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Offshore wind resource mapping in Cambodia: Sensitivity assessment of the weather research and forecasting model

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Abstract

The objective of this paper is to assess the sensitivity of the weather research and forecasting (WRF) to three important parameters: nesting with nudging options, planetary boundary layer (PBL) options, and nudged variable options for Cambodian territory. Three tests are set up and carried out, and each of the test, intended for each parameter, is comprised of several experiments. All experiments are simulated for the same period of 15-day. Then the outputs of the WRF model are validated against measured wind data from four meteorological stations at 10 m above the ground level. The results show that the WRF is unlikely influenced by the nesting choices but more sensitive to the PBL options for wind speed simulation. In term of wind direction, the model is insensitive to any of the tested parameters. Through statistical and graphical analyses, the best experiments are found to be the two-way nesting with gridded nudging for nesting with nudging options, MYNN2.5 scheme for PBL options, and nudged wind components for nudged variable. With these optimal configurations, the model is then applied for simulations of higher vertical-level wind and for mapping the offshore wind resource in Cambodia. The offshore winds at 80 and 100 m above sea-level are found to be around 5–7 m/s over Cambodian EEZ.

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Keywords: Nesting; Nudging; Offshore wind; Planetary boundary layer; Weather research and forecasting; Renewable energy

1. Introduction

Cambodia, a country in Southeast Asia, has recently allowed the integration of renewable energy into its national grid to reduce the reliance on fossil fuels and hydro power. Beside high potential in the solar source, Cambodia has not realized its offshore wind power resource yet despite a few studies on the onshore wind potential assessment

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such as [1–3]. Due to unavailability of offshore wind measurement in Cambodian sea, the study on offshore wind potential is viable with numerical weather predictions (NWPs).

The well-performed NWP for evaluating wind resource has been claimed to be the WRF [4–6]. Carvalho et al. [7] suggested that simulated results could be much improved by calibrating the model for appropriate physic and numerical options for studied areas. Similarly, many works have investigated the model's sensitivity, and their findings can be summarized as following: PBL schemes together with surface layer schemes have a strong impact on the model; shorter initialization and higher-resolution domains can improve the output accuracy; driving lateral and boundary condition data types slightly affect the model performance; 1-way or 2-way nesting option caused no changes to the results [7–11]. Moreover, the previous studies on nudging methods have provided several recommendations as following: long simulations should be run with enabled nudging options above PBL levels; gridded nudging without interior nudging could improve consistency and accuracy; the spectral nudging works well on precipitation downscaling whereas analysis nudging outperforms on simulating 10 m wind speed, 2 m relative humidity, and air humidity [8,12–14]. However, Mai et al. [15] noted that more research should be done due to the appropriate nudging option varying with regard to the studied areas and layers.

With these prior findings, PBL choice is a site-specific and key configuration for a near-surface wind simulation. The nudging options are also site-specific. Moreover, it is still difficult to locate a study evaluating the effect of all nudged variable combinations. Therefore, in this work, the WRF sensitivity to these three parameter options is examined for Cambodian territory for the purpose of offshore wind resource estimation.

2. Materials and method

2.1. In-situ data

Provided by the Department of Meteorology, Ministry of Water Resource and Meteorology, the wind data observed by four onshore automatic weather stations (AWSs), namely Kampot station (KP), Koh Kong station (KK), Kampong Speu station (KPS), and Takeo station (TK), at the 10 m above ground level (AGL) were retrieved for two years from 01 January 2018 to 31 December 2019. All data were recorded hourly, and a quality check was done with boxplots. Missing data are removed from analyses. The locations and details of the AWS are shown in Fig. 1 and Table 1.

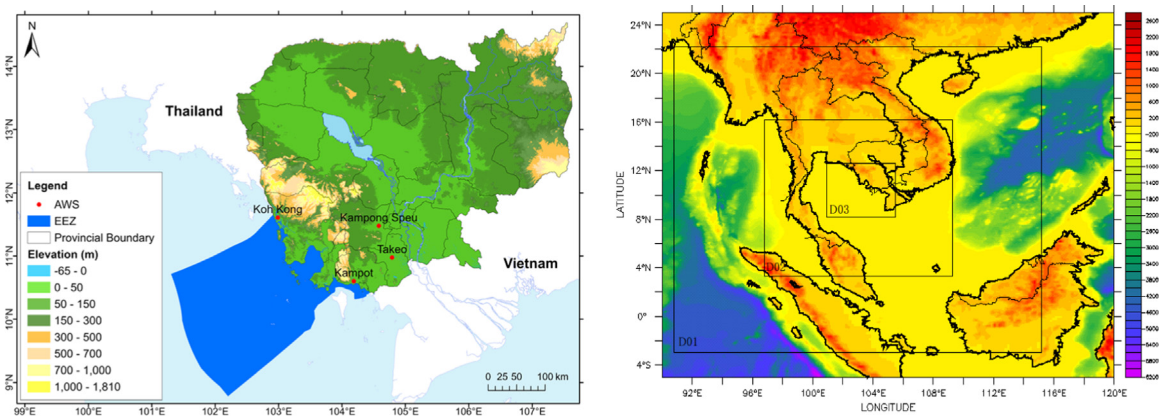

Fig. 1. A map of Cambodia along with the exclusive economic zone (EEZ) and onshore AWS in Kampot, Koh Kong, Kampong Speu, and Takeo provinces (left), and three domains setup for the WRF simulations (right).

2.2. The WRF model design

Three domains are created with a horizontal grid size of 15 km, 5 km, and 1.66 km (Fig. 1). The center of the domains is at 9.8741°N latitudes and 102.9705°E longitudes. For an initial run, the model physic configuration is adopted from Doan et al. [16] with a modification to a cumulus scheme as in Table 2.

Table 1. Overall information of AWSs and elevation differences between the default USGS GTOPO30s topographical data for WRF and the 30m-gridded SRTM elevation dataset.

AWS	Coordinates (Lat (°N), Lon (°E))	Elevation (m) above sea level	Province	Distance from the sea (km)	Elevation difference (m) (GTOPO30 – SRTM)
KP	10.60277, 104.18638	5	coastal	5.3	3.16
KK	11.60833, 102.98805	5	coastal	1.15	15.03
KPS	11.47666, 104.58138	32	inland	110	−0.29
TK	10.97666, 104.79027	9	inland	72	1.41

Table 2. The model setup and initial parameter configuration.

Set-ups/physic parameterizations	Domain 1 (D01)	Domain 2 (D02)	Domain 3 (D03)
Model	WRF-ARW version 3.6.1		
Initial and boundary condition	ERA5 reanalysis, 38 vertical levels		
Vertical layers	38		
Projection	Mercator		
SST update	enabled		
Grid spacing	15 km	5 km	1.66 km
Domain size	180 × 190	277 × 289	298 × 298
PBL scheme	Yonsei University (YSU)		
Surface layer scheme	Revived Monin–Obukhov (Revised MM5)		
Land surface scheme	Unified Noah land surface layer		
Microphysic scheme	WRF Single-Moment 6-class (WSM6)		
Shortwave radiation scheme	Dudhia		
Longwave radiation scheme	RRTMG		
Cumulus scheme	Bett–Miller–Janjic (BMJ)		

Table 3. List of experiments conducted within each test of the WRF sensitivity. The bold indicates the best result of the test (1 = one-way nesting, 2 = two-way nesting, NN = no-nudging, GN = gridded nudging, SN = spectral nudging, V = wind components, T = potential temperature, Q = water vapor mixing ratio, Re. = Revised).

Test	Experiments					
T1	Nesting with nudging options					
	1NN	1GN	1SN	2NN	**2GN**	2SN	
T2	PBL options with respective surface layers					
	YSU	MYJ	QNSE	**MYNN2.5**	ACM2	UW
	Re. MM5	Janjic Eta	QNSE	**MYNN**	Re. MM5	Re. MM5
T3	Nudged variable options					
	V	T	Q	VT	VQ	TQ	VTQ

2.3. Sensitivity tests

To investigate the model's sensitivity to the above three parameters, three subsequent tests, namely test 1 (T1) for checking nesting and nudging options, test 2 (T2) for PBL options, and test 3 (T3) for nudged variable options, are carried out. The tests are related because the best results in the prior tests are used in the subsequent ones. Each test is comprised of several experiments as summarized in Table 3. All tests are simulated for the same length of 17 days (from 29 November to 15 December 2019) with the first two days discarded as a spin-up. The simulated outputs of the experiments are validated with the measured wind data from the four AWSs at 10 m AGL. The hourly observed data are collocated with the hourly modeled wind vectors retrieved from D03 at the nearest grid points to the four AWS locations. The best experiment of each test is selected based mainly on Taylor diagrams with statistical indexes. With these optimal configurations, the model is applied for simulations of higher vertical-level wind and for mapping the offshore wind resource in Cambodia.