Accuracy comparison of mesoscale model simulated offshore wind speeds between Japanese and German coastal waters

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1. Introduction

In the previous studies [1] [2] using the FINO met masts located in German coastal waters, numerical simulations with a mesoscale model are found to typically have a bias of ±5 % in annual mean wind speed and a root-mean-square-error (RMSE) of about 15 % through a year. On the other hand, in Japanese coastal waters, accuracy verifications of mesoscale modelling, mostly carried out using surface wind speed measurements from observation platforms and buoys, show that the bias is within ±10 %, and RMSE is around 40 % [3]. In our latest study [4], which uses Japanese met mast measurements for accuracy verification, it is found that the bias at a hub height ranges within ±5 % but the RMSE is still around 30 %. These results indicate that the accuracy of offshore wind speed simulation for Japanese coastal waters is worse than for German coastal waters. However, there is still room for discussion in this indication, because there are differences among the above verifications, such as evaluation height, measurement method, model configuration and input data. Thus, this study attempts to make an accuracy comparison of mesoscale model simulated offshore wind speeds between Japanese and German coastal waters by using the same model configuration and input data as well as by using surface wind speed measurements.

2. Approach

In this study, the Advanced Research WRF (the Weather Research and Forecasting model) is used as a mesoscale model. The WRF simulations are performed for Japanese and German coastal waters with the domains shown in Figure 1. These simulations are performed for one year from January to December 2009 for Japan and from May 2009 to April 2010 for Germany. The model configuration used in the simulation is shown in Table 1. The model configuration, including input data, the number of grids and physics options, is completely identical for the two simulations. The observation sites used in this study are listed in Table 2. At each site, hourly 10-min average wind speed data is used for the accuracy verification.

3. Main body of abstract

All the results are summarized in Table 3, which shows statistics (bias, RMSE and correlation coefficient (CC)) on the accuracy of WRF-simulated wind speed at each observation site. The parentheses in the bias and RMSE columns indicate their relative values (%) to mean wind speed.
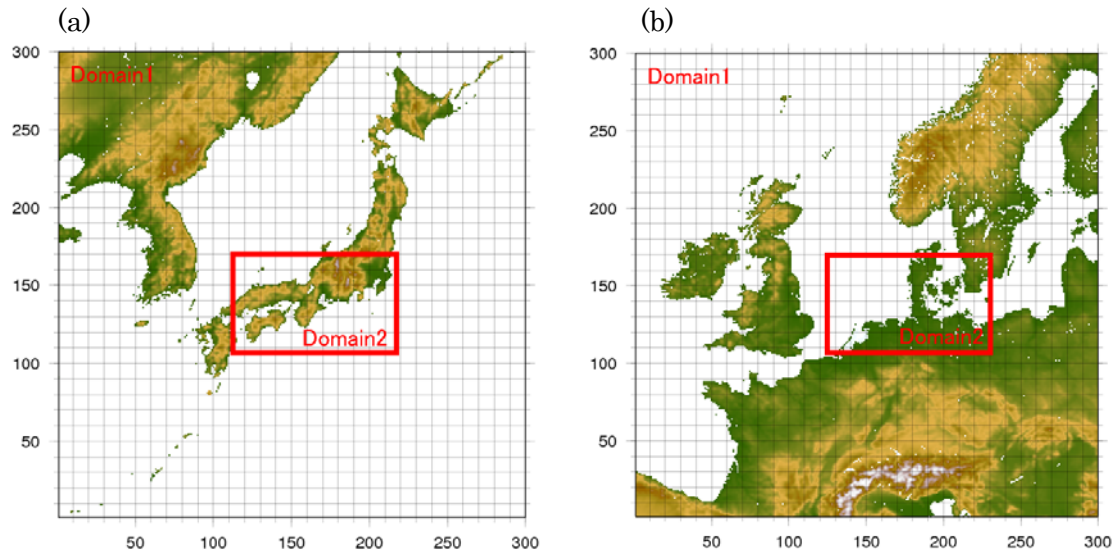
Figure 1 Domains used in the simulations for (a) Japanese and (b) German coastal waters.

Table 1 Model configuration

Model	Advanced Research WRF (ARW) ver. 3.4.1
Period	Germany : 1 May 2009 through 30 April 2010 (1 year)
	Japan : 1 January 2009 through 31 December 2009 (1 year)
Grids	Domain 1 : 8km x 8km, 300 x 300 grids
	Domain 2 : 2km x 2km, 420 x 260 grids
Levels	40 levels (Surface to 50 hPa)
	Lowest levels : 12 m, 40 m, 76 m, 116 m, 161 m, 214 m
Input data	30 s x 30 s USGS terrain height and land use
	6-hourly, 0.25° x 0.25° ECMWF Operational Analysis
	Daily, 0.05° x 0.05° UK Met Office OSTIA SST
4DDA	Domain 1 : Enabled
	Domain 2 : Enabled, but excluding below 2,000 m
Physics options	Dudhia shortwave scheme
	RRTM longwave scheme
	Eta microphysics scheme
	Betts-Miller-Janjic cumulus parameterization scheme
	Mellor-Yamada-Janjic (Eta) TKE PBL scheme
	Monin-Obukhov (Janjic Eta) surface-layer scheme
	Noah land surface scheme

Table 2 Inventory of observation sites used in this study

No.	Country	Site name	Period	Measure. Height	Lontitude	Latitude
1	Japan	Hazaki	01/01 ~ 12/31	10 m	140.7636 ºE	35.8419 ºN
2	Japan	Hiratsuka	01/01 ~ 06/30	24 m	139.3467 ºE	35.3061 ºN
3	Japan	Omaezaki	02/12 ~ 12/04	7 m	138.2750 ºE	34.4033 ºN
4	Japan	Owase	01/01 ~ 12/31	7 m	136.2594 ºE	33.9022 ºN
5	Japan	Shirahama	01/01 ~ 12/31	23 m	135.3327 ºE	33.7088 ºN
6	Japan	Nansei-Buoy	01/01 ~ 12/31	10 m	135.1066 ºE	33.6422 ºN
7	Japan	KBB10	01/01 ~ 05/31	10 m	134.1272 ºE	33.0258 ºN
8	Japan	KBB13	01/01 ~ 05/31	10 m	132.8733 ºE	32.3897 ºN
9	Japan	Kochinishi	01/01 ~ 12/31	7 m	133.1558 ºE	32.6311 ºN
10	Germany	Arkona Becken	05/01 ~ 12/31	10 m	13.8666 ºE	54.8833 ºN
11	Germany	Darßer Schwelle	05/01 ~ 12/31	9 m	12.7000 ºE	54.7000 ºN
12	Germany	Fehmarn Belt	05/01 ~ 12/31	8 m	11.1500 ºE	54.6000 ºN
13	Germany	Ober Bank	05/01 ~ 12/31	9 m	14.1666 ºE	54.0833 ºN

Table 3 Statistics on accuracy of WRF-simulated wind speed at each observation sites

No.	Site name	Mean wind speed (OBS)	WRF-simulated wind speed		
			Bias	RMSE	CC
1	Hazaki	5.94 m/s	0.12 m/s (2.1 %)	2.23 m/s (36.8 %)	0.76
2	Hiratsuka	5.58 m/s	0.32 m/s (5.9 %)	2.01 m/s (37.4 %)	0.75
3	Omaezaki	6.67 m/s	0.47 m/s (6.6 %)	2.17 m/s (30.4 %)	0.85
4	Owase	4.64 m/s	0.51 m/s (10.0 %)	2.31 m/s (44.8 %)	0.72
5	Shirahama	5.06 m/s	0.45 m/s (8.2 %)	2.05 m/s (37.2 %)	0.77
6	Nansei-Buoy	6.95 m/s	0.32 m/s (4.4 %)	2.17 m/s (29.8 %)	0.83
7	KBB10	7.71 m/s	-0.34 m/s (-4.6 %)	2.80 m/s (38.0 %)	0.74
8	KBB13	8.44 m/s	-0.88 m/s (-11.6 %)	2.86 m/s (37.8 %)	0.77
9	Kochinishi	6.28 m/s	0.34 m/s (5.1 %)	1.99 m/s (30.0 %)	0.82
10	Arkona Becken	7.75 m/s	-0.37 m/s (-5.1 %)	1.38 m/s (18.7 %)	0.93
11	Darßer Schwelle	7.47 m/s	-0.23 m/s (-3.2 %)	1.37 m/s (19.0 %)	0.92
12	Fehmarn Belt	7.38 m/s	-0.31 m/s (-4.4 %)	1.62 m/s (23.0 %)	0.89
13	Ober Bank	6.79 m/s	-0.24 m/s (-3.7 %)	1.33 m/s (20.3 %)	0.92

According to Table 3, the relative bias is -5.1 to -3.2 % at the German sites and -11.6 to 10.0 % in the Japanese sites. That is, the bias is obviously larger at the Japanese sites. In the Japanese national offshore wind map project (NEDO, http://www.nedo.go.jp/english/news/AA5en_100056.html), an annual bias of ±5 % at a hub height is a development target. It is found in Table 3 that this target value can be achieved even at lower heights in the German coastal waters, while a relative bias exceeds ±5 % at five of nine sites in the Japanese coastal waters.

As for a relative RMSE, the value is around 20 % at the German sites, whereas it is 30 to 45 % at the Japanese sites. To see these differences more clearly, the relative RMSE is depicted as a bar graph, shown in Figure 2. This figure also shows the values at the 100m-height of FINO-1, FINO-2, and FINO-3 [1], and they are found to be around 15 %. Taking the result that the RMSEs are approximately 20 % at the surface into account, it is speculated that a relative RMSE falls to 3/4 in magnitude from the surface up to the hub height. Applying this speculation to the case of Japan, where the relative RMSE is 30 to 45 % in the surface, the relative RMSE at a hub height is expected to roughly 25 to 35 %. This estimation is consistent with the value of around 30 %, which is found at the height of 80 m on the met mast at Kitakyushu in our latest study [4].
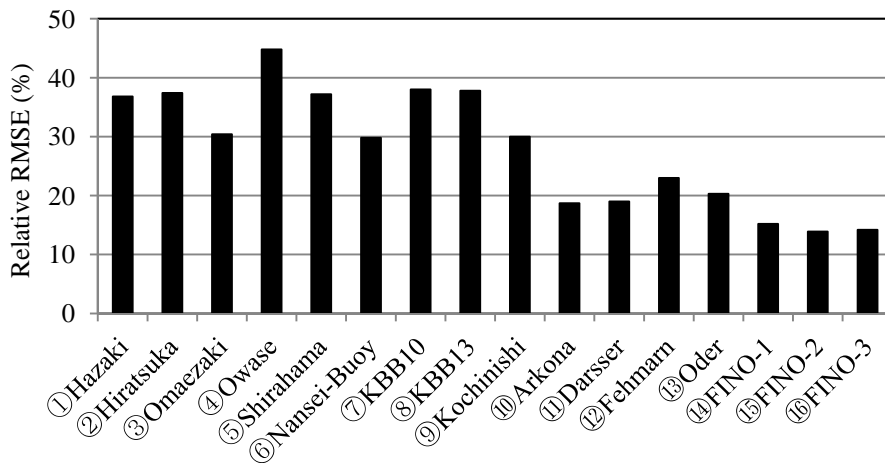

Figure 2 Relative RMSE (%).

Finally, correlation coefficient (CC) is discussed. According to Table 3, CC is 0.72 to 0.85 at the Japanese sites, while it is 0.89 to 0.93 at the German sites. CC is obviously lower in the Japanese coastal waters. Figure 3 shows wind speed correlation charts for each representative sites of Japan (KBB10) and Germany (Arkona Becken). These sites are selected because they have similar observation conditions (distance from coastal line, observation height, and mean wind speed). Comparing the two charts, Arkona Becken clearly exhibits a smaller dispersion of wind speed, having a higher CC (0.93) than KBB10 (0.74).
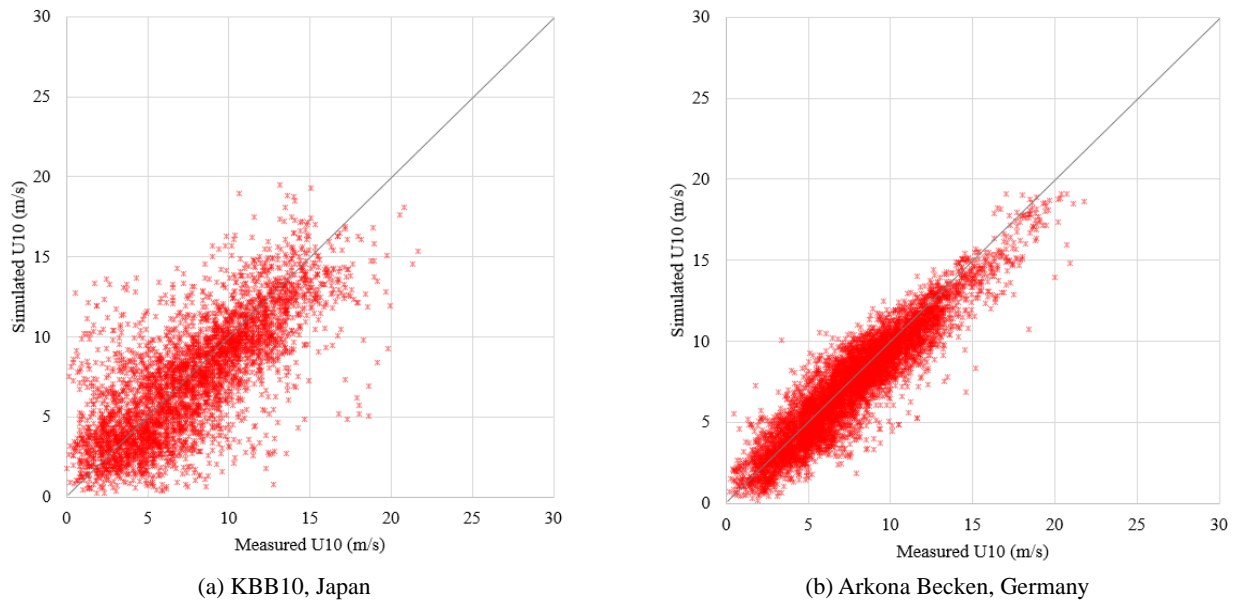

(a) KBB10, Japan   (b) Arkona Becken, Germany

Figure 3 Wind speed correlation charts for each representative site of Japan and Germany.

4. Conclusions

Main conclusions in this study are summarized as follows.

1. Accuracy verifications of WRF-simulated offshore winds show that nine sites in Japanese coastal waters have an annual bias of within ±10 %, a RMSE of 30 to 45 % and a CC of 0.72 to 0.85, while at four sites in the German coastal waters they are within ±5 %, around 20 % and 0.89 to 0.93, respectively.

2. These results indicate that even if the same model configuration, input data and verification method are used, the accuracy of mesoscale model simulated offshore wind speed is worse in the Japanese coastal waters, compared to that in the German coastal waters.

The differences between Japan and Germany are probably caused by the difference in the accuracy of objective analysis (ECMWF operational analysis in this study) used as input into WRF, as well as differences in complexity of topography and associated wind conditions.

5. Learning objectives

The quality of offshore wind resource maps in Japan can be lower compared to that of European offshore wind resource maps, due to the lower accuracy of offshore wind simulation with a mesoscale model.

References

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