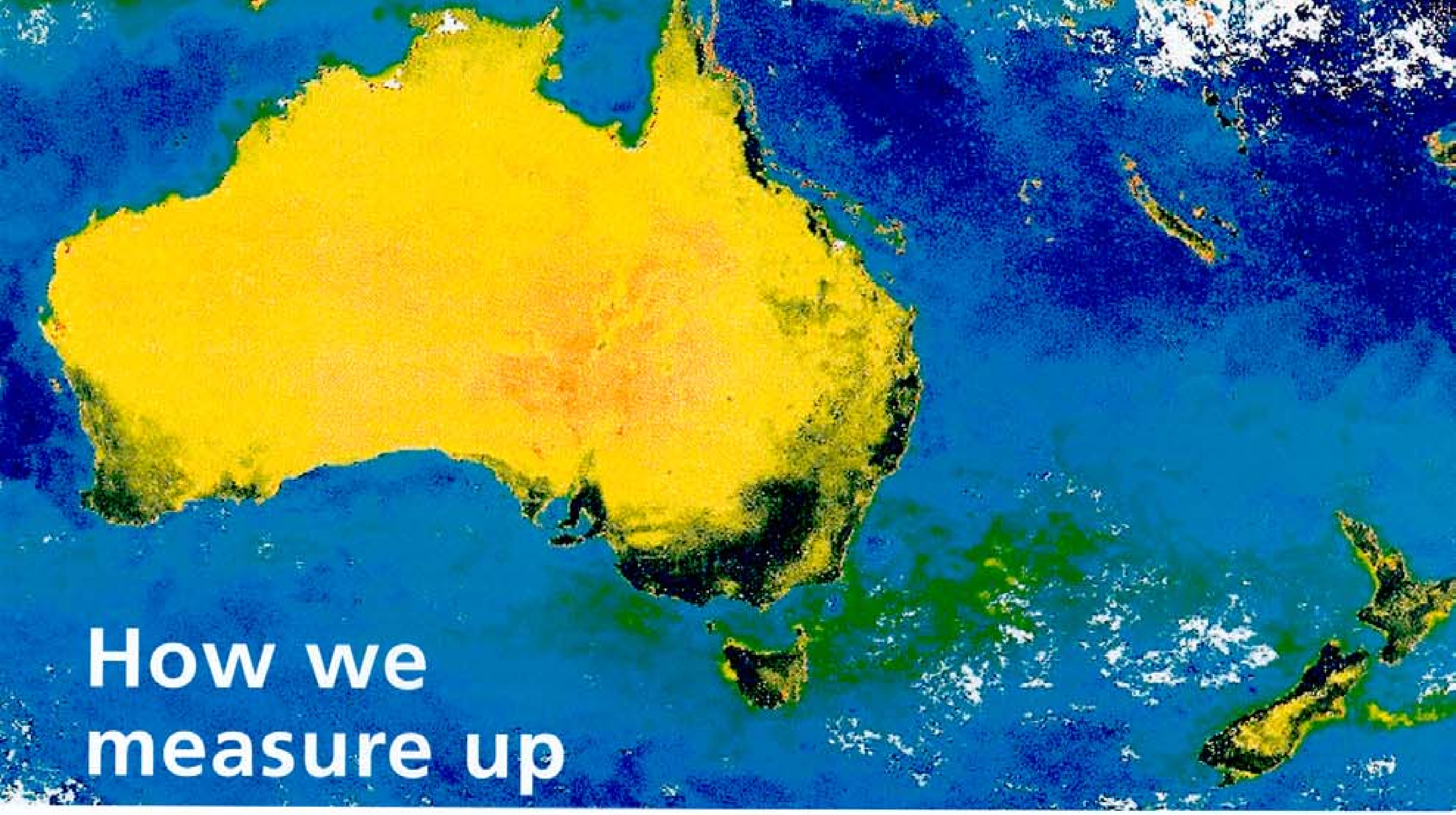


How we measure up

Shortly after the disastrous El Niño of 1982-83, CSIRO set up an innovative ocean monitoring system to watch for tell-tale changes in the Pacific and Indian oceans and the connecting Indonesian archipelago.

Since then, regular and consistent ocean measurements, to a depth of 750 metres, have been collected by a trusty network of commercial boats and ships. Together with data from US and Japanese instruments moored along the Pacific equator, and satellite readings of sea level and surface temperatures, the network provides a window on the region for the world's climatologists.

Sea-surface temperatures in the Indian and Pacific oceans, in an endless dance with the region's winds and currents, exert a major influence on Australia's climate. During an El Niño Southern Oscillation (ENSO) event, a pool of warm water (typically 30°C) in the western Pacific moves several hundred kilometres eastward, resulting in less convection and less rain near Australia, and more rain in the eastern Pacific, near countries such as Peru.

The eastward shift of the warm pool is known to coincide with a weakening of trade winds that blow from east to west across the Pacific. Research by Dr Gary Meyers at CSIRO Marine Research, based on the records of their ocean observing network, has shown these winds in turn respond to a ceasing of the Indonesian throughflow, a warm current linking the Pacific to the Indian ocean. This current may be an equally-important contributor to ENSO events. Meyers' research has also shown that El Niño rainfall, particularly in western and southern Australia, can vary according to temperatures in the Indian Ocean.

In 1982, El Niño arrived without warning. But in 1997, Meyers and his colleagues were able to watch its evolution, checking real-time ocean observations against a record of currents and temperatures collected in the past 14-years. During October, the warm pool extended from the International dateline to 150°W, with a maximum sea-surface temperature of 30°C north of Samoa. This temperature extended to a depth of almost 100 m, 50 m deeper than normal.

With an eye firmly fixed on their ocean-observation window, Meyers and his colleagues, together with the Bureau of Meteorology, are developing a model for predicting at least six months ahead significant variations in Australia's climate. 'If we can truly understand the trigger mechanisms for El Niño we may be able to predict rainfall trends with the sort of precision that now applies to weather forecasts,' Meyers says. 'We may also be able to forecast the severity of droughts.'

Under the weather

A new technique to help climatologists understand links between the sea-surface and rainfall fluctuations has been developed under the guidance of CSIRO's Ken Ridgway. The technique relies on knowing how sea-surface temperatures relate to undulations in sea level, and how these in turn reflect variations in temperature and salinity (or density), from the surface to a depth of about 2 km. These variations create eddies and currents, just as variations in atmospheric pressure create winds.

Using ocean observations from European and US/French satellites, Ridgway and his colleagues produce a weekly series of underwater 'weather maps' relating to conditions at the sea surface. Ridgway says the ocean maps will enhance Australia's defence capabilities by indicating altered conditions such as

Ocean colour instruments measure the spectrum of light reflected from the oceans. The colours indicate areas of ocean upwelling which bring nutrients to the surface. As phytoplankton chlorophyll increases, the colour of reflected light shifts from deep blue to green. This ocean colour image, taken in September 1997, shows areas of high productivity (green) across southern Australia. (Image: NASA SeaWifs project at the Goddard Space Flight Center.)

varying densities which affect sonar and radar. They will also assist management of Australia's Exclusive Economic Zone by profiling interactions between the physical, chemical and biological properties of the ocean. This knowledge can aid the sustainable management of Australian fisheries.

Another key indicator of fish distribution is the abundance of phytoplankton, the foundation of the ocean food chain. Phytoplankton chlorophyll has a measurable effect on the colour of the ocean. As it increases, the colour of light upwelling from the ocean shifts from deep blue to green. An ocean colour instrument called SeaWiFS, mounted on the satellite Orbview-2, measures precisely the spectrum of light reflected from the oceans, allowing accurate estimates of chlorophyll concentration.

In 1997, CSIRO at Hobart, the Australian Institute of Marine Science at Townsville, and Perth's Western Australian Satellite Technology Applications Consortium began receiving ocean colour data from SeaWiFs for Australian waters. The images will enable the response of phytoplankton to changes in the ocean and coastal environment to be modelled, and offer clues to the global ocean uptake of carbon dioxide.

Carbon dioxide is absorbed from the atmosphere by the ocean's surface waters which, in the process of sinking, pump it into the deep sea. Without this ocean absorption, the buildup of carbon dioxide in the atmosphere would be much more rapid. The role of the Southern Ocean in absorbing carbon dioxide is emerging through ocean measurements collected during two international research projects: the World Ocean Circulation Experiment and the Joint Global Ocean Flux Study.

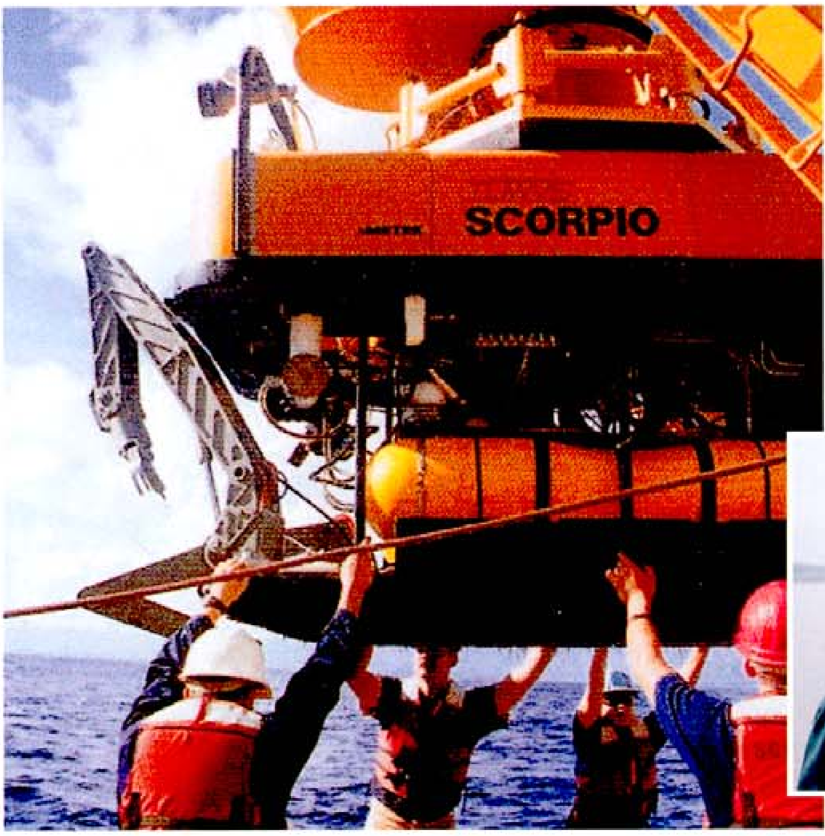
'We want to find out just how much carbon dioxide is absorbed, and how that might change if the earth's climate changes in the future,' CSIRO's Dr Bronte Tilbrook says. Central to the research is the state of the ocean surface, where currents, temperatures and the marine ecosystem affect the rate of exchange of gases between atmosphere and ocean.

In another international effort to gather ocean observations, US and Australian oceanographers have been working since 1995 with acoustic signals to measure ocean warming. The US$35 million Acoustic Thermometry of Ocean Climate project involves transmitting temperature-related acoustic signals from California and Hawaii to receivers thousands of kilometres away in the North Pacific.

Dr Andrew Forbes of CSIRO Marine Research headed the project's development phase while on secondment to Scripps Institute of Oceanography in the US. He says the acoustic technique is based on the principle that speed of sound in the ocean increases with rising temperature. Therefore, an acoustic pulse will take less time to travel between a source and a receiver in an ocean that has warmed due to the enhanced greenhouse effect. The experiments have clearly revealed the seasonal temperature cycle, proving the capacity of acoustic signals to measure temperature variations on ocean-basin scales.

'Acoustic transmissions are possibly the most efficient and sensitive means available to measure changes in the ocean's interior temperature across ocean basins, and so measure global ocean warming,' Forbes says. 'The experiment enables scientists to greatly increase the frequency of observations of changing temperatures across and within entire ocean basins, which were previously supplied only sporadically during research voyages or only at the surface by satellite.'

The project is also monitoring the response of marine mammals to acoustic transmissions. Early results of this research, in which the acoustic signal has been played to a range of marine mammals such as humpback whales, elephant seals and sea lions off Hawaii and California, have revealed no obvious responses. The observations will continue until 1988. If biologists observe any acute behavioural changes, the acoustic experiment will cease.



The Acoustic Thermometry of Ocean Climate project involves transmitting temperature-related acoustic signals from California and Hawaii to receivers in the North Pacific. CSIRO's Dr Andrew Forbes worked on the project with Walter Munk of the US Scripps Institute of Oceanography.