NCAR「Joint WRF/MPAS Users Workshop 2024」

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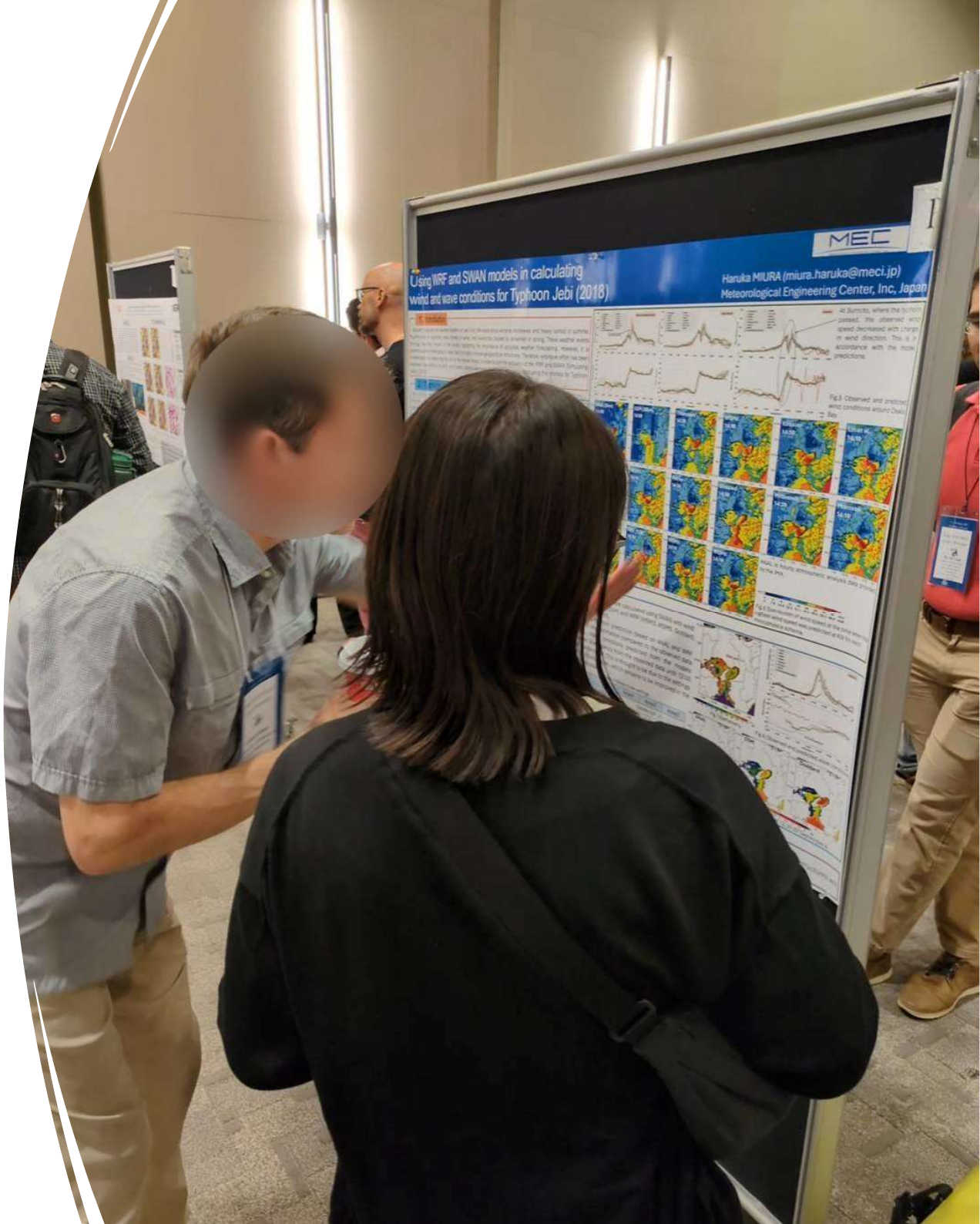

Using WRF and SWAN models in calculating wind and wave conditions for Typhoon Jebi (2018)

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1. Introduction

Japan experiences weather disasters all year long. We experience extreme heatwaves and heavy rainfall in summer, typhoons in autumns, heavy snowfall in winter, and avalanche caused by snowmelt in spring. These weather events bring harmful impact to the society, highlighting the importance of accurate weather forecasting. However, it is particularly challenging in Japan due to its highly complex geographical structures. Therefore, extensive effort has been invested into improving the skill of the forecast models. In order to test the accuracy of the WRF and SWAN (Simulating Waves Nearshore) models, wind speed, direction and wave conditions were calculated using the models for Typhoon Jebi (2018).

2. Typhoon Jebi (2018)

In 2018, Typhoon Jebi brought significant damages around Osaka Bay, located in the western areas of Japan. It made landfall as a Category 3 typhoon for the first time in 25 years, and brought extremely strong winds and high waves.

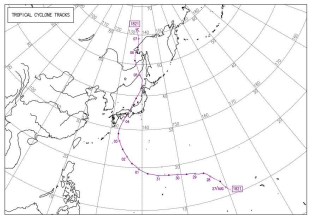


Fig.1 Track chart of Typhoon Jebi.
○ is 9:00 JST. ● is 21:00 JST.

Fig.2 ↑A tanker crashes into Kansai International Airport's bridge due to strong winds.
→Fallen utility poles blocking a road in Osaka.

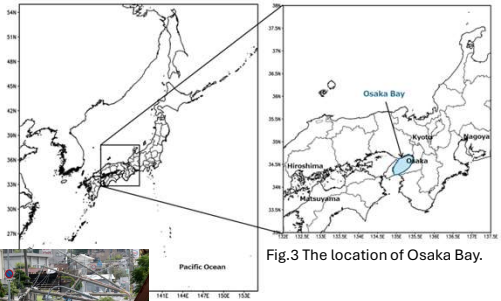


Fig.3 The location of Osaka Bay.

3. WRF

Table.1 shows the WRF model settings used for this experiment. The initial and boundary conditions were derived from GSM (Japan Meteorological Agency's Global Spectral Model). It is a global numerical forecast model produced by the JMA, which produces separate datasets for both the entire globe and Japan. The current study utilized the regional dataset. In order to perform a sensitivity analysis, the simulations were done with 14 different microphysics schemes (Table.2).

Table.1 WRF model settings.

	Area1	Area2	Area3
Model	WRF V4.2		
Horizontal resolution [km]	18	6	2
Mesh	94	112	133
Number of vertical layers	27		
Cumulus convection	Kain-Fritsch		-
Microphysics	listed in Table.2		
Long wave radiation	RRTM		
Sort wave radiation	Dudhia		
Surface layer	Revised MM5 Monin-Obukhov		
Land surface	Noah land-surface		
Planetary	YSU		
Geog_data_res	gtopo_30s		

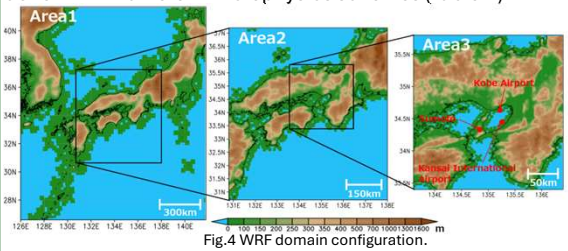
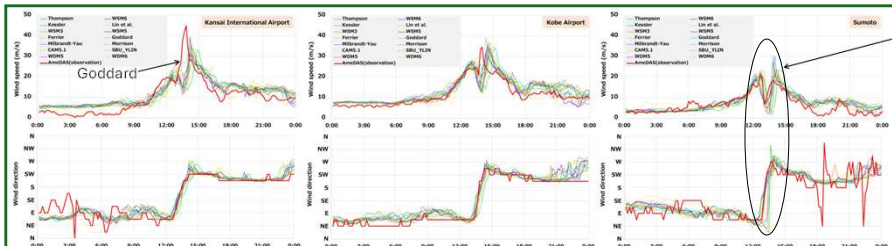


Fig.4 WRF domain configuration.

Table.2 Microphysics schemes.

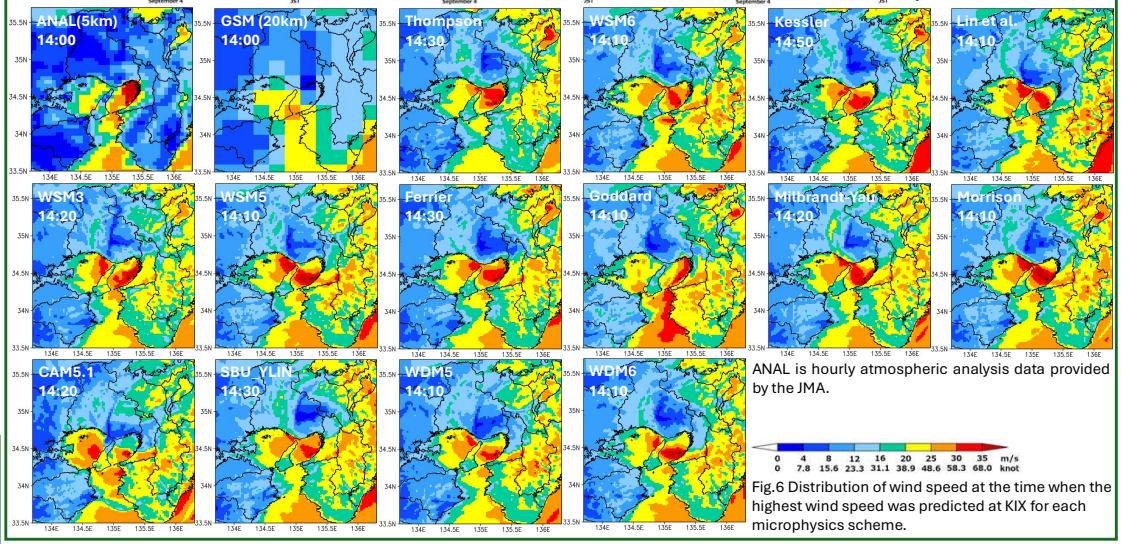
case		case		case	
1	Thompson	6	WSM5	11	CAM5.1
2	WSM6	7	Ferrier	12	SBU_YLIN
3	Kessler	8	Goddard	13	WDM5
4	Lin at al.	9	Milbrandt-Yau	14	WDM6
5	WSM3	10	Morrison		

By looking at the results of observed and predicted wind speeds, simulations with most physical schemes showed a reduction in wind speed at Kansai International Airport (KIX) and Kobe Airport at 14:00 JST September 4 (Fig.5). However, Goddard was able to calculate an increase in wind speed without such reduction at KIX. Overall, the maximum wind speeds were accurately calculated, despite the variations in times at which the peaks occurred. Fig.6 shows the distribution of wind speed at which the maximum wind speed was predicted at KIX. As a result, ANAL showed the strong wind exceeding 35m/s in Osaka Bay at 14:00 JST September 4. Similarly, the schemes such as WSM3, WSM5, Goddard, Morrison, and WDM6 were able to predict strong winds in the location, of which WSM3 and Goddard in particular were able to simulate the wind condition in the inner part of the bay.



At Sumoto, where the typhoon passed, the observed wind speed decreased with change in wind direction. This is in accordance with the model predictions.

Fig.5 Observed and predicted wind conditions around Osaka Bay.



ANAL is hourly atmospheric analysis data provided by the JMA.

Fig.6 Distribution of wind speed at the time when the highest wind speed was predicted at KIX for each microphysics scheme.

4. SWAN

Wave conditions were calculated using SWAN with wind data from ANAL, GSM, and WRF (WSM3, WSM5, Goddard, Morrison, WDM6).

The results from prediction based on ANAL and WRF showed overestimation compared to the observed data (Fig.8). Wave directions predicted from the models showed discrepancy from the observed data until 12:00 JST September 4. This is thought to be due to the settings of the SWAN model, which remains to be improved in the future studies.

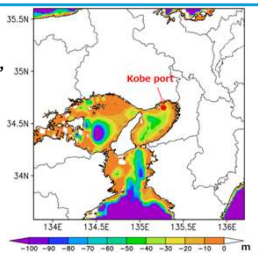


Fig.7 Bathymetry.

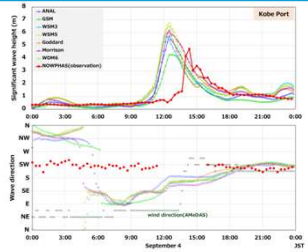


Fig.8 Observed and predicted wave conditions.

Table.3 SWAN model settings.

	Area1	Area2	Area3
Model	SWAN V41.31		
Horizontal resolution [°]	0.1	0.05	0.005
Time interval [minutes]	10		
Physics	GEN3 JANSsen AGROW, BRE, FRICTION, TRI, OFF FSHIFT		
Bathymetry	1km		

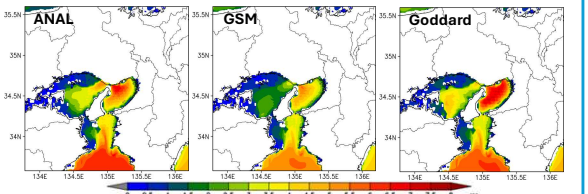


Fig.9 Distribution of significant wave height at 12:20 JST September 4.

5. Conclusions

We believe the advancement in the predictive ability of wind in Japan with such a highly complex coastal structures will be of great use in the future wave protection and the development of offshore wind power generation.