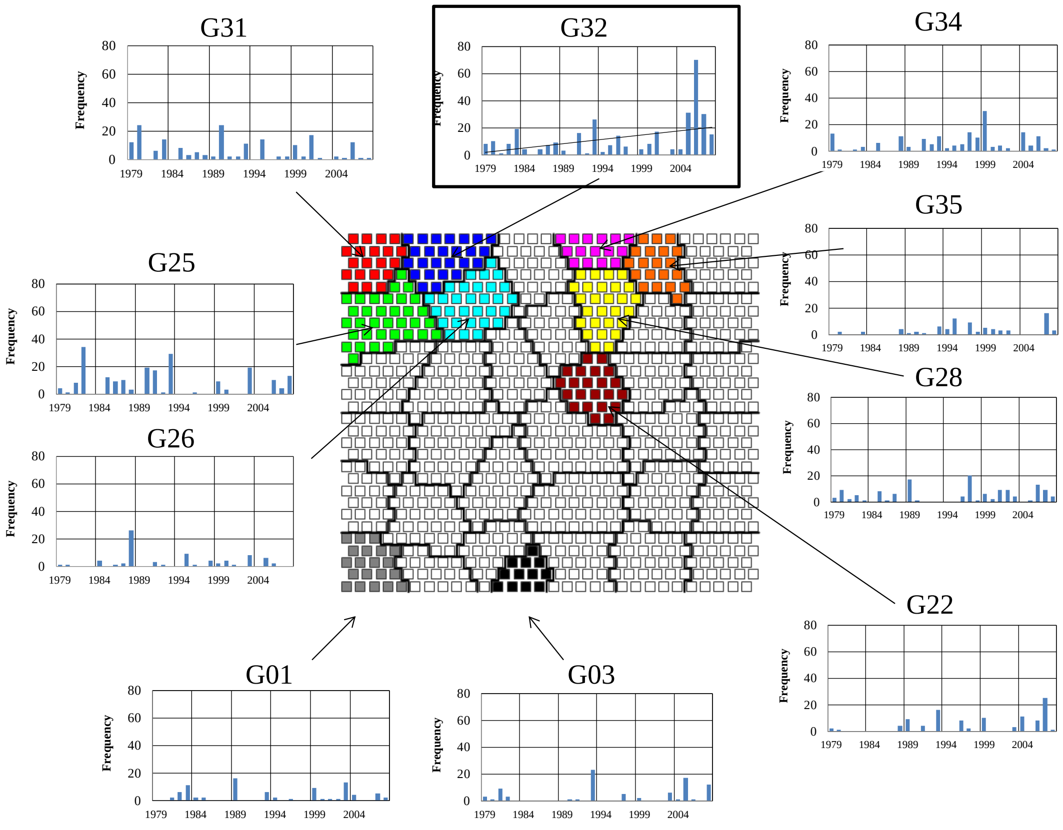


Fig.5 Annual variation in the frequency of heavy rainfall of R>= 50 mm/h per each group

other words, each unit on the map can be interpreted as the assembly of similar input samples with a reference vector, which shows representative features among these input samples. Moreover, the neighboring units in the map are similar to each other while distant units are dissimilar on the map. Therefore, the SOM provides visually recognizable information for interpreting non-linear complicated features.

In this study, the SOM training uses input

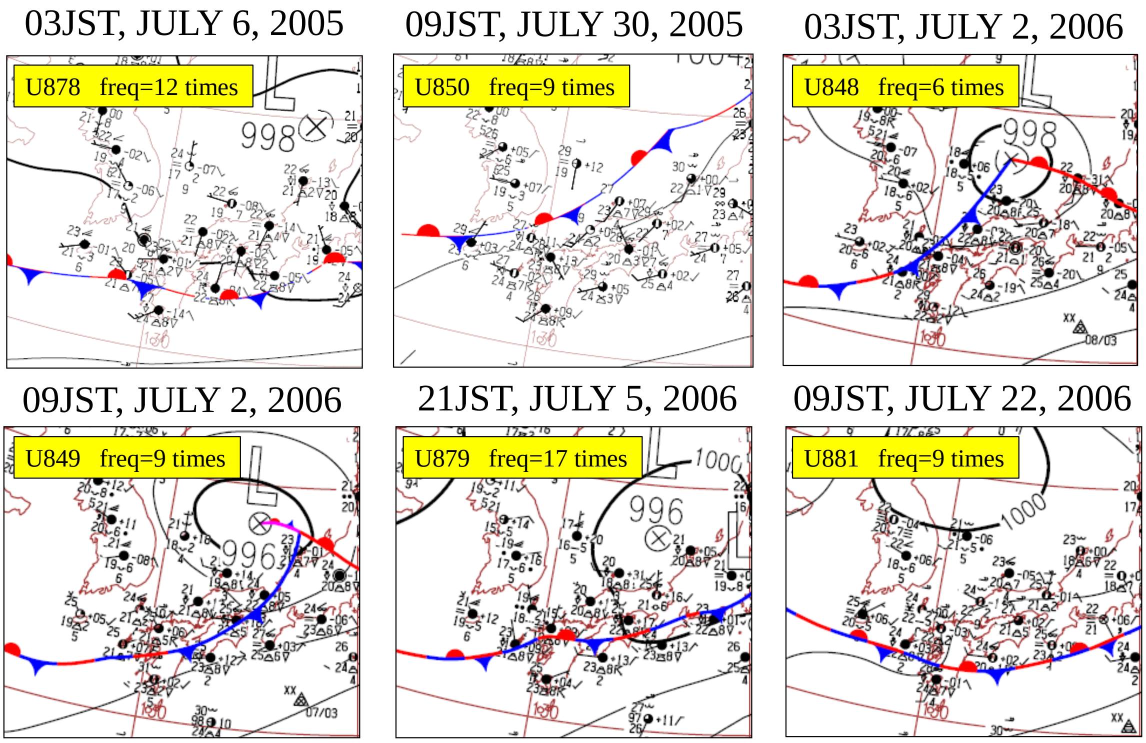


Fig.6 Weather map relating to high heavy rainfall frequency (2005, 2006) in G32

samples (*total_num*=14648) obtained from the outputs (NCAR-NCEP reanalysis data) of 4 times (T=0, 6, 12, 18UT) per a day in the warm season (June-September) for 30 years. Here, it should be noted that rainfall data such as heavy rainfall frequency are not used for the SOM training. In other words, rainfall data is treated as a variable independent of synoptic field patterns classified by the SOM.

As a result of SOM training, the input samples are classified into the 30 (x-axis) ×30 (y-axis) hexagonal units, as shown in Fig.2, in other words, 900 synoptic field patterns. Each unit includes a reference vector and the most similar input samples to it. The reference vector obtained by the SOM training shows a representative feature among the input samples classified in the unit. In addition, after all the patterns formed by the SOM training are divided into 36 groups (25 units per a group) using the K-means clustering.

3. RESULTS

3.1 Synoptic Field Patterns on the Map

Fig.3 shows the distribution of heavy rainfall frequency on the map constructed by the SOM. The frequency is defined as the total number of heavy rainfall >= 50 mm/h observed in all the events classified in each unit. This study focuses on the top ten groups with high heavy rainfall frequency >=50mm/h, as shown by the grey rows of Table.1. Hereafter, the top ten groups are called as ‘heavy rainfall groups’. The synoptic field characterizing each group is obtained by averaging all the reference vectors in each heavy rainfall group. The group-based synoptic fields are arranged around the map in Fig. 3.

Fig.3 shows that dominant heavy rainfall activity is related to the groups (G1 and 3) located in the lower left of the map, the groups (G25, 26, 31, and 32) located in the upper left of the map, and the groups (G22, 28, 34, and 35) located in the upper right of the map

Heavy rainfall caused by G1 and 3 are related to cyclonic motion of typhoons. The feature of G1 shows that a typhoon moves northward around the East China Sea situated in the west of Kyushu. The feature of G3 shows the approach of a typhoon towards Kyushu from the south.

On the other hand, G25, 26, 31, 32 are characterized by high PW distribution and strong wind, the Low Level Jet (LLJ) at 850hPa. G31 shows typical synoptic field pattern in a rainy season in Japan. G32 is similar to G31 in that Kyushu is affected by the dominant area of high PW, accompanying strong LLJ. However, G32 is characterized by eastward LLJ and a steep gradient of PW in the northern area of Kyushu. The upper left of the map includes top three groups (G25, 31, and 32) of heavy rainfall frequency as shown in Table. 1. Especially, G32 shows the highest heavy rainfall frequency.

Finally, G22, 28, 34, and are characterized by the passage of cyclonic motion (typhoon, small-scale low pressure depression) in the high PW area. Especially, G34 shows the existence of low-pressure depression in the northwest edge of the target area, and shows the fourth highest heavy rainfall frequency.

3.2 Annual Variation in Heavy Rainfall Frequency Characterized by Synoptic Field Patterns

Fig.4(a) shows Annual variation in heavy rainfall frequencyFig.4(b) shows what kinds of groups contribute to the variation in the decadal trend. Fig.5 shows annual variation in the frequency of heavy rainfall of R>= 50 mm/h per each group

As shown in Fig.4(a), the annual variation is characterized by high frequency of heavy rainfall in 1993, 1999, 2006, and 2007. The peak of 1993 consists mainly of G3, G25, and G32 under the influence of the approach of typhoon towards the Southern Kyushu and dominant LLJ with high PW area. The peak of 1999 consists mainly of G34, which is characterized by the influence of small-scale low pressure depression including typhoons in the northwest side of the target area. The peaks of 2006 and 2007 consist mainly of G32, which is characterized by the frontal activities with steep gradient of PW in the north of the target area as shown by actual weather maps of Fig.6.

4. CONCLUSION REMARKS

In this study, using Self-Organizing Map, annual variation in heavy rainfall frequency in each synoptic field pattern was investigated. The results could show the contribution of synoptic patterns to the formation of the annual variation. In other words, it could be clearly understood that what kinds of groups affected the formation of the annual variation. Therefore, it was found that the SOM is available for pattern-based analysis of heavy rainfall trend.

Actually, high frequency of heavy rainfall was observed in the recent period after 1999. This feature is due to the fact that frontal activities in a warm season enhanced heavy rainfall frequency in Kyushu, Japan after 1999.

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