4th International Workshops on Waves, Storm Surge and Coastal Hazards Santander, Spain

Estimation of historical typhoon-generated high waves around Japan by long-term microseism observations

Haruka Yamamoto[1)], Tomoya Shimura[2)], Nobuhito Mori[2)], Takuya Miyashita[2)]

1) Graduate School of Engineering (M1) , Kyoto University

2) Disaster Prevention Research Institute, Kyoto University

京都大学

防災研究所

Background/Research objective

Typhoon-generated high wave estimation is needed

- Typhoon-generated high waves should be understood more deeply because of coastal disaster prevention.
- Historical ocean wave observation is very few.

Microseisms are useful for ocean wave estimation

- Microseism is generated by ocean waves (Ardhuin et al. 2019).
- There is more historical seismic observation data than ocean wave.
- Previously, estimation of historical ocean wave height is studied (Bromirski 2023).

Objective

- We aim to estimate historical typhoon-generated high wave from seismograms.
- For this goal, we analyzed present ocean wave and microseism.

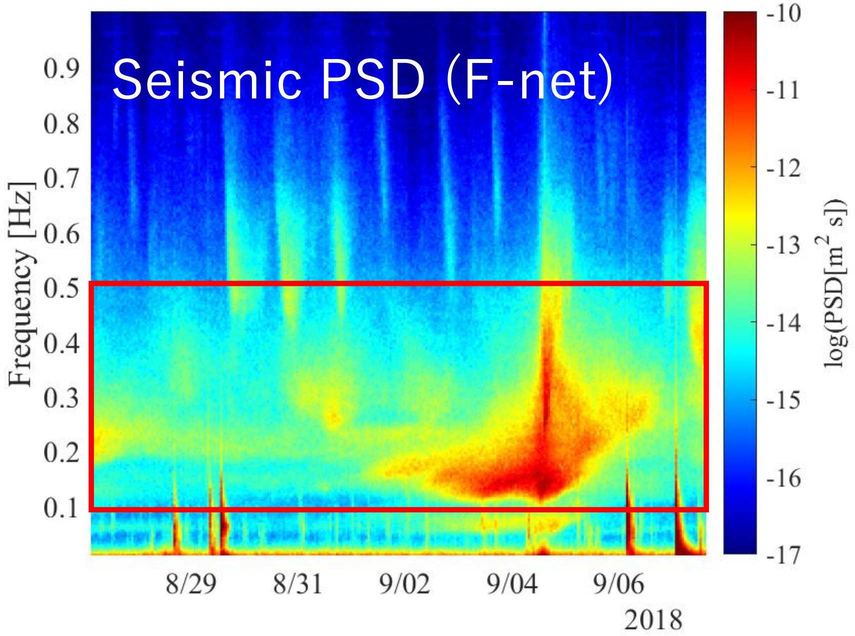
Microseism generation

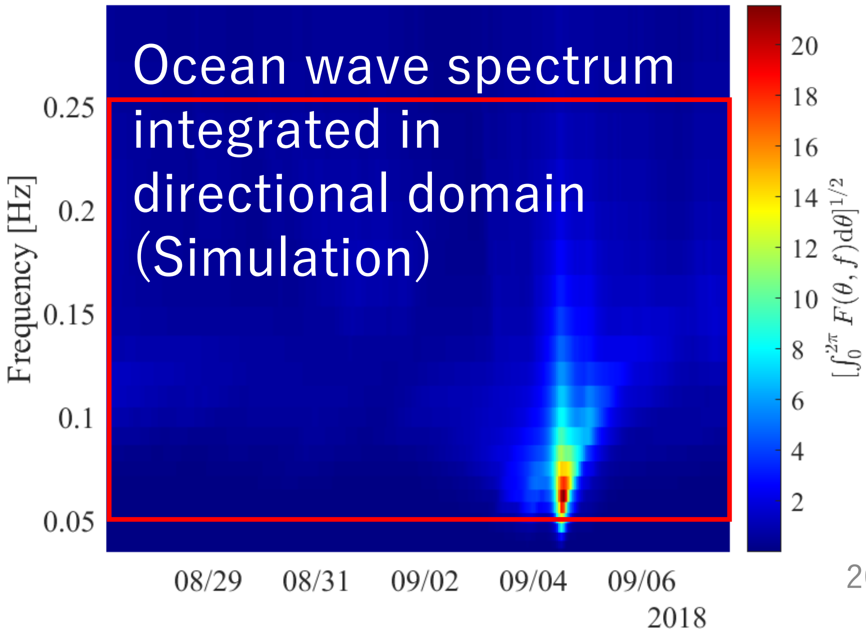
Microseism

- Microseism is the very small vibration usually treated as noise in seismograms
- Microseism is generated by ocean wave

Secondary microseism

- Secondary microseisms are generated by nonlinear interaction in a pair of ocean waves with nearly opposite direction and nearly same frequency (Longuet-Higgins 1950, Hasselman 1963, Ardhuin et.al 2019).





Research overview

Statistically analysis	• Analyzing seismic record, observation and hindcasting ocean wave data
Physically analysis	• Considering secondary microseism source • Estimating F-net Abuyama secondary microseism
Statistic estimation of ocean wave	• Estimating wave height in coastal observation point

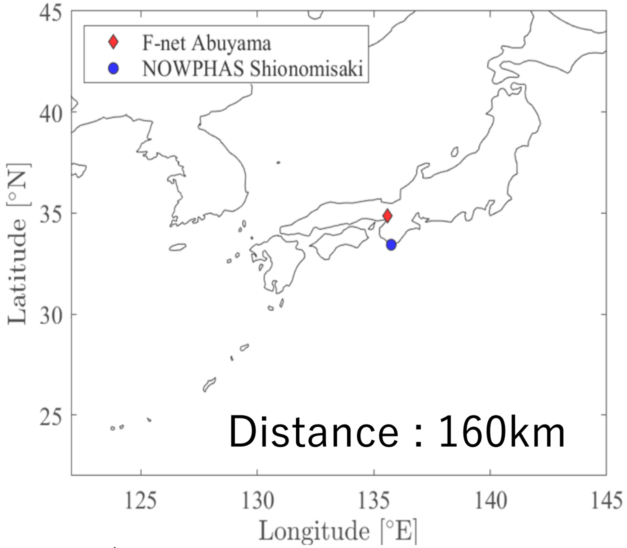
→ **Analysis of the present can be useful for estimation of past ocean wave**

Data

- Microseism observation record : F-net Abuyama in Osaka(F-net: a broadband seismic observation network by National Research Institute for Earth Science and Disaster Resilience(NIED))
- Ocean wave observation data : NOWPHAS (Wave height)
- Ocean wave hindcasting : WAVEWATCH III

  (Significant wave height, Wave spectrum,

  Equivalent surface pressure PSD(Power Spectral Density) : F_p)



$$F_p = \rho^2 g^2 f_s E(f)^2 \int_0^{\pi} \frac{F(f,\theta)F(f,\theta+\pi)}{E(f)^2} d\theta$$ (from Ardhuin and Herbers 2013)

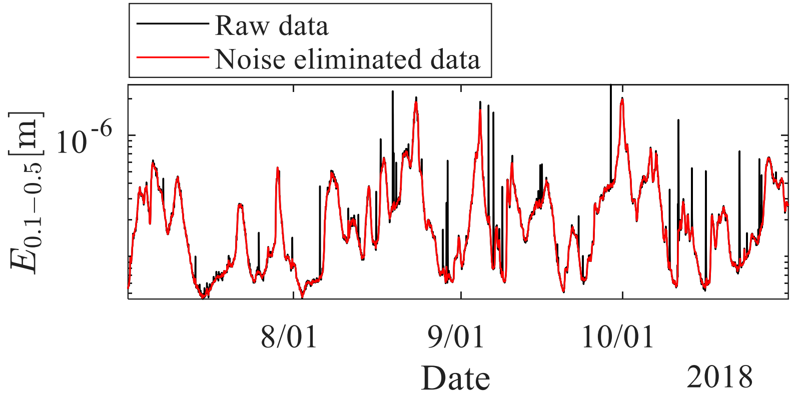
ρ : sea water density, g : gravity acceleration, f_s : secondary microseism frequency, f : ocean wave frequency,

θ : ocean wave direction, E : ocean wave frequency spectrum, F : ocean wave directional spectrum

Variables for microseism assessment

- F_s : hourly PSD of seismic displacement
- $E_{f_1-f_2}$: Noise eliminated secondary microseisms energy

$$E_{f_1-f_2} = \sqrt{\int_{f_1}^{f_2} F_s \, df}$$



- S_{DF} : The source of secondary microseisms

$$S_{DF}(f_s) = \frac{4\pi^2 f_s}{\rho_s^2 \beta^5} \left(\sum_{i=0}^{4} c_i^2 \right) F_p$$

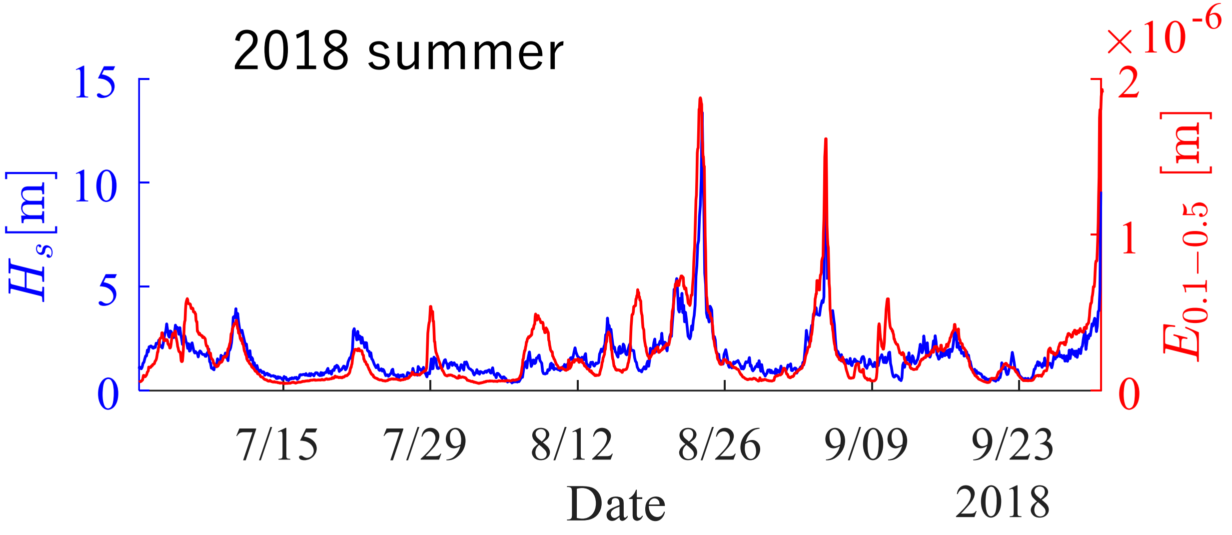
ρ_s: Rock density, β: Shear wave velocity,

c_i : Non-dimensional amplification factor for Rayleigh mode number i

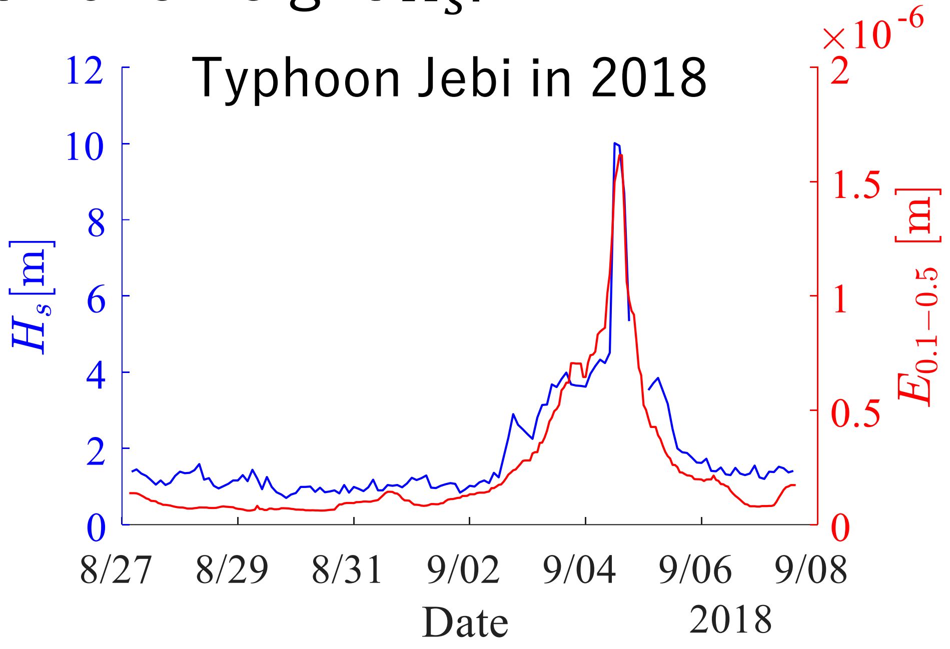
(Using Ardhuin and Herbers 2013 as reference)

Time series of secondary microseism and wave height

We statistically analyzed F-net Abuyama secondary microseisms energy and NOWPHAS Shionomisaki significant wave height H_s.



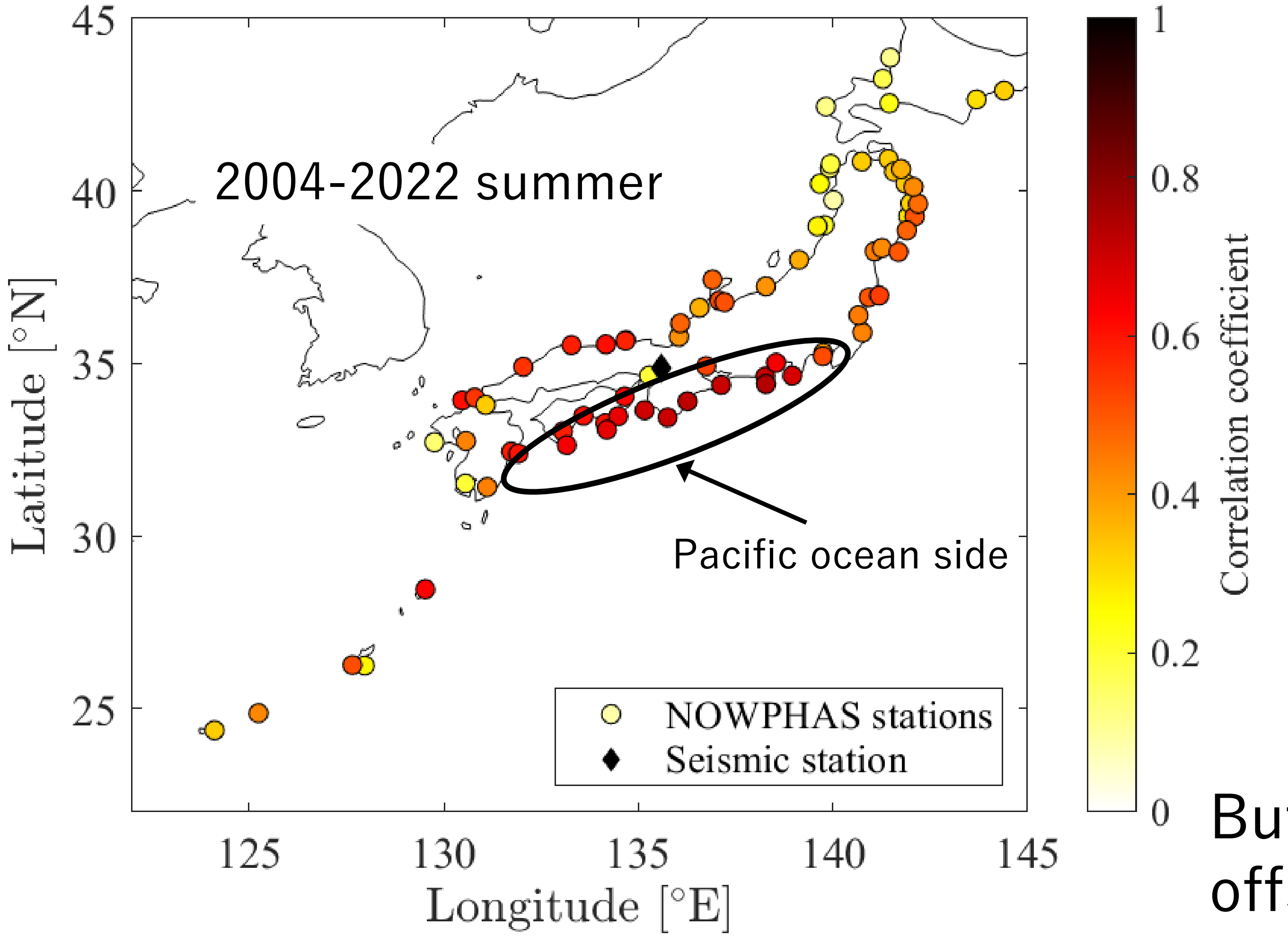
Correlation coefficient : 0.86



Correlation coefficient: 0.96

➢ **Secondary microseisms have high correlation with observational wave height.**

Correlation in all observation point

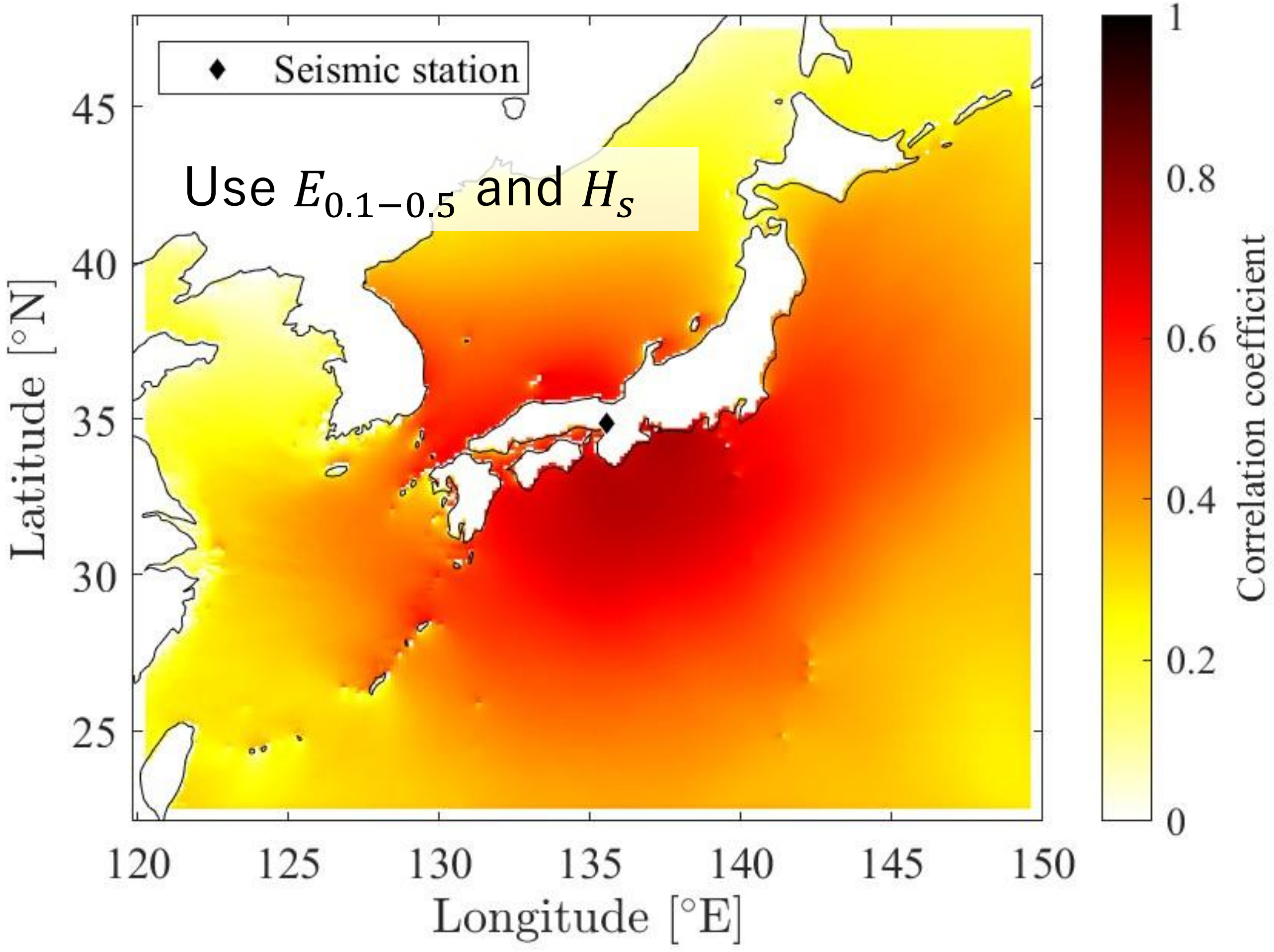


Correlation coefficient between F-net Abuyama $E_{0.1-0.5}$ and all NOWPHAS H_s.

- **Correlation is high around the seismic station and in Pacific ocean side.**

But, Observation is sparse and not in offshore, so finer information is needed.

Statistically analysis by using ocean wave hindcasting

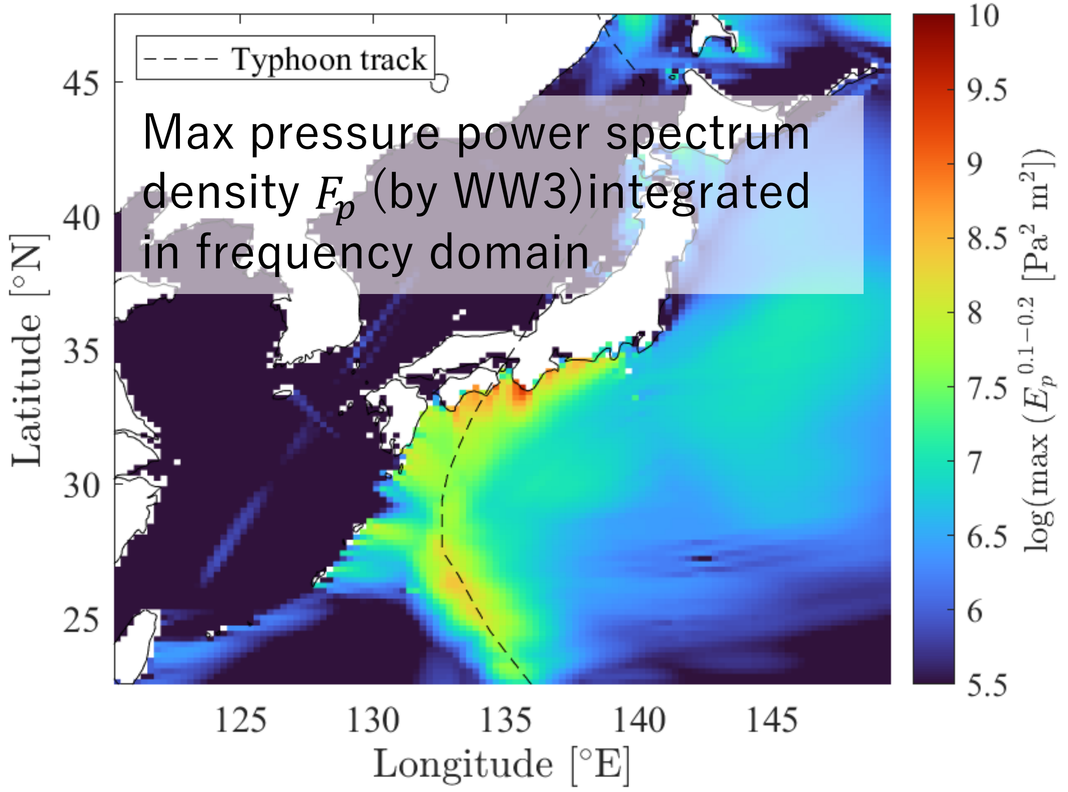


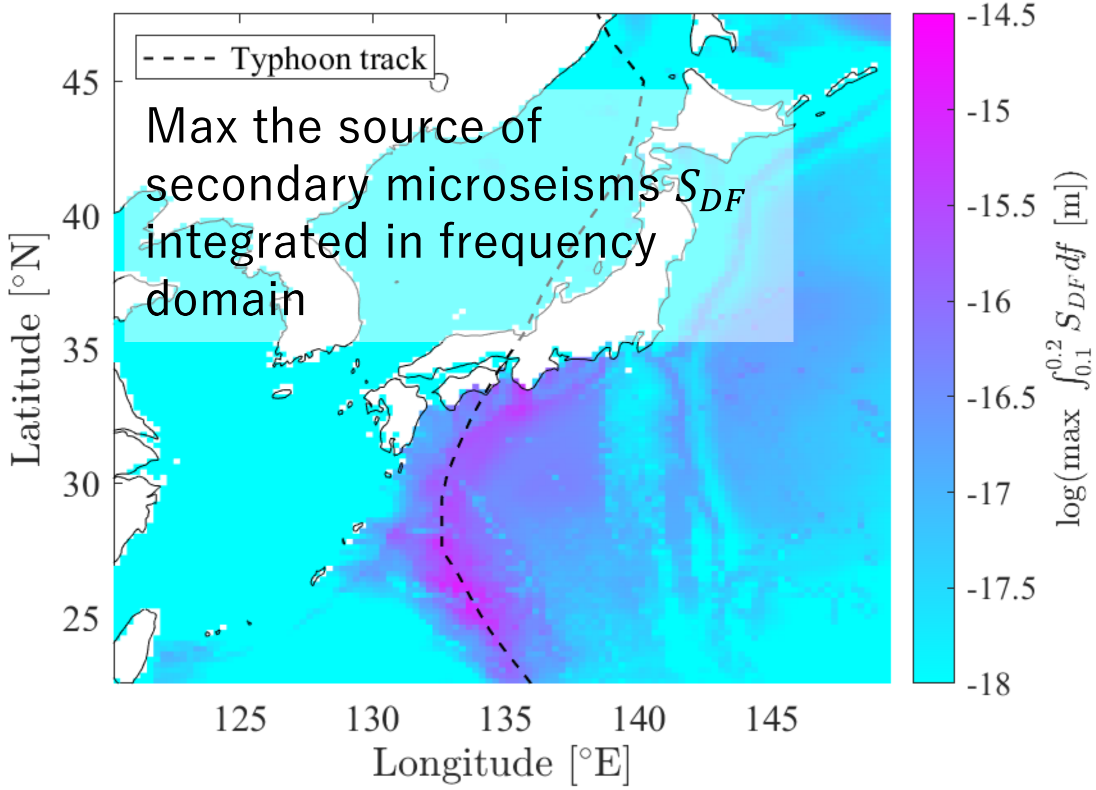
Correlation coefficient between H_s calculated by WAVEWATCHⅢ and microseism energy in 2014-2023 summer

➢ **We can statistically estimate typhoon-generated high wave in Pacific side around the station.**

Physically analysis when 2018 Jebi was close

Considering physical variables allows us to assess the effect of ocean wave for secondary microseisms.

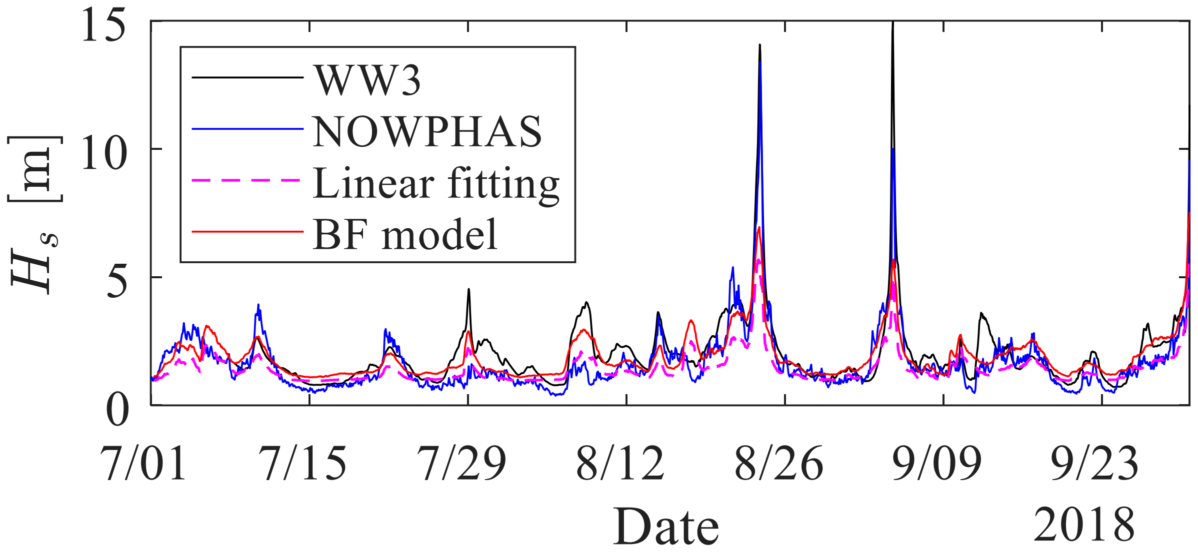


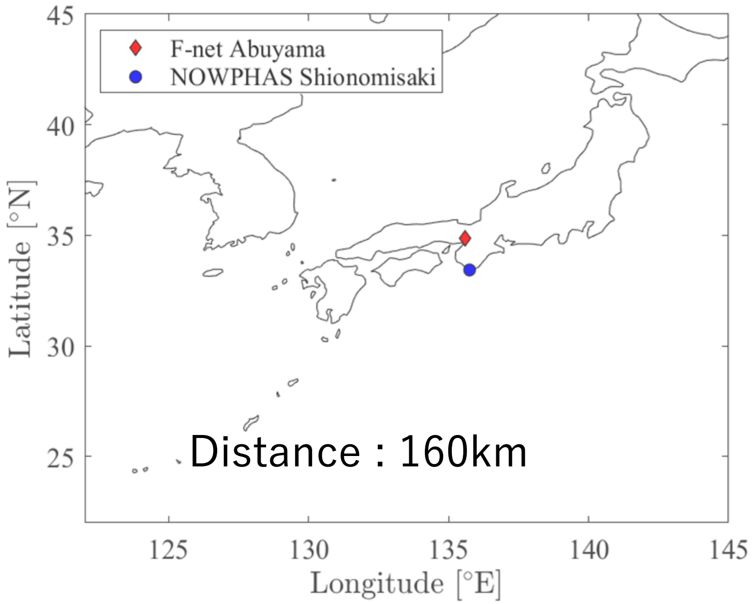


➢ **Typhoon can excite secondary microseism.**

Wave height estimation

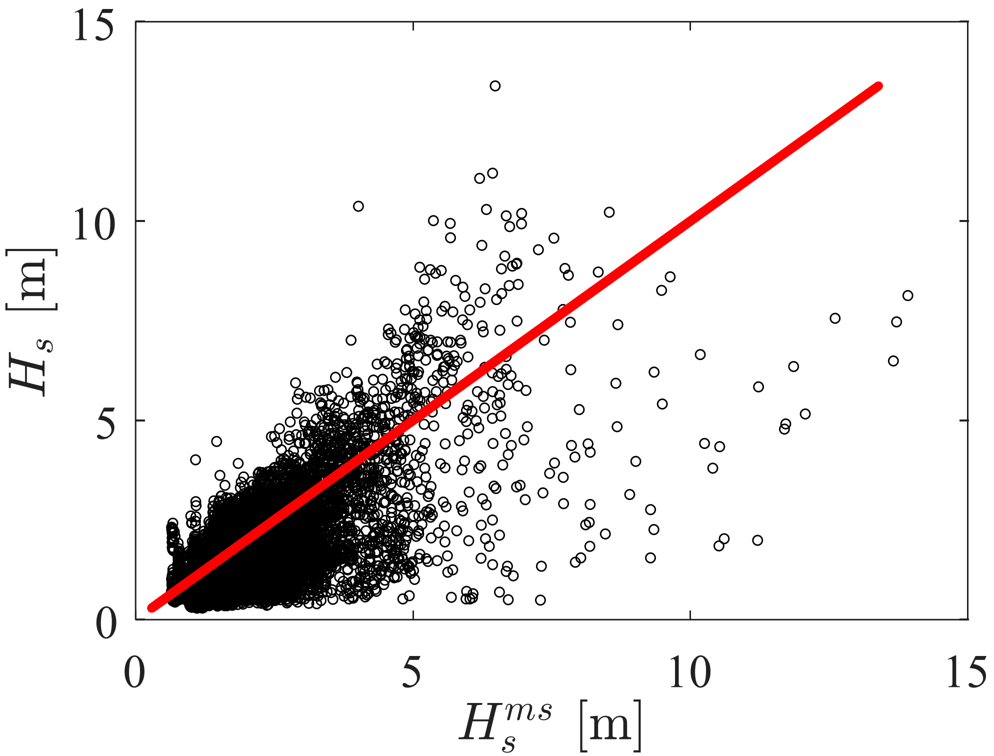
- H_s is statistically estimated from observational secondary microseism by using the method of Bromirski and Flick 2020.
- Learning data is ocean wave spectrum of WW3 and seismic PSD observed in F-net Abuyama.



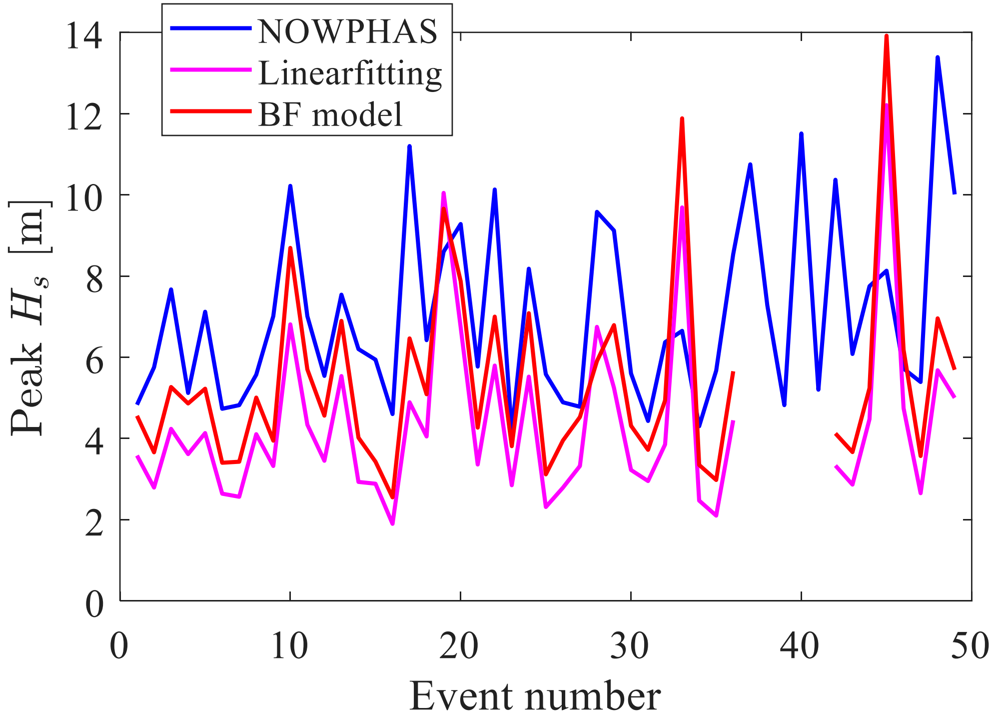


- ➢ **Estimation is somewhat consistent with observations.**
- ➢ **High wave cannot be estimated.**

Accuracy of ocean wave estimation



Estimation is compared with observation from 2004 to 2018.



Accuracy of high wave are checked by peak H_s

- **Typhoon-generated high waves are not reproduced well and underestimated.**
- **Model refining is needed.**

Conclusion

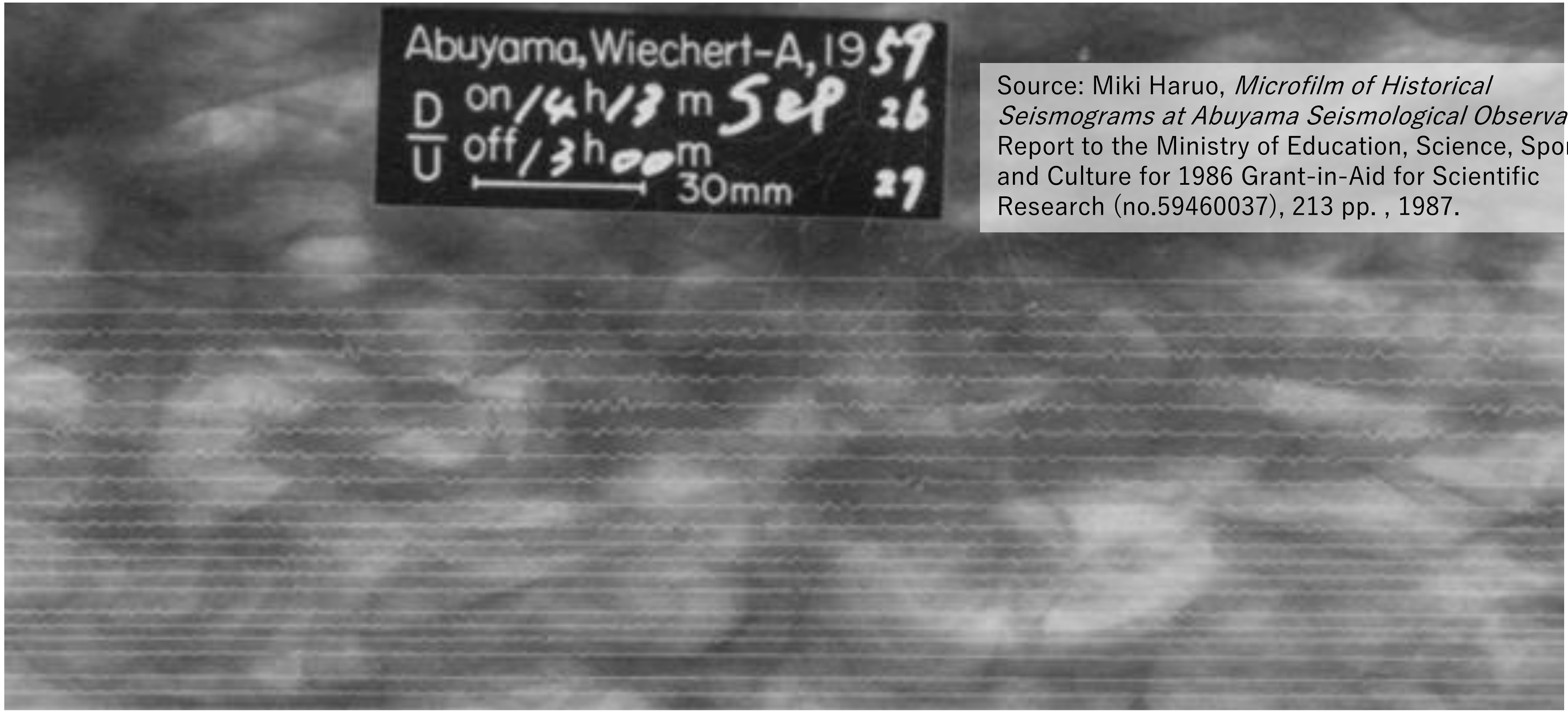
- Wave height around the seismic station and secondary microseisms energy have high correlation.
- Typhoon-generated high wave excite microseisms.
- High wave cannot be estimated accurately. However, wave height can be estimated statistically.

→ **If we can read historical seismic record, we can assess historical typhoon-generated high wave**

Future research

- Assessment of historical typhoon-generated high wave
- Accurate typhoon-generated high wave estimation
- More detailed physical analysis

Analogue seismogram



Source: Miki Haruo, *Microfilm of Historical Seismograms at Abuyama Seismological Observatory*, Report to the Ministry of Education, Science, Sports and Culture for 1986 Grant-in-Aid for Scientific Research (no.59460037), 213 pp. , 1987.

Seismic record on Abuyama observatory when typhoon Vera in 1959 was close to Japan

➤ **Digitalizing the record and estimating wave height**