El Nio-Southern Oscillation variations based on a background of global warming

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Abstract. ENSO stimulates large-scale teleportation by modulating convection heating anomalies in the tropics of the Pacific, which in turn affects agriculture, ecosystems and the global climate worldwide. The tropical Pacific precipitation anomaly excited by ENSO moves eastward as the central Pacific region sea surface temperature continues to rise. In order to observe and study this anomaly, the sea surface temperature and rainfall changes in the Pacific region is investigated. The impact of global warming on human society is introduced, and then the data sources and reasons for selection are introduced. Then use the data to draw and analyze, the most results and explain the reasons, indicating the importance of the study.

Keywords: ENSO, global warming, precipitation, SST

1. Introduction

As a strong inter-annual climate change in low latitudes, the most prominent manifestation of the ENSO cycle is the large-scale atmospheric pressure and temperature oscillations on the Indian Ocean and tropical Pacific sea surface [1]. Every 2–7 years, the cold and hot phases of ENSO cycle will occur East Equatorial Pacific and Indonesia – Australia. The anomalous fluctuation of ocean-atmosphere interaction caused by ENSO events has a huge impact on all regions of the world, especially in the winter of the year (December to February of the next year), the ENSO osscillation will reach the peak [2]. Each occurrence of ENSO events will cause severe droughts and floods around the world. ENSO phenomenon from 1997 to 1998 led to continuous rainstorms in the Americas, while continuous droughts and large-scale forest fires occurred in Southeast Asia.

Human activities have caused extremely serious impacts on climate change and earth ecology: The atmosphere and ocean temperature increased significantly, and the sea level increased year by year [3]. But following the abnormal climate change caused by global warming, these climatic factors will be more and more unpredictable and unstable using the previous climate models. To better predict the future climate change, the IPCC sixth Assessment Report proposes a more reliable emission pathway, SSP (Shared Socioeconomic Pathway) to correct the inaccuracy parts in RCP (Representative Concentration Pathway) [4]. This is a stark illustration of the increasing effects of global warming and also reflects the awareness of scientists that studying and addressing global warming has become an important part of meteorological research and forecasting

Due to the great impact of global warming on the ocean, there are also many problems to be explained in the study of ENSO activities. For example, whether different CO2 emission scenarios are related to precipitation anomalies and eastward shift trends caused by ENSO oscillations in the Pacific, the mechanism and causes of eastward shift of ENSO, etc. As a result, the study of ENSO in the context of global warming is vitally important.

2. Methods

The global average of sea surface temperature (SST) data measured by The NOAA Physical Sciences Laboratory (PSL) from 1850 to the present (https://psl.noaa.gov/) is used in this paper. Data extracted from 1990 to 2020 is used in this reserach. In the study of precipitation changes in the Pacific region, we selected the global mean precipitation data released by PSL to avoid errors caused by data source and resolution.

Because ENSO events have an impact on the ocean and land. Many meteorological elements such as sea surface temperature (SST), atmospheric pressure, rainfall, etc. have changed in varying degrees, and there are direct or indirect effects between these meteorological elements. Based on previous observations and assessments of ENSO events, observation and record of sea surface temperature change is not as accurate as before and wind fields separately due to the impact of global warming-induced sea surface temperature anomalies on the positive feedback process of the ENSO cycle [5]. In order to more concisely and accurately represent the intensity of ENSO events, El Niño index is used and the mixed El Niño index from 1950 to 2020 is selected to represent the intensity of ENSO events [6].

$$Mixed\ type = EP + CP \approx Niño3.4_{normalized} \tag{1}$$

$$EP = Niño3_{normalized} - 0.5 * Niño4_{normalized} \tag{2}$$

$$CP = Niño4_{normalized} - 0.5 * Niño3_{normalized} \tag{3}$$

$Niño3_{normalized}$, $Niño4_{normalized}$ and $Niño3.4_{normalized}$ are the standardized SST abnormality in Niño3, Niño4 and Niño3.4.

3. Results

3.1. The changes in climate system by global warming

Since 2019, the average temperature has been increased about 1.1 °C worldwide, comparing with the pre-industrial levels. Since the 1980s, the temperature in each continuous decade is warmer than the previous. In 2022 summer, many cities in all around the world have experienced unprecedented high temperature and heavy rainfall. From the data in National Climate Centre in China, it shows that the average number of high temperature events in China since June was about 5.3 days, 2.4 days more than the same period in the regular year, the highest since 1961. In terms of rainfall, severe regional floods have also appeared throughout China, with higher annual rainfall than previous. Coastal areas are also affected by seasonal climate phenomena from marine such as typhoons and other disasters.

In the case of global warming, various global climate factors are changing. In terms of precipitation, condensation and water vapor transfer account for the majority of the uncertainty surrounding long-term changes in precipitation under global warming [7]. The quantity of water vapor in the atmosphere rises as a result of greenhouse gas emissions. As a result, the trend of precipitation data predicted in the past has also fluctuated greatly, increasing the uncertainty. In addition, changes in global precipitation are associated with surface energy budgets and convection through evaporation [8,9,10]. Now, the surface and tropospheric temperatures have continued to increase due to rising GHG concentrations in the air, resulting in a decrease in the amount of tropospheric radiation absorbed from the outside world. But at the same time, in order to ensure the surface energy balance, atmospheric latent heat must be increased to balance this cooling, resulting in increased precipitation.

Similarly, global warming has a large impact on the global monsoon and the circulation area. For instance, some studies indicate the close connection with sea surface temperature (SST) and variation of global monsoon circulation. The rapidly increasing of greenhouse gases (GHG) concentrations arouse a positive correlation with mean surface temperature and cause an elevation of the inter-hemispheric temperature gradient and land-sea thermal contrasts, driving the global monsoon have a trend to move northwards [11, 12]. Based on the simulation with CMIP6 model, it was found that the Indian summer monsoon precipitation increased significantly in this century under the overall warming scenario. At the same time, the global summer monsoon precipitation increment in the low emission model is significantly stronger than that in the high emission model.

3.2. Impacts caused by Global Warming on ENSO

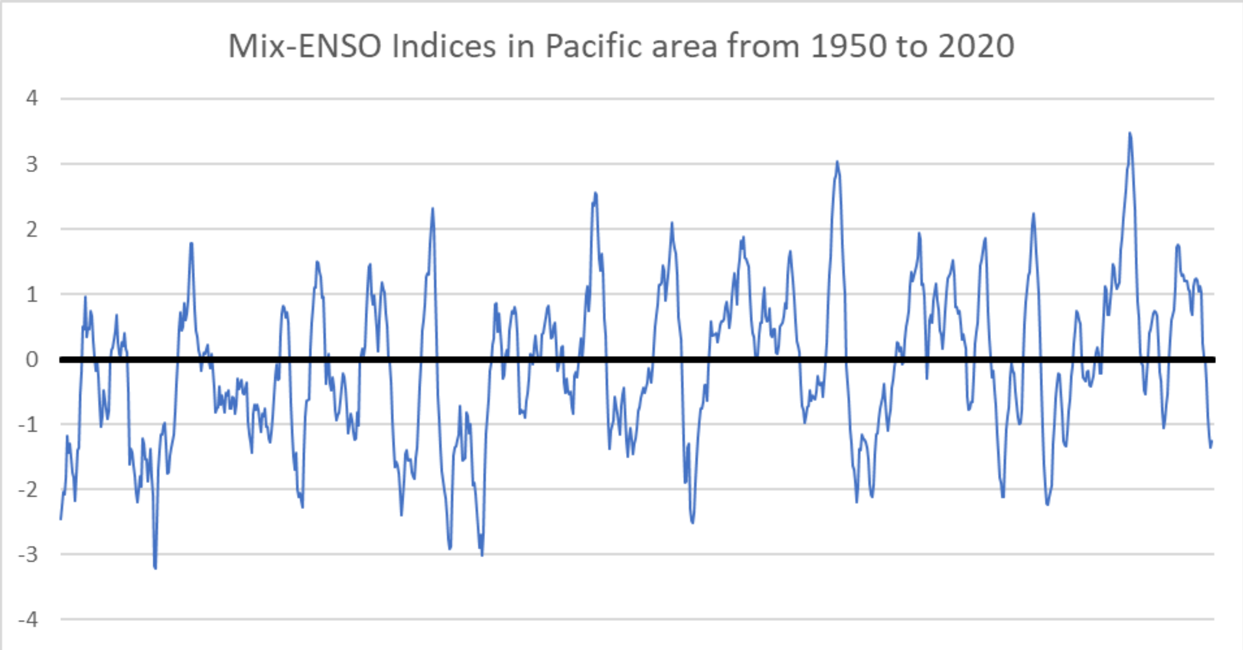

Fig. 1 Indices for El Niño on the center Pacific (EP) region from1950 to 2020

From the results on EP regions, since the mid-19th century, the intensity of ENSO has gradually increased, and the frequency and intensity of warm (positive) phase events are significantly higher than those of cold (negative) phases, which also indicates that the global climate mean state has become unstable due to human activities. At the same time, due to the increase of the positive phase period, it is expected to lead to the weakening of the cold water overturning activity along the equatorial eastern Pacific coast, the increase of the thermocline depth and the abnormal increase of the sea surface temperature. If the prediction is correct, the impact on rainfall and sea surface temperature will be reflected from the following figure. Changes in these underlying factors are also estimated to have an impact on atmospheric circulation and other climatic elements, but the results are unclear.

3.3. Current trends of ENSO precipitation and evaluation of the results

Due to the long duration of ENSO events, generally in about 2-7 years. It is not meaningful to count the rainfall data of a certain time when ENSO occurs to indicate the precipitation caused by the current ENSO time, and it is more prone to errors. However, if the recording time of the data is too long, it will be due to the increasing global warming. It is necessary to consider the change trend of greenhouse gases such as CO_2 in the air in the data statistics. At the same time, climate change caused by the increase of CO_2 content in the atmosphere will also change marine physical factors, such as marine carbon stocks; when the concentration of CO_2 in the atmosphere increases due to human activities such as automobile exhaust and industrial emissions, the radiative forcing from CO_2 in the atmosphere gradually increases [13]. Shifting the carbon cycle and carbon storage in the ocean are not isolated. Reducing the absorption of marine carbon from climate change could in turn speed up the growth of CO_2 in the atmosphere [14]. Therefore, we use the global average precipitation data released by PSL, only the monthly average precipitation data recorded from 1990 to 2020 are selected for 10-year moving average processing to avoid the impact of time span. The results are as follows:

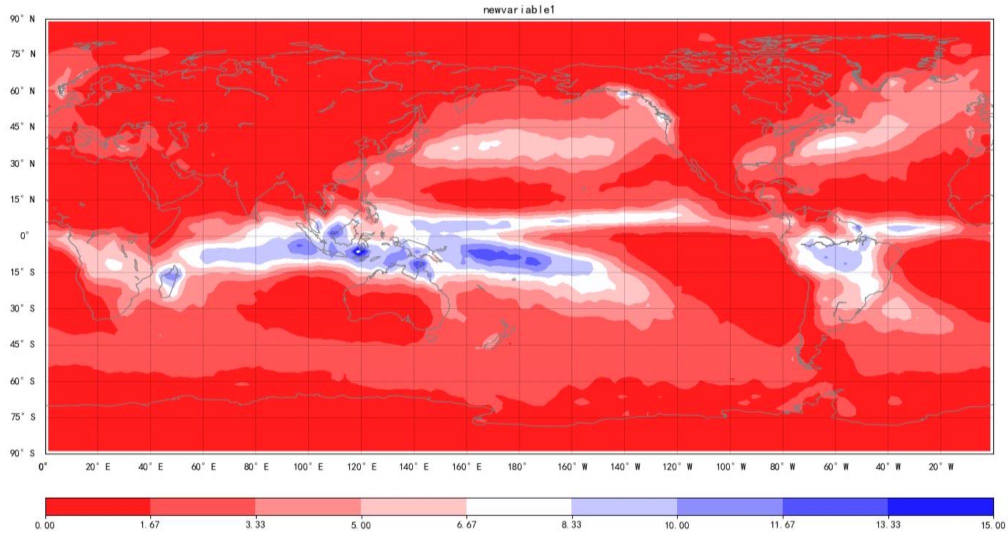

Fig. 2 Global Average Precipitation in ENSO mature period in winter from 1990 to 2000 [15]

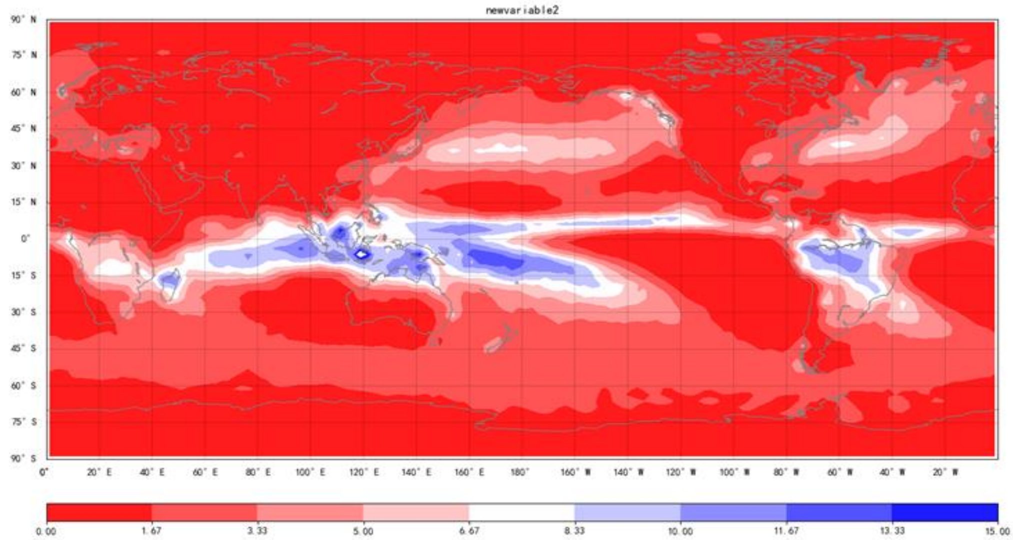

Fig. 3 Global Average Precipitation from 2000 to 2010 [15]

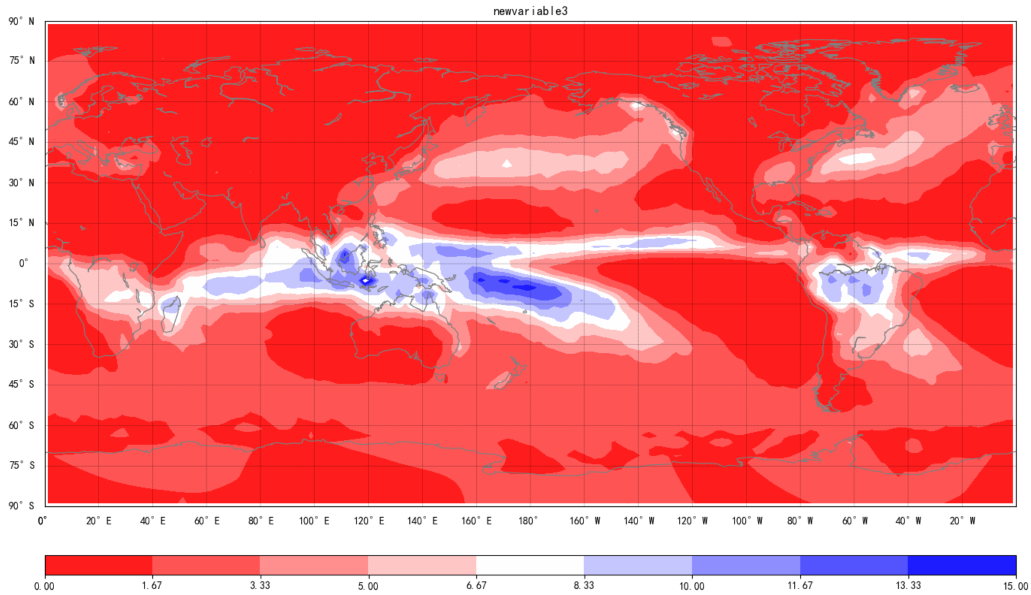

Fig. 4 Global Average Precipitation from 2010 to 2020 [15]

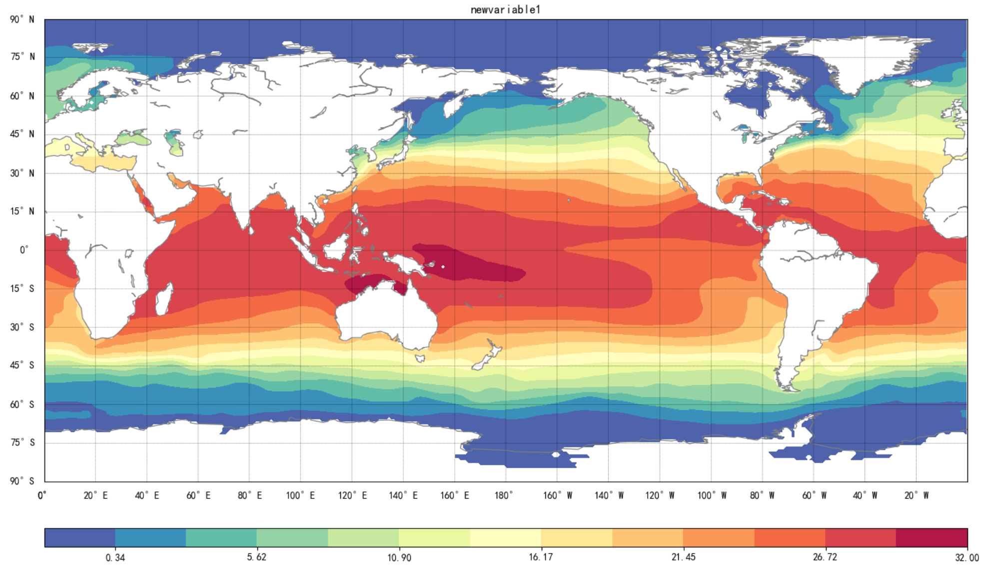

Fig. 5 Global Average SST in winter from 1990 to 2000 [15]

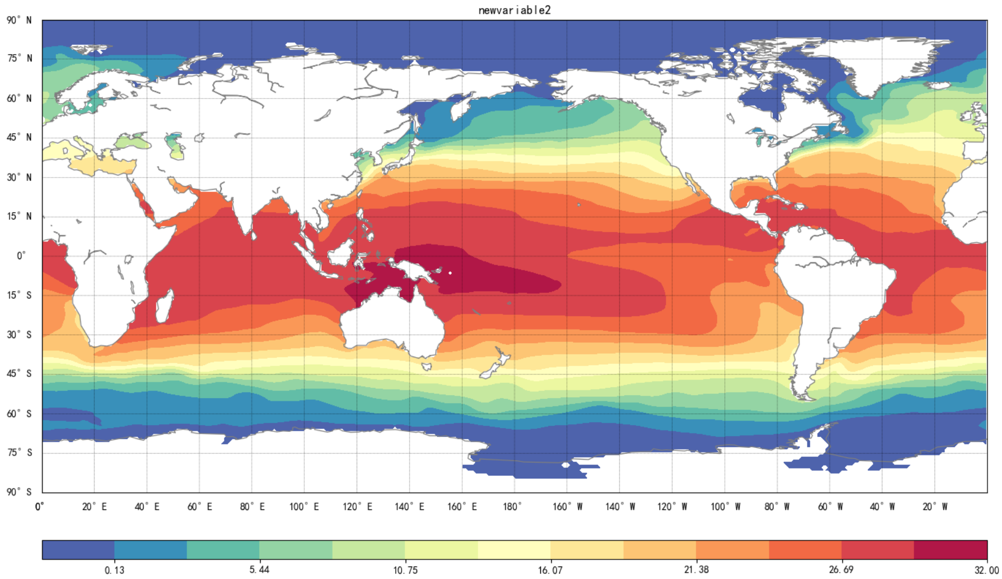

Fig. 6 Global Average SST from 2000 to 2010 [15]

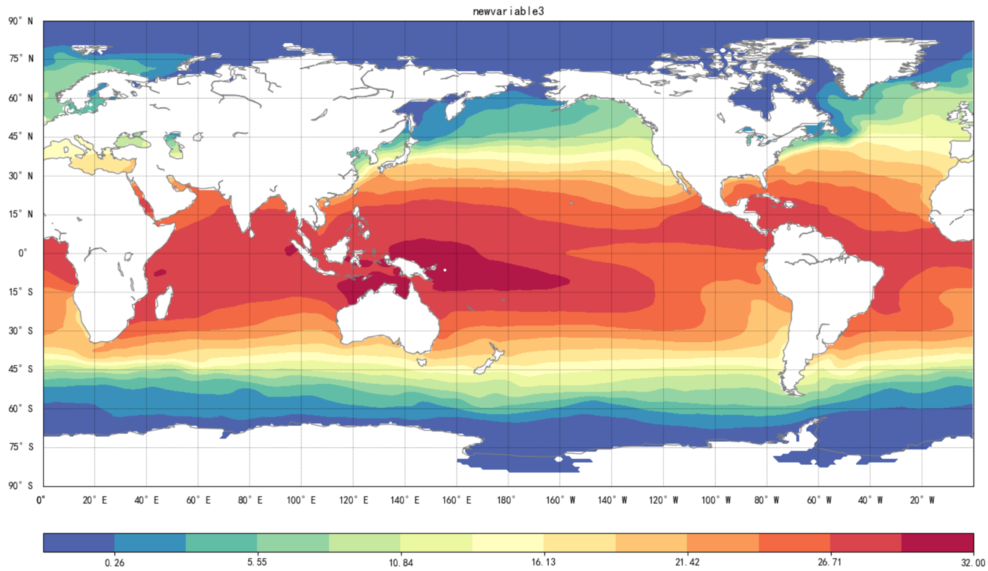

Fig. 7 Global Average SST from 2010 to 2020 [15]

The assessment in Fig.2, Fig.3 and Fig.4 shows that the average annual rainfall in the equatorial Pacific is generally higher during the mature period of ENSO events. At the same time, according to the definition of Niño3.4 _ normalized, the average winter rainfall in the west of Niño3.4 region (Niño4 region) has remained the highest in the world. Between 1990 and 2000, the average winter rainfall in Niño 3.4 was about 10.5 millimetres, after which rainfall gradually increased. From 2010 to 2020, the maximum average rainfall in the Niño3.4 area reached more than 13 mm. At the same time, in terms of the regional distribution of rainfall, we found that under the current global warming trend, the rainfall caused by the ENSO cycle is gradually moving eastward. Until 2020, the impact of ENSO on precipitation in the central Pacific has completely covered the central and eastern tropical regions of the Southern Hemisphere. Rainfall is also moving eastward in the North America - Pacific region.

The areas where El Nio and La Nia occurrences are most common coincide with the regions with the warmest sea surface temperatures during the winter. By 2020, the central Pacific will also be affected by ENSO's effects on sea surface temperature. The development of high temperature zones is particularly visible, especially between 1990 and 2010. These demonstrate the influence of ENSO on the Pacific region and the major influence of global warming on ENSO events, as evidenced by the rising sea surface temperature close to the west coast of North America.

According to earlier research on the equatorial Pacific circulation and sea surface temperature, we are aware that abnormally increased SST might alter atmospheric convection in the Pacific, which in turn affects anomalies in tropical and temperate climates [16,17]. At the same time, El Niño and La Nina phenomena can also cause tropical and temperate climate anomalies after reaching maturity. These commonalities have also become the entry point for many scholars. The eastern equatorial region experiences more atmospheric convection as a result of the surface warming over the equatorial Pacific being greater than the warming of the surrounding seawater, according to research findings from Cai W J in 2015 [18] about the relationship between ENSO oscillation and greenhouse warming. This conclusion also supports the notion that there is a direct relationship between rising ENSO index and corresponding growth and expansion [18].

4. Conclusion

ENSO is a significant signal of interannual and interdecadal climate change on a global scale, and is closely related to various climate phenomena such as global monsoon and atmospheric circulation. However, the causes of ENSO have not been fully understood. Therefore, studying the changes of meteorological factors caused by El Niño-Southern Oscillation is an important part of studying the interaction between land and sea under the increasingly serious global warming effect. At the same time, it is also an important step to improve the accuracy of marine climate prediction and develop a more reliable meteorological prediction system, making outstanding contributions to social and economic development and daily life.

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