INVESTIGATING PARENT DISTRIBUTION OF TYPHOON-GENERATED ANNUAL MAXIMUM WAVE HEIGHT AND SAMPLE DISTRIBUTION OF RETURN WAVE HEIGHT ON THE EAST CHINA SEA

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1. Aim of the Study

- Identifying the parent distribtion of extreme waves may contribute to an improvement of statistical reliability of the estimated return wave height. From this point of view,
- by using a Monte-Carlo simulation model, we make a huge size sample of typhoon-generated(**TG**) annual maximum(**AM**) wave height on the East China Sea with extensive shallow water area, where AM wave height is usually produced by a strong typhoon.

The extreme value analyses using the sample are conducted for two purposes.

1) Estimation of a parent distribution of **TG-AM** wave height

   - a **TG-AM** sample with size of 10,000

2) Investigation of sample distribution of return wave height

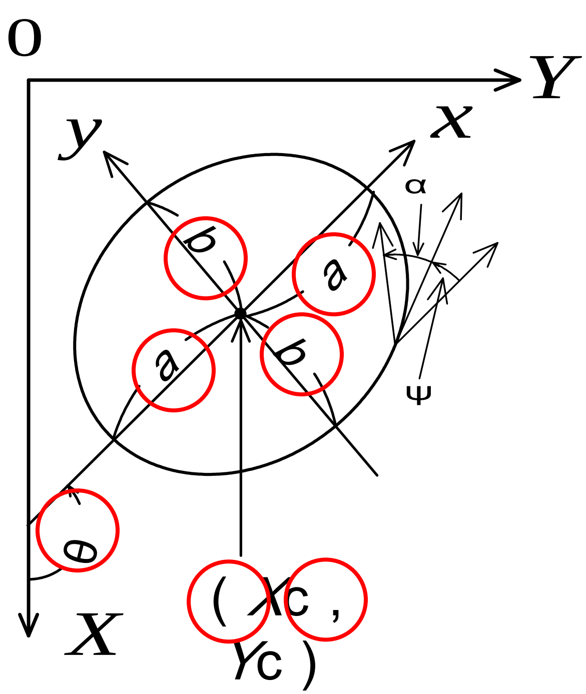
   - 200 sets of a **TG-AM** sample with size of 50

2. Description of the Method

Model for Pressure Distribution in a Typhoon

Elliptical distribution(considering decay of typhoon power)

$$p=p_c + (1013-p_c)\cdot \exp[-\{(x/a)^2+(y/b)^2\}^{-1/2}]$$



X_c , Y_c , p_c , θ, a, b

6 parameters

$R=(a+b)/2$:
mean typhoon radius

Monte-Carlo Simulation Model

consists of 4 sub-models for

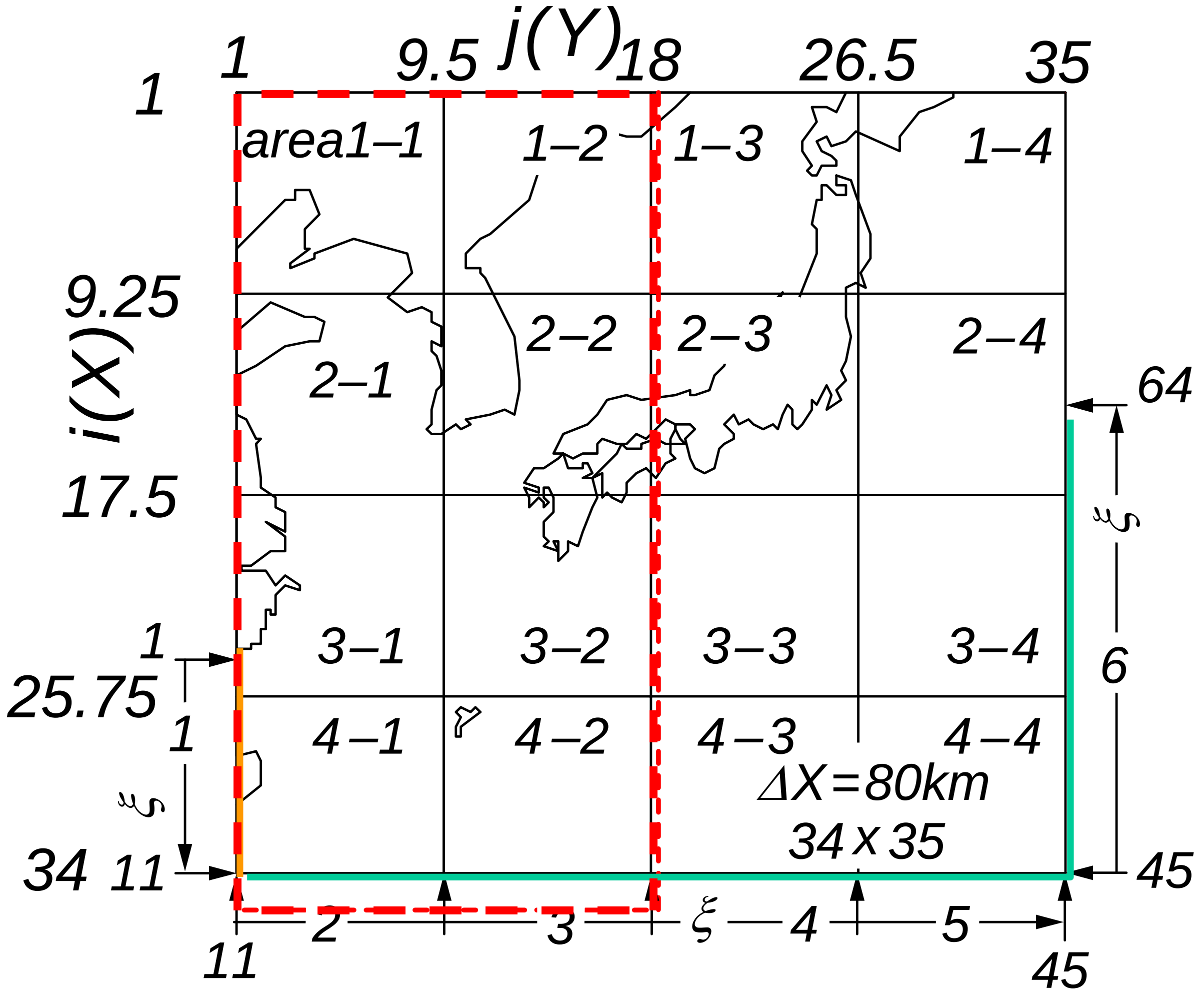
1) stochastic generation model for parameters of a typhoon

2) gradient wind model

3) 2-G shallow water wave model

4) LSM-based extreme value analysis model

Modeling Domain



Wave computation is conducted on the East China Sea area enclosed by dotted line.

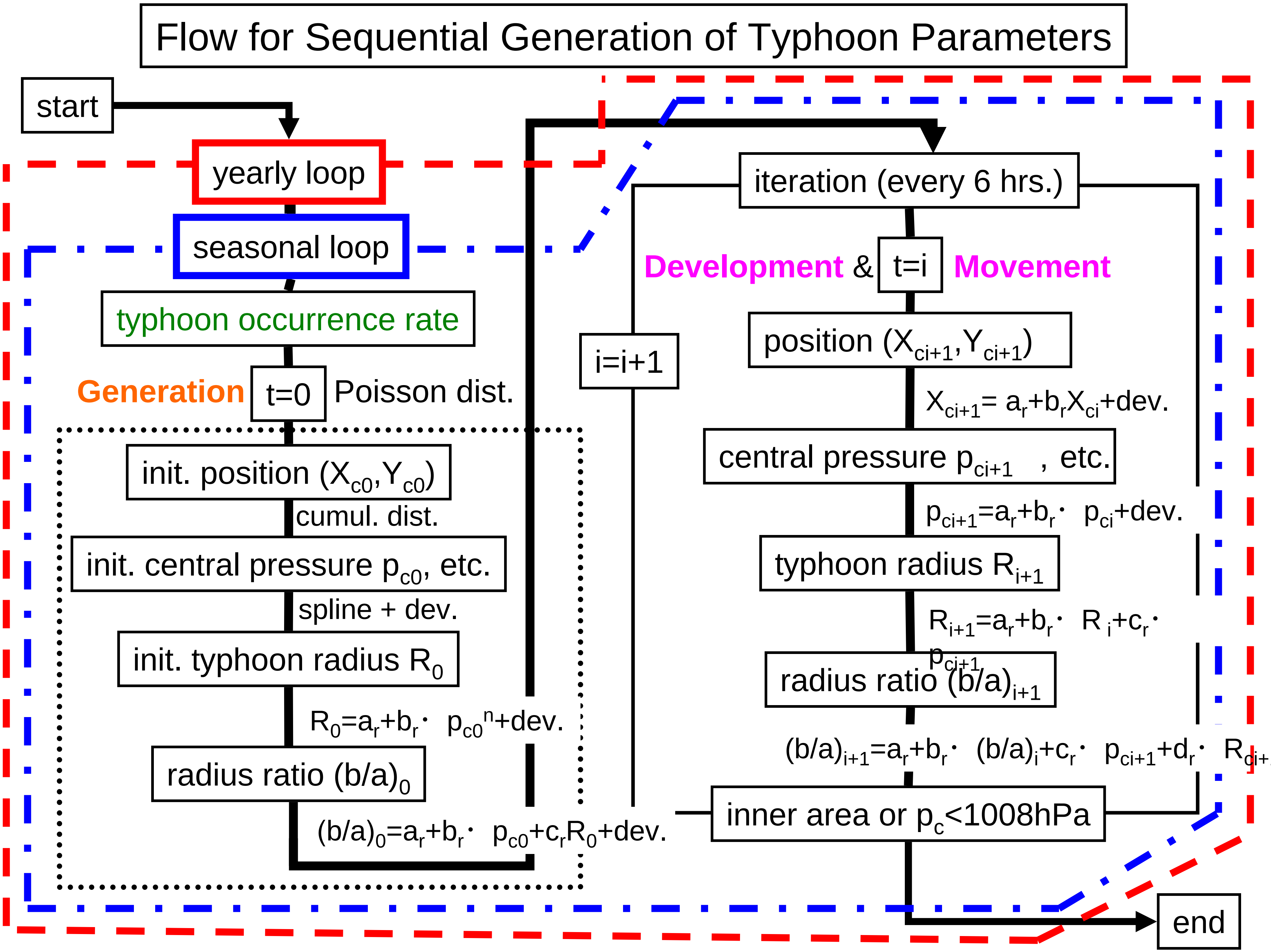
Stochastic Typhoon Model

consists of 3 sub-models for

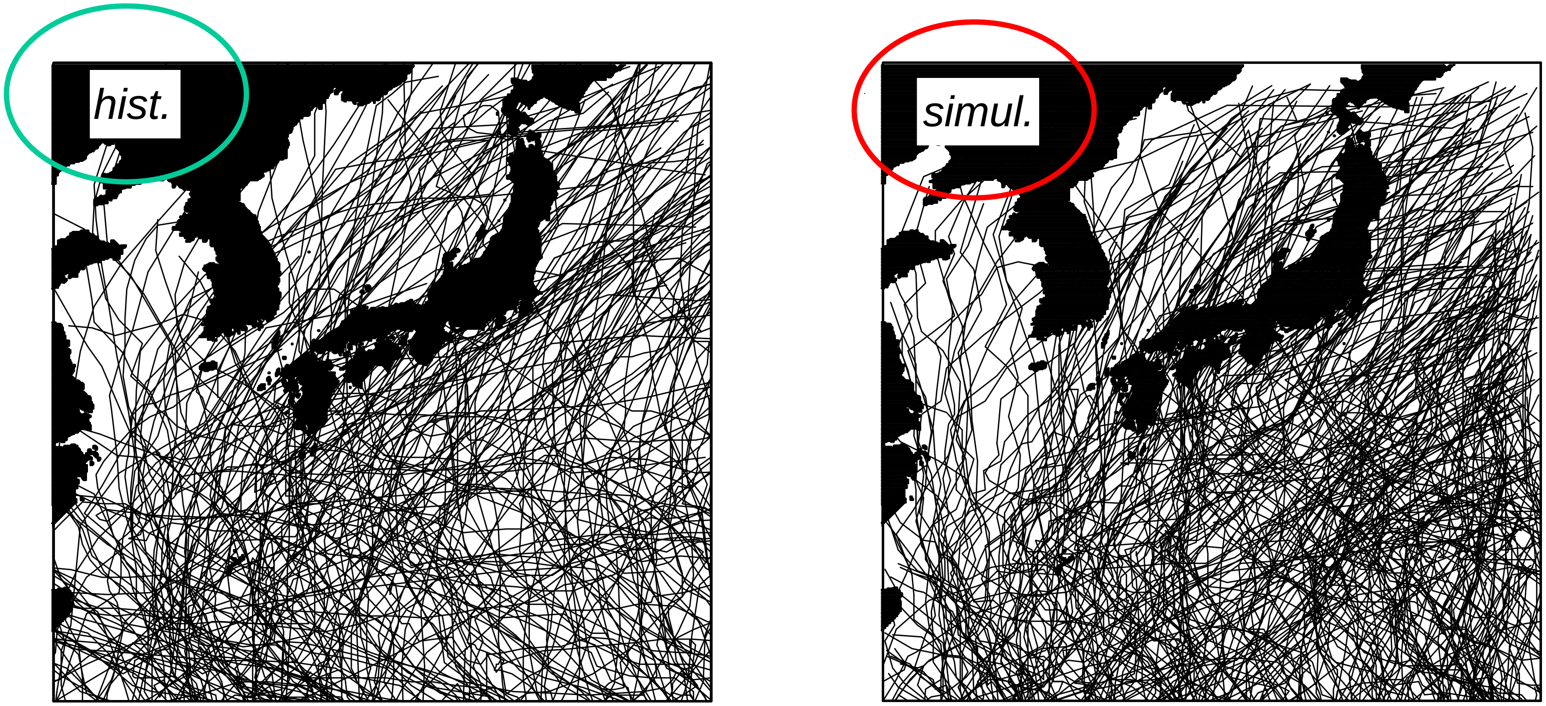
1) the annual occurrence rate : Poisson dist.

2) generation of the parameters of a typhoon
on the boundary

3) change of the parameters with movement
of a typhoon in the inner region



Flow for Sequential Generation of Typhoon Parameters
start
yearly loop
seasonal loop
typhoon occurrence rate
Generation
t=0
Poisson dist.
init. position (Xc0,Yc0)
cumul. dist.
init. central pressure pc0, etc.
spline + dev.
init. typhoon radius R0
R0=ar+br· pc0n+dev.
radius ratio (b/a)0
(b/a)0=ar+br· pc0+crR0+dev.
iteration (every 6 hrs.)
Development
&
t=i
Movement
i=i+1
position (Xci+1,Yci+1)
Xci+1= ar+brXci+dev.
central pressure pci+1 , etc.
pci+1=ar+br· pci+dev.
typhoon radius Ri+1
Ri+1=ar+br· R i+cr· pci+1
radius ratio (b/a)i+1
(b/a)i+1=ar+br· (b/a)i+cr· pci+1+dr· Rci+1
inner area or pc<1008hPa
end



Tracks of historical and simulated typhoons in 47 years

LSM-Based Extreme Value Analysis Model

- Candidate distributions:

  a) Gumbel distribution

  $$F(x)=\exp[-\exp\{-(x-B)/A\}]$$

  b) Weibull distribution with 27 kinds of fixed shape parameter (k=0.5 - 10)

  $$F(x)=1-\exp[-\{(x-B)/A\}^{k}]$$

  where A : scale parameter, B:location parameter

- Criterion of the largest correlation coefficient

Conditions of Wave Computation on the East China Sea (40 km grid)

1) about 40,000 typhoons
   simulated over 10,000 years

2) 315 strong historical typhoons in
   51 years from 1948 to 1998

3. Estimation of a Parent Distribution

a) Simulated typhoon case

- A sample of **TG-AM** wave height with size of 10,000

b) Historical typhoon case

- A sample of **TG-AM** wave height with size of 51

- Gumbel distribution (A, B) is also represented by

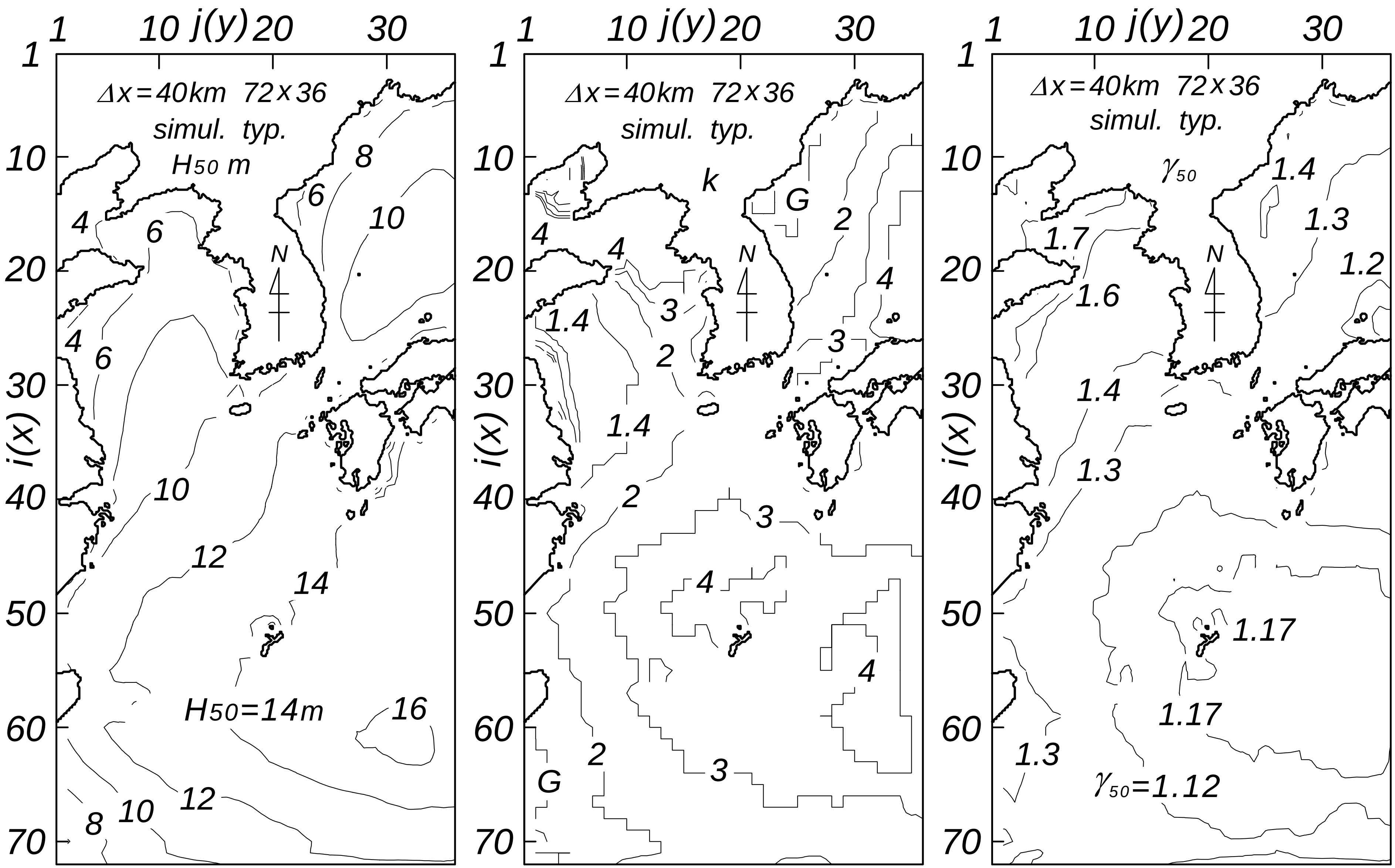
H_{50} and γ_{50} (=H_{50}/H_{10})

γ_{50}:spread parameter(Goda)

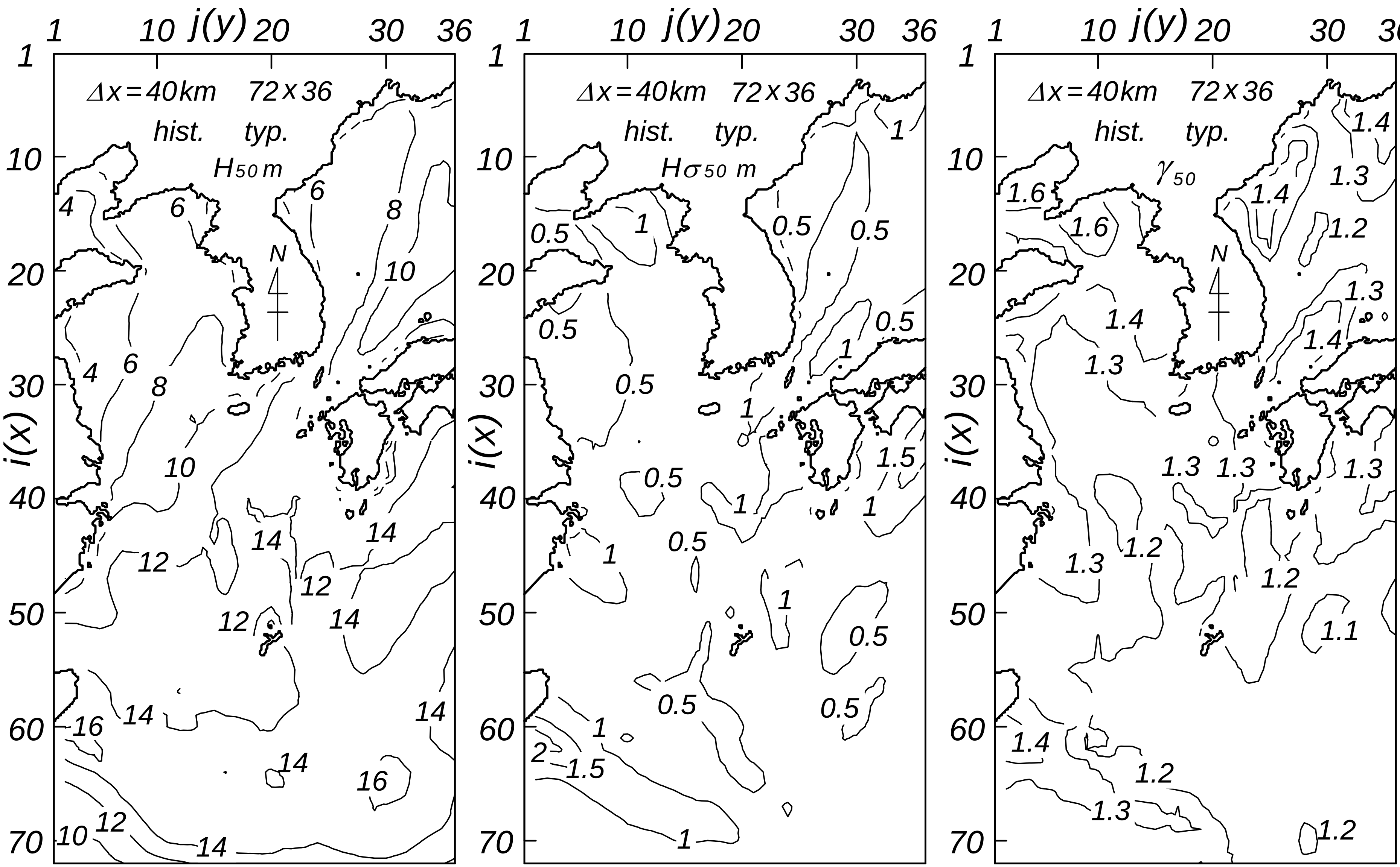
H_r : r-year return wave height

- Weibull distribution (k, A, B) is also represented by

k, H_{50} and γ_{50} (=H_{50}/H_{10})



H_{50}, k, $\gamma_{50}=H_{50}/H_{10}$(simulated typhoon case)



H_{50}, $H_{\sigma 50}$, $\gamma_{50} = H_{50}/H_{10}$(historical typhoon case)

4. Sample Distribution of Return Wave Height

- Extreme value analyses for 200 sets of

  a TG-AM sample with size 50 are conducted in

a) Fixed Shape Parameter (**FSP**) case

✧ shape parameter is fixed to that estimated using
  a sample with size 10,000.

and

b) Variable Shape Parameter (**VSP**) case

✧ shape parameter is variable.
  (criterion of the largest correlation coefficient)

From a return wave height sample with size 200 in FSP or VSP case,

statistics such as

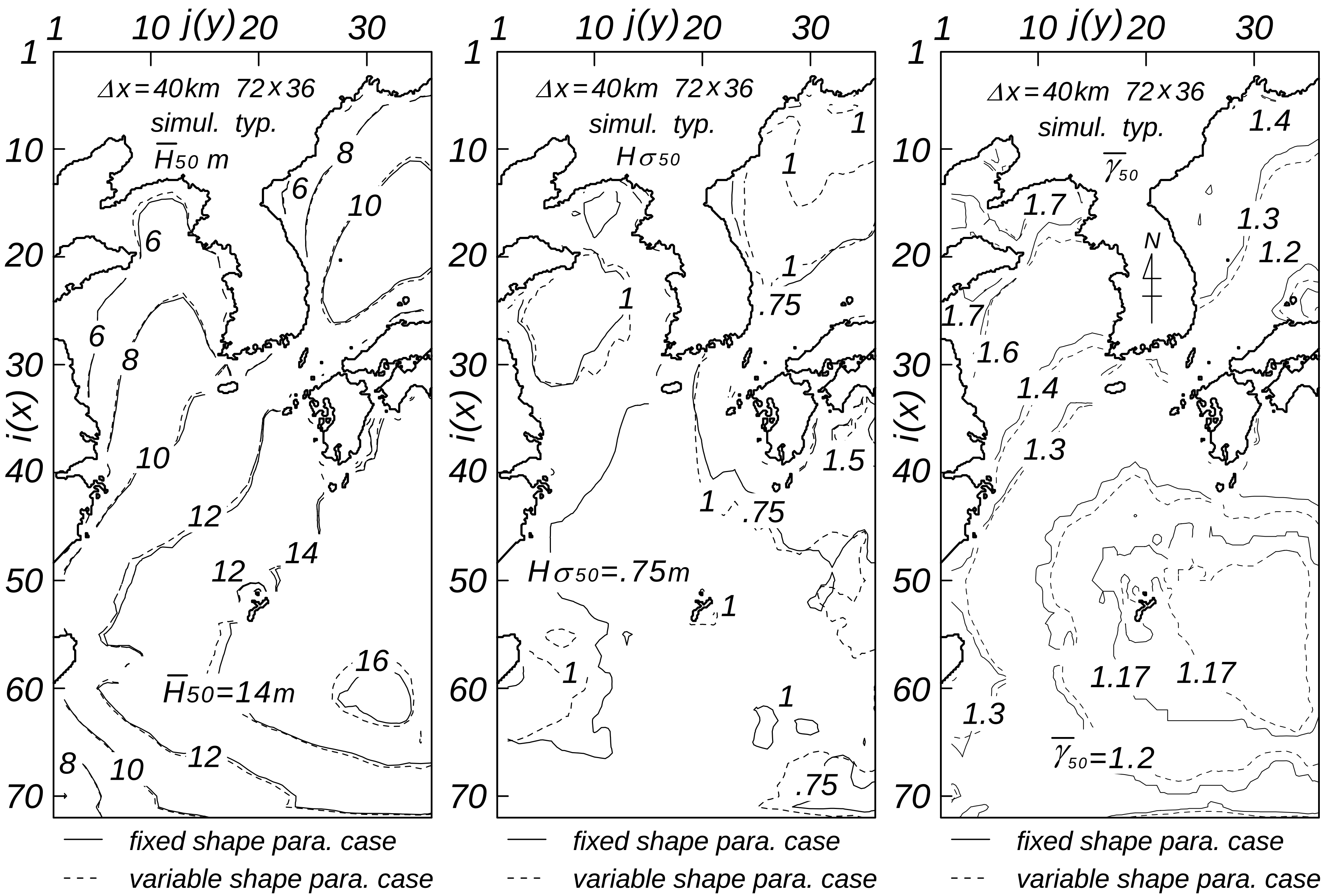
mean $\overline{H}_r$

standard deviation $H_{\sigma r}$

skewness α_r

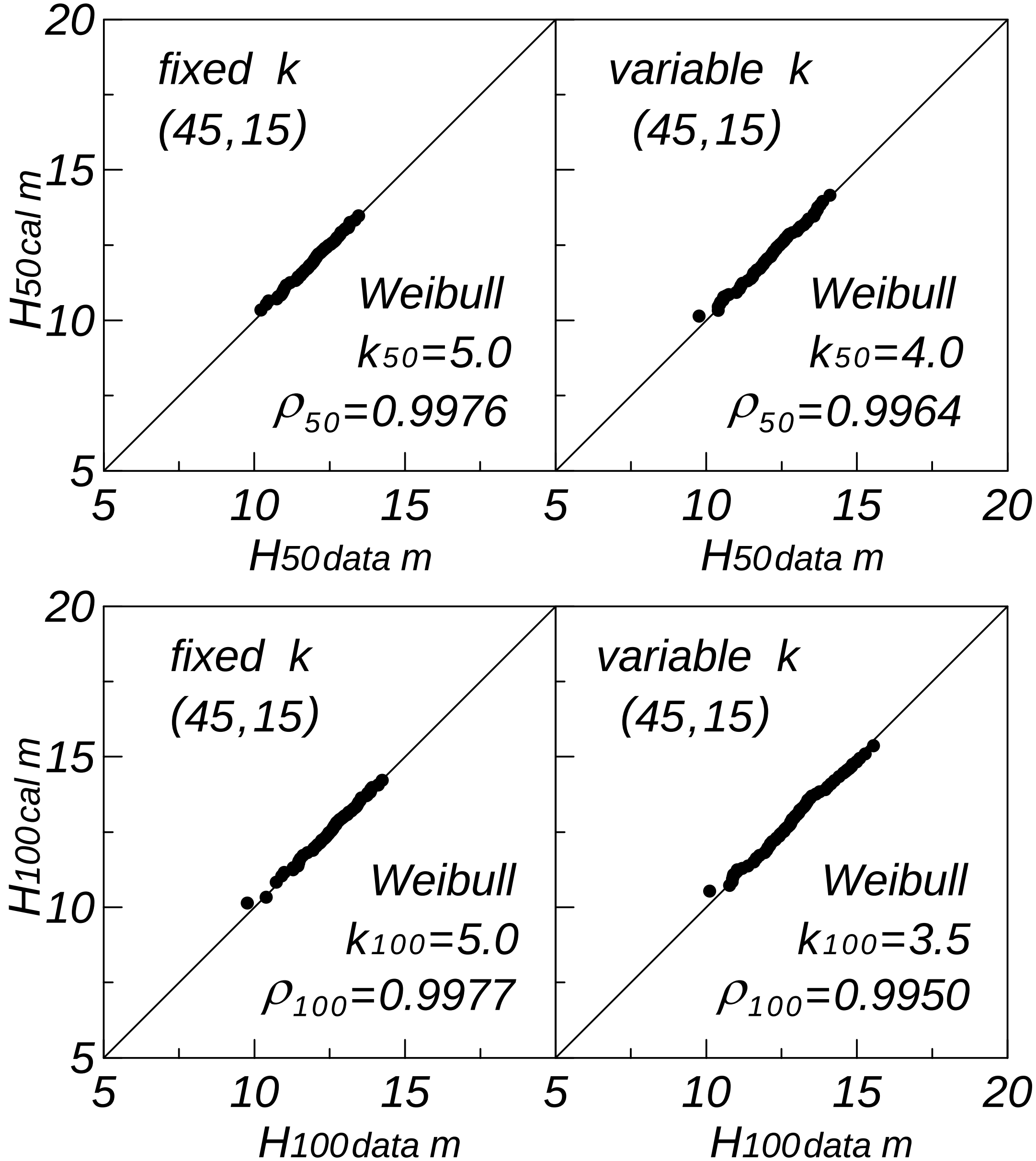
kurtosis β_r

are calculated. r : return period



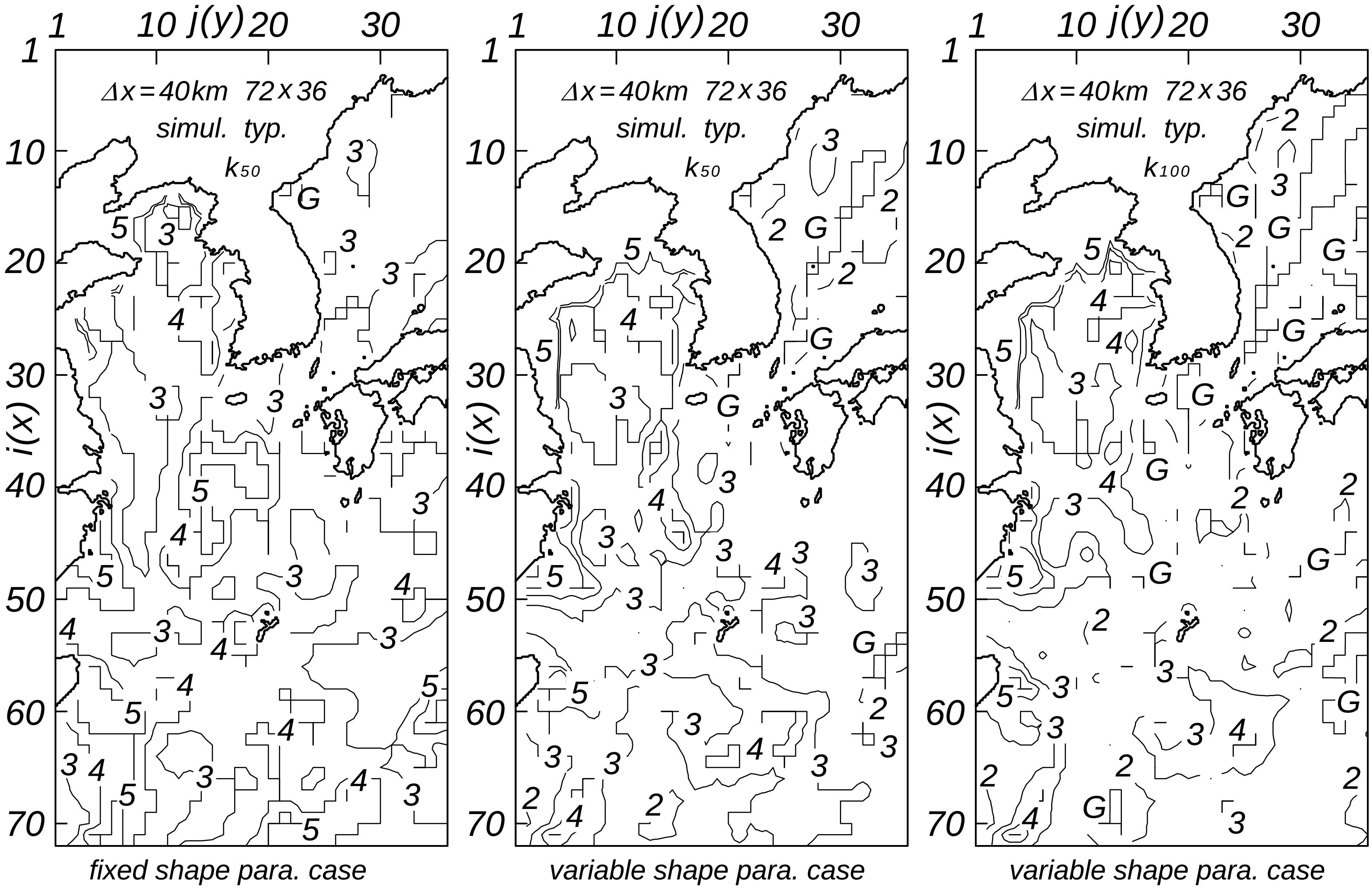
Statistics of return wave height sample ($\overline{H}_{50}$, $H_{\sigma 50}$, $\overline{\gamma}_{50}$) in FSP or VSP case. VSP case > FSP case for $\overline{H}_{50}$,$H_{\sigma 50}$,$\overline{\gamma}_{50}$

The LSM – Based Model is also applied for approximating a distribution of return wave height sample with size 200 in FSP or VSDP case.



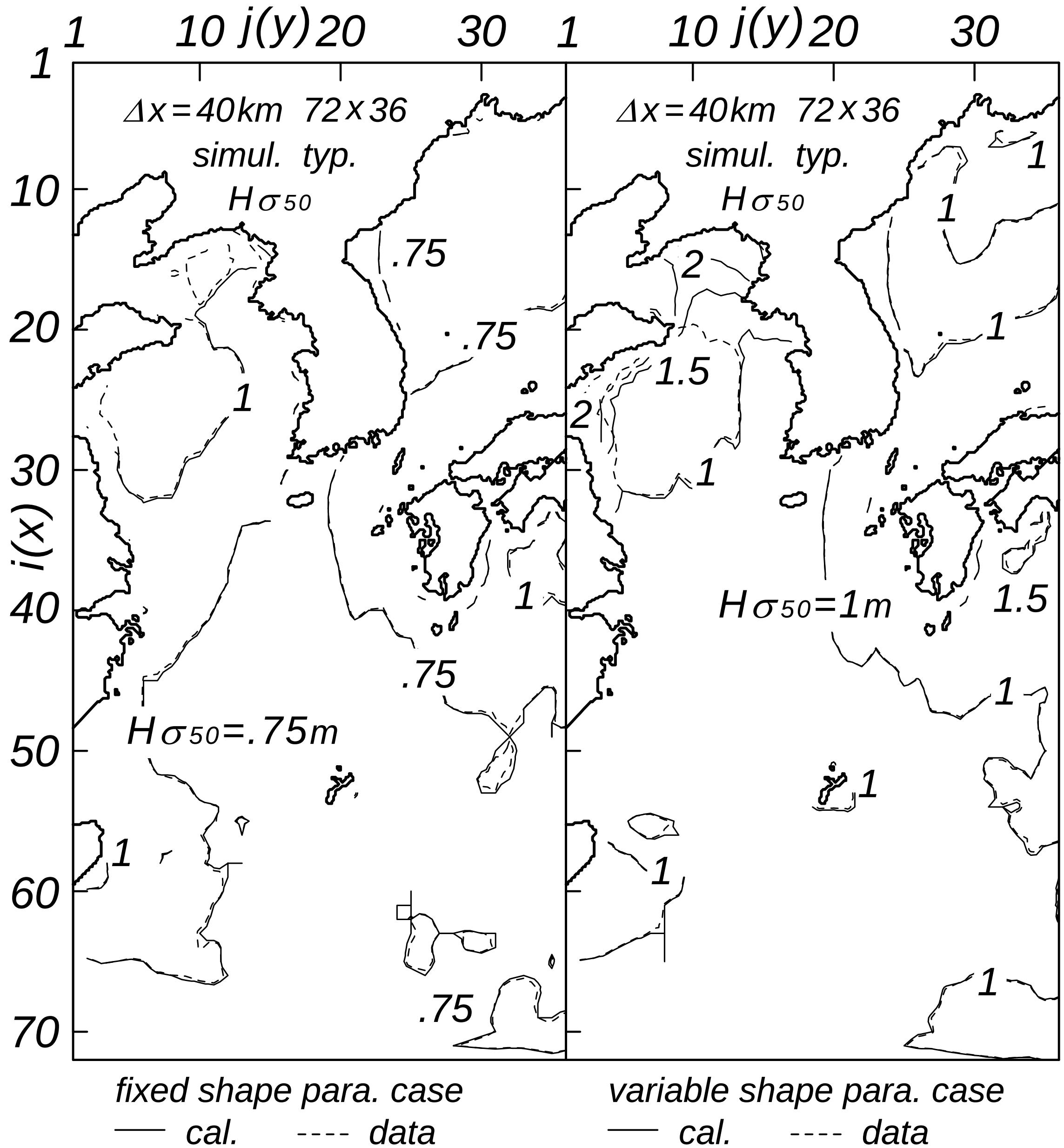
Q–Q plot to a return wave height sample in FSP or VSP case

ρ_r(FSP) > ρ_r(VSP), k_r(FSP) > k_r(VSP), r =50,100

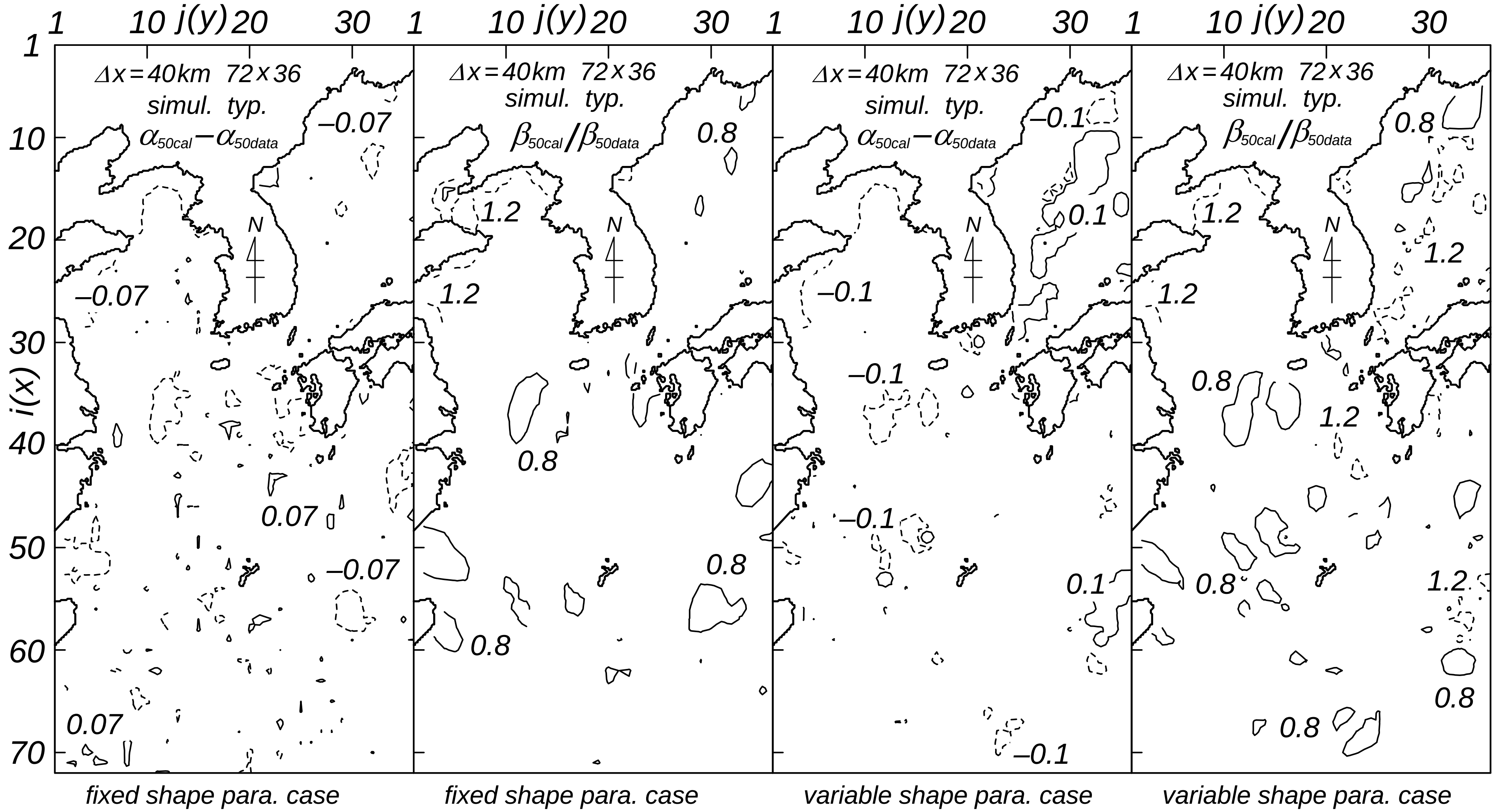


Shape parameter of Weibull distribution in FSP or VSP case

k_{50}(FSP) > k_{50}(VSP) > k_{100}(VSP) : smaller variability



Comparison between sample statistics and calculated statistics in FSP or VSP case ($H_{\sigma 50}$)



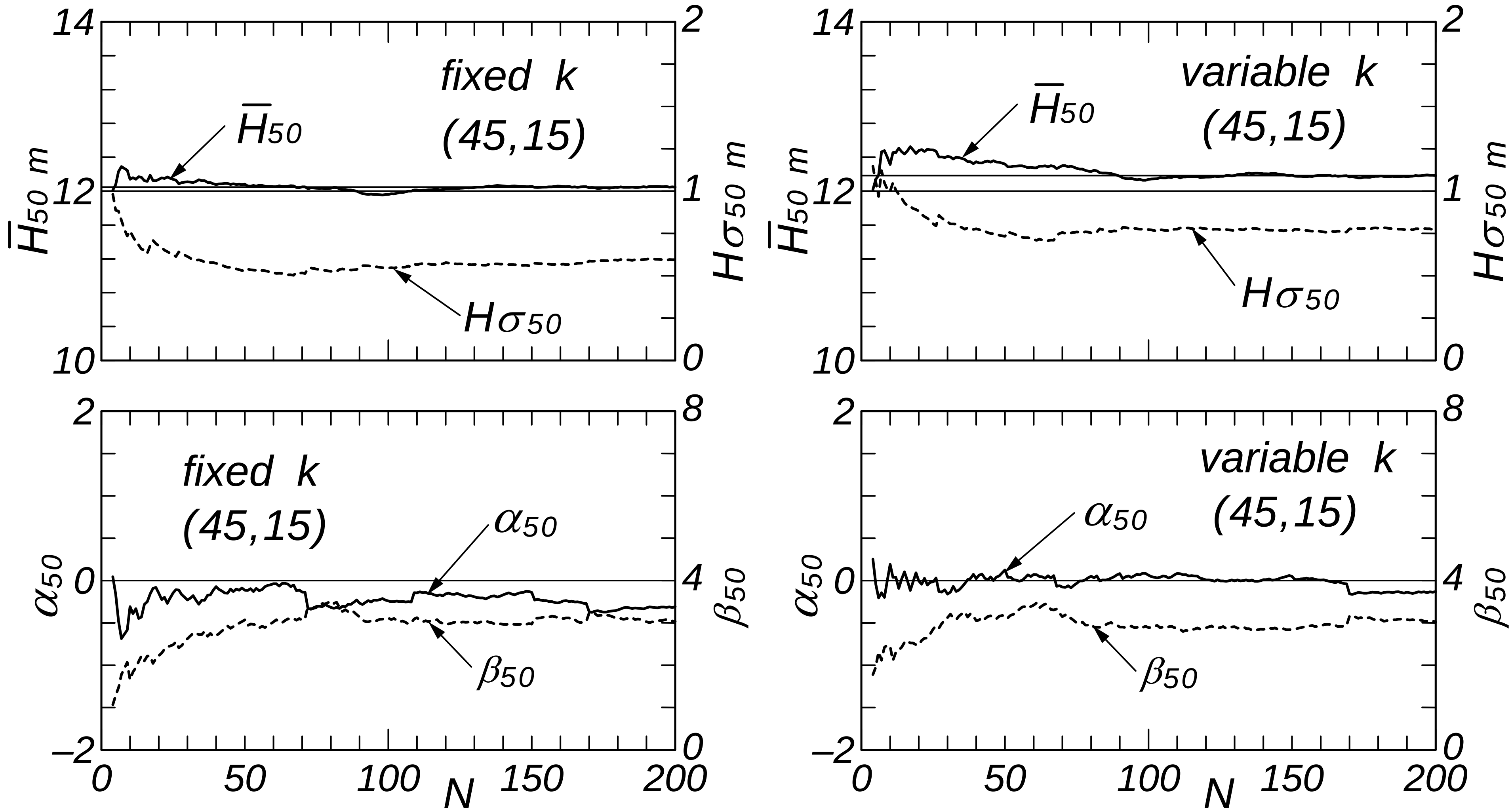
Comparison in FSP or VSP case (skewness $\alpha_{50}\approx 0$, kurtosis $\beta_{50}\approx 3$)

Lower moment – statistics yields better agreement.

Fitting is better in FSP case than in VSP case.

5. Conclusions

1) Parent distribution of typhoon-generated AM wave height is well-expressed by the **Weibull** distribution.
2) Shape parameter and the other parameters of the parent distribution are space-dependent.
3) Identification of the parent distribution of AM wave height contributes to more efficient estimation of return wave height.
4) Sample of return wave height is subject to the normal distribution in a rough sense, but is well approximated by asymmetrical distribution such as the Weibull or Gumbel distribution in detailed aspects.



Variation of statistics with sample size *N*.

Each statistics approaches nearly constant value.

A typhoon is represented with 6 parameters such as

1) position of typhoon center (X_c , Y_c)

2) central pressure p_c

3) inclination angle of ellipse θ

4) typhoon radii (a, b) ,

$R=(a+b)/2$: mean typhoon radius

Spatial variation of parameters of estimated parent distribution in simulated typhoon case.

1) H_{50} is more than 16 m on the southeastern area and reduces to 6 - 8 m towards the northwestern area due to the decay of typhoon intensity.

2) Shape parameter *k* tends to decrease from 4 on the central and southeastern areas toward around 1.4 on the northwestern area.

3) Spread parameter γ_{50} indicates almost opposite spatial distribution to the case of shape parameter.

Frequent passage of typhoons on the southeastern area may bring about a sharper probability distribution of typhoon - generated AM wave height data.

Spatial distribution of return wave height statistics in historical typhoon case.

1) Distribution of return wave height and spread parameter are similar to those in simulated typhoon case.

2) Standard deviation from 0.5 to 1.5m is much larger than the maximum value of 0.07m in the simulated typhoon case.

Spatial distribution of return wave height statistics($\overline{H}_{50}$, $H_{\sigma 50}$, $\bar{\gamma}_{50}$) in FSP or VSP case

1) Mean value $\overline{H}_{50}$, $\bar{\gamma}_{50}$ in Fixed SP case almost completely agrees with H_{50}, $\bar{\gamma}_{50}$ obtained form 10,000 sample respectively.

2) Fixed Shape Parameter case gives a bit smaller $\overline{H}_{50}$, smaller $H_{\sigma 50}$, and smaller spread parameter $\bar{\gamma}_{50}$ than Variable Shape Parameter case.

In FSP case

- ρ_r, k_r is independent of return period.
- ρ_r, k_r is greater than in VSP case.

better fitting of optimum distribution and smaller variability of return wave height.

In VSP case

- ρ_r, k_r is smaller with increasing return period.

lesser fitting and larger variability of return wave height.

with increasing return period.

Conditions of Wave Computation on the Northwestern Pacific Ocean(80 km grid)

A. Typhoon case

✧About 150,000 - typhoon simulations over 20,000 years yield

* an AM sample with size 20,000 or
* 400 sets of sample with size 50

2. Analysis Method of Sample

LSM-Based Extreme Value Analysis Model

- Candidate distributions:

  a) Gumbel distribution

  $F(x)=\exp[-\exp\{-(x-B)/A\}]$

  b) Weibull distribution with 27 kinds of

  fixed shape parameter (k=0.5 - 10)

  $F(x)=1-\exp[-\{(x-B)/A\}^k]$

  where A : scale parameter, B:location parameter

  to be estimated by the least square method

- Criterion of largest correlation coefficient

- LSM – Based Model is applied for

  extreme value analysis of typhoon - generated AM sample

a) a sample with size 20,000

b) each of 400 sets of sample with size 50

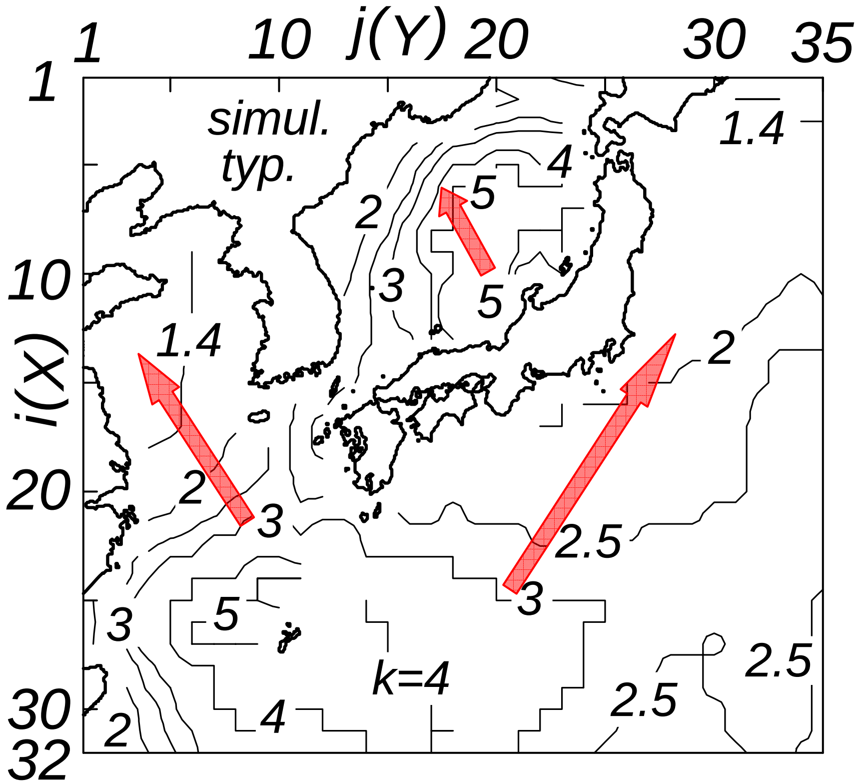
- Low case is the same as typhoon case.

a) a sample with size 10,000

b) each of 200 sets of sample with size 50

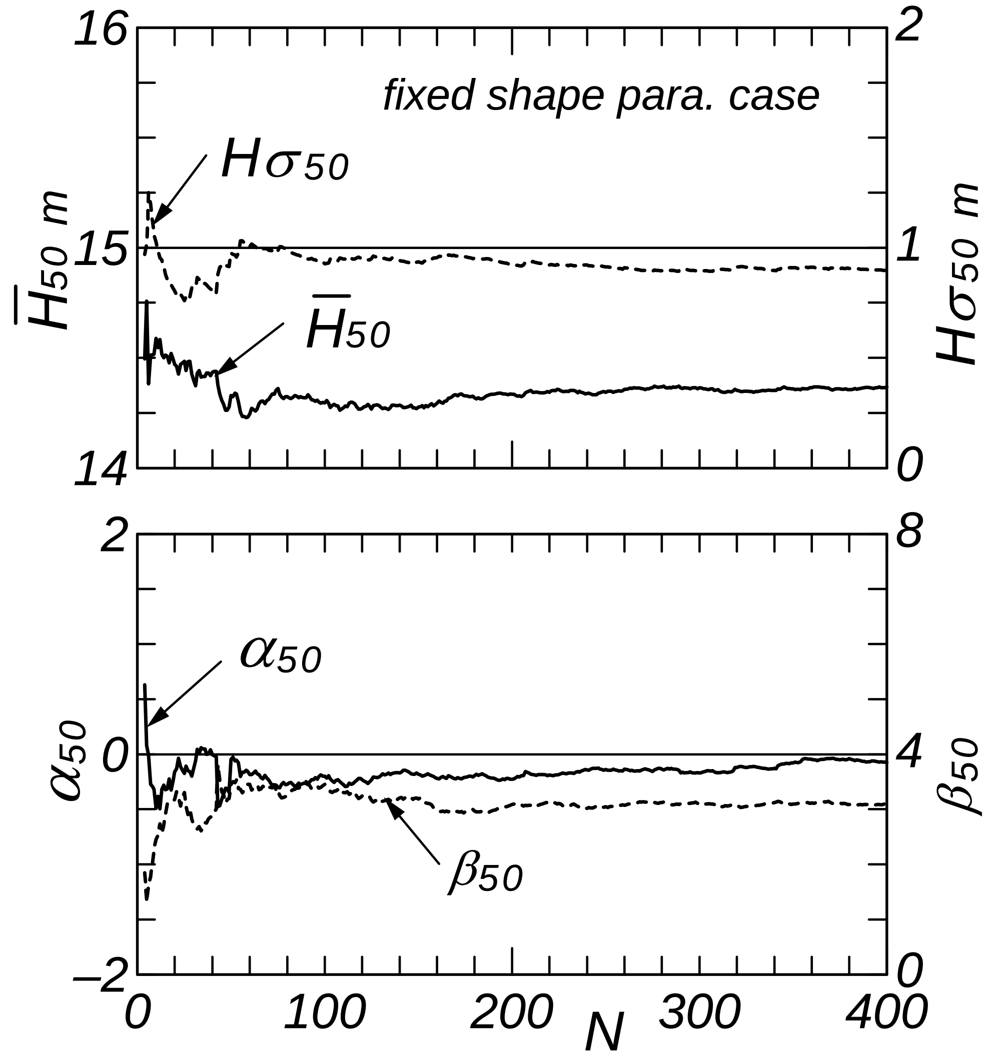
3. Sample Distribution of Return Wave Height

1) **Typhoon** – Generated Wave Case



Shape parameter k (Weibull distribution) of a parent distribution

Shape parameter tends to decrease from 4 or 5 on the southwestern area toward around 1.4 on the northwestern area and on the northeastern area.



Variation of statistics associated with sample size

Each statistics takes almost constant value for N > 200.

4. Conclusions

① Identification of the parent distribution of return wave height contributes to more efficient estimation of return wave height.

② Sample of return wave height is subject to the normal distribution in a rough sense, but is approximated well by asymmetrical distribution such as the Weibull or Gumbel distribution in detailed aspects.

③ Shape parameter k_R hardly depends on return period R in KPD case, but it decreases in UKPD case (growing variability of return wave height).