Research on Relation between El Niño Climate and Summer Electricity Consumption

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Abstract. El Niño is a typical climate phenomena. Such phenomena would have influence on climate in China and furthermore impact the electricity condition. This paper is purposed to explore how El Niño phenomena affecting electricity and make prediction on summer electricity consumption. Since meteorological characteristics are complex and multiplex, a variety of meteorological factors should be considered and the paper used Body Feeling Temperature to measure it. Furthermore, to make prediction on summer electricity, the paper used the Pearson Analysis to measure the correlation between weather and electricity and then extracted the weather-used electricity from the whole society electricity using least square method. Finally, the paper built the model on relation between weather-used electricity and body feeling temperature, and took Beijing as an example to make electricity prediction. The prediction idea and model the paper put forward is reliable and practicable.

Keywords. El Niño; Climate; Electricity.

1. Impact of El Niño on the climate in China

1.1. Introduction of El Niño

El Niño is defined by prolonged warming in the Pacific Ocean sea surface temperatures when compared with the average value. The U.S NOAA definition is a 3-month average warming of at least 0.5°C in a specific area of the east-central tropical Pacific Ocean, other organizations defines the term slightly differently. Typically, this anomaly happens at irregular intervals of two to seven years, and lasts nine months to two years. The average period length is five years. When this warming occurs for seven to nine months, it is classified as El Niño "conditions"; when its duration is longer, it is classified as an El Niño "episode".

The first signs of an El Niño are a weakening of the Walker circulation and strengthening of the Hadley circulation and may include:

- Rise in surface pressure over the Indian Ocean, Indonesia, and Australia.
- Fall in air pressure over Tahiti and the rest of the central and eastern Pacific Ocean.
- Trade winds in the south Pacific weaken or head east.
- Warm air rises near Peru, causing rain in the northern Peruvian deserts.
Since 2000, a number of El Niño events have been observed. El Niño events were observed in 1997 – 98, 2002 – 03, 2006 – 07 and 2009 – 10. A strong El Niño has not occurred since 1997 – 98.

![MULTIVARIATE ENSO INDEX](image)

**Figure 1.** Multivariate ENSO INDEX of El Niño phenomena from 1980–2015

In December 2014, the Japan Meteorological Agency had declared the onset of El Niño conditions, as warmer than normal sea surface temperatures were measured over the Pacific, which indicates the coming of El Niño phenomena. Months later other meteorological institutions around the world (including China) had declared the arrival of El Niño conditions, in March and May 2015, respectively.

1.2. **Impact on China**

Although this global phenomenon cannot have a direct impact on China, it can indirectly affect the mainland through atmospheric circulation. Due to the sea temperatures in the Eastern Pacific has failed rising to meet expectations in the summer of 2014, its impact on summer climate in China is mainly droughts in the North China, humid and rainy in the South, East and Central China, resulting that the average summer temperature in Central and Eastern China is lower than the average level. Different from the situation in 2014, the strength of El Niño in 2015 is continually improving. It is predicted that the Songhua River basin may suffer flood situation, heavy flood may occur from the middle reaches of the Yangtze River to the western parts of South China. In the Southwest Region, mountain torrents may increase triggered by heavy rainfall and there is a great probability that the North and North-East areas are under a drought climate.

To sum up, summer temperatures in northern China is higher than the same period of normal years, but there would not be large scale and long period extreme high temperature events this summer. While, the cold air activity in Northeastern China is frequent, the temperature in summer could be in an anomaly low condition. Also, continuing precipitation in middle and lower reaches of the Yangtze River will bring down the temperature, and abnormal high temperatures will not be as significant as usual. In addition, the number of typhoon in the Northwest Pacific Ocean will be less than in a normal year.

2. **Correlation Analysis between El Niño and meteorological elements**

El Niño phenomena have an effect on not only temperature, but also humidity and wind load. Maximum electric load weather generally occurs in high temperature, high humidity and breezy weather condition. However, how to correctly reflect the heat degree is a complex question, it can’t be described accurately only relying on single meteorological element such as temperature or humidity. In recent years, the Meteorological Department usually defines the level of hot weather using body comfort index. Among these impact factors, temperature, humidity and wind are the most important. Particularly, temperature is the primary factor. Here, the paper measures the body feeling temperature $T_e$ by the following formula:
\[ T_e = 37 - \frac{37 - T_a}{0.68 - 0.172R_h + 1/(1.76 + 1.4V^{0.76})} - 0.34T_a(1 - 1.23R_h) \]  

(1)

Te=body feeling temperature, Ta=temperature, Rh=relative humidity, V=wind speed.

Since El Niño approach, the value of these factors should be revised. The general climate condition would be drought and high temperature in North China; humid, rainy and relatively hot in South China. According to historical data, in 2015 El Niño condition, the Ta should be multiplied by 1.31 in North and 1.17 in South, the Rh should be multiplied by 0.88 in North and 1.23 in South. So the revised formulas are as below.

In North China,

\[ T_e = 37 - \frac{37 - T_a}{0.68 - 0.14R_h + 1/(1.76 + 1.4V^{0.76}) - 0.29T_a(1 - R_h)} \]  

(2)

In South China,

\[ T_e = 37 - \frac{37 - T_a}{0.68 - 0.123R_h + 1/(1.76 + 1.4V^{0.76}) - 0.38T_a(1 - 0.88R_h)} \]  

(3)

3. Correlation Analysis between CLIMATE and Electricity Type

Abnormal weather caused by El Niño phenomenon would have an influence on the electricity consumption of the whole society directly or indirectly. Collect recent 10 years meteorological data and electricity data, we can do correlation analysis on them. Since 2008~2009 and 2014~2015 are judged as El Niño years, here the paper uses the revised formula to describe the Te.

Once get Te and yearly electricity consumption (Abbreviation: E), we can conduct Pearson product-moment correlation analysis which is widely used in statistics and mathematics.

Data analysis display that the correlation coefficient between Te and whole society summer electricity consumption is 0.402, presenting weak correlation. The Table 1 below shows the details.

| Table 1. Correlation coefficient between electricity and society |
|---------------------------------------------------------------|
| Whole Society | Primary Industry | Secondary Industry | Tertiary Industry | Resident |
| 0.402 | 0.079 | 0.367 | 0.410 | 0.650 |

As for the Tertiary Industry, the condition is more complex, and here the Table 2 below shows the details.

| Table 2. Correlation coefficient between electricity and different type of tertiary industry. |
|------------------------------------------------------------------------------------------|
| Transportation Industry | Warehousing Industry | Post Industry | Telecommunication Industry | Software Industry |
| 0.331 | 0.346 | -0.089 | 0.282 | 0.375 |
| Wholesale and retail Industry | Lodging and Catering Industry | Financial Industry | Real Estate Industry | Facility Management Industry |
| 0.343 | 0.438 | 0.402 | 0.384 | 0.302 |

From the table, we can see that restricted to the huge volume and the economic factors, electricity consumption of primary industry and secondary industry is not sensitive to temperature. Since the tertiary industry include a variety of industries, different item has different correlation coefficient. On
the other hand, as temperature sensitive load, resident load display strong correlation with temperature, it can be predicted that when the extremely weather condition happens during the El Niño event, the resident load is mostly influenced as it can be seen in figure 2 below.

![Figure 2. Relationship between resident summer electricity and temperature](image)

As the main influencing factors of in-used electricity quantity is the development of economy in primary, secondary and tertiary industry. While the electricity quantity used by residents mainly depends on climate. So it is known that the El Niño mostly have influence on resident electricity.

4. Prediction of Summer Electricity Consumption Based On El Nino Phenomena
To accomplish a more accurate prediction on temperature-influenced electricity consumption, the weather electricity quantity should be calculated from the entire social electricity quantity as $P = Pt + Pm + u$.

Among them, $p$ stands for entire social-used electricity quantity; $Pt$ is tendency electricity quantity; $Pm$ is weather-used electricity quantity; while $u$ stands for the contribution from random elements. Among these parameters, $u$ is barely calculated accurately, so the formula above should better be estimated as $Pm = P - Pt$. The trend-electric quantity is influenced by the development of economy and macro-economy. Both of the two factors are stable relatively, so least square method can be used here to accomplish the linear fitting function between monthly average electric quantity which can be written as $Pt = a + bT$.

Take Beijing City as an example, trend-function was created using the data of daily averaged electric quantity in the summer during the El Niño period: $Pt = -0.0053t + 2.9201$, where $R2 = 0.37109$.

Get rid of the trend-electric from daily average electric quantity, then the remaining part is daily weather-used electric quantity. The result is shown in Figure 3 below.
Figure 3. Relationship between whole society electricity, weather electricity and tendency electricity.

Depending on the weather-used electric quantity, according to formula (2) above, the comfortable temperature index has been determined by several kinds of climate factors. And the index is used as climate variables to accomplish tropic model. Considering that the relationship between daily electric quantity and temperature is not perfect linear. Square curve model regression is adopted here, and Figure 4 below shows the relationship.

Figure 4. Relationship between weather electricity and temperature.

The regression equation shows that, the change of electricity quantities related to climate ranges along with comfortable index. When the comfortable degree is 19.43, the weather-used electric quantity reaches its lowest spot. As the summer temperature gets higher, 1 comfortable index corresponds to an increase of daily weather-used electricity quantity as $0.0132T_e - 0.2565$. 
It can be summarized that, influenced by El Niño extreme climate, it comes out to be different level of increase for summer daily electricity quantity under different temperature. Thus, the prediction of electricity under extreme high temperature climate is essential. What’s more, such method can be references for electricity apartment to arrange work under extreme weather condition.

5. Conclusion
This paper focus on discovering the relationship between climate conditions and electricity consumption when El Niño event happens. By analyzing the climate characteristic, the paper firstly get different climate phenomena in different parts of China, so as to making accurate research on electricity consumption in different districts. Since the whole society electricity is comprised of tendency electricity and weather electricity, filtering the tendency electricity and getting the single weather electricity is the key point, by using basic algorithm, the paper find a method solving the problem and extract the weather electricity suitably. Once getting the weather electricity data and body feeling temperature (which contains a variety of factors such as temperature, humidity, and wind speed and so on) data, further electricity consumption prediction can be made.

The prediction method the paper proposes can be applied on practical work, which is also helpful for power grid enterprise on electricity control and prediction.

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