

# Research on the impact of extreme climate on renewable energy development

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**Abstract.** In recent years, due to the combined effects of human activities and natural factors, the global climate has been experiencing a wide range of anomalies. Complex weather and extreme weather and climate events continue to emerge, which will have a certain impact on renewable energy such as wind and solar resources. Accurate impact analysis of complex weather conditions on the spatio-temporal distribution characteristics of renewable energy, and scientific development of the global new renewable energy development layout, play a decisive role in the shape and scope of the global energy internet, and provide basic information support for the research and construction of the global energy internet. This paper analyzes the extreme weather and climate characteristics of El Niño and La Nina, and studies its influence mechanism and scope of action on the distribution characteristics of wind energy and solar energy resources in key regions of the world.

**Key words:** Extreme Climate; Global Energy Interconnection; El Niño; La Nina.

## 1. Introduction

In recent years, due to the combined effects of human activities and natural factors, the global climate has been experiencing a wide range of anomalies. Complex weather and extreme weather and climate events continue to emerge, which will have a certain impact on renewable energy such as wind and solar resources [1-3]. The Arctic wind energy resources are affected by the cold current. The solar energy resources in the equatorial region are affected by strong convection factors. The weather of El Niño and La Nina further affects the wind conditions and solar radiation intensity in other parts of the world. In addition, these complex weather factors bring new challenges to traditional resource assessment methods. Other weather factors such as cold current and strong convective weather have a greater impact on renewable energy resources such as wind and solar resources, and the mechanism of action is complex. Accurate impact analysis of complex weather conditions on the spatio-temporal distribution characteristics of renewable energy, and scientific development of the global new renewable energy development layout, play a decisive role in the shape and scope of the global energy internet, and provide basic information support for the research and construction of the global energy internet. This paper focuses on the causes and characteristics of El Niño and La Nina phenomena, and draws on relevant research results to analyze the possible impacts and mechanisms of El Niño and La Nina on wind energy and solar energy resources [4-7].



## 2. El Niño/La Nina phenomenon

### 2.1. Basic characteristics of the El Niño/La Nina phenomenon

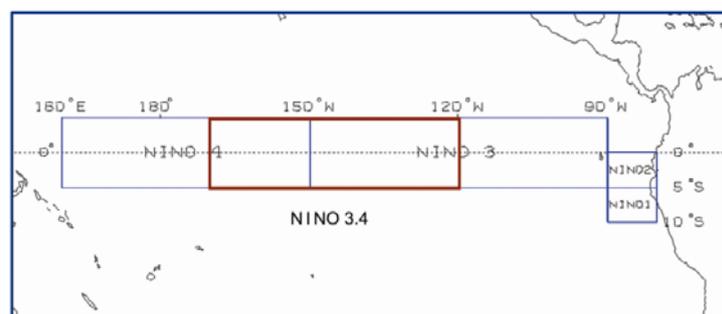
The word El Niño comes from the transliteration of the Spanish "EL Niño", the original meaning is "the son of Jesus - the Holy Child." It is a marine phenomenon along the coast of Peru in South America. The first report of Dr. Luis Carranza, President of the Lima Geophysical Association of Peru in 1891, in the association's bulletin, found that there was a warm current from north to south which is the opposite of normal ocean currents. The normal ocean current should be from the south. Because of this reverse warm current, it always appears shortly after Christmas every year, and it also brings a lot of catch to the local fishermen. So it is called El Niño, symbolizing God's gift or gospel. It is clear that El Niño originally referred to the annual natural warming of the sea along the coast of Peru. Subsequent observations also found that the abnormal warming of seawater along the coast of South America every few years is specifically referred to as the El Niño phenomenon. With an understanding of the SST over the tropical Pacific, the anomalous warming of the seawater that occurs on the South American coast is not a local phenomenon, but rather an extension of the abnormal increase in sea surface temperature over a larger area of the equatorial central and eastern Pacific[8,9].

La Nina literally means "little girl, saint" and sometimes called "anti-El Niño". It refers to a phenomenon in which the water temperature in the eastern Pacific near the equator is abnormally declining, which is manifested by the apparent cooling of the eastern Pacific.

### 2.2. Quantitative criteria for El Niño/La Nina phenomenon

The quantitative definition of the El Niño/La Nina event is as follows: in the five latitudes of the equator above and below the equator, the waters of the Middle East and the Pacific between 160°E and 85°W are used as the sea area for determining El Niño. In this sea area, the average sea surface temperature is divided into four regions as the regional average as shown in Figure 1. The red coil area is the Niño 3.4 area, and its average (time and space average) sea surface temperature is often used as the main basis for El Niño. If the sea surface temperature in the region lasts (3~6 months or more) is 0.5°C higher than other regions, or if the SST anomalies in the region (above 3 months) are higher than 0.5°C, it is determined to be El Niño. The corresponding anomaly value is defined as the "Niño Index"[10-13].

This is because when the SST is warmed to this extent, the obvious climate anomaly will occur under the heat generated by the abnormal SST. La Nina as a counter-phenomenon of "El Niño", during which the cold flow from the south to the north of the Peruvian coast became stronger and colder. The negative SST anomalies in the Niño 3.4 area exceeded -0.5 °C for more than three consecutive months. . If the absolute value of the extreme value of the index exceeds 1.0 ° C, it is a strong El Niño and La Nina event.

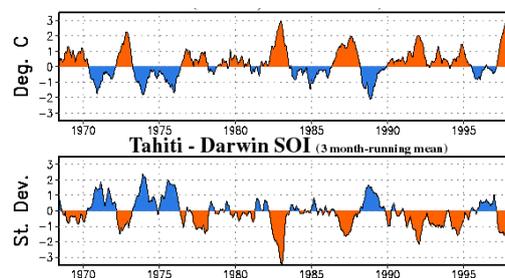


**Figure 1.** Division of sea surface temperature monitoring in the eastern equatorial Pacific.

The mention of the El Niño phenomenon must also mention another important meteorological concept - Southern Oscillation. Gilbert Walker found that there is a seesaw relationship between the

pressures of the Indian Ocean and the Western Pacific in the Southeast Pacific from the global temperature, pressure and precipitation data. That is, when the pressure in one area increases, the pressure in the other area decreases. Therefore, this inverse correlation of sea level pressure on both sides of the Pacific Ocean is called Southern Oscillation. According to the theory of Walker, meteorologists selected the Tahiti station to represent the southeastern Pacific, selected the Darwin station to represent the Indian Ocean and the western Pacific, and applied mathematical statistics to process the sea level pressure difference between the two stations to obtain a measure of the south, which called the Southern Oscillation Index (SOI).

This inverse correlation between the atmospheres on both sides of the Pacific Ocean is closely related to changes in ocean surface temperatures. When the sea level temperature in the eastern equatorial Pacific increases, the sea temperature in the west tends to decrease, and the seawater with higher temperature decreases the atmospheric pressure above it. The seawater with a lower temperature increases the atmospheric pressure above it. Compared with the normal situation, the upper air pressure will increase in the east and decrease in the west, and the southern oscillation index will decrease to a negative index; otherwise, it will be a positive index. Combine them together and name them ENSO, which is the abbreviation of El Niño and Southern Oscillation. Normally, the smooth time series of SOI corresponds to the change in SST in the eastern equatorial Pacific. The long negative phase of the SOI index corresponds to a typical El Niño event, and the positive phase corresponds to a typical La Niña event. The time series of SOI and East Pacific sea surface temperature shows that although the ENSO cycle in the history changes between 2 and 7 years, on average there are about four cycles alternating. The ENSO cycle was very active during the 1980s and 1990s, with five occurrences (1982/83, 1986/87, 1991/92, 1994/95 and 1997/98) and three La Niña events (1984/85, 1988/89, 1995/96). Among them, 1982/83 and 1997/98 had two strong events, and between 1991 and 1995 were two consecutive El Niño events, with no cold incident involved [14-16].



**Figure 2.** Time series of sea surface temperature anomalies (a) and SOI index moving averages in Nino 3.4 area.

### 3. Impact on the climate of El Niño/La Nina

Atmospheric motion affects the flow of ocean surface waters, which are a treasure trove of atmospheric energy. During the El Niño, the sea temperature in the central and eastern Pacific Ocean is often 1~3°C higher or even more. The atmosphere absorbs the heat and water vapor of the ocean and becomes active. The air is wet and warm and rises upwards. It rises to a certain height and the condensation of water vapor causes rain, which directly increase the precipitation of this generation. The countries along the coast of South America are extremely rainy and even cause floods disaster. The eastward movement of the convective zone has led to a significant reduction in precipitation in the western Pacific and droughts in Indonesia, eastern Australia and surrounding countries. Disasters such as floods and droughts in these countries are almost in sync with the formation of El Niño. Atmospheric circulation transmits anomalous signals from the tropics to other parts of the tropics and to the mid- and high-latitude regions, affecting many parts of the world. El Niño often causes drought in southeastern Africa and northeastern Brazil, warm winters in western Canada and northern United States, and wet and rainy winters in the southern United States. It is also related to precipitation in China and Japan, northeastern China, and summer low temperatures in Japan.

La Nina's impact on the climate is roughly the opposite of El Niño, and the impact is not as strong as El Niño. When La Nina occurred, precipitation on the coast of South America was even rarer. Indonesia and eastern Australia were rainier. In the equatorial oceans, droughts often occurred in the east, Argentina, Equatorial Africa, and the southeastern United States; floods were common in northeastern Brazil, India, and southern Africa.

#### 4. Impacts on wind and solar resources of El Niño/La Nina

The El Niño phenomenon will generate strong atmospheric circulation anomalies in the tropics, which will directly affect the intensity of the Hadley circulation and the Walker circulation at low latitudes. Due to the transport of matter and energy by them and other transport ties, resulting in different latitudes. And the interaction between the same latitude changes. In this context, the distribution of renewable resources directly related to the distribution of wind speed and solar radiation is bound to produce anomalies, so in this section we assess the spatial variation of renewable resources under the influence of ENSO.

Using the Nino 3.4 index provided by NOAA, according to the criteria for strong El Niño/La Nina events, five El Niño and four La Niña events were selected from all abnormal years between 1979 and 2010, based on ground reanalysis data for that year. And then, based on the ground reanalysis data of the year, wind energy and solar energy resources are evaluated.

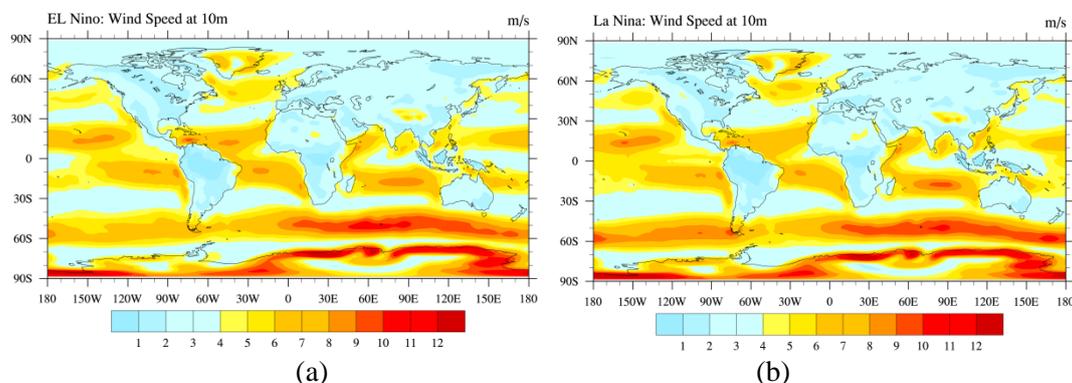
The ground wind speed data and radiation data used are from the reanalysis data of the National Center for Environmental Prediction (NCEP). The data space grid is the global T62 Gaussian grid and the time resolution is the monthly average.

**Table 1.** 1979-2010 El Niño/La Nina Year.

Type	Year number	Year
EL Nino	5	1982, 1987, 1992, 1997, 2002
La Nina	4	1984, 1989, 1999, 2008

##### 4.1. The impact of El Niño/La Nina on wind energy resources

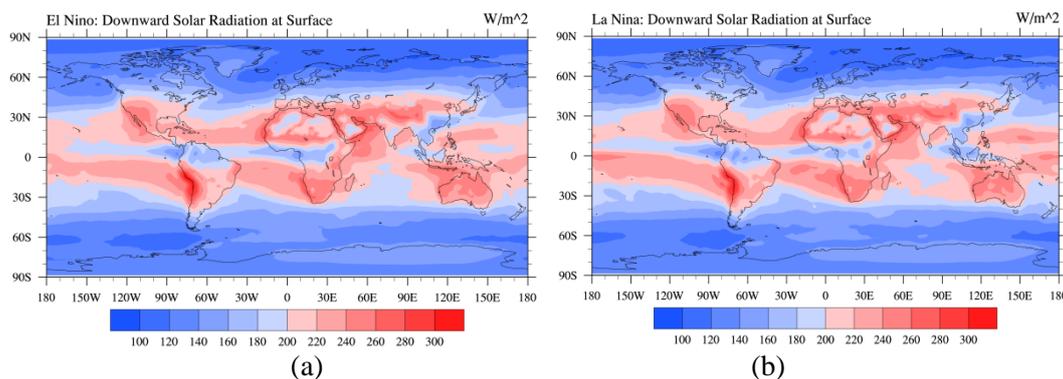
Figure 2-9 shows the variation of near-surface wind speed under two types of climate anomalies. It is found in the comparison of warm events (El Niño: Figure 2-9a) and cold events (La Niña: Figure 2-9b). In the anomalous tropical Pacific region, the wind speed on the east coast of the ocean and the west coast of the ocean decreased during warm events, and the wind speed in the central Atlantic increased. It is seen from the difference between the two that the wind speed in the Eurasia has increased, the wind speed in the east coast has decreased, the wind speed in the North American continent has decreased slightly, and the wind speed in most parts of South America has increased. The wind speed in Africa and Australia is small and there is no obvious law.



**Figure 3.** Annual average wind speed distribution in El Niño (a) and La Nina (b) years

#### 4.2. The impact of El Niño/La Nina on solar energy resources

Figure 5.4 shows the solar short-wave radiation distribution received by the ground under two types of climatic anomalies. It is found in the warm event (Fig. 2-10a) and the cold event (Fig. 2-10b) that the sea in the eastern tropical Pacific is warmer. This will increase the annual average of the region, and the amount of radiation in the central region will decrease, while the solar radiation received in the western Southeast Asia will increase significantly. From the difference between the two, in the El Niño year, the Eurasia and South American continents will have less ground radiation in most of the mid-latitudes, and the radiation in most parts of Africa and South America will increase, high latitudes. The amount of radiation will increase.



**Figure 4.** Average ground receiving short-wave radiation distribution in El Niño (a) and La Nina (b) years

## 5. Conclusion

Complex weather and extreme weather and climate events continue to emerge, which will have a certain impact on renewable energy such as wind and solar resources. This paper analyzes the extreme weather and climate characteristics of El Niño and La Nina, and studies its influence mechanism and scope of action on the distribution characteristics of wind energy and solar energy resources in key regions of the world. The main conclusions are as follows:

(1) Impact of the El Niño/La Nina event on wind energy: In the El Niño and La Nina events, the changes in the position and intensity of the Hadley circulation and the Walker circulation combined with the changes in the monsoon system are important reasons for the regional differences in the annual low-level wind speeds, which in turn affects the distribution and size of wind energy resources.

(2) The impact of the El Niño/La Nina event on solar energy: The results of the relationship between El Niño and La Nina's annual abnormal years and cloud cover indicate that in the El Niño event, the tropical ocean temperature is significantly increased, which is conducive to ocean evaporation and easy to generate cloud cover. It is stacked, so there are deep clouds in the tropics, and the large value is located in the central and western Pacific Ocean. In the La Niña event, due to the low temperature of the tropical ocean, the interaction between the tropical air and sea is weak, and the evaporation of the ocean is less, which is not conducive to the cloud. The formation of clouds is lower than the average, and is most pronounced in the central equatorial Pacific and the eastern equatorial Pacific. Since the global potential solar energy resources are mainly concentrated in low latitudes, from the above changes in the low-latitude cloud amount, the cloud radiation reduction to the ground will also change in the abnormal year, although the cloud type, thickness, etc. The reduction of radiation is not the same, but the amount of solar radiation received by the ground will still change with the amount of cloud.

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