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FUTURE WAVE PROJECTION DURING THE TYPHOON AND WINTER STORM SEASON

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1. Introduction

■Background

- IPCC's AR5 stated that it is more likely than not that the frequency of tropical cyclones (TCs) will decrease and that the intensity of TCs will increase over the Western North Pacific in the late 21st century.

- Many researches consider the Sea Surface Temperature (SST) change, which may influence the future climate and wave field according to various climate change scenarios.
  - Hemer et al. (2013)
  - Shimura et al. (2015)

■The aim of this study

- To evaluate the effects of future climate change on wave conditions from one-month simulations including periods of extreme events based on the pseudo-warming method with the most recent IPCC scenario.

2. Target area and period

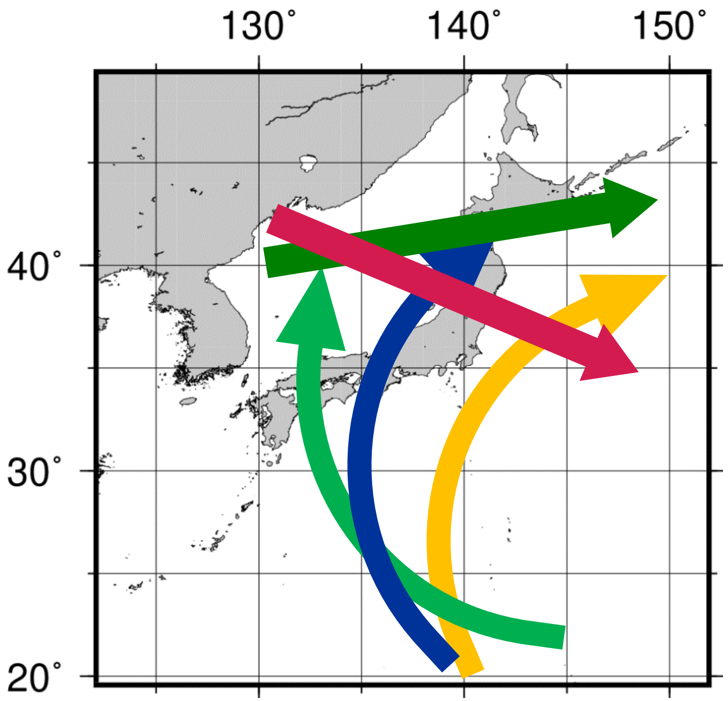


***Figure 1**. Severe climate events around Japanese islands*

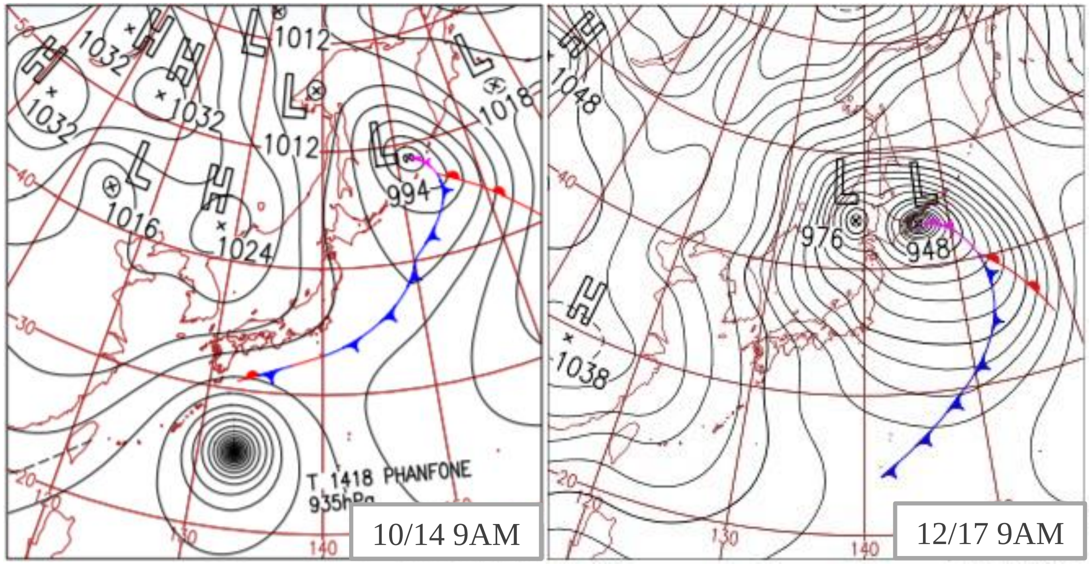


***Figure 2**. Historical events in Oct. and Dec., 2014 (image after; Japan Meteorological Agency)*

- 2 Typhoons, Phanfone and Vongfong, landed at Japanese islands in October 2014 and maximum recorded significant wave heights were observed
- One extratropical cyclone developed at northern Japan and caused a storm surge in Nemuro, Hokkaido in December 2014
- The year 2014 is considered to be one of the most active years in terms of wave heights

3.1 Methodology (Present Case)

Meteorological data (NCEP FNL)

- Temperature
- Relative humidity
- Atmospheric pressure
- Wind speed
- etc...

- Sea surface temperature

Give initial and boundary conditions

Meteorological Model WRF
(Skamarock et al., 2008)

WPS + **WRF**

Input wind results extracted from WRF simulation

Wave Model SWAN
(Booij et al., 1999)

Calculate significant wave heights and periods

Compare with measured data of NOWPHAS

3.2 Methodology (Future Case)

Meteorological data (NCEP FNL)

- Temperature
- Relative humidity
- Atmospheric pressure
- Wind speed
- etc…
- Sea surface temperature

Sea surface temperature

Ensemble results of 26 GCMs are used for the difference of SST between present and future cases.

Give initial and boundary conditions

Meteorological Model WRF
(Skamarock et al., 2008)

WPS + **WRF**

Input wind results extracted from WRF simulation

Wave Model SWAN
(Booij et al., 1999)

Calculate significant wave heights and periods

Predict future waves

3.2 Methodology (Future Case)

■The amount of SST increase

The amount of SST increase are set as mean values in October and December averaged over 2061-2080 relative to 2006-2015 based on IPCC RCP8.5 scenario.

- The amount of SST increase in October : 1.75～3.24℃
- The amount of SST increase in December : 1.25～2.85℃

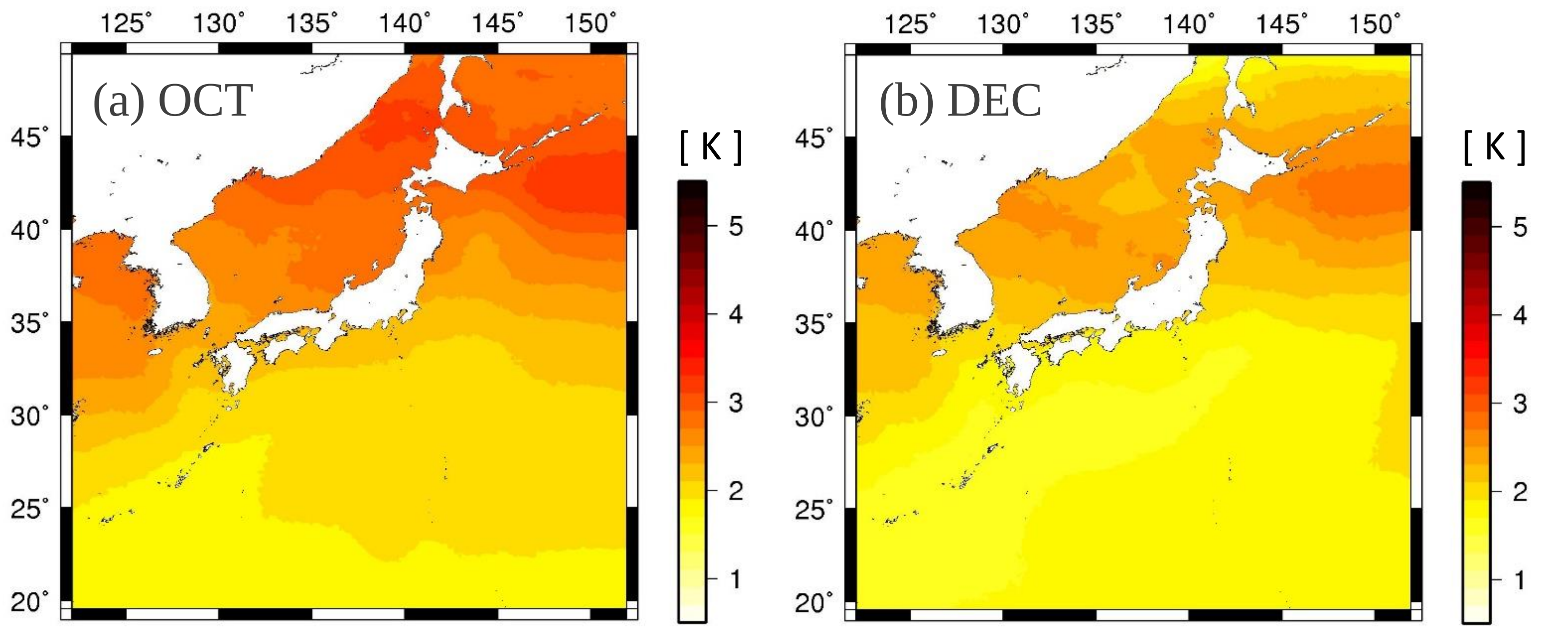


Figure 3. *The distribution of SST increase over calculation domain*

3.3 Calculation conditions

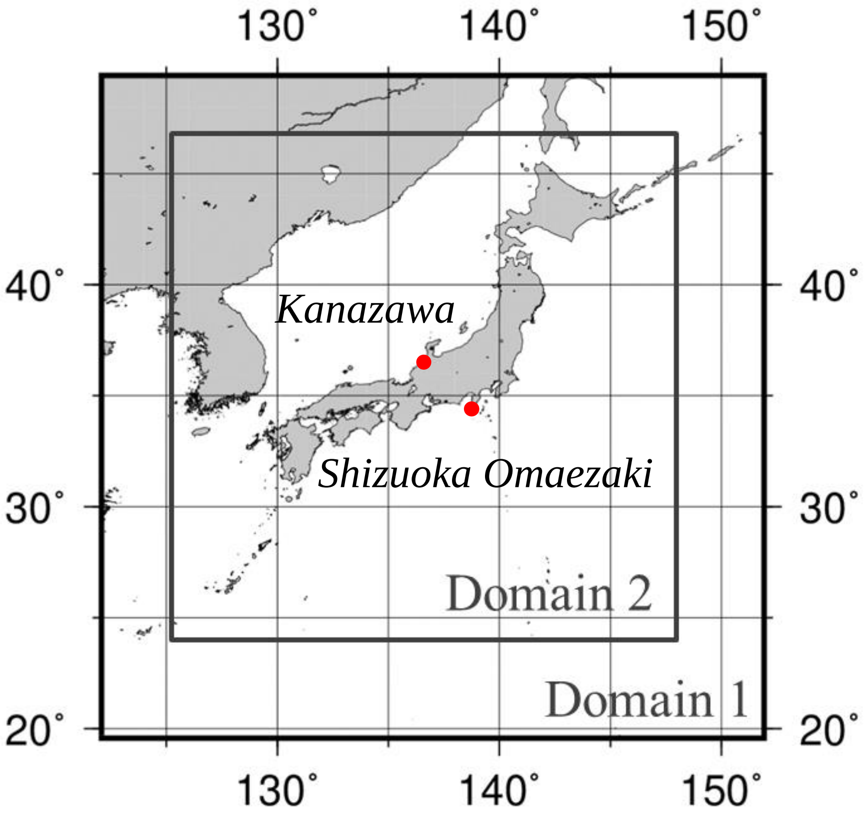


***Figure 4**. Calculation domains for WRF and SWAN*

***Table 1**. Calculation conditions for WRF*

Calculation Period (UTC)			10/01/2014 00:00 ~ 11/01/2014 00:00	
			12/01/2014 00:00 ~ 01/01/2015 00:00	
Domain settings	Area	domain 1	122.1°E ~ 151.9°E	19.6°N ~ 49.4°N
		domain 2	125.6°E ~ 147.8°E	23.9°N ~ 46.8°N
	resolution	domain 1	0.15°	201 × 201
		domain 2	0.05°	445 × 460
Input data intervals			6 hours	
Calculation intervals			60 s	
Number of vertical layers			36 layers	
Micro physics			WSM 3-class simple ice scheme	
Shortwave radiation			rrtmg scheme	
Longwave radiation			rrtmg scheme	
Planetary Boundary Layer			YSU scheme	
Meteorological data			FNL (1° × 1°)	
Geography data			USGS	

***Table 2**. Calculation conditions for SWAN*

Calculation Period (UTC)			10/01/2014 00:00 ~ 11/01/2014 00:00	
			12/01/2014 00:00 ~ 01/01/2015 00:00	
Domain Settings	Area	domain 1	122.5°E ~ 151.0°E	20.0°N ~ 48.5°N
		domain 2	127.0°E ~ 147.5°E	25.0°N ~ 46.0°N
	resolution	domain 1	0.15°	190 × 190
		domain 2	0.05°	410 × 420
Calculation mode			Non-stationary / 2 dimension	
Whitecapping			Komen	
Direction division number			36 (θ=10°)	
Frequency division number			39 (0.025 ~ 1.0 Hz)	
maximum number of iterations			5	
time step			5 min	
Bathymetry data			GEBCO2014	

4.1 WRF Result (Present Case)

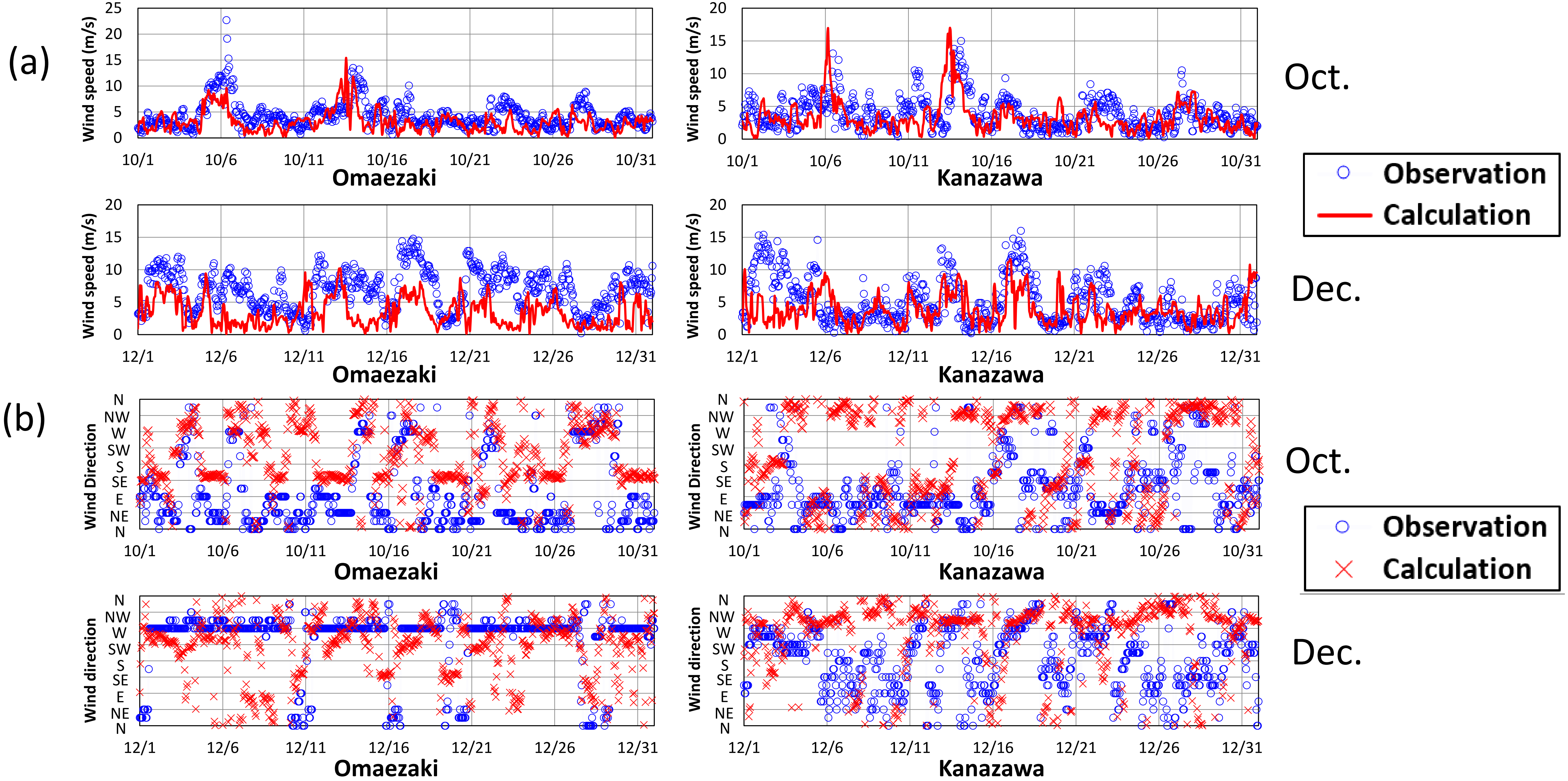


Figure 5. *The time history of (a) wind speed and (b) wind direction*

4.2 SWAN Result (Present Case)

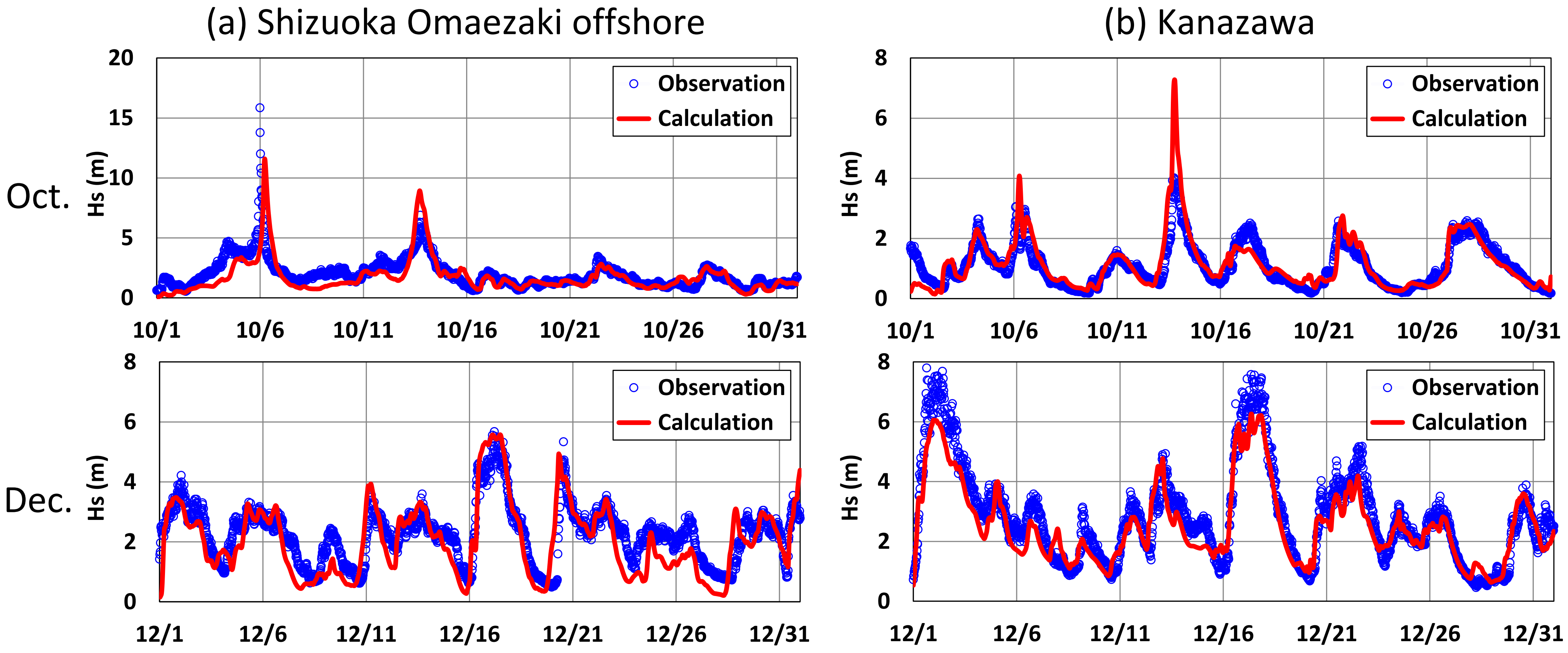


Figure 6. *Comparison of the time history of significant wave height*

4.2 SWAN Result (Present Case)

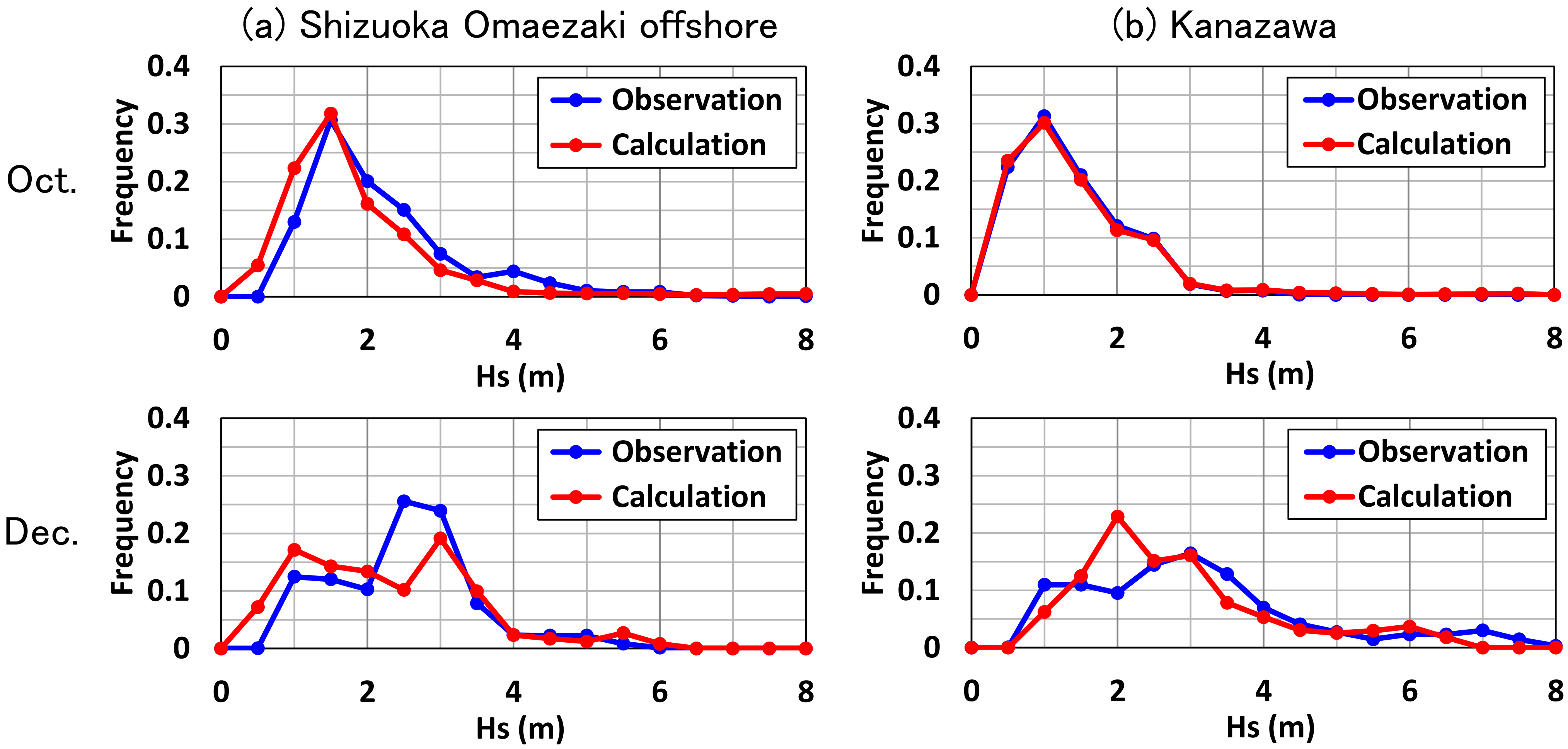


Figure 7. *The frequency distribution of significant wave height*

4.3 WRF Result (Future Case)

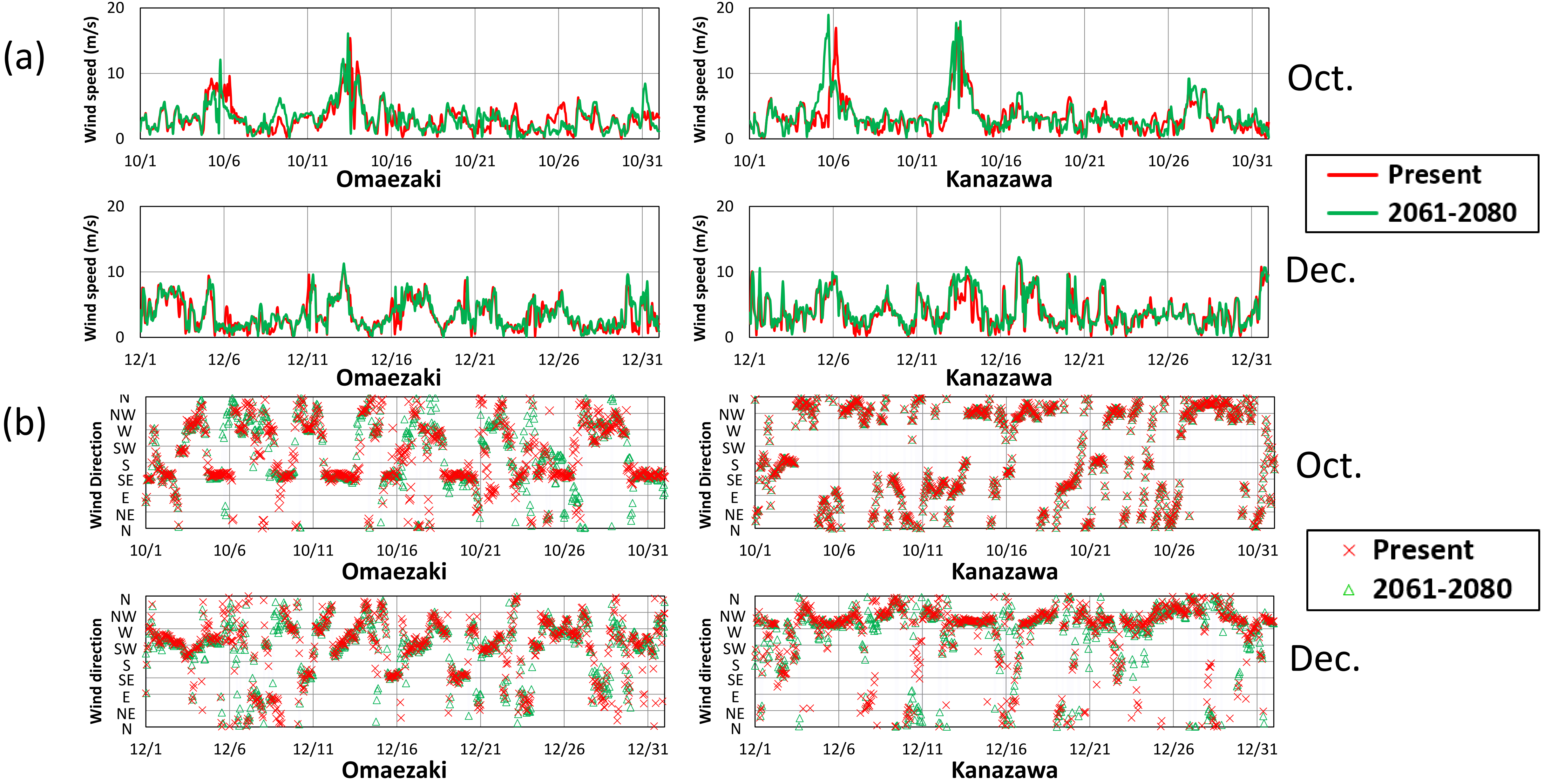


***Figure 8**. The time history of (a) wind speed and (b) wind direction between present and future case*

4.4 SWAN Result (Future Case)

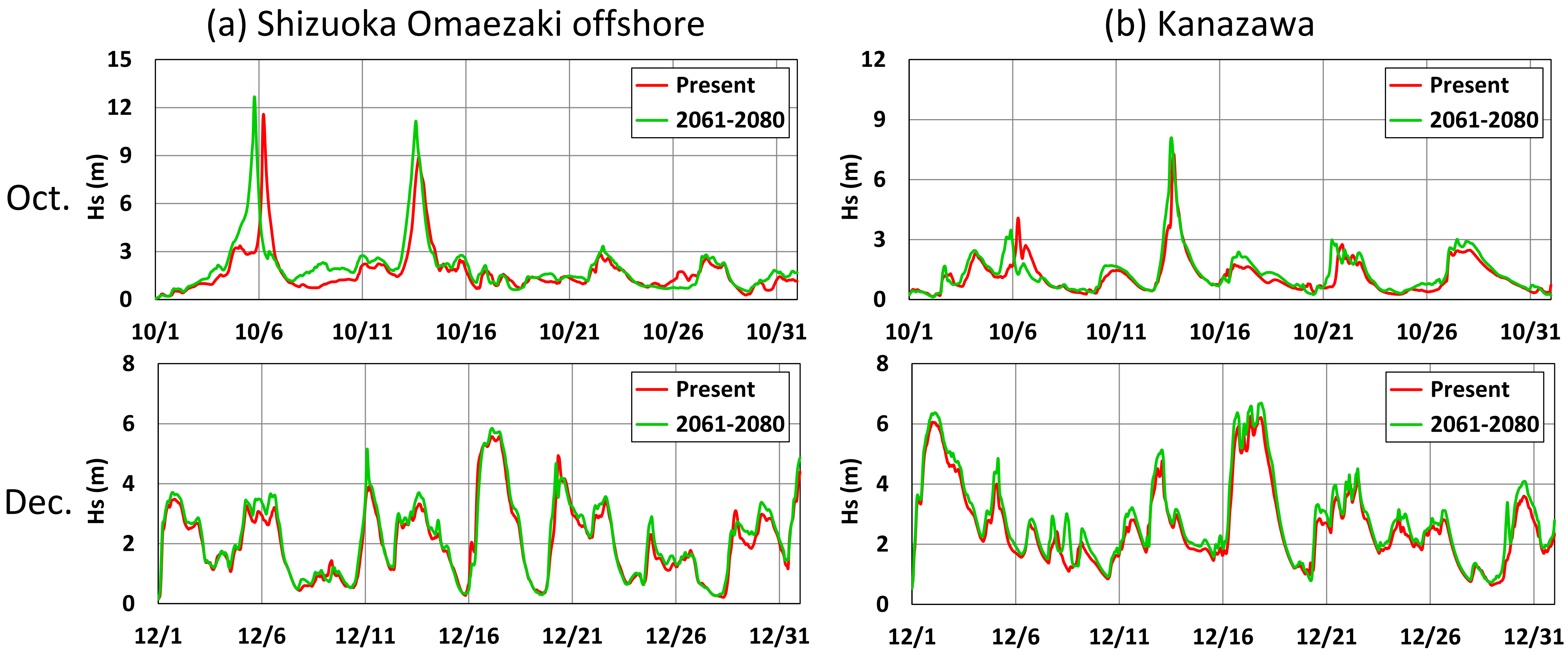


Figure 9. *Comparison of the time history of significant wave height between present and future case*

5. Discussion

■The change of mean significant wave height

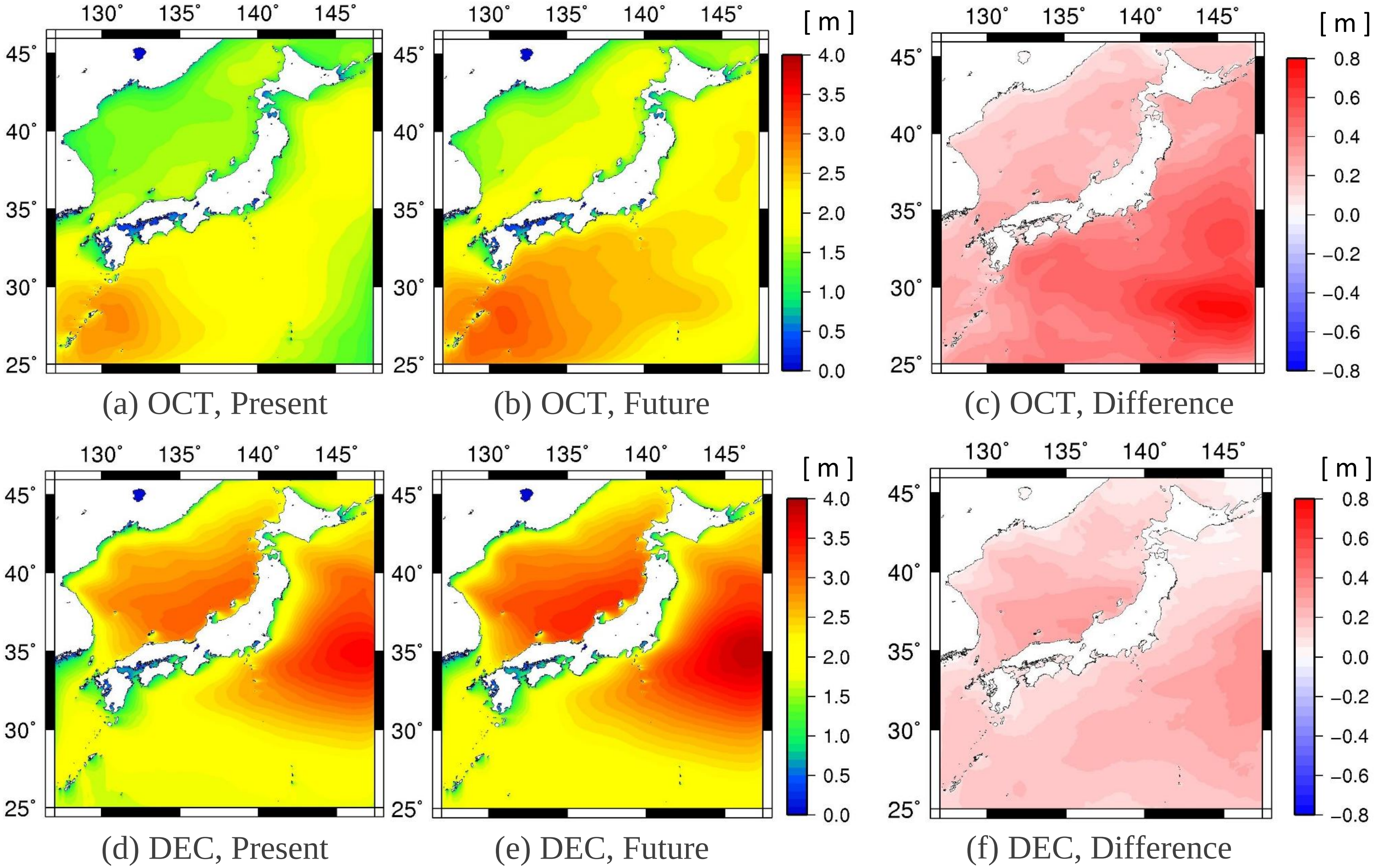
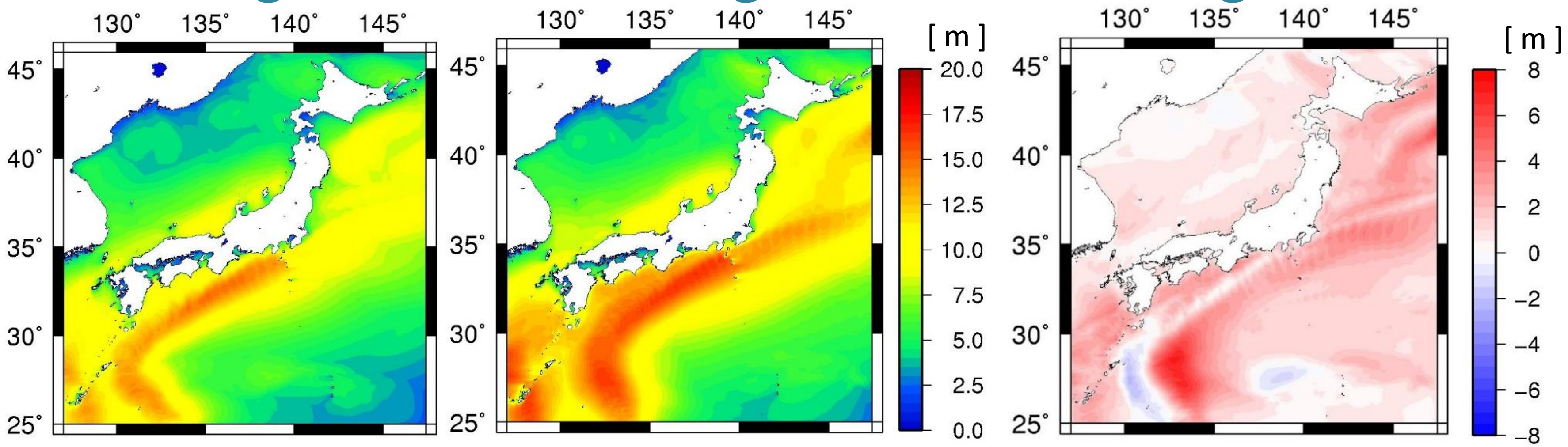
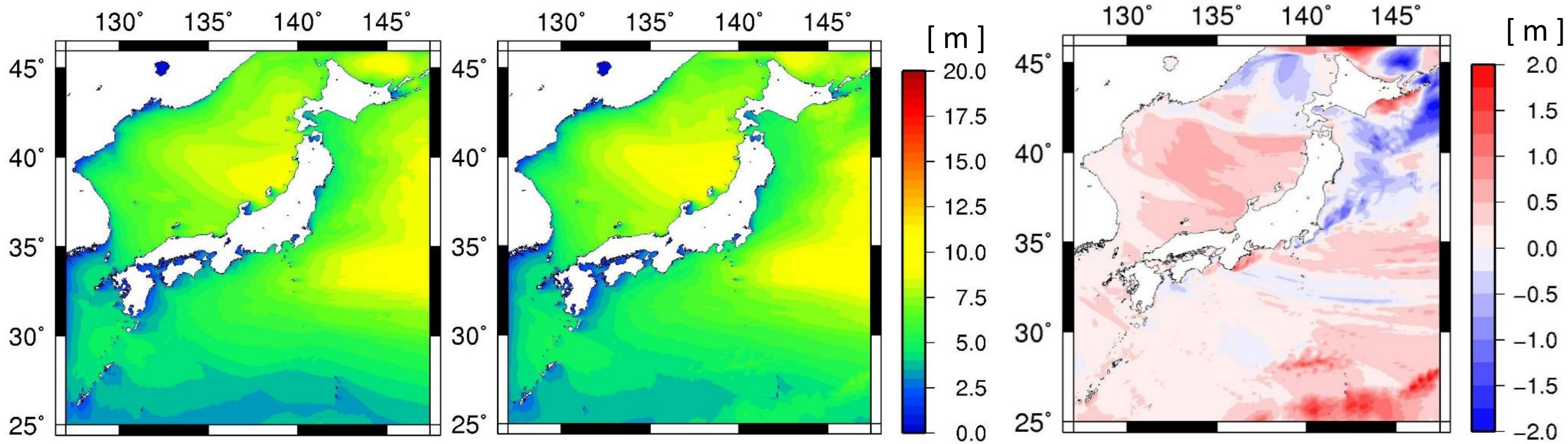


***Figure 10**. Spatial distribution of mean significant wave height*

■The change of maximum significant wave height



(a) OCT, Present (b) OCT, Future (c) OCT, Difference



(d) DEC, Present (e) DEC, Future (f) DEC, Difference

***Figure 10**. Spatial distribution of maximum significant wave height*

5. Discussion

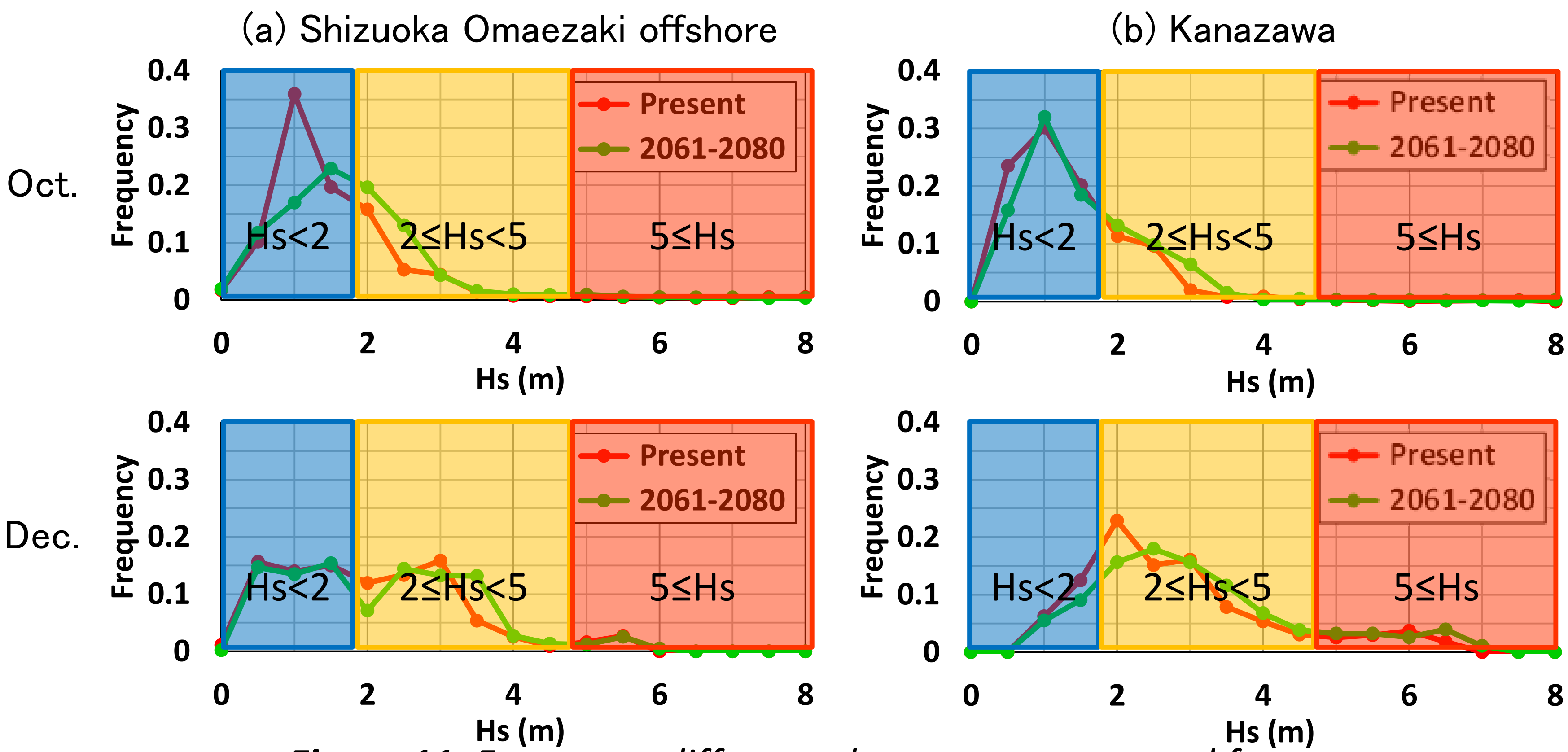


Figure 11. *Frequency difference between present and future case*

Table 3. *Frequency difference between present and future case*

	October						*December*					
Hs	*Shizuoka Omaezaki*			*Kanazawa*			*Shizuoka Omaezaki*			*Kanazawa*		
	Present	*Future*	*Difference*	*Present*	*Future*	*Difference*	*Present*	*Future*	*Difference*	*Present*	*Future*	*Difference*
0≤Hs<2	67.5	53.6	**-13.9**	73.8	66.3	**-7.5**	45.7	43.8	**-2.0**	18.7	14.5	**-4.2**
2≤Hs<5	28.2	40.4	**12.2**	25.0	31.9	**6.9**	50.0	52.0	**2.1**	70.3	71.4	**1.1**
5≤Hs	4.3	6.0	**1.7**	1.1	1.7	**0.6**	4.3	4.2	**-0.1**	11.0	14.1	**3.1**

6. Conclusion

- Although the SST increase resulted in more intense typhoons and it led to higher Hs on the Pacific Ocean in October, the effects of SST increase were less important for the extratropical cyclones in December.
- It is clearer that $Hs < 2.0$ m decreased and $2.0 \text{ m} \leq Hs < 5.0$ m increased on the Pacific Ocean in October when more intense typhoons were formed.
- It is probable that the frequency distribution of significant waves will change around the area where future SST increment is dominant.

Thank you for your attention!!

References

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2. T. Shimura, N. Mori and H. Mase, Future projection of ocean wave climate: Analysis of SST impacts on wave climate changes in the western North Pacific, *Journal of Climate* 28.8 (2015): 3171-3190.
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