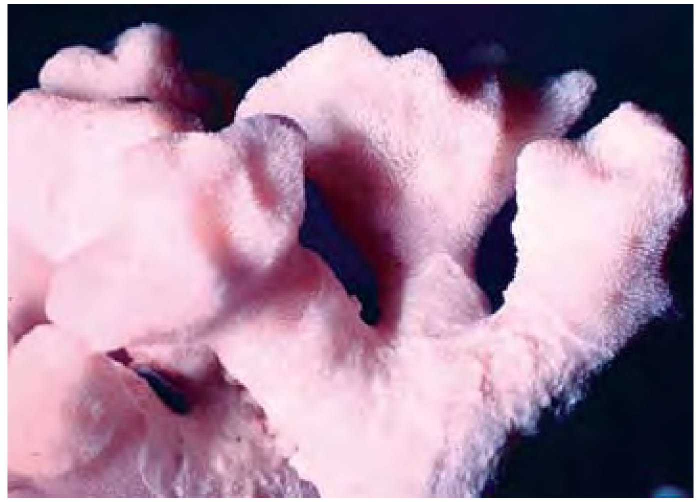
Unlocking El Niño's Past to Forecast its Future



Associated with droughts, floods, and other weather disturbances, the El Niño-Southern Oscillation has grave consequences for agriculture and fisheries worldwide. Thus a rather urgent question is, how will El Niño change with the warming projected for the 21st century? Clues to El Niño's future behavior might be found in its past. Scientists have been reconstructing climate from such records as tree rings, ice cores, corals, and sediments that reflect past El Niño events. These proxy records, however, have a drawback. They vary greatly amongst each other for reasons that could range from inaccurate dating of the proxy to contamination from non-El Niño-related climate signals. And this is where a new proxy index of El Niño events is making a significant contribution. Developed by IPRC scientists **Shayne McGregor, Axel Timmermann,** and **Oliver Timm**, the new index matches the instrumental record closely, but extends much further back, to 1650. Already it has confirmed suspicions that El Niño events have been becoming stronger and that volcanic eruptions may create favorable conditions for El Niño.

The El Niño-Southern Oscillation, called ENSO for short, manifests itself by alternating warm phases (El Niño) and cool phases (La Niña) of surface waters in the central and eastern tropical Pacific Ocean and by a large-scale seesaw in atmospheric surface pressure between Tahiti and Darwin, Australia. The phase of the oscillation is monitored by measurements of sea surface temperature (SST) between 120°W–170°W and 5°S–5°N (the Niño 3.4 region, the box in Figure 1), and surface pressure in Tahiti and Darwin.

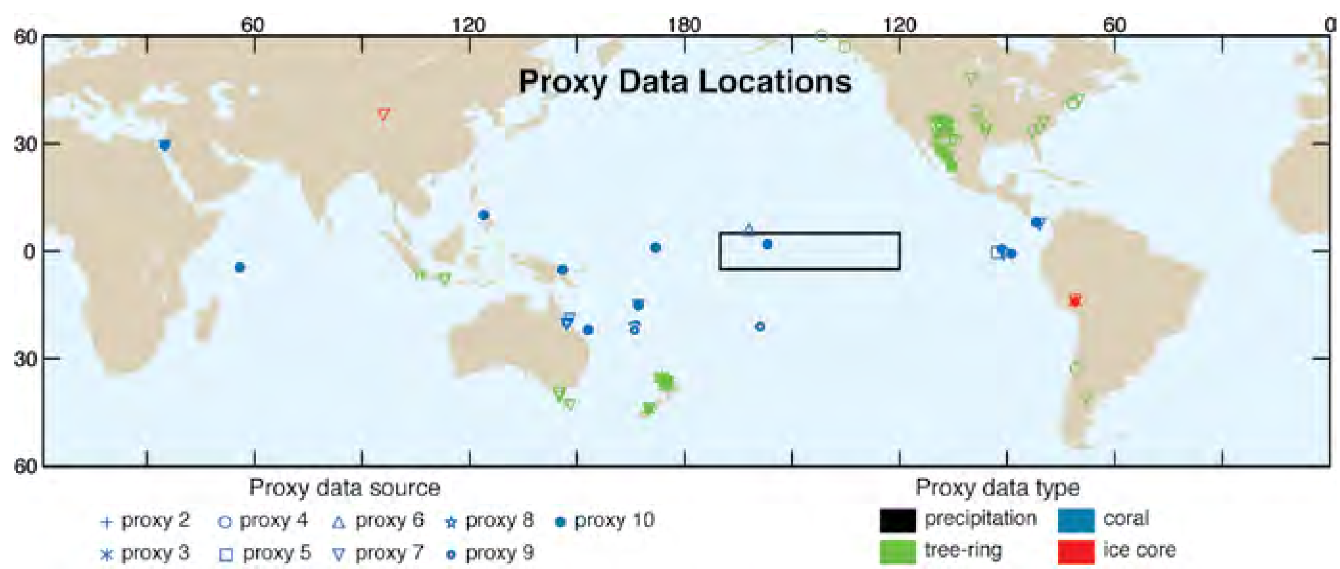


Figure 1. Proxy location and source-type for the Unified Proxy Index derivation. Black box shows Niño3.4 sea surface temperature region.

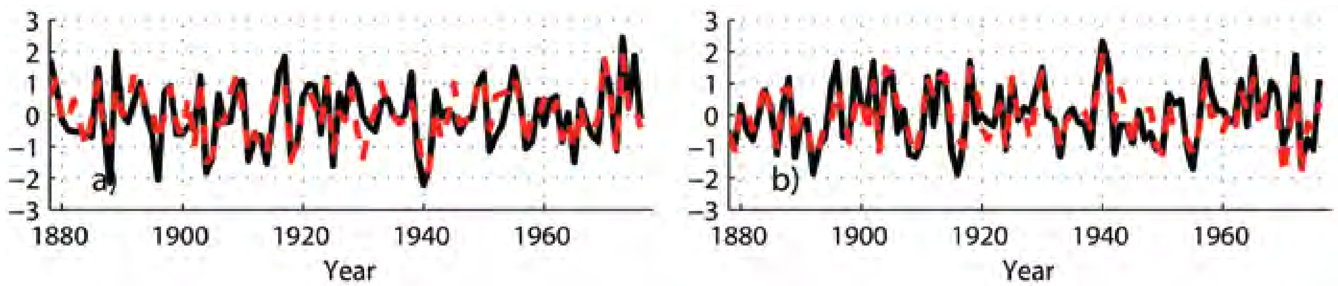


Figure 2. Time series of the (a) Southern Oscillation Index, and (b) Niño3.4 sea surface temperature both show close correspondence between observations in black, and the Unified ENSO Proxy Index in red.

To create a reliable and valid index of El Niño past behavior, the IPRC team selected 10 proxy records of ENSO variability that had been defined in previous studies and that compared well to the instrumental record of Niño 3.4 SST or sea level pressure at Tahiti and Darwin. The proxies are derived from networks of precipitation, tree-ring, coral, and ice-core records. The input to the networks is geographically widely distributed, from the Indian Ocean and Tibet, to Australia and New Zealand, to South and North America (Figure 1). Some of the proxies are in regions directly influenced by ENSO, other network regions sampled are far away and influenced by teleconnection signals. By using principal component analysis, the team extracted a coherent ENSO signal for the 10 input proxies. This signal accounts for over half of the covariation in the 10 proxy networks during the period 1650–1977. Since the new proxy correlates nearly perfectly with the mean of the 10 proxies from which it is derived, the scientists named it the "Unified ENSO Proxy."

This unified proxy fared well on rigorous testing. A comparison with instrumental ENSO records from 1856 to 1977 showed that it correlated better (> 0.80) with Niño 3.4 SST regions and with the Southern Oscillation Index (–.81) than any of the individual proxy sets. The index captured more discrete El Niño and La Niña events, i.e., periods in which Niño 3.4 SST was above or below the defined respective thresholds, than any of the original input proxies. The unified index was also compared to different historical documentations of El Niño and La Niña events from 1650 to 1977, and once again the index identified their occurrences well and performed better than any of the individual input proxy reconstructions.

The unified proxy has already answered several significant questions. Previous El Niño reconstructions have suggested that El Niño and La Niña events have gradually become stronger since 1650. The trend could stem from uncertainties in the reconstructions. After controlling for such uncertainties, however, the scientists found that the unified proxy still showed clear evidence to support the increasing amplitude. In other words, from the early period (1650 to about 1720) until present day, the year-to-year swings in Niño 3.4 SST and the seesaw in Tahiti–Darwin sea level pressure have grown larger (Figure 3). This

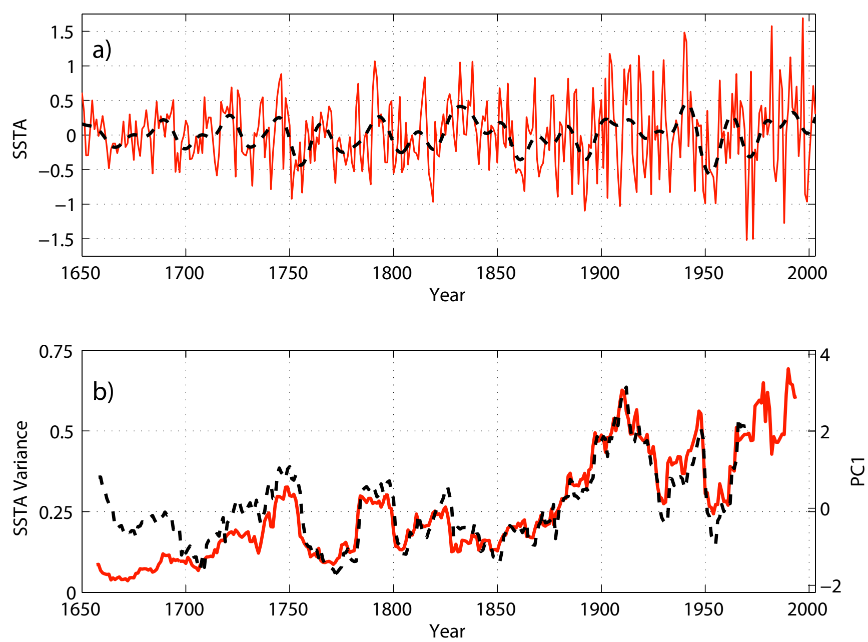
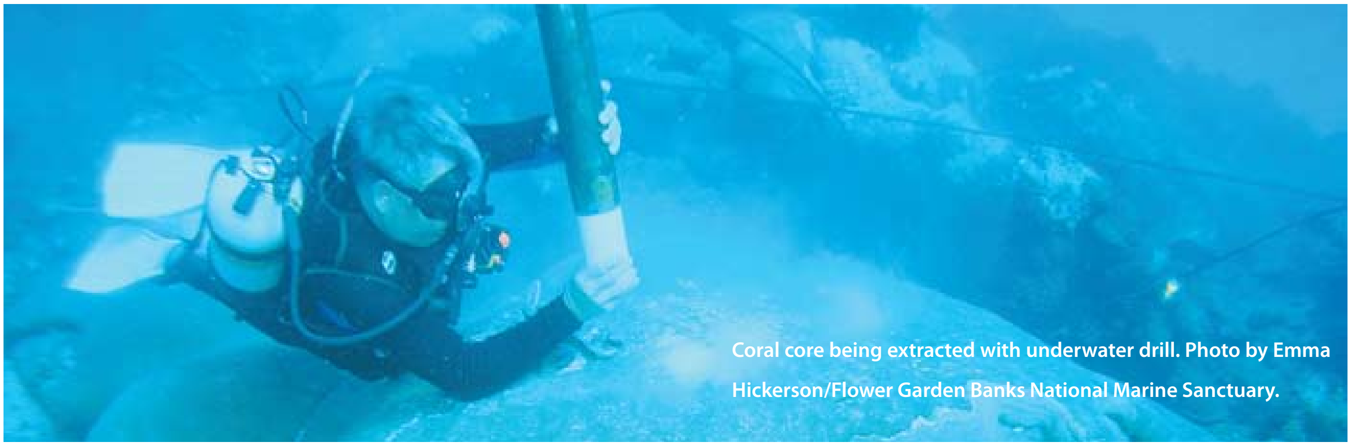


Figure 3. (a) The scaled Unified ENSO Proxy (red) and its 13-year low-pass filtered variability (black); (b) the 16-year running window variance of the scaled index (red) and the first principal component of the running variance of all 10 input proxies (black).



Coral core being extracted with underwater drill. Photo by Emma Hickerson/Flower Garden Banks National Marine Sanctuary.

increase in variance is supported by the historical chronologies and by proxies not used in creating the new ENSO proxy. The source of this increase in ENSO variance is unclear, but the team notes an interesting parallel with a reported increase in the Western Pacific warm pool temperature, an increase that theoretically could bring about greater ENSO variance.

It has long been known that the amount of energy the Earth receives from solar radiation directly affects global climate. Changes in solar radiation, therefore, have been thought to impact ENSO. The current view is that less solar radiation leads to greater ENSO swings. The unified proxy record, however, suggests the opposite: the increased variance is accompanied by increased solar radiation. Thus there is reason to question the previously proposed mechanisms on how solar radiation impacts ENSO.

The new proxy calls into question another previously proposed idea. In the early 1990s, an El Niño event persisted for about 5 years. This unusual event became the topic of many scientific papers, with one study concluding that such an event can occur only once in every 1500 to 3000 years. Over the 350-year period, the Unified ENSO Proxy shows that events of such long duration occur more frequently (about every 100 or so years) suggesting that these long events were not as unusual as first thought. The unified proxy, however, does agree with earlier studies of the instrumental record which suggest that the large shift noted in Pacific climate in the late 1970s was not unusual but appears to be part of a multi-decadal signal.

Finally, the team tested the hypothesis that volcanic eruptions affect the mean state or the probability of occurrence of El Niño or La Niña events. They analyzed two ice-core-derived indices of volcanic events from 1650 to 1977. For each reported eruption, they catalogued the values of the unified proxy for 2 years before, during, and 5 years after the event. They found that in the year of an eruption, the ENSO mean state was impacted and the probability of an El Niño (i.e., SST 0.5°C above the mean) rose from 26% in non-eruption years to either 58% or 70% depending upon the ice-core record used. Three years after a volcanic event the chances of a La Niña event occurring increased significantly from 25% to 55% or 50%, even though no significant change was detectable in the mean state.

The greatest contribution of the unified proxy is that it provides a robust index of ENSO activity over the last 350 years, an index that now allows solid validation of numerical modeling experiments. Used together with computational models of the ocean-atmosphere system, this index will improve our understanding of the source of ENSO variability.

This story is based on

McGregor, S. A. Timmermann, O. Timm, 2009: A Unified Proxy for ENSO and PDO variability since 1650. *Climate of the Past Discussions*, **5**, 2177–2222.

A Bristle Cone Pine. Reaching an age of over 5000 years, these trees are invaluable as climate proxies for research.