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Evaluation and improvement of offshore atmospheric stability in WRF simulation

P08

Yuma Shimatani[1], Teruo Ohsawa[2]

1. Meteorological Engineering Center, Inc., Japan 2. Graduate School of Maritime Sciences, Kobe University, Japan

1. Introduction

In offshore areas, the vertical wind shear and wake recovery are dependent on atmospheric stability, which play important roles for the design and performance of wind turbines. However, the estimation of atmospheric stability requires large-scale observations, and a numerical model would be useful to make wind resource assessments more efficiently and accurately. Here, this study evaluates and improves the estimation of the Monin-Obukohv length, the index of the atmospheric stability in the surface layer, using the Weather Research and Forecasting (WRF) model.

2. Data and Methods

(1) In-situ measurements

The Monin-Obukhov length was calculated from the measurements of the sonic anemometer installed on the Hazaki Oceanographical Research Station (HORS) in Ibaraki, Japan (Fig.2 (a)). Only the wind measurements from the directions depicted as seaward in Fig.2 (b) are used for this study.

Monin-Obukhov length L

$$L = -\frac{u_*^3 \overline{\theta_v}}{g \kappa \overline{w'\theta_v'}}$$

u_*: the friction velocity, $\overline{w'\theta_v'}$: the vertical heat flux, $\overline{\theta_v}$: the average virtual temperature, g: the gravitational acceleration, κ: the von Kármán constant

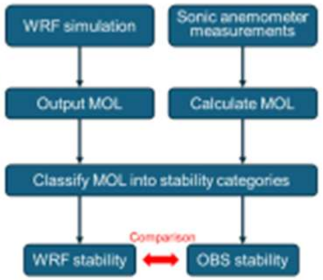

Fig.1 Overall flow of this study

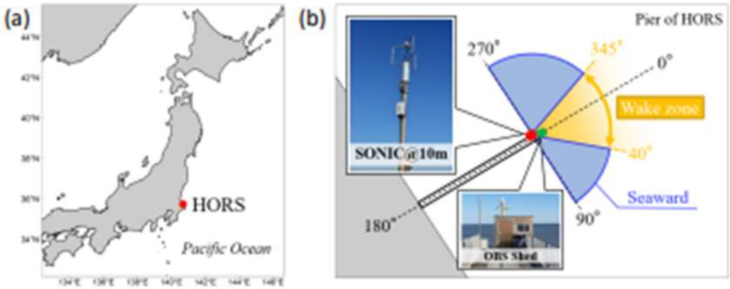

Fig.2 (a) Location of the Hazaki Oceanographical Research Station (HORS) and (b) the diagram of the sonic anemometer installed.

(2) WRF configurations

Table 1 The WRF model configurations

Model	Advanced Research WRF (ARW) V3.8.1
Domains	Domain1: 2.5 km×2.5 km (100×100 grids) Domain2: 0.5 km×0.5 km (100×100 grids) Domain3: 0.1 km×0.1 km (100×100 grids)
Vertical level	43 levels (up to 100hPa)
Input data	JMA MSM-GPV (3 hourly, 5km×5km) NCEP FNL (6 hourly, 1.00°×1.00°) AIST and Kobe Univ. IHSST (3 hourly, 0.02°×0.02°)
Physics	Shortwave: Dudhia scheme Longwave: PRTM scheme Microphysics: Eta scheme PBL: Mellor-Yamada-Janjic scheme Surface layer: Eta similarity (Janjic-eta) scheme Land surface: Noah Land scheme Cumulus parameterization: Beltte-Miller-Janjic scheme

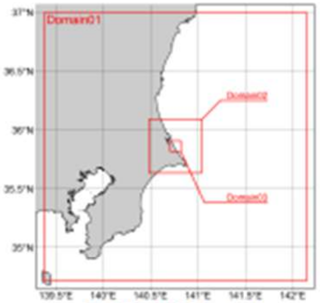

Fig.3 The WRF domains

(3) Atmospheric stability classifications

The seven and three stability classifications defined with the Monin-Obukhov length are shown in Table 2.

Table 2 Atmospheric stability classifications

MOL L [m]	7 classifications Atmospheric Stability	3 classifications Atmospheric Stability
$-50 < L < 0$	VU: Very Unstable	U: Unstable
$-200 < L < -50$	U: Unstable	
$-500 < L < -200$	NU: Near-neutral Unstable	
$\lvert L \rvert > 500$	N: Neutral	N: Neutral
$200 < L < 500$	NS: Near-neutral Stable	S: Stable
$50 < L < 200$	S: Stable	
$0 < L < 50$	VS: Very Stable	

3. Improvement of atmospheric stability estimation

A preliminary study was performed in order to improve the accuracy of the atmospheric stability in the WRF simulation by (1) correction of sea surface temperature (SST) and air temperature and (2) comparison of PBL + SFCLAY schemes for four months from March to June 2019.

(1) Correction of SST and air temperature

We tested two correction patterns: SST_COR (only correcting SST) and SST+T_COR (correcting both SST and air temperature) (Table 3). The matching rates of the three atmospheric stability classifications were then calculated for each correction pattern (Table 4). As a result, SST_COR has a higher matching rate than SST+T_COR in Unstable (U), Neutral (N) and when grouped all together (ALL). This indicates the simulation with SST correction shows the most accurate result for the atmospheric stability estimates.

Table 3 Correction patterns

Case	Correction of SST	Correction of Temp
RAW	×	×
SST_COR	○	×
SST+T_COR	○	○

Table 4 Matching rate (%) of the three atmospheric stability classifications.

Case	Atmospheric Stability Classifications U	N	S	ALL
RAW	85.3 (318)	46.0 (40)	81.5 (194)	79.1 (552)
SST_COR	87.9 (328)	59.8 (52)	92.9 (221)	86.1 (601)
SST+T_COR	79.4 (296)	54.0 (47)	98.3 (234)	82.7 (577)

The highest matching rate

(2) Comparison of PBL + SFCLAY schemes

Table 5 shows the matching rates of the three atmospheric stability classifications in five PBL + SFCLAY schemes. We found that the MYJ + Eta Similarity scheme has the highest matching rate in Stable (S) and ALL. Therefore, we concluded that it is most fitting to use the MYJ + Eta Similarity scheme for the atmospheric stability simulation.

Table 5 Matching rate (%) of the three atmospheric stability classifications

PBL + SFCLAY scheme	Atmospheric Stability Classifications U	N	S	ALL
MYJ + Eta Similarity	89.0 (315)	60.7 (51)	91.6 (207)	86.3 (573)
MYNN Level3 + MYNN	86.4 (306)	73.8 (62)	83.2 (188)	83.7 (556)
MYNN Level3 + Eta Similarity	91.0 (322)	48.8 (41)	86.7 (196)	84.2 (559)
MYNN Level3 + Revised MM5	91.0 (322)	50.0 (42)	82.7 (187)	83.0 (551)
YSU + Revised MM5	89.5 (317)	65.5 (55)	88.1 (199)	86.0 (571)

The highest matching rate

*The values given in parentheses are the number of samples where the classifications matched.

4. Evaluation of accuracy in atmospheric stability estimation

The accuracy of the atmospheric stability in the WRF simulation using the corrected SST was tested for a duration of a year from July 2018 to June 2019. Fig.4 and 5 show the occurrence rates of the WRF stabilities for each class when classified into seven and three categories, respectively. The atmospheric stability in control experiments tended to be biased towards instability since the matching rate of stable air is lower than that of unstable air. On the other hand, with corrected SST and MYJ + Eta Similarity scheme, the accuracy for the stable air improves to the same extent as the unstable air. This resulted in matching rates being over 70% under Very Stable (VS) and Very Unstable (VU) when classified into seven categories, and around 90% under Stable (S) and Unstable (U) when classified into three categories.

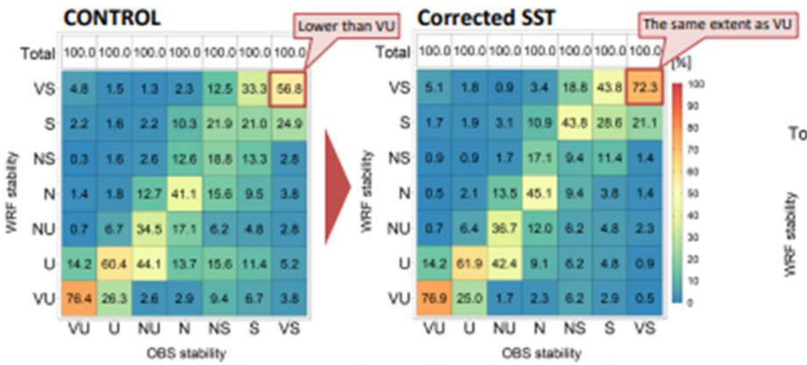

Fig.4 Occurrence rates of the WRF atmospheric stability under seven classifications

*The MYJ + Eta Similarity scheme is used in both simulations

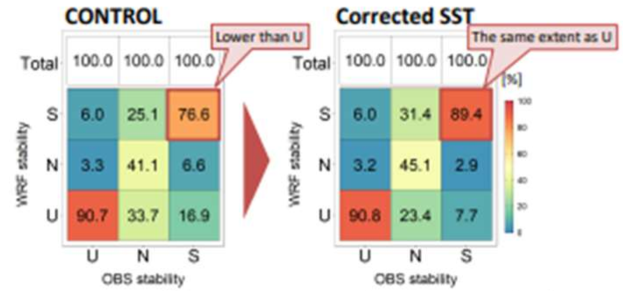

Fig.5 Occurrence rates of the WRF atmospheric stability under three classifications

5. Conclusions

This study suggests that the atmospheric stability classification of the WRF models with the corrected SST would prove useful in understanding the atmospheric stability conditions in the offshore areas.

Acknowledgments

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