

Investigation of WRF configuration for offshore wind resource maps in Japan

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1. Introduction

Since July 2015, the national project for making offshore wind resource maps in Japan has been undertaken under 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 coast, 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. Accuracy verifications are being carried out using wind speed measurements from two offshore met masts of NEDO located off the coasts of Kitakyushu, Fukuoka Prefecture and Choshi, Chiba Prefecture. This paper describes simulation experiments to define the model configuration for a large amount of simulation to make offshore wind resource maps.

2. Approach

In this study, the simulation experiments are conducted using measurements from the met mast at Kitakyushu, shown in Figure 1. On this met mast, six cup anemometers are installed at heights from 30 m to 80 m with an interval of 10 m, and hourly 10-min average wind speed measurements are used for accuracy verification. 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. The tests are conducted in terms of 1) selection of the planetary boundary layer (PBL) scheme, 2) method of four dimensional data assimilation (FDDA), 3) configuration of vertical levels, 4) selection of sea surface temperature dataset, and 5) differences in simulation accuracy between years. The choices in each term are described in Table 1. In total, seven WRF simulations are carried out with slightly different model configuration. They are named Case 1 through Case 7 and are compared each other to find the best model configuration.



Figure 1 NEDO offshore meteorological mast off Kitakyushu, Fukuoka Prefecture (from NEDO website)

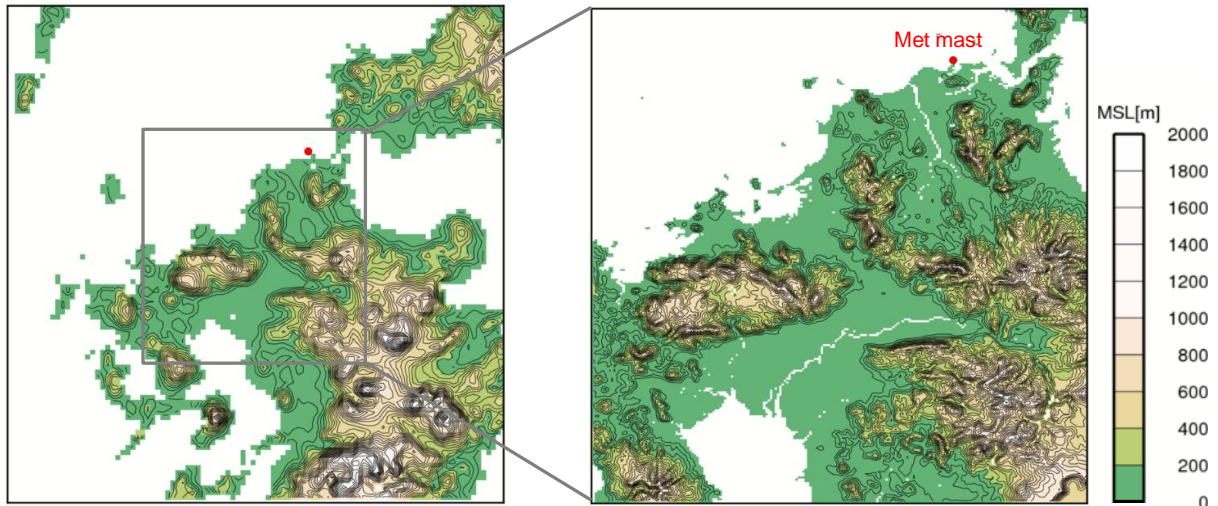


Figure 2 Domains used in WRF simulation (Left: 2.5 km-gridded domain. Right: 0.5 km-gridded domain).

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-hourly, 5 km × 5 km) Soil: NCEL Final Analysis FNL (6-hourly, 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 cumulus parameterization

3. Main body of abstract

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 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		Manual	Manual	Manual	Manual	Auto	Auto	Manual
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

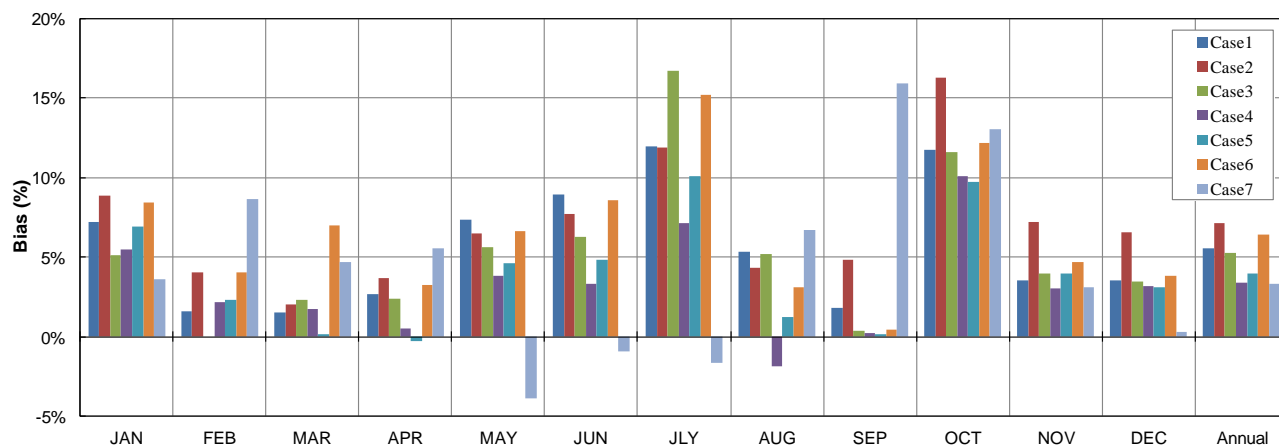


Figure 3 Monthly and annual biases in WRF-simulated 80m-height wind speeds for all cases.

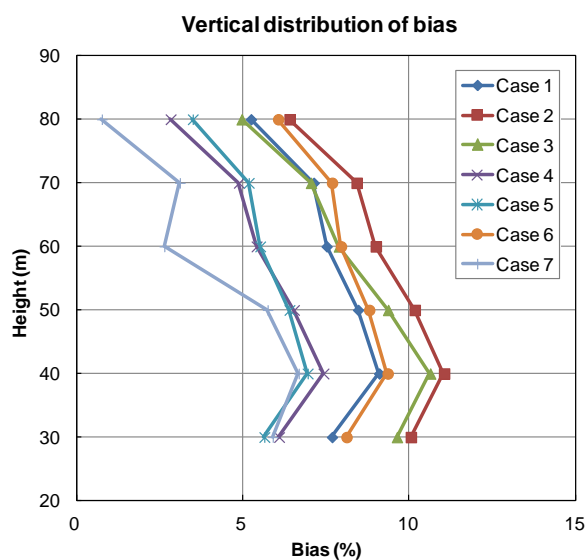


Figure 4 Biases in annual mean wind speed at measurement heights from 30 m to 80 m for all cases.

First, Cases 1, 2 and 3 are compared to examine which PBL scheme has the best performance. The YSU scheme (Case 2) exhibits large biases at all heights, as found in Figure 4. The MYNN scheme (Case 3) seems to have a problem in vertical profile, showing large biases at lower heights in spite of the lowest bias at 80 m. Compared to these two cases, the MYJ scheme is found to have high and stable accuracies as a whole. Thus, the MYJ scheme is decided to be used as a PBL option.

Second, the method of how to disable FDDA in the PBL is discussed by comparing Cases 1 and 4. In Case 1, FDDA is disabled below the fixed height of 1 km in the domain 2, because the height of 1 km can be recognized as a mean PBL height. On the other hand, in Case 4, FDDA is disabled below the PBL height calculated by the PBL scheme itself. In this case, the PBL height temporally varies from 0 m to a few kilometers. All the statistics in Table 2, Figure 3 and Figure 4 show that Case 4 is more accurate than Case 1. Accordingly, it is decided to disable FDDA below the PBL height calculated with the PBL scheme.

Third, two cases with manually (Case 4) and automatically (Case 5) configured vertical levels are compared. Heights of the lowest five levels are 11 m, 38 m, 71 m, 109 m and 151 m for Case 4, while they are 28 m, 97 m, 192 m, 311 m and 461 m for Case 5. Differences between these two cases are found to be very small, in spite of the large differences in heights of the lowest five levels. This means that the accuracy of wind speed in the layer from the surface to 80 m does not greatly depend on the configuration of vertical levels. But, since it is also fact that the accuracy of Case 4 is slightly better, further study will be planned to decide how to set up vertical levels manually.

Fourth, two kinds of input data of sea surface temperature are compared. Case 6 uses UK Met Office's Operational Sea Surface Temperatures and Sea Ice Analysis (OSTIA), while Case 5 uses the MODIS (MODerate resolution Imaging Spectroradiometer)-based SST (MOSST), developed by the National Institute of Advanced Industrial Science and Technology (AIST) and Kobe University^[1]. MOSST is characterized by the 11-day running average applied in order to interpolate missing values due to cloud coverage. The temporal running average has an advantage that a SST field can maintain a high spatial resolution, which is especially effective for seas with spatially variable SST like Japanese coastal waters. As expected, the comparison result shows that Case 5 using MOSST is found to have a higher accuracy than Case 6 using OSTIA.

The afore-mentioned four experiments indicate that Case 4 is the best configuration. Finally, the same configuration is tested for another year (2014) in Case 7. The statistics are found to be at almost the same level as those in Case 4. The annual bias is 3.4 % for 2013 and 3.3 % for 2014, indicating that the WRF simulation with the configuration of Case 4 can achieve the development target accuracy of ± 5 %.

4. Conclusions

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

- 1) Mellor-Yamada-Janjic (MYJ) scheme seems to be the best of the PBL schemes.
- 2) FDDA should be disabled in the domain 2 (0.5km-grid domain) below the PBL height calculated by the PBL scheme.
- 3) There is still room for how to set up vertical levels manually, though the configuration does not greatly affect the accuracy of simulated wind speed.

4) The use of a new SST product MOSST can improve the surface wind speed accuracy in the WRF simulation. Effectiveness of the configuration of Case 4 is confirmed for both 2013 and 2014. In addition, the same configuration is used in the WRF simulation for the other NEDO met mast at Choshi, and as a result it is shown that the annual bias is 0.6 %.

5. Learning objectives

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 Europe due to their complex topography and wind climate ^[2]. 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

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