12: SOI/ENSO and their influence

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The El Niño Southern Oscillation (ENSO) is an anomalous large scale ocean-atmosphere system associated with strong fluctuations in ocean currents and surface temperatures. It causes abnormal atmospheric and environmental conditions, primarily in equatorial regions within the Pacific Basin. ENSO is a major example of the interconnectedness between ocean currents and atmospheric conditions and the name "El Niño Southern Oscillation" reflects this by consisting of two components.

El Niño

Early sailors fishing off the coast of South America noticed a phenomenon where during certain years the coastal waters near Peru were abnormally warm, causing unfavorable fishing conditions. This would usually occur during the Christmas period, so the occurrence became known as El Niño meaning "The Little Boy" or "the Christ Child". Today the term is often used in reference to unusually warm ocean surface temperatures in the Equatorial region of the Pacific.

La Niña

La Niña is Spanish for "The Little Girl" and refers to abnormal cold ocean surface temperatures in the Equatorial Pacific. Other terms used, although less often, are El Viejo (Old Man) and anti-El Niño.

The Southern Oscillation

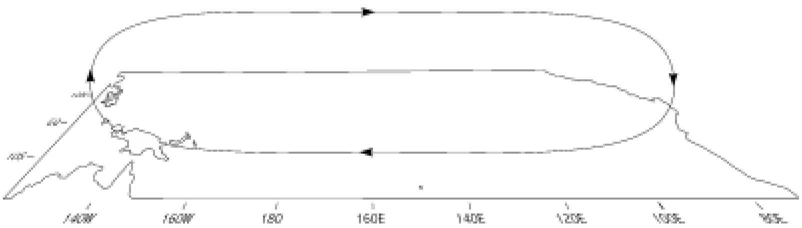

Figure 1: Map of the region showing the Walker circulation.

The Walker circulation (Walker, 1924) is an east-west atmospheric circulation pattern characterised by rising air above Indonesia and the western Pacific and sinking air above the eastern Pacific, as shown in Figure 1. Associated with the rise in air above Indonesia are heavy convective rains. The term "Southern Oscillation" refers to the variability of the strength of the Walker Circulation system and is quantified through the Southern Oscillation Index. During El Niño events there is a weakening of the Walker circulation, generally bringing drier conditions to the western Pacific region. During La Niña events the Walker circulation is especially strong, and rainfall may be unusually high over Indonesia. El Niño and the Southern Oscillation are two characteristics of the one large ocean-atmosphere event which we now refer to as ENSO (Rasmusson and Carpenter, 1982).

Calculating the Southern Oscillation Index (SOI)

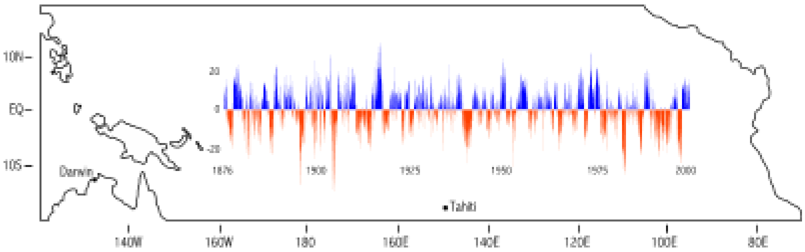

Figure 2: Map of the region and the monthly Southern Oscillation Index.

The SOI is an index used to quantify the strength of an ENSO event. It is calculated from the difference between the sea level pressure (SLP) at Tahiti and Darwin. Although there are several methods of determining this relationship, a method often used, and shown in Figure 2, was presented by Troup (1965):

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                        [ SLPdiff - avSLPdiff ]
SOI = 10.0 x            -----------------------
                             StdDev(SLPdiff)
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where

SLPdiff = (mean Tahiti SLP for the month) - (mean Darwin SLP for the month),
avSLPdiff = long term mean of SLPdiff for the month in question, and
StdDev(SLPdiff) = standard deviation of SLPdiff for the month in question.

In Figure 2, negative values (red) represent warmer than average conditions or El Niño events. Large positive values represent La Niña conditions. While the graph shows considerable variability in the SOI, the general pattern is for an ENSO event every four to seven years, with each event lasting between one and two years.

Physical characteristics

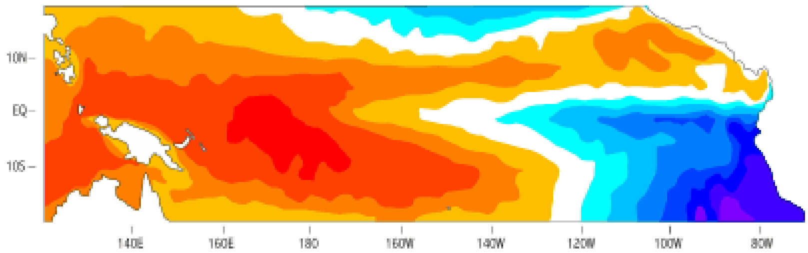

Figure 3: Map of the sea surface temperatures in the equatorial Pacific during normal conditions.

While the SOI is a measure based on atmospheric pressure, an ENSO event is also portrayed by sea surface temperature (SST) maps. The "normal" conditions are for warmer SSTs to the west of the equatorial Pacific basin and cooler SSTs to the east, as shown in Figure 3. This, combined with the normal Walker atmospheric circulation, produces higher precipitation on the islands bordering the west Pacific and little rainfall over the eastern Pacific. It also influences the ocean surface salinity values in these regions.

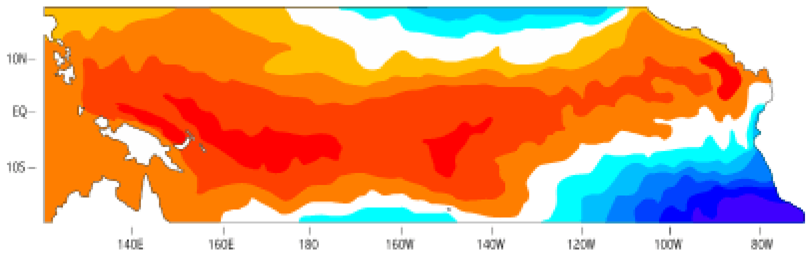

Figure 4: Map of the sea surface temperatures during an El Niño event.

During typical El Niño conditions, warmer SSTs spread further east, producing the warmer ocean surface temperatures (Figure 4). This coincides with a weakening of the Walker circulation and may cause a lower rainfall over the western Pacific and excessive rain on parts of Peru and Ecuador. Other notable anomalies during these events are changes in sea surface heights, with higher than average heights experienced to the east of the Pacific. Convective cloud, usually situated over the western Pacific shifts to the east and centres itself in the middle of the equatorial region of the Pacific. It should be noted that while ENSO conditions provide the basis for such impacts other factors can also cause equally opposite reactions.

La Niña events are associated with cooler SSTs extending further west and warmer temperatures contracting to the west (Figure 5). Strengthening of the Walker circulation causes an increase in precipitation, particularly over Indonesia, and abnormally high sea surface heights over the western Pacific. Generally drier conditions are experienced over Peru and Ecuador. A strengthening of the Trade winds is also observed.

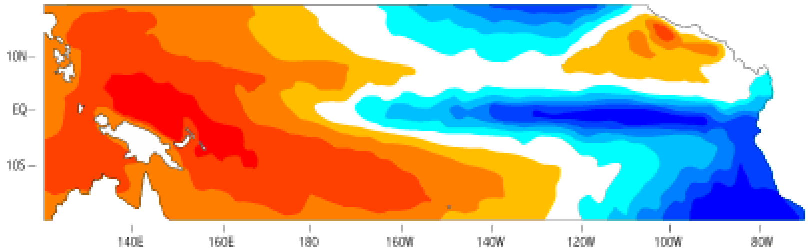

Figure 5: Map of the sea surface temperatures during a La Niña event.

Further areas of influence

While the effects of an ENSO period are directly linked to areas within the Pacific Basin, its signal is noticeable as far away as India, Africa, Antarctica (Bromwich et al, 2000) and North America. Impacts are usually expressed in the form of a change in the precipitation regime.

Causes

We know that ENSO events are a mix of changes in atmospheric and oceanic conditions, and that SST warming and a low SOI are signals of an El Niño event. But what causes the onset of these conditions? Several causes have been put forward. These include:

- climate cycles or ocean-atmosphere oscillations
- underwater earthquakes on the East Pacific Rise
- solar activity

Of these the last two are generally regarded as being less likely causes of ENSO events. It is more probable that the onset of an ENSO event is caused by complex oscillations in a dynamic ocean-atmospheric system. Is there a link between ENSO events and climate change/global warming? At this stage there is no consensus on this matter. There is, however, evidence that the characteristics of ENSO are changing. Although El Niño's are is normally cited as being a relatively rare event, it has become apparent that in the 1980s and 1990s El Niño events occurred more frequently, and lasted longer. The longest El Niño of the 20th Century persisted from 1991 to 1995, and was rapidly succeeded by the most intense El Niño of the 20th century, which occurred in the period 1997-98 (WMO, 1999). In the three decades since 1970, the WMO lists five El Niño events, in 1972-73, 1982-83, 1986-88, 1991-95 and 1997-98. In the preceding seven decades the same number of events are listed, in 1899-1900, 1904-5, 1913-15, 1925-26 and 1940-41 (WMO, 1999).

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