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


Teruo Ohsawa[1)], Fuko Okayama[1)], Takeshi Misaki[1)*], Susumu Shimada[2)], Koji Kawaguchi[3)]
Gerald Steinfeld[4)], Michael Schmidt[4)], Detlev Heinemann[4)], Martin Dörenkämper[5)]

1) Graduate school of Maritime Sciences, Kobe University, Japan
2) National Institute of Advanced Industrial Science and Technology, Japan
3) Port and Airport Research Institute, Japan
4) ForWind, University of Oldenburg, Germany
5) Fraunhofer Institute for Wind Energy and Energy System Technology, Germany

1) * Graduate School of Maritime Science, Kobe university, 5-1-1 Fukaeminami, Higashinada, Kobe, Hyogo, 658-0022, Japan; E-mail: 143w802w@stu.kobe-u.ac.jp


## Abstract


In this study, the accuracy of mesoscale model-simulated offshore wind speeds is compared between Japanese and German coastal waters. To investigate the differences in detail, this study attempts to carry out the mesoscale model simulations by using the same model configuration and input data as well as by using similar kinds of surface wind speed measurements for model verification. The results show that German sites obviously have a better accuracy than Japanese sites. The result implies that in Japan, where a national project for making offshore wind resource maps is being carried out, offshore wind resource maps can be less accurate, compared to European offshore wind resource maps, due to the lower accuracy of offshore wind simulation with a mesoscale model.



**Keyword:** Offshore wind resource assessment, mesoscale model, WRF, wind map


## 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 measurements from a meteorological mast in Japan 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 similar surface wind speed measurements.

## 2. Data and method

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.

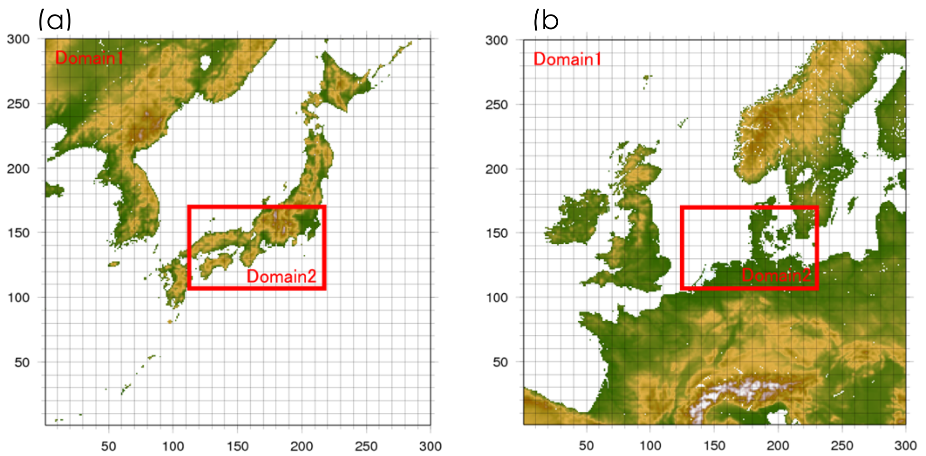


Figure 1: Domains used in the simulations for (a) Japanese and (b) German coastal waters.

Table 1: Model configuration

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

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.

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 |

## 3. Results

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.

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 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 includes 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 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 % at 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].

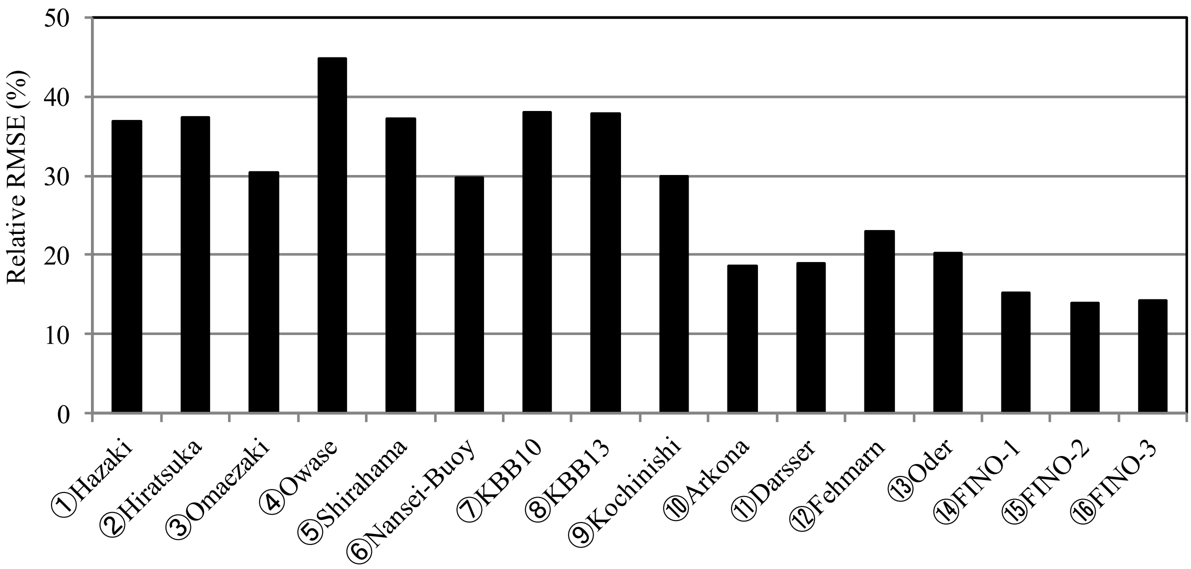
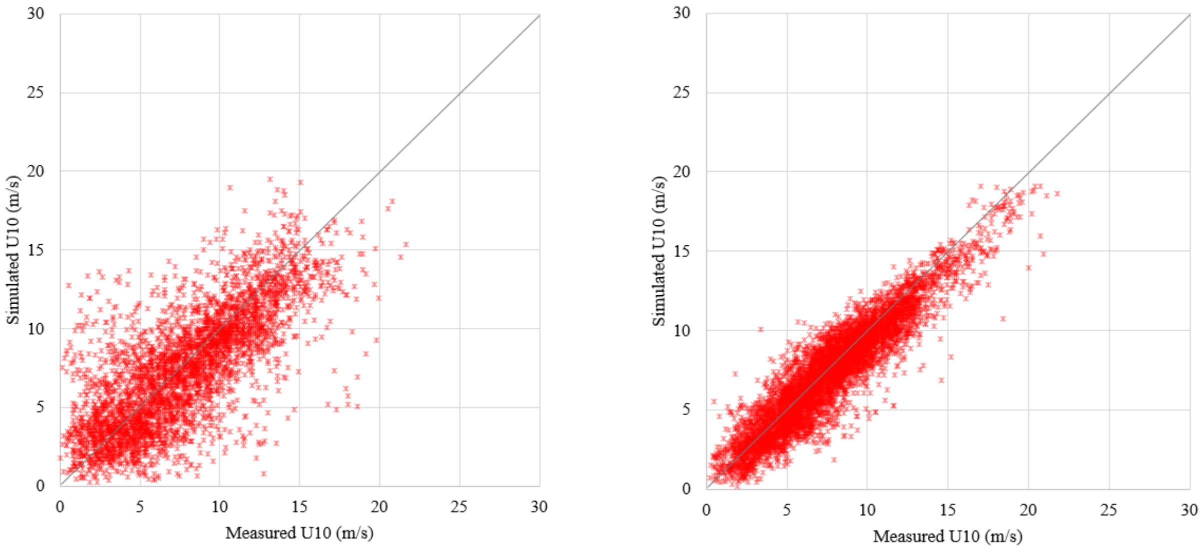



Figure 2: Relative RMSE (%).

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 correlation coefficient of 0.72 to 0.85, while at four sites in the German coastal waters those values 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 than 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. This indicates that 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.

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Hydrographic Agency). The authors wish to thank them for providing precious data.

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