Scientific Research Publishing

Atmospheric and Climate Sciences, 2024, 14, 233-249
https://www.scirp.org/journal/acs
ISSN Online: 2160-0422
ISSN Print: 2160-0414

El Niño-Southern Oscillation (ENSO) Variations and Climate Changes Worldwide

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How to cite this paper: Hagen, M. and Azevedo, A. (2024) El Niño-Southern Oscillation (ENSO) Variations and Climate Changes Worldwide. *Atmospheric and Climate Sciences*, **14**, 233-249.
https://doi.org/10.4236/acs.2024.142015

Received: March 11, 2024
Accepted: April 16, 2024
Published: April 19, 2024

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Abstract

This investigation aims to study the El-Niño-Southern Oscillation (ENSO) events in these three phases: El Niño, La Niña, and neutral. Warm and cold events relate to the Spring/Summer seasons. This paper will search for connections between the ENSO events and climate anomalies worldwide. There is some speculation that those events would be necessary for the climate anomalies observed worldwide. After analyzing the data from the reports to the ENSO, it shows almost periodicity from 1950-2023. We emphasized the occurrence of El Niño two years, when it was most prominent, and the climate anomalies (following NOAA maps), 2015 and 2023. The results indicated that the observed climate anomalies couldn't be linked to the abnormal events observed. The worldwide temperatures in those years enhanced mostly in 2023. It shows an abnormal behavior compared with all the years scrutinized and analyzed since the records began. Therefore, there must be unknown factors beyond ENSO that rule the worldwide temperatures and the climate anomalies observed.

Keywords

ENSO, Southern Oscillation, El Niño, Climate Anomalies

1. Introduction

ENSO is paramount on Earth because it can change global atmospheric circulation, influencing temperatures and precipitation worldwide. ENSO has three states or phases: two opposite phases, El Niño, La Niña, and Neutral.

El Niño warms the ocean surface, causing sea surface temperatures (SST) to rise in the central and eastern tropical Pacific Ocean.

La Niña is cooling the ocean surface, or below-average sea surface tempera-

tures, in the central and eastern tropical Pacific Ocean. Neutral means the absence of the two other phenomena. Sometimes, the Ocean seems like it is in El Niño or La Niña state, but the atmosphere is not playing along (or vice-versa) [1].

El Niño and La Niña both happen in the tropical South Pacific Ocean, developing high pressure alternating the tropical Indian Ocean experiments with low-pressure conditions. However, the pressure conditions may reverse, resulting in low pressure in the Pacific and high pressure in the Indian Ocean [2] [3].

El Niño and La Niña have opposite phases of a naturally occurring global climate cycle known as the El Niño Southern Oscillation, or ENSO. ENSO influences rainfall, temperature, and wind patterns around the globe, including New Zealand [4].

What causes El Niño and La Niña events? The cycle is the consequence of slow feedback in the ocean-atmosphere system acting alongside the air-sea solid interaction processes in the tropics that allow the growth of minor disturbances to the large-scale ocean state. Usually, the equatorial Pacific Ocean has a pool of relatively warm water in the upper Ocean in the West and a shallower layer of relatively cool water in the East, maintained by and in balance with easterly surface winds. The well-mixed upper ocean layer (a few tens of meters deep) lies above a thin "thermocline" layer, with icy water below. An El Niño event can start in several ways, usually with the sea surface temperature raised slightly in the central/east Pacific. This may be, for example, through the action of "westerly wind bursts" (short-lived storm-like events in the Western Pacific) that disturb the "balance" maintained by easterly winds or through the slow evolution of the ocean thermocline because of a previous event. The increased sea surface temperature influences the atmospheric winds, which affect the upper Ocean and the thermocline such that the sea surface temperature is increased further—a positive feedback. When conditions are favorable, this feedback generates an El Niño event.

El Niño warms the waters in the Pacific, causing the Pacific jet stream to move south of its neutral position. The Northern Pacific, the U.S., and Canada became dryer and warmer than usual with this shift. Nevertheless, during the stronger El Niño, it is wetter in the Southeast, and the flooding is increasing.

Nowadays, the name "El Niño" is widely used to describe the anomalous sustained warming of sea surface temperature every few years, typically concentrated in the central-east equatorial Pacific.

La Niña is a "cold event", trade winds becoming more potent than usual, pushing warm water toward Asia. The icy waters in the Pacific move the jet stream northward. The tendency is to lead to drought in the southern U.S., heavy rains, and flooding in the Pacific Northwest and Canada (2020-2023). During La Niña, winter temperatures are warmer than usual in the southern hemisphere and cooler than average in the north. El Niño and La Niña events are self-limiting, evolving so that the equatorial sea surface temperatures gradually return to normal, and the event ends after several months. Often, the system overshoots to

start the opposite phase of the cycle rather than return to neutral conditions. An essential feature of the ENSO cycle is that its evolution is predictable. Such events result from stout and extensive interactions between the Ocean and the atmosphere. They are associated with widespread changes in the climate system that last several months and can lead to significant socio-economic impacts affecting infrastructure, agriculture, health, and energy sectors, for example. The ENSO cycle is illustrated in the figure by a time series of the monthly sea surface temperature anomalies in a region of the central equatorial Pacific. This "Niño3.4" region (5˚S - 5˚N, 120˚W - 170˚W) is one of several used to monitor changes in the tropical Pacific. Definitions vary, but as a guide, the El Niño and La Niña episodes occur when anomalies in this region are more significant than about 0.5˚C in magnitude for several months. While a typical episode might last for three or four seasons, peaking in size in boreal winter, the time series demonstrates that events are not entirely regular and have assorted sizes and durations. The climate system does not always alternate between El Niño and La Niña: the same event can occur successively or be sustained over several years.

The ENSO cycle is a natural climate phenomenon; proxy evidence (e.g., coral growth rate measurements) indicates that ENSO has been active for thousands of years. ENSO events have widespread effects on seasonal weather and climate through their influence on large-scale circulation patterns [4].

The name "ENSO" is a reminder that close interaction between the atmosphere and Ocean is an essential part of the process. While the global climate system contains many processes, ENSO is the dominant feature of climate variability on inter-annual timescales [5].

The event is a periodic change; it is named Southern Oscillation. When those oscillations combine with El-Niño, it is called ENSO or El-Niño Southern Oscillation. The Southern Oscillation Index (SOI) measures the intensity or strength of the Walker Circulation [6]. SOI measures the differences in surface air pressure between Tahiti and Darwin. Prolonged periods of negative SOI values coincide with abnormally warm ocean water across the eastern tropical Pacific, typical of El Niño episodes. Extended periods of positive SOI coincide with abnormally cold ocean waters across the eastern tropical Pacific, typical of La Niña episodes.

In the period 1980-1990, five El Niño episodes and three La Niña events occurred. The longest episode was La Niña 1998-2001, with approximately 30 months duration, and the neutral waters during 36 months from 1980-1982.

La Niña is periodically recurring for two or seven years—the latest La Niña started in 2020 Spring lasts until January 2023. La Niña appears when energized easterly trade winds intensify the upwelling of cooler water from the depths of the eastern tropical Pacific Ocean surface near the Equator. El-Niño and La Niña are opposite phases of the El-Niño-Southern Oscillation (ENSO) cycle, with La Niña referred to as the cold phase of ENSO and El Niño as the warm phase of Enso [7].

The effects of La Niña are to alter the global atmospheric circulation. They can

cause shifts in the path of mid-latitude jet streams to intensify rainfall in some regions and droughts in others. In North America, weather typically becomes warmer and drier, causing cooling and stormier conditions often across the Pacific Northwest; weather typically becomes warmer and drier across Southern USA and Northern Mexico. La Niña and El-Niño vary with seasons, most vital in December. Much of the USA's average above-normal rainfall in many western states will dry out after a wet, cool winter [8] [9].

NOAA, National Oceanic and Atmospheric Administration Climate Prediction Center (CPC) monitors changes in sea surface temperatures (SSTs) in the tropical Pacific Ocean to forecast the onset and track the life cycle of El Niño events. Our paper will study El Niño and La Niña separately, the events occurring during the extensive La Niña events, and the same for El Niño. El Niño recurs at some time, the maximum when it started in 2014 and lasts 19 months.

From 1950 to 2023, 24 El Niño episodes occurred using NOAA's Oceanic Nino Index. This paper will overview El Niño and La Niña and their weather-related anomalies. The Climate Prediction Center (NOAA) published a Table (**Appendix**) with the "Cold & Warm episodes by Season". The description pointed out that warm (red) and cold (blue) periods are based on a threshold of +/− ˚C for the Oceanic Nino Index (ONI). Natural episodes have no color; when they surpass +/−0.5˚C they will become red or blue. In the next section of this paper, we calculate the periods when El Niño became more active, analyzing its climatic effects. We do the same thing with La Niña. Last, it compares the impact of both events and their consequences on significant climate anomalies and events worldwide for each time. Our following paragraphs are all based on the NOAA data, the Oceanic Nino Index, and the worldwide climate anomalies for each year chosen to study El Nino variations.

2. El Niño, La Niña Evolution

2.1. El Niño Events

First, we found the years when we had El Niño uninterruptedly during a significant period happened two times in the range 1950-2023; the first was 1986-1988 for 18 months, and the second was 2014-2016 for 19 months. Since El Niño is a seasonal event occurring during the Summer in the Southern Hemisphere, those anomalies may start during late Spring and finish in late Summer. The interval between those two anomalies for El Niño took 28 years to repeat the same pattern. **Figure 1** shows the El Niño occurrences in the period 1950-2023. El Niño has only two extended periods, one in 1987 and the other in 2014. Overall, El Niño is the shortest event compared with La Niña or the neutral waters in the region. Its last appearance was in 2019, lasted six months, and at the end of 2023, when it is still going. Our analysis takes the 2014-2016 interval to examine the worldwide climate anomalies. El Niño happened for 19 months. We searched the same for La Niña and found a different result. In the same period (1950-2023), La Niña happened seven times with dissimilar intervals.

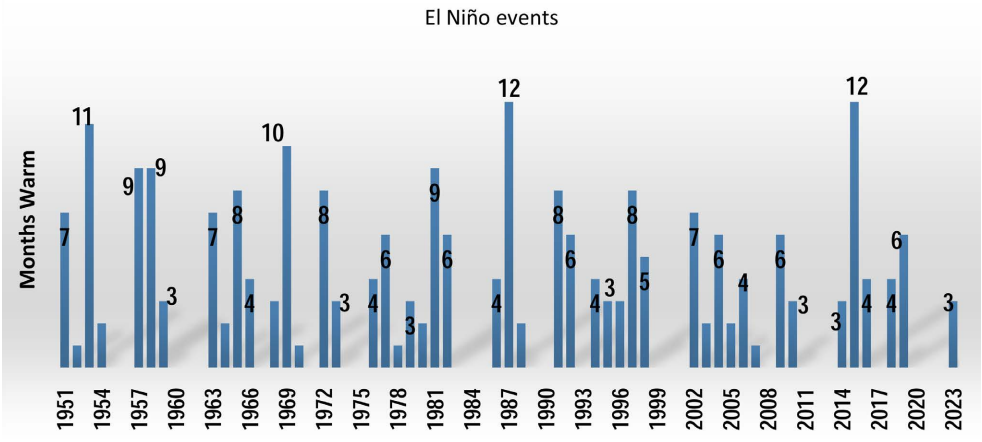

Figure 1. Shows El Niño's years from 1950 to 2023. Observe the two periods with El Niño lasting more than twelve months.

In 1970, La Niña lasted 19 months; in 1999-2001, it was 32 months; and finally, in 2020-2023, the last 30 months, the gap between the events was the first 28 years and the second just 12 years. Therefore, against expectations, La Niña is recurring more often than El Niño, and their lifetime is also longer. However, it does not look as periodical as El Nino, and its extension varied from 19 to 32 months (**Figure 2**).

The El Niño events often happen during short months number, and for many years, it did not appear. Events during the twelve months since 1950 happened twice, with many climate disturbances. Later, we analyze how those phenomena influenced the weather nearby and further. Nevertheless, we also need to consider that it is possible that when the weather becomes highly harmful, other factors play a role in climate development. We will also compare the prolonged El Niño, which took place in 2015, with the same event in 2023/2024.

2.2. La Niña Events

Next, **Figure 2** shows how La Niña varied in the same time range, the number of 12-month occurrences, and when it occurred. El Niño or La Niña seldom happens throughout the year.

La Niña variation offered longer intervals during the observed sequence between 1950 and 2023. La Niña happened six times in twelve months since the beginning of records. La Niña last 20 years had a longer period from 2020-2023; the preceding year, it happened just in the first months of the year, followed by neutral months, and then the El Nino presence started.

Investigating the Enso neutral phase is also essential since it is the phenomenon or the absence of an event that occurred more in that region.

The effects of La Niña are mild, probably dependent on other circumstances; for example, in 2022, we had the Tonga submarine volcano and La Niña during one of the most extended time ranges in the records. Therefore, we analyze the last period of La Niña's presence between 2020 and 2023.

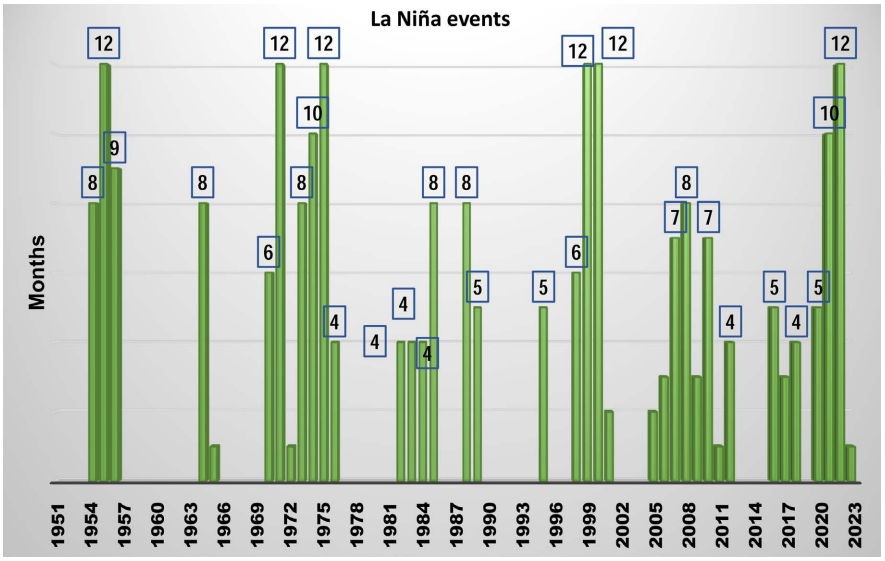

Figure 2. The La Niña variation in 1950-2023 lasts longer than the prior El Niño.

2.3. The ONI Neutral Waters in the Pacific

The years with neutral variations are shown in Figure 3. This figure shows the period when the Ocean Nino Index was neutral, which means the waters were not warm or cold. It was observed that the number of months when water was neutral for 12 months exceeded El Nino or La Niña in the same pattern. It happened seven times; between 1959 and 1966, the seas were four times neutral. We marked the years with more than three months of neutral. The last year, with 12 months neutral, was in 2013. Against the expectations, the observations of significant anomalies in the weather and climate events are also important when the ENSO does not present any warm or cold episode on the El Niño Southern Oscillation variations. The meaning would be that the event per se does not represent the observed climate variation worldwide. The presence of one of them is not the response to harsh weather changes. Most probably, climate anomalies are a more complicated task to analyze or understand than to blame the presence of ENSO. It is also under discussion that it affects many parts of the globe but most intensely impacts the tropics, including countries and areas in Africa, Latin America, and South and Southeast Asia that are particularly vulnerable to natural hazards. Resuming this part of the paper was to clear up the ENSO events during the period 1950-2023, which is vital to the next step of the study on working on the possible influences on the weather worldwide. Next, we will use data from the NOAA to define the significant climate anomalies and events that have occurred over the last twenty years. First, we are going to develop an analysis of how or if El Nino, La Niña, and neutral events influence the weather or enhance the hurricane seasons, typhoons, cyclones, rainfalls, dryness, and the Arctic and Antarctica sea extent. Then, define last year's sudden climate anomalies presented on the 2023 end and connect them with the El Nino appearance. There was also an anomaly in the climate at the beginning of 2024, with the bitter cold in the USA and extreme anomalies in other locations such as South

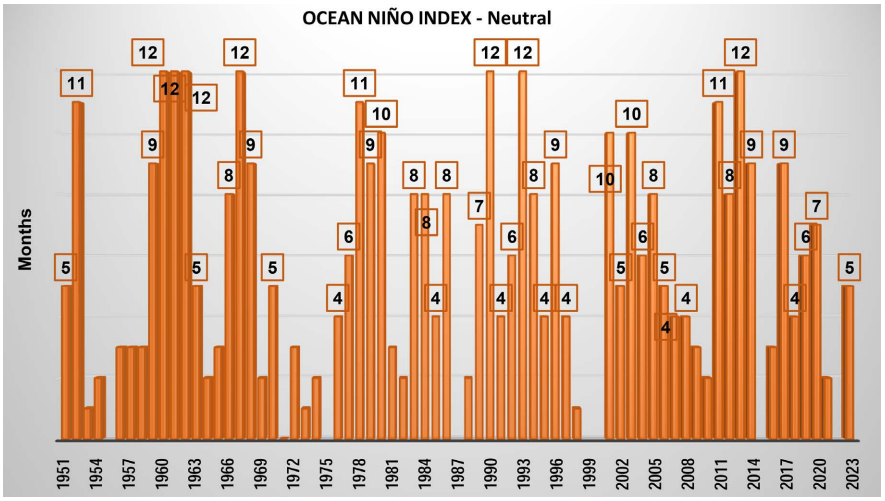

Figure 3. The number of months the Ocean was neutral by year.

America. Before analyzing the possible connections between climate anomalies and Enso, we will work in the last decade, 2014-2024, to project the potential connections between oceans and land anomalies.

The NOAA catalog for ENSO has three kinds of events: El Nino, La Niña, and Neutral. Investigating the last decade, the frequency of observing a warm or cold episode in the Pacific had grown with few gaps with neutral waters.

In 2017, most of the year was neutral, then La Niña was followed by the next El Nino with some months in neutral waters. The 2019 year finished with neutral waters, followed by the most extended La Niña in the decade, which lasted until 2023. Notice the peak of El Nino in 2023, Pacific waters were 1.9˚C; in 2015, it was 2.6˚C. Although there have been some unusual phenomena in the last decade, there were also other unique occurrences, such as the Tonga eruption (a submarine volcano) in 2021.

3. Connections ENSO Events and Weather Worldwide

We are considering periods over twelve months for El Niño or La Niña and check the worldwide climate anomalies. The years analyzed are 2014-2016 for El Niño and 2020-2023 for La Niña. El Niño started in the last three months of 2014, stayed all year of 2015, and finished in 2016. The 2015 was blasted for extreme climate anomalies around the Pacific coast and the Southern Hemisphere. The Ring of Fire presented heavy hurricanes on the east side and typhoons on the West. Unusual warm temperatures in the USA on the west side, South America, Africa, India, Europe, and Southeastern Asia. Hurricanes Kilo, Inacio, and Jimena heavily affected the Ring of Fire, and the last one has been the biggest since 1949 when the records began.

The maximum winds (230 km/h) for Hurricane Sandra and Cyclone Chapala in Yemen with maximum winds 250 km/h. Typhoon season was above average as well. The globe experienced the usual warm temperatures, such as the USA on the west side, South America, Africa, India, Europe, and North Asia. The dry-

ness occurred in the Americas, with extreme drought in western Canada and the Eastern North Pacific, and the hurricane season had above-average activity with 13 hurricanes.

See Figure 4 for the Climate Anomalies events during December 2015. El Niño in 2015 warmed the waters for an entire 12 months; after September, the temperatures kept increasing, and the last three sets of Oceanic Nino Index (ONI) presented, August/September/October-ASO (2.2), September/October/November SON (2.4) and NDJ (2.6). Those are the highest values recorded in the entire period 1950-2023. In December 2015, the temperature in the oceans reached 1.11˚C, and following the catalog, it is above the records from 1880-2023.

The following year, 2016, the hurricane season continued to be strong; however, the location was moved to the Atlantic. El Niño was over after April with some neutral months; a mild La Niña took place to the end of the year, with an oceanic El Niño index that was neutral for most of 2017. At the end of 2017, La Niña retook place until April 2018.

4. Study of La Niña Event on Weather from 2020-2023

The period from 2020 to 2023, when La Niña occurred, is analyzed. The La Niña record shows the phenomenon was longer than El Niño in 2015. The 2022 had

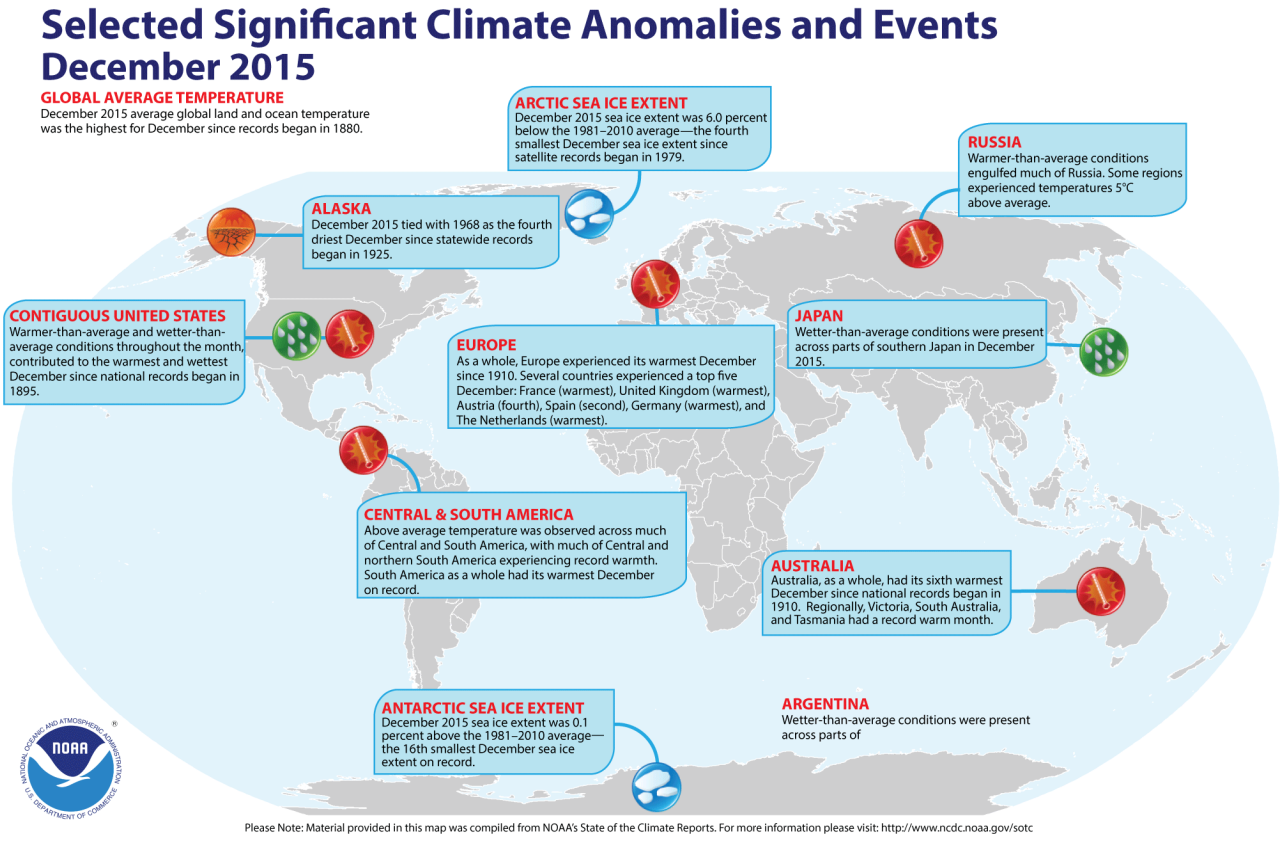

Figure 4. The climate anomalies observed during December 2015. Unusual warm conditions during the Winter in the Northern Hemisphere. Wetter conditions in Japan and west of the USA.

the calendar year with La Niña's presence. However, the event did not increase the global temperatures as much as El Niño in 2015. La Niña longest record in the last 70 years was 2020-2023, the three-month record from the **Appendix** indicating it started JAS (July/August/September) 2020 and was over in 2023 in the first year's quarter.

A gap occurred between May and July (2021) and returned in the second semester of the same year. La Niña made a different pattern of severe climate changes than El Niño. It affected rainfalls and draughts. The following year, examined in 2022, showed increased hurricanes close to the Equator. The heat weather affected the northwestern U.S. and western Canada in June when La Niña was paused from July-August; it continued through the year's end. In 2022, the beginning of the year was plagued with heavy rain in some locations in the South Hemisphere, with three storms making' landfall in Madagascar in the same month. The temperatures reached record highs in the first months in the Southern Hemisphere. The contiguous U.S. started wildfires across the Southwest. In April, there was heavy rainfall in Colombia and South Africa. The wet weather continues in May in Southern South America, South Africa, and Australia. The Northern Hemisphere experienced record temperatures in the USA, Europe, and Asia. Droughts affected Mexico in June, and South America had the coolest June.

In 2023, significant climate anomalies studies revealed that the year was warmer than the records from 1850, both on land and in the ocean. Most cyclones happened on the east side of the Pacific. The hurricane season did not occur in the Atlantic, and the ocean temperature increased after June (it makes part of the record of the warmest global ocean temperatures).

Heavy rainfalls occurred in analyzed locations by month. January registered rainfalls in California, Central Europe, and New Zealand. February still shows records of rain in California and Indonesia. However, the Caribbean Islands (winter season) and Oceania (Summer) showed the coolest Summer in 2012. May indicated that globally, the highest temperatures are observed. It has higher temperatures throughout July, August, September, and October. Some anomalies were observed in Scandinavian countries in the cooler October. However, the totality of the globe had an increased anomaly in the temperature never observed before.

The ENSO variations alone cannot explain the events of 2023; another factor must be implied to explain those climate disturbances.

5. Study Neutral Events 2012-2014 on Weather

Next, we investigated when Oceanic Nino Index values were neutral. Following the previous data, we got a period of most extended neutral values, and it was 2012-2014. The year 2013 was into neutrality, and El Niño was back in the last three months of 2014. In 2013, notable weather events occurred in various countries and regions. France experienced the second coldest May since 1950, while Spain had its wettest March since 2004.

The Philippines was severely affected by Typhoon Haiyan, the world's most robust tropical cyclone, to make landfall. Brazil's southeastern states had heavy rains triggering floods and landslides, with Aimores city receiving 400 percent of the average December rainfall. This year (2014) was the fourth warmest since the records began in 1880. The land's global average surface temperature was above the 20th-century average. Unusual phenomena happened as Israel, Lebanon, and Jordan received rare snowfall. Brazil experienced a second consecutive year of severe drought conditions. And 2013 is considered the worst in the past 50 years. In October 2012 and early 2013, New Zealand suffered the worst drought in many years. After more than a century, Russia observed heavy snowfalls in Moscow in 2013. However, in November, Russia had the warmest weather since 1891 (the records began). The years have been severely affected by the wettest or driest months; during those three years, most started in 2012. The weather in 2014, earlier to the El Niño year (2015), showed neutral Enso, presenting mild anomalies with cold waves at the start of the year in the USA. Also, diverse world locations showed heavy rainfalls and floods. Europe, Western Canada, India, Afghanistan, Sri Lanka, and Java had the most harmful rainfalls and floods. However, it happened with the Pacific waters in the neutral stage. There were no droughts reported around the world. The following section is a detailed view of 2015.

6. El Niño Weather Effects One Year Event (2015)

El Niño occurred over a long period of twelve months in 2015; during this year, the Pacific and Atlantic Ocean basins experienced several extreme weather events and climate anomalies; in the Eastern North Pacific basin, there was a rare occurrence of three major hurricanes, Kilo, Ignacio and Jimena simultaneously at the end of August, it was the first time it happened since records began in 1949. Additionally, the Hurricane season in Mexico saw above-average activity, with 11 storms and four hurricanes, and Morocco experienced heavy precipitation, receiving over 13 times its monthly average in one hour. During the Typhoon season, we have had above-average activity in the Western Pacific Ocean, with 28 storms and 21 typhoons. We had near-average activity in the Southwest Pacific Ocean Cyclone Season, with six storms and two cyclones. These events and anomalies significantly impacted the respective regions and underscored the dynamic and impact of natural weather patterns in this ocean basin during 2015. Extreme climate anomalies marked the 2015 El Niño Event, such as,

Global Impact:

- Hurricanes and Typhoon
- Hot temperatures in multiple regions.
- Increased precipitation and storm activities

The Pacific Coast and Southern Hemisphere have severe weather conditions. The USA, South America, Africa, India, Europe, and Southeastern Asia reported

unusual climate patterns.

Worldwide:

Specific Phenomena and records

Hurricane Kilo Impact the Ring of Fire

Above average typhoon season.

Increased number of hurricanes, 13 in total

- Droughts in Western Canada and Eastern North Pacific
- Record-breaking ONI values.
- Highest temperature anomalies on December 15.

The Oceanic Nino Index (ONI) values of 2.6˚C reached record levels during the period, and the highest temperature anomalies occurred in December 2015. As we discussed, this value is above the average; see the earlier discussion in this paper. Next, we will describe what happened during the La Niña event.

7. La Niña Effects during Periods of Long Event

La Niña event from 2021-2024 was a remarkable event that lasted 30 months, like another 1998-2001 event that persisted for 32 months. The investigation on the ONI index pointed out that the ONI in December 1999 peaked at −1.5˚C. 2020, the El Niña event peaked at −1.2˚C in December 2020. The data for significant climate anomalies and events was limited and started in the 90's. Therefore, we will investigate the last two El Niña mentioned above in the records. Our investigation suggests that the La Niña, not predicted by computer models, was influenced by the Tonga submarine eruption in the south of the Pacific in 2021.

The 1999-2001 event was preceded by a strong El Niño in 1997-1998, resulting in a contrast in the ocean heat content and atmospheric circulation between the two phases of ENSO. The 2020-2023 event was not headed by a strong El Niño but rather by a period of neutral or borderline El Niño in 2019. In 2022, several climate anomalies were observed worldwide. The average global surface temperature for January-December 2022 was the sixth highest since records started in 1880. Europe experienced its second-highest yearly temperature, exacerbating drought and severe wildfires due to warm and dry summer conditions. Asia witnessed its second warmest year on record; China and Japan had extreme heat waves. North America tied for the 15th warmest year on record, contributing to damaging wildfires across the West. The Atlantic hurricane season has near-average activity, with 14 storms and eight hurricanes.

Pakistan experienced record-breaking rainfall that led to severe flooding, while heavy rain in southern China devasted floods. During the Western North Pacific typhoon season, there was below-average activity. Australia faced extreme rain and flooding, and Madagascar saw major cyclones and tropical storms making landfall. Lastly, the Antarctic recorded its fourth-smallest annual maximum and most minor yearly minimum extent of sea ice. At the beginning of 2023, a period of neutrality in the waters had started.

8. Climate Anomalies in December 2010-2023

Table 1 below shows December between 2010-2023 and all the observed events, temperatures, and anomalies. The peak of ENSO events is in December, as we know the events as El Niño and La Niña. December observations differ for each event; no event happened in the last decade. La Niña years showed this month with no notable difference since observed the years when it happened, 2010, 2011, 2016, 2017, 2020-2023.

Some of those La Niña years, such as 2010, had no anomalies; others, such as 2011, 2016, 2017, handed typhoons, and regions recorded the coldest as long as 2021, 2022. The El Niño event has a similar pattern: 2014 typhoon, 2015 no anomaly (although it was a decisive event in the former decades), 2018 presented no event, and 2023 presented just one powerful cyclone in Japan. Those events are the extremes. They will not be involved in all worldwide temperature changes in the ENSO warm or cold waters. The following results are the most significant anomalies that started during neutral Enso, 2010, 2013, and 2019, which brought variations in worldwide temperatures. El Niño did not bring extreme anomalies until 2023 when El Niño happened in June, and a powerful cyclone occurred in December. However, the years with the highest recorded temperatures (Table 1) were during the extreme El Niño presence in 2015 and 2023. Table 1 shows the climate anomalies happening independently of the Enso

Table 1. Represents the Enso events, anomalies, and temperature variations between 2010 and 2023 (this table was constructed based on NOAA data).

Year	ENSO	Anomalies	Temperature ANOMALY
2010	La Niña	NO	Coolest since 2000
2011	La Niña	3 cyclones	No cold
2012	Neutral	NO	Coolest Eurasian in 28 years
2013	Neutral	snow Israel	3rd warmest since 1880
2014	El Niño	Typhoon	2nd warmest since 1880
2015	El Niño	None	1st warmest since 1880
2016	La Niña	Typhoon	4th warmest
2017	La Niña	Anomaly Temperature Port/Spain	5th warmest
2018	El Niño	NO	2nd warmest 1880 behind 2015
2019	Neutral	Typhoon	3rd warmest since 1880
2020	La Niña	cyclone	none
2021	La Niña	Typhoon, Sweden, USA, coldest 35 years	none
2022	La Niña	Cooler in UK, N. America, Oceania	none
2023	El Niño	Cyclone Japan	1st record temperatures

phases. The analysis shows that extreme climate events are not attached to any ENSO event. There is a connection between El Nino's presence and high temperatures worldwide. Therefore, El Nino looked to enhance worldwide temperatures in 2015 and 2023.

9. Connections of Enso and Weather Anomalies Worldwide

The search for significant climate anomalies since 2014 has shown that in the last ten years, the anomalies and disturbances in climate have grown in several locations worldwide. The NOAA catalog gives maps with the anomalies on land in the previous decade. Several locations presented the highest temperatures in historical records. The problem with calculating average temperatures worldwide is ignoring that some places' responses were different; therefore, this average must be a more accurate conclusion. Consider 2014, when there was a mixed presence of neutral ENSO and El Niño at the year's end. It was considered the warmer-than-average period for Europe, Russia, Mexico, Argentina, Alaska, New Zealand, and Australia. However, in the records, it was freezing for Canada and extremely wet, with damaging floods in South America, West Pacific, Japan, India, Pakistan, and Morocco (during the Fall). Then, there were places colder or wetter and others warmest, but the scientists just concluded that was the warmest year without specifying any details.

In the range 2020-2023, during La Niña, the significant climate anomalies presented like the ones observed in the presence of El Niño or neutral waters—nevertheless, 2023 showed a new development concerning the three phases of events. This particular year, the three-phase ONI occurred in the same year. It started with La Niña some months were neutral, and finally, El Niño from June to the year's end. However, the event reached the same peak as in December 2015 (see the **Appendix**). Climate anomalies and temperatures oscillated between January and June, with the seventh-highest temperature in January and the highest global surface temperature since 1850 in June. These top temperatures continued to increase until December 2023, showing the highest temperatures on record for all year.

South America experienced intense rainfall and unusual floods. It also occurred in the contiguous USA (abnormal rainfall in N.Y.), and Brazil presented an extratropical cyclone reaching Southern Brazil in September. In October, the highest record temperatures caused droughts in the USA. Worldwide records show October 2023 as the highest temperature, except for Fermoscandia, which had a cooler-than-average temperature. November 2023, the climate hazard events did not happen as usual, and only two hurricanes fell in North America and another in Fiji. The Arctic and Antarctic had opposite responses, the Antarctic presenting the coldest November since 1983 and the Arctic the second warmest November in the records. December 2023 (see **Figure 4**) had an absence of climate disturbances, with the highest temperature for December since the recording started.

An event happened in Australia with heavy rainfall. If we analyze the significant climate anomalies from January to December 2023, we observe that a few cataclysms in 2023 occurred between January-June. After that, the records for each month indicate an enhancement in the temperatures and a few climate anomalies in the following months. We will catch the climate anomalies as far as the records were good enough in December; unfortunately, accurate maps, as we have now, only started in 2010. Then, we are relying on the data from 2010-2023.

However, in the next paragraph, we discuss the consequences of El Nino's increased prominence worldwide in the past two years.

Figure 5 shows the anomaly events during December 2023; only one disturbance was recorded, the cyclone Jasper category 4 in Australia; nevertheless, there were similar events after August, but in the first part of the year until June, there were fewer significant climate events, coinciding with the beginning of El Niño. The first hurricane from the season was Hurricane Don, July, category 1, and lasted for ten days. The next one was Hurricane Idalia, category 3, which, in August, was reported to be the strongest in 125 years. Many locations worldwide felt the impact of heavy rainfalls in unusual places for the next six months. Although there are temperature anomalies worldwide, they were not as in 2015 (see Figure 4) when it most happened in the Northern Hemisphere.

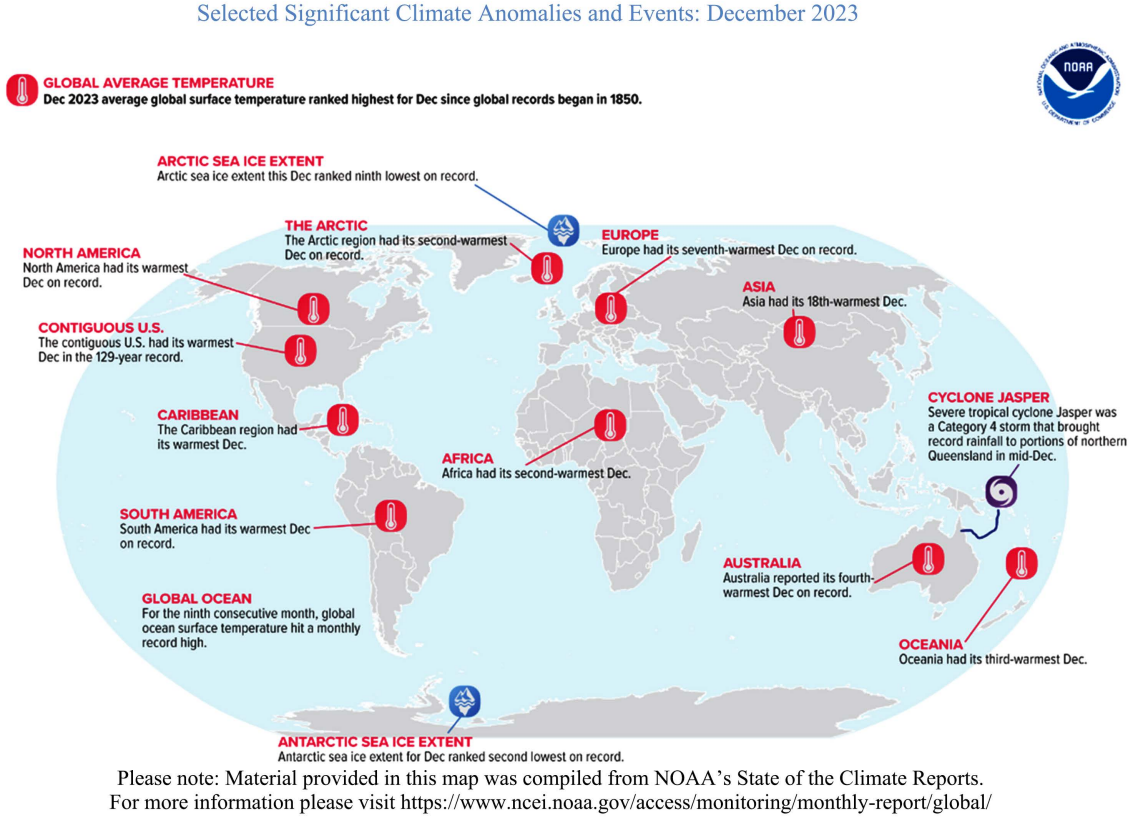

Figure 5. The worldwide map in December 2023 observes the absence of climate anomaly events. The only remarkable anomaly was the cyclone Jasper.

Most anomalies observed in 2015 were heavy rainfalls in the Northern Hemisphere, most in Japan and the contiguous USA. During the year, it was reported that there was a heavy season of storms in the East Pacific Basin in August. However, it presented unusually cooler conditions, such as in Spain, Alaska, parts of Europe, and Russia, in the next few months until December.

Regarding December 2015 (Figure 4), the only anomaly reported was heavy rainfalls, mainly in the Northern Hemisphere. Remember that 2015 was when El Niño reached the highest temperatures in the Pacific. The year ends at 2.7˚C compared with 2.0˚C in 2023. Therefore, the comparison between Figure 4 and Figure 5 show differences between the two phenomena worldwide. Observe in Figure 4 that last month, when El Niño was at its maximum, higher temperatures occurred in the Northern Hemisphere, as well as the wetter conditions in Japan and west of the USA. Most of the damage reached by 2015 warming compared with 2023 shows some differences and consequences for the same event on Enso.

10. Conclusions

Our investigation of the phenomenon known as Enso on the South American coast showed the three events that composed the phenomena, and we have the following conclusions.

1) The ENSO, the event itself, can't answer the temperature anomaly observed in 2023 [10] [11].

2) No evidence exists that El Niño could enhance climate disturbances observed as droughts, cyclones, or typhoons worldwide.

3) There is no indication that only Enso can change the worldwide temperatures as it has happened in recent years. Remember that in 2022, North America's weather was devastating in the California area during the El Nina event.

This paper worked only with the possible connections between ENSO and weather worldwide, from 1950-2023, Enso variations, and a smaller range of 2010-2023 for the ONI events. Although we found similar variations and anomalies in the El Niño or La Nina presence, the intensity of the last temperatures can't fit with those variations. Therefore, we suggest that other kinds of anomalies are happening without being attached to ENSO and are contributing to the global temperature increase.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

This table represents the years and variations of the ENSO events for each of the three months displayed as DJF (December/January/February), the last of which will be NDJ (November/December/January). The blue values are for La Nina, and the red values are for El Niño. The table shows partial catalog values for ONI from 2010-2023.

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2010	**1.5**	**1.2**	**0.8**	0.4	−0.2	**−0.7**	**−1.0**	**−1.3**	**−1.6**	**−1.6**	**−1.6**	**−1.6**
2011	**−1.4**	**−1.2**	**−0.9**	**−0.7**	**−0.6**	−0.4	**−0.5**	**−0.6**	**−0.8**	**−1.0**	**−1.1**	**−1.0**
2012	**−0.9**	**−0.7**	**−0.6**	**−0.5**	−0.3	0.0	0.2	0.4	0.4	0.3	0.1	−0.2
2013	−0.4	−0.4	−0.3	−0.3	−0.4	−0.4	−0.4	−0.3	−0.3	−0.2	−0.2	−0.3
2014	−0.4	−0.5	−0.3	0.0	0.2	0.2	0.0	0.1	0.2	**0.5**	**0.6**	**0.7**
2015	**0.5**	**0.5**	**0.5**	**0.7**	**0.9**	**1.2**	**1.5**	**1.9**	**2.2**	**2.4**	**2.6**	**2.6**
2016	**2.5**	**2.1**	**1.6**	**0.9**	0.4	−0.1	−0.4	**−0.5**	**−0.6**	**−0.7**	**−0.7**	**−0.6**
2017	−0.3	−0.2	0.1	0.2	0.3	0.3	0.1	−0.1	−0.4	**−0.7**	**−0.8**	**−1.0**
2018	**−0.9**	**−0.9**	**−0.7**	**−0.5**	−0.2	0.0	0.1	0.2	**0.5**	**0.8**	**0.9**	**0.8**
2019	**0.7**	**0.7**	**0.7**	**0.7**	**0.5**	**0.5**	0.3	0.1	0.2	0.3	0.5	0.5
2020	0.5	0.5	0.4	0.2	−0.1	−0.3	−0.4	**−0.6**	**−0.9**	**−1.2**	**−1.3**	**−1.2**
2021	**−1.0**	**−0.9**	**−0.8**	**−0.7**	**−0.5**	−0.4	−0.4	**−0.5**	**−0.7**	**−0.8**	**−1.0**	**−1.0**
2022	**−1.0**	**−0.9**	**−1.0**	**−1.1**	**−1.0**	**−0.9**	**−0.8**	**−0.9**	**−1.0**	**−1.0**	**−0.9**	**−0.8**
2023	**−0.7**	−0.4	−0.1	0.2	**0.5**	**0.8**	**1.1**	**1.3**	**1.6**	**1.8**	**1.9**	**2.0**
2024	**1.8**											

Climate Prediction Center-ONI; NOAA/National Weather Service; National Centers for Environmental Prediction; Disclaimer Information Quality; Privacy Policy Freedom of Information Act (FOIA).