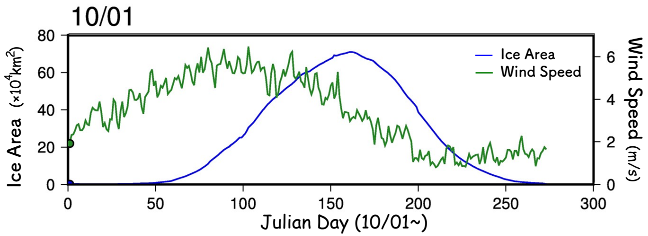
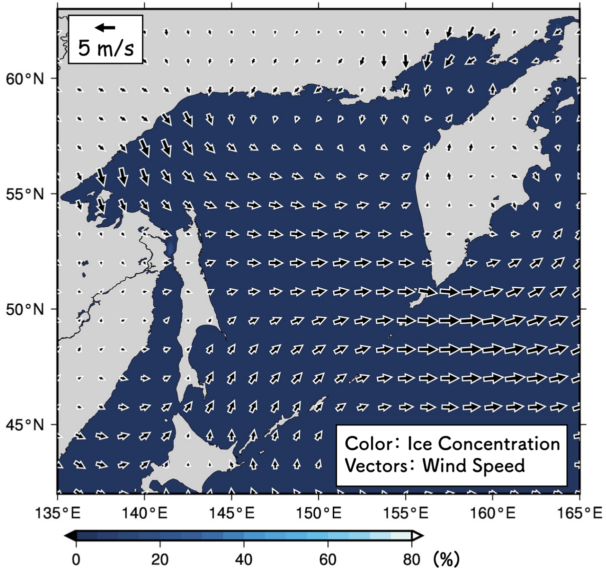
# Increase in the wave power due to the reduction of sea ice over the Sea of Okhotsk




**Shinsuke IWASAKI**

**Port and Coast Research Team**
**Civil Engineering Research Institute for Cold Region (CERI)**
**Public Works Research Institute (PWRI)**



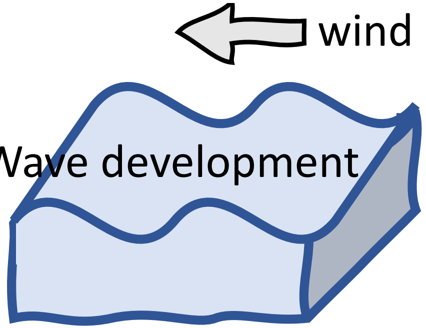

**For more information ↓**

**Increase in the wave power caused by decreasing sea ice over the Sea of Okhotsk in winter**

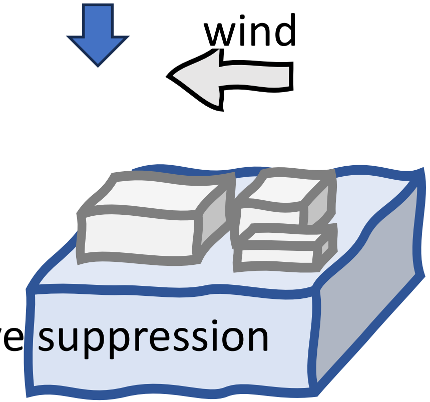
**Iwasaki (2023; Scientific Reports)**


**Engineering Top 100 of 2023**
**Earth, Environment and Ecology Top 100 of 2023**

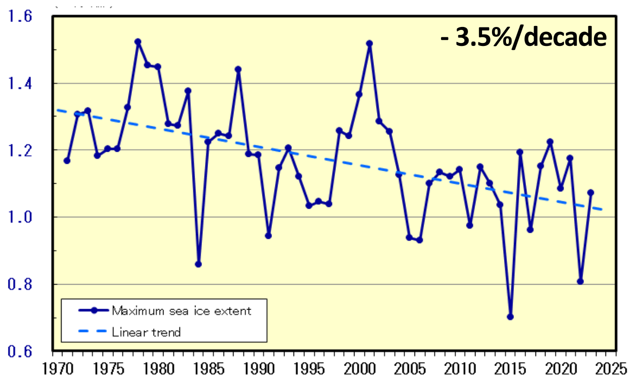
# Introduction




**Sea ice has a wave attenuation effect.**




**Inter-annual change of maximum sea ice extent ($10^4 km^2$ )**




**From JMA's HP**

**Increased waves coming to the coastal areas, and with them,**

- **Increased high wave damage**
- **Acceleration of coastal erosion**
- **Decreased coastal structure stability**

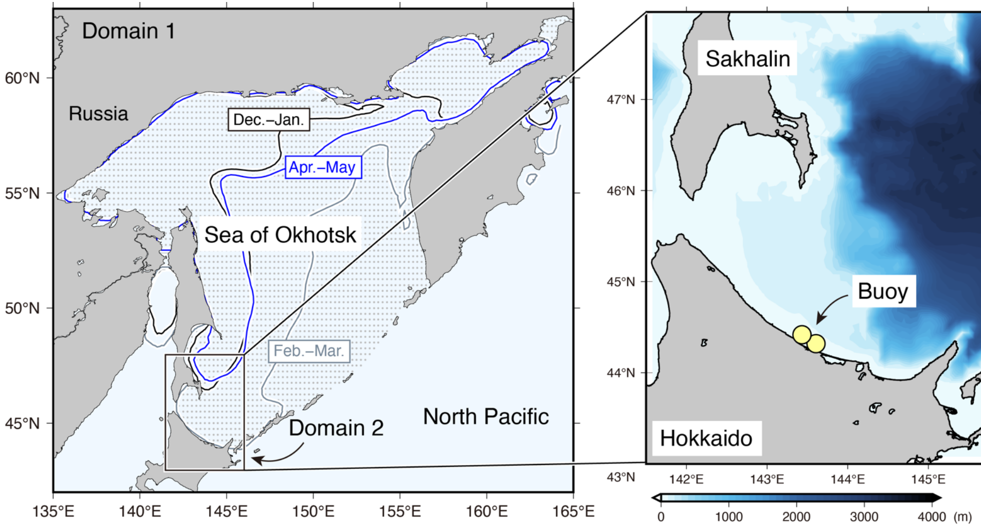
**Concerned about the increase in disaster cases.**

- **Are waves in the Sea of Okhotsk increasing? If so, what are the causes ?**

# Method (Wave Model)

## Input data

| Wind | Sea Ice | Reference |
|---|---|---|
| JRA55 | NOAA OISST | Kobayashi et al., (2015), Reynolds et al., (2007), Huang et al., (2021) |
| ERA5 | ERA5 | Hersbach et al., (2020) |
| MERRA2 | MERRA2 | Gelaro et al., (2017) |




## Wave model (WW3)

Input

| Model | WAVEWATCH III (Ver. 6.07) |
|---|---|
| Spatial reso. | Domain1 (0.25°), Domain2 (0.08°) |
| Frequency space | 0.035-1.1 Hz (30 increments) |
| Directional reso. | 10° |
| Input・Dissipation term | ST6 |
| Ice source term | IC4M2 (Meylan et al., 2014) |
| Coastline・Bottom Topo. | GEBCO2020 |

Computation period : 1981/09~2021/08 (40 years)

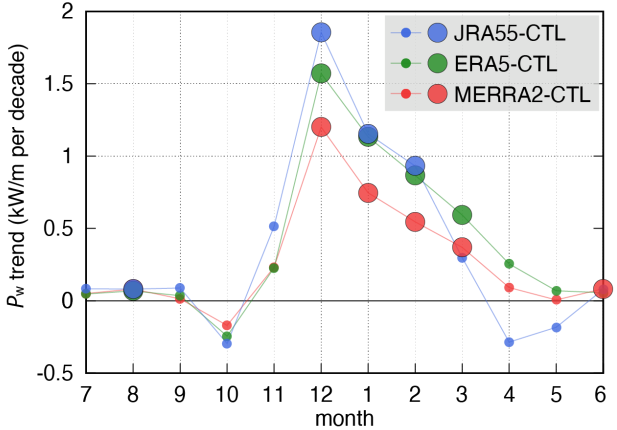
## Model Experiments

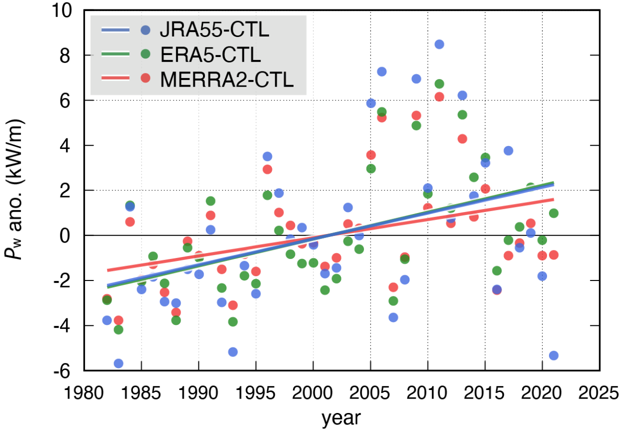
・**CTL runs (3 case)**
・**Clim-ICE runs（3 case)**

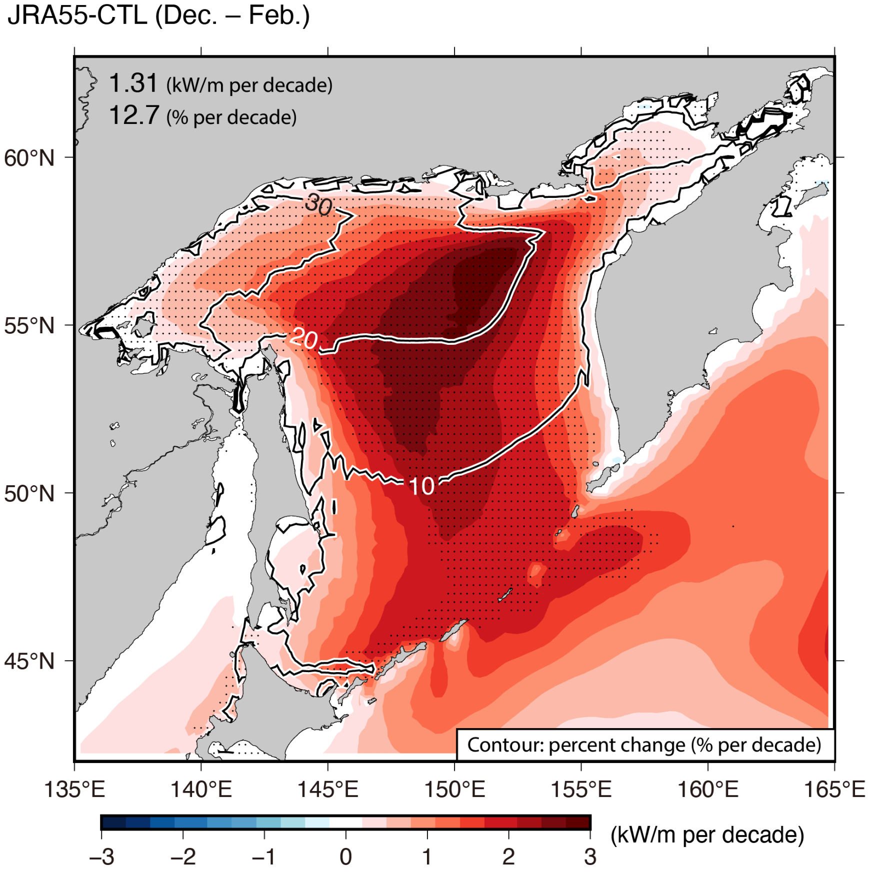
Clim-ICE（Climatological sea ice values used)
→ Wave variation due to surface wind only
CTL−Clim-ICE → Wave variation due to sea ice only

CERI 国立研究開発法人 土木研究所 寒地土木研究所 COLD REGION

# Trend of Wave Power (Pw) over the Sea of Okhotsk



# Trend of Wave Power (Pw) over the Sea of Okhotsk

**Linear trend of wave power (Dec—Feb.)**

| | Trend [kW m$^{-1}$/decade] | Ratio [%/decade] |
|---|---|---|
| JRA55 | 1.31 | 12.7 |
| ERA5 | 1.19 | 15.3 |
| MERRA2 | 0.83 | 12.1 |

**Linear trends of surface wind and ice area (Dec—Feb.)**

| | Wind [ms$^{-1}$/decade] | Ice Area [×10$^4$ km$^2$/decade] |
|---|---|---|
| JRA55, NOAA OI | 0.27 (3.21) | -1.26 (-3.52) |
| ERA5 | 0.17 (2.11) | -4.65 (-10.73) |
| MERRA2 | 0.14 (1.73) | -2.45 (-6.79) |

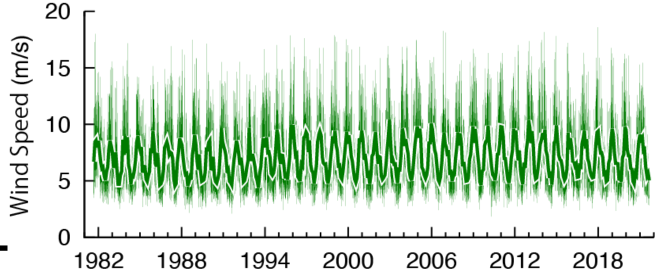
Values in parentheses indicate the relative trends (%/decade)

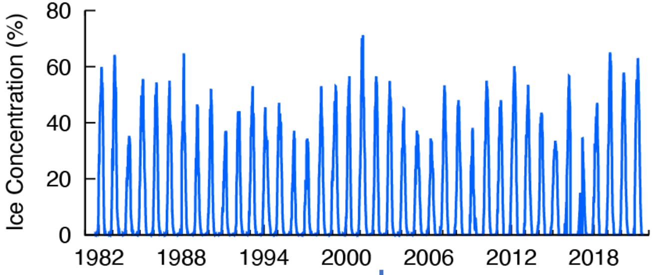
**Increased surface wind ? or Reduced sea ice ?**

# Numerical Experiments (CTL and Clim-ICE runs)

**CTL run**

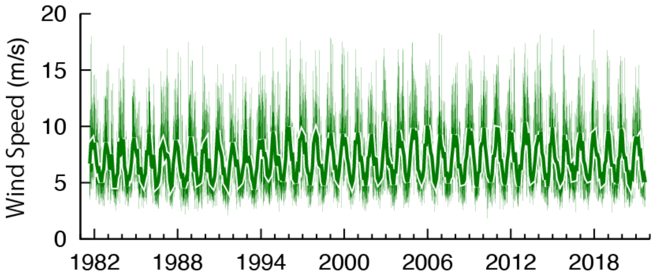
**CTL (Increased wind + Reduced ice)**



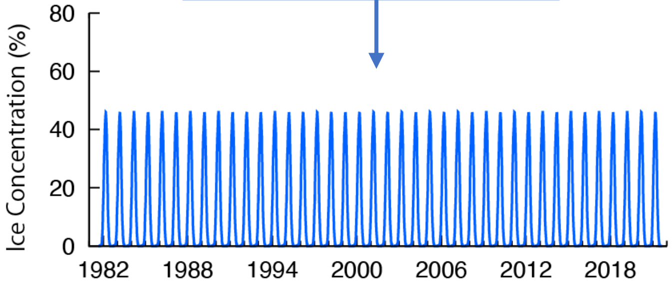




**Wave model** ←

**Clim-ICE run** → **(Increased wind only)**



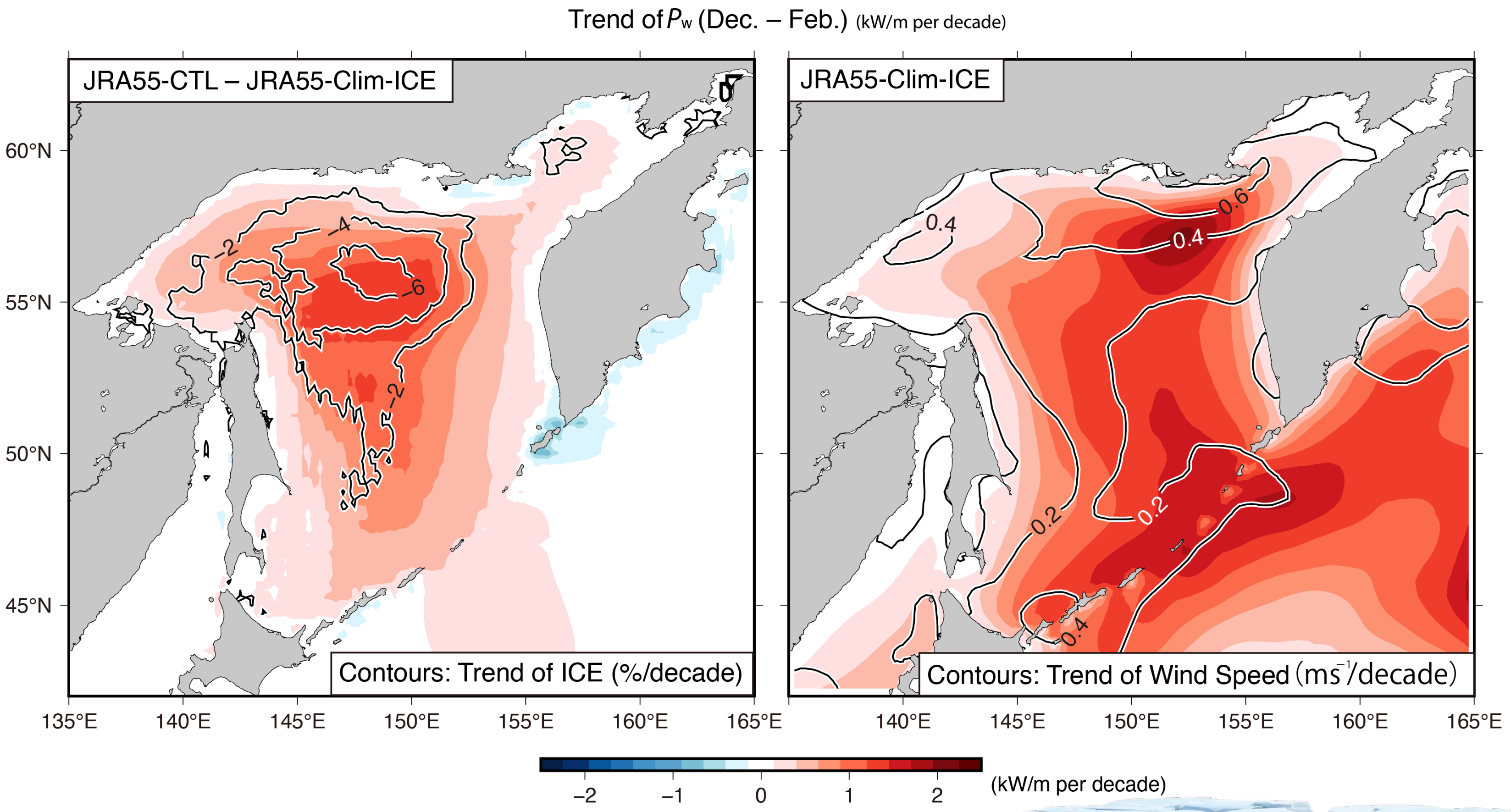

**Climatological Sea Ice**




→ **Wave model**

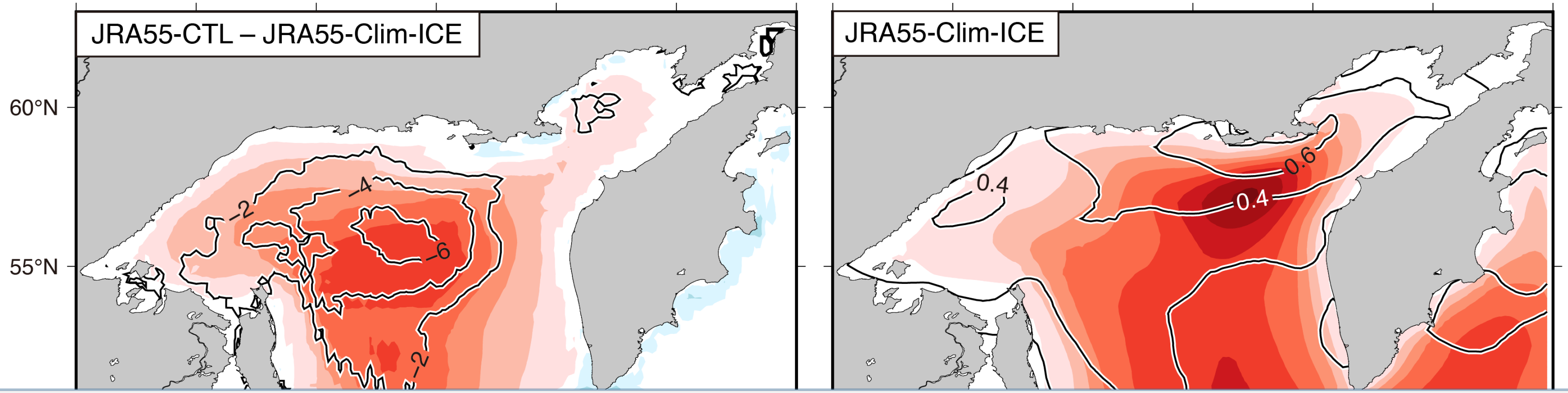
**CTL run – Clim-ICE run = Reduced Sea Ice Only**

# Contributions of wind and sea ice



# Contributions of wind and sea ice

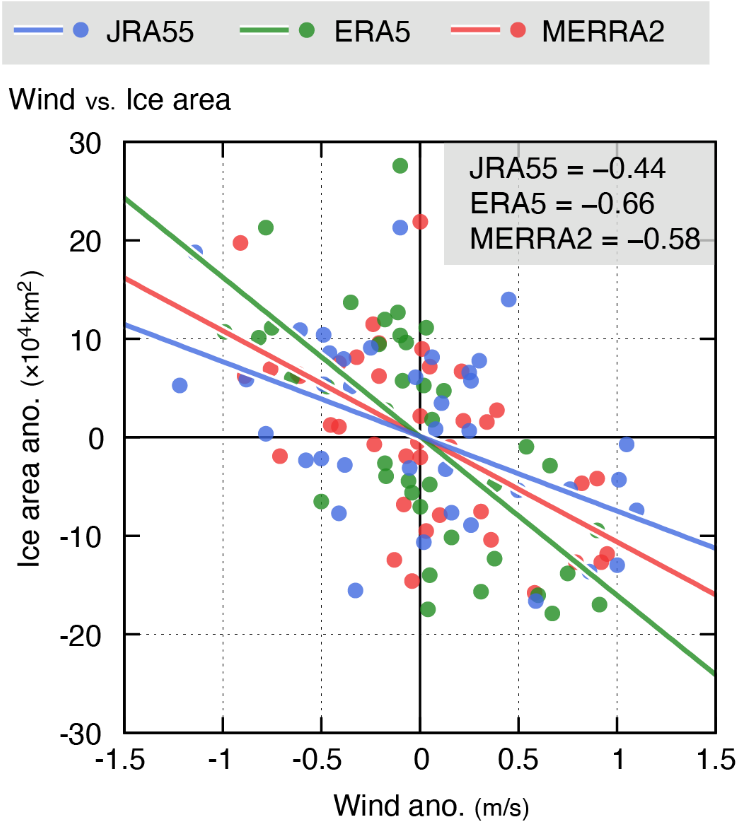
Trend of $P_w$ (Dec. – Feb.) (kW/m per decade)

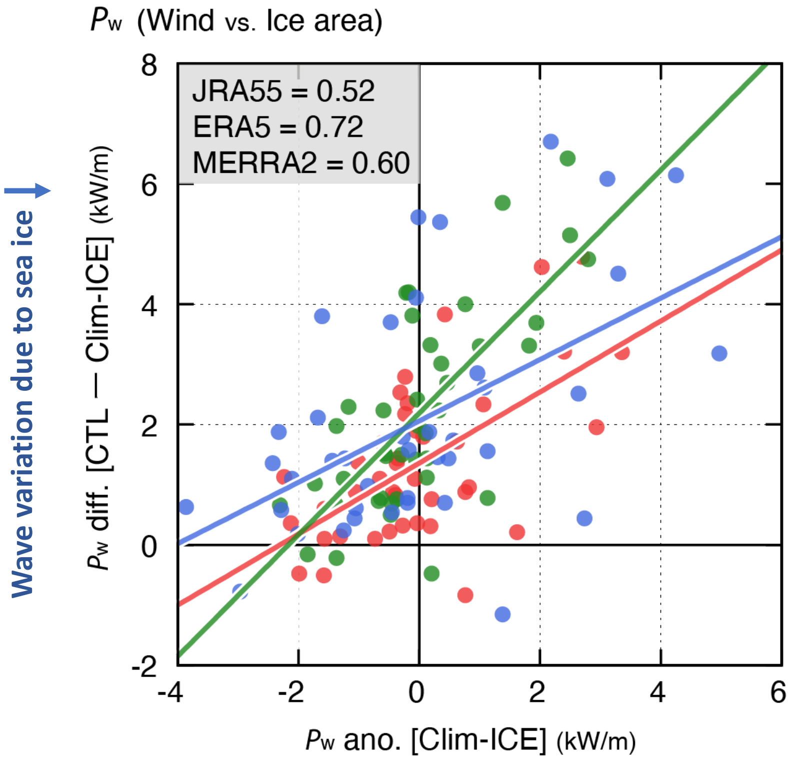



**Linear trend of wave power (Dec—Feb.)**

| | Contribution of surface wind | Contribution of sea ice |
|---|---|---|
| | **Clim-ICE [kWm$^{-1}$/decade]** | **CTL – Clim-ICE [kWm$^{-1}$/decade]** |
| JRA55 | 0.81 | 0.5 |
| ERA5 | 0.5 | 0.69 |
| MERRA2 | 0.36 | 0.47 |

# Relationship between surface wind and Sea ice
## (Inter-annual variability:Dec.-Feb.)



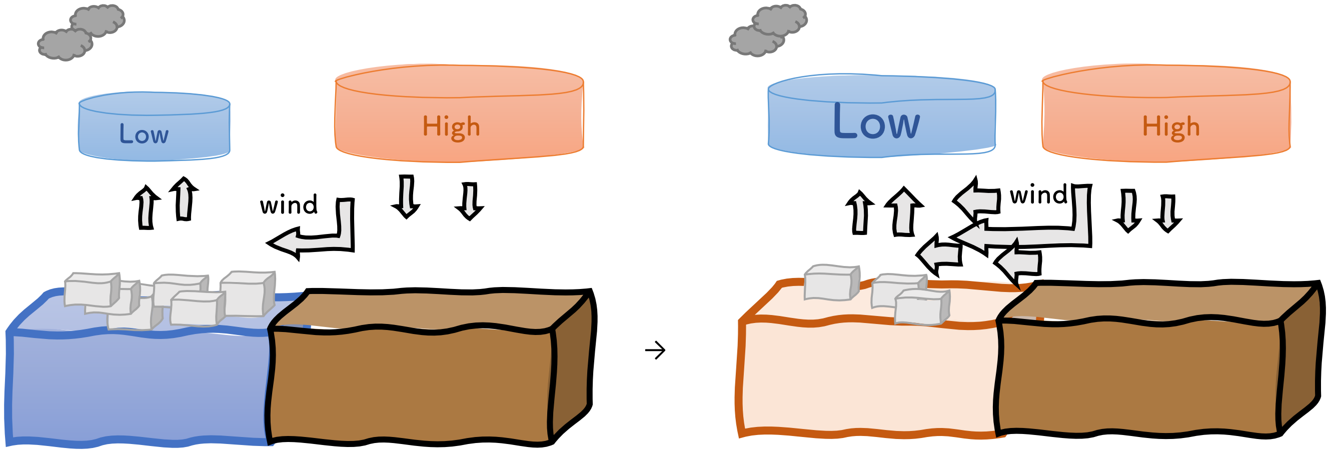

Data number :40

↑ Wave variation due to surface wind

# Modification of winds by sea ice

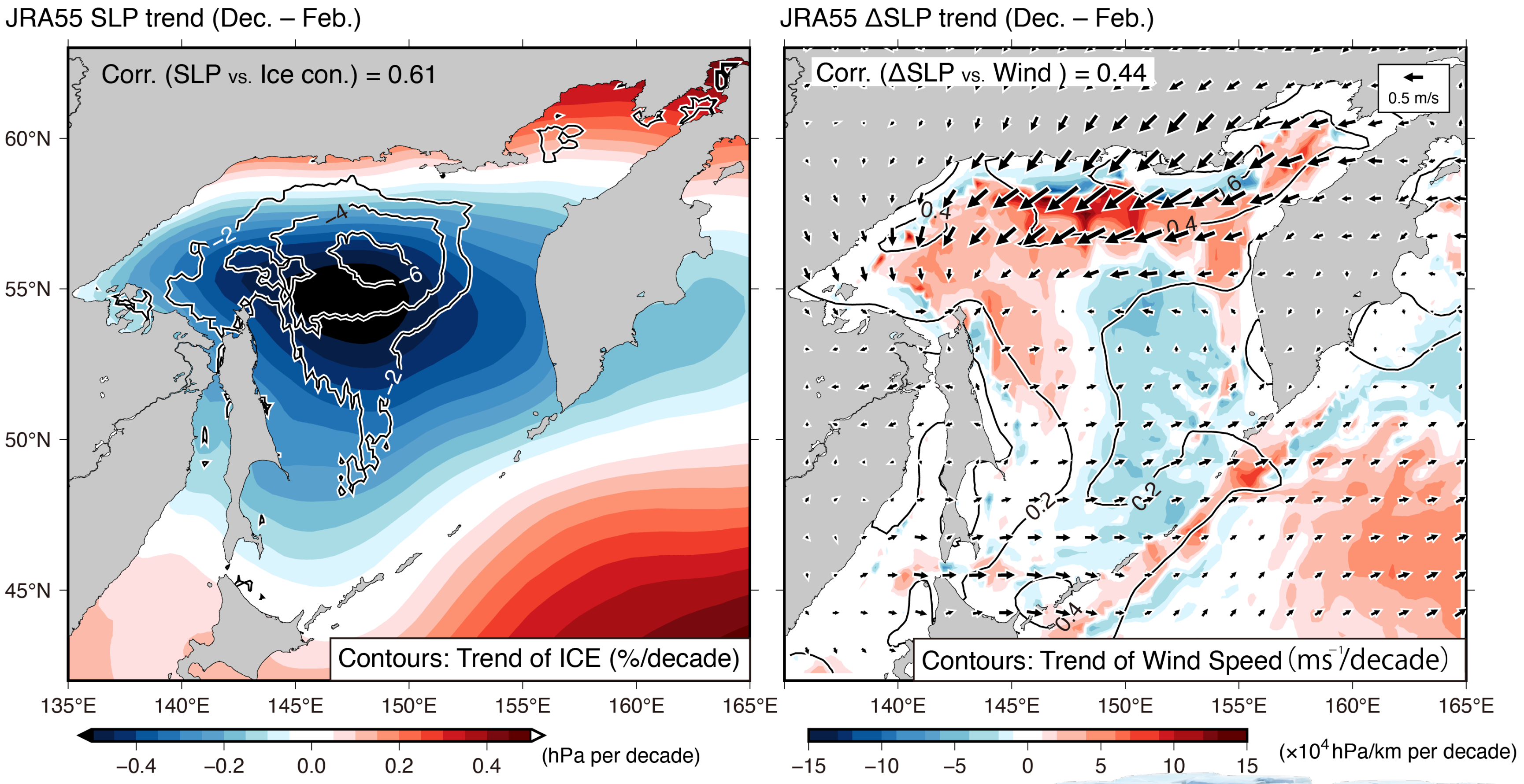
## Pressure adjustment mechanism

Lindzen et al., (1987), Alkama et al., (2020)




Sea ice reduction → Decrease in sea level pressure (SLP)
→ Enhanced horizontal gradient of SLP → Increased surface wind

# Modification of winds by sea ice

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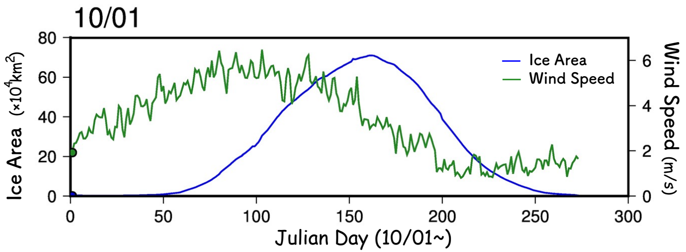
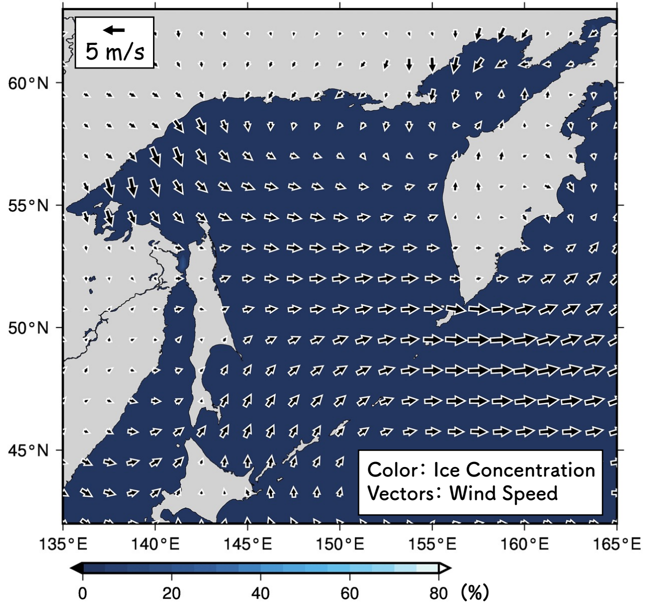
# Summary

- **The long–term trends of wave power (*Pw*) in the Sea of Okhotsk were investigated using the 40-year (from the 1980s) simulations.**
- **Wave power (*Pw*) showed a significantly positive trend (～12-15% per decade) during winter (Dec. - Feb.).**
- **The reduction of sea ice is the most important factor responsible for the positive *Pw* trend.**



# Summary

## Thank you for your attention