Historic Literature Review: El Nino Southern Oscillation

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Introduction

Climate oscillations are cyclic, temporal shifts in climactic variables such as wind patterns, ocean surface temperatures, ocean currents etc. El Nino Southern Oscillation (ENSO) is the name given to the oscillation that describes the warming of the upper ocean near the equatorial, eastern Pacific Ocean. The purpose of this research is to provide a timeline and description of the initial discovery and the most significant research advances that have led to the current scientific understanding of the El Nino Southern Oscillation. The intent is to provide a review of both the series of papers by Gilbert T. Walker in the early 1900's that are considered to be the discovery of the phenomenon, and the paper by Jacob Bjerknes in the 1960's that provided a geophysical mechanism by which the phenomenon discovered by Gilbert, could be explained. A description of the advances since Bjerknes that have led to the current multidisciplinary scientific understanding of ENSO will also be included. Information on ENSO and the series of publications will be obtained through major professional reference sources such as the Encyclopedia of Global Warming and Climate Change, and the Encyclopedia of Geomorphology, and papers from contributors through databases such as JSTOR and ScienceDirect. The oldest applicable research was that of Walker in the 1920's, published by the Royal Academy of Meteorology, which is available through the JSTOR database.

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Background

El Nino Southern Oscillation (ENSO) is the name given to the oscillation that describes the warming of the upper ocean near the equatorial, eastern Pacific Ocean. The warming is related to periodic changes in atmospheric pressure, described as the Southern Oscillation. ENSO is made up of the El Nino phase in which the equatorial Pacific Ocean is uncharacteristically warm and the La Nina phase in which the ocean temperatures of the region are cooler. The oscillation has a return period of 3-7 years and lasts for 1-2 years. The warming of this region of the Pacific has far reaching effects such as drier conditions in Australia and the Philippines, drier conditions over south-eastern Africa, and increased rainfall and thunderstorms along the subtropical regions of North America (Goudie, 2003). The term “El Nino” has a cultural background. The waters along the coast of Peru are usually cold and flow northward along the coast. Every few years around Christmas time the currents warm and flow southward. This shift to warm southward flowing currents was originally called El Nino which is Spanish for “the boy”, which is also a reference to Jesus. This is because the shift was locally considered a blessing as the warmer waters brought heavy rainfall to the usually desert landscape. Today the event is considered a disaster as the warmer waters quell upwelling and reduce the usually abundant fish populations off the coast. The cultural language has remained in the scientific literature and today the two separate phases of ENSO are termed El Nino and La Nina, the latter referring to the more stable, “normal” conditions (Philander, 2012). Other effects of ENSO include a weakening of easterly trade winds near the equatorial pacific which causes a decrease in the upwelling of the eastern south Pacific. High atmospheric pressure shifts westward towards Australia causing droughts and warmer than normal ocean temperatures across the eastern and central south Pacific (Nicholson et. al., 2016).

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Early Studies

El Nino was discovered in two steps. The first was by Gilbert Walker in the 1920's. Walker recognized the statistical climate anomaly by analyzing available data and published his findings in a series of papers between 1914 and 1930. Walker discovered the statistical phenomenon of the Southern Oscillation, but proposed no mechanism through which the results could be explained. Walker's focus was primarily on the development of new statistical methods for analyzing global weather patterns. The second step in the discovery of El Nino came in the late 1960's when Jacob Bjerknes made the connection between the global climate processes today as El Nino and Walker's Southern Oscillation. In doing so Bjerknes provided a mechanism that could explain the observations and statistical anomaly discovered by Walker 40 years earlier.

The beginnings of Walker's studies on atmospheric teleconnections are found in his 1914 paper, *Correlation in seasonal variations of weather.* Walker was working in the isolation of India trying to use then recent developments in statistics such as correlation, and regression to sift through recently compiled data. Making use of these new techniques, Walker helped to develop a formal treatment of the problem of multiple comparisons (Walker 1914), (Katz 2002).

In his 1923 paper, *Correlation in seasonal variations of weather,* Walker continued his development of statistics and asserted that his new methods were the best way to analyze global weather patterns, "the relations between weather over the earth are so complex that it seems useless to try to derive them from theoretical considerations" (Walker 1923). Today, we would call the statistics that Walker was developing, autocorrelation and cross correlation coefficients (Katz 2002). Solely relying on statistics, Walker discovered three teleconnections (though the term didn't exist at the time) that were affecting global weather. "There is a swaying of pressure on a big scale backwards and forwards between the Pacific Ocean and the Indian Ocean, there are swayings, on a much smaller scale, between the Azores and Iceland, and between the areas of high and low pressure in the N. Pacific" (Walker 1923). Walker further suggested that the swaying in the Pacific exerted the most control on global weather patterns, "the influence of the Pacific Ocean– Indian Ocean swayings upon world weather seems to be much greater than that of either of the other two" (Walker 1923).

Though much of his work was detailed in his 1923 paper, Walker didn't give formal names to the swayings of pressure he observed until his 1924 paper, *Correlation in seasonal variations of weather.* It was in this paper that he summarized his results and coined not only the term "Southern Oscillation", but also the "North Atlantic Oscillation", and the "North Pacific Oscillation" (Walker 1924).

42 years after Walker formally named the statistical anomalies he discovered, Jacob Bjerknes started to put together the pieces. Climate data had increased substantially in both accuracy and availability since Walker's day and Bjerknes first focused on data from 1957 and 1958. In his 1966 paper, *A possible response of the atmospheric Hadley circulation to the equatorial anomalies of ocean temperature*, Bjerknes noted the connection between weakening trade winds and reduced upwelling off pacific coast of South America. "Weakness and temporary elimination of the equatorial easterly winds over the eastern and central Pacific in late 1957 and early 1958 brought about a brief cessation of equatorial upwelling" (Bjerknes 1966). In the same paper, Bjerknes posed other climate-ocean reactions that could be caused by the same events, "…caused the occurrence of above-normal surface water temperatures in the tropical Pacific from the American coast westward to the dateline" (Bjerknes 1966).

Bjerknes expanded his research and found similar patterns of climate-ocean relations for the winters of 1963-1964 and 1965-1966. He detailed these findings in his 1969 paper, *Atmospheric teleconnections from the equatorial Pacific.* It was in this paper that Bjerknes attributed his findings to those of Walker's statistical anomalies. "The maxima of the sea temperature in the eastern and central equatorial Pacific occur as a result of anomalous weakening of the trade winds of the Southern

Hemisphere with inherent weakening of the equatorial upwelling. These anomalies are shown to be closely tied to the "Southern Oscillation" of Sir Gilbert Walker" (figure 1) (Bjerknes 1969). In doing so, Bjerknes provided the geophysical mechanisms that explained the anomalies discovered by walker 40 years earlier.

Modern Studies

Today the primary research on ENSO is done through computer modeling, with the intent of discovering how far reaching the effects of the oscillation are on a global scale. Scientists today are trying to figure out which global weather events may be tied to ENSO, as a means of separating these events from climate change. A few recent papers will be outlined here.

In a 2000 paper published in the Journal, Geophysical Research Letters, scientists sought to combine the many different regional ENSO precipitation studies to form a more complete, global view of the effects of ENSO on precipitation. They state in their findings that, "The patterns suggest that the re-arrangement of convection centers of the Walker circulation during ENSO events induces large precipitation anomalies in the tropics, while associated changes in the monsoon systems (through the Hadley cell) over the Pacific, Indian and Atlantic Oceans, and their interactions with midlatitude westerlies generate coherent anomaly patterns over the extratropics" (Dai, Wigley 2000).

A more recent study from 2015 exemplifies the complexity of attributing ENSO to other climate phenomena such as droughts across North America. Scientists attempted to, "study the influence of El Niño-Southern Oscillation teleconnection on meteorological droughts represented by the Palmer severity drought index across North America from 1870 to 1990" (Choi et. al. 2015). They developed a model to analyze the data and found that effects of ENSO vary spatially and temporally across North America and that it is difficult to attribute ENSO to patterns of drought.

Conclusion

ENSO, like many scientific phenomena was discovered first as an anomaly, and after much research was later given a geophysical mechanism through which the anomaly could be explained. This process should be familiar to any geologist; think Alfred Wegener and the anomalies regarding continental drift that were later given a mechanism that we know today as plate tectonics. First Gilbert Walker observed statistical anomalies in the atmospheric and oceanic climate data available to him. He explained and revised his observations in a series of papers published between 1914 and 1930. Thirty years after Walker's observations, Jacob Bjerknes made the connection between the statistical anomalies and the Southern Oscillation. In doing so Bjerknes provided a mechanism to explain Walker's observations. Today the primary research on ENSO is done through computer modeling with the intent on discovering just how far reaching the phenomenon's effects are on global weather patterns. Scientists are trying to figure out which global weather events may be tied to ENSO versus those that can be attributed to global climate change.

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Appendix A: Illustrations

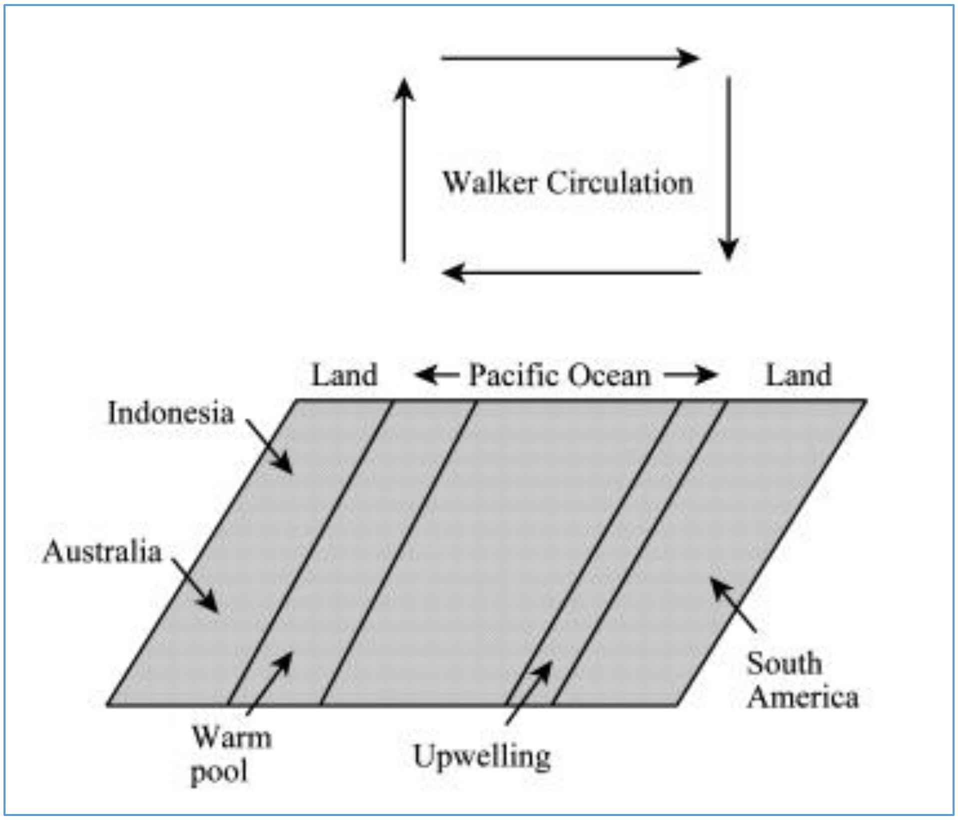

Figure 1: diagram of Normal Phase of Walker Circulation from Katz, 2002.

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