The impact of El Niño-southern oscillation to the wind and solar data in Malaysia

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Abstract. Malaysia has initiated initiatives to use renewable energy as a resource of electricity generation since 2011 through the establishment of laws and policies related to renewable energy. The geographical location of Malaysia has led to limited intermittent renewable energy resources and requires a more detailed study of the various factors impacting electricity generation. This paper aims to understand the impact of El Niño-Southern Oscillation (ENSO) events on the reanalysis wind and solar data. The Wavelet Transform will be used to study the relationship between the reanalysis wind and solar dataset with the Multivariate ENSO index in the Malaysia region. During Very Strong and Strong El-Nino, the site experienced an increment of both wind velocity and solar irradiance and reduced during La-Nina. This ENSO impact study is essential as a reference for future wind and solar energy development planning, energy predicting, and risk valuation in Malaysia.

Keywords: ENSO, Renewable Energy, Malaysia

1. Introduction

Malaysia is advantageously located near the equator that benefits for the solar uptake. The monthly solar irradiation for Malaysia is about 111–167 kWh/m² [1]. The irradiation is higher during Northeast monsoon and lower during Southwest monsoon [1]. Malaysia has sunshiny weather entirely year [2] and could generate up to 6.50 GW of solar energy [3].

Wind is another type of renewable energy resource that has the potential for particular sites in Malaysia. The country was located in the low wind velocity region. Besides, the strong wind in Malaysia is blowing from the South China Sea and the Indian Ocean. Kudat in Sabah is the windiest areas for energy generation in the country [4-6].

Defining the impact of ENSO is essential, especially Malaysia as a low wind velocity region [7]. The energy produced in the area with relatively low wind velocity generally at the point of the edge of economic viability. The wind turbines are typically operated below the rated power and close to the cut-in wind velocity. Accordingly, a reduction in wind velocity will cause a drop in production, which is proportionally more massive compared to sites with high wind velocity.

Many literatures discussed the impact of ENSO on several sector in Malaysia such as agricultural and aquacultural explicitly. However, there less study, specifically the impact of ENSO on renewable energy resources. This paper will fill the gap in the field.
The project aims to understand the influence of ENSO on both wind and solar data. The influence of ENSO would be determined using the Dimensionless median absolute deviation (DMAD) and Wavelet Coherence (WTC).

2. Methodology
This study will utilize the ERA5 solar and wind data, which is a climate reanalysis dataset developed through the Copernicus Climate Change Service (C3S) and processed and delivered by the European Centre for Medium-Range Weather Forecasts (ECMWF). The ERA5 dataset has several improvements compared to ERA-Interim, including; (i) newer modeling system, (ii) more observations, and (iii) higher spatial resolution (31 km). The site is positioned in the northern part of Sabah, namely, as Kudat with the coordinate is at E 116.719, N 6.885 (see Figure 1), and the period is from 1 January 1989 to 31 December 2018 (30 Years).

The ENSO cycle is the most noteworthy coupled ocean-atmosphere phenomenon to impact global climate variability on inter-annual time scales. The warm phase in the cycle is referred as El Niño, and the cold phase is referred as La Niña. The multivariate ENSO Index (MEI) is the most frequently used ENSO index in Southeast Asian [8]. The benefits of MEI include;

(i) Better in integrates extra information
(ii) Better in reflects the nature of the coupled ocean-atmosphere system than either component
(iii) Less vulnerable to occasional data glitches in the monthly update cycles

Hence, in this study, MEI is used as ENSO indicators. Five variables were used to develop the new version of the MEI (MEI.v2) to yield a time series of ENSO conditions from 1979 to the present. The variables include; (i) sea level pressure (SLP), sea surface temperature (SST), surface zonal winds (U), surface meridional winds (V), and Outgoing Longwave Radiation (OLR).

![Figure 1. The location of Kudat, Sabah.](image-url)
The determination of the deviations of the data from normal ranges is necessary to study the impacts of ENSO events on the variability of wind velocity and solar irradiance.

The median absolute deviation (MAD) is defined as the median of the absolute deviations from the median of data. The MAD is a robust measure of the statistical dispersion and central tendency [9]. The sets of standardized indexes that vary between negative and positive values are possible to be generated using the dimensionless MAD (DMAD). The DMAD value can be positive or negative and shows the number of MADs the data is from the median [10].

The MATLAB toolbox developed by [11] was utilized to plot the Wavelet coherence (WTC). The WTC finds regions in time-frequency space where the two-time series co-vary (but does not necessarily have high power).

3. Results and Discussions

Figure 2 showed the dimensionless median absolute deviation of ERA5 Wind/ Solar and the Multivariate ENSO Index (MEI). The strength of the ENSO event based on the MEI index is identified as classification by [12]. The MEI strength are classified as Extreme (SI=1, 0 ≤ MEI<0.6), very weak (SI=1, 0 ≤ MEI<0.6), weak (SI=2, 0.6 ≤ MEI<1.2), moderate (SI=3, 1.2 ≤ MEI<1.8), strong (SI=4, 1.8 ≤ MEI<2.4), very strong (SI = 5, 2.4 ≤ MEI<3.0) and extreme (SI=6, MEI=3.0).

The wind velocity is typically less than the normal range during the Weak El-Nino. However, it was remarked that the site experienced mostly higher wind velocity during a Very Strong El Nino and Strong El Nino. The ENSO influences on wind velocity are always different for each ENSO event, as each event has unique lineaments in terms of specific pattern changes, timing, and intensity.

For Solar-MEI, during El-Nino, the solar irradiance is increased, and decrease during La-Nina than the normal range.

![Figure 2. The Dimensionless Median Absolute Deviation (DMAD) of ERA5 Wind/ Solar and the Multivariate ENSO Index (MEI).](image-url)
Figure 3 showed the wavelet coherence of wind and solar data with the Multivariate ENSO Index. To interpret the wavelet coherence, two time-series have better coherencies if the WTC close to 1. The horizontal axis is the time scale, while the vertical axis is the period (1/frequency). The line with cone-shaped is the cone of influence, which specifies the region affected by the edge-effect. The 5% significance level against yellow noise is shown as a thick contour. The coherency ranges were indicated based on a color code from dark blue (low coherency, close to 0) to yellow (high coherency, close to 1).

Furthermore, the phase difference between two sets of time-series was indicated by the black arrows which only plotted for coherence equal or more than 0.5. Following is the interpretation of results for the phase arrows pointing:

(i) Right: in-phase (Solar data decreases with the decrease of MEI value)
(ii) Left: anti-phase (Solar decreases when the increase of MEI value)
(iii) Down: Solar leading ENSO by 90°
(iv) Up: ENSO leading Solar by 90°

The coherence between solar and MEI value was tended to be in phase in the period of 16 to 90. A similar result is also shown for the coherency between wind and MEI value, were tended to be in-phase in a period of 16 to 70.

4. Conclusions
There is coherence between wind-solar and the ENSO index, with various periods and variations. The wind velocity is typically less than the normal range during a Weak El-Nino. However, it was remarked that the site experienced mostly higher wind velocity during a Very Strong El Nino and Strong El Nino. For Solar-MEI, during El-Nino, the solar irradiance is increased, and decrease during La-Nina than the normal range. The predominant coherence tends to be in phase with the ENSO influence the distribution of wind-solar data with a period of approximately 16-70 for wind-ENSO and 16-90 for solar-ENSO. This ENSO impact study is essential as a reference for future wind and solar energy development planning, energy forecasting, and risk assessment in Malaysia.
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