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Development of microscale wind maps for Phaluay Island, Thailand

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Abstract

Phaluay Island (9° 31' 30.27" N 99° 41' 19.66" E), located in the Gulf of Thailand, was selected by the Ministry of Energy of Thailand as a pilot model to demonstrate the development of a 'Green Island'. Renewable energy including wind energy has been promoted as an energy resource for the island. In this study, a microscale wind map with a resolution of 90 m x 90 m was developed from a mesoscale wind data with the resolution of 3 x 3 km^2 using Meteodyn WT wind resource assessment software. The results revealed the spatial variation of the microscale wind over the island. The high wind speed was found mostly in the mountainous area and finally the potential site for the installation of wind turbine on Phaluay Island was identified.

Keywords: Wind energy; microscale wind; wind map; Phaluay Island

1. Introduction

Wind energy, with its long history of successful usage for centuries in Europe, is proven to be the world fastest growing energy resource. Novel approach to utilize wind energy has paved the way for more secure and prosperous future. Renewable energy, wind in particular, is abundant in nature and available to everyone. Increasing in wind energy utilization and other renewable energy resources will speed up economic growth, create job opportunity, enhance national security, and protect consumers from price spikes or supply shortages associated with global fuel markets.

Additionally, renewable energies are regarded as a key factor in reducing the pollutants causing greenhouse effect and climate change. Among various renewable energy resources, wind energy in

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specific has achieved maturity in the energy market. It has experienced the greatest growth worldwide over the past decades, in terms of annual percentage of installed capacity per technology source. There also has been a significant increase in electrical energy demand due to the economical and technological developments over the world. Therefore, to tackle the future crisis, study on an electrical energy production with renewable energy (such as wind, solar, biomass, hydro, etc.) is essential.

To deal with those issues, all nations around the world have set up an energy policy which is the country's strategy addressing issues of energy development along with the development of the energy industry to sustain its growth including energy production, distribution and consumption. The Royal Thai Government considers its foremost mission to lead the country through the current crisis. The government has a strong policy to elevate alternative energy as a national agenda through the current 15-year renewable energy development plan 2008 – 2022 to enhance energy security while reducing environmental impact.

'Green Island' is one among the projects implemented by the government concerning the renewable energy. The objective of the project is to promote the utilization of clean energy and ecological tourism on the island. Phaluay island (9^o 31' 30.27" N 99^o 41' 19.66" E) is located at Tambon Angtong, Koh Samui District, in Surathani. It is chosen to be the first pilot model of 'Green Island' under the project "Reducing the Global Warming for King" founded to honor and cerebrate the 60^{th} anniversary of His Majesty the King Coronation and his 84^{th} birthday on December 5, 2011.

In this study, a high resolution wind maps for Phaluay island was developed by downscaling from mesoscale wind (3x3 km^2 in resolution) retrieved from our previous work on a purpose of evaluating the wind resource over the island.

2. Methodology

To identify the wind energy potential, high-quality wind measurement data is necessary. However, in many parts of the world, including Thailand, there is only poor or even no wind data available. Therefore, in the past few years, several methods of wind resource assessment have been developed and applied ranging from ground-based measurement network to numerical modeling. Additionally, the resolution scales of the maps have been taken into account ranging from synoptic scale (horizontal resolution of greater than 2,000 km) Mesoscale (horizontal extents are between 2 km – 2,000 km) and Microscale (horizontal resolution of smaller than 2 km). In this work, we propose to use mesoscale simulations to obtain more appropriate boundary conditions for microscale modeling. The numerical techniques used in the simulations of the mesoscale and microscale are presented as following.

2.1. Meso-scale modeling

The methodology used to develop the mesoscale wind maps for the southern part of Thailand is based on KAMM (Karlsruhe Atmospheric Mesoscale Model) developed at University of Karlsruhe, Germany [1]. The KAMM, three-dimensional, non-hydrostatic, numerical simulation model was used to solve the momentum, heat, and humidity equations. The equations were transformed to a coordinate system according to the terrain.

The model requires large-scale meteorological data as input data in order to drive the processes in the simulation area (i.e. the terrain altitude as a function of the geographical location, data on soil and vegetation types). The large-scale flow is described by the components of the geostrophic wind as well as the large-scale field of potential temperature and specific humidity. The model's outputs are space-dependent and time-dependent distributions of wind (horizontal and vertical components), potential temperature, and specific humidity. The model has been validated and used widely for several meteorological process studies [2-6]. It was also applied for wind energy purposes [7-8].

2.2. Micro-scale modeling

The microscale modeling used in this study is based on Meteodyn WT, a program well known for CFD wind resource assessment application. It makes use of the turbulence flow method RaNS (Raynolds averaged Navier Stokes) and solves the three-dimensional momentum and mass conservation questions to estimate the 3D wind speed vector, u, v and w [9]. The turbulent environment is obtained through implementation of a transportation equation for turbulence kinetic energy, which considers topography and thermal effects as well as the presence of the forests.

To initialize simulations, the model uses a 10-year (2000-2009) mesoscale wind profile at the center of Phaluay island (9° 31’ 35.54” N 99° 41’ 4.04” E) with variable height to the ground for each simulated wind direction, with or without thermal stability. Due to the resolution of the mesoscale simulation, the wind was spatially averaged over an area of 3 km x 3 km at 50-m height. The microscale computations, using Meteodyn WT, were made with a grid step of 90 m on the whole domain of 6 km x 6 km covering the whole island. Topographic and roughness data were used as inputs for defining the site in the CFD software Meteodyn WT. Digital topographic data used in this study is shown in Fig. 1. It was derived from NASA’s Shuttle Radar Topography Mission (STRM) dataset. Roughness data used in this work derived from the United States Geological Survey (USGS) Global Land Cover Classification by mean of a look up table as shown in the legend. Finally, Meteodyn WT gave the microscale grid coefficients as the results. Afterward, the microscale wind at each point was determined from weighting the mesoscale value of the point with the calculated microscale grid coefficients.

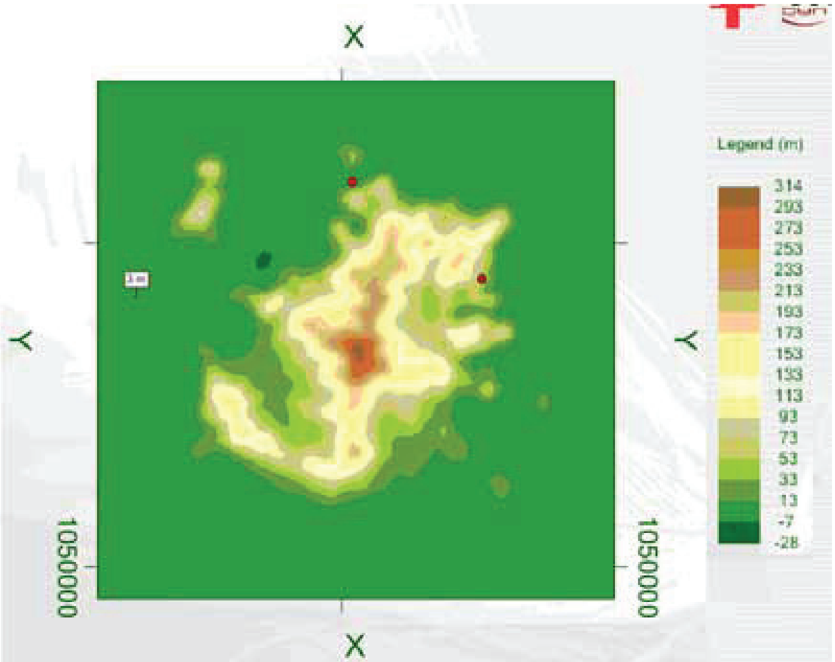

Fig. 1. Phaluay island topographic data used in this study

3. Results and discussions

In our previous work [10], a collaborative project between the Department of Alternative Energy Development and Efficiency (DEDE) and Silpakorn University, KAMM was used to simulate the evolution of atmospheric conditions for each hour at the resolution of 3 km x 3 km for all initial and boundary condition data of 15 years (1995 – 2009). The mesoscale simulation results were validated against the measurements and an acceptable agreement was found (with a root mean square less than 15%). Due to a non-availability of measurement data for Phaluay island at the moment, the mesoscale wind results were considered for downscaling in order to predict the wind distribution on the island. The long term mesoscale wind of the southern part of Thailand from our previous work and is presented in Fig. 2. As it was mentioned earlier that the mesoscale modeling could not show the effect of objects that are smaller than its resolutions, therefore, the wind speed of the whole Phaluay island is represented by only a few wind speed values.

The microscale winds from this approach are presented as monthly average results were determined and presented in maps as in Fig. 3. The patterns of stronger wind speed areas on the island were not only similar from month to month, but also similar to that of the long-term average. The monthly average results reveal that wind speed during December to March was higher than other periods. Phaluay island is located in the Gulf of Thailand and during theses months wind is mostly affected by the northeastern monsoon, while there is nothing to obstruct the wind in that direction. On the other hand, during the southwest monsoon, the wind is obstructed by the main land causing the wind speed during April to November a little lower. However, the areas with higher wind speed on the island are almost the same areas which are mostly on the higher altitude. Nevertheless, as the highest average wind speed found was less than 5 m/s, low speed wind turbine would be a better alternative for developing a wind energy resource on Phaluay island. A long-term average wind speed (Fig. 4.) shows the distribution of wind speed on Phaluay island. In general, wind speed on the island was relatively low, 2-3 m/s. However, some areas with higher wind speed (4m/s) were found in the mountain range across from the north to the south of the island which is similar to the monthly average results.

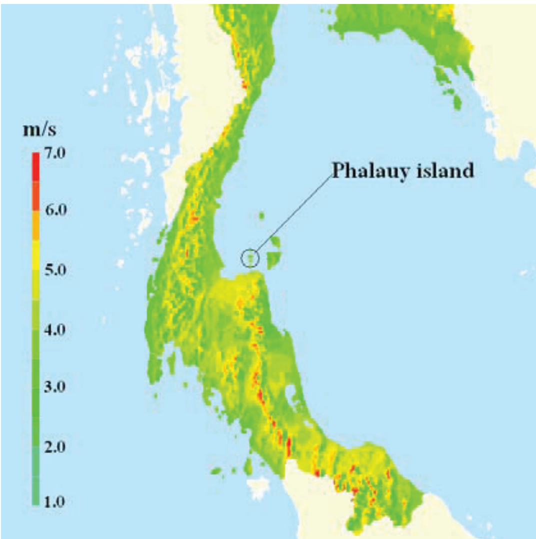

Fig. 2. Mesoscale wind for the southern part of Thailand

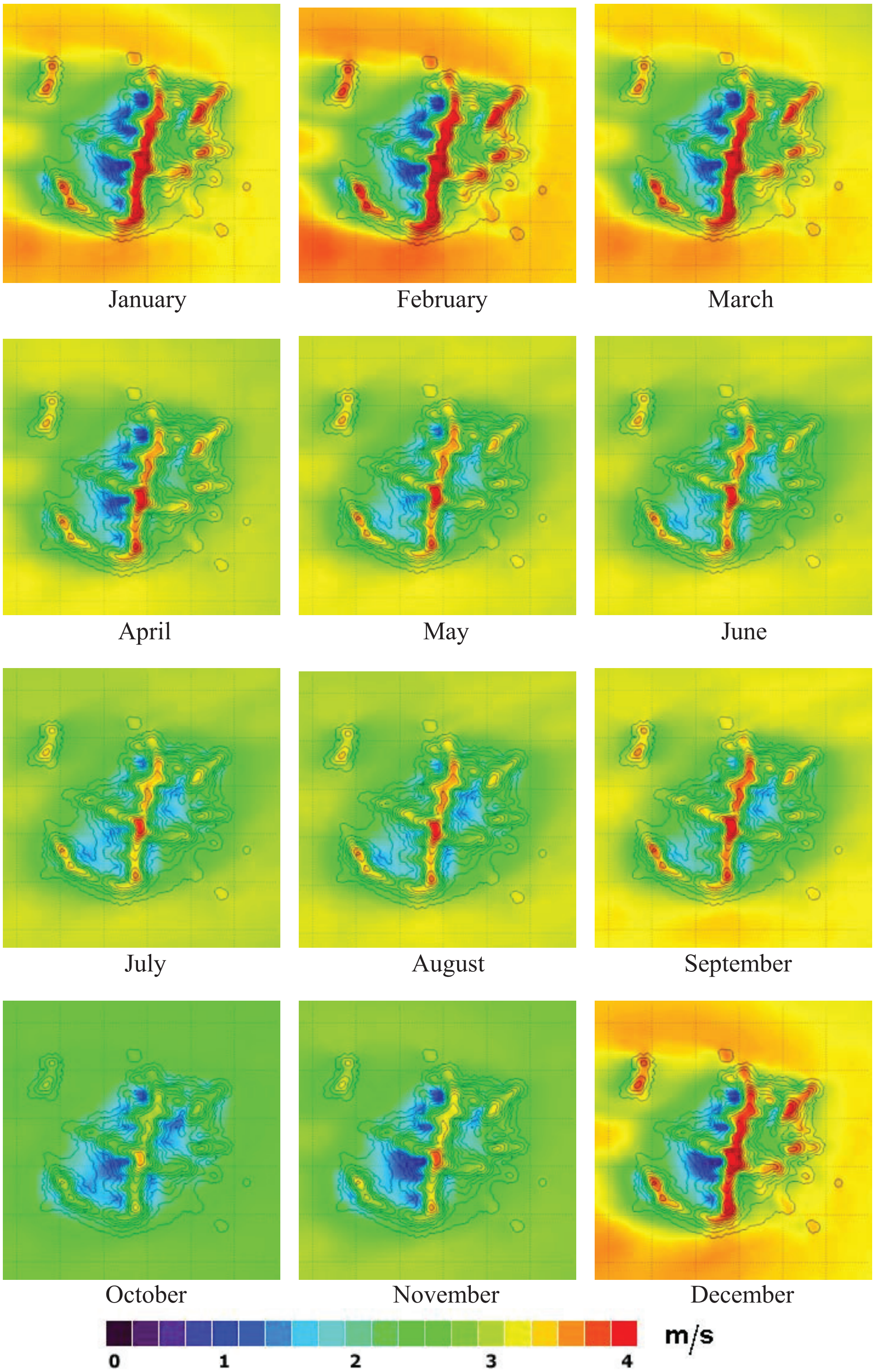

Fig. 3. Monthly average microscale wind speed of Phaluay island at 50 m above the ground

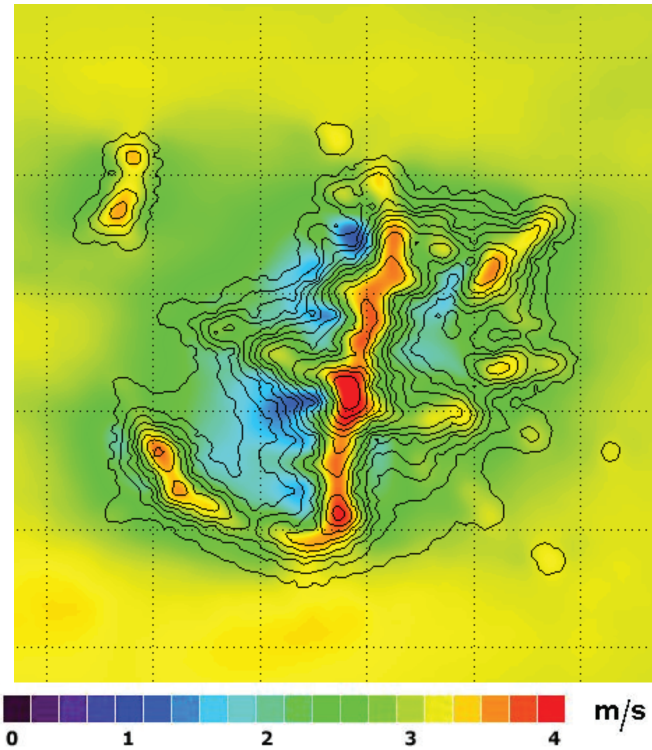

Fig. 4. Long-term average microscale wind speed of Phaluay island at 50 m above ground level

4. Conclusions

The microscale wind maps of Phaluay island with the resolution of 90 m x 90 m were developed by using a downscaling technique. The meteodyn WT software together with mesoscale wind data were used for the downscaling. The microscale wind maps revealed the wind distribution on the island. Overall, the wind speed on Phaluay island was relatively low, however, the highest wind speed (about 4 m/s) was found in the mountainous area of the island. In order to use wind energy resource, the potential site for installing the wind turbine should be along the mountain range across from north to south of the island. However, according to the relatively low wind speed of this island, low speed wind turbine would be a better alternative. Most importantly, wind monitoring station must be set up in the area for at least a year to evaluate the potential wind resource in detail.

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References

[1] Adrian G., Fiedler F. Simulation of unstationary wind and temperature fields over complex terrain and comparison with observations. *Beitr. Phys. Atmosph.* 1991;**64**:27-48.

[2] Bischoff-Gauß I., Kalthoff N., Fiedler F., The impact of secondary flow systems on air pollution in the area of Sao Paulo. *J. Appl. Meteor.*1998;**37**:269-287.

[3] Fiedler F., Bischoff-Gauss I., Kalthoff N., Adrian G. Modeling of the transport and difusion of a tracer in the Freiburg-Schauinsland area. *J. Geophys. Res.* 2000;**105**:1599-1610.

[4] Kalthoff N., Bischoff-Gauss I., Fiebig-Wittmaack M., Fiedler F., Thurauf J., Nova E., Pizarro C., Castillo R., Gallardo L., Rondanelli R., Kohler M., Mesoscale wind regime in Chile at 30^{o}S. *J. Appl Meteorol.* 2002;**41**:953-970.

[5] Kalthoff N., Bischof-Gauss I., Fiedler F. Regional effects of large-scale extreme wind events over orographically structured terrain. *Theor. Appl. Climateol.* 2003;**74**:53-67.

[6] Bischoff-Gauß I., Kalthoff N., Khodayar S., Fiebig-Wittmaack M., Montecinos S. Model Simulations of the Boundary-Layer Evolution over an Arid Andes Valley. *Bound.-Layer Meteor.* 2008;**128**:357-379.

[7] Frank HP. *Wind simulations for the Gulf of Suez with KAMM.* Risø National Laboratory:Roskilde; 1970.

[8] Mortensen NG., Hansen JC., Badger J., Jørgensen BH., Hasager CB., Youssef LG., Said U., El-Salam Moussa A., Mahmoud MA., El Sayed Yousef A., Abd-El Raheem Ahmed M., Sayed MAM., Korany MH., Abd-El Baky Tarad M. *Wind Atlas for Egypt, Measurements and Modeling 1991-2005.* New and Renewable Energy Authority, Egyptian Meteorological Authority and Risø National Laboratory; Roskilde; 2005.

[9] Meteodyn WT, “Help Facility and Online Documentation”.

[10] Janjai S. Development of wind resource maps for Thailand. Final report: Department of Alternative Energy Development and Efficiency and Silpakorn University: PKprinting; 2010.