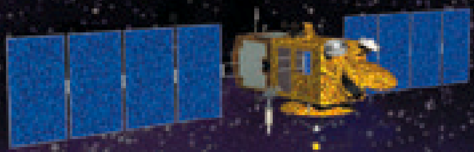
Observing the oceans from space

Watching for El Niño

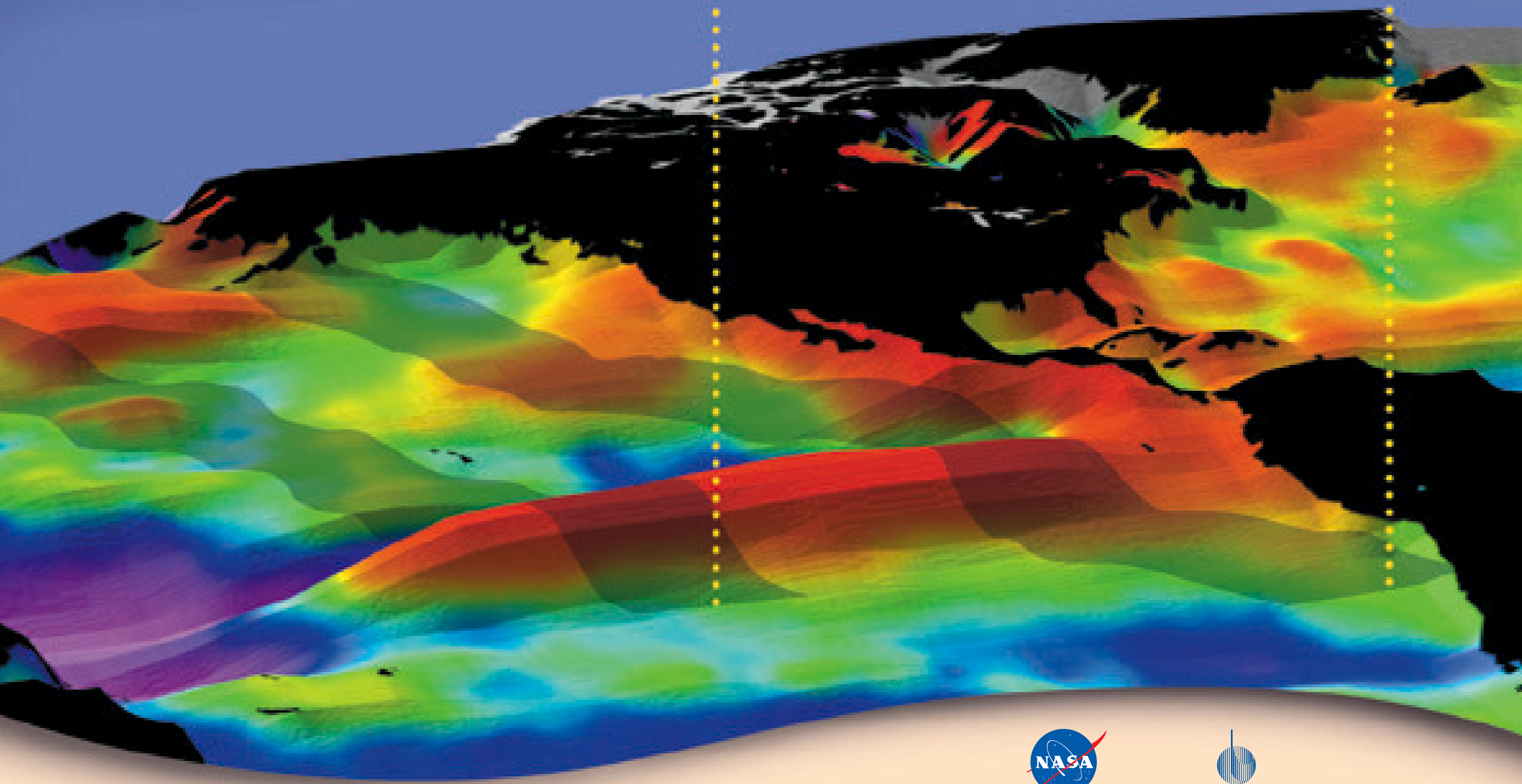
For centuries, Peruvian fishermen have feared the sea warming called El Niño which, every few years, around Christmas, drastically reduces their fishing catches.

These El Niño events are part of a broader disruption to normal weather patterns which cause drought, flooding and hurricanes around the world. What do we know about El Niño? Can we predict it before it strikes?



The 1997-98 event gave scientists a chance to analyse the complex relationship between the ocean and the atmosphere. The key to maximising the opportunity was the TOPEX/POSEIDON satellite altimetry-mission, which has precisely measured variations in sea level and upper ocean currents since 1992.

Altimetry data are vital for the early detection, analysis and close monitoring of large-scale tropical climate anomalies. The purpose: to predict when and how events will develop and, ultimately, to anticipate and mitigate the impacts. Following on from TOPEX/POSEIDON in the new millennium, the Jason series of satellites will provide continuity, compatibility, and even higher quality data.



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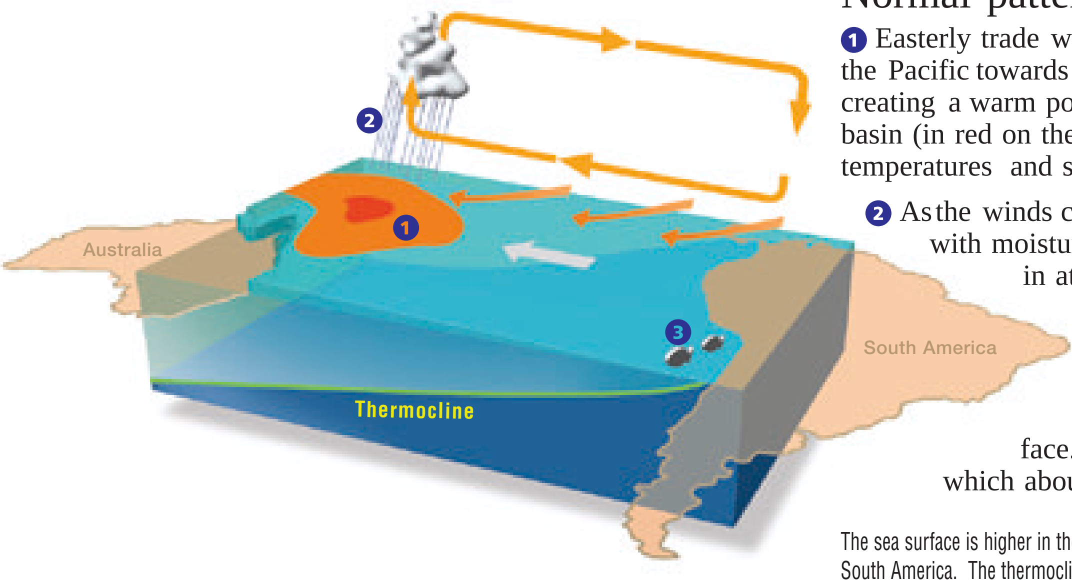
In the tropical Pacific, ocean and atmosphere circulations are closely linked, each reacting quickly to changes in the other.



Normal pattern

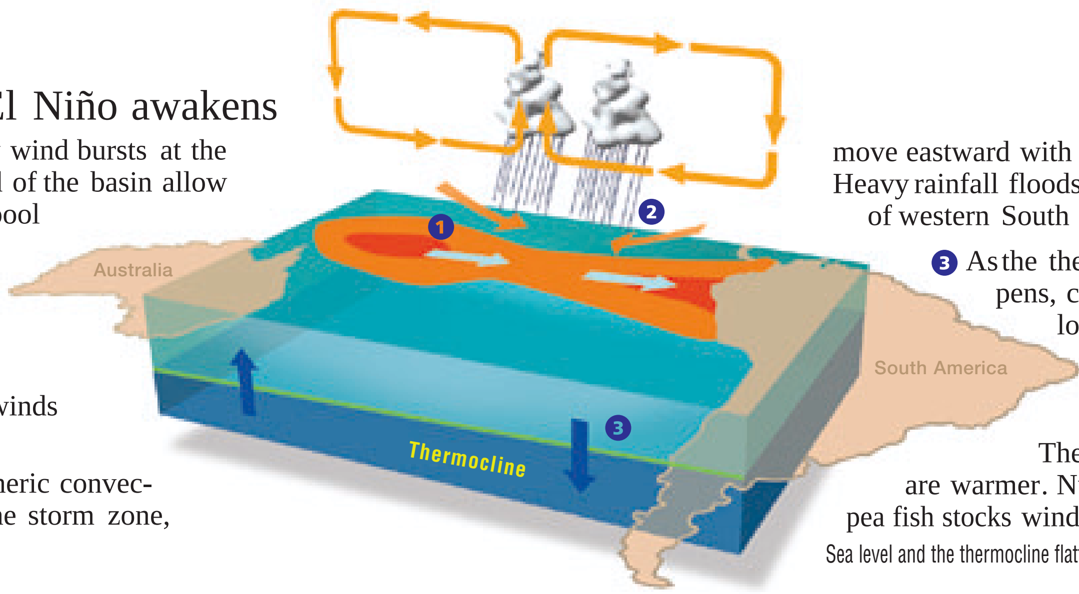
1 Easterly trade winds push surface waters in the Pacific towards Australia and the Philippines, creating a warm pool at the western end of the basin (in red on the illustration) with higher temperatures and sea level.

2 As the winds cross the ocean, they load up with moisture and release it as heavy rains in atmos-pheric convection over the warm pool.

3 Meanwhile, at the eastern end of the basin, nutrient-rich cold waters well up to the surface. This is favourable for anchovy, which abounds along the Peruvian coast.

The sea surface is higher in the west, in Asia, than in the east, along the coast of South America. The thermocline (the boundary layer between the warm surface waters and the colder underlying water) is, on the contrary, tilted up to the east.

When El Niño awakens



1 Westerly wind bursts at the eastern end of the basin allow the warm pool to drift eastward into the central Pacific. The trade winds weaken.

2 Atmospheric convection, and the storm zone, move eastward with the warm pool. Heavy rainfall floods coastal areas of western South America.

3 As the thermocline deepens, cold water no longer upwells off the coasts of Chile and Peru. The surface waters are warmer. Nutrients disappea fish stocks windle.

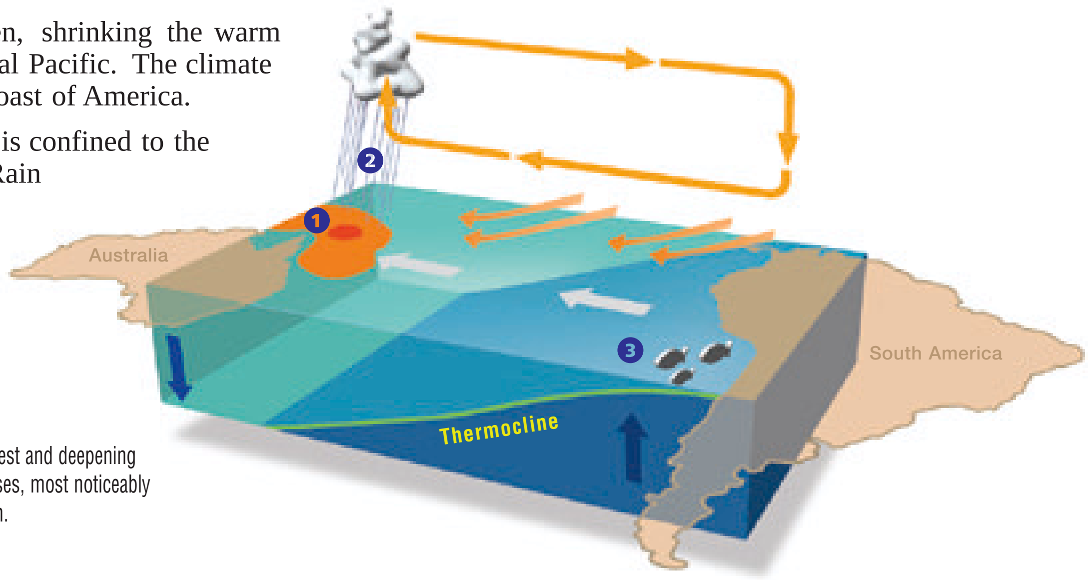
Sea level and the thermocline flatten to near-horizontal.

La Niña pattern

1 The tradewinds strengthen, shrinking the warm pool and cooling the Tropical Pacific. The climate is drier and colder off the coast of America.

2 Atmospheric convection is confined to the western end of the basin. Rain is abundant over Indonesia.

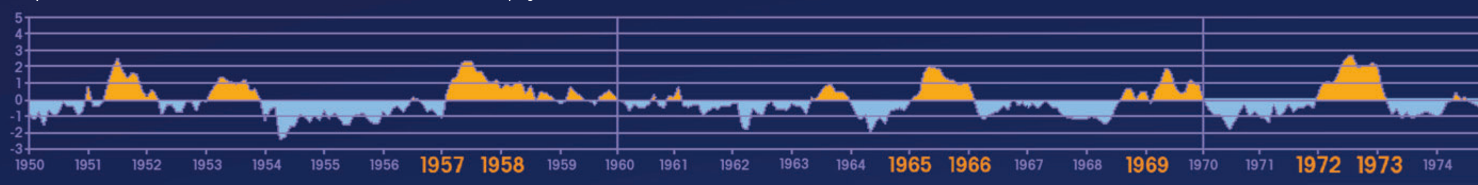
3 Cold waters upwells more strongly along the west coast of south America; anchovy is plentiful.



Sea level tilt increases, rising more in the west and deepening in the east. The thermocline tilt also increases, most noticeably at the western and eastern ends of the basin.

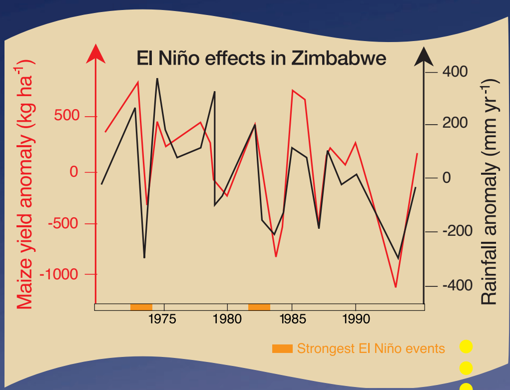
The El Niño c

Temperature deviations from the mean. Ecuador, west of the Gal·pagos Islands.



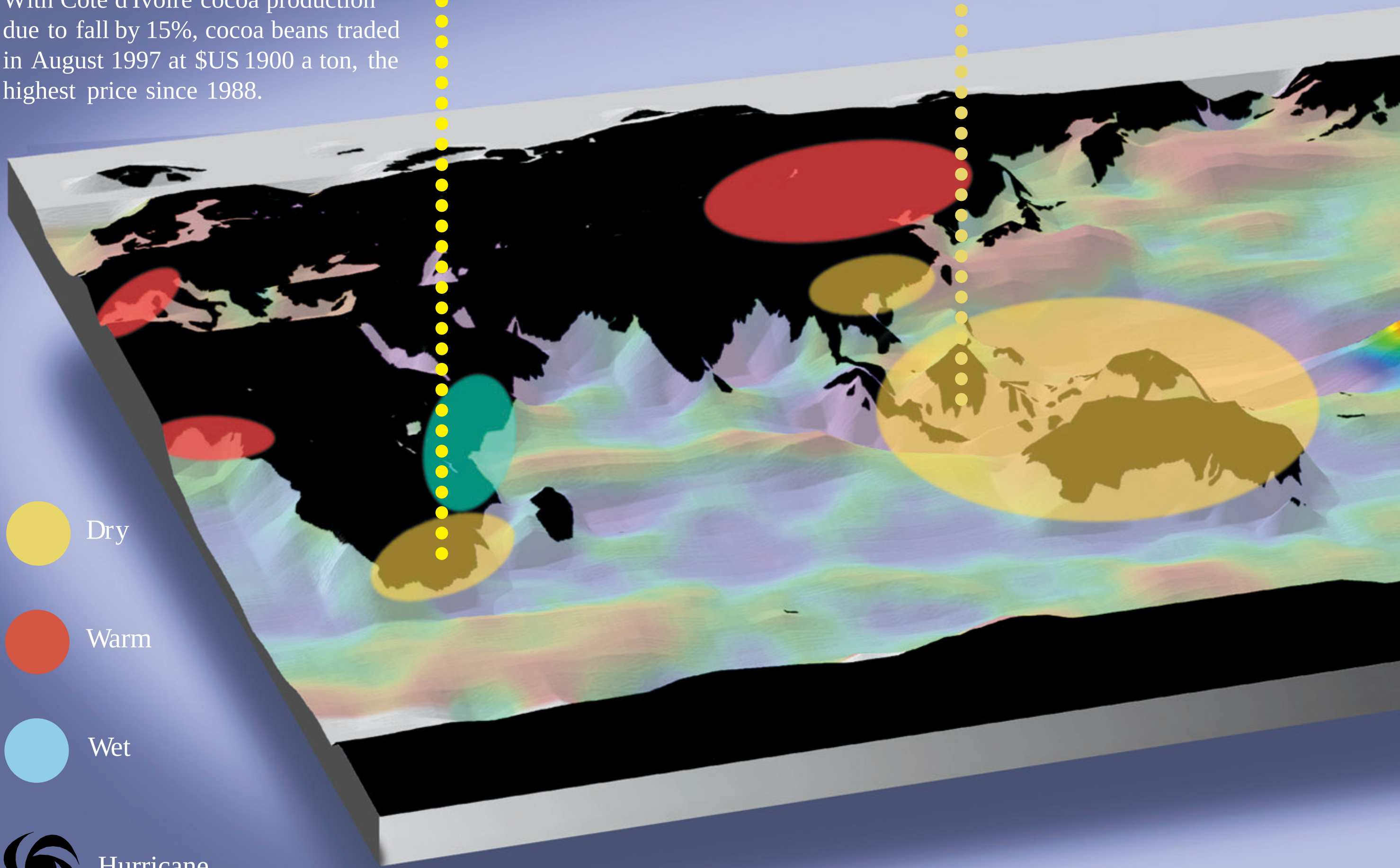
Warm El Niños and cold La Niñas follow each o
Variable in intensity, these surface temperature a
cause major heat exchanges between the ocean

El Niño around th



Crop yields were destabilised around the world, with major impacts on national economies. Unusually warm weather in much of southern Africa led to the loss of 50% of the wheat crop, worth $US 130 million. With Côte d'Ivoire cocoa production due to fall by 15%, cocoa beans traded in August 1997 at $US 1900 a ton, the highest price since 1988.

Drought over Indonesia and Papua New Guinea caused the destruction of 2.1 million hectares of trees, through forest fires. Total damage was estimated at $US 4.4 billion, with hundreds of casualties through famine and disease.



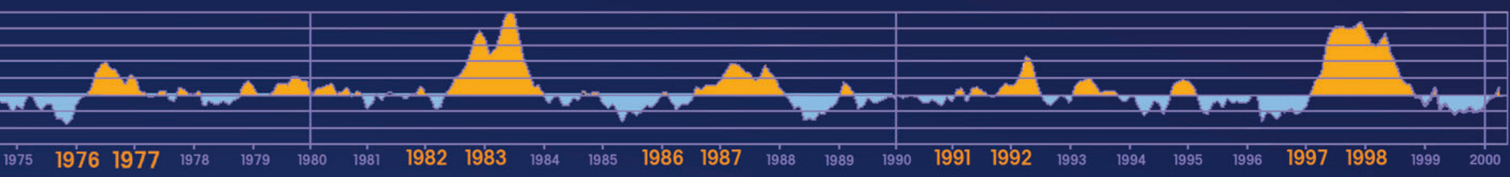
Dry

Warm

Wet

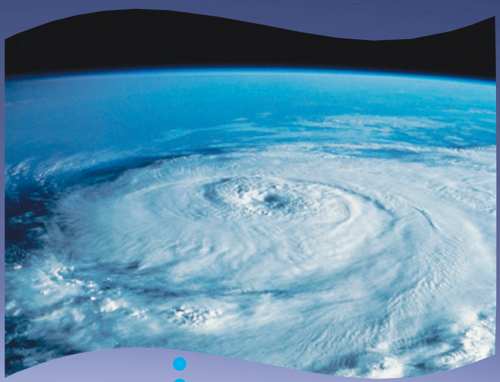
Hurricane

of the century?



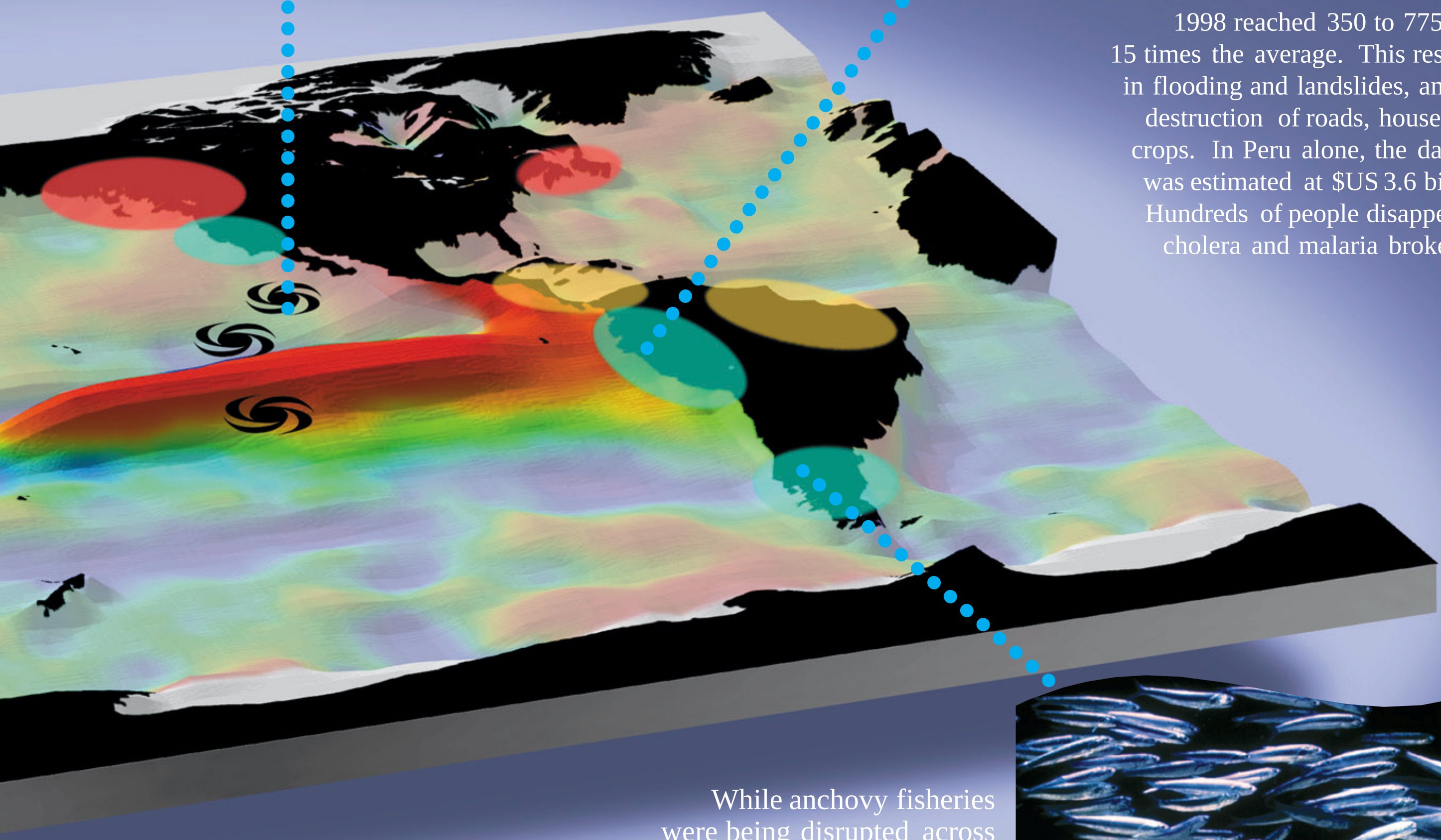
ther against the backdrop of the ocean seasons.
nd sea level anomalies in the intertropical Pacific
and atmosphere, affecting climate worldwide.

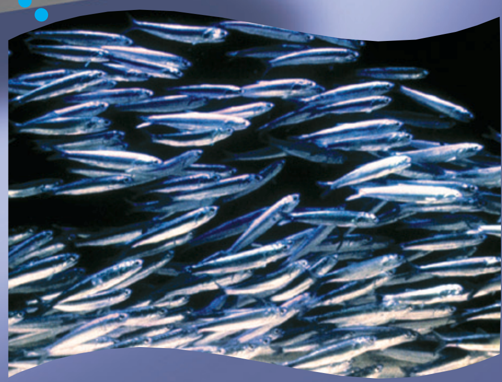
ne world, 1997-98



With storms shifting to the central Pacific, the Caribbean was calmer. And parts of North America and Japan enjoyed milder winters.

With sea-surface temperature exceeding 28°C off the coast of Ecuador and northern Peru, rainfall in December 1997 and January 1998 reached 350 to 775 mm, 15 times the average. This resulted in flooding and landslides, and the destruction of roads, houses and crops. In Peru alone, the damage was estimated at $US 3.6 billion. Hundreds of people disappeared, cholera and malaria broke out.





While anchovy fisheries were being disrupted across South America's western seaboard, sardine and tuna were thriving in the warmer waters off Santiago, Chile, producing a bumper year for fishermen.

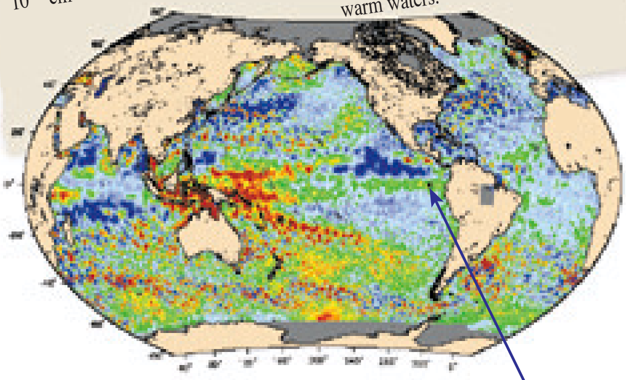
TOPEX/POSEIDON scoops 1997-98 El Niño story

El Niño revealed

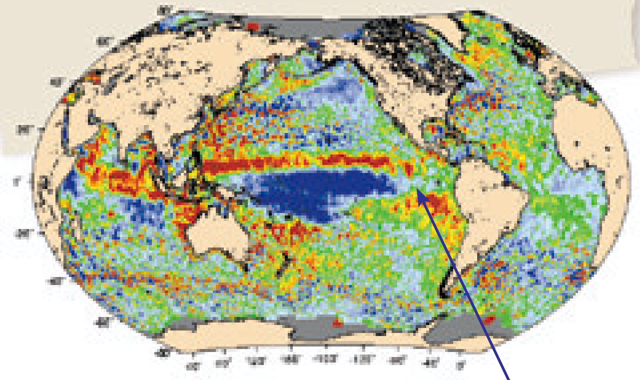
From February to April 1997, TOPEX/POSEIDON satellite data pinpointed a large eastward-moving swelling of waters in the central Pacific. This positive sea-level anom-aly, over 10 cm and increasing as the months went by, peaked near the coast. In July 1997, the signature was plain and south-east Asia was hit by severe drought. The anomaly, in red on the map, covered an area 1.5 times that of the United States. It corresponded to "extra" warm waters.

Closely monitoring the tropical ocean

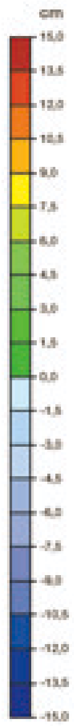
TOPEX/POSEIDON tracked the development of El Niño, highlighting a maximum anomaly of more than 20 cm in the northern winter. By June 1998, surface height was returning to normal. In July 1998, TOPEX/POSEIDON revealed favourable conditions for La Niña, which developped in 1999. In 2000, ocean once more returned to normal.



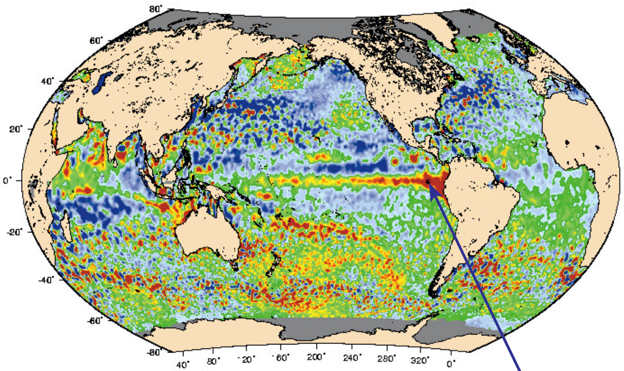
February 1997



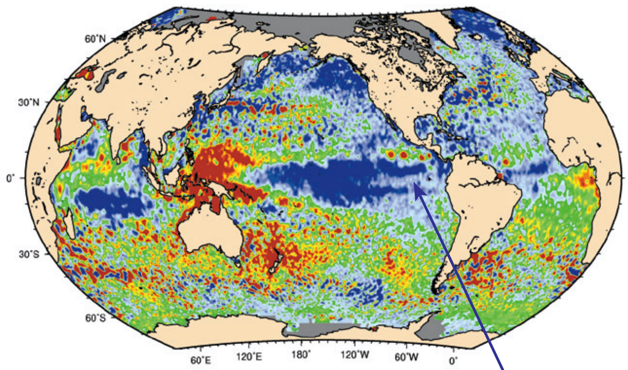
July 1998



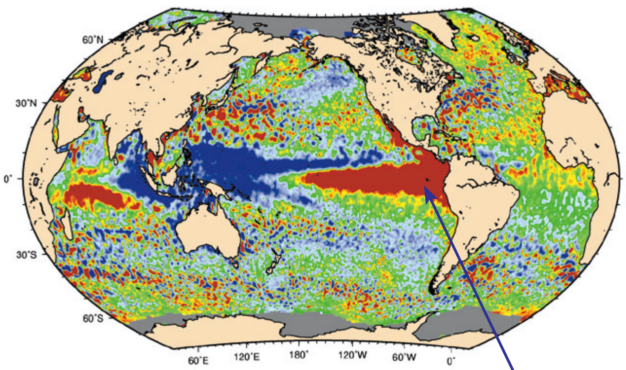
Sea surface height



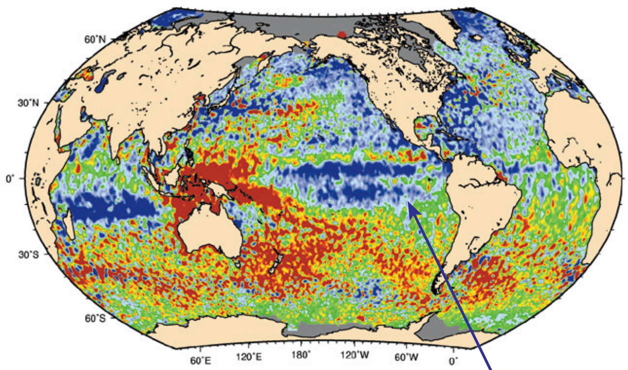
April 1997



April 1999



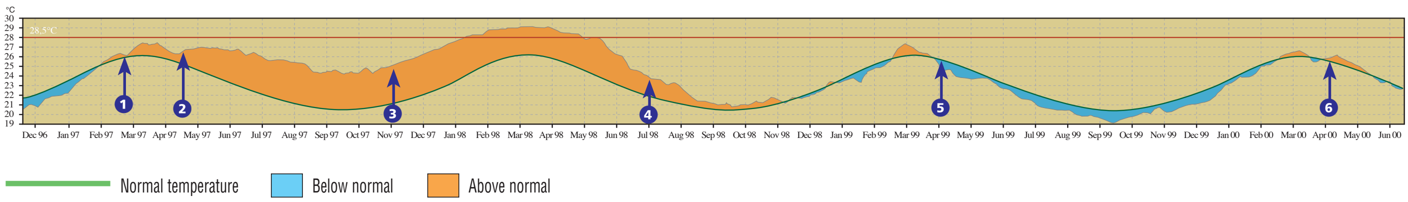
November 1997



April 2000

Sea level rises, temperature too

Surface temperatures near the Gal·pagos Islands increased clearly during the northern summer, reaching more than 5°C above normal. These anomalies signalled the start of slack trade winds and increased ocean-atmosphere interactions. The 28.5°C temperature threshold triggered atmospheric convection, producing heavy rains over coastal Ecuador and Peru.



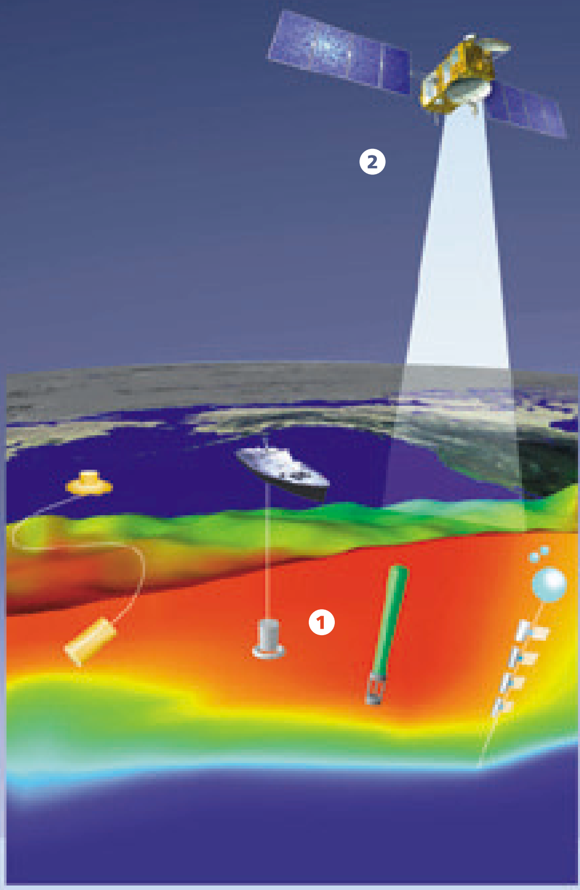
Understanding and Forecasting El Niño

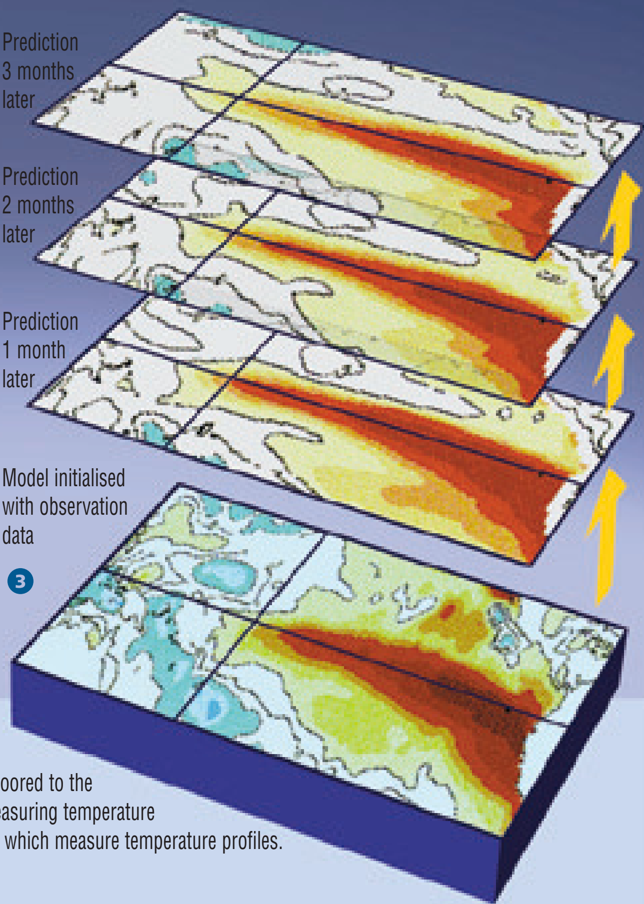
Anticipating, alerting, protecting

Since the 1990s, an in situ observation system has been set up in the Pacific and new satellites have continuously scanned the global ocean. The 1997-98 El Niño was the first closely monitored event. The TOPEX/POSEIDON mission showed that precise satellite altimetry reveals the general features of an event several months ahead.

These observation systems contribute to testing and refining our knowledge of ocean-climate interactions and numerical models of the climate. For the first time, climatologists have produced global-scale seasonal forecasts. Though we cannot avoid El Niño's whims, we can predict and mitigate its impacts.

Setting up an alerting system is important for all phases of natural hazard management, from outreach and education to preparing for danger. The ultimate goals are to:
- protect human populations from floods and diseases,
- better manage forests, energy resources and farmlands (e.g. by developing drought-resistant crops),
- help fish farming, aquaculture and deep sea fisheries (e.g. by surveying stock quantities and distributions).





The *in situ* observing system (1) includes a network of meteorological/oceanographic buoys moored to the seafloor (measuring ocean surface atmospheric and subsurface conditions), drifting buoys (measuring temperature and currents) and tide gauges. Some merchant ships are also fitted with scientific instruments which measure temperature profiles. Most of the data are sent in near-real time via the Argos system.

To obtain a global view of the Pacific, oceanographers use altimeter measurements (2). These provide an accurate index of surface variations, sea surface currents and changes in ocean heat content. Other satellites are used, to measure ocean colour and temperature, surface winds.

Scientists use all these high-quality measurements to better constrain prediction models (3), adjusting conditions in real time to converge on reality.

For more information:

- Tropical Atmosphere Ocean observation system: http://www.pmel.noaa.gov/toga-tao/
- Ocean-Climate Prediction Centers: http://nic.fb4.noaa.gov; http://www.ecmwf.int/html/seasonal/forecast/
- Satellite Altimetry: http://www-aviso.cnes.fr
- Near-Real Time ocean data: http://www.cls.fr/duacs/

Sources:

CLS, CNES, CNRS/LEGOS, GSFC, IRD, NASA,NOAA.

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