I. TITLE AND AUTHORS

ESTIMATION OF PROBABLE MAXIMUM SIGNIFICANT WAVE HEIGHT IN THE SEA AREAS AROUND JAPAN BASED ON SIMULATIONS OF TYPHOON- AND DEPRESSION (STORM)-GENERATED WAVES

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II. MOTIVATION

- A proper estimation of Probable (the most likely) Maximum Significant Wave Height (PMSWH) in a specified sea may provide valuable information for ensuring maritime facilities and so on to the maximum degree.

A next step is to improve

`a reliability of the estimate of return wave height by introducing PMSWH into an upper value-limited extreme value distribution'.

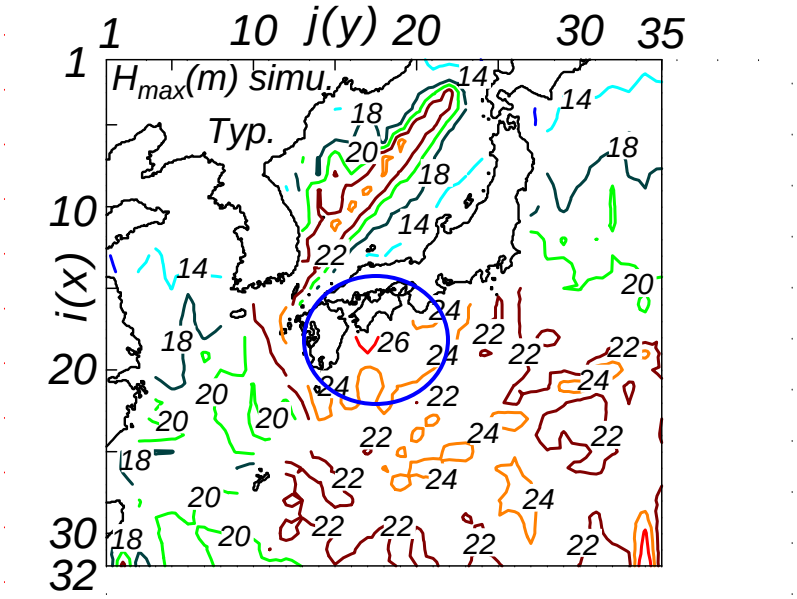
III. METHODOLOGY

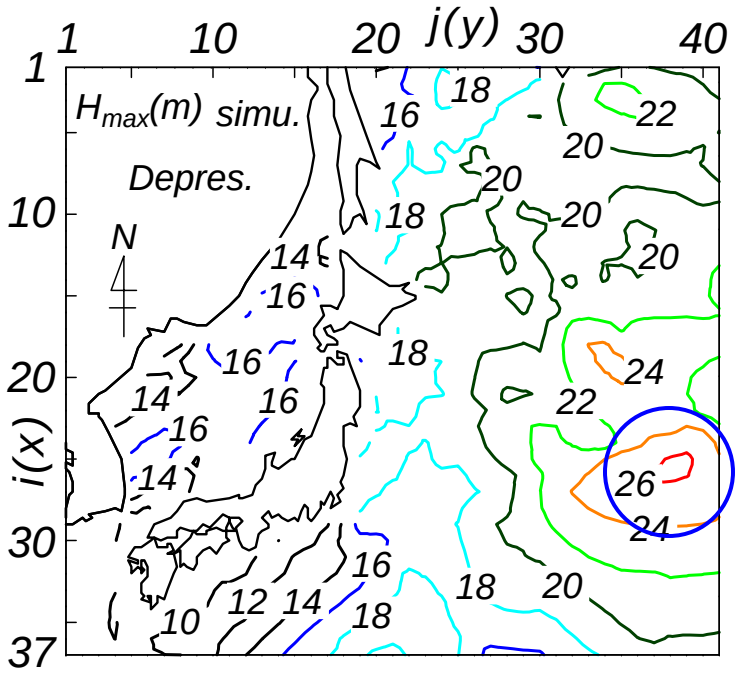
Wind and wave computations for a huge number of typhoons or depressions produced in the NW Pacific Ocean over 100,000 years by using a Monte-Carlo simulation model of storm parameters.

Extraction of the largest significant wave height (SWH) generated by a typhoon or depression at each grid point set on the Ocean. This may be regarded as a typhoon-generated(TG-) PMSWH or a depression-generated(DG-) PMSWH.

IV. SUMMARY OF CONCLUSIONS

- TG-PMSWH exceeds 26 m in the sea area off southwest Japan.
- DG-PMSWH is over 26 m in the eastern area far from Japan.





1. Introduction

As for PMSWH,

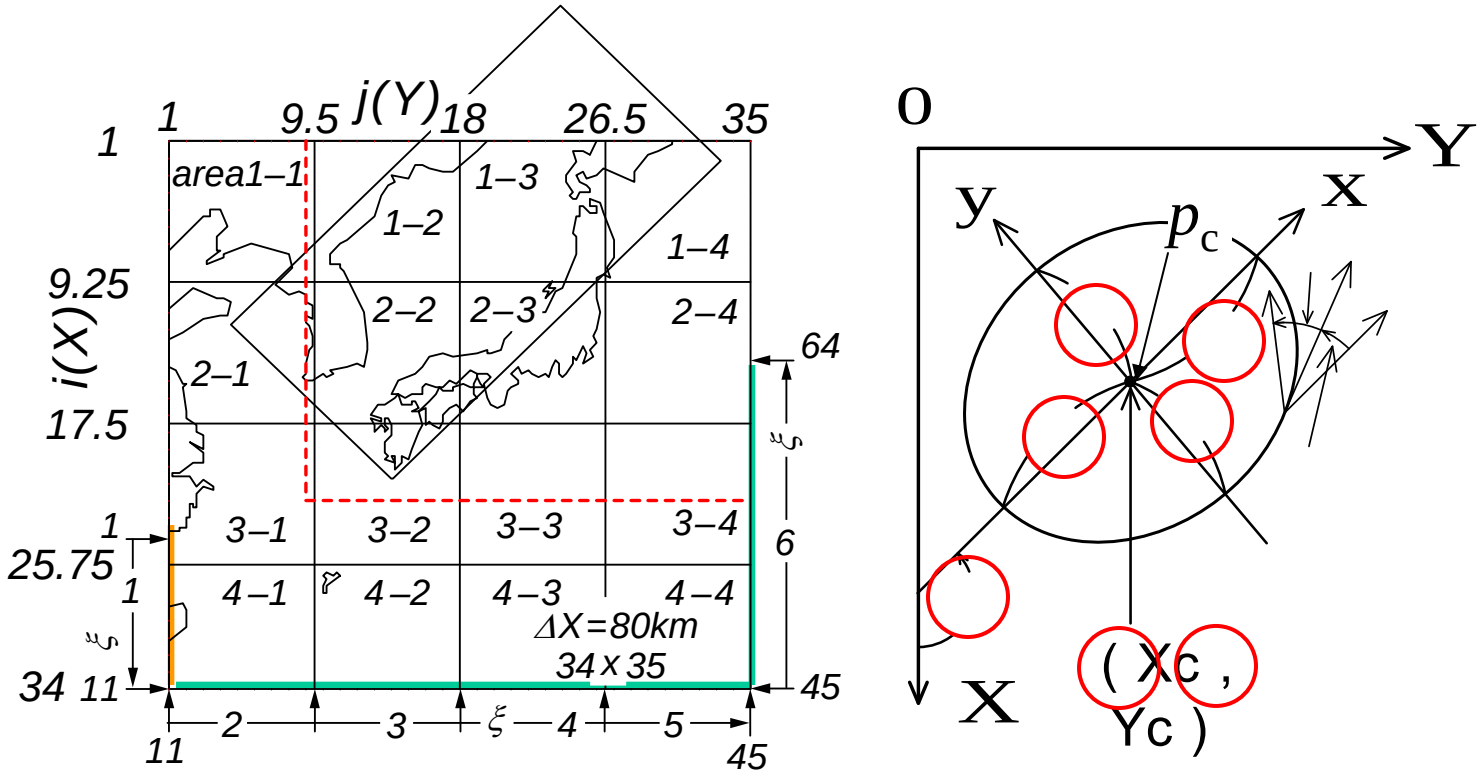
- Holthuijsen et al.(1994) and Reistad et al.(2005) have tried to estimate PMSWH in the North Sea areas and the Norwegian Continental Shelf.
- The problem in the cases may be in how an extra-ordinary storm is specified.
- In this study, we use a Monte-Carlo simulation model for generating either typhoon or depression and estimate PMSWH based on a huge number of wave computations in the Northwestern (NW) Pacific Ocean.

2. Description of the Method

The model consists of 3 sub-models such as

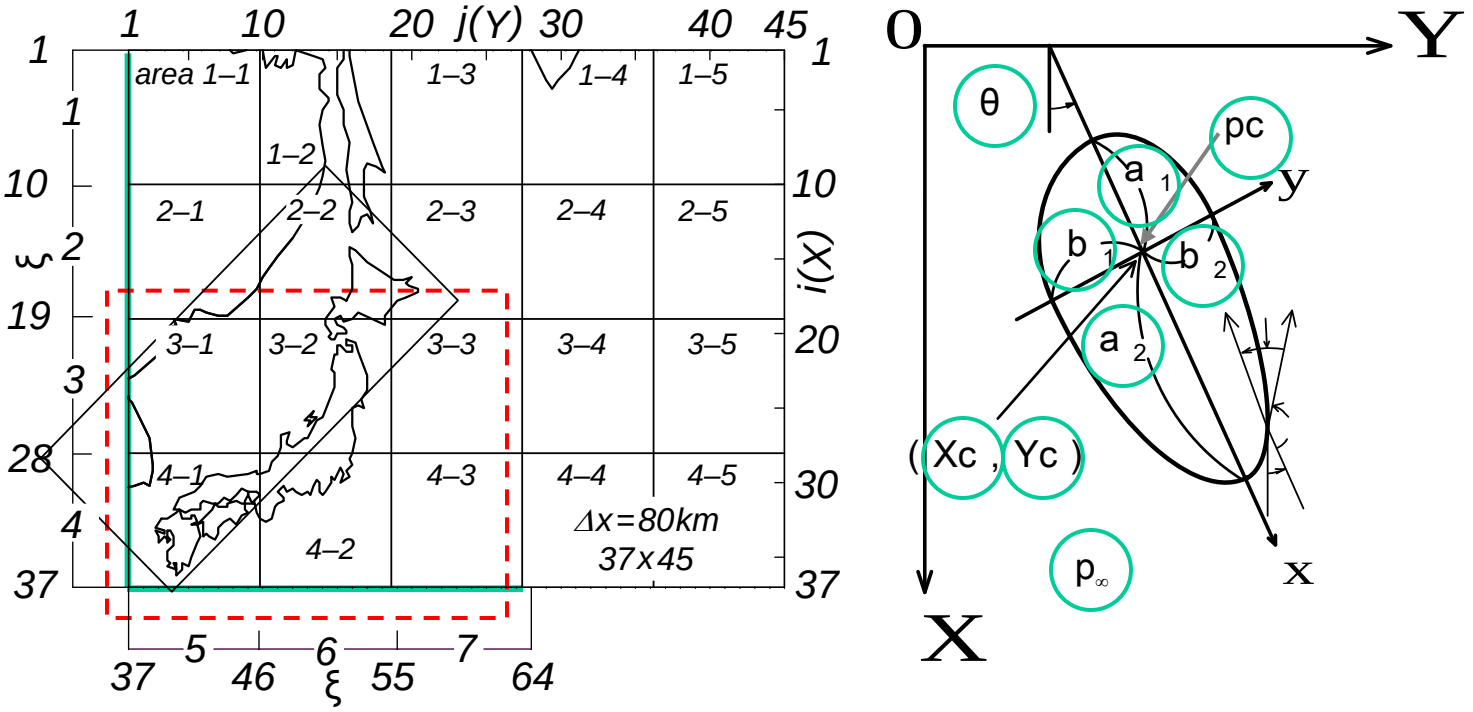
1) probabilistic generation model for parameters of a typhoon or depression (Monte-Carlo simulation)
2) gradient wind model, including a moving storm effect
3) deep water version of 2-G shallow water wave model.

- the Northwestern Pacific Ocean with 80 km grid.
- the Japan Sea with 40 km grid.



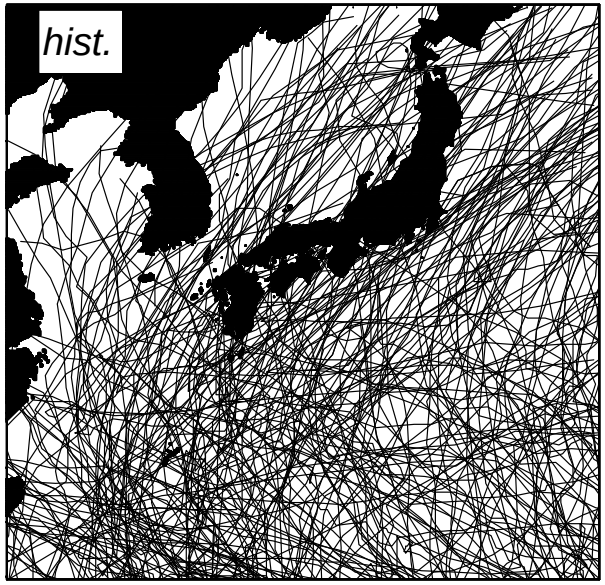
Definition sketch of 6 typhoon parameters

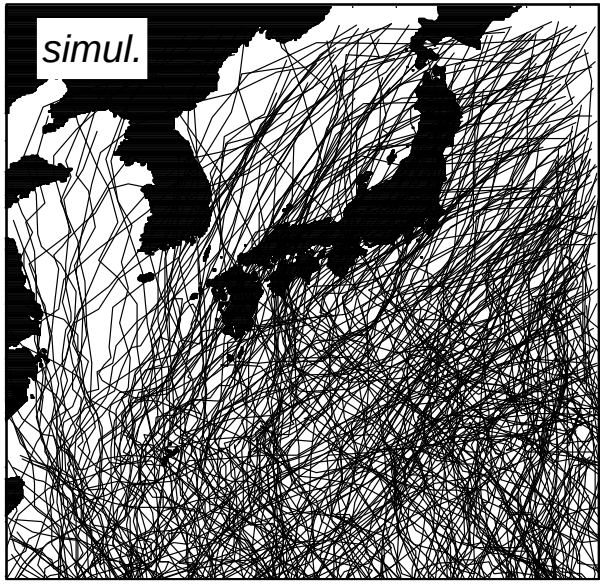
The modeling domains are overlapped only for the area around Japan enclosed by a dotted line, because the generation areas of typhoons and depressions are different from each other.



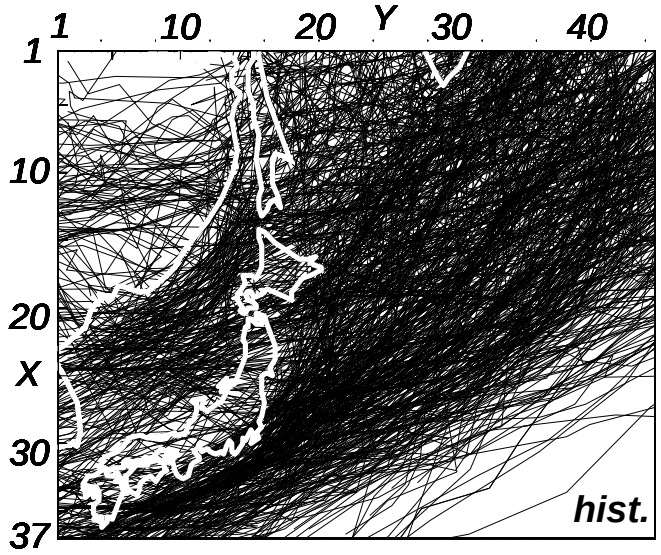
Definition sketch of 9 depression parameters

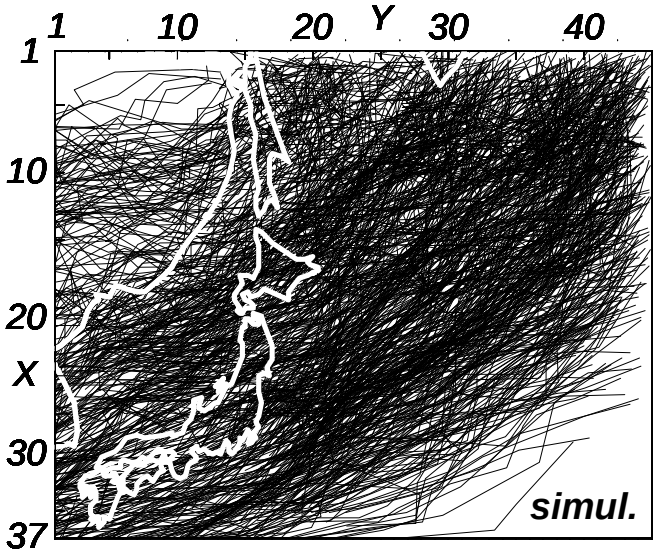
The modeling domains are overlapped only for the area around Japan enclosed by a dotted line.





Tracks of historical and simulated typhoons in 47 years





Tracks of historical and simulated depressions in 20 years

Conditions of Wave Computations in the Northwestern Pacific Ocean(80 km grid)

A. Typhoon case (about 780,000 typhoons)

1) 6,084 typhoons selected from simulations over 100,000 years

2) 519 strong historical typhoons in 58 years of 1948 ~ 2005

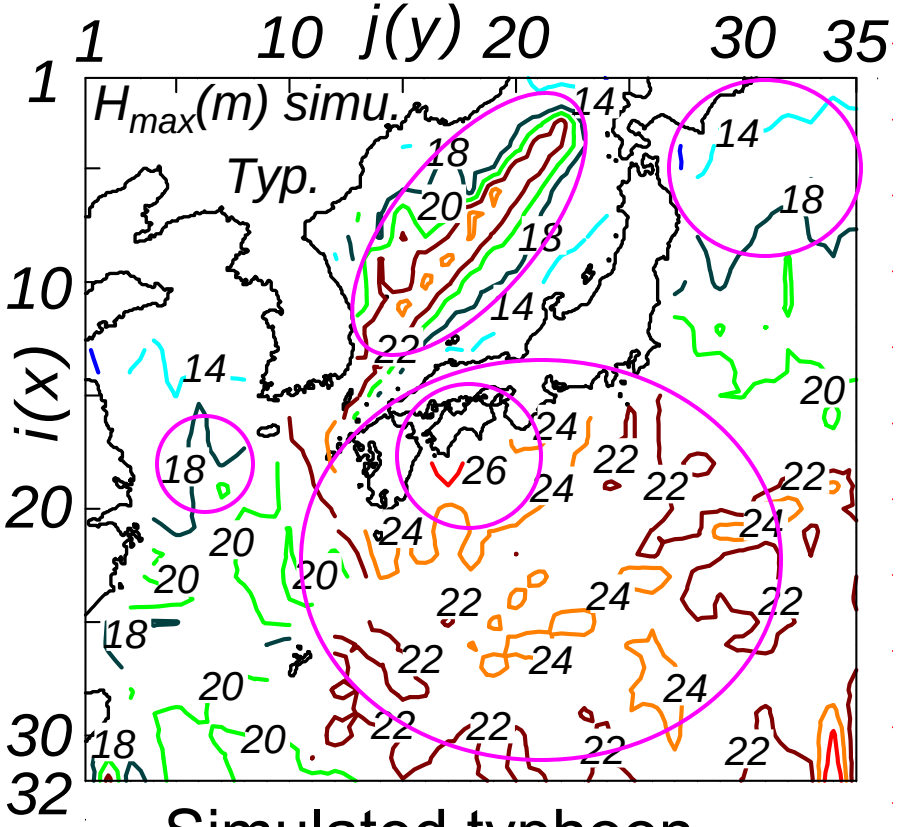
B. Depression case (about 3,800,000 depressions)

1) 37,042 depressions selected from simulations over 100,000 years

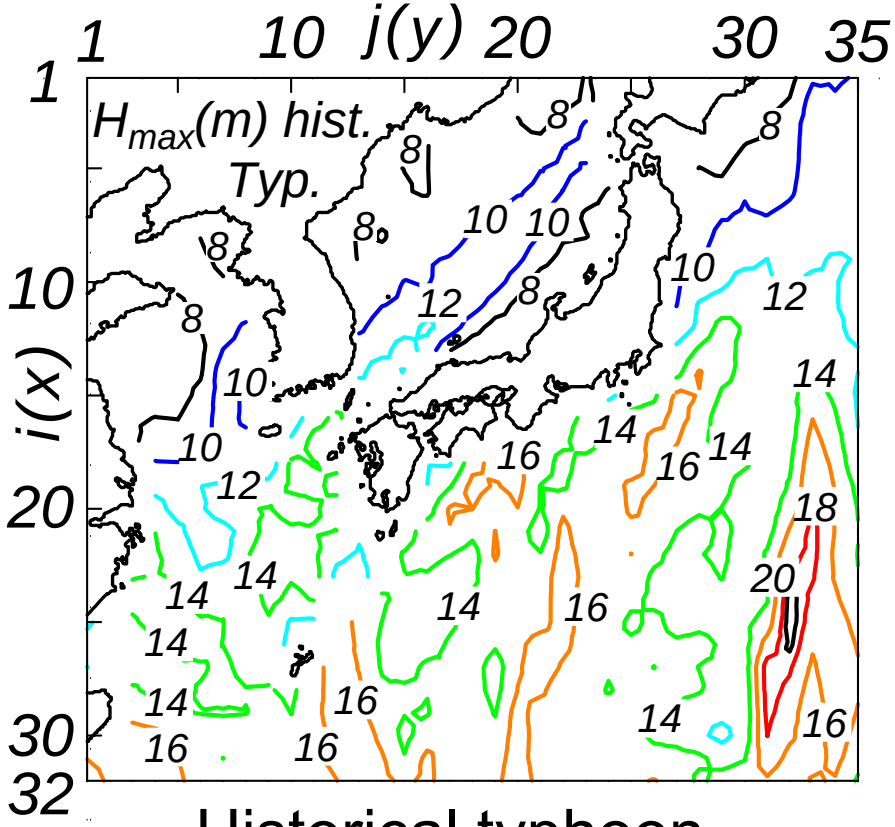
2) 148 strong storms in 20 years of 1979 ~ 1998

The largest significant wave height (SWH) at each grid point is regarded as TG-PMSWH or DG-PMSWH.

3. TG-PMSWH in the NW Pacific Ocea



Simulated typhoon

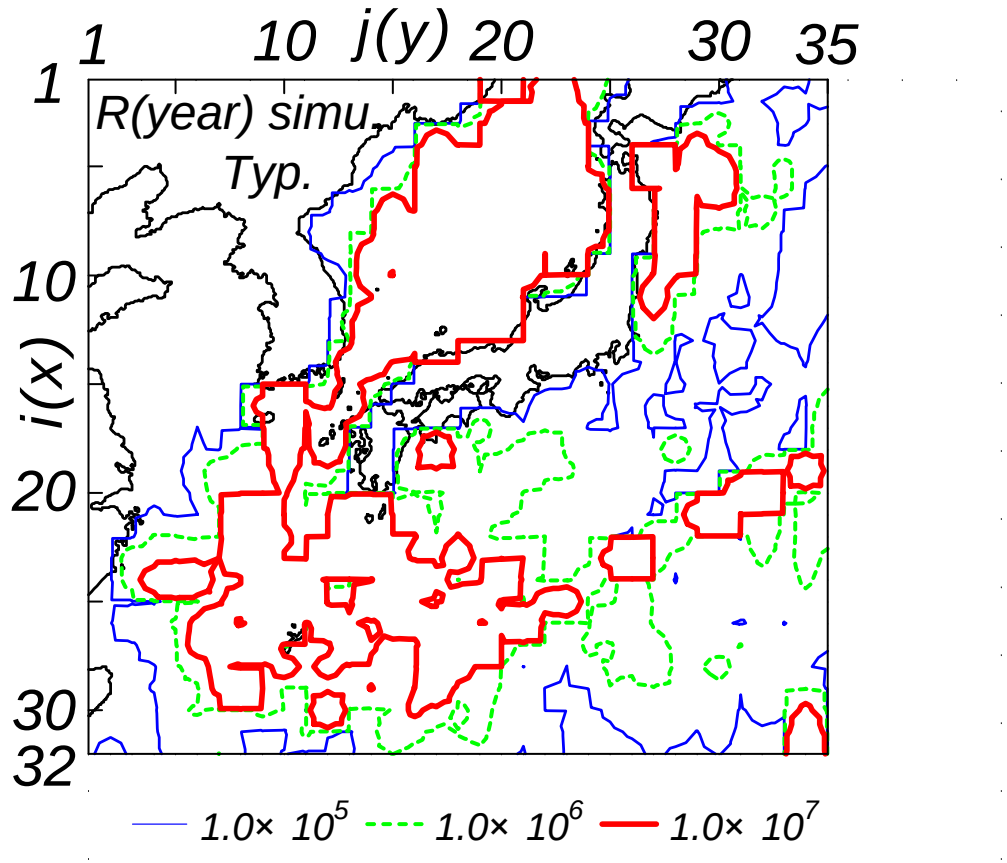


Historical typhoon

- extensive areas of 22 m height
- the largest height over 26 m
- 18 m area in the East China Sea
- 22 m area in the Japan Sea

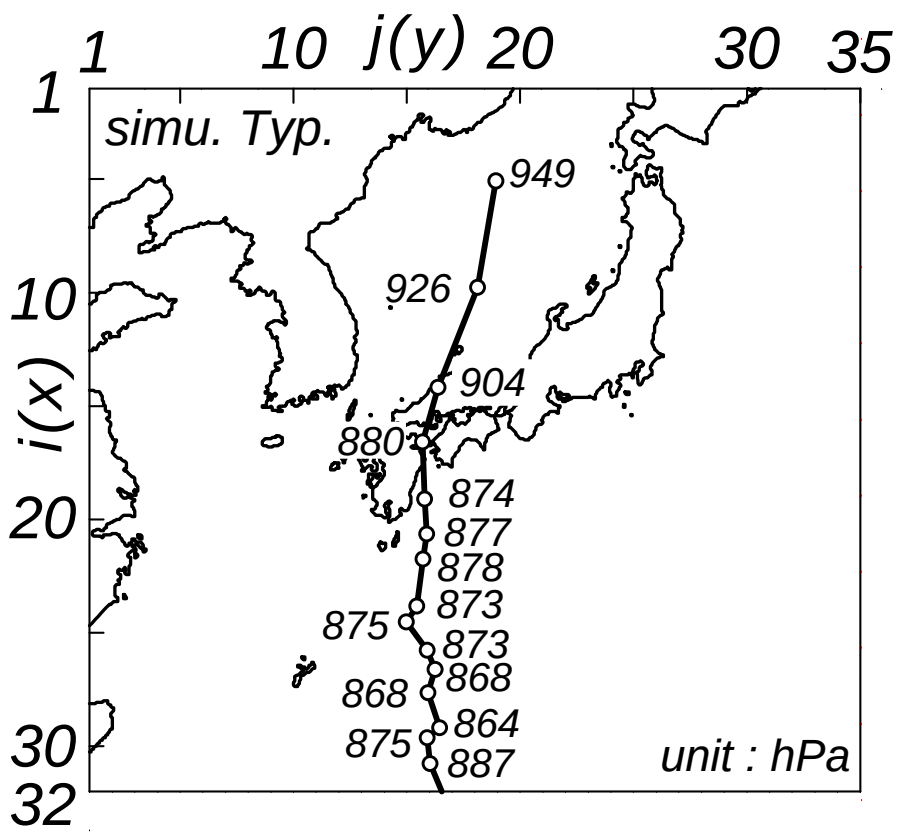
- TG-PMSWH is about 10 m greater than historical typhoon case at the maximum level.

Return Year Period of TG-PMSWH



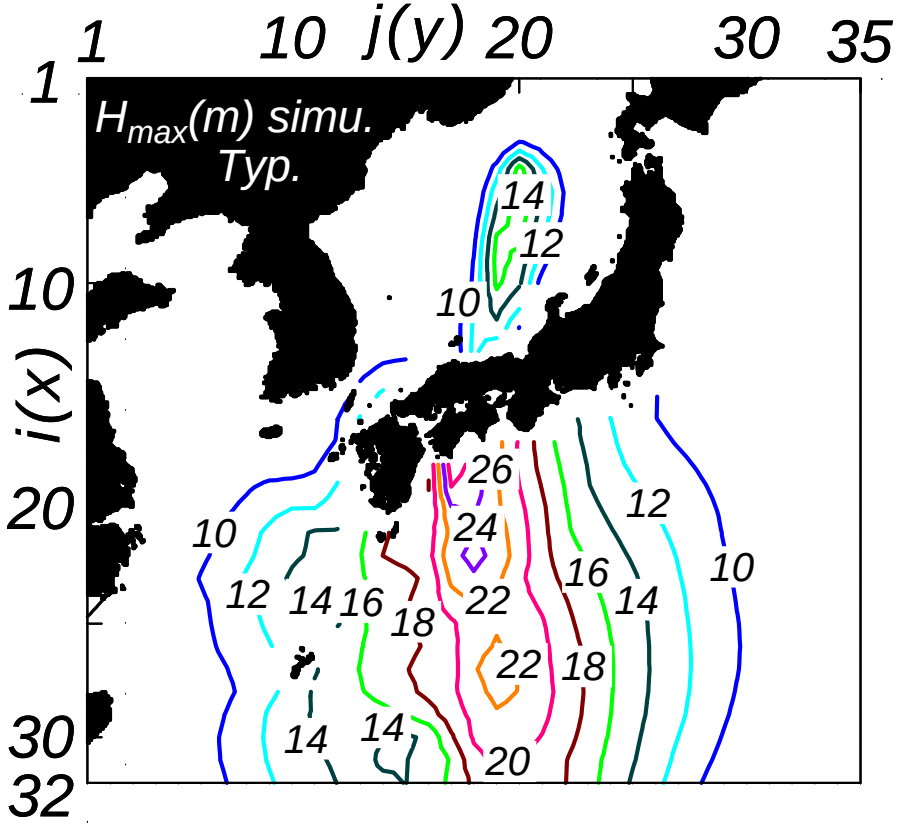
- A parent distribution of TG-annual maximum SWH estimated from simulations over 20,000 years is used.
- Occurrence probability of TG-PMSWH is very low(10^{-5}) in most of the area.

PMSWH-Generating Typhoon in Offshore Area of Southwest Japan and Maximum SWH Distribution



Position and central pressure

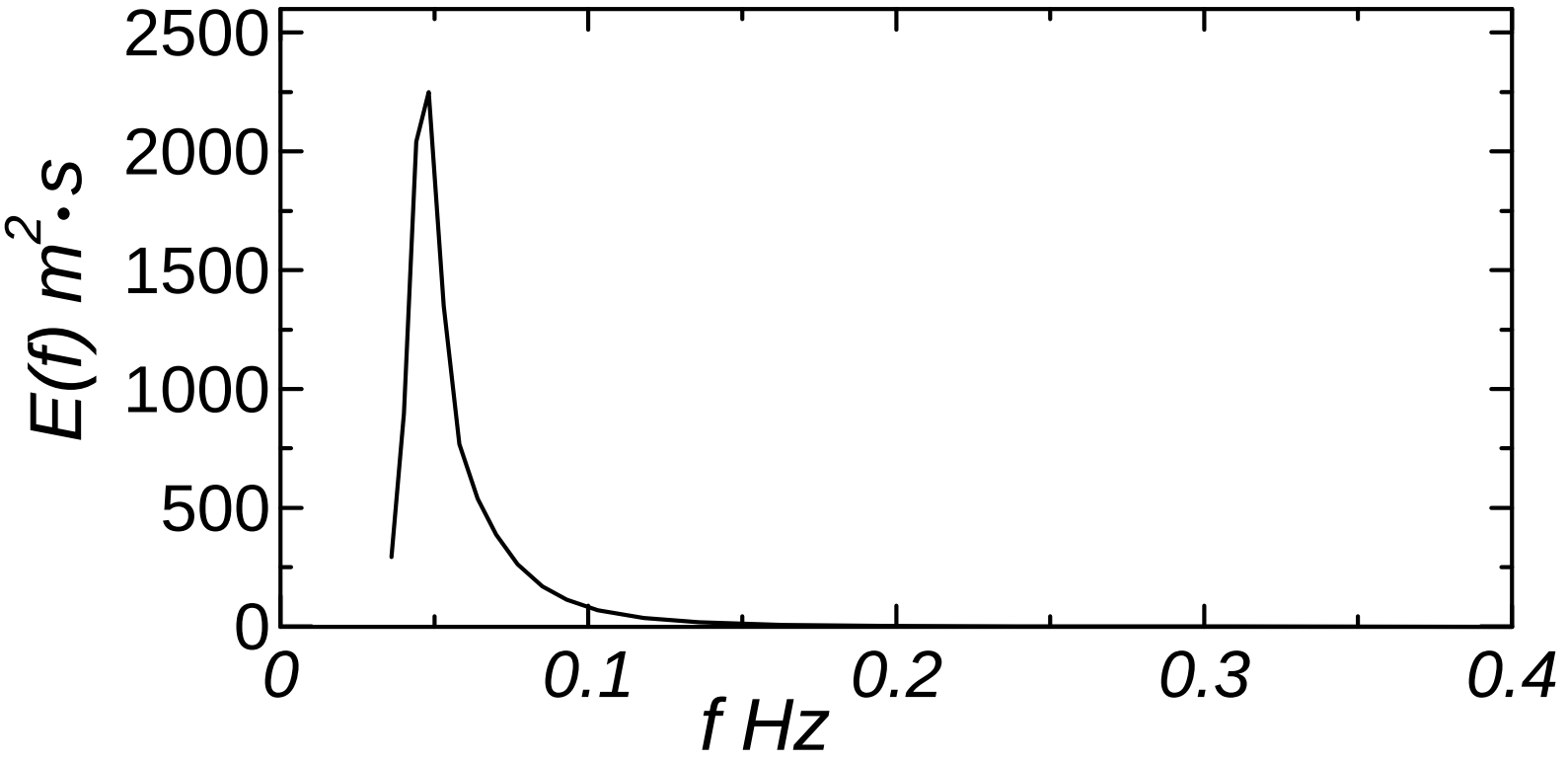
- Northward movement
- Central pressure keeps 880hPa.



Maximum SWH with a typhoon

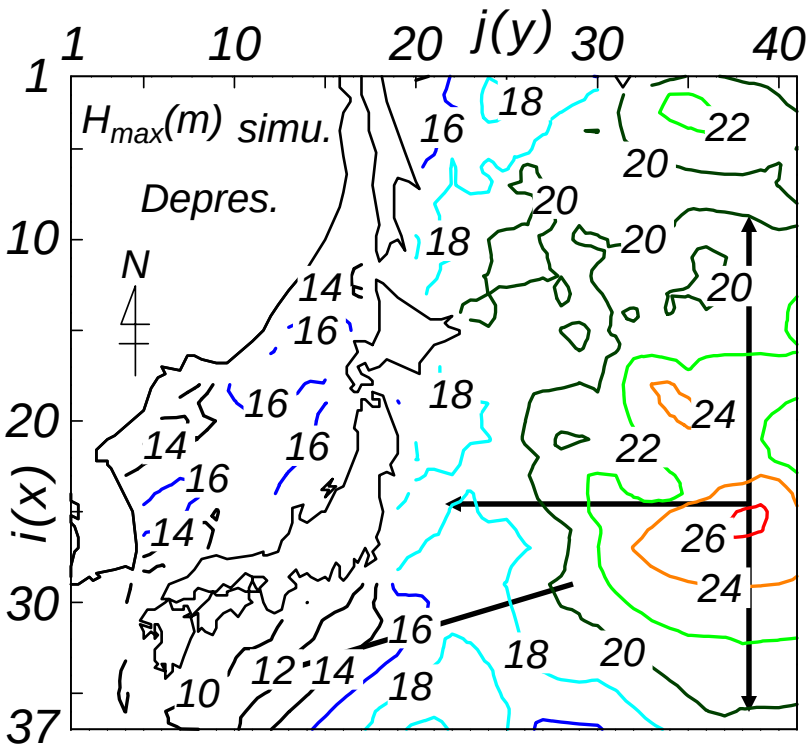
- Occurrence of 26 m SWH
- Extensive area of 20 m SWH formed along right hand side of the typhoon path

Frequency Spectrum of 26 m SWH Waves

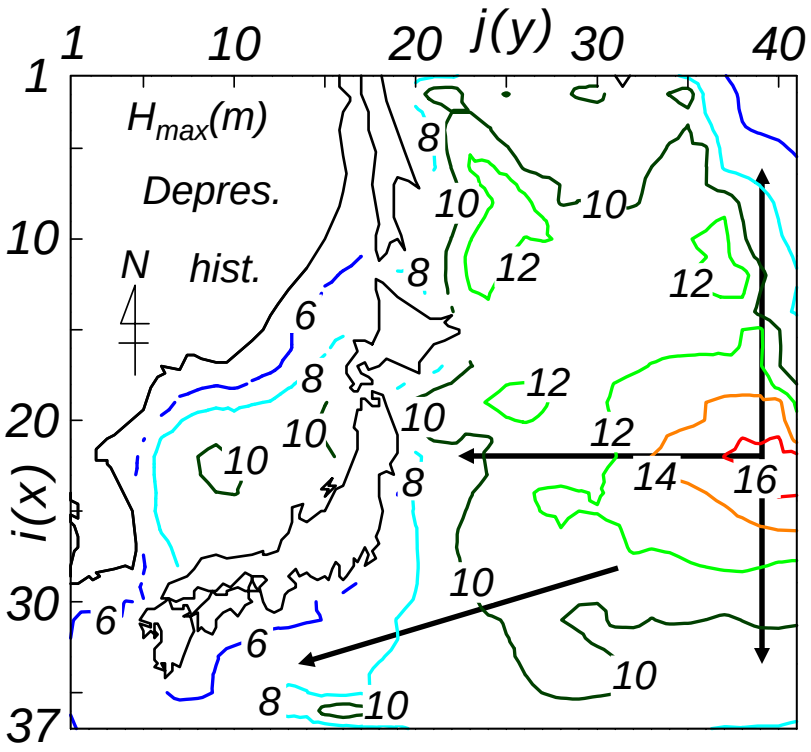


Single-peaked spectrum with a peak frequency of 0.047Hz

DG-PMSWH in the NW Pacific Ocean



Simulated depression

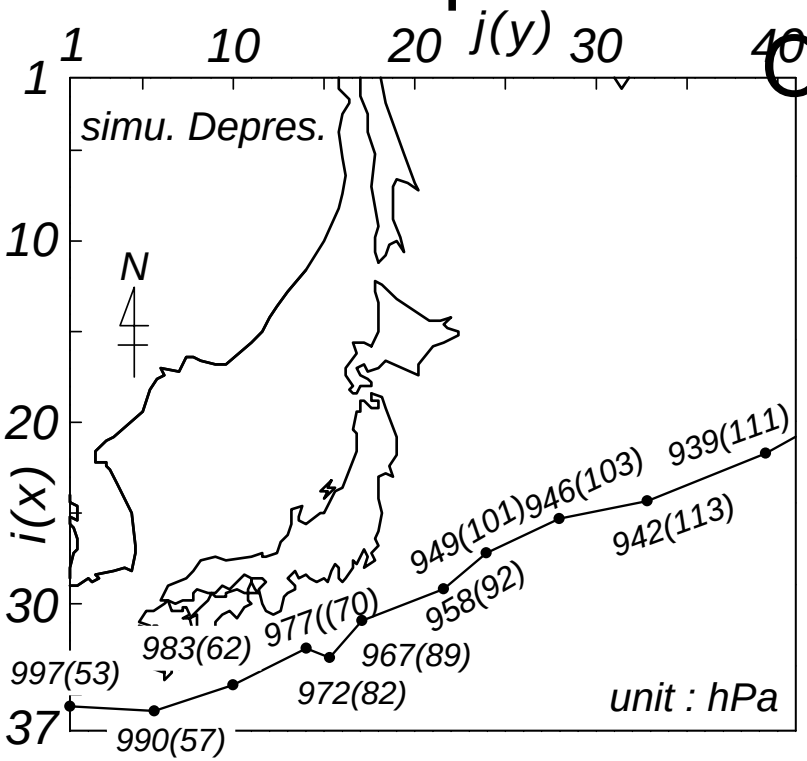


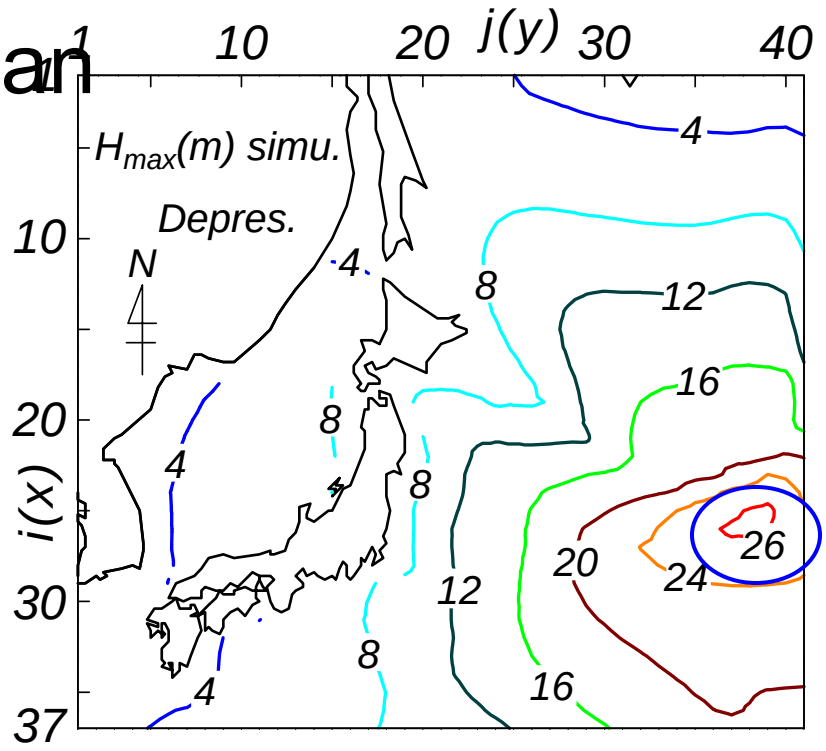
Historical depression

- The largest DG-PMSWH in the eastern area
- Circularly decreasing trend from the largest DG-PMSWH area to 10 ~ 18 m areas along the Pacific coasts of Japan

- Similar SWH distribution between both depress. cases.
- DG-PMSWH is 6 ~ 10 m greater than historical depress. case

PMSWH-Generating Depression in the NW Pacific Ocean





<u>Path, central pressure and pressure difference</u>

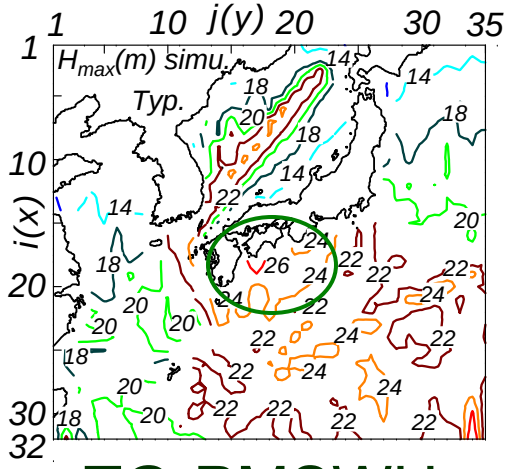
p_c : 939hPa

$p_\infty - p_c$: 113hPa

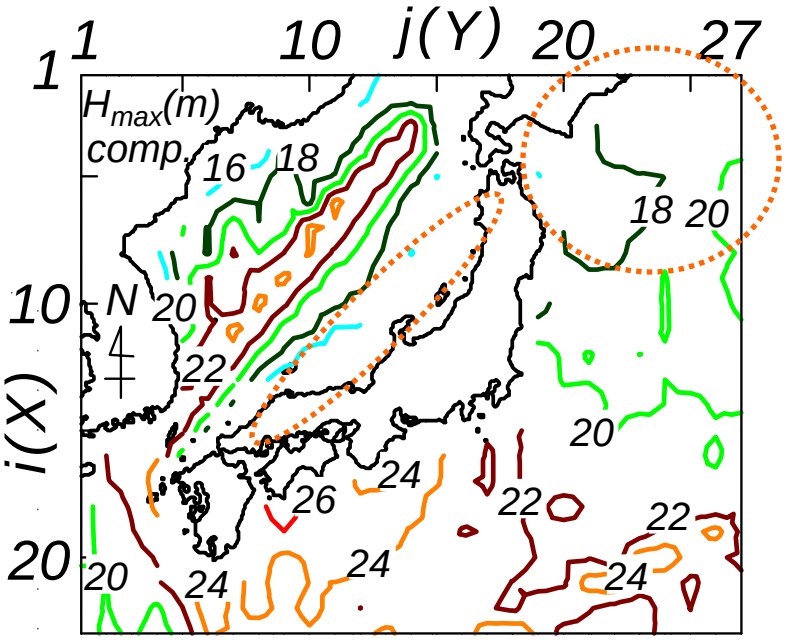
Maximum SWH with a depression

- The largest SWH of 26 m
- Circularly decreasing trend of SWH towards the Japanese coasts

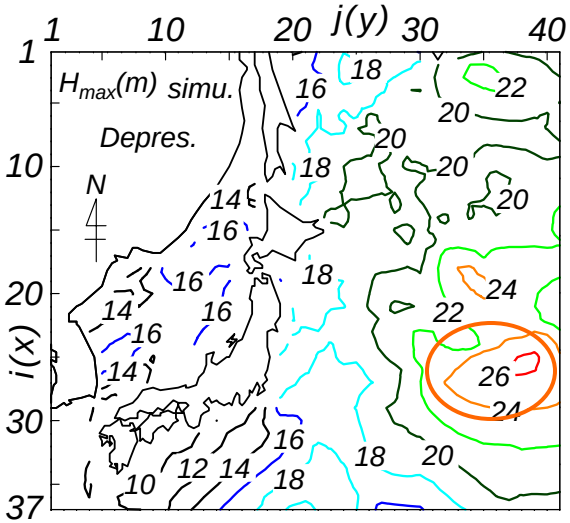
Comparison of TG-PMSWH and DG-PMSWH in the NW Pacific Ocean



TG-PMSWH



PMSWH in overlapped area

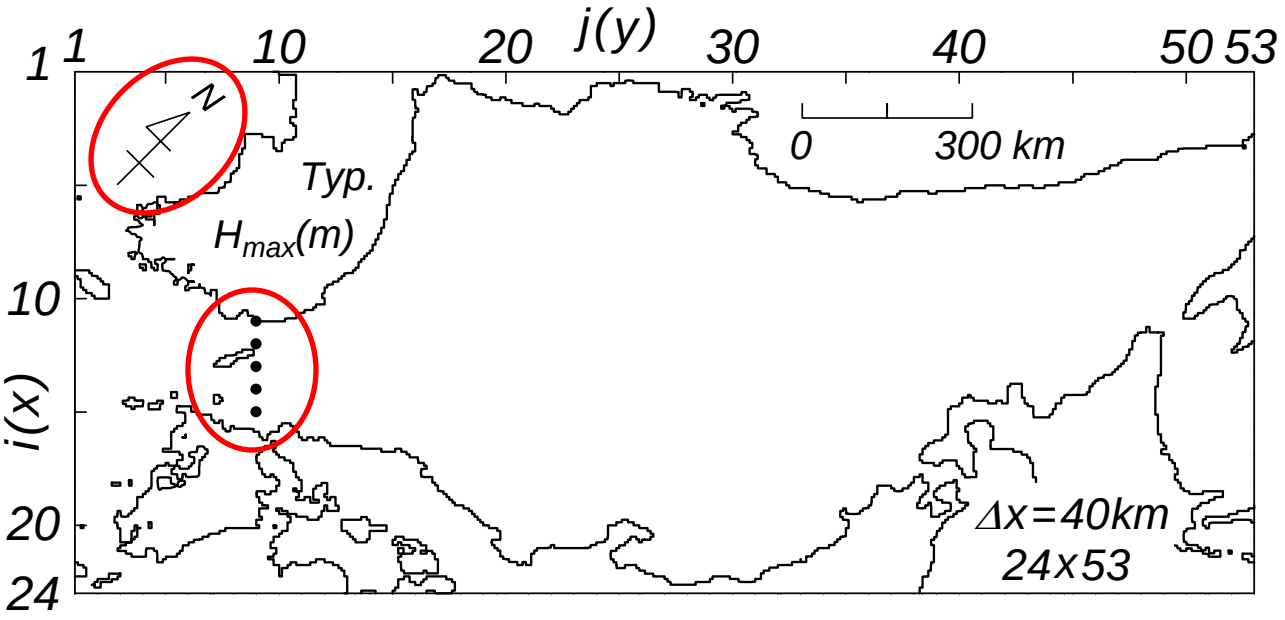


DG-PMSWH

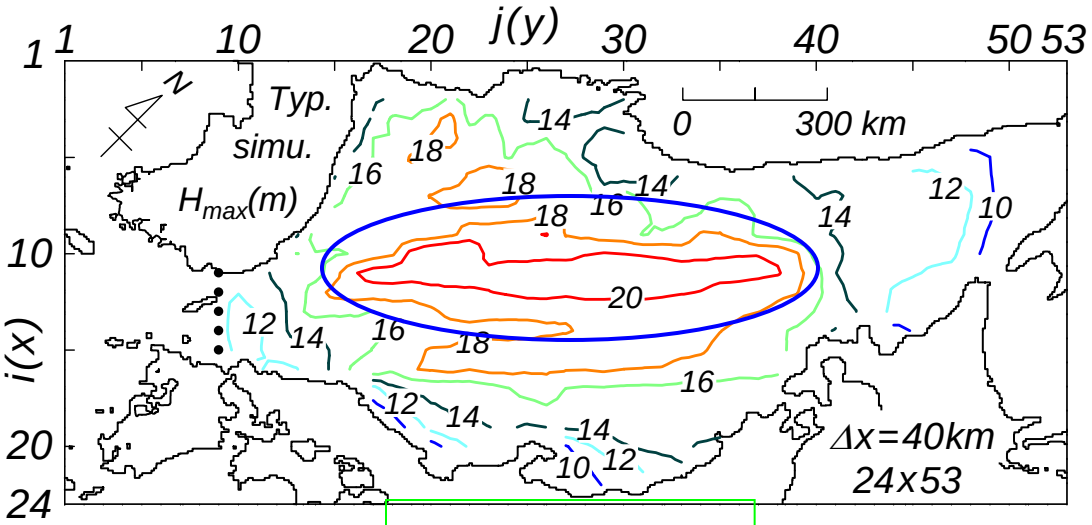
- TG-PMSWH is generally greater than DG-PMSWH.
- DG-PMSWH is greater than or comparable to TG-PMSWH in the eastern and north eastern areas.

4. PMSWH in the Japan Sea

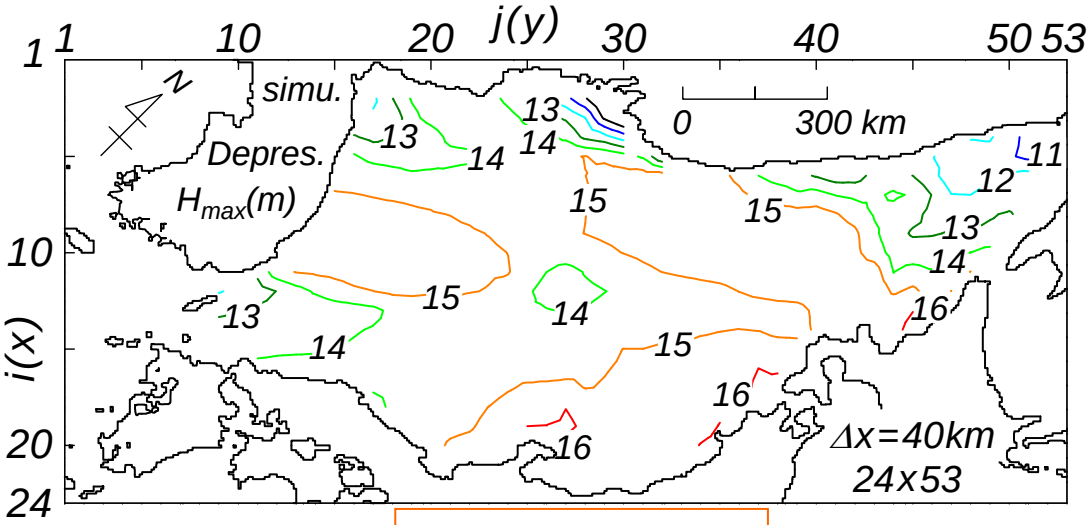
- Higher geographical resolution by usage of a 45 °rotated grid with 40 km distance
- Proper estimation of inflow energy from Korea-Tsushima Straits



TG-PMSWH and DG-PMSWH in the Japan S



TG-PMSWH



DG-PMSWH

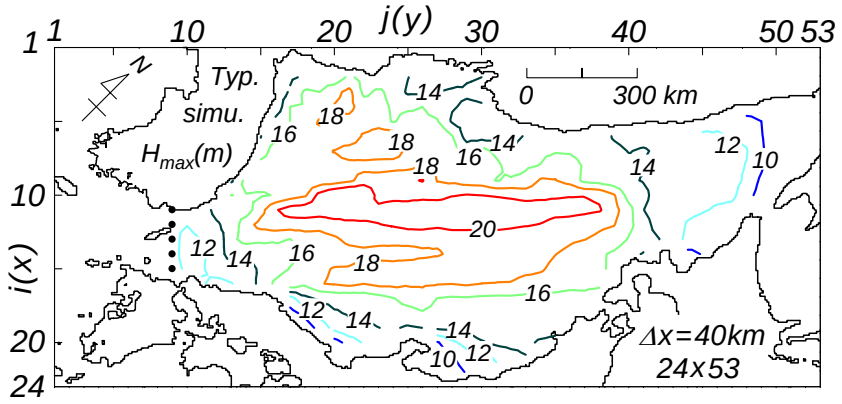
- 20 m SWH in central area
- 14 ~ 16 m SWH in surrounding nearshore area
- 2 m decrease of SWH

- 15 ~ 16 m SWH in extensive area
- 4 extreme depressions

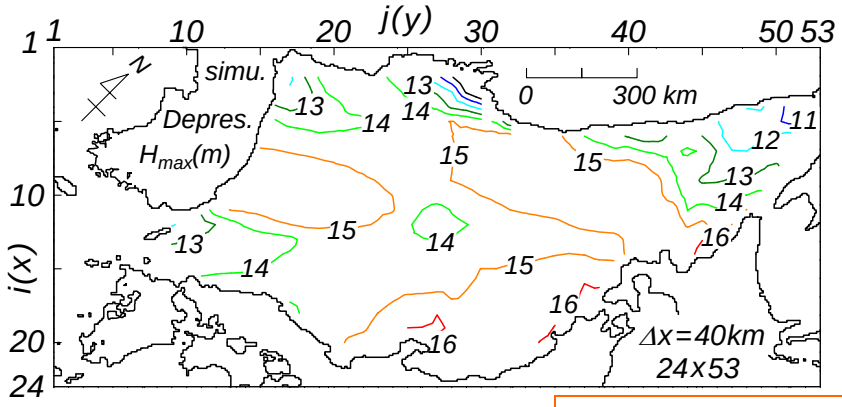
p_c : 940 ~ 950 hPa

$p_n - p_c$: 81 ~ 96 hPa

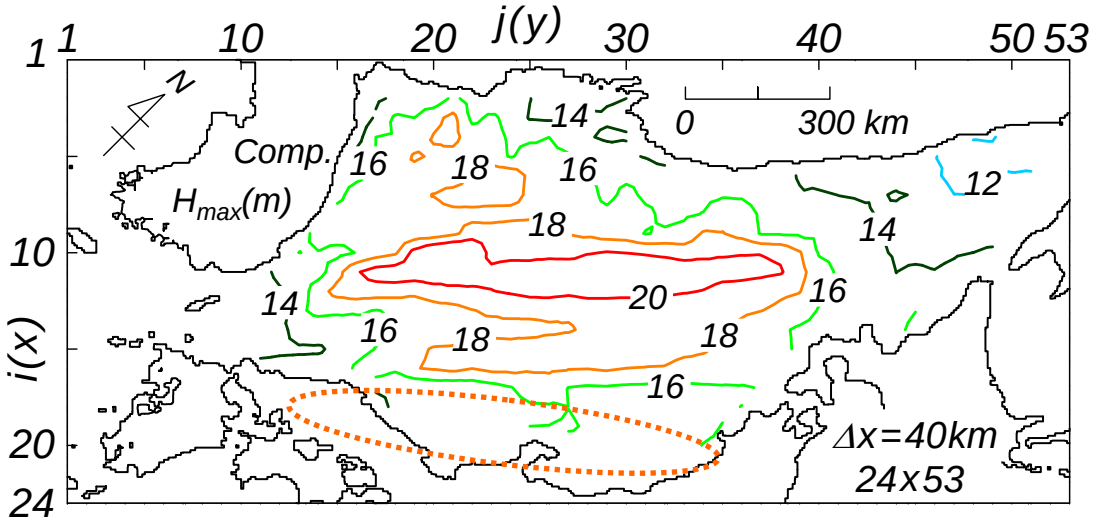
Comparison of TG-PMSWH and DG-PMSWH in the Japan Sea



Typhoon



Depression

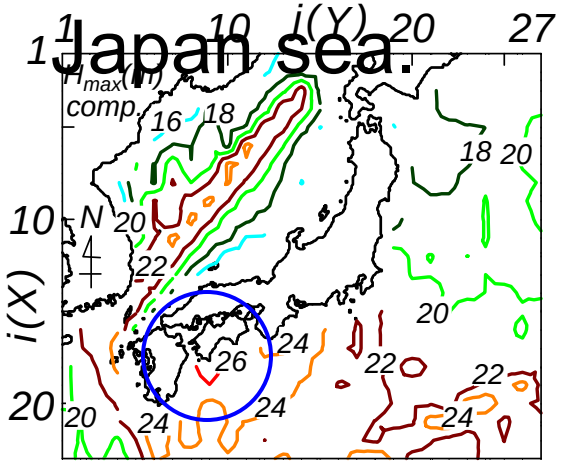


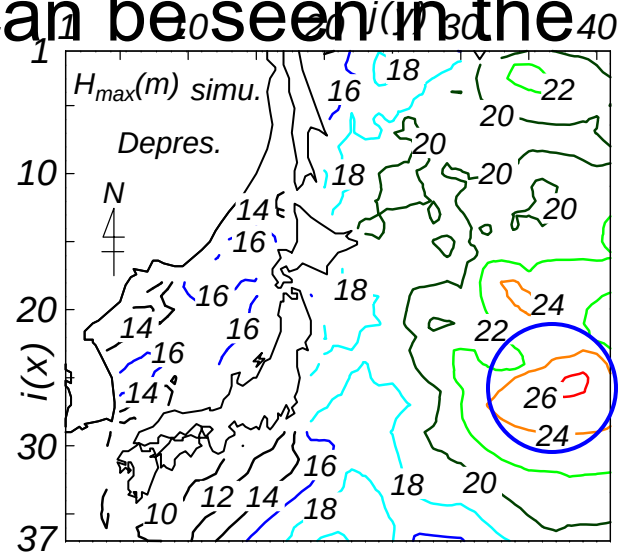
T+D

- TG-PMSWH > DG-PMSWH in most of the area
- DG-PMSWH > TG-PMSWH along the Japanese coasts

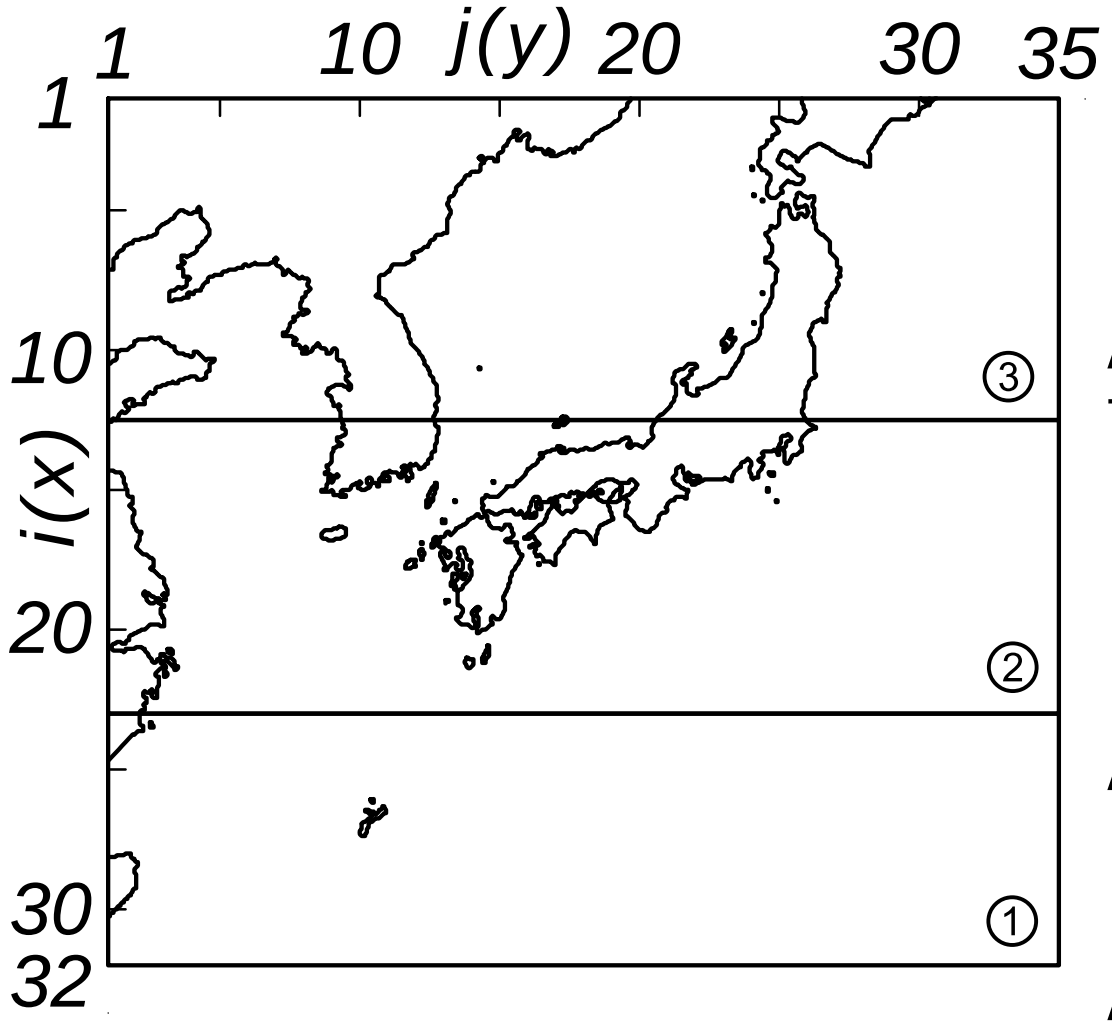
5. Conclusions

1) TG-PMSWH exceeds 26 m in the sea are off Southwest Japan.
2) DG-PMSWH is over 26 m in the eastern area far from Japan.
3) PMSWHs are 10 m to 13 m greater than the largest SWH in the past several ten years.
4) Similar characteristics can be seen in the Japan sea.





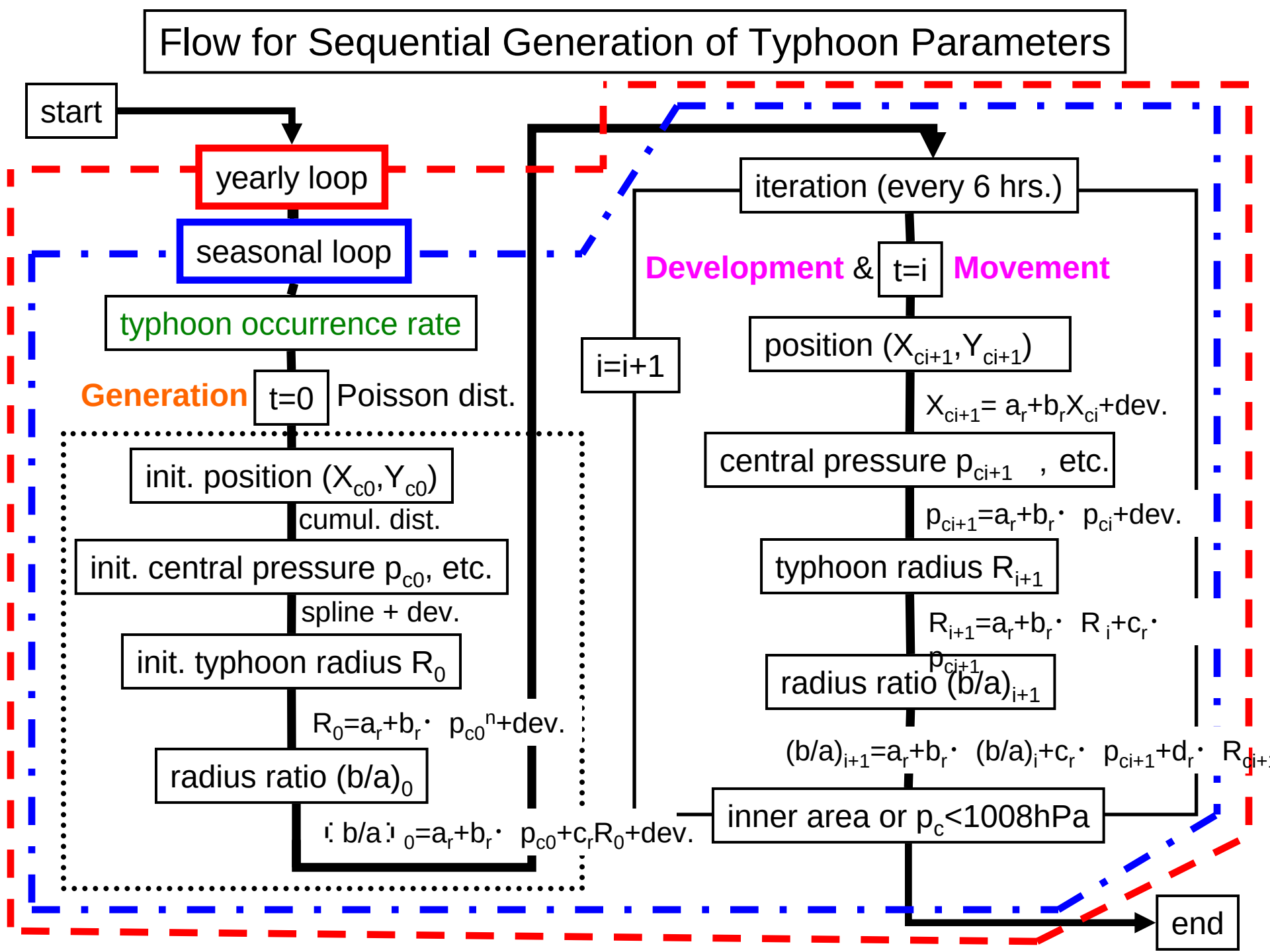
Sub-regions divided for extracting extraordinary typhoons.



p_C<950hPa - experiencing ty.

p_C<930hPa - sustaining ty.

p_C<910hPa - sustaining ty.


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
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· Ri+cr· pci+1
radius ratio (b/a)i+1
(b/a)i+1=ar+br· (b/a)i+cr· pci+1+dr· Rci+1
i=i+1
inner area or pc<1008hPa
end