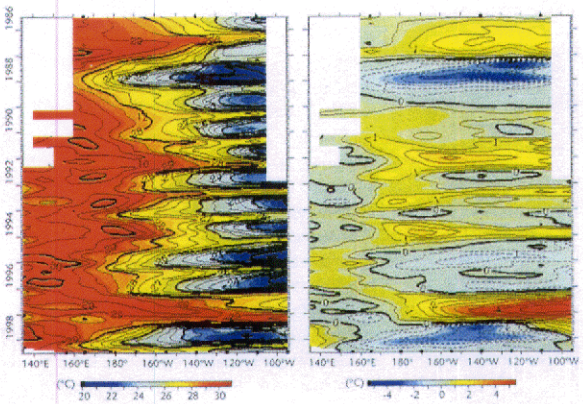

This panel shows departure of sea surface temperature from the long-term seasonal average with time at the equator (vertical axis) across the longitudes of the Pacific Ocean (horizontal axis). Several periods of warm anomaly (shaded yellow to red) can be identified, but each with different magnitude and characteristics. During 1987, 1991 and 1994 the sea surface temperature over the central equatorial Pacific Ocean is abnormally warm and, although the magnitude of anomaly is small, warmer than normal sea surface temperatures also extend to the eastern equatorial Pacific Ocean. During 1993 the weak warm anomaly is confined mainly to the eastern equatorial Pacific Ocean. The major event of 1997–98 is very strong compared to the other events in the sequence and will be discussed separately in Part II.

There are also periods of abnormal cooling across the eastern and central equatorial Pacific Ocean, indicating abnormally strong upwelling and westward advection of cold water. A strong cold event, or La Niña, occurred in 1988 and there was the onset of another cooling event in 1998. A weak cold event occurred in 1995.

The timing of the anomalous warming is important in the ocean forcing on the dynamics of the atmosphere and the impact on climate. For example, although the 1987 event achieved a warm anomaly of about 2°C, the 28°C isotherm did not extend to the eastern equatorial Pacific Ocean (see the left panel of Figure I.1). During late 1991 and early 1992 the 28°C isotherm extended much further eastward but the magnitude of abnormal warming achieved was only about the same magnitude as 1987. The 1987 warm event was collapsing during the Southern Hemisphere summer of 1987–88 and the event of 1993 is observed as a late onset of the seasonal cycle of cooling. The warm events of 1991–92 and 1994–95 had developed early in the first year and persisted into the second year; they were at their peak during the Southern Hemisphere summer.

The variations in timing and geographic patterns of anomalous warming identify the difficulty in establishing quantitative and universal definitions for El Niño and La Niña

TOGA – The Tropical Ocean Global Atmosphere Project

The TOGA project was a decade-long (1985–94) activity of the World Climate Research Programme. TOGA was established through international cooperation to encompass observations, empirical and theoretical studies, and modelling of ocean and atmosphere processes. Its objective was to better understand processes linking the ocean and atmosphere circulations, particularly ENSO. An important process to be studied was forcing of large-scale atmospheric circulations by tropical ocean temperature anomalies such as El Niño, with a view to improved predictions on seasonal to interannual timescales.

The focus of new TOGA observations was the Tropical Atmosphere Ocean (TAO) array of moored buoys across the equatorial Pacific Ocean, completed in 1994. The moored buoys provide surface meteorological and subsurface ocean observations. Subsurface ocean observations were also expanded by increased numbers of expendable bathythermograph (XBT — instruments dropped from ships that report temperature and salinity with depth during descent). The XBT are released by merchant vessels of the WMO-coordinated Volunteer Observing Ships (VOS) project.

Data from the TAO array and the XBT observations have provided new insights into the climatology and variability of the subsurface layers of the oceans, particularly those of the equatorial Pacific Ocean. These data have also been crucial for modelling and setting initial conditions for climate predictions.

The CLIVAR project is the successor to TOGA and will adapt and enhance existing atmosphere and ocean observing systems. A network of moored buoys similar to the TAO array is being established across the equatorial Atlantic Ocean. The CLIVAR scientific plan includes a network of moored buoys across the equatorial Indian Ocean but implementation in this latter region requires a commitment of funds by governments.