Lab 2: Exploratory Data Analysis: Time Series

Chun-Liang Wu

Introduction

The renewable generation is a global trend to address the critical issues of global warming. However, due to uncertain renewable generation and expensive utility cost, it is especially important to assess the renewable potential before the deployment of renewable utility in each location. Therefore, the report explores the potential wind and solar generation at two sites, Ashton, Idaho and Deer Lodge, Montana based on the hourly weather data file at 2014.

Dataset

The two dataset contains hourly weather data at 2014, collected from this repository of weather information: http://www.usbr.gov/pn/agrimet/webaghrread.html.

The following weather variables are included for each site in the dataset:

- OBM = Air Temperature, 15 Minute Average (degrees F)
- TU = Relative Humidity, 15 Minute Average (percent)
- WD = Wind Direction, Mean of Wind Vector (degrees azimuth)
- WG = Peak Wind Gust last 15 minutes (mph)
- WS = Wind Speed, Hourly Average (mph)
- SI = 15 minute Solar Radiation,(langleys/hour)

And since this is the hourly weather data, the dataset contains each hour of weather variables ranging from 01/01/2014 to 12/31/2014, 8758 rows in total. In addition, these two datasets don't contain any nan, therefore, the report won't do any preprocessing steps.

Analysis

The analysis will be divided into two parts. First part discusses the wind generation potential in two sites in term of sequence of wind properties, wind strength, and predictability. Second part discusses the solar generation potential in term of sequence of solar properties, solar strength, and predictability.

Wind generation

- Sequence of wind properties (wind speed, wind gust, and wind direction)

Since wind speed and wind gust have a strong positive linear relationship (correlation: 0.97), the sequence of these two properties are also very similar. Both properties are higher in winter than they are in summer. The wind speed and wind gust are especially high in February to the mid of July, and are especially low in the end of January and the mid of December. For Deer Lodge, a

particularly high spike appears in February (around 18 mph). In addition, an extremely low point of wind strength appears in the end of January, shown as Fig 1.

In term of wind direction, as the Fig 2 shows the fluctuation of wind direction in Deer Lodge is more obvious than the wind direction in Ashton. The distance between 25% to 75% of wind direction in Deer Lodge is larger than the distance in Ashton. The inconsistent wind direction is harmful for the wind power generation, since the maintenance cost may be higher.

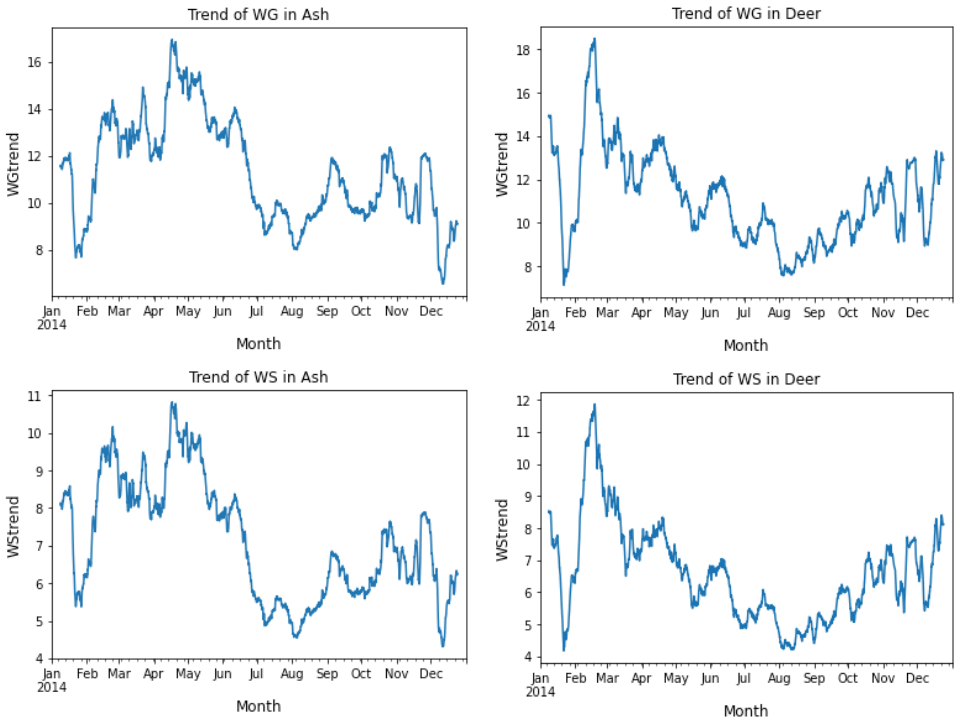

Fig 1. Trend of wind direction and wind gust in Ashton and Deer Lodge

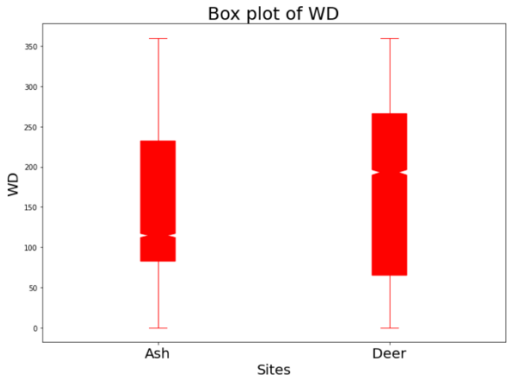

Fig 2. Box plot of wind direction in Ashton and Deer Lodge

- Wind strength

According to *the website*, most of the large-scale wind turbines typically start turning in wind of seven to nine miles per hour. As Table 1 and Fig 3 show, the wind speed in Deer Lodge is a little bit slower than the wind speed in Ashton. The average of wind speed in Deer Lodge doesn't even

exceed the required wind velocity. For wind gust, the range between 25% and 75% in Deer Lodge is slightly larger than the range in Ashton.

Table 1. comparison table of wind speed and wind gust in Ashton and Deer Lodge

	Ashton		Deer Lodge	
	Wind speed (mph)	Wind gust (mph)	Wind speed (mph)	Wind gust (mph)
Mean	7.1	11.3	6.6	11.2
25%	3.7	6.1	2.9	7.9
50%	5.7	9.2	4.9	8.6
75%	8.8	14.1	9.1	15.3

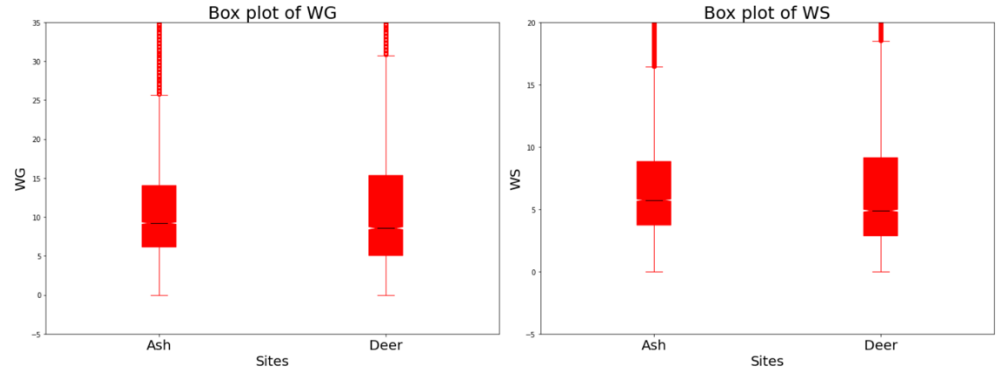

Fig 3. Box plots of wind gust and speed in Ashton and Deer Lodge

- Predictability of wind generation

Predictability is a very important factor for renewable generation. In this part, the report only focuses on the prediction of wind speed since the speed matters the most in wind generation.

As Fig 4 shows, the predictivity of wind speed is low at both sites. Only lag-1 wind speed has a strong correlation with current wind speed, meaning it's hard to perform long-term prediction (> next 5 hours). In addition, in autocorrelation plot, the correlation stops at 0.5 around lag-5, which also means a weak correlation between the current variable and lagged variable. The other variables (OBM, TU, SI) also show a weak correlation with the wind speed.

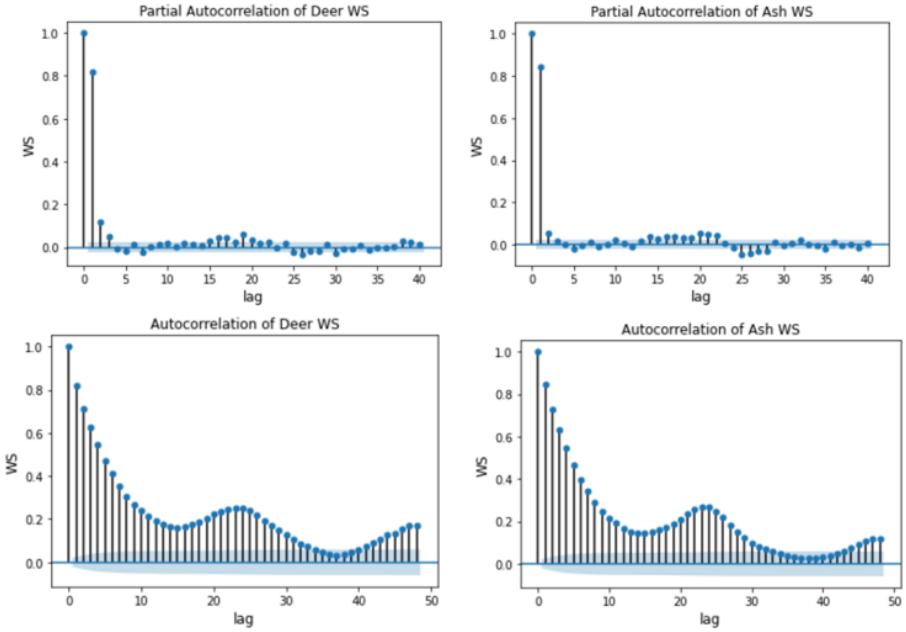

Fig 4. PACF and ACF of wind speed in Ashton and Deer Lodge

Solar generation

- Sequence of solar irradiation

The distribution of SI is similar in both sites, higher in summer and lower in winter. In Ashton, two obvious peaks happen in June and July. In Deer Lodge, the peak happens in July and Augest. The SI achieves 70 (langleys/hour) in summer whereas the SI achieves 15 (langleys/hour) in winter, shown as Fig 5.

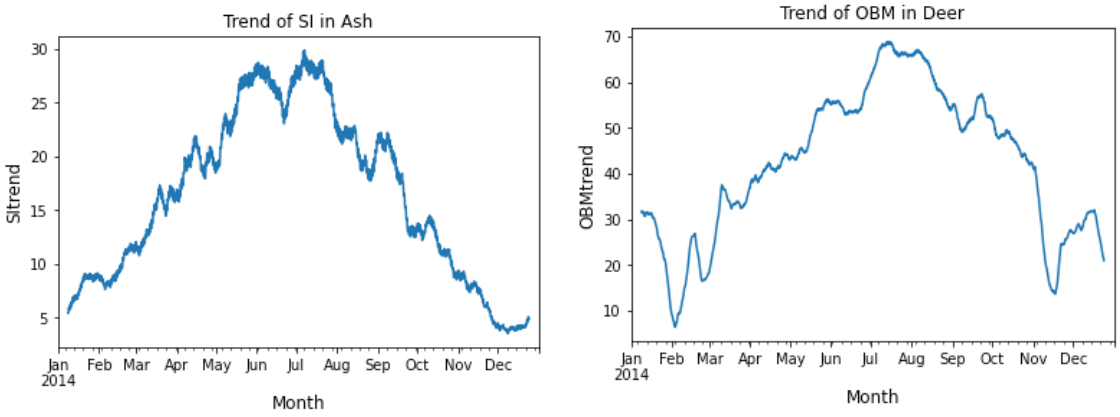

Fig 5. sequence plot of solar irradiation in Ashton and Deer Lodge

- Solar strength

Table 2 shows that the mean of SI in both sites are around 15.5 (langleys/hour). Around 50% of SI is below 0.5 because of night time. As Fig 6 shows, 50% to 75% of SI is between 26.3 and 0.45 (same in both sites). If we use 15.8 (langleys/hour) to calculate the yearly solar potential in Ashton,

it can achieve 21,253 J/m2. And 15.2 (langleys/hour) in Ashton can achieve 20,445 J/m2. The difference between SI of two site is 808 J/ m^2 per year.

Table 2. comparison table of wind speed and wind gust in Ashton and Deer Lodge

	Ashton	Deer Lodge
	SI (langleys/hour)	SI (langleys/hour)
Mean	15.8	15.2
25%	0.01	0.00
50%	0.45	0.45
75%	26.3	25.6
Total generation per year	21,253 J/m2	20,445 J/m2.

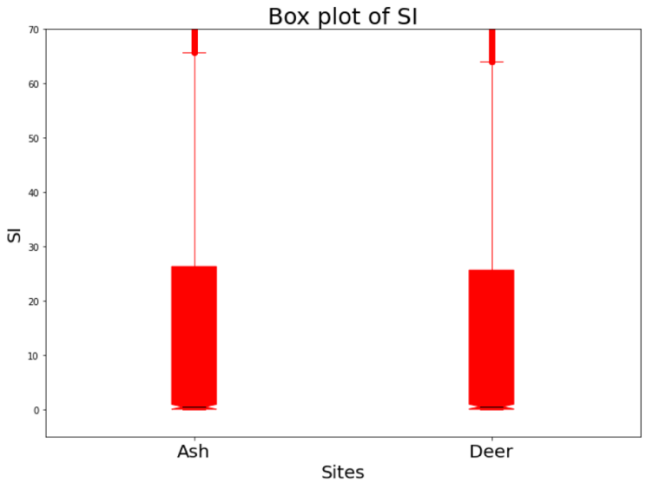

Fig 6. box plot of solar irradiation in Ashton and Deer Lodge

- Predictability of solar generation

Predictability for solar generation is relatively higher than the predictability of wind speed in both sites. As Fig 7 shows, lag-1 to lag-5 of SI have a correlation with current SI. This correlation is helpful for the long-term prediction. The ACF plots also shows a strong relationship between the lagged and current variable. From 48 hours from now, the correlation still remains around 0.8. In addition, the other variables (OBM, TU) show a correlation with solar irradiation. The Fig 8 shows that the cross correlation between OBM and SI in both sites is around 0.5 to 0.7, and the cross correlation between TU and SI in both sites is around 0.6 and 0.7, indicating a strong relationship between the lagged TU and current SI, and lagged OBM and current SI.

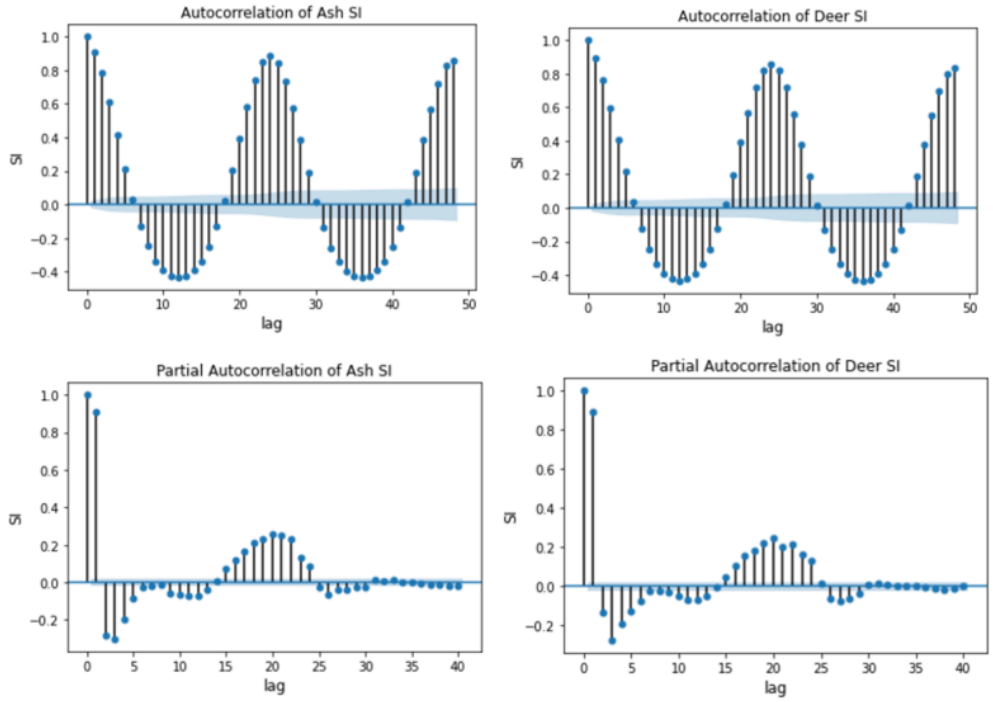

Fig 7. PACF and ACF of SI in Ashton and Deer Lodge

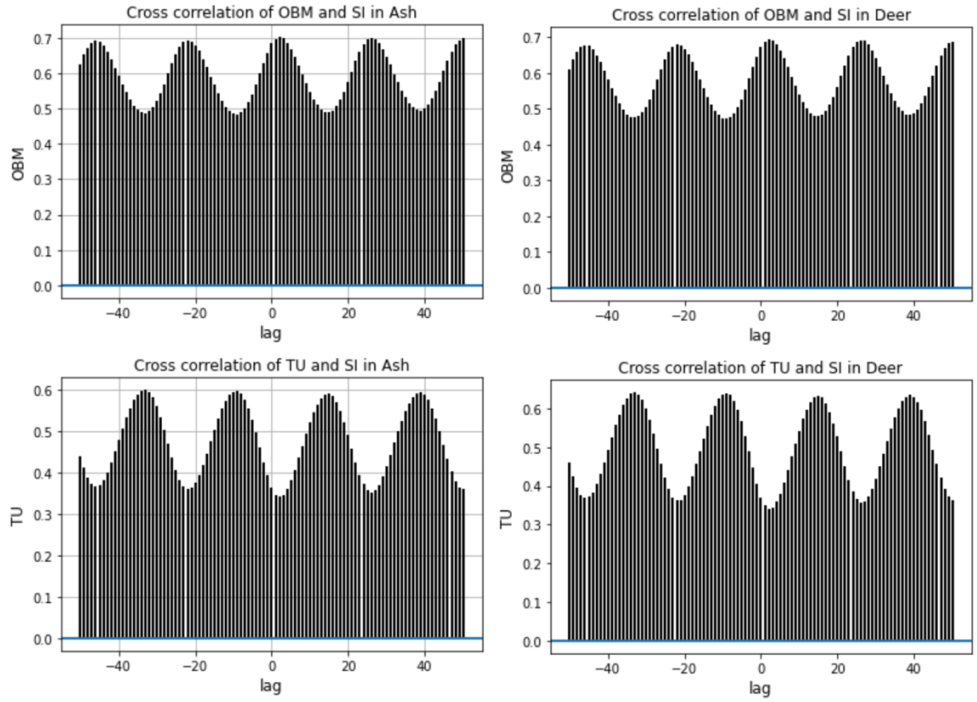

Fig 8. Cross correlation of SI and OBM and TU in Ashton and Deer Lodge

Conclusion

A summary of the analysis and conclusions is as follow:

- Wind generation potential

In term of wind direction, wind in Deer Lodge is more inconsistent than Ashton. For wind strength (wind speed and wind gust), the strength is higher in two sites in winter (especially February to June), indicating the good potential in this period. However, something worth noticing is that there is an extremely low point of wind strength in January. The average wind speed in Ashton is higher than the wind speed in Deer Lodge. In addition, predictability of wind speed in two sites are quite low compared to the solar irradiation predictability. The cross correlation of other variables with wind speed is also low for the predictability. In conclusion, the wind generation shows a good potential in winter. The wind generation in Ashton is higher than the potential in Deer Lodge because of higher wind speed. But however, the wind potential in both sites is low because of low average wind speed and poor predictability.

- Solar generation potential

Contrary to wind generation potential, solar irradiation is higher in summer (especially June and July in Ashton and July and August in Deer Lodge). The solar strength is similar in both sites. The difference is only about 808 J/ m^2 per year. Unlike wind generation, predictability of solar generation is higher in both sites. The trend is easy to capture even at lagged 48 hours, showing the good reliability of solar generation for two places. The cross correlation of OBM and SI and TU and SI is high enough to capture the trend in SI by OBM and TU. In conclusion, the solar generation shows a good potential in summer. The generation potential is very similar in both places, and shows a very good predictability at both sites.

It is clear that for these two sites, the power generation can rely on wind generation in winter and solar generation in summer. And worth noticing is that the low point of wind speed in the end of January in two sites. They need to prepare some storage plan in that period.