Relation between Shape of Extreme Wave Height Distributions and Weather System

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Research Background

- How physical mechanism determining probability distribution of extreme wave data hasn't revealed.
- There are 2 main weather systems which can cause coastal disasters around Japan. These are different in the season and area.
  - Typhoon (Tropical Cyclone; TC)
    - Summer and Autumn, heavy influence to the Pacific Ocean side
  - Bomb Cyclone; BC (Explosively developing extratropical cyclone)
    - Winter and Spring, heavy influence to the Japan Sea side
- We analyzed the relationship between the weather systems that bring extreme waves in the coast around Japan and the statistical characteristics.

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clarifying factors that determine
the probability distribution of the extreme wave height

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   - EVA not considering weather systems
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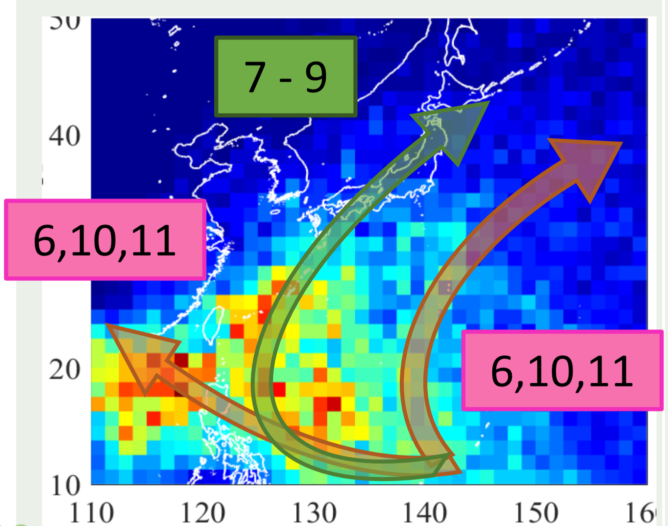
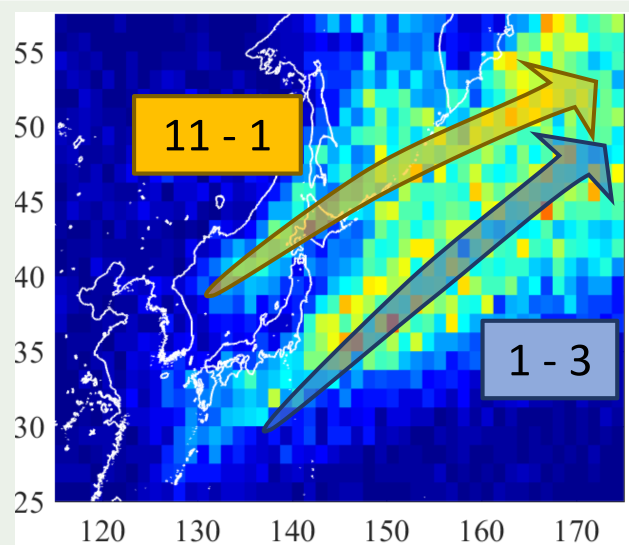
Features of Weather System around Japan

Typhoon; TC		Bomb Cyclone; BC
Tropical Cyclone	Category	Extratropical Cyclone
Summer / Autumn	Peak Season	Winter / Spring
$u \geq 34$ [kt] ($\fallingdotseq 17.2$ [m/s]) u: maximum wind speed (10 minutes average)	Definition	$\varepsilon_{max} \geq 1$ [hPa/hour] $\varepsilon = \frac{p_{t-12} - p_{t+12}}{24} \frac{\sin 60°}{\sin \varphi}$ p: SLP (hPa) φ: latitude t: time
minimum: 870 hPa (1979) mean: 972 hPa, std: 30.0 hPa	Minimum Center Pressure	min: 924 hPa (1981) mean: 971 hPa, std: 11.5 hPa
26	Number / year	32 (only in Nov - Apr)
	Passing Frequency / Major Track by Season	

Outline of Analysis

Atmospheric reanalysis data

JRA-55 ($\Delta x = 60$ km)

- wind speed ($\Delta t = 6$ hour)
- sea ice concentration (monthly)

WNP by WAVEWATCH Ⅲ

Wave Height data

- $\Delta t = 1$ hour, $\Delta x = 7$ km
- 34 years (1979 - 2012)

Weather system data

IBTrACS → TC track data

JRA-55 SLP ($\Delta t = 6$ hour) → extract → BC track data

divide systems → **AMS data by system**

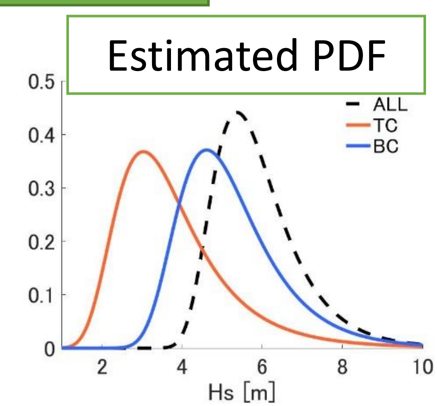
GEV parameter estimation by PWM method

GEV parameters by system

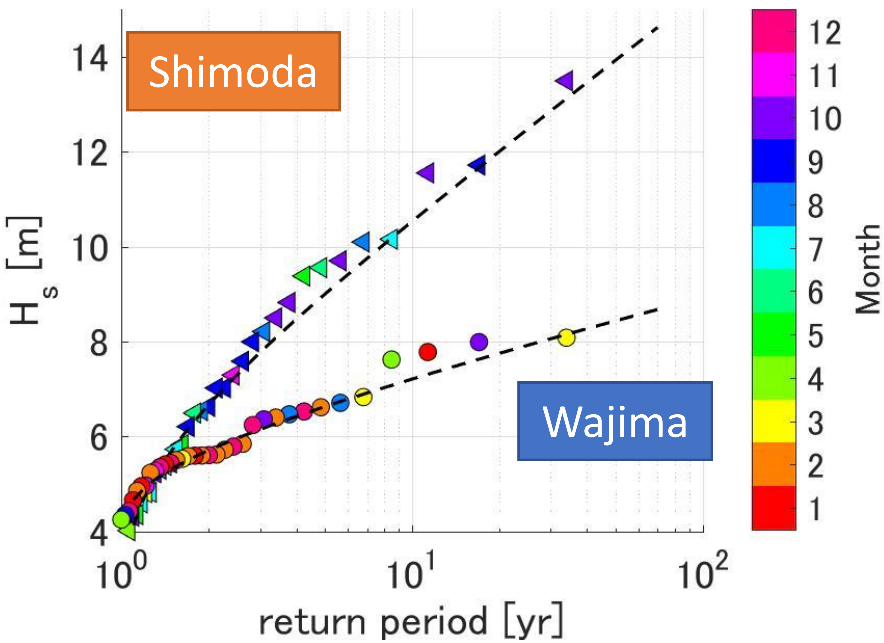
GEV distribution

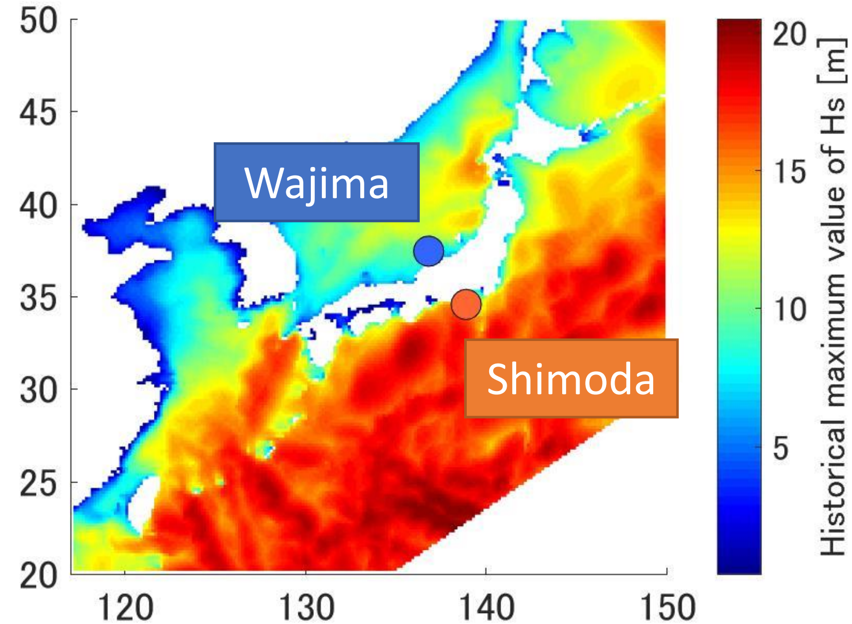
$$F_X(x) = \exp\left[-\left(1 - k\frac{x-\mu}{\sigma}\right)^{1/k}\right]$$

k : shape, σ: scale, μ: location parameter



Example: Extreme Wave height at the Japan Sea and the Pacific Ocean

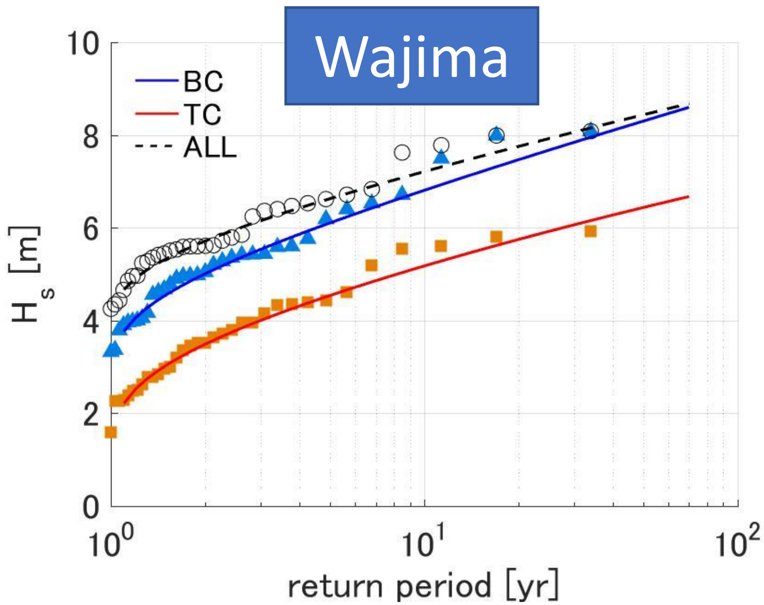


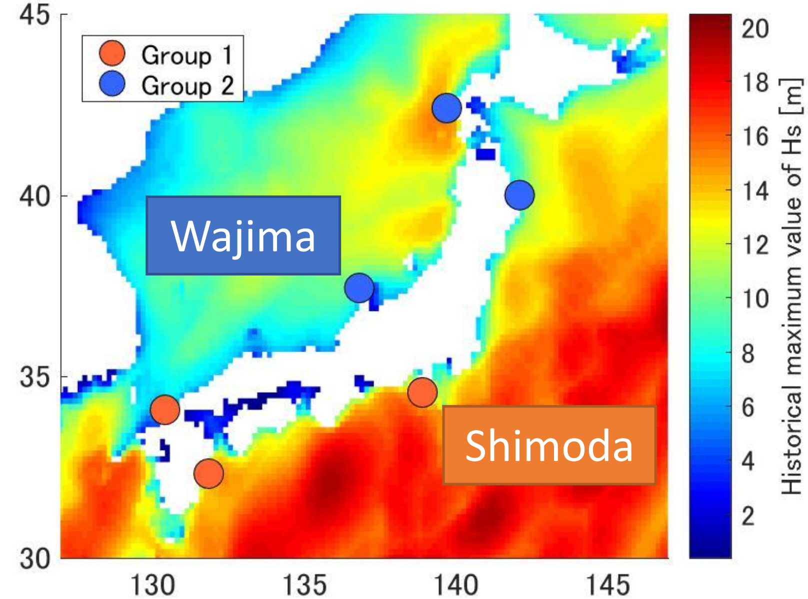


- Differences between 2 points

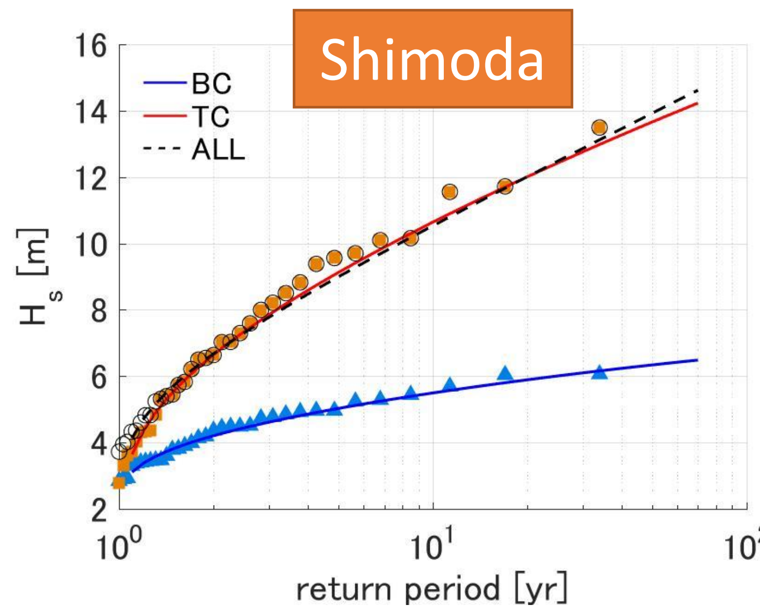
	Japan Sea	Pacific Ocean
Extreme Hs Value	Smaller	Larger
Peak season	Dec, Jan, Feb	Sep, Oct
Dominant system	Bomb Cyclone	Typhoon

Comparison of Dominant Weather System for High Waves





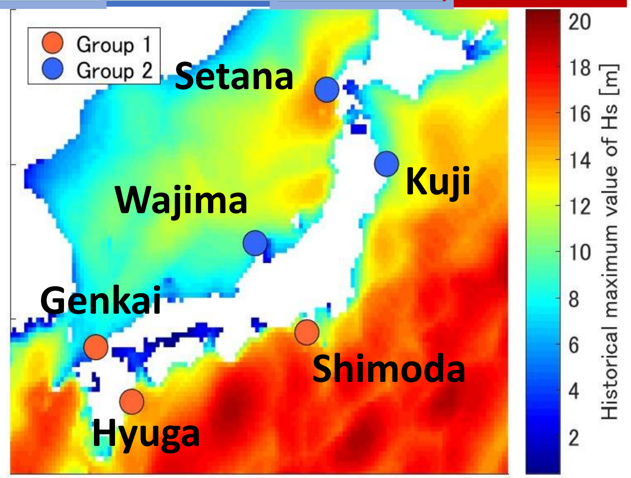
- Gr1: High waves by TC are dominant.
  - TC: cause 2 - 3 times larger waves than BC
  - BC: not cause significantly high waves
- Gr2: High waves by BC are dominant.
  - BC: high frequent, mean value of extreme waves is higher than TC
  - TC: low frequent, but can cause larger waves than BC



GEV Parameters at Each Points

System	ALL			TC			BC		
loc＼par	k	σ	μ	k	σ	μ	k	σ	μ
Gr1 Hyuga	0.09	2.26	7.01	0.08	2.18	6.80	0.28	0.65	2.93
Gr1 Shimoda	0.00	2.05	5.92	0.11	2.21	5.4[illegible]	0.12	[illegible].78	3.71
Gr1 Genkai	0.01	0.68	4.24	0.10	1.07	3.23	-0.10	0.45	2.88
Gr2 Wajima	0.04	0.84	5.40	0.11	1.00	2.97	0.02	0.98	4.34
Gr2 Kuji	0.02	1.00	6.29	0.32	1.42	4.9[illegible]	0.02	1.28	4.94
Gr2 Setana	0.08	1.10	6.06	-0.05	1.23	2.75	0.18	1.22	5.13

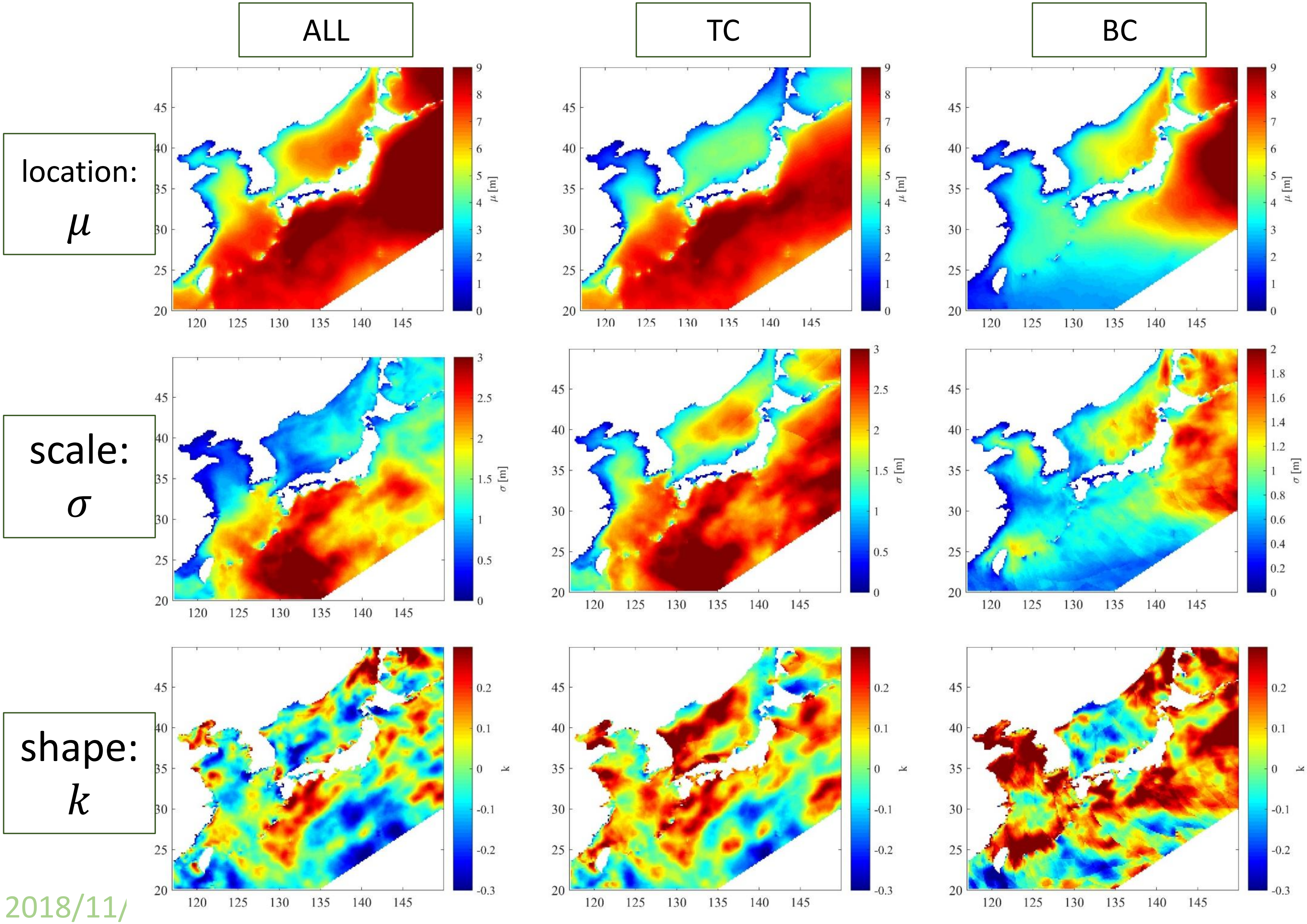
- location parameter: μ
  - average of extreme wave height
  - μ of dominant system → large
- scale parameter: σ
  - deviation of extreme wave height
  - σ of TC > σ of BC
- shape parameter: k
  - value determining tail of the distribution
  - large k → long tail



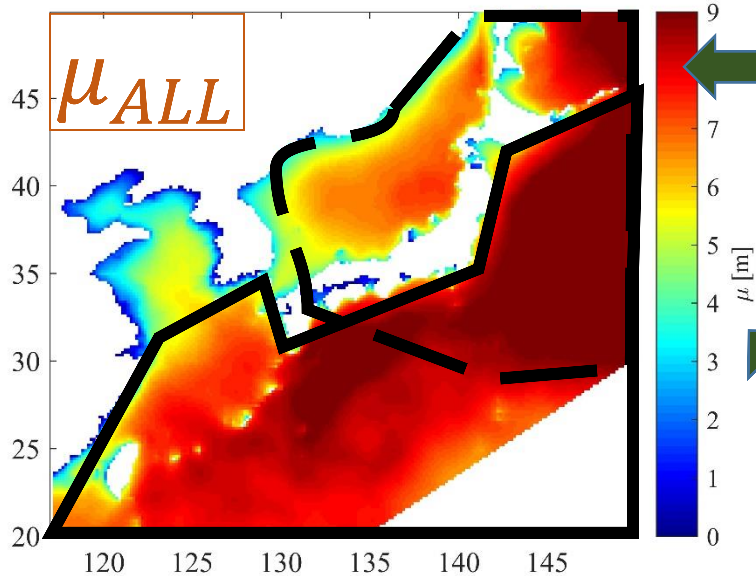
GEV distribution

$$F_X(x) = \exp\left[-\left(1 - k\frac{x-\mu}{\sigma}\right)^{1/k}\right]$$

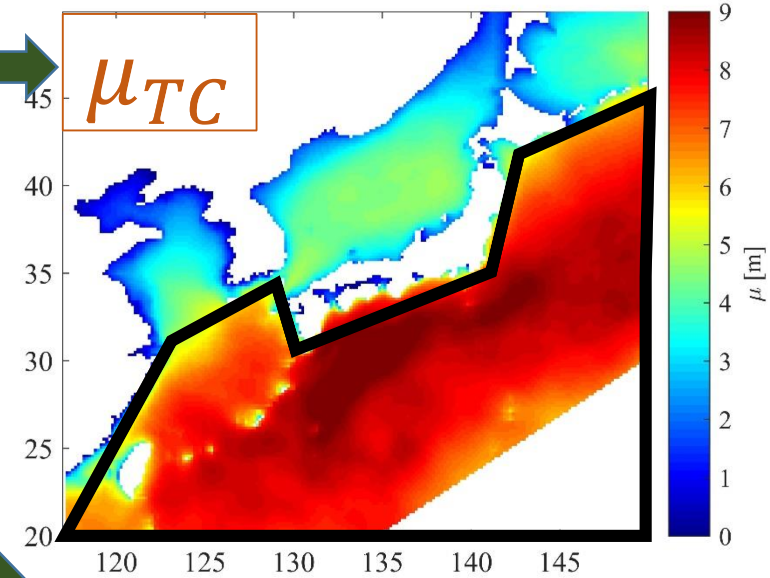
Estimation of GEV Parameters by Weather System



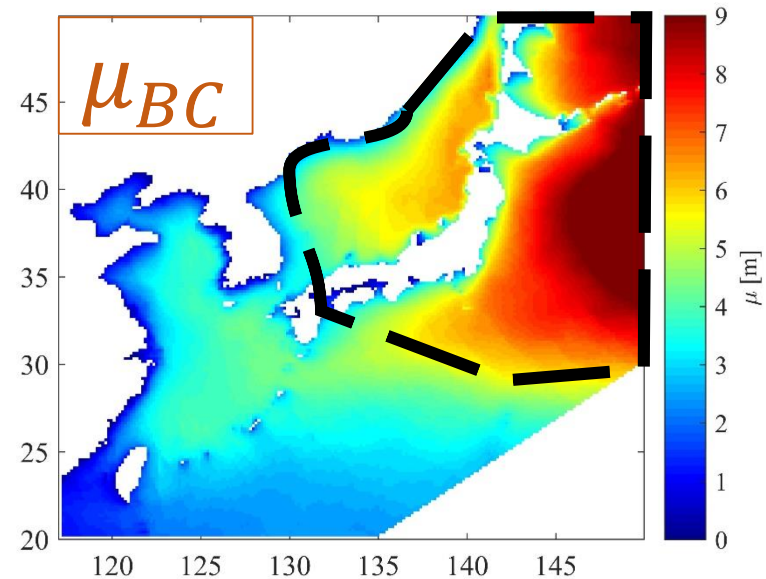
Spatial Distribution of Location Parameter: μ



R = 0.84

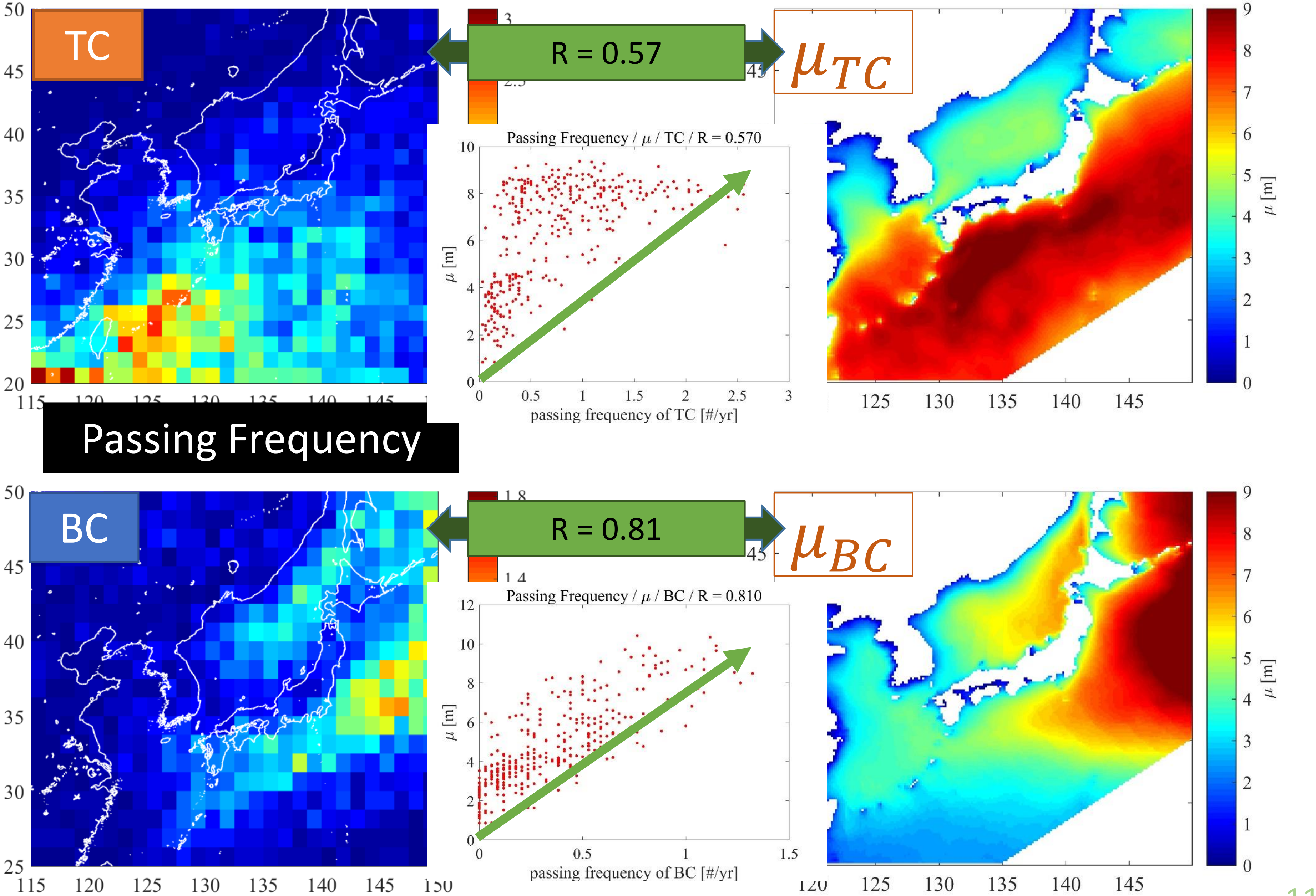


R = 0.69

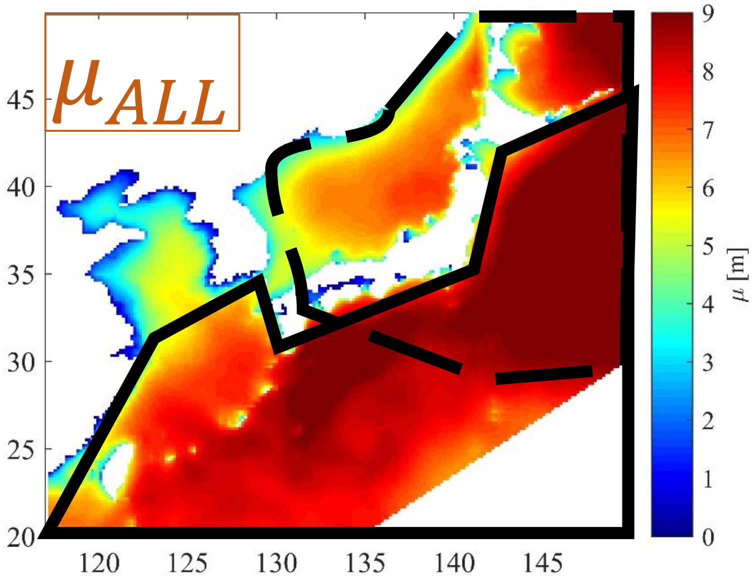


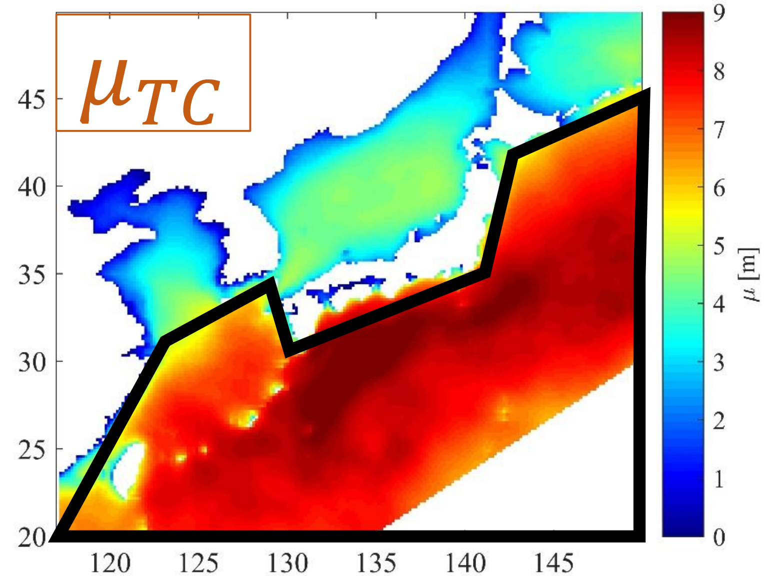
- ◆ μ_{TC} is large in the entire Pacific
- ◆ μ_{BC} is large in the east of Japan sea, the Okhotsk and the Pacific
- ◆ μ_{ALL}: like an overlap of μ_{TC} and μ_{BC}

Spatial Distribution of Location Parameter: μ

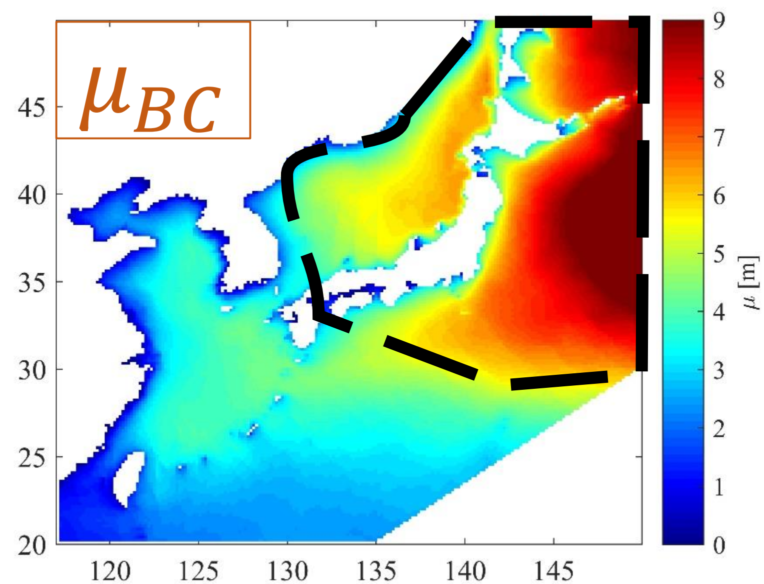


Spatial Distribution of Location Parameter: μ

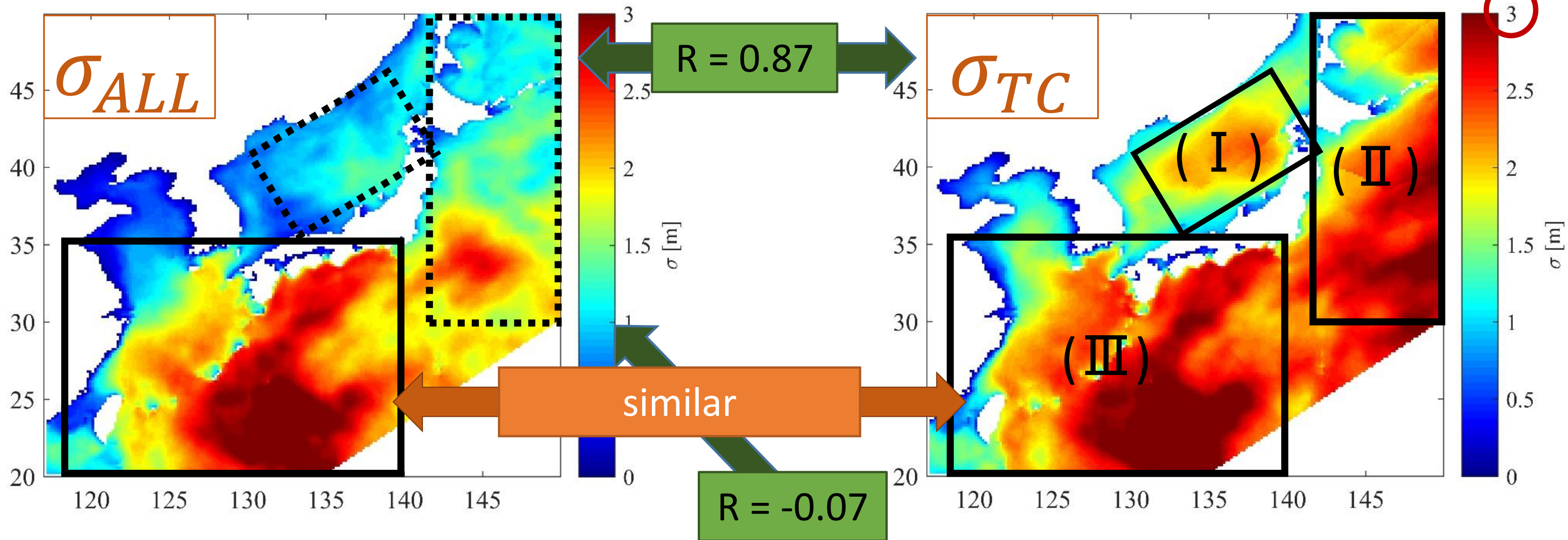




- μ_{TC} is large in the entire Pacific
  - passing frequency / moving direction
- μ_{BC} is large in the east of Japan sea, the Okhotsk and the Pacific
  - passing frequency / moving direction
- μ_{ALL}: like an overlap of μ_{TC} and μ_{BC}

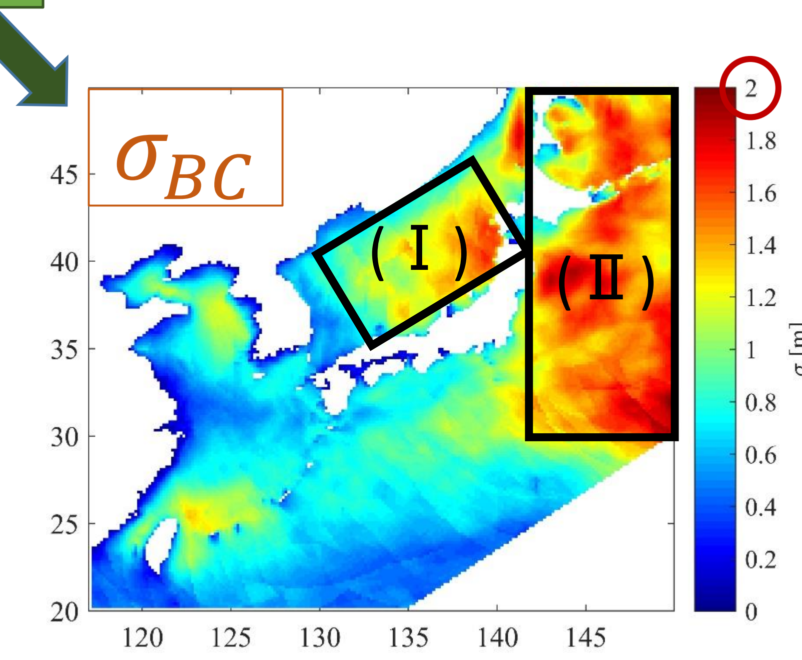


Spatial Distribution of Scale Parameter: σ

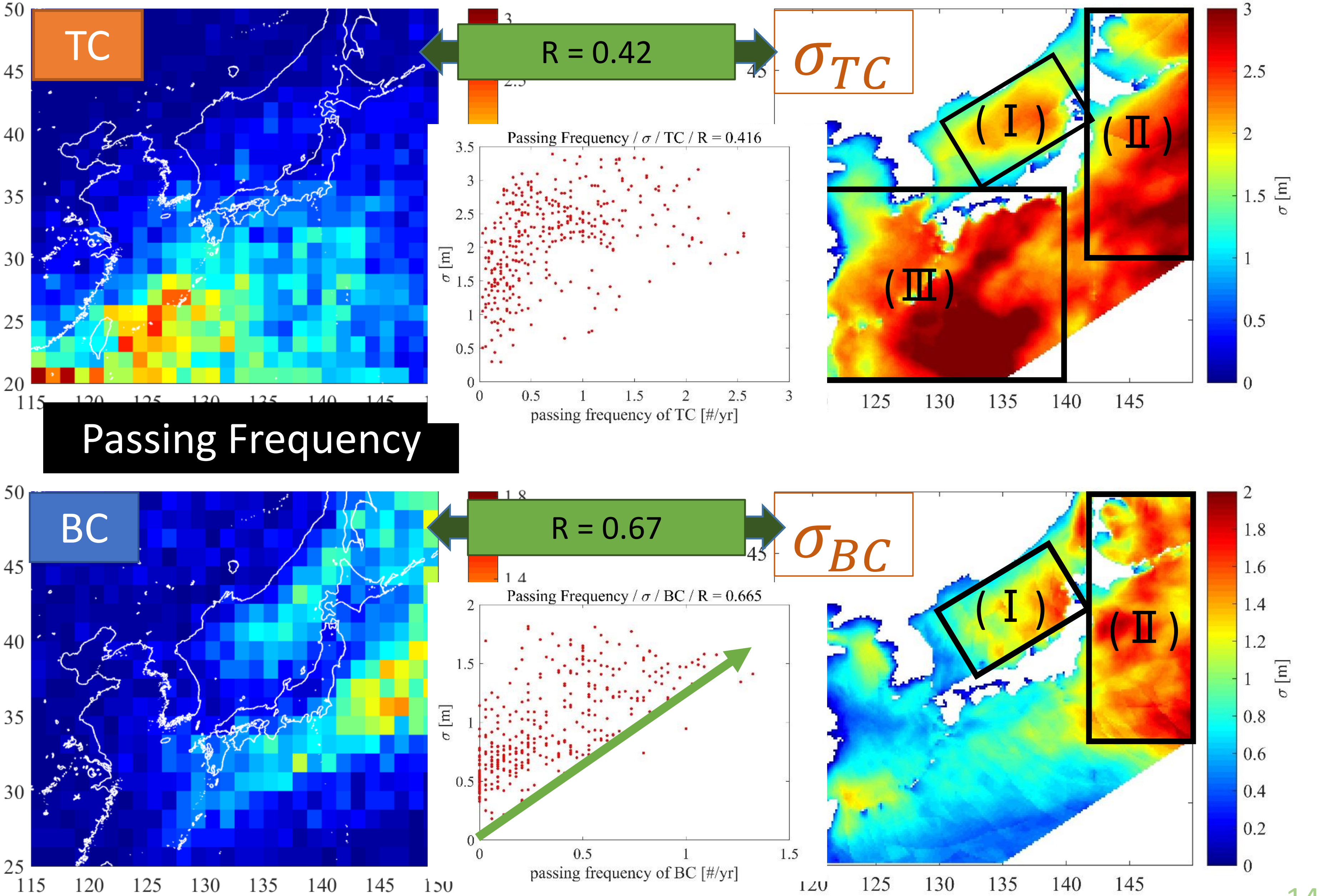


- σ_{TC} is large in Ⅰ , Ⅱ , Ⅲ

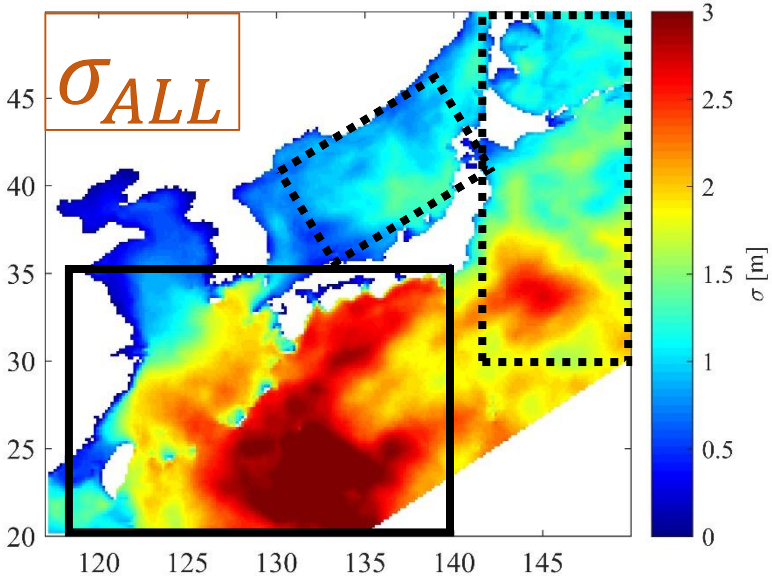
- σ_{BC} is large in Ⅰ , Ⅱ

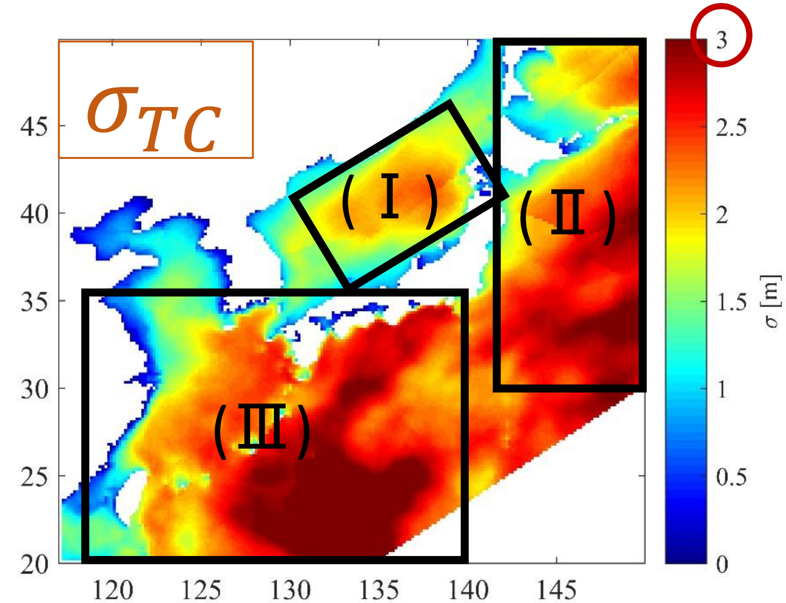


Spatial Distribution of Scale Parameter: σ

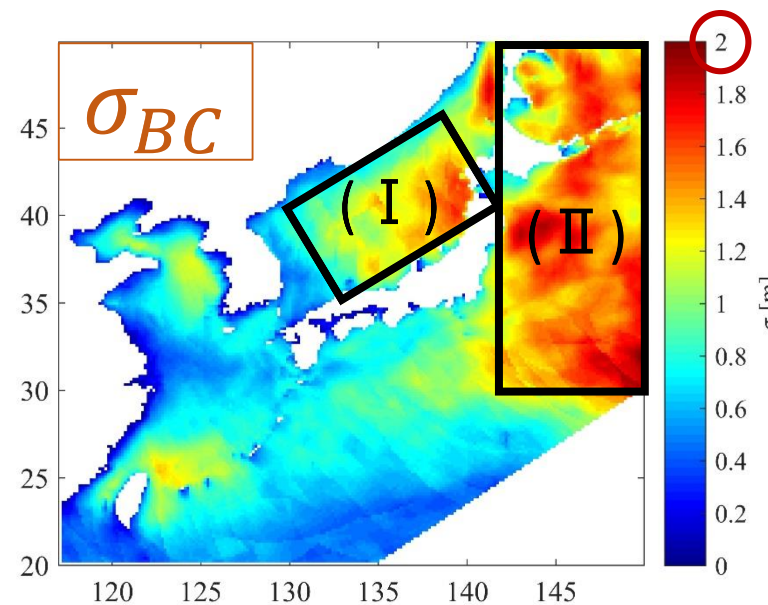


Spatial Distribution of Scale Parameter: σ

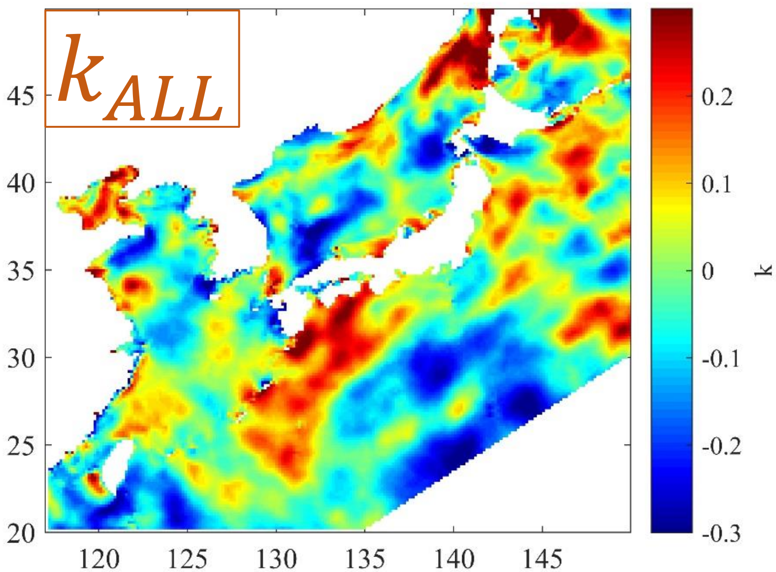


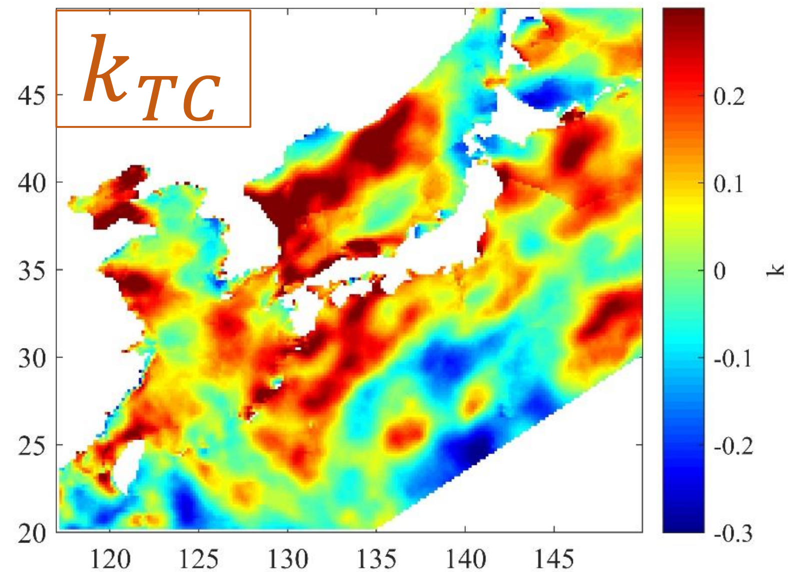


- ◆ σ_{TC} is large in Ⅰ, Ⅱ, Ⅲ
  - (Ⅲ) high TC frequency:
    TC development and distance to TC
  - (Ⅰ), (Ⅱ) low TC frequency:
    Ⅰ : arrival, Ⅱ : moving direction of TC
- ◆ σ_{BC} is large in Ⅰ, Ⅱ
  - (Ⅰ), (Ⅱ) high BC frequency
    BC development
- ◆ σ_{ALL} is small in Ⅰ, Ⅱ
  - both TC and BC influence

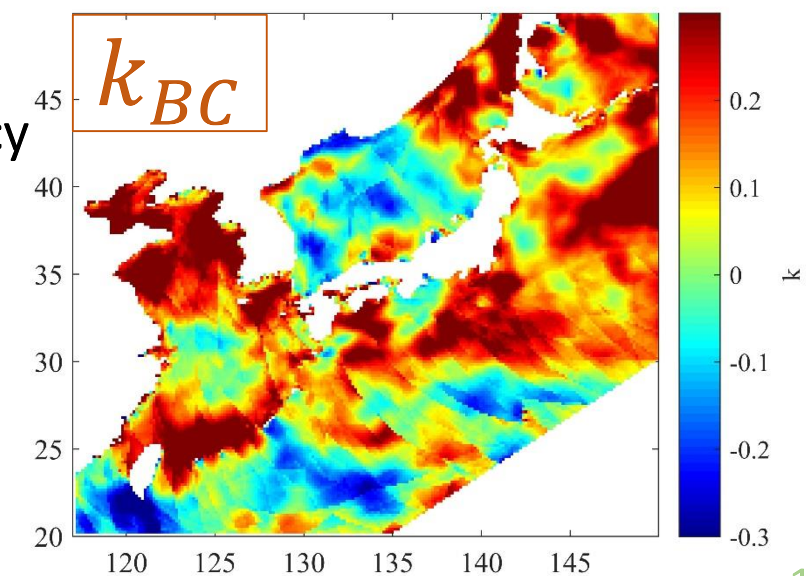


Spatial Distribution of Shape Parameter: k





- shape parameter k: determine tail of distribution
  → very important
  - no correlation with passing frequency of the systems
  - affected by various factors or just random



Analysis to identify the factors is my future work.

Conclusion

- We analyzed the relationship between weather systems and GEV distribution of extreme wave height and tried to identify the factors which determine the parameters of GEV.
  - Location parameter: μ, Scale parameter: σ
    - Characteristic spatial distribution correlated with passing frequency and moving direction of systems
  - Shape parameter: k
    - Complex spatial distribution affected by various factors or determined just randomly
- Future work
  - Quantitative evaluation of factors to determine GEV parameters, especially σ and μ
  - Analysis to identify the factors to influence shape parameter k