Estimation of wind speed and energy potential by atmospheric model for day-ahead market and wind power plants in Turkey

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Abstract. The requirement for energy has expanded day by day due to excessive consumption, developing technology, and population growth, especially after the Industrial Revolution. Since the investments for promoting renewable energy sources, The Turkish energy sector has been progressing in the way of renewable energy. This inevitable change in the energy sector and variable power generation values in wind energy directly affect the energy markets. Accompanying with the structural transformation of the energy sector, Turkey had launched the Day-Ahead electricity marketing system in December 2011. The price per megawatt-hour is determined on the open market by the supply and demand. Hatay province was selected in this study because of its highest wind potential. Temperature and wind speed values, observed in Hatay Samandağı for October 2019, were determined. The data was configured with The Weather Research and Forecasting Model. The results indicate that the wind speed at high altitudes could reach above 7 meters per second on Turkey's eastern Mediterranean coast, Hatay. The results were compared with the real-time data, and the error rates were determined. In the selected region, the electrical energy values generated using the model results were calculated the day before.

1. Introduction

Since the highly increasing consumption of energy and population growth rate, in other words, raised demand on the global scale and the decline of fossil-based fuels, the motive for alternative energy is advancing day by day. Obstacles caused by climate change and the social sensitivity about the environmental policies force the energy sector into ongoing reform. Due to the international sanctions, most countries have been tasked with reducing CO2 emissions, so that the incentive programs for renewable energy have widespread internationally. In 2015, the Paris Agreement was ratified along with international accession, including Turkey. In the agreement, Turkey has set its target limits for 2030 and has made commitments for its realization. The commitment is endorsed to reduce the anticipated greenhouse gas emissions by 21% within the next 10 years and increase solar energy power usage to 10 GW and wind energy power to 16 GW [1]. Because of the policies such as credit facilities, full purchase of guaranteed renewable energy, investment incentives; wind power generation has been advancing over the last decades. Managing wind energy potential not only gear up economic development and reduces carbon emission but also contributes to environmental quality, energy security and independence, and conditions to restore life quality [2]. In 2019, wind power generation expanded by 3.34% compared to the previous year and reached an energy capacity of 7615 MWh [3].

The electric power generated from wind energy depends directly on wind speed parameters, and deviations in wind speed are at a level that will affect energy markets [4]. Zhao et al had the idea that fluctuations in wind speed, stochasticity, and wind outages could challenge the stabilization of electrical networks in high penetration level situations [5].

Turkish Energy Market, as of December 2011, market swap prices and purchase and sale amounts are announced in line with the offers offered by market participants in the Day Ahead Markets. After the new system, stock market prices are created with bids submitted by market participants. The price of electricity per MWh, together with the pre-day markets, is determined according to supply and demand conditions and is intended to balance the energy markets [6]. In deregulated markets, daily prices are considered reference prices. Unpredicted situations in the operation systems, such as deviations in demand, generation unit failures, and other supply issues, can lead to price fluctuations in the real-time market, referred to as price imbalances [7]. In order to eliminate these problems, high wind potential regions of Turkey have been identified, and studies have been started.

Turkey's average wind speed is 2.45 m/s over a year period. Wind energy sources are commonly located in the coastal areas of Turkey.[8]. Turkey's top-level wind energy potential areas are the Marmara and Aegean coasts and higher altitude soils with an average annual wind speed of 6.9 m / s at 50 m altitudes. East parts of Mediterranean coastal areas also have high potential wind energy. [9]. Analysis of statistical data about wind distribution, average wind density, and speed for the Hatay region demonstrate that wind speeds above 4 m/s are observed at an altitude of 10 m above the surface for more than 80% of the year [10].

2. Materials and Methods

2.1 Study Area and Data

Hatay province, one of the highest wind potential areas of Turkey, is considered as this study area. In the first stage, the fields to run the model have been determined. Turkey was chosen as the main region. The area covering the Samandag coast, a part of Hatay province, was then defined as the sub-region. The main domain of the work area was also demonstrated in figure 1.

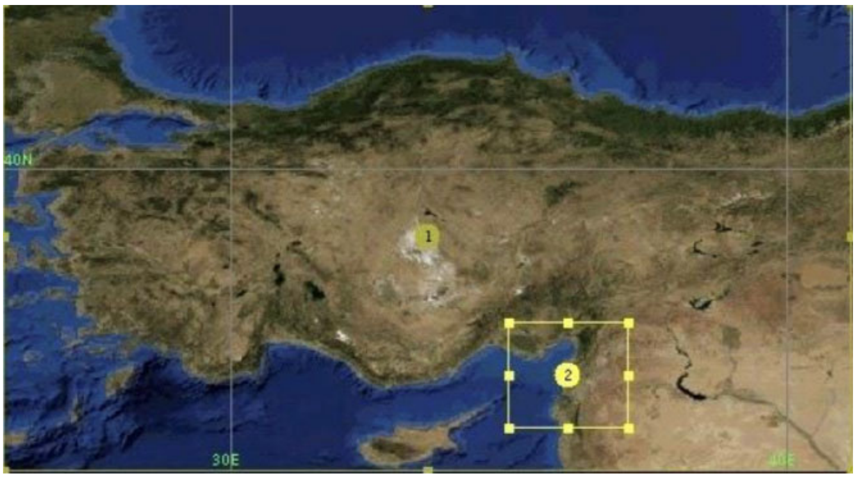

Figure 1. Field Of Study.

2.2 *Methods*

The data analyzed in this research were obtained by Weather Research and Forecasting Model (WRF). A basic set of physics components is included in WRF to determine and calculate variables and to get data outputs at high accuracy. The model was configured with the physical conditions as in table 1 [11].

Table 1. WRF physics options.

Function	Parameter	Description
ra_lw_physics	longwave radiation	RRTM scheme: Rapid Radiative Transfer Model. An accurate scheme using look-up tables for efficiency.
ra_sw_physics	shortwave radiation	Dudhia scheme: Simple downward integration allowing for efficient cloud and clear-sky absorption and scattering.
bl_physics	planetary boundary layer	YSU scheme
cu_physics	cumulus	Kain-Fritsch (new Eta) scheme: deep and shallow sub-grid scheme using a mass flux approach with downdrafts and CAPE removal time scale and no cumulus
mp_physics	microphysics	WRF Single-Moment (WSM) 3-class simple ice scheme: A simple, efficient scheme with ice and snow processes suitable for mesoscale grid sizes.
sfclay_physics	surface layer	Monin-Obukhov Similarity scheme: Based on Monin-Obukhov with Carslon-Boland viscous sub-layer and standard similarity functions from look-up tables

Study areas with defined limits are structured to receive 25 days of data. After the configuration was completed, first static geographic data and then the global prediction system (GFS) data were defined in the study areas. The defined GFS data were applied in 3-hour periods with a resolution of 0.25 degrees. The model was run through October 2019. The data taken from the model is configured to predict 24 hours before each working day. Version 1.9.3 of the Climate Data Operators (CDO) software is used to visualize the data. Measured data were observed from 25 locations for the working area. The average wind speed of 25 locations has been measured, and the wind energy power that can be generated from these locations has been calculated.

3. Results

As a result of the data received from the atmospheric model of October 2019 in Turkey, the average temperature and wind speed values are visualized. As a result of the data outputs, it was determined that high wind speed values were reached in the locations where the temperature increased and in the coastal regions where the temperature difference was intense. Average temperature and wind speed maps are shown in figure 2 and figure 3.

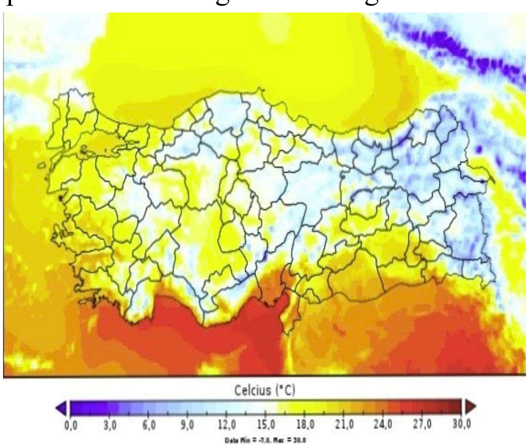

Figure 2. October 2019 Temperature Map.

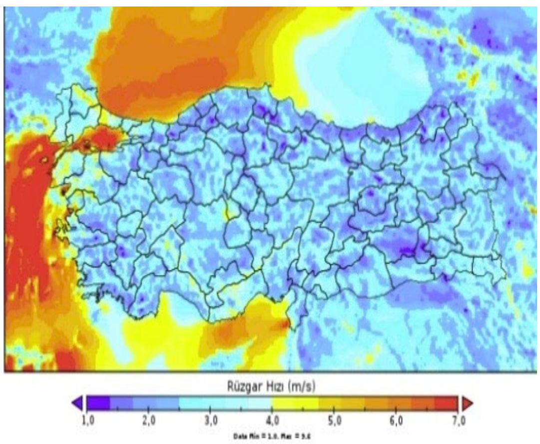

Figure 3. October 2019 Wind Speed Map.

Wind speed values were taken from the measurement centers in the Samandag region during October 2019 at eighty meters. The average of the measurement data taken in hourly periods is shown in figure 4.

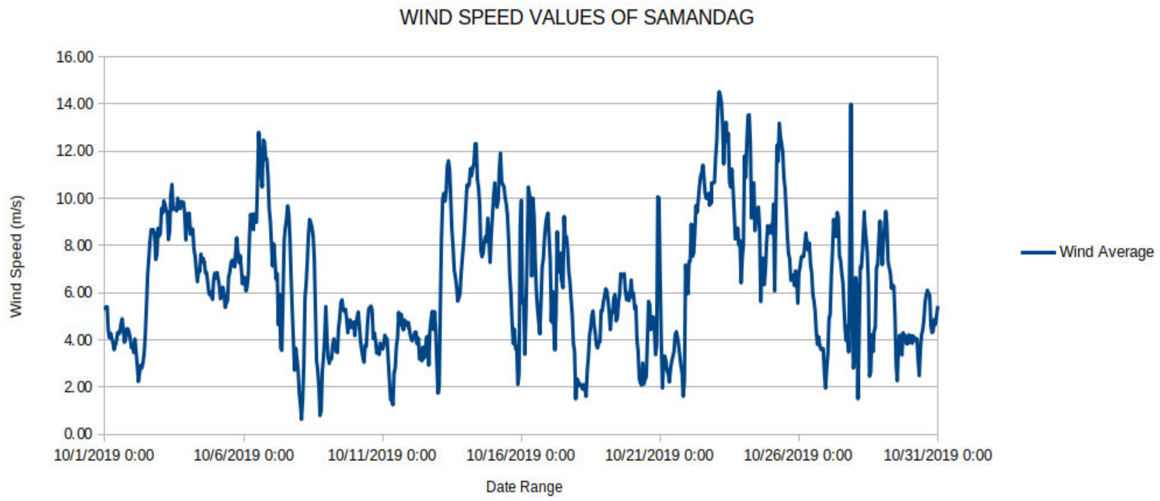

Figure 4. Wind velocity graph at measured locations.

The wind speed fluctuated at a low level between the 9th and 13th of October in the Samandag region. Between 23th and 25th of October, the wind speed fluctuated at a high level. While the lowest wind speed values were encountered between the 9th and 13th days of October, the highest wind speed values were reached on the 22nd and 25th days. The amount of electrical power that can be produced with the wind velocity values obtained from the measurement and atmospheric model data is shown in figure 5.

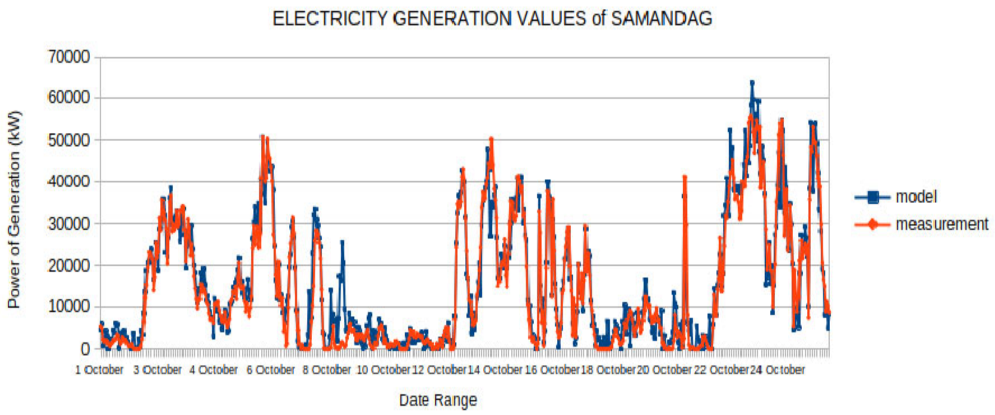

Figure 5. Electric power graph that can be generated from model and measurement data.

As a result of the measurement data and the wind parameter values obtained from the atmospheric model, both production values were examined by regression analysis. Analysis results are shown in figure 6.

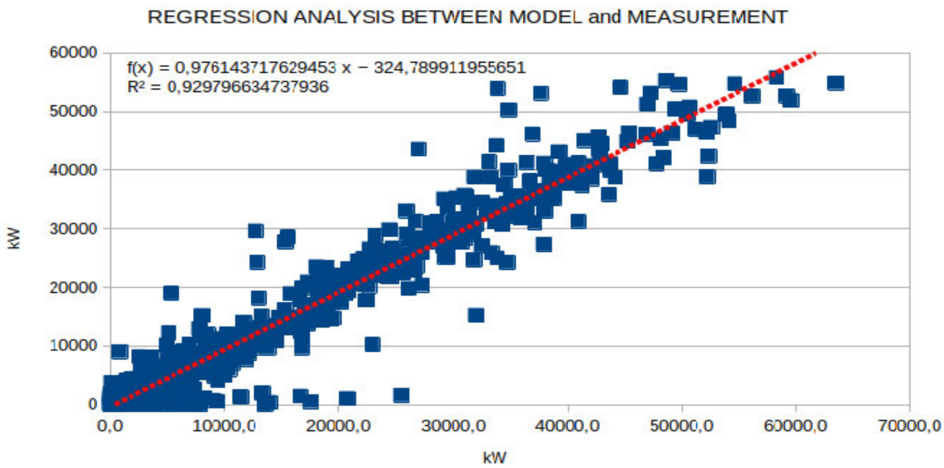

Figure 6. Regression analysis graph of model and measurement data.

As a result of our analysis, the consistency between our model and the measurement values was observed at a rate of 92%.

4. Discussion

In our study, atmospheric wind velocity parameter estimates with the high resolution WRF model were determined with pre-day reports. The shares of the obtained data outputs in electricity generation were compared with real-time data, and the consistency between them was observed at a rate of 92%. As a result of the analysis, wind production values can be estimated one day earlier, and the fluctuations in the Turkish Energy Market can be surpassed. In their study, Sahin et al. (2005) found that October wind velocity values of the Samandag region between 1997 and 2001 were between 3 and 4 m / s at an altitude of 10 meters [12]. According to the previous study, in the WRF model we used, the wind speed values at 10 meters height were higher than 1 m / s. The two studies' value changes may be caused by differences in data set and positions in the study area. Also, the physics packages we used in our WRF model and the degree of resolution affected the data's accuracy. Temporal differences and atmospheric changes caused by climate change can also affect the wind speed and electricity generation power. In the coming years, changes in the temperature difference and unplanned urbanization may cause a sudden decrease and increase in wind speed and electrical energy generated from wind energy.

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