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Investigation of WRF configuration for offshore wind resource maps in Japan

Teruo Ohsawa[1)], Mari Kato[1)]*, Hirokazu Uede[1)], Susumu Shimada[2)], Yuko Takeyama[2)], Takeshi Ishihara[3)]
1) Graduate school of Maritime Sciences, Kobe University, Japan, 2) National Institute of Advanced Industrial Science and Technology, Japan, 3) Department of Civil Engineering, University of Tokyo, Japan

Introduction

Since July 2015, the national project for making offshore wind resource maps in Japan has been undertaken by the New Energy and Industrial Technology Development Organization (NEDO). In this project, 500m-gridded offshore wind resource maps are planned to be created for the coastal waters within 30 km from the coasts, using the mesoscale model WRF (the Weather Research and Forecasting model). The development target on the map accuracy is a bias of within ±5% in annual mean wind speed at the height of 80 m. This paper describes simulation experiments to define the model configuration for a large amount of simulation to make offshore wind resource maps.

Methods

In this study, the simulation experiments are conducted using in-situ measurements from the met mast at Kitakyushu, Fukuoka Prefecture, shown in Figure 1. Simulations with the Advanced Research WRF version 3.6.1 are performed using two domains with 2.5 km and 0.5 km grids, as shown in Figure 2. Table 1 summarizes the model configuration tested in this study. In total, seven WRF simulations are carried out with slightly different model configurations. They are named Case 1 through Case7 and are compared each other to find the best model configuration.

Figure 1 NEDO offshore meteorological mast off Kitakyushu (NEDO HP)

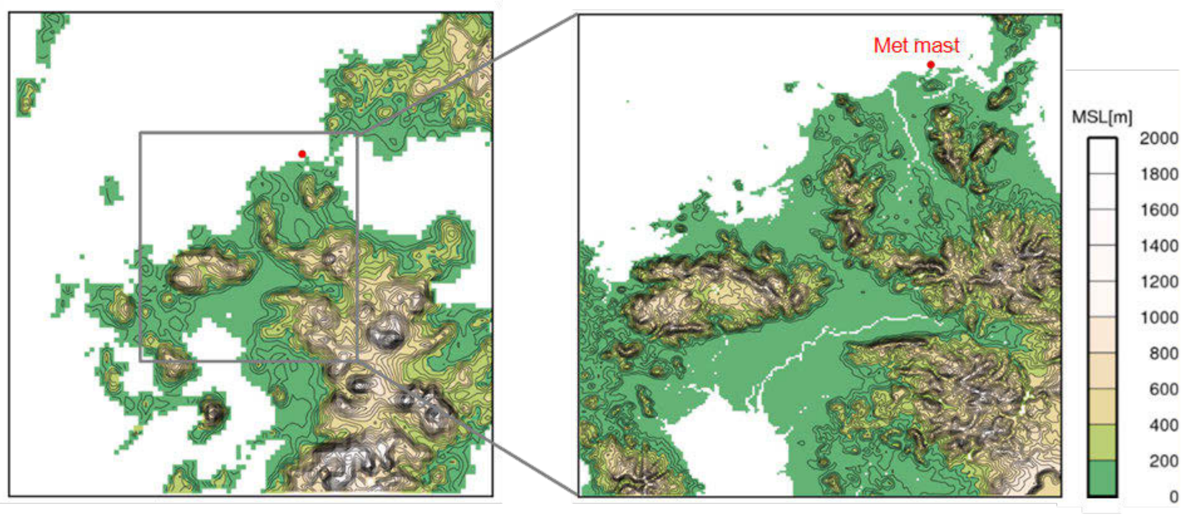


Figure 2 Domains used in WRF simulations (Left: 2.5 km-gridded domain. Right: 0.5 km-gridded domain)

Table 1 Model configuration (Red: choices tested in this study)

Model	Advanced Research WRF (ARW) ver 3.6.1
Period	One year for 2013 or 2014
Input data	Met: JMA Meso Analysis MANAL (3-houly, 5 km × 5 km) Soil: NCEL Final Analysis FNL (6-houly, 1° × 1°) SST: MOSST (daily, 0.05° × 0.05°) or UK Met Office OSTIA (daily, 0.05° × 0.05°)
Grids	Domain1: 2.5 km × 2.5 km (101 × 101 grids) Domain2: 0.5 km × 0.5 km (201 × 201 grids)
Vertical Levels	40 levels (Surface to 100 hPa); Manual setting (11 m, 38 m, 71 m, 109 m, 151 m, …) or Auto Setting (28m, 97m, 192 m, 311 m, 461 m, …)
FDDA	Domain1: Enable Domain2: Enable, but excluding below 1,000 m or excluding below the PBL height
PBL options	MYJ scheme (Mellor-Yamada level 2.5 model), YSU scheme (K-theory with non-local mixing), or MYNN3 scheme (Mellor-Yamada level 3 model)
Other physics options	Dudhia shortwave scheme RRTM longwave scheme Eta microphysics scheme Mellor-Yamada-Janjic (Eta) TKE PBL scheme Monin-Obukhov (Janjic Eta) surface-layer scheme Noah land surface scheme No cummulus parameterization

Results

Table 2 summarizes statistics (bias, root-mean-square-error (RMSE), their relative values to mean wind speed, correlation coefficient (CC), and ratio of observed and simulated standard deviations) on the accuracy of WRF-simulated wind speeds at the height of 80 m. Figure 3 shows monthly and annual biases in the WRF-simulated 80m-height wind speeds. Figure 4 depicts annual biases at each measurement height, meaning vertical profiles of the bias from 30 m to 80 m.

Table 2 Accuracy comparison of WRF-simulated 80m-height wind speeds among Cases 1 to 7

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
1) PBL		MYJ	YSU	MYNN	MYJ	MYJ	MYJ	MYJ
2) FDDA		1km	1km	1km	PBLH	PBLH	PBLH	1km
3) η-level		Mannual	Mannual	Mannual	Mannual	Auto	Auto	Mannual
4) SST		MOSST	MOSST	MOSST	MOSST	MOSST	OSTIA	MOSST
5) Year		2013	2013	2013	2013	2013	2013	2014
OBS Ave.	(m/s)	7.00	7.00	7.00	7.00	7.00	7.00	6.98
Bias	(m/s)	0.39	0.50	0.37	0.24	0.28	0.45	0.2
	(%)	5.6	7.1	5.3	3.4	4.0	6.4	3.3
RMSE	(m/s)	2.03	2.09	2.09	1.96	1.97	2.08	2.06
	(%)	29.0	29.8	29.9	28.0	28.2	29.7	29.6
Correlation	(-)	0.851	0.848	0.843	0.860	0.857	0.847	0.853
SD_{WRF} / SD_{OBS}	(-)	0.940	0.960	0.953	0.958	0.944	0.959	1.033

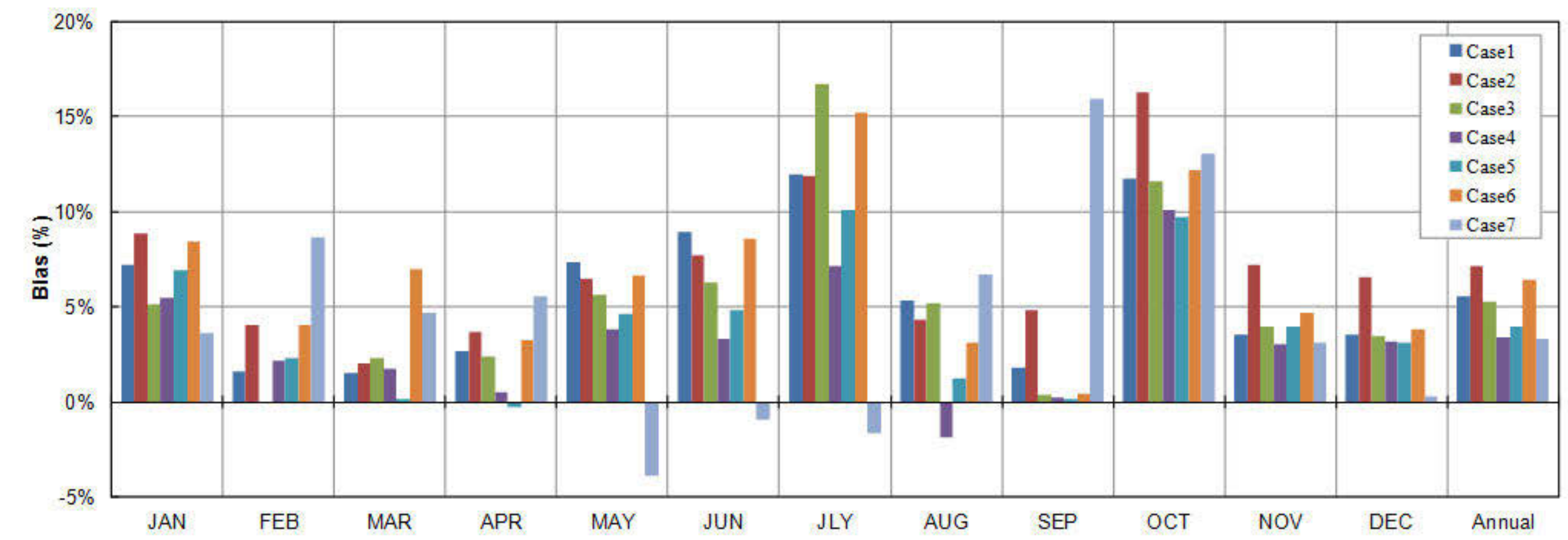
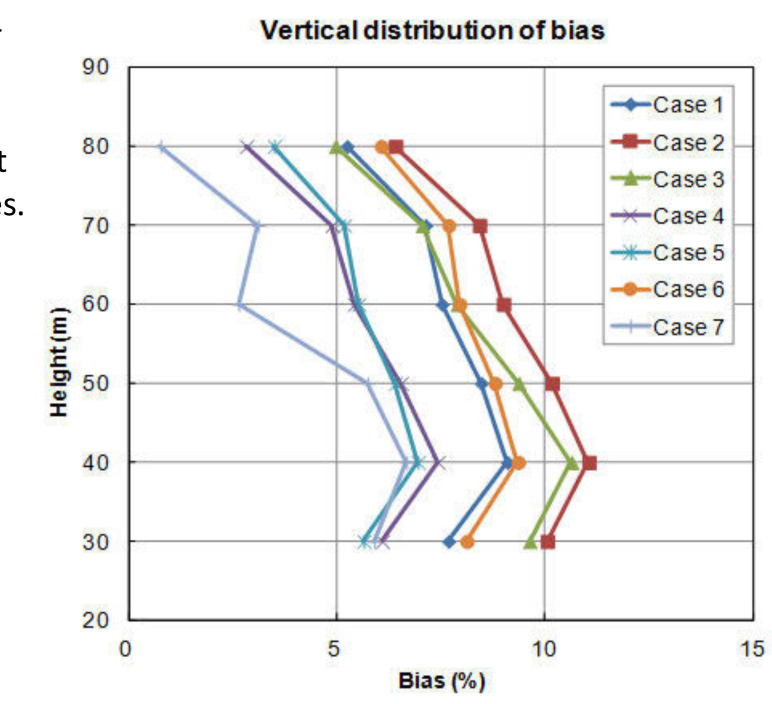


Figure 3 (Upper) Monthly and annual biases in WRF-simulated 80m-height wind speeds for all cases

Figure 4 (right) Biases in annual mean wind speed at measurement heights from 30 m to 80 m for all cases.



Based on results from the all simulation experiments in this study, the WRF configuration suitable for offshore wind simulation in Japanese coastal waters are summarized as follows.

1)The MYJ PBL scheme seems to be the best of the three schemes.
2)FDDA should be disabled in the domain 2 (0.5km-grid domain) below the PBL height calculated by the PBL scheme.
3)Although there is still room for how to set up vertical levels manually, it is found that the configuration does not greatly affect the accuracy of simulated wind speed in the surface layer.
4)The use of our new SST product MOSST can improve the accuracy of the surface wind speed in the WRF simulation.
5)Case 4 is found to be able to achieve the target value of within ±5% at 80 m. The effectiveness is confirmed for 2014 (Case 7) as well as 2013.
6)The configuration of Case 4 is tested for the other NEDO met mast at Choshi, Chiba Prefecture, and it is confirmed that the annual bias is 0.6 %, achieving the target value of within ±5%.

Conclusions

By setting up simulation conditions properly and selecting higher quality input data, the WRF simulation can achieve a target bias of ±5 % in annual mean wind speed at a hub height (80m) even in Japanese coastal waters, where it is known that the accuracy of mesoscale modelling cannot be higher compared to European seas due to their complex topography and wind climate [1]. The best model configuration found in this study will be used in the ongoing national project for making offshore wind resource maps under NEDO.

References

[1] Ohsawa, T., F. Okayama, T. Misaki, S. Shimada, G. Steinfeld, M. Schmidt, D. Heinemann, M. Dörenkämper, 2016: Accuracy comparison of mesoscale model simulated offshore wind speeds between Japanese and German coastal waters, Proc. of WindEurope Summit 2016, Sep. 27 - 29, 2016, Hamburg, Germany. (submitted)