# Frequency analysis of heavy rainfall and associated synoptic weather patterns in Kyushu, Japan using self-organizing map

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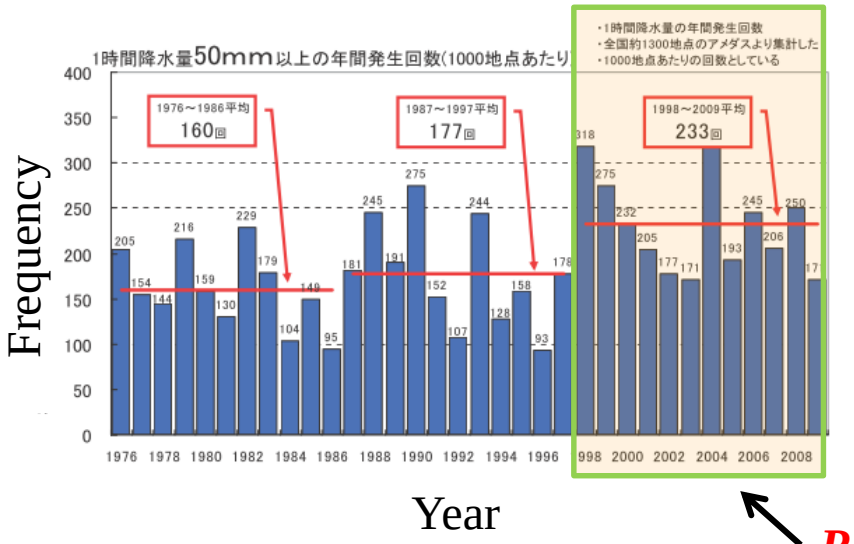
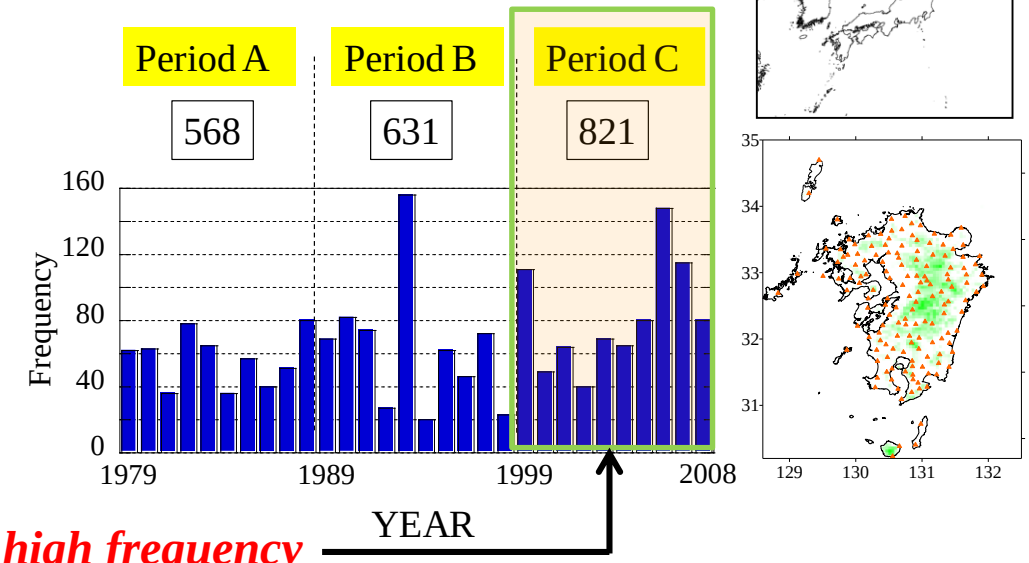
# Background

All areas in Japan

***Frequency of R >= 50mm/h***

Kyushu, Japan





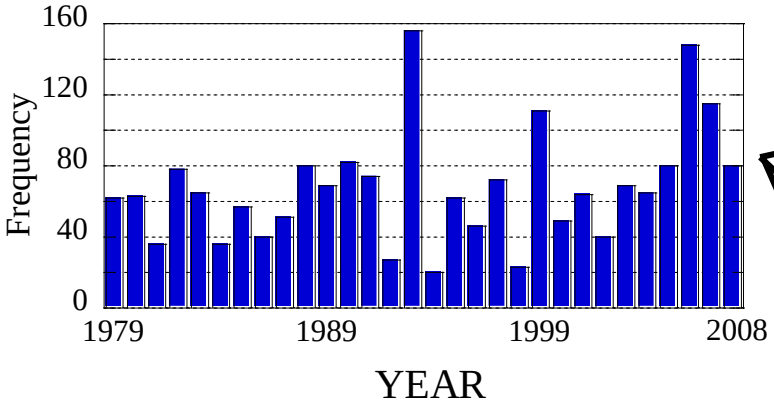

***Recent high frequency***

***Many kinds of weather patterns make up decadal trend of heavy rainfall frequency***

***Complicated !!***

***What kinds of patterns highly contribute to the formation of decadal variation of heavy rainfall frequency ??***

# *The aim of this study*



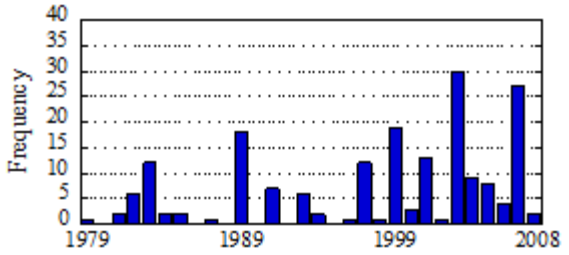

***Main topic***

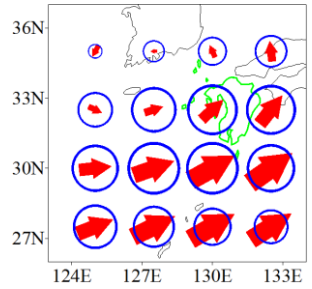
***What kinds of patterns cause high frequency of heavy rainfall ??***

***Methodology***

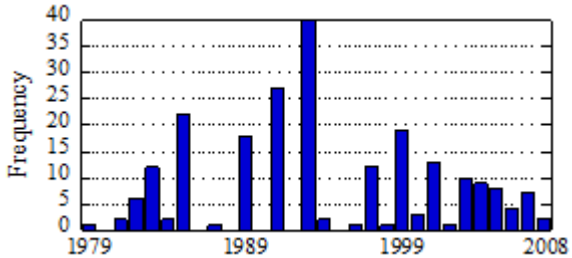
***Pattern recognition using the Self-Organizing Map(SOM)***

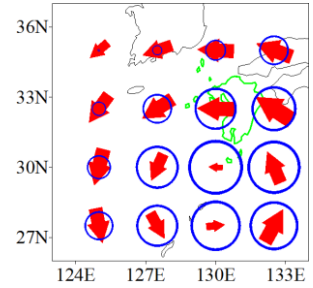
Heavy rainfall freq for pattern 1




Heavy rainfall freq for pattern 2




Heavy rainfall freq for pattern N

# *Self-Organizing Map (SOM) : Kohonen (1995)*

**Complicated high dimensional data** ***are non-linearly classified into***

**Visually-understanding patterns in the two dimensional array**

Each unit (pattern)

(1) Reference vector showing a pattern
(2) Samples classified by SOM training

‘***unit***’ means ‘***pattern***’

*Unit*32

Sample 1
Sample 5

**Different features (distant)**

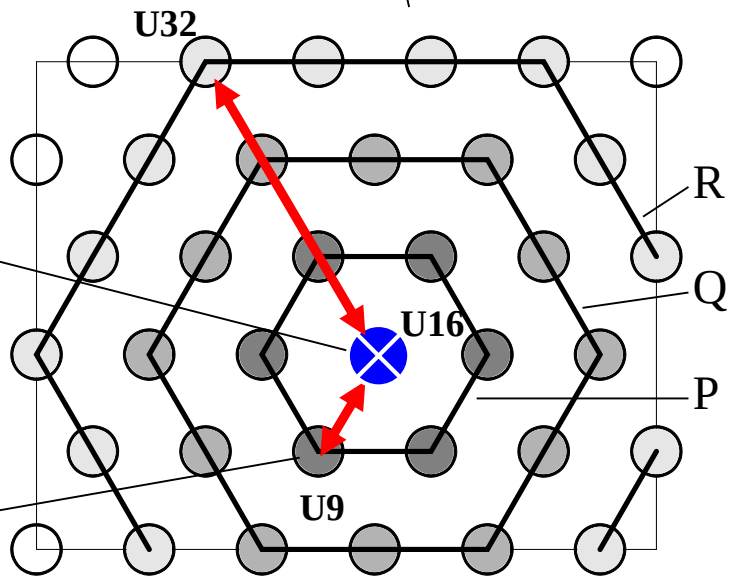
Sample 17
Sample 34

*Unit*16

**Similar features (close)**

Sample 76
Sample 51

*Unit*9



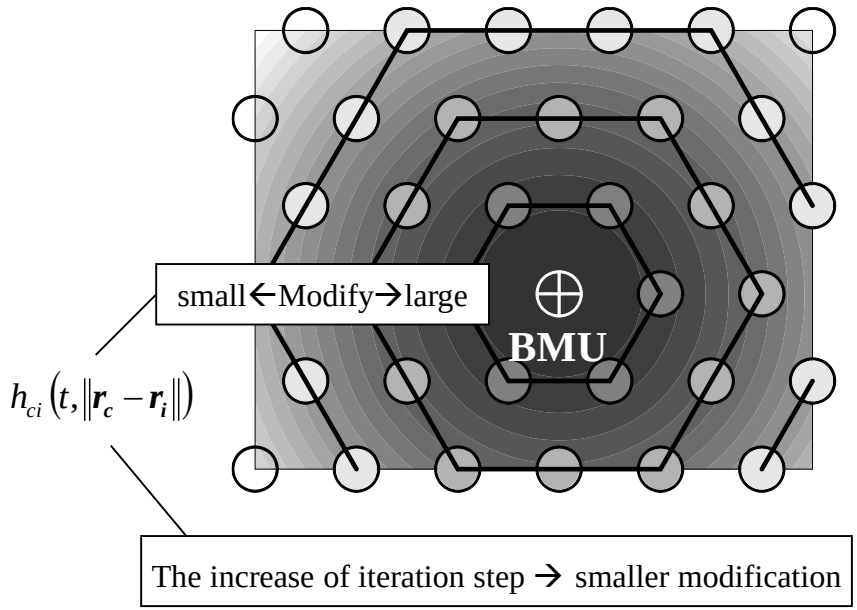
# SOM training algorithm

(a) Input of sample vector for SOM training

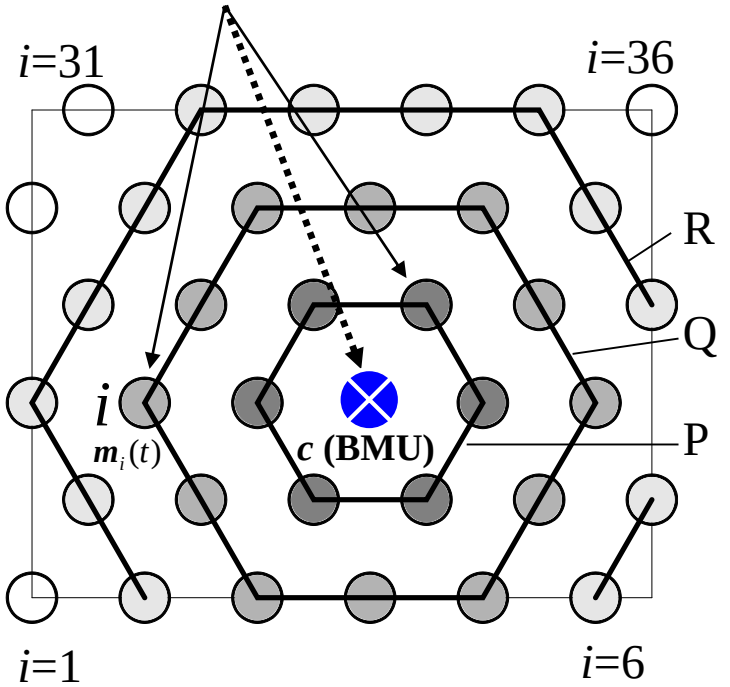
(b) Determination of BMU（Best Matching Unit）

(c) Modification of reference vector $m_i(t)$ depending on Neighboring function $h_{ci}$

$$\mathbf{m_i}(t+1) = \mathbf{m_i}(t) + h_{ci}\left(t, \|\mathbf{r_c} - \mathbf{r_i}\|\right)\left[\mathbf{x}(t) - \mathbf{m_i}(t)\right]$$



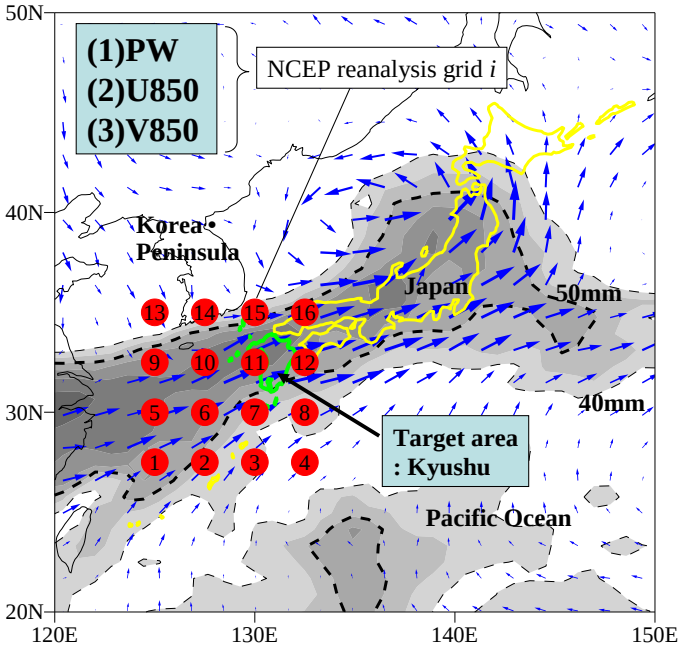

$$\boldsymbol{x}(t) = (x_1(t), x_2(t) \cdots x_n(t)) \quad (t = 1, ....., T)$$




$$\|x(t) - m_i(t)\| \rightarrow Min \ (i = c(\mathrm{BMU}))$$

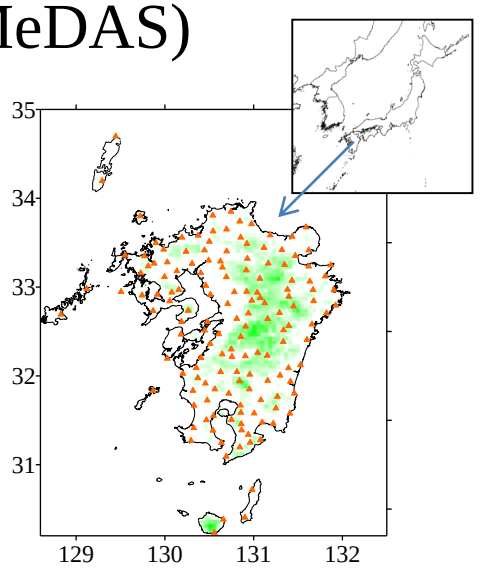
# *Synoptic weather and rainfall obs area*

## Synoptic weather for the SOM




Linking

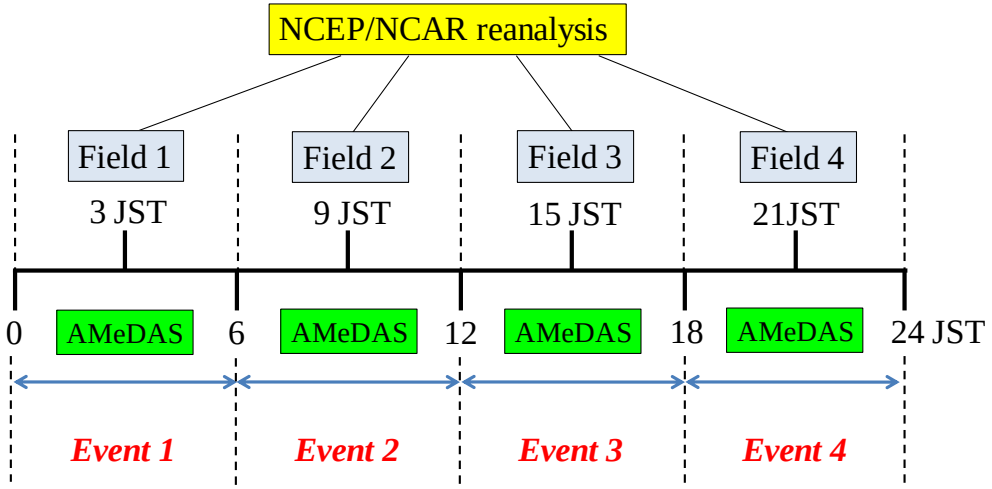
## Rainfall observation (AMeDAS)




**1979～2008 (30 years)**
**（June～September）**
**14648 samples**
**(4 times per day)**

NCEP/NCAR Reanalysis

| Feature | Index |
|---|---|
| Moisture inflow into Japan | PW (Precipitable Water) |
| Low level Jet | *u*, *v* (850hPa) |




**AMeDAS: Automated Meteorological Data Acquisition System**

**Input vector for the SOM training**

$\boldsymbol{x}=(PW_1 \sim PW_{16}, U_1 \sim U_{16}, V_1 \sim V_{16})$

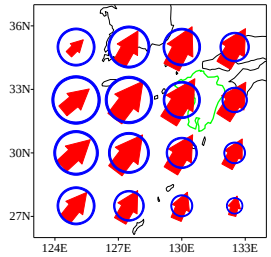
# *Specification of the SOM structure*

**All samples for 30 years (14648 fields)**

SOM training

30 (x) by 30 (y) patterns

U900




2000 8/31 06UTC
2000 8/31 12UTC
2002 8 /7 12UTC
:

*Unit 871* *Unit 900*

**900 patterns**

31 32 33 34 35 36
25 26 27 28 29 30
19 20 21 22 23 24
13 14 15 16 17 18
07 08 09 10 11 12
01 02 03 04 05 06

*y-axis*

*Unit 1* *Unit 30*

*x-axis*

K-means Clustering

**36 groups**

31 32 33 34 35 36
25 26 27 28 29 30
19 20 21 23 24
13 14 16 17 18
07 08 15 10 11 12
01 02 09 03 04 05 06

*y-axis*

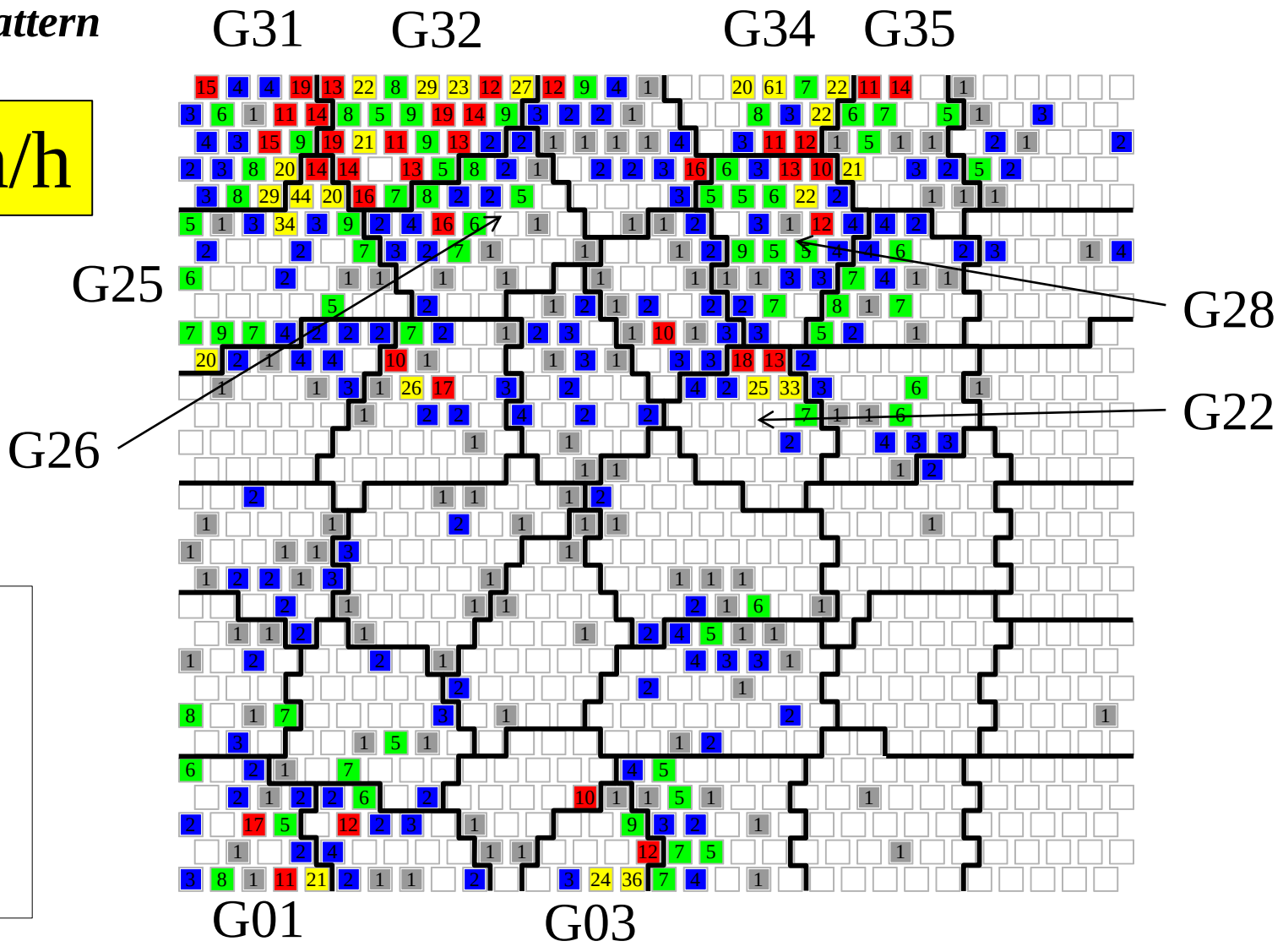
*x-axis*

**Heavy rainfall frequency**

# *Heavy rainfall frequency per each pattern*

***Each unit = Each pattern***

$R \geq 50mm/h$




Frequency

- $20 \leq f < 100$
- $10 \leq f < 20$
- $5 \leq f < 10$
- $2 \leq f < 5$
- $1 \leq f < 2$

# *Heavy rainfall frequency per each group*

$R \geq 50mm/h$

Period A: 1979-1988, Period B: 1989-1998
Period C: 1999-2008

| Group Number | Period A | Period B | Period C | Frequency |
|---|---|---|---|---|
| 1 | 23 | 25 | 36 | 84 |
| 2 | 8 | 10 | 17 | 35 |
| 3 | 16 | 30 | 39 | 85 |
| 4 | 8 | 22 | 16 | 46 |
| 5 | 1 | 0 | 1 | 2 |
| 6 | 0 | 0 | 0 | 0 |
| 7 | 1 | 16 | 7 | 24 |
| 8 | 7 | 6 | 9 | 22 |
| 9 | 7 | 4 | 2 | 13 |
| 10 | 18 | 2 | 10 | 30 |
| 11 | 0 | 0 | 0 | 0 |
| 12 | 0 | 1 | 0 | 1 |
| 13 | 8 | 7 | 5 | 20 |
| 14 | 7 | 3 | 4 | 14 |
| 15 | 3 | 3 | 1 | 7 |
| 16 | 5 | 8 | 6 | 19 |
| 17 | 0 | 0 | 3 | 3 |
| 18 | 0 | 0 | 0 | 0 |

| Group Number | Period A | Period B | Period C | Frequency |
|---|---|---|---|---|
| 19 | 13 | 4 | 5 | 22 |
| 20 | 7 | 32 | 35 | 74 |
| 21 | 5 | 9 | 11 | 25 |
| 22 | 7 | 39 | 58 | 104 |
| 23 | 12 | 6 | 12 | 30 |
| 24 | 1 | 0 | 0 | 1 |
| 25 | 81 | 67 | 58 | 206 |
| 26 | 35 | 18 | 23 | 76 |
| 27 | 19 | 6 | 9 | 34 |
| 28 | 35 | 43 | 57 | 135 |
| 29 | 15 | 13 | 27 | 55 |
| 30 | 2 | 0 | 6 | 8 |
| 31 | 75 | 59 | 47 | 181 |
| 32 | 70 | 75 | 183 | 328 |
| 33 | 24 | 19 | 27 | 70 |
| 34 | 35 | 63 | 71 | 169 |
| 35 | 8 | 37 | 34 | 79 |
| 36 | 12 | 4 | 2 | 18 |
| total | 568 | 631 | 821 | 2020 |

Heavy rainfall groups (selected top 10 groups )
: 71.6% of all heavy rainfall records of R >= 50mm/h

# *Synoptic weather patterns constructed by the SOM (heavy rainfall groups :10 groups)*

plots :
Average reference vector in each group

**PW ( Precipitable Water)**:
- An index of convective activity
- ***large value***
  → (1) strong convective activity
  (2) ample water vapor

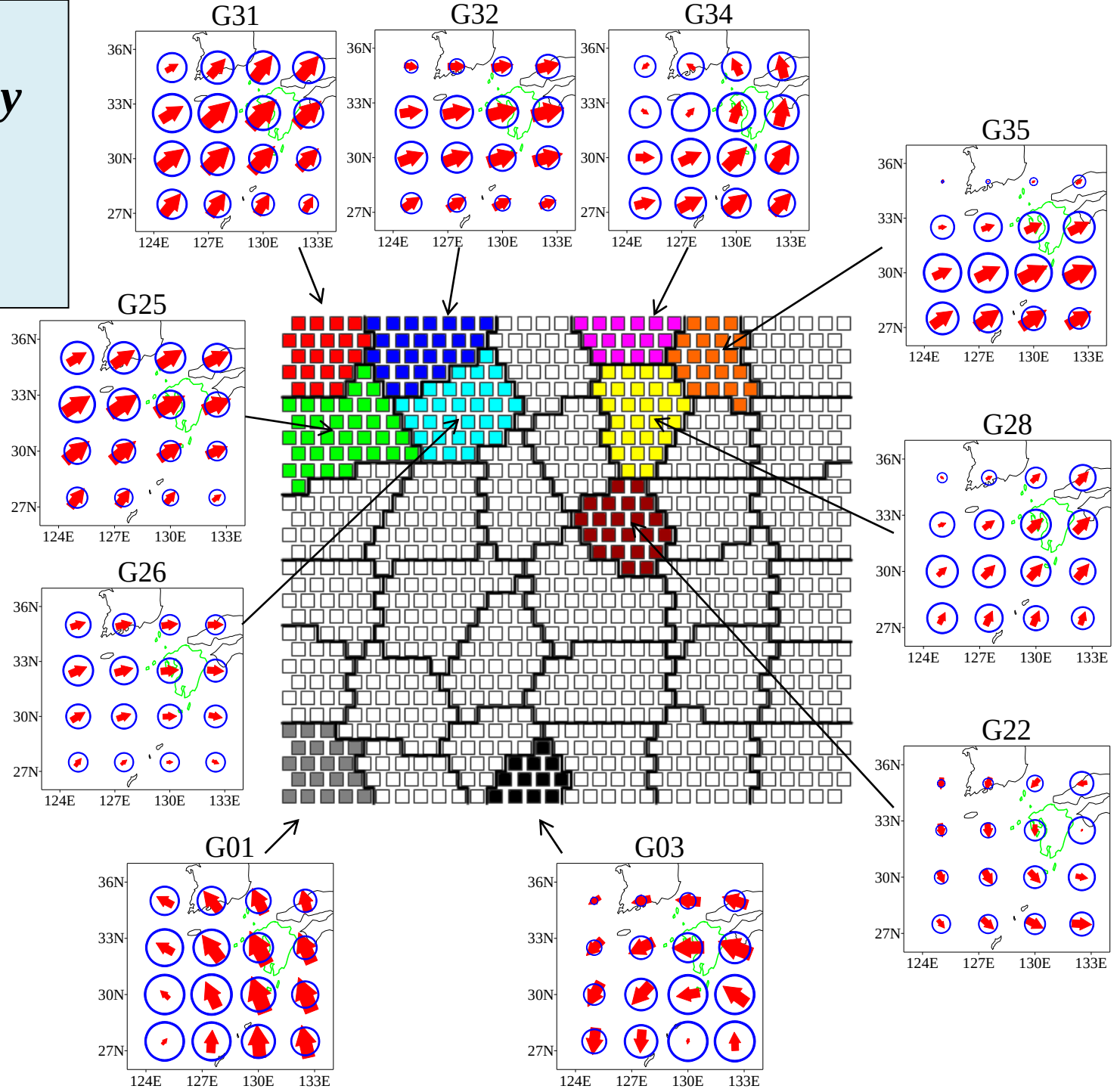
**WIND850 (u, v)**:
- Low Level Jet (LLJ)
- Monsoon

15m/s

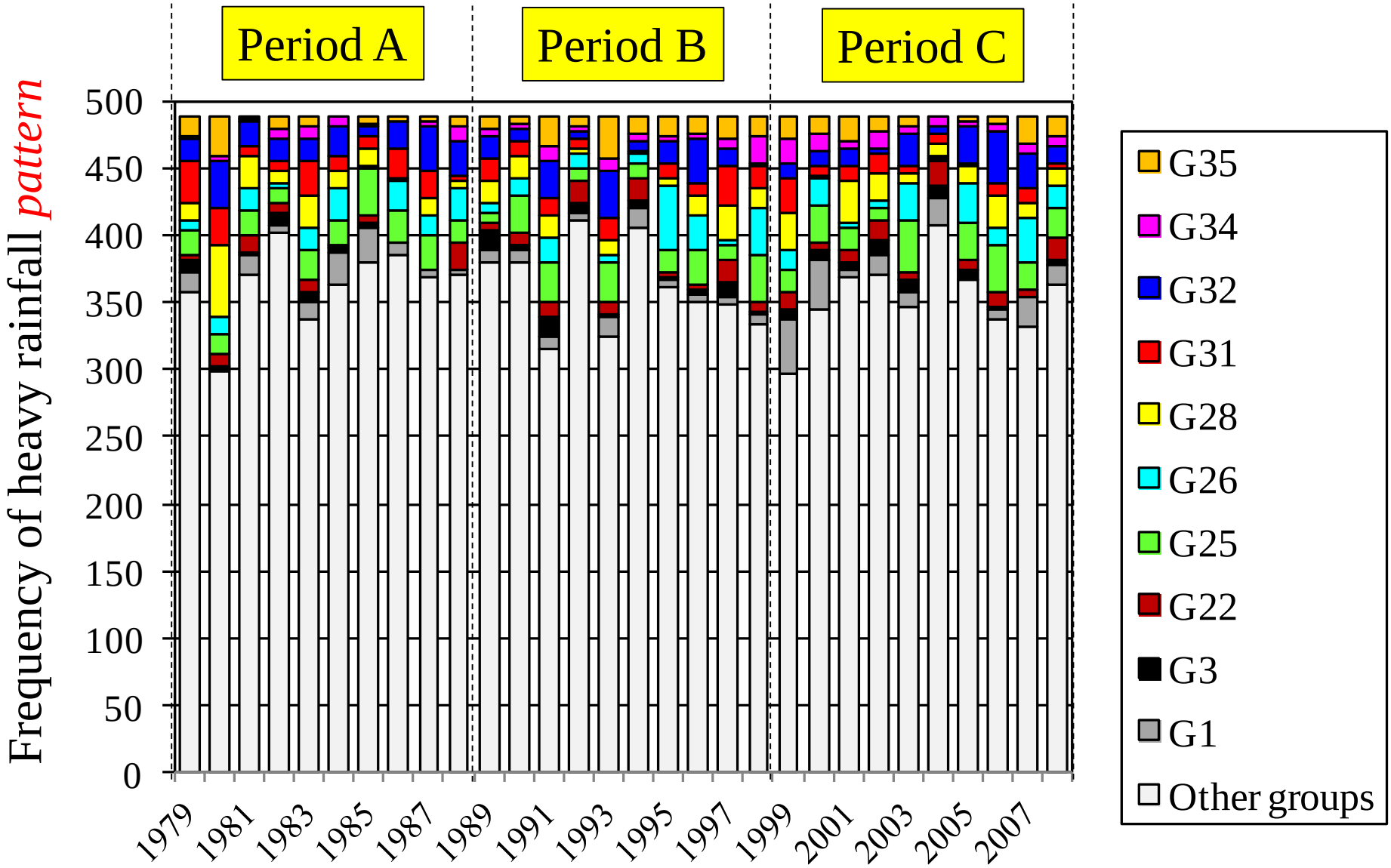
10m/s

60mm 40mm

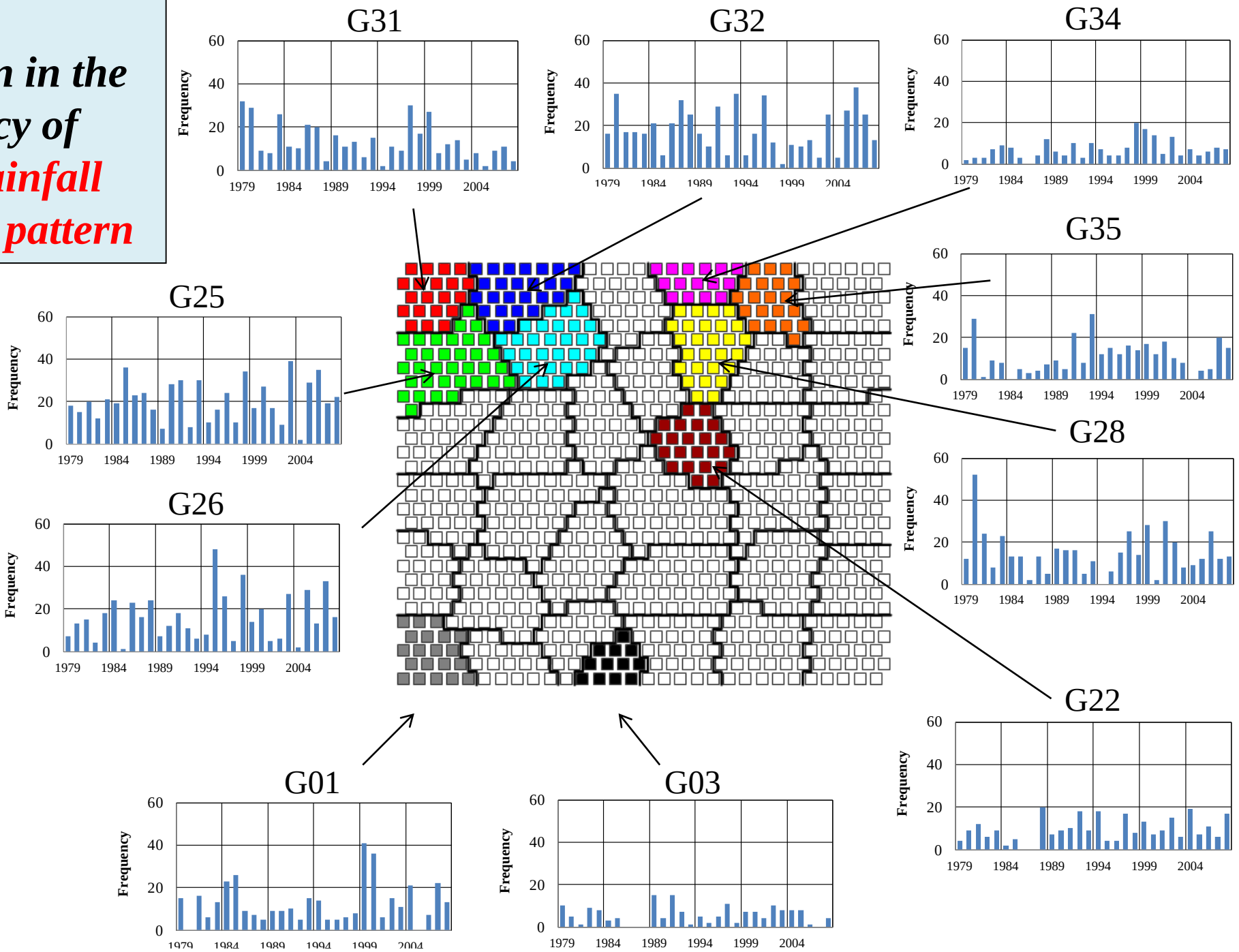
No circle : PW < 30mm



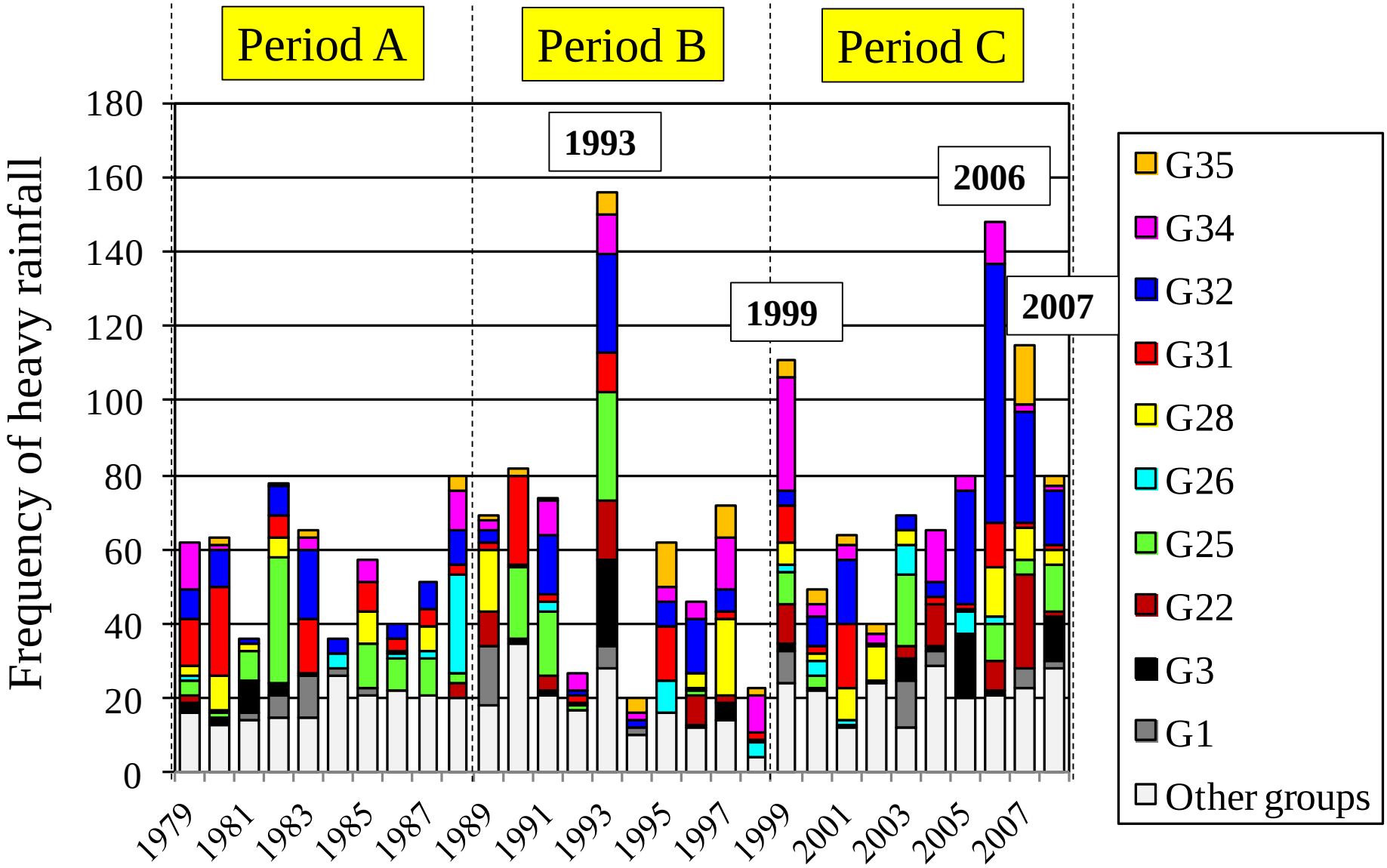
# *Decadal variation in heavy rainfall weather patterns (10 groups)*



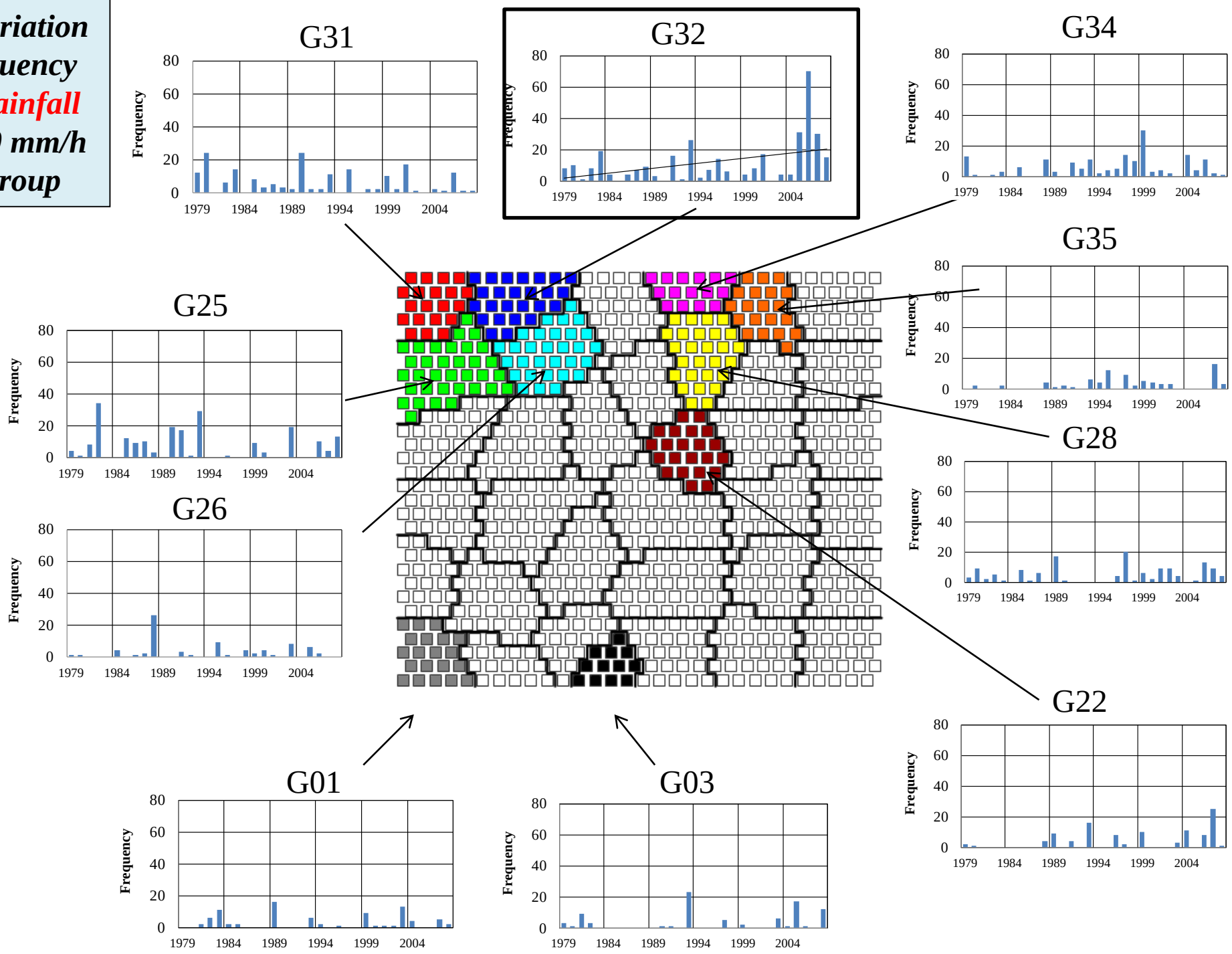
***Annual variation in the frequency of heavy rainfall weather pattern***



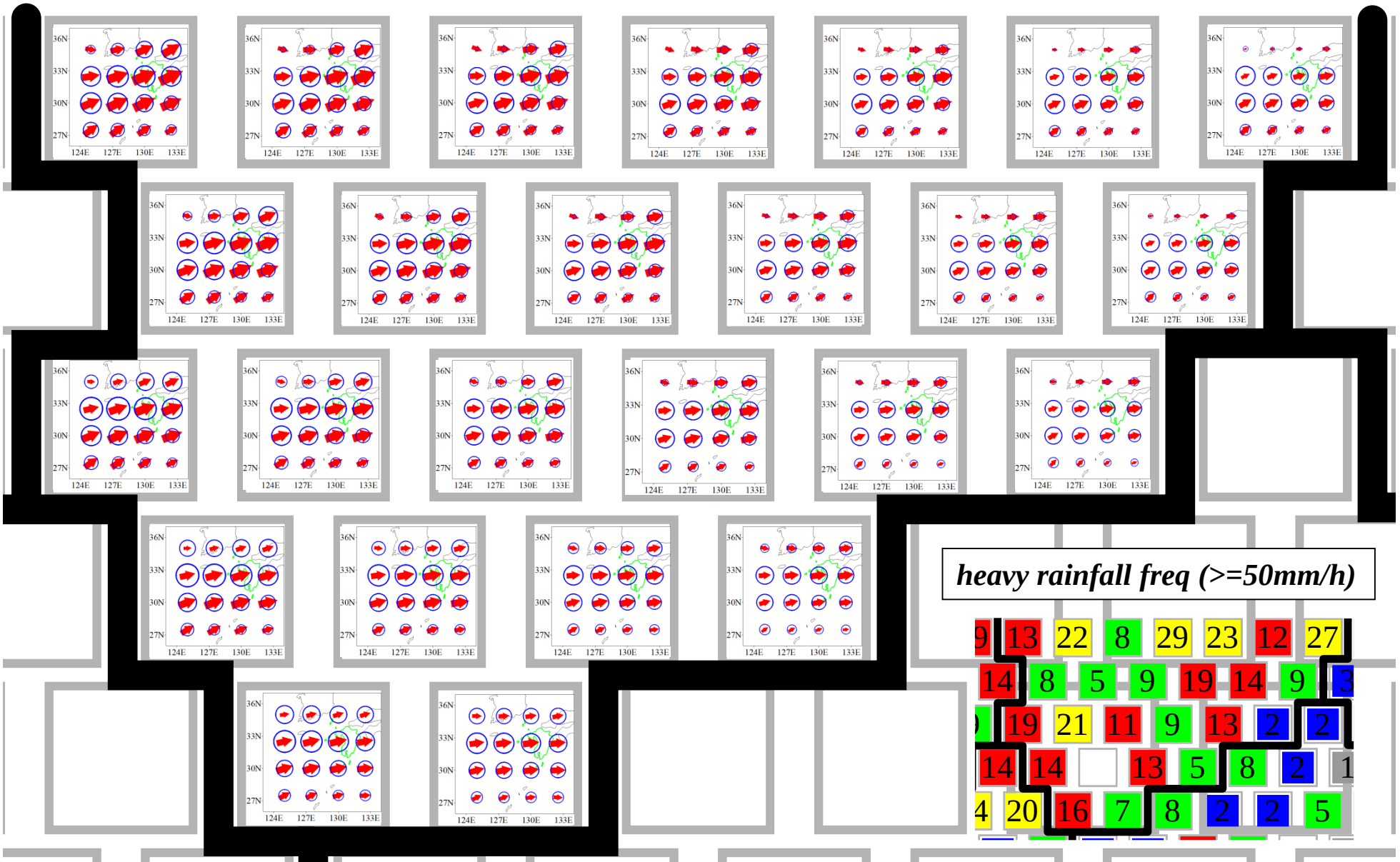
# *Decadal variation in heavy rainfall frequency of 10 HR groups*



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

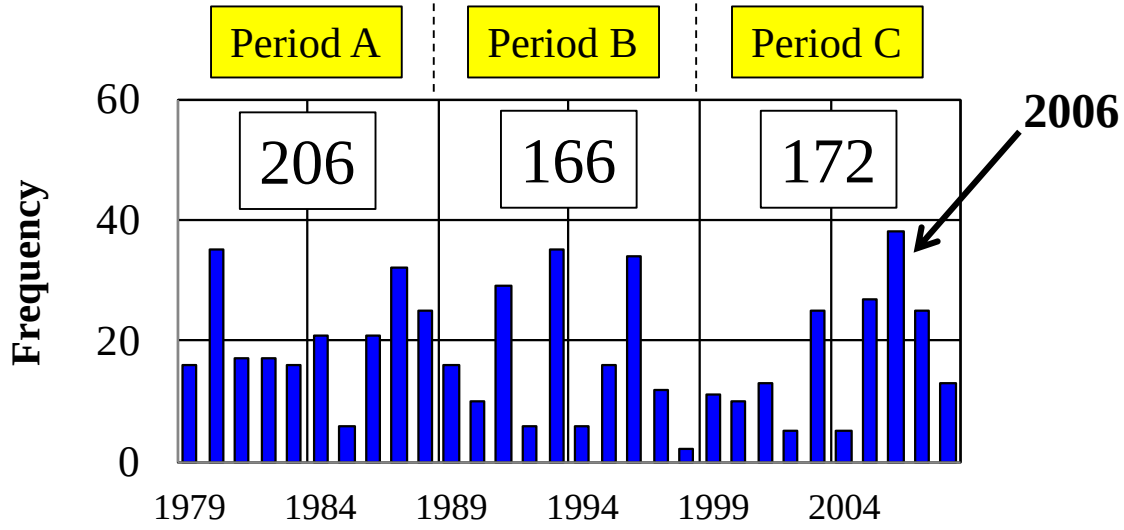


# *Unit patterns and heavy rainfall freq (>=50mm/h) in G32*

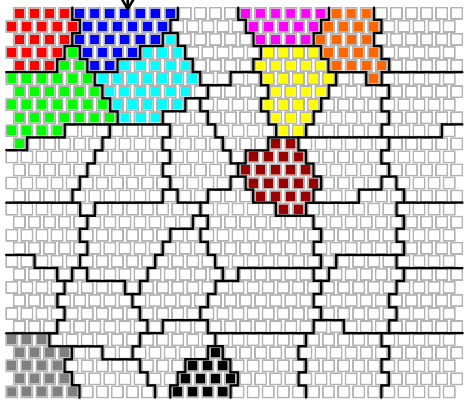


# *Heavy rainfall properties of all the patterns included in G32*

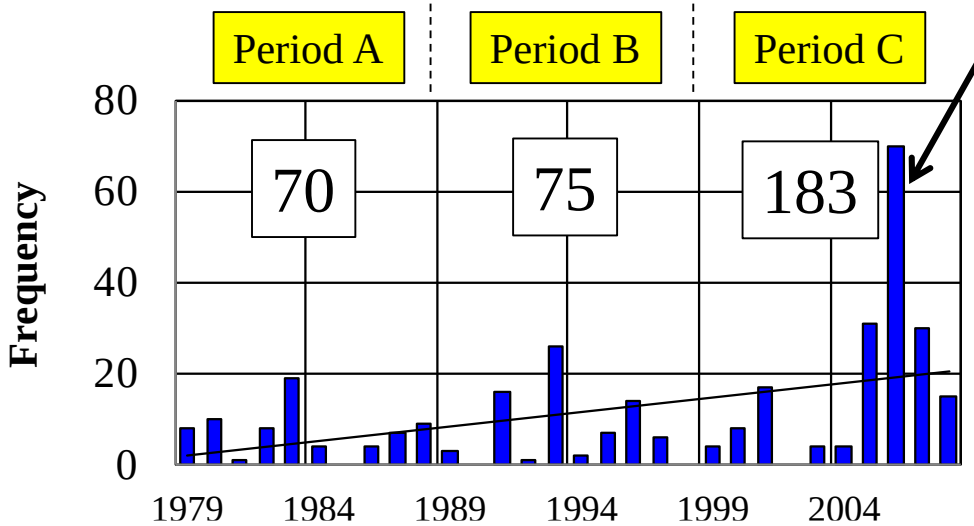
**Pattern frequency**




*G32*

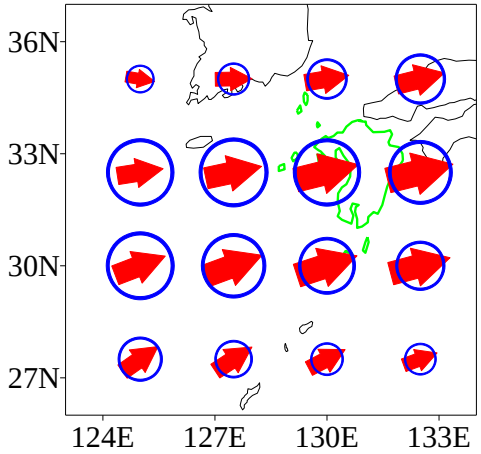


**Heavy rainfall frequency >= 50mm/h**



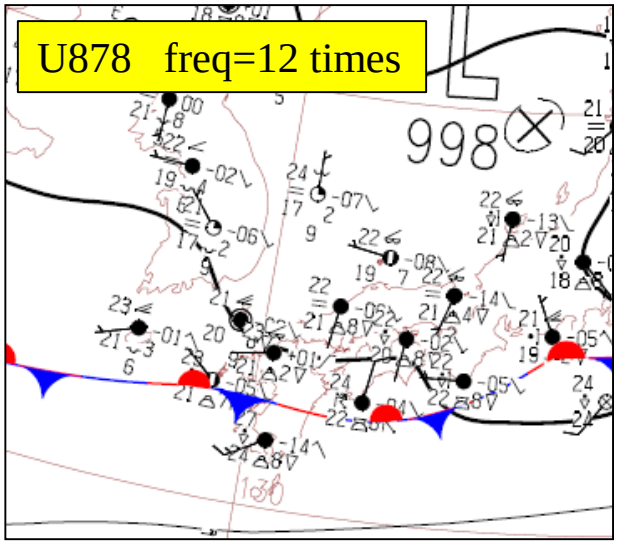

***Notable peak of heavy rainfall frequency in 2006***

G32

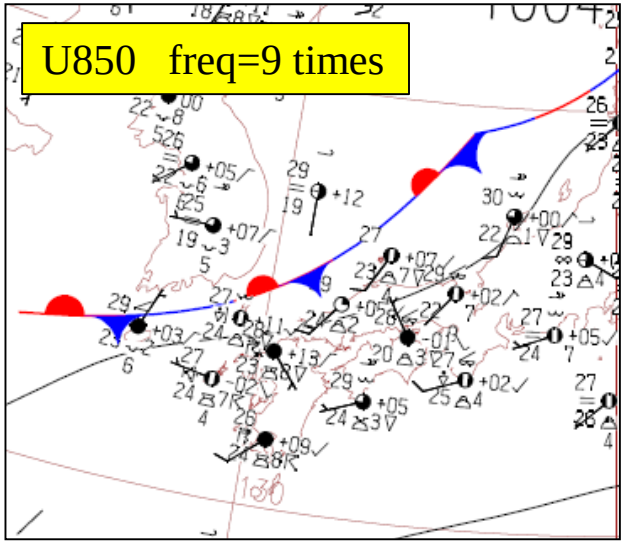


# Weather map with high heavy rainfall frequency in G32

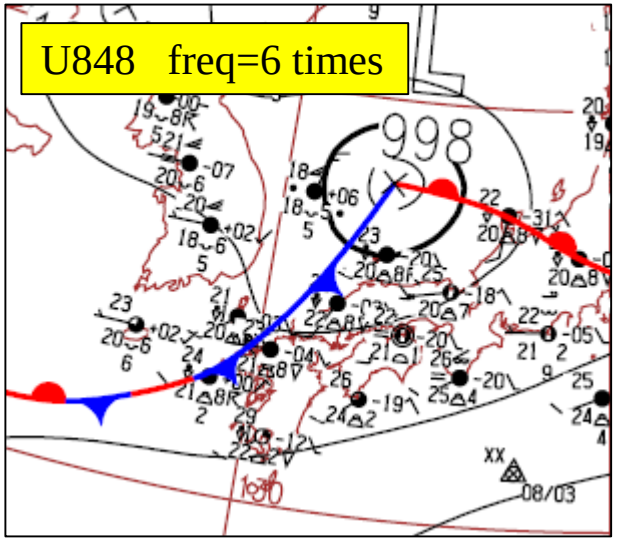
03JST, JULY 6, 2005



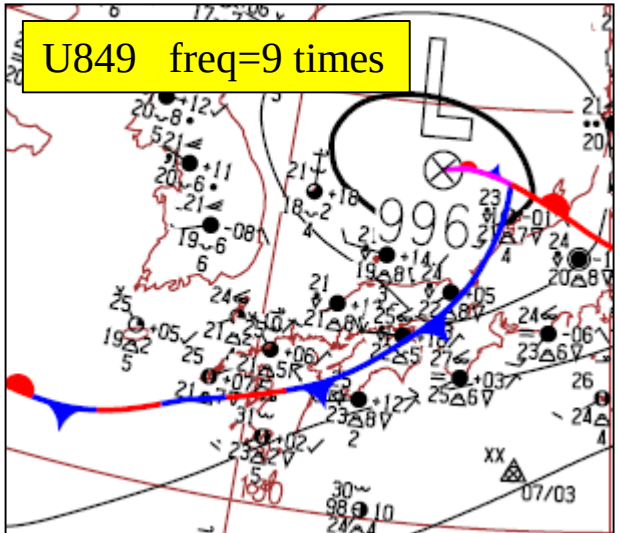

09JST, JULY 30, 2005



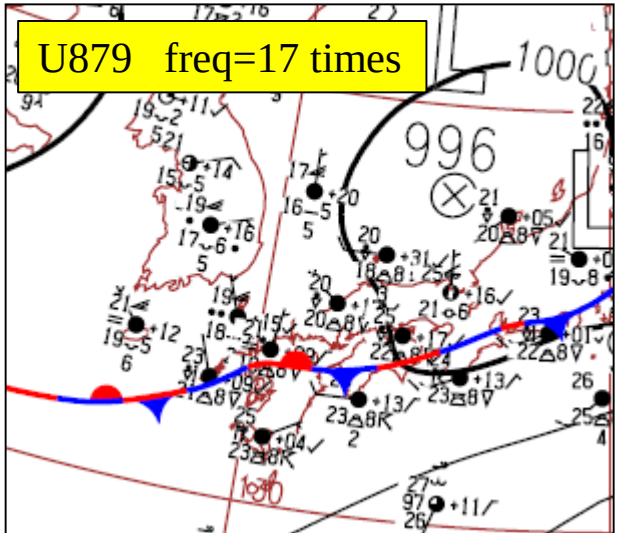

03JST, JULY 2, 2006



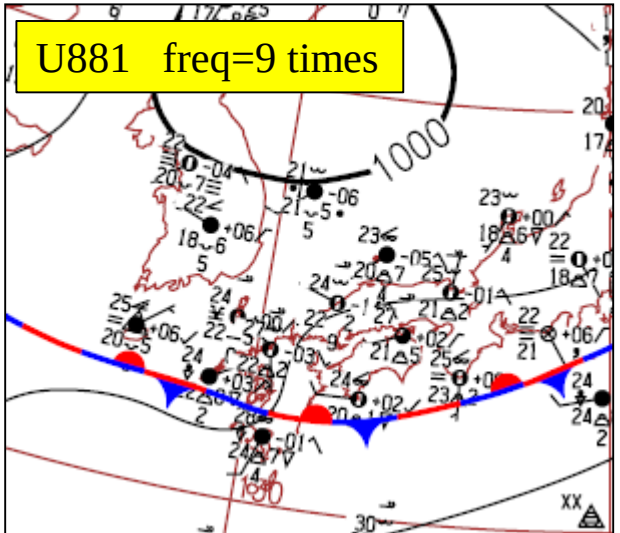

09JST, JULY 2, 2006




21JST, JULY 5, 2006

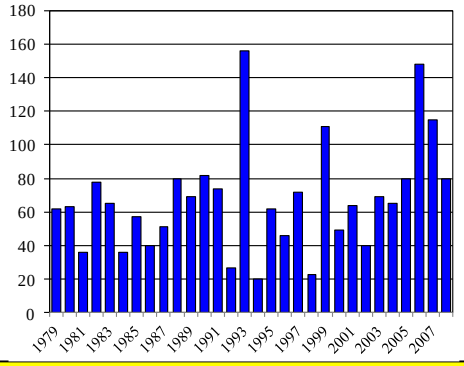


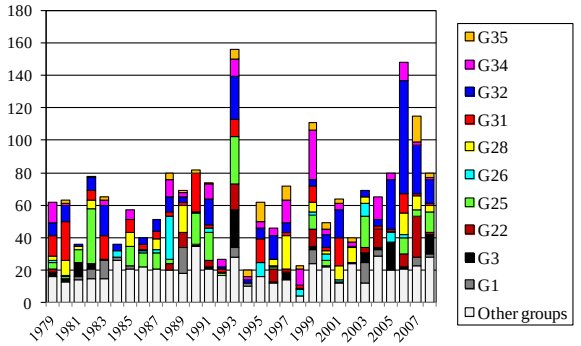

09JST, JULY 22, 2006



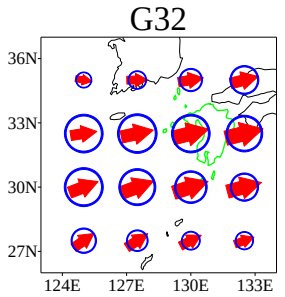
# Conclusion

Annual variation in heavy rainfall frequency in Kyushu, Japan can be divided into the groups of heavy rainfall patterns using the SOM.




Patterns with Low-level jet and frontal activity affected annual variation in heavy rainfall frequency.




It was found that the SOM is available for trend analysis of heavy rainfall frequency linking to weather patterns.