9th GEWEX Open Science Conference Poster board number: P56

Extraction of Aspect Ratio of Quasi-Stationary Band-Shaped Precipitation Systems, Named “Senjo-Kousuitai” Using Directional Variogram along with Its Evaluation

Hina Tsuchiya[1], Hiroshi Matsuyama[1] 1: Tokyo Metropolitan University E-mail: tsuchiya-hina@ed.tmu.ac.jp

Introduction

In recent years, quasi-stationary band-shaped precipitation systems, named “Senjo-Kousuitai” have caused many floods and landslide disasters in Japan. In response, Japan Meteorological Agency (JMA) began issuing **"Information on Significant Heavy Rainfall"** to warn the occurrence of “Senjo-Kousuitai” from June 2021. However, the criteria and thresholds for extracting “Senjo-Kousuitai” are purposefully and subjectively determined by each study. In order to prevent missing “Senjo-Kousuitai”, we considered it necessary to unify the criteria and thresholds, along with proposing a new method to examine the thresholds effectively.

Target cases and data used

◆Target cases

(a) “Heavy rainfall in northern Kyushu in July 2017”

(b) 17 cases with "Information on Significant Heavy Rainfall" announced in 2022 from JMA.

◆Data used

- Radar/Raingauge Analyzed Precipitation (RAP)

converted from 1km (0.00833° ×0.0125°) to 5 km (0.0625° ×0.05°) using the method of Urita et al. (2011, HRL)

◆Target area and period

(a) “Heavy rainfall in northern Kyushu in July 2017”

- The target area was set to 128.8° E to 132.5° E, 32.4° N to 35.5° N, and the target period was set to 2:00 to 7:00 on July 7, 2017 (In order to reproduce the same setting of Hirockawa et al. 2020, JMSJ)

(b) 17 cases with "Information on Significant Heavy Rainfall" announced in 2022 from JMA

- The target area was set to 4 degrees latitude and 6 degrees longitude to cover the entire area of intense rainfall. Since only hourly RAP could be obtained in this study, the period of coverage was set to three-hourly accumulated RAP, which includes the time when the "Information on Significant Heavy Rainfall" was announced.

Methods

◆Variogram

A variogram($\gamma^*(\mathfrak{h}_k)$) is method for capturing the extent of spatial autocorrelation of data.

$$\gamma^*(\mathfrak{h}_k) = \frac{\sum_{i=1}^{N_h}\{Z(x+h)-Z(x)\}^2}{2N_h}$$

N_h : Number of pairs of location within the target area
Z : precipitation x : coordinate h : distance from x

There are several theoretical variogram models that can be applied. In this study, the most commonly used spherical model ($C(h)$) was used.

$$C(h) = \begin{cases} b\left(1 - \frac{3}{2}\frac{|h|}{a} + \frac{1}{2}\frac{|h|^3}{a^3}\right) & (0 \le h \le a) \\ 0 & (|h| \ge a) \end{cases}$$

a : Range(Distance representing spatial autocorrelation)
b : Sill

◆Omni-directional variogram

The behavior of the variogram differs markedly depending on the direction.
= Anisotropic behavior

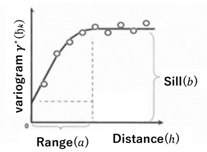

Fig. 1. Typical variogram
Addendum to Hatano et al.(2004, Theory and Applications of GIS),

Consider anisotropy

◆Directional variogram

Calculate a variogram for each 5-degree angle, and calculate and plot the range
→Extract the shape of “Senjo-Kousuitai”
Longest Range = major axis
Shortest Range = minor axis
→Extraction of aspect ratio of “Senjo-Kousuitai”

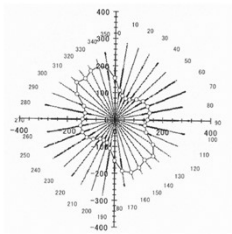

Fig. 2. Example of directional variogram
Shoji and Koike(2007, J. Geotherm. Res. Soc. Japan)

Results

(a)“Heavy rainfall in northern Kyushu in July 2017”

✓ Comparison with previous studies (Hirockawa et al. 2020, JMSJ)

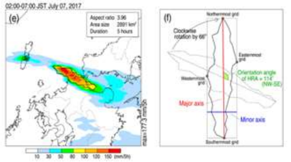

Fig. 3. Result of “Heavy rainfall in northern Kyushu in July 2017 and method of extraction of “Senjo-Kousuitai” from Hirockawa et al. (2020, JMSJ)

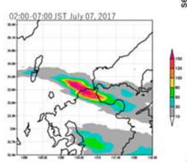

Fig. 4. Same as Fig .3. but is composited by the authors

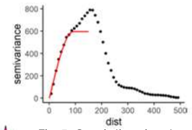

Fig. 5. Omni-directional variogram

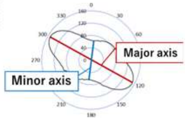

Fig. 6. Directional variogram

Result of Hirockawa et al. (2020)
Aspect ratio : **3.96**

Result of variogram (non precipitation threshold)
Aspect ratio : **2.41**

✓ Establishing precipitation threshold

Table 1.Result of major axis ,minor axis and aspect ratio with threshold

threshold	major axis(km)	minor axis(km)	aspect ratio
No threshold	153	63	2.41
10mm/5h	152	62	2.45
20mm/5h	149	59	2.52
30mm/5h	142	53	2.67
40mm/5h	139	49	2.82
50mm/5h	134	48	2.81
60mm/5h	131	47	2.80
70mm/5h	127	46	2.77
80mm/5h	125	44	2.83
90mm/5h	119	39	3.01
100mm/5h	114	38	3.04

When the threshold value increases, the aspect ratio also increases. Because setting a threshold value allows for more clear extraction of intense rainfall areas.

Thresholds were also applied to case(b) in the same way, and variogram was computed.

(b) 17 cases with "Information on Significant Heavy Rainfall" announced in 2022 from JMA.

✓ Comparison of aspect ratio of JMA with that from directional variogram (non precipitation thresholds)

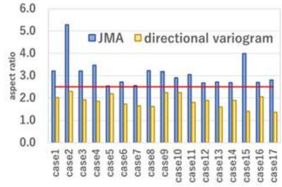

Fig. 7. Result of aspect ratios of JMA's and Directional Variogram

Aspect ratio of directional variogram showed smaller values than the JMA's because when no threshold was set, all rainfall areas within the target area, other than the heavy rainfall areas as “Senjo-Kousuitai” by the JMA, were included for the calculation.

✓ Variation of RMSE when precipitation threshold was set from 10mm/3h~100mm/3h (10mm/3h interval)

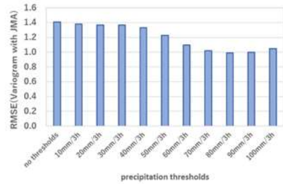

Fig. 8. Result of RMSE

RMSE was smallest when the threshold was set at **80 mm/3h.**

Setting the threshold at 80 mm/3h is most optimal for extracting “Senjo-Kousuitai”.

This threshold has been used in Hirockawa et al. (2020, JMSJ). it is said that driving or walking becomes dangerous at 30 mm/h. Therefore, the threshold value of 80mm/3h is considered to be a valid value.

Discussion

✓ Example of “Senjo-Kousitai” in Yamagata and Niigata Prefectures in August 2022

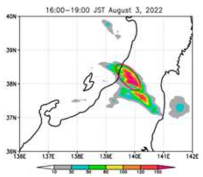

Fig. 9. Distribution of 3hourly rainfall

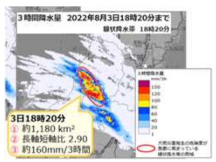

Fig. 10. "Information on Significant Heavy Rainfall" announced in 2022 from JMA

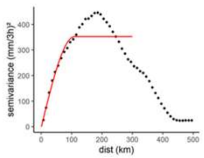

Fig. 11. Omni-directional Variogram

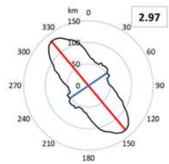

Fig. 12. Directional Variogram

Aspect ratio obtained in this case was close to that of JMA.

Since there were almost no precipitation systems other than the heavy rainfall area considered to be “Senjo-Kousuitai” within the target area, it was possible to extract aspect ratio only for the desired heavy rainfall area.

✓ Example of “Senjo-Kousitai” in Miyazaki Prefectures in August 2022

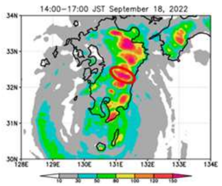

Fig. 13. Distribution of 3hourly rainfall

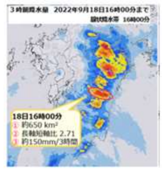

Fig. 14. "Information on Significant Heavy Rainfall" announced in 2022 from JMA

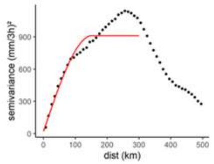

Fig. 15. Omni-directional Variogram

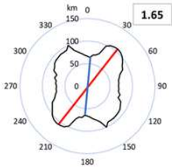

Fig. 16. Directional Variogram

- Aspect ratio obtained in this case was smaller than that of the JMA.
- Orientation of “Senjo-Kousuitai” was not reproduced.

Because there are many precipitation systems other than “senjo-Kousuitai” within the target area due to typhoons.

Conclusions

- **When the precipitation threshold used to extract “Senjo-Kousuitai” was set at 80mm/3h, aspect ratios are closest to the values announced by JMA.**
- **It is particularly difficult to extract “Senjo-Kousuitai” and aspect ratios when there are multiple precipitation systems other than “Senjo-Kousuitai” within the area of interest.**

→ Quantitative study of the setting of the target area is necessary.

- **The method proposed in this study is not suitable for the extraction of “Senjo-Kousuitai” caused by typhoons.**