Keys to understanding the El Niño-Oscillation phenomenon in south Mexico

Llaves para comprender El Fenómeno del Niño-Oscilación en el sur de México

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DOI: 10.35429/EJM.2022.28.13.11.19 Received January 15, 2022; Accepted June 30, 2022

Abstract

The El Niño-Southern Oscillation phenomenon leaves its mark both in North America and in South America, both in the natural and cultural coastal landscape, where its implications cover the areas: economic, social, political, cultural and institutional. The objective of the present was to expose four keys so that the population understands said phenomenon. The method used was geographical since it exposes the causes, explains the development and its dynamics over time while proposing a solution to mitigate this phenomenon, especially at the local level. The methodology involved office work complemented with field work on the Mexican coast, particularly in Guerrero. Among the results are: a) a global planisphere where the intensity with which the El Niño-Southern Oscillation affects the different continents is shown in different colors and b) the climatic variability is increasing, so the negative effects for some people and positive for others will continue. Conclusions: 1) El Niño-Southern Oscillation is recurrent in an average period of two to seven years; the phenomenon is identified between the months between December-March of each year and 2) The link between environmental protection with sustainable development is urgent in order to protect human health, increase biodiversity, sustainable management of fragile ecosystems present in coastal areas.

Climate variability, El Niño-Southern Oscillation, Vulnerability

Resumen

El fenómeno El Niño-Oscilación del Sur, deja su impronta tanto en América del Norte como en América del Sur tanto en el paisaje natural como cultural costero donde sus implicaciones abarcan los rubros: económico, social, político, cultural e institucional. El objetivo del presente fue exponer cuatro claves para que la población comprenda dicho fenómeno. El método empleado fue el geográfico dado que expone las causas, explica el desarrollo y su dinámica en el tiempo a le vez que se propone una solución para mitigar dicho fenómeno sobre todo a nivel local. La metodología implicó trabajo de gabinete complementado con trabajo de campo en las costas del litoral mexicano, particularmente en Guerrero. Entre los resultados se tienen: a) un planisferio a nivel global donde se muestra en diversos colores la intensidad con que afecta el Niño-Oscilación del Sur a los diferentes continentes y b) la variabilidad climática cada vez es mayor por lo que, los efectos negativos para algunas personas y positivos para otras continuarán. Conclusiones: 1) El Niño-Oscilación del Sur es recurrente en un periodo promedio de dos a siete años; el fenómeno es identificado entre los meses comprendidos entre diciembre-marzo de cada año y 2) La vinculación entre la protección ambiental con el desarrollo sustentable es urgente a fin de, proteger la salud humana, incremento de la biodiversidad, manejo sostenible de ecosistemas frágiles presentes en las zonas costeras.

El Niño-Oscilación del Sur, variabilidad climática, Vulnerabilidad

Citation: NIÑO-GUTIÉRREZ, Naú Silverio. Keys to understanding the El Niño-Oscillation phenomenon in south Mexico. ECORFAN Journal-Mexico. 2022. 13-28:11-19.

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Introduction

The earth's surface where man has lived has undergone environmental changes since its origins, but with the passage of time they are increasingly noticeable due to the frequency of some phenomena such as earthquakes, storms, high waves, floods, landslides, droughts, among others, which affect to a greater or lesser extent the practice of various economic activities of the current population. For this reason, studies are carried out from different perspectives and knowledge is applied to contribute to the reduction of risks and disasters, both natural and anthropogenic. The El Niño-Southern Oscillation phenomenon is related to the exchange of heat between the ocean and the atmosphere, a fact that modifies the general circulation of the atmosphere on a planetary level, examples of which are the modification of precipitation, temperatures and the frequency and/or intensity of tropical cyclones (Ledezma, 2021).

The elements of nature located between zero degrees Latitude where the Equator is located and 23° 27' to the north and south, where the Tropics of Cancer and Capricorn are located respectively, boast exceptional hydro-meteorological conditions that allow for the flourishing of biodiversity, which allows for the development of economic activities that bring as a collateral effect, the current climate variability that mainly affects those who reside near the coastal plains in each of the continents of the globe (Pérez-Ortíz et al., 2022). Hence, this article engages with the debate in favour of landscape conservation and sustainable management of existing natural resources to achieve sustainability at a local level, but with global significance.

The global risks and threats that are on the horizon in 2022 are: the current pandemic will persist until 2025; recurrent global natural events such as tornadoes, hurricanes, typhoons, earthquakes, floods (Luna-Luy, 2022), loss of biodiversity, but most seriously, climate inaction on the part of the political leaders who set the guidelines for the world economy, which will mean that the rest of the population will live in the same situation as the rest of the world, the rest of the population will live with greater uncertainty and will need to be more connected than ever and more locally self-sufficient and low-carbon or there will be the possibility of erosion of social cohesion at all levels (WEF, 2021 and WEF, 2022).

The problems faced by the countries located in the spatial fringe where El Niño-Southern Oscillation originates and impacts are linked to the alteration of the natural landscape, often associated with extreme poverty-poverty; the loss of natural resources; water stress (Ortiz-Gaviria, 2022), extinction of flora and fauna; environmental pollution; climate variability; effects of global climate change and the economic indebtedness of its inhabitants. Therefore, the study method used was the geographical approach enriched with the consultation of digital or printed bibliography of articles published in reference databases: Web of Science, Scopus, SciELO, Latindex, among others, and access to remote statistical databases of the National Office of Oceanic and Atmospheric Administration (NOAA). The sections that make up the article are: introduction, methodology, results, conclusions and references.

Methodology

The method used was the geographical approach, given that the causes, explanation, evolution over time and possible solution to the El Niño-Southern Oscillation phenomenon are presented. The methodology employed was of a mixed nature, since qualitative techniques were used initially and later complemented with quantitative techniques, through the information gathered in the field. Thus, the qualitative technique applied during the documentary research involved a first phase of a conceptual nature in which a review of the literature was carried out on topics related to the following: El Niño-Southern Oscillation phenomenon, climate variability and vulnerability; determination of the variables viz: El Niño-Southern Oscillation and Southern Mexico to find the answer to what are the keys to understanding said phenomenon; phase two, comprised the planning of the work through the research design that included the search for sources of information, instruments and affected population. To do this, we proceeded to consult digital reference databases such as: Web of Science, Scopus, Latindex, Redalyc, SciELO, Google Scholar, among others, together with the consultation of printed thematic cartographic material and NOAA digital satellite images, which are updated to 2022 on the area under study; the third phase was of an empirical nature comprising the processing of the selected information, the analysis of the data and information and phase four was eminently interpretative which was set out in the results, discussion, conclusions and references.

Results

Hence, the phenomenon is made up of two key elements: 1) the oceanic component known as El Niño where the behaviour of the Sea Surface Temperature (SST) is of the greatest importance, so meteorologists incorporate physical and technological effort in the collection of data in order to identify the spatial variability of these SST anomalies because this will bring with it more or less intense impacts where these anomalies are appreciated and 2) the atmospheric component (Southern Oscillation), here it is transcendental to identify the spatial variability of these anomalies, 2) the atmospheric component (Southern Oscillation), here the atmospheric pressure of the surface mass of sea water is transcendental, given that atmospheric pressure causes winds to move from higher to lower pressure, which corresponds to an inverse behaviour of temperature. Latin American and Caribbean marine ecosystems boast biodiversity as well as ecosystem services that translate into tangible benefits such as food security and recreational opportunities, among others (ECLAC, 2021).

El Niño-Southern Oscillation (ENSO) refers to the fact that the central Pacific Ocean is experiencing warmer than usual temperatures and is therefore an anomaly in the Pacific climate system. According to Climate Watch Magazine on the Oceanic Niño Index (ONI). It is important to bear in mind that, in order to determine this index, the average of 30 years of informative climate data is taken as a basis to determine whether or not there is any anomaly, for example, the ONI that currently governs was the result of the period 1991-2021, whose influence is global in nature, among which ecological changes in the various ecosystems are cited, which alter other factors that have a negative impact on both time and space, the population and their economies (CPC-NCEP-NOAA, 2020).

Among the elements of weather and climate, which refer to temperature, precipitation and humidity, wind direction and strength, atmospheric pressure, cloud cover, solar radiation and visibility. In other words, weather is the sum total of the physical properties of the atmosphere at a given instant, which is what is known as atmospheric weather. Climate, on the other hand, is the sum total of all the climatic variables expressed above over a minimum period of 30 years to determine precisely the climate of a site on the earth's surface (Garcia, 1989).

Climate factors: latitude, altitude, relief, land and water distribution and ocean currents, any one or all of them, or the combination of some of them, modify the elements that make up the climate. Here, ocean currents and their influence on the world's climates are important, since the El Niño-Southern Oscillation phenomenon is an example of the displacement of large masses of sea water from one part of the ocean to another, caused by the uneven warming of the oceans' waters, This, together with the friction of the winds on the ocean surfaces, causes the surface water to be displaced in the direction of these winds, which can be Trade Winds (global North) and Contra Trade Winds (global South), and even the differences in the total salinity of seawater resulting from the difference between precipitation and evaporation of water from the earth's surface, which among other effects is due to the greater or lesser presence of phytoplankton in the oceanic province (Ayala-Galván et al. , 2021).

It should be remembered that there are marine currents in the Atlantic Ocean where warm currents are located, such as the Gulf of Guinea current which travels from East to West and when it meets Cape San Roque in South America, it divides into two branches, the smaller current follows its trajectory towards the south, thus bordering the eastern coasts of South America, hence it is called the South Equatorial Current, the effects of which are felt in Peru and Chile (Pino-Vargas & Chávarri-Velarde, 2022).

The operational definition of the Niño-Southern Oscillation, according to NOAA, is when seasonal temperatures are 0.5°C warmer than average in the central tropical Pacific (Figure 1) (between 5° north and south latitude at 120°-170° west longitude), between the months December-January-February-March-April or January-February-March-April-May as long as it comprises an average of five consecutive months from Christmas and from there to the end of spring each year in the case of the northern hemisphere. For the Niño-Southern Oscillation to become a full episode and acquire the status of an "anomaly", since this phenomenon comprises twelve months in total (Lindsey-L'Hereux-Halpert-Blunden, 2021).

ISSN-Print: 2007-1582- ISSN-On line: 2007-3682

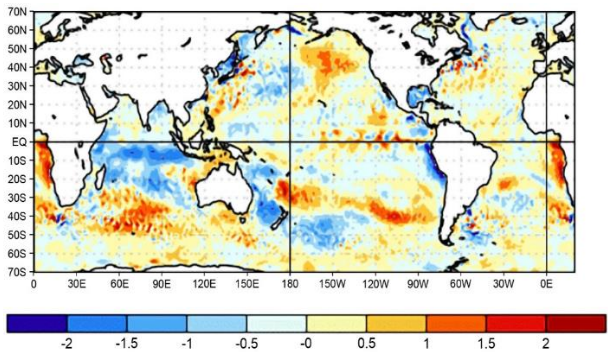

Figure 1 Change in weekly anomalies in (°C) during 19 January to 16 February 2022
Source: CPC-NCEP-NOAA, 2022.

According to the Scientific Committee on Ocean Research (SCOR) of UNESCO, the Niño-Southern Oscillation occurs when sea waters are extremely warm along the Pacific Ocean coastline, as it has been observed that the average monthly temperature in the South Pacific exceeds the annual mean temperature for five months, which makes it an "anomaly" given that it is not common for this to occur over several years (CPC-NCEP-NOAA, 2021).

A severe example of the El Niño-Southern Oscillation phenomenon occurred in 1997, during the month of July in the tropical Pacific at equatorial latitude, with notable warming events of the ocean surface water. In the central-eastern equatorial Pacific, the Sea Surface Temperature (SST) increased from April to May, but as it corresponds to the Southern Hemisphere winter, it would normally have decreased. Meanwhile, SSTs peaked in several parts of the South Equatorial Pacific. Temperature differences were greater than 4°C east of 120°W over the Equator and passed 5°C in the longitude of the Galapagos Islands. It should be noted that the El Niño-Southern Oscillation began in March 1997, and its largest anomaly was recorded in December 1997. Between January and March 1998, the anomaly was decreasing (Ibidem, 2021).

The El Niño-Southern Oscillation of late 1997 was one of the most outstanding natural weather phenomena, developing a power greater than that of a million nuclear bombs. Months later, when it came to an end, it had affected the climate in various parts of the planet, caused the deaths of 2,100 people and caused material damage estimated at 34.8 billion dollars. In 1997, 17 storms were recorded in the eastern North Pacific, 14 of which became hurricanes and seven of which reached great magnitude (Sánchez, 2001).

The years 2009, 2010, 2015, 2016 and 2019 have been recorded as the most evident El Niño-Southern Oscillation phenomena due to their high temperatures and adverse effects on the territories, ecosystems and populations they affected, the consequences of which involved loss of human lives and millions of dollars for restoration and to re-establish the minimum characteristics to keep the population and diversity alive (CPC-NCEP-NOAA, 2021).

The causes of the "Anomaly" are the elevated temperatures of the upper layers of ocean water that in their interrelationship with wind speed result in thermal exchange between the ocean and the atmosphere. Where, the atmosphere emits and receives heat from the oceanic water mass (by releasing heat through evaporation) and the ocean in turn receives heat through solar radiation and heat exchange with the atmosphere. For example, the 2013 El Niño events in Latin America included: severe droughts in Mexico (Niño-Castillo et al., 2020); excessive rainfall in Central America; stages of drought in Colombia; lack of rainfall in the north and centre of Brazil and heavy rainfall in Argentina, Peru and Chile, which affected agricultural, livestock, fishing, energy and transport activities or diseases transmitted to the population by vectors such as dengue fever, transmitted by contaminated water or food such as cholera and typhoid fever; respiratory diseases such as influenza (Hijar et al., 2016).

It should be noted that for the three decades between 1991-2021, NOAA has reliable data that the climate has recently changed abruptly, with warmer temperatures both globally and in the central tropical Pacific, normally between the months of January and June each year, which means that there is a strong possibility of an El Niño phenomenon in 2023. There is always the possibility of coastal flooding due to intense precipitation at the sea-land interface in Latin America (Niño-Gutierrez & Luna-Nemecio, 2021) and the Caribbean, among other territories, as a consequence of current climate variability (Serrano *et al*., 2016).

ISSN-Print: 2007-1582- ISSN-On line: 2007-3682

Meanwhile, the other branch is known as the North Equatorial Current, which skirts the coasts of South America, the West Indies, the Gulf of Mexico, where in the midst of the 2020 to 2022 pandemic, rainfall, more intense cold in winter will be felt, which translates into a greater number of respiratory illnesses closely related to COVID-19 (Niño-Gutiérrez, 2021) and is incorporated into the Atlantic Ocean through the strait of the Florida peninsula and continues its journey in such a way that it returns to its place of origin. But there are also cold currents such as the Arctic Ocean and Antarctic Ocean cold currents where two small cold currents originate, one of which skirts the southeastern coasts of South America and the other heads towards the southwestern coasts of Africa. There are also the Indian Ocean Sea currents, both cold and warm, especially in the case of the latter, which is related to the transmission of the dengue virus to humans (Stephenson *et al*., 2022).

For Mexico (Figure 2), the ones that have the greatest impact are the Pacific Ocean ocean currents since: on the western coasts of South and Central America, two warm currents originate from east to west, the N(east) and S(ur) equatorial currents, separated by a countercurrent that travels in the opposite direction from W (west) to E (east) and reaches the coasts of the Equator; This is known as the El Niño current, as it only occasionally manifests itself on the surface because it frequently occurs around 6 January, causing unusual rainfall on the coasts of Peru. This phenomenon lasts nine months on average (García, 1989: 73).

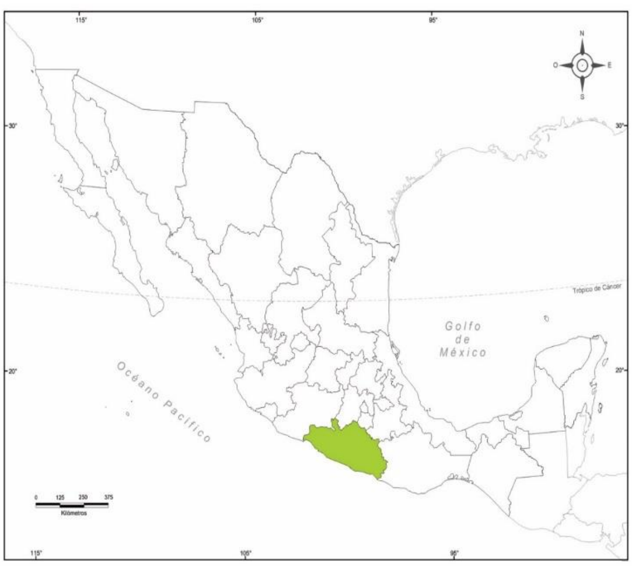

Figure 2 Location of Mexico
Source: Niño-Castillo et al., 2020

The state of Guerrero, one of the 32 entities that make up the United Mexican States, is located in the Mexican South Pacific and was created on 28 October 1847. It is named in honour of General Vicente Guerrero, hero and consummator of National Independence. Guerrero's territory extends over 64,282 km2, is located in the south of the country and is bordered to the north by the states of Mexico, Morelos, Puebla and part of Michoacán, to the east by the state of Oaxaca, to the south by the Pacific Ocean and to the west by the state of Michoacán (Figure 3).

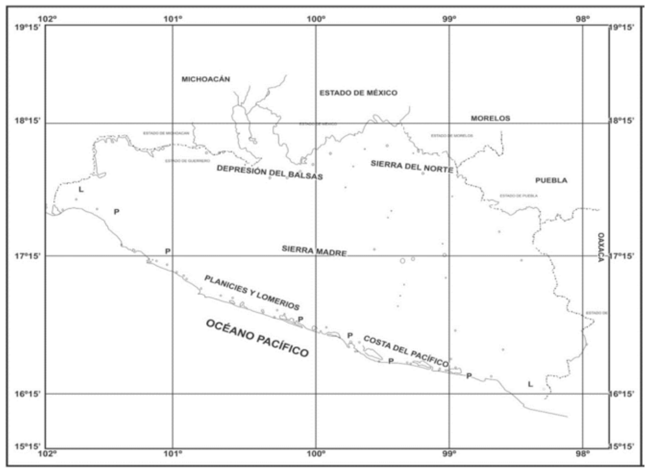

Figure 3 Geographical boundaries of Guerrero
Source: Niño-Gutiérrez et al., 2016

In the state of Guerrero, warm climates with summer rainfall predominate, comprising 58%; temperate climates comprise 25%, while dry climates comprise the remaining 17%. This entity is located in the intertropical zone (Gonzales-Zenteno, 2022), where high temperatures are modified by the altitude of hills and volcanoes such that, at 1,800 m above sea level, the temperature is less than 18°C on average.

Average annual temperatures range from 30°C to 20°C and are hot in the lower portions leading to the coasts and the Balsas Depression. Above 1700 masl and 2400 masl, temperatures between 19°C and 14°C occur in the middle and upper parts of the Sierra Madre del Sur and in the extreme north where there is a transitional portion between the Transverse Volcanic System and the Balsas Depression. Average temperatures below 14°C are found above 2 400 m above sea level, especially in the Sierra Madre del Sur.

Rainfall, to a greater or lesser degree, is linked to the factors mentioned above, as well as to humidity and winds. The summer rains, which last until autumn, are of the monsoon type from warm and humid air masses coming from the sea, or from tropical cyclones associated with ascending convection phenomena originating locally or from the relief. In winter, it is caused by fronts of cold air masses from the north when they collide with warm air masses from the south. From the northeast there are trade winds whose direction changes due to the orogenic barriers that also bring humidity from the sea with east-west orientations, which are also related to cyclones and wind waves from the east.

The dominant climate is tropical with summer rains (Aw), located on the coast and in the Balsas Depression located to the extreme NW, the NNW, Central-East and NE (29%) with maximum altitude of 1750 meters (58%), the temperate climate with summer rains (CWa and CWb), located in the Sierra Madre del Sur and Northern mountains and the Volcanic System above 1750 m (26%), the Dry Steppe climate with scarce rainfall in summer, located in canyon areas east of the Balsas Depression, among other places. In the state of has an average annual temperature of 20°C and an average annual rainfall of 800 mm.

A lower average precipitation of 600 mm corresponds to the Balsas River Depression at its limits with Michoacán (Infiernillo Dam), and in the Balsas river basin area in the Central-Northeastern part of the state. The 800 mm isohyet is located in the northwest and in the centre-east in the extreme NE and from Acapulco to the mouth of the Balsas in the coastal portions. It also coincides with the middle to high relief of the Sierra Madre del Sur. A further 1 200 mm is located in the north of the state, north of the parallel 18° 10' N latitude. The 1 500 mm isohyet surrounds high reliefs in the Sierra Madre del Sur, and the 2 000 mm isohyet corresponds to higher reliefs at the eastern end of the Sierra Madre (Correa, 2007).

According to W. Koeppen, Guerrero has the following climates: Awg, hot or tropical rainy with summer precipitation, whose maximum temperature is recorded before June 21 in this case in 2022 also known as the summer solstice and covers the hills located between 1 700 to 1 800 m asl, both on the coastal slope and in the Balsas Depression and a portion of the centre-west of the Sierra Madre del Sur, to the west and another to the east, at the eastern end.

Cwag, temperate with summer rainfall, whose average temperature of the hottest month is higher than 22°C and the temperature of four months or more higher than 10°C, with the maximum recorded before the summer solstice, located between contour lines 1 700 to 1 800 masl and 2 400 masl in the Sierra Madre del Sur, as well as in the north of the state where the municipalities of Ixcateopan and Taxco de Alarcón, Guerrero, are located.

Cwbg, temperate with summer rainfall, whose average temperature of the warmest month is below 22°C and the maximum temperature is before the summer solstice, located between 2 400 and 2 800-2 900 masl in the Sierra Madre del Sur.

Cwcg, temperate with summer rainfall, with mean temperature of the warmest month above 18°C and temperature of four months or more below 12°C, with a maximum before summer solstice located above 2 900 masl, in the eastern and central-western portions of the Sierra Madre del Sur.

BShwg, dry steppe, warm with scarce rainfall throughout the year, less than 800-700 mm, in summer average temperatures are above 18°C and the monthly average of some months is below 18°C. It is located in the NW of the state, next to the Infiernillo Dam and the Balsas-Cutzamala river, on the border with Michoacán, as well as in the canyon area of the Balsas-Tlapaneco river. One result is gastrointestinal illnesses due to the high temperatures, including fevers, diarrhoea, rapid food spoilage, throat problems and now COVID-19 or its variants (Niño-Gutiérrez, 2021).

From the hydrographic point of view, most of the entity corresponds to the Balsas River Basin, where other rivers such as Tlapaneco, Amacuzac and Cutzamala stand out in the continental portion, and in the coastal slope there are surface runoffs integrated by Omitlán-Papagayo, Ometepec-Río Verde; Atoyac River, Nexpa River, among others. In addition to the Chautengo and Tecomate lagoons in Costa Chica, Tres Palos in the municipality of Acapulco and the Coyuca lagoon in the municipality of the same name.

Professionals and health geography professionals are on high alert during the months of May-August each year to warn the population to take responsible individual and collective care as the influence and effects of the El Niño-Southern Oscillation phenomenon are triggered, among the evidence are: cases of dengue, dengue haemorrhagic fever, fevers, diarrhoea, flu and colds, among others. These have resulted in high morbidity rates and saturation of public health care services.

Conclusions

The methodology applied allowed the achievement of the objectives set out, firstly, to characterise the El Niño-Southern Oscillation phenomenon and, secondly, to synthesise the vulnerability of natural elements and the population established in the coastal areas of Latin America and the Caribbean. In the central tropical Pacific, where El Niño-Southern Oscillation occurs, there are exceptional geographical enclaves and reservoirs of biodiversity, and it is therefore important to contribute as far as possible to the mitigation of current climate change.

It is well known that El Niño-Southern Oscillation is recurrent in an average period of two to seven years; the phenomenon is identified between the months of December-March of each year, when normally cold temperatures tend to present anomalies of 0.5°C above average and it is estimated that the next El Niño event in Latin America and the Caribbean will have effects in 2023.

The link between environmental protection and sustainable development is urgent in order to protect human health, increase biodiversity, sustainably manage fragile ecosystems present in coastal areas, among others, and thus promote sustainability through the implementation of activities that mitigate the negative impacts of this phenomenon on the environment.

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