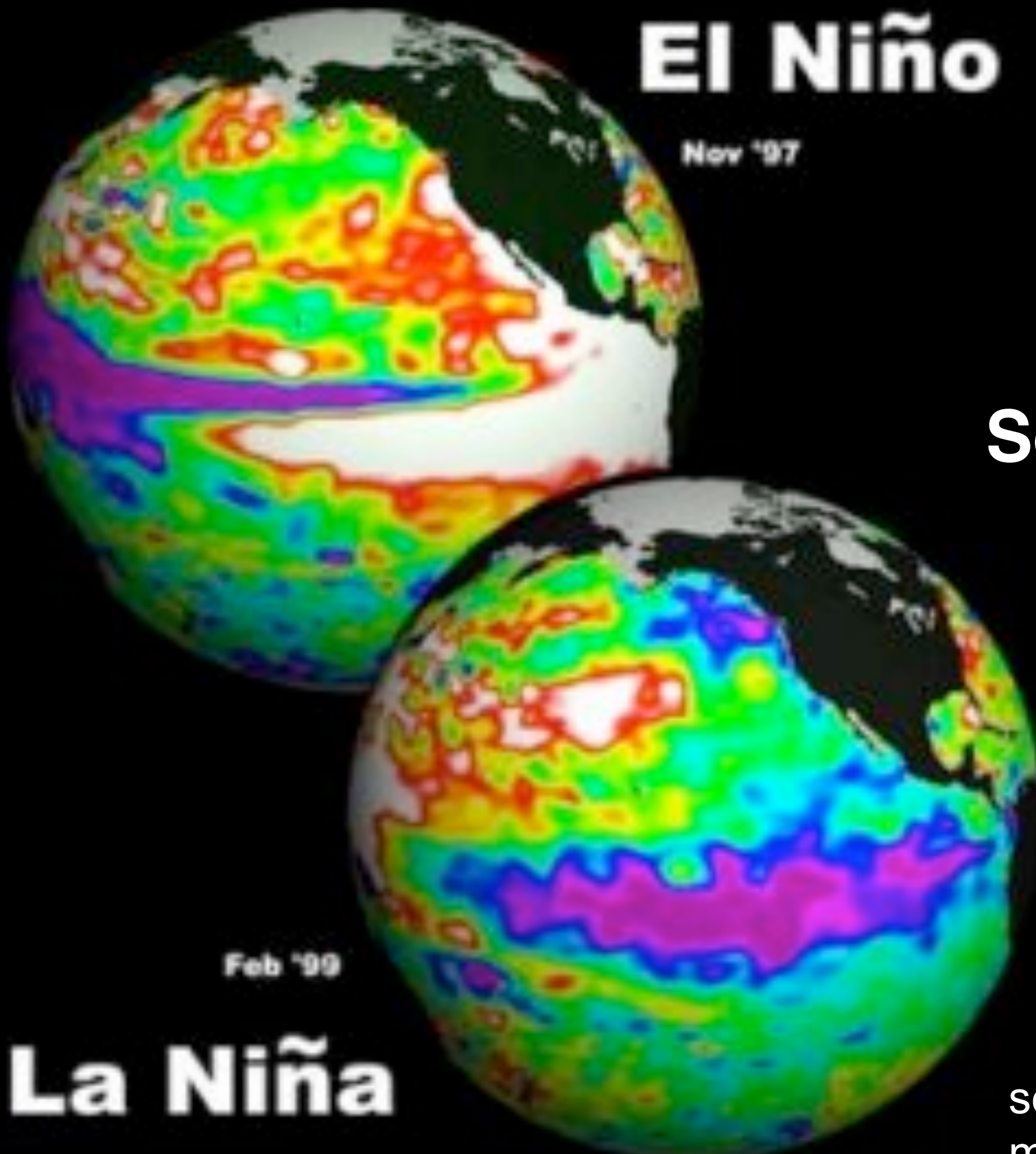
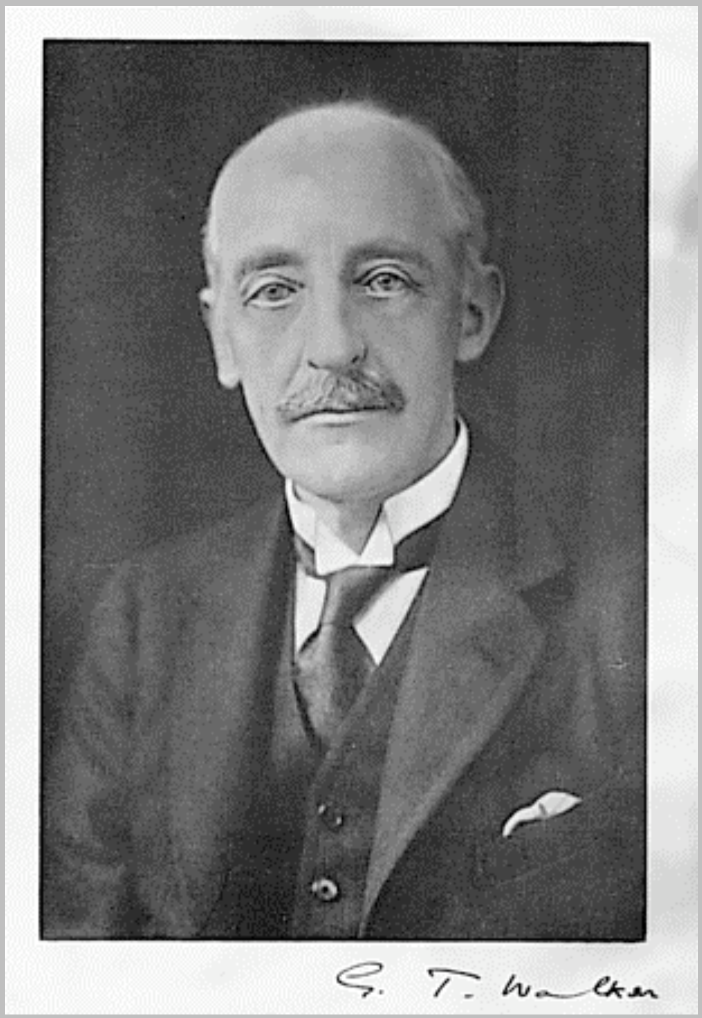


lecture 10

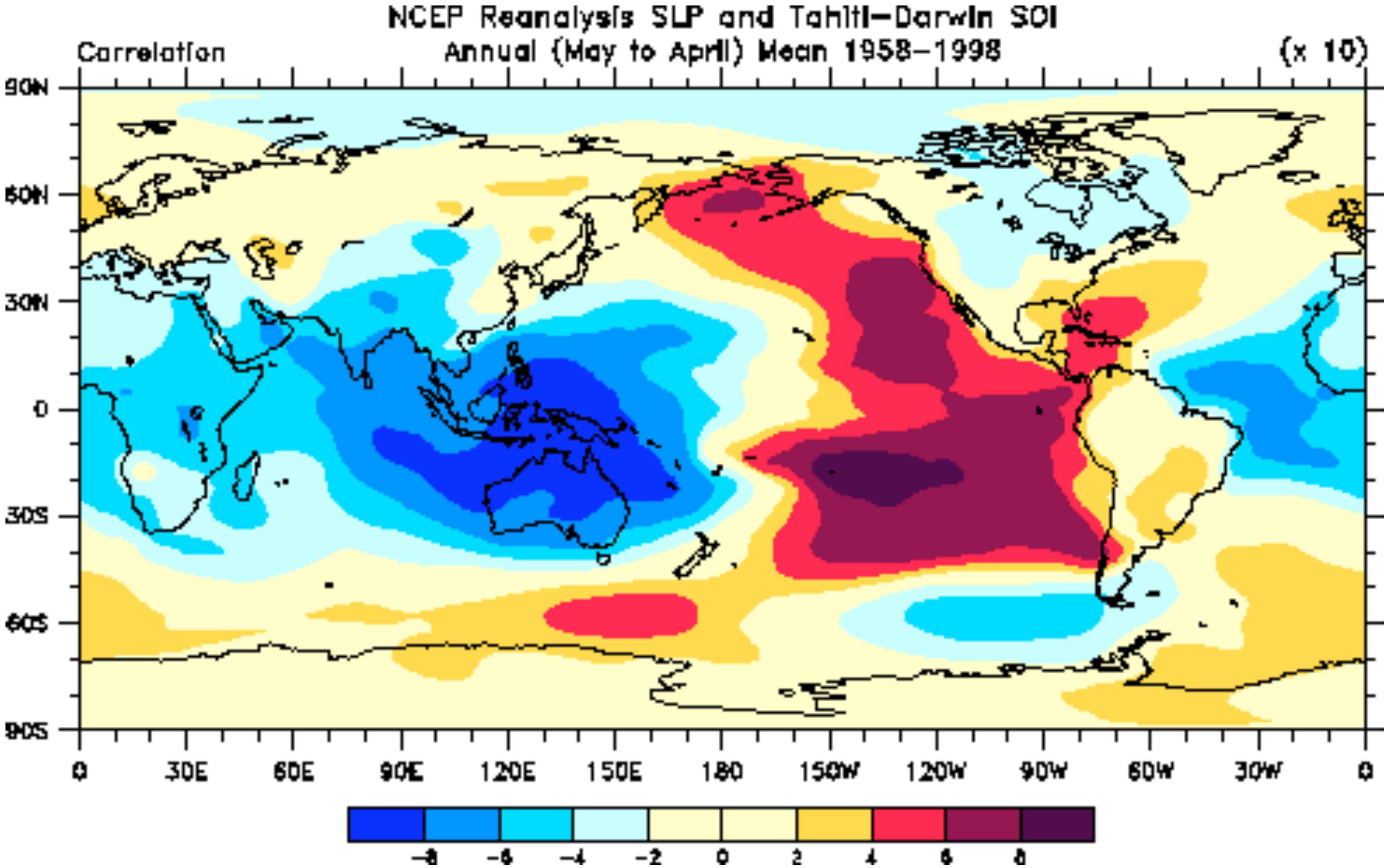
El Niño and the Southern Oscillation
(ENSO)
Part I

sea surface height anomalies as measured by satellite altimetry

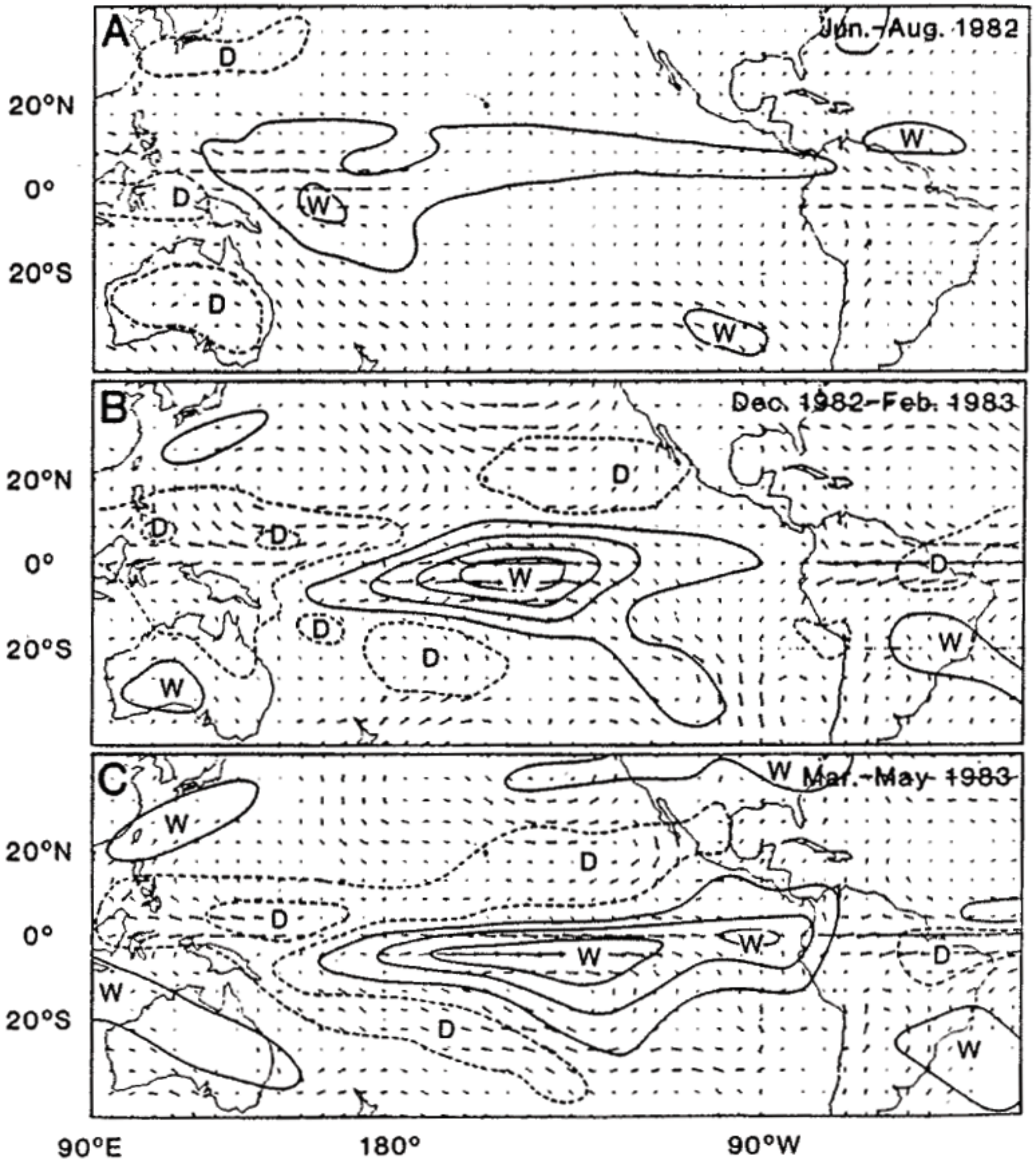
SPATIAL STRUCTURE OF ENSO



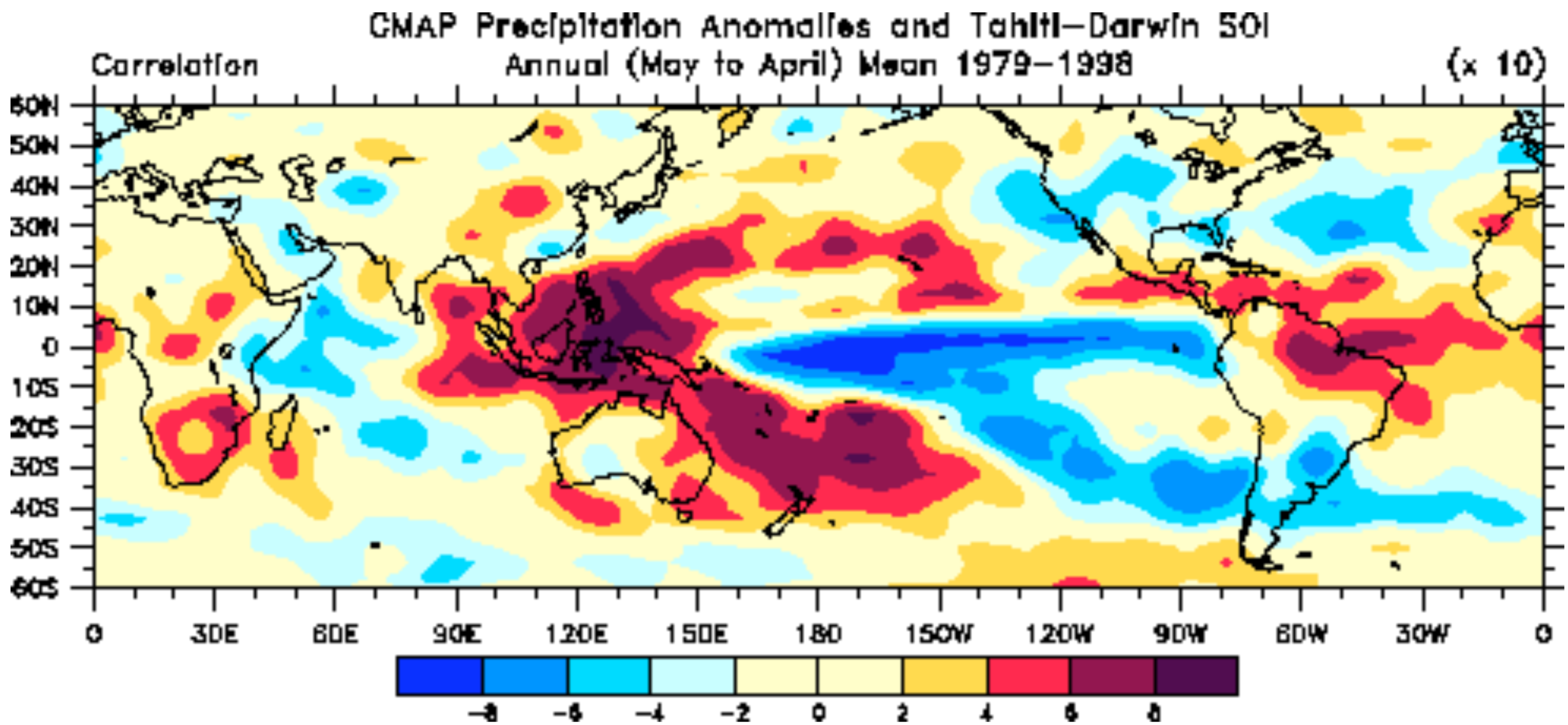
In 1899, the Indian monsoon failed, leading to drought and famine in India. This led **Gilbert Walker**, the head of the Indian Meteorological Service, to search for a way to predict the Indian monsoon. By the early 20th century, he had identified a peculiar see-saw relationship between pressure over the maritime continent and India and the Pacific near South America. When pressure is high over the eastern Pacific, it is low over the maritime continent, and vice versa. He called this relationship the **Southern Oscillation**.



Here is the contemporary view of the oscillation Walker discovered. This is the correlation of annual mean surface pressure with the surface pressure gradient across the equatorial Pacific (pressure at Tahiti minus Darwin). [Trenberth and Caron 2000]

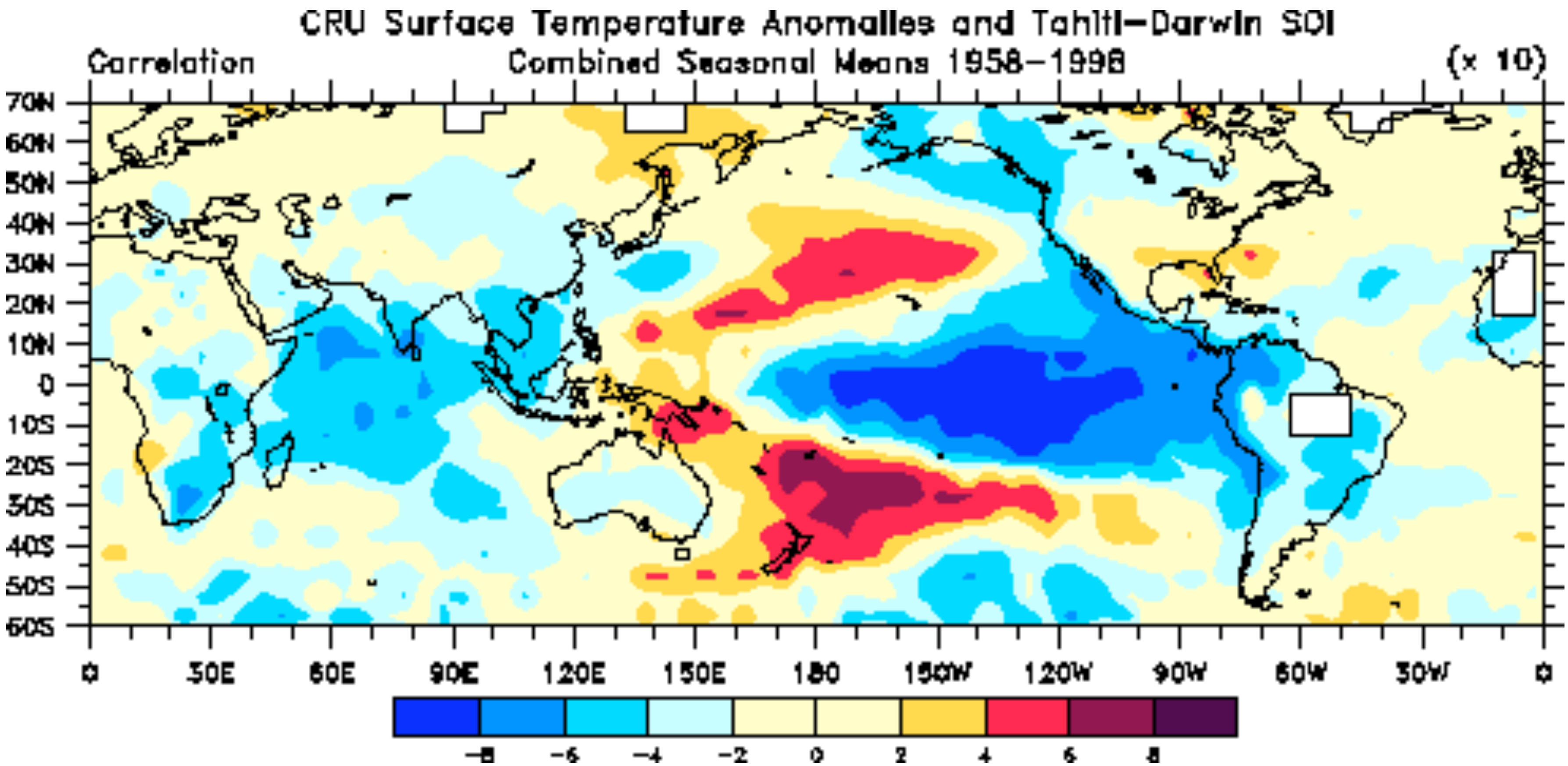


In 1982, El Nino conditions first appeared to the west of the date line and gradually expanded eastward. The panels show how, along the equator, the easterly trade winds collapsed and were replaced by westerly winds, while the zone of heavy precipitation migrated eastward. The arrows indicate the anomalous winds. Precipitation is unusually high where contours are solid, and is unusually low where contours are dotted. D indicated dry; W, wet. From Rasmussen and Wallace (1983), reprinted in Philander (1998).



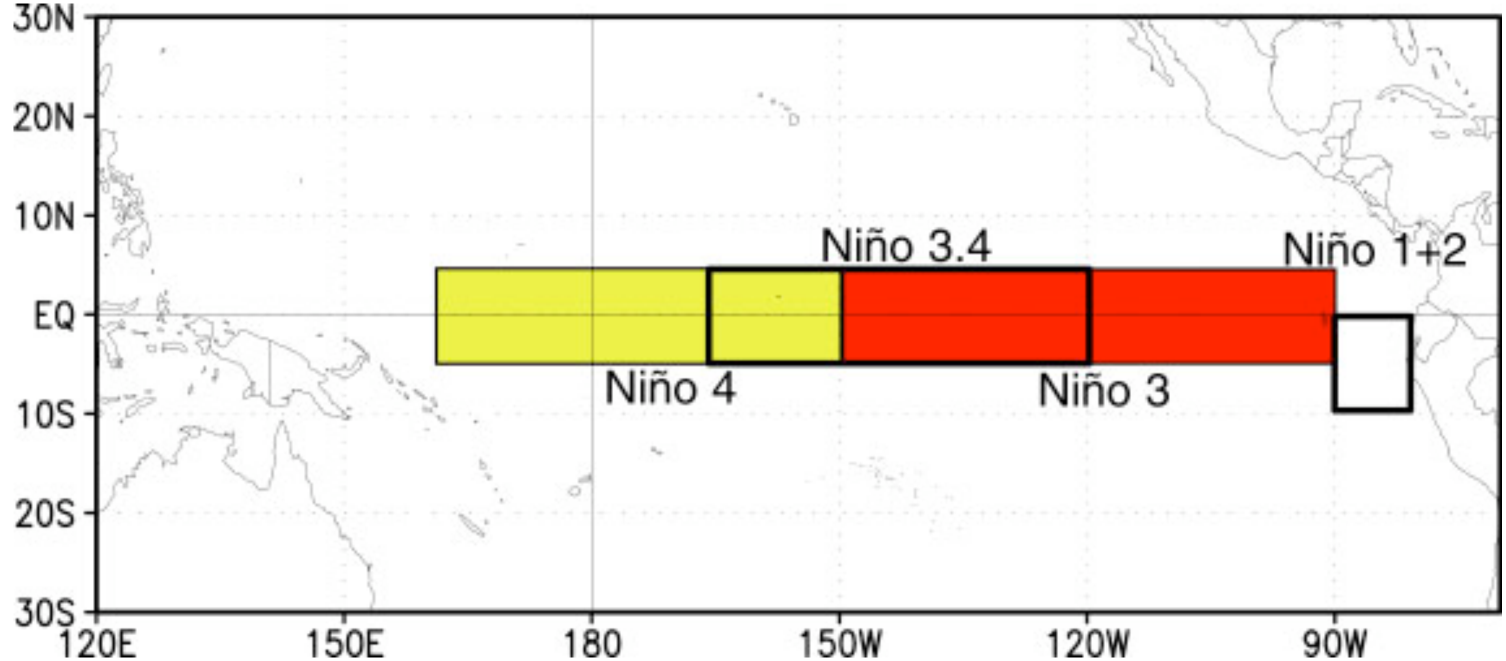
The pressure pattern is associated with a very large-scale pattern of precipitation anomalies. This is the correlation of annual mean precipitation with the Southern Oscillation Index (pressure at Tahiti minus Darwin). [Trenberth and Caron 2000]

Since the 1800s, Peruvian fisherman noticed that their harvest completely failed every few years. This periodic event was associated with unusually warm waters off the coast of Peru. These warm waters resulted from a shutdown of the upwelling circulation normally found along the equator. Since upwelling supplies nutrients to the surface waters, this resulted in mass starvation of plant and animal life in the eastern equatorial Pacific. Since the periodic warming almost always occurred around December, the fisherman named it El Niño, in reference to the Christ child.

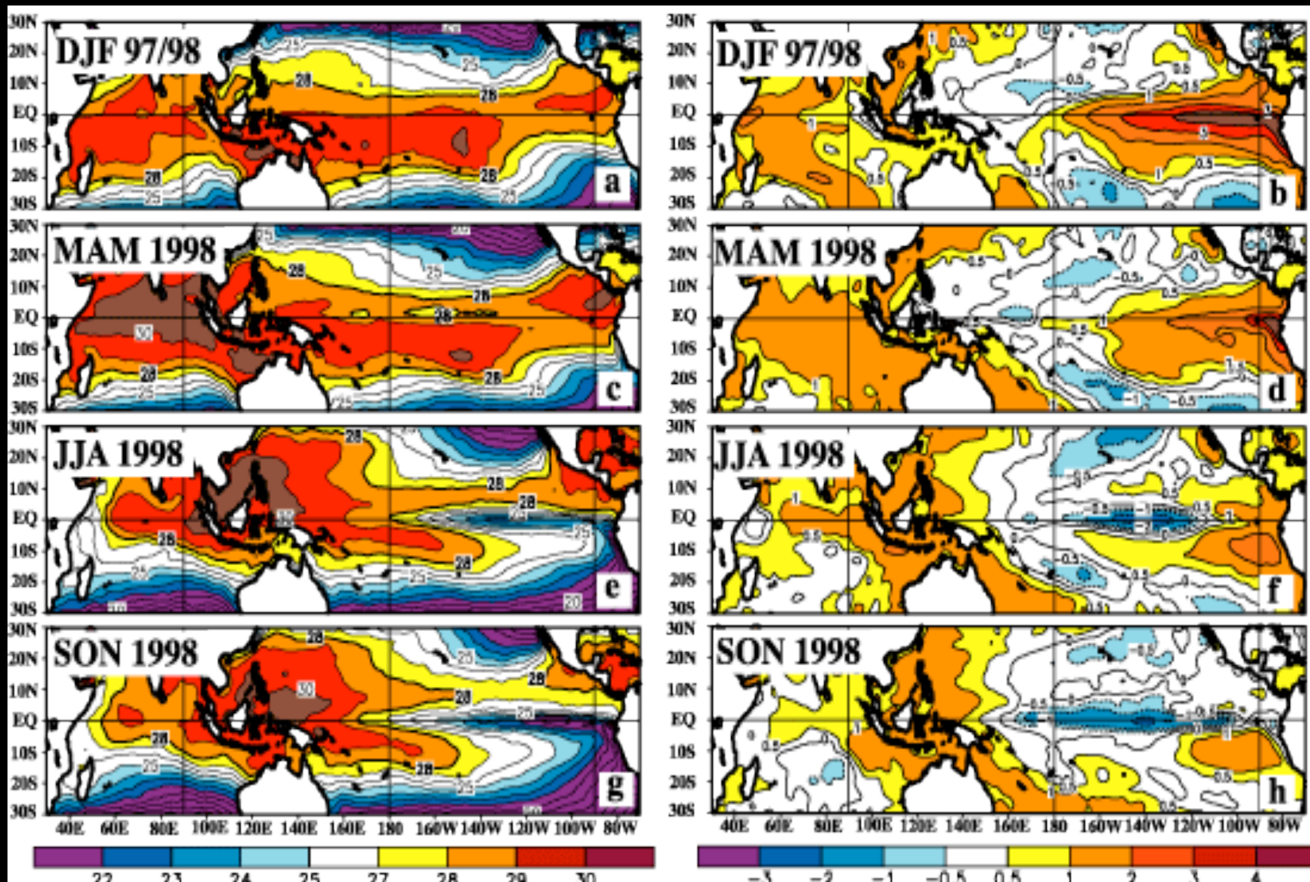


Here is the contemporary view of sea surface temperature change associated with the Southern Oscillation. This is the correlation of annual mean SST with the Southern Oscillation Index (pressure at Tahiti minus Darwin). [Trenberth and Caron 2000]

There are a number of indices of the oceanic component of ENSO. They involve averages over various regions of the equatorial Pacific.

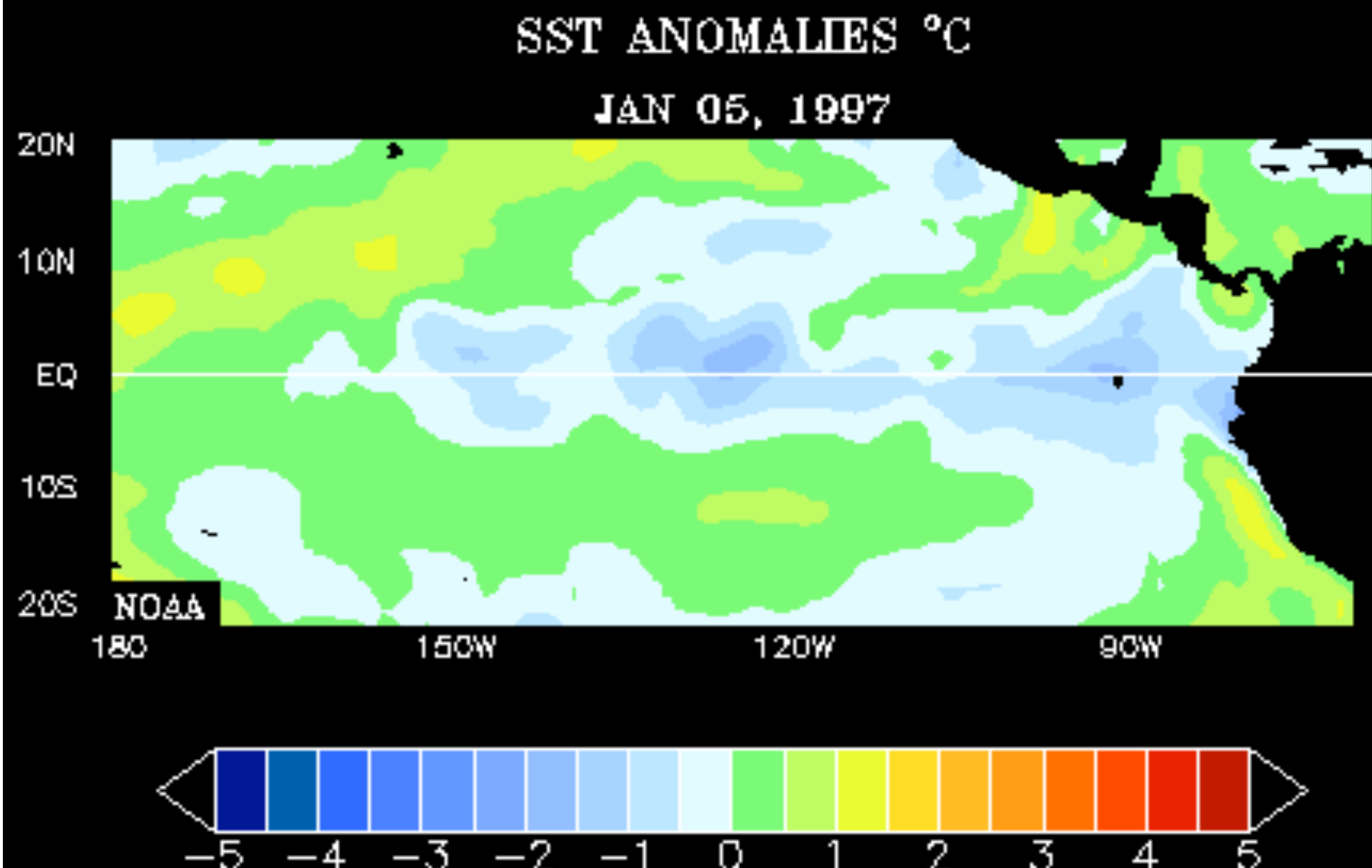


1997/98 ENSO Evolution

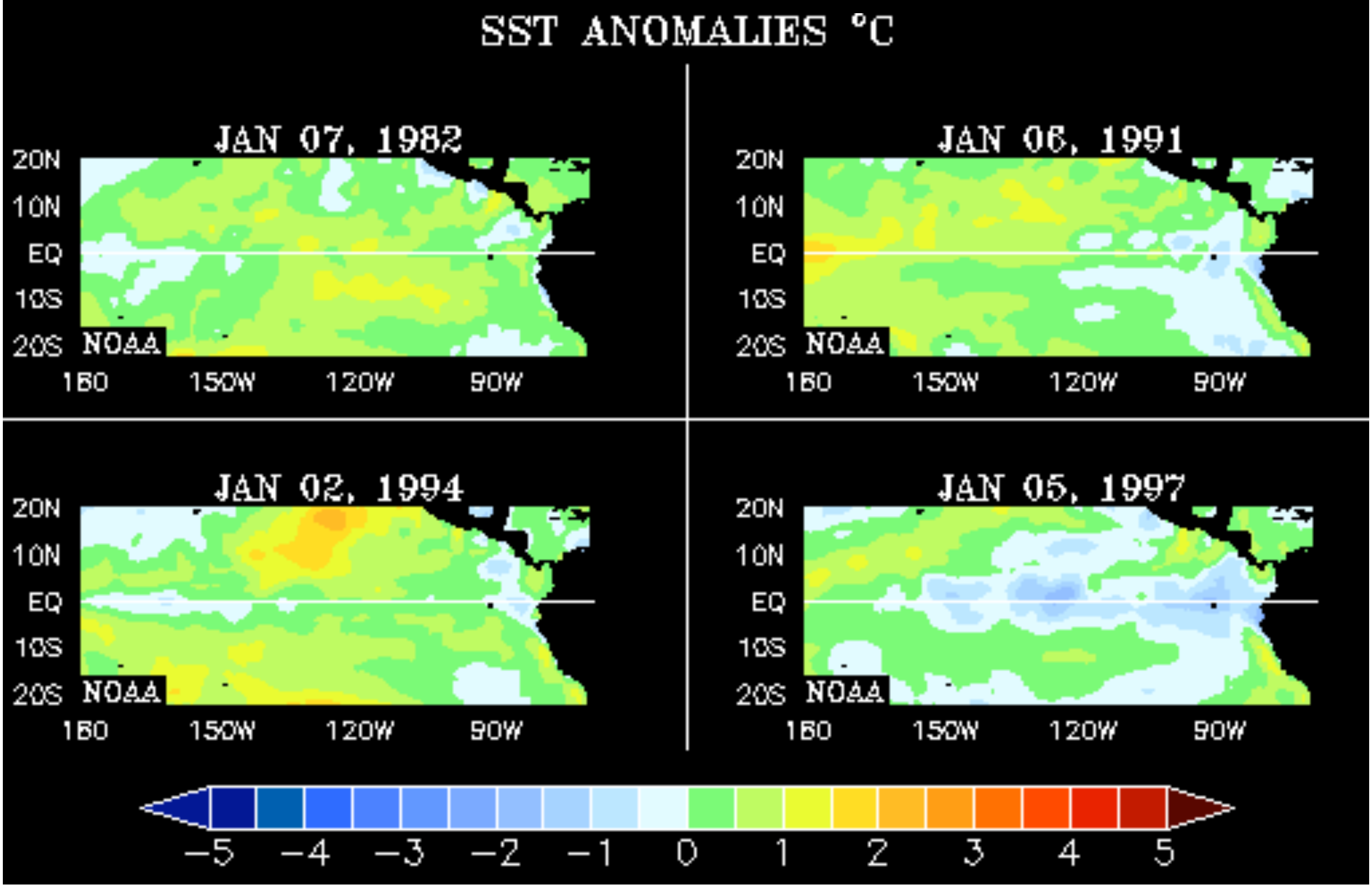


Seasonal SST (left) and anomaly (right) for (a,b) DJF 1997/98, (c,d) MAM 1998, (e,f) JJA 1998, (g,h) SON 1998. Contour interval is 1ºC, with the 0.5ºC contour included. Anomalies are departures from the 1950-79 adjusted OI climatology (Reynolds and Smith, 1995) (from BAMS, 1999, 80, S1-48)

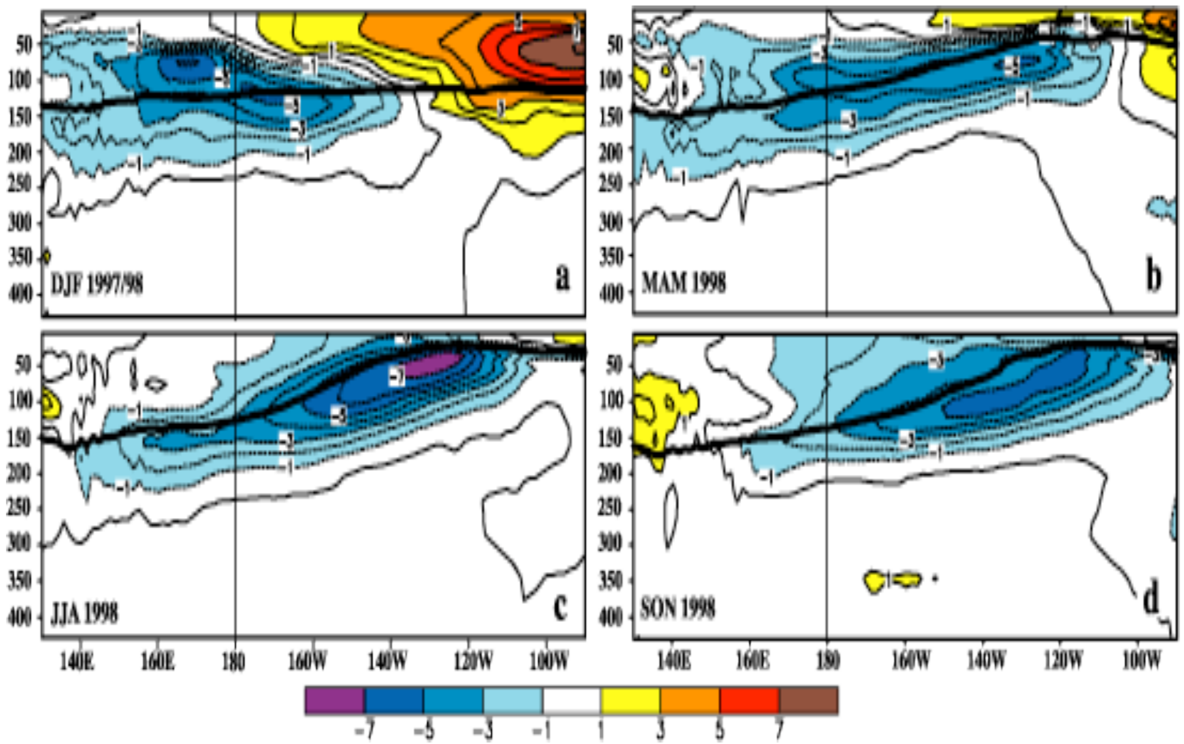
Animation of the 1997-98 ENSO event



Animation of 4 El Niño events



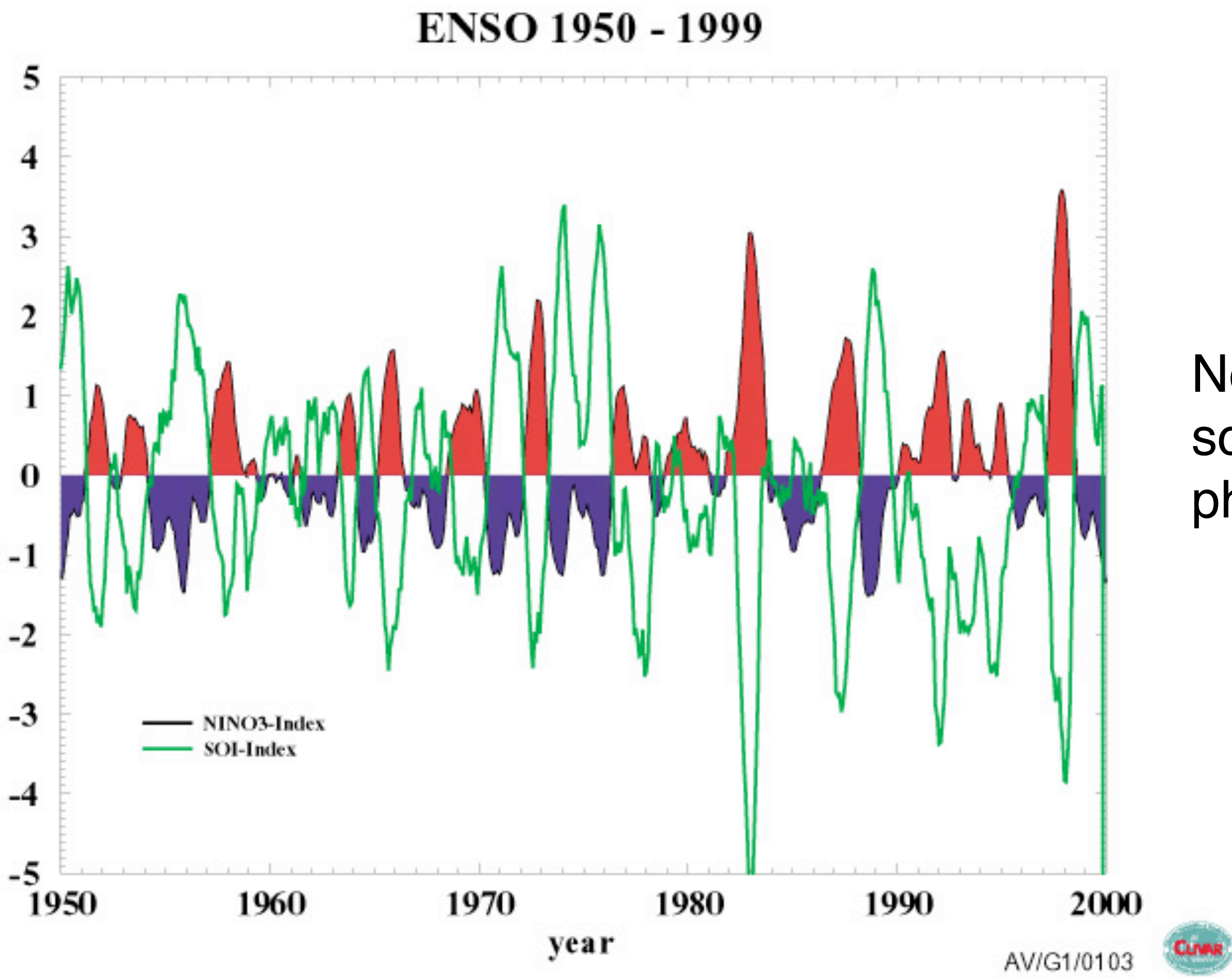
Variations in thermocline depth during ENSO



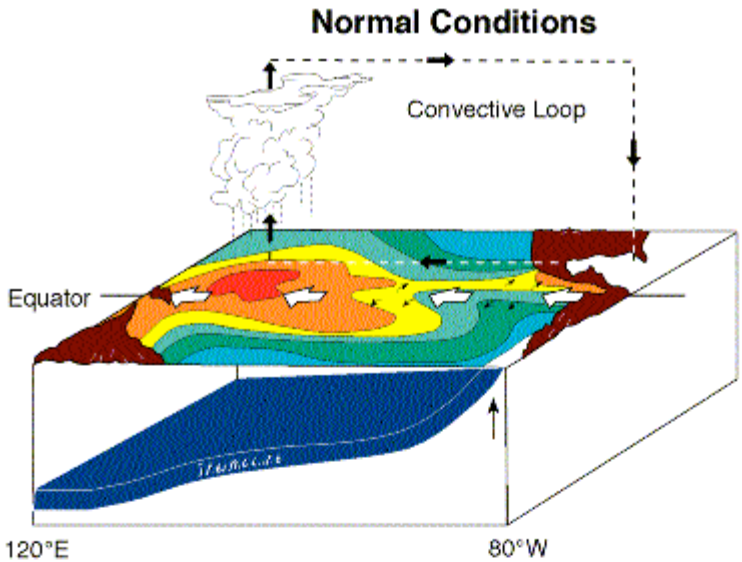
Equatorial depth-longitude section of ocean temperature anomalies for (a) DJF 1997/98, (b) MAM 1998, (c) JJA 1998, (d) SON 1998. Contour interval is 1ºC. The dark line is the 20ºC isotherm. Data are derived from an analysis system that assimilates oceanic observations into an oceanic GCM (Behringer et al., 1998). Anomalies are departures from the 1983-92 base period means.

UNSTABLE AIR-SEA INTERACTIONS IN THE TROPICS

If you look at sea surface temperature in the central equatorial Pacific and the difference in pressure between Tahiti and Darwin, you see a very clear anti-correlation. Both of these are indices for the ENSO phenomenon. The red portions are El Niño years, while the blue portions are La Niña years.

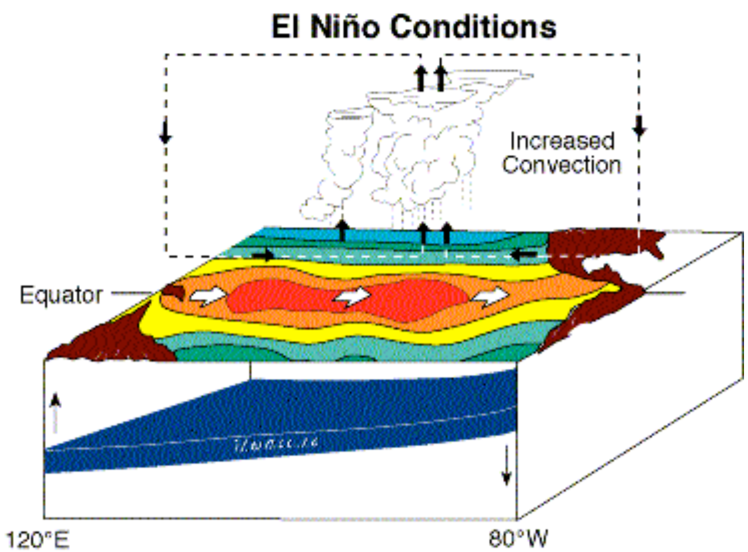


Note the typical time scale of the ENSO phenomenon.



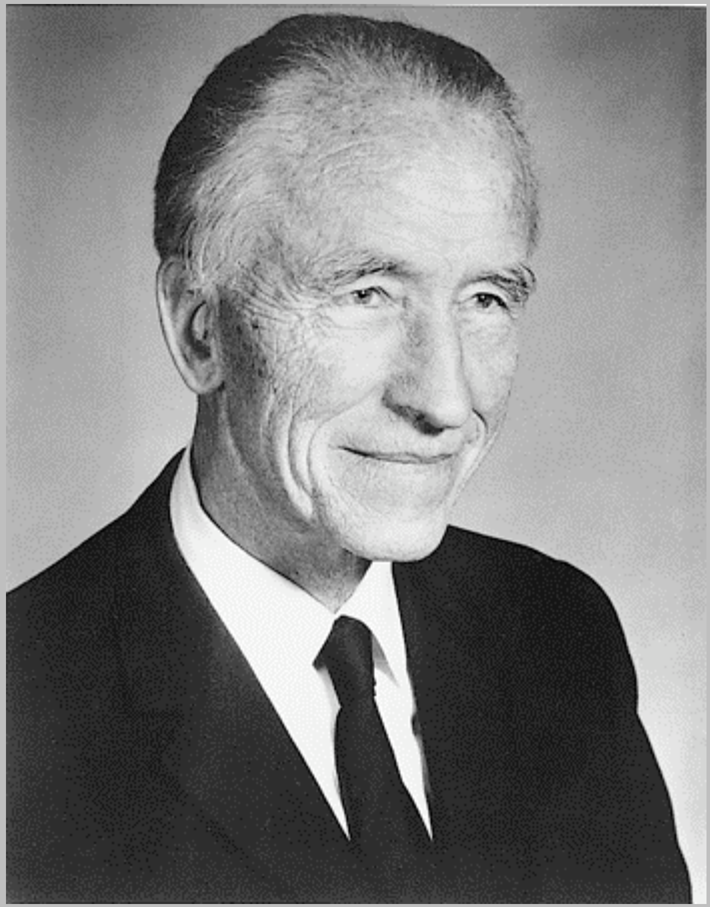
How are atmosphere and oceanic conditions related during an El Niño?

Under “normal” conditions, often referred to by the term La Niña, the easterly trade winds blow across the Pacific, generating upwelling along the equator across most the Pacific, and piling up warm water in the west. The east-west contrast in sea surface temperature sets up low pressure and rising motion in the west, and high pressure and sinking motion in the east.



NOAA/PMEL/TAO

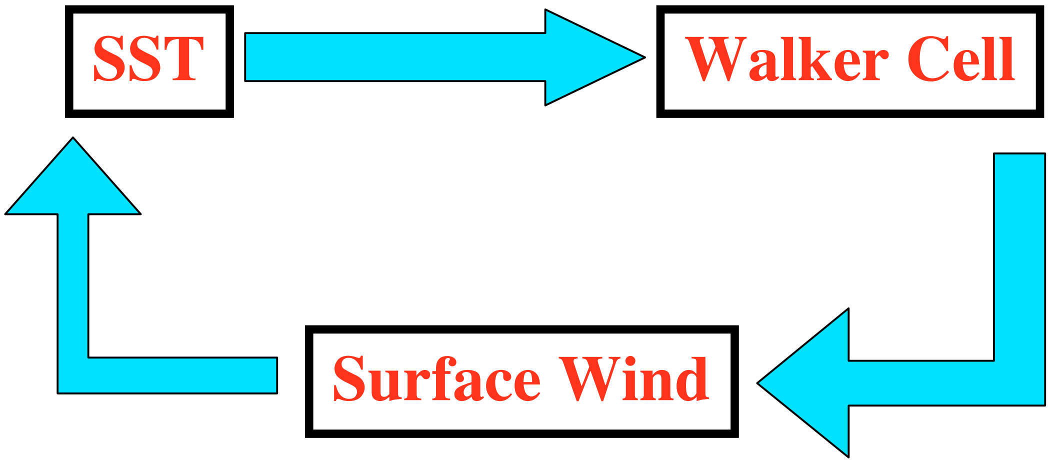
When an El Niño occurs, the trade winds collapse, upwelling of cold water ceases along the equator, and sea surface temperatures rise in the central and eastern equatorial Pacific. Pressure decreases in these regions, and rising motion leads to precipitation. Note also the changes in the tilt of the thermocline going from El Niño to La Niña.

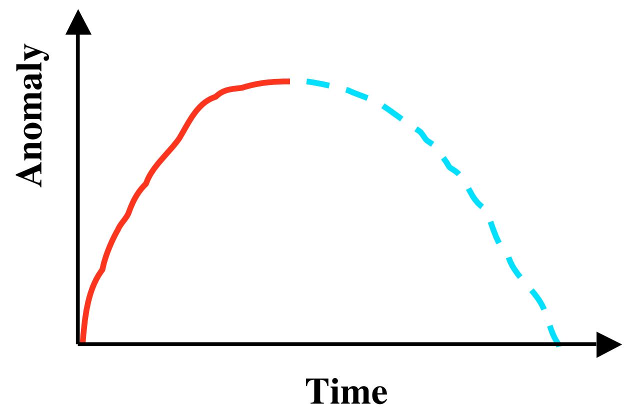


In 1969, UCLA professor Jacob Bjerknes was the first to recognize that El Niño and the Southern Oscillation are actually manifestations of the same physical phenomenon and that it results from an unstable interaction between the atmosphere and the ocean. This resulted in the term ENSO to refer to this phenomenon.

The Bjerknes Mechanism for growth of anomalies

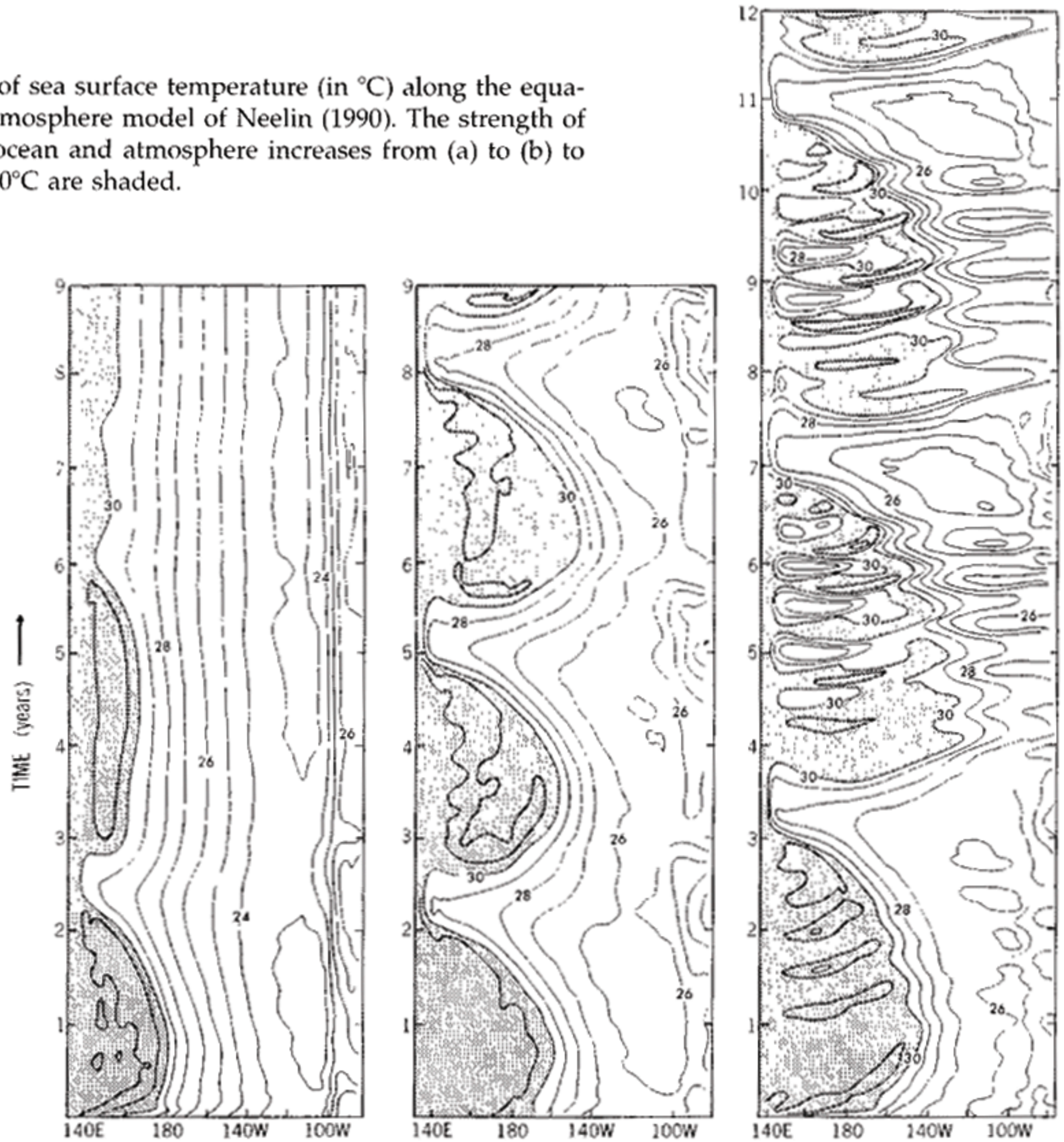
Bjerknes (1969) recognized that El Niño is the product of interaction between the ocean and atmosphere: A positive ocean-atmosphere feedback.





- **However, for the coupled system to oscillate, an out-of-phase restoring force is needed.**
- **At the time, Bjerknes did not know what causes a turnabout from a warm phase to a cold phase.**
- **After the 1980s, the search began for the restoring force.**

Figure 9.5 The evolution of sea surface temperature (in °C) along the equator in the coupled ocean-atmosphere model of Neelin (1990). The strength of the coupling between the ocean and atmosphere increases from (a) to (b) to (c). Regions warmer than 30°C are shaded.



The effect of variations in the intensity of the Bjerknes coupled feedback strength on ENSO behavior.

A physical interpretation of the variations in feedback strength is variations in the mean depth of the thermocline.

reprinted in Philander (1998)