Climate Change and Variability

Introduction: You will learn about the El Niño Southern Oscillation as an example of climatic variability; and how it can impact ecosystems. You will examine how El Niño and La Niña influence drought and forest fire occurrence in the SW United States, as well as the fishing and farming economies in equatorial Pacific countries of South America.

Key Concepts:
- El Niño, La Niña, Southern Oscillation are part of what is called the ENSO Variability.
- ENSO's effects on global weather patterns and life.

What's due?
After filling in the answers, below, log onto D2L Workshop 8 and answer the multiple-choice questions. **10 pts**

The El Niño Southern Oscillation

When atmospheric and oceanic conditions are "normal", high atmospheric pressure exists over the eastern Pacific Ocean, near Peru, and low pressure over the western Pacific, near Australia. This pressure gradient creates strong easterly (east to west) winds which "push" warm ocean surface waters westward. Cold waters from the depths of the eastern Pacific rise, or upwell, to fill in the space where the warm waters were. Look at the figures of the sea surface temperature anomalies (the deviations from normal sea surface temperatures) in Figure 1

During an **El Niño** event, the atmospheric pressure decreases over the eastern Pacific, decreasing the pressure gradient, which causes the winds to weaken. The warm surface water is no longer "pushed" westward, and the upwelling of cold waters off the South American coast decreases. As a result, the surface waters in the eastern equatorial Pacific are warmer than normal.

El Niño events are usually followed by **La Niña** events, in which the opposite occurs. The atmospheric pressure gradient over the equatorial Pacific is greater than usual, and more cold water upwells from the depths of the ocean near the coast of South America near Peru.

The variation of the atmospheric pressure gradient over the equatorial Pacific Ocean is known as the Southern Oscillation. Because the southern oscillation is the driving force of an El Niño (or La Niña) event, the phenomenon is often referred to as **ENSO** (El Niño – Southern Oscillation).

Global climate can be affected during an ENSO event (either El Niño or La Niña). However, weather patterns for the equatorial regions in and around the Pacific are the most strongly influenced. During normal years, the western Pacific near Indonesia (where the warmest waters usually sit) receives heavy rainfall. During El Niño years, the rains migrate eastward, following the warmest waters. This situation can cause droughts in Indonesia, Australia,

eastern Africa, and floods in Ecuador and Peru. El Niño and La Niña also influence the weather patterns in the United States, though to a lesser extent.

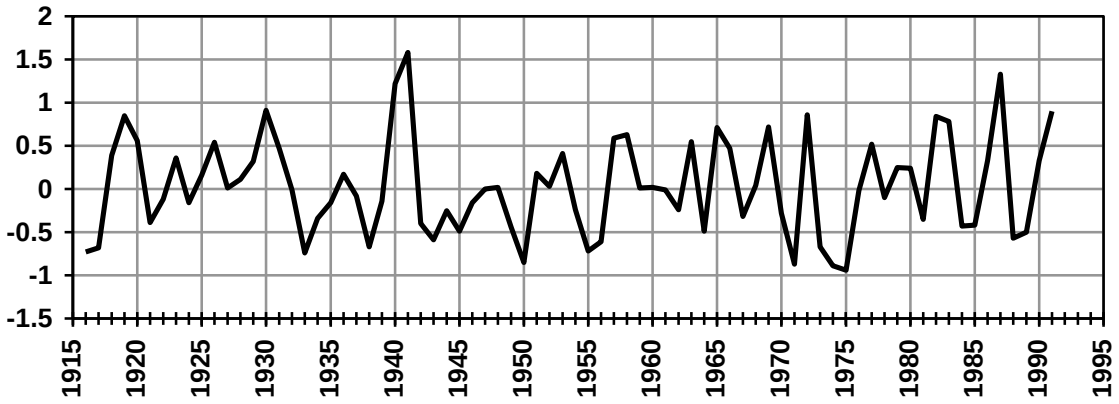
1. Sea surface temperature patterns El Niño *vs.* La Niña. Goto http://www.pitt.edu/~mabbott1/climate/mark/Images/sst_nino_nina.gif (you need a color image to answer these questions) Compare closely the temperature departures (lower 2 panels). Calculate the sea surface temperature differences between(El Niño (left panel) minus La Niña (right panel) in the following five locations?

Location	Longitude - Latitude	˚C Niño minus Niña
Western Equat. Pacific	110˚W - 0˚N (Eq)	
South Pacific	120˚W - 30˚S	
North Pacific	150˚W - 35˚N	
Baja California	115˚W - 25˚N	
Caribbean	60˚W - 20˚N	

2. **El Niño and La Niña events in the last century.** Sea surface temperatures (SST) are routinely measured by buoys and satellites across the equatorial Pacific in order observe conditions and to try to predict ENSO events. Below is a graph of sea surface temperature anomalies (SSTA) of the equatorial Pacific Ocean near the South American coast. Positive numbers mean the water is warmer than usual; negative numbers mean the water is colder than usual.

On the figure below circle the El Niño and La Niña events (any anomaly less than or greater than 0.4^{o}C) and put a star next to the events that are especially strong.

Figure 1. Sea Surface Temperature Anomalies for the eastern equatorial Pacific



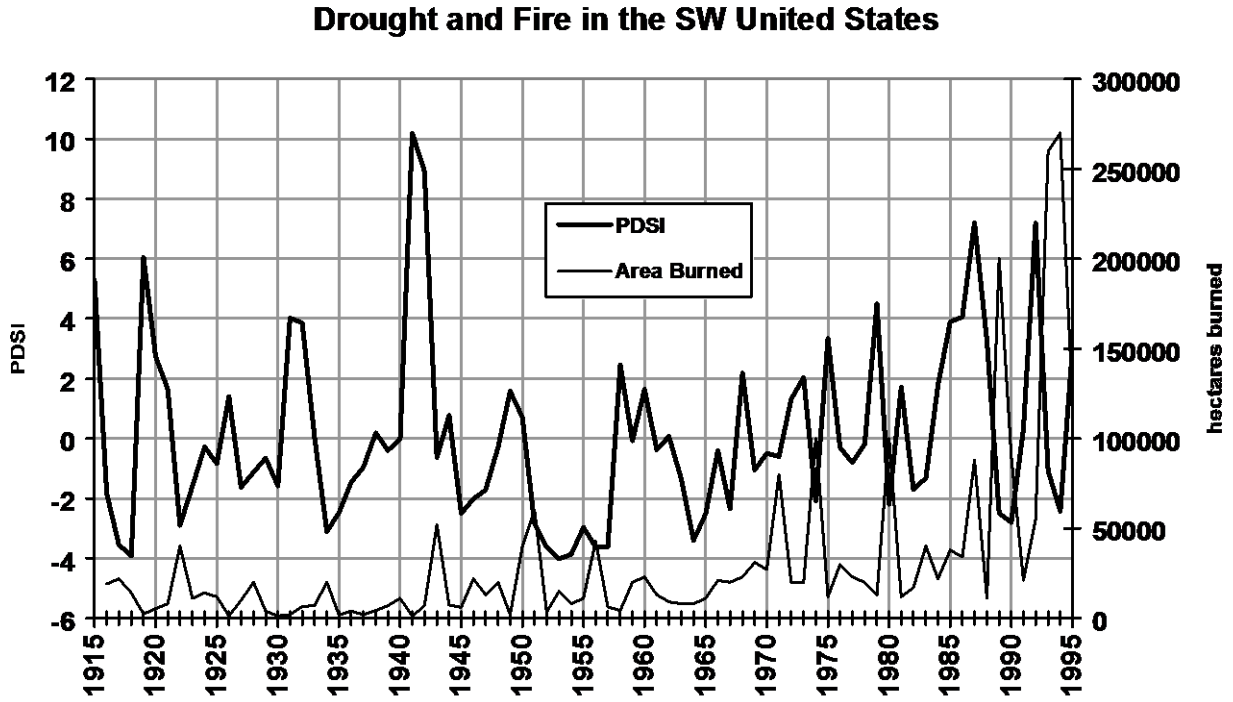
Data Source: Kaplan, A. et al. 1998.

3. ENSO and Its Impact on Forest Fires in the SW United States

The Palmer Drought Severity Index (PDSI) uses local temperature and rainfall information to determine dryness. Numbers are calculated to represent long term (months) drought conditions. **Negative numbers are considered drought**

conditions, positive numbers are considered excessive rainfall conditions, and zero is normal. So a –4 means severe drought, -2 means moderate drought, 2 means moderate rainfall, 4 means heavy rainfall. Below is a graph of PDSI values and hectares burned by forest fire for the SW United States in the last century.

What is the correlation between drought and fire occurrence? (Do the peaks on the fire-acerage graph match with the valleys on the PDSI graph?) If so, what does this suggest?



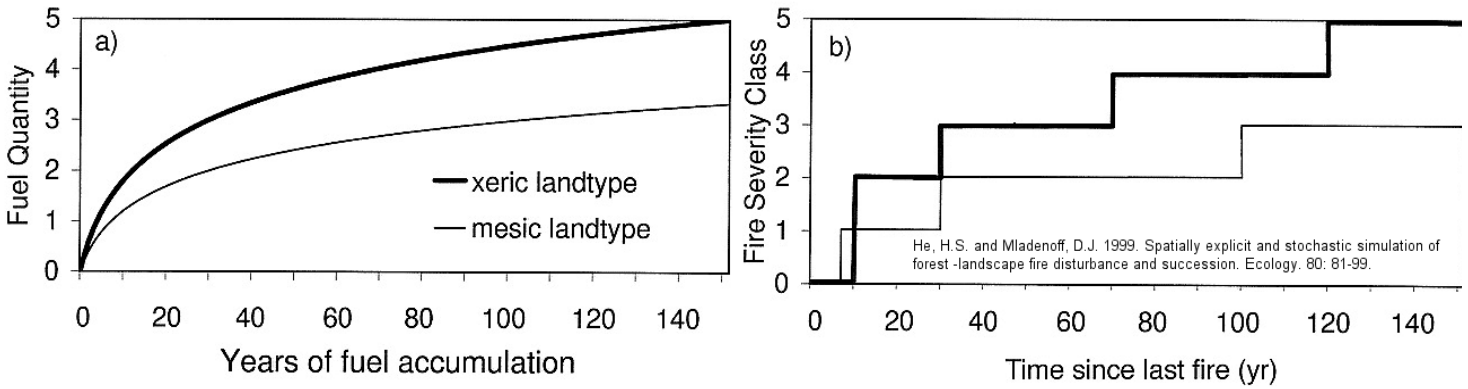
Fire data source: Hughes, 2000 (unpublished)
Drought data source: Cook, E.R. et al., 1999

4. **The correlation between La Niña events and drought/fire in the SW United States?**

On the figure for Q. 3 circle the years when there are both drought and widespread fires. Now compare these years to the La Niña years in Q. 2. What is the relationship between La Niña events and fires in the American Southwest.

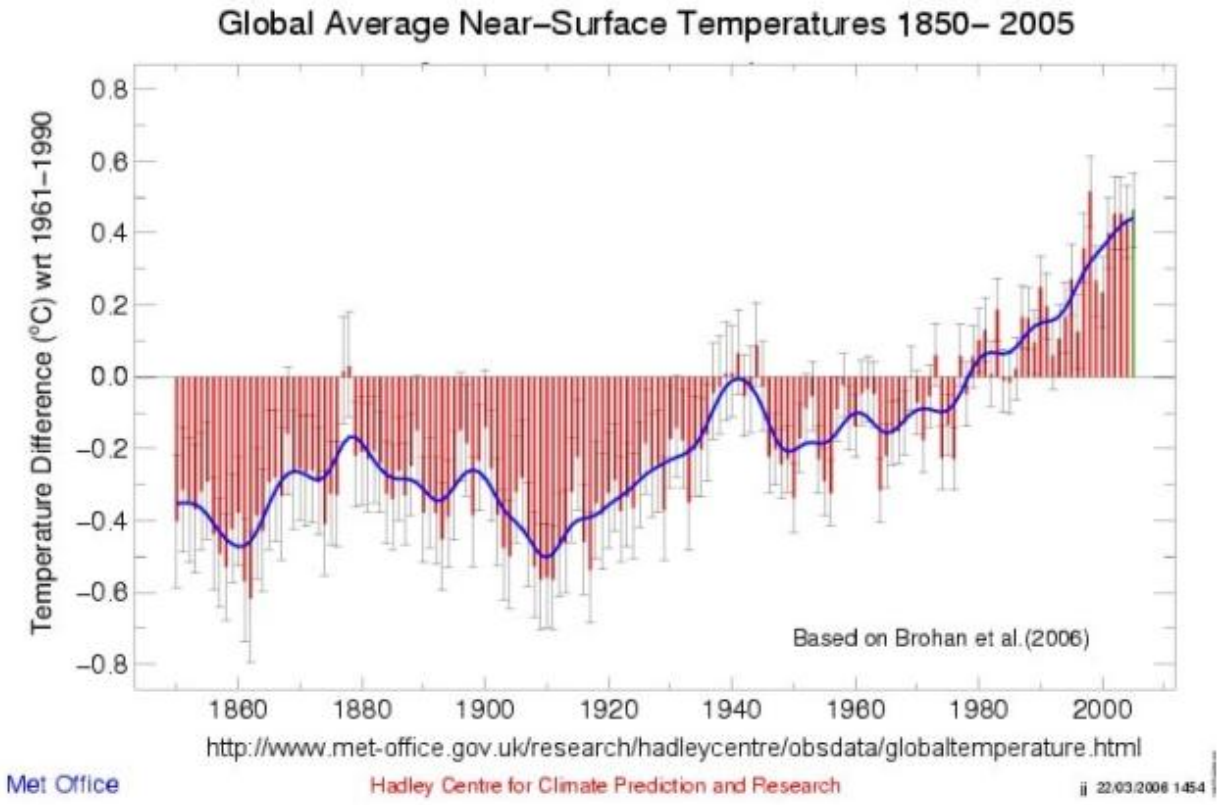
5. Additional climate factors that have influenced forest fires in the SW United States.

In the beginning of the twentieth century, fire management policy was to quickly extinguish forest fires. This led to less land area being burned, and the build-up of fuel in the unburned areas. This can be modeled as an exponential curve, which leads to increasing fire severity as fuels accumulate (figure below).



He, H.S. and Mladenoff, D.J. 1999. Spatially explicit and stochastic simulation of forest-landscape fire disturbance and succession. Ecology. 80: 81-99. http://www.esajournals.org/

At the same time, global average temperature increased by nearly 1˚C. In addition to influencing ENSO and other climate patterns, the generally higher temperatures may have enhanced forest fire intensity. Compare the two figures above and below, with the figure of fire frequency in question 3. Which is a more plausible explanation for the long term patterns in fire frequency not explained by ENSO -- management, global warming, or both?



Samadi, S. 2006. Die Rekonstruktion des globalen temperaturverlaufs der vergangenen 1000 jahre - methoden, probleme, Erkenntnisse, hausarbeit. Atmosphäre Strukturen, Funktionen, Reaktionen 40. http://www.hausarbeiten.de/faecher/vorschau/110138.html