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Scientists fishing for answers

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It was a spring season to remember. Instead of the usual, goosebump-cold water, the ocean was a balmy 22 degrees in the September of 2006, which drew unseasonally large crowds to bathe at Sydney's beaches.

The cause was a monster warm-core eddy off the coast, more than 300 kilometres in diameter and rotating slowly in an anti-clockwise direction, which bathed the coastline in warm tropical water from the north. Five months later, a smaller cold-core eddy, rotating in the opposite direction off Port Stephens, chilled the coastal water by about 5 degrees and shut down local game fishing.

They were both dramatic examples of the impact of the East Australian Current (EAC), a marine conveyor belt, made famous in the movie *Finding Nemo*, that sweeps down the NSW coast from the Coral Sea, breaking into eddies off Sydney.

''It is so important for the rainwater we drink, for the climate, for our bushfire risk and our fisheries,'' says Professor Iain Suthers, of the Sydney Institute of Marine Science (SIMS) and University of NSW.

This large, warm current is the reason about 50 species of tropical fish now spend summer each year in Sydney Harbour and there is also a possibility it could influence the prevalence of shark attacks on the beaches of the city.

Warm-core eddies may help bring welcome winter rain by fuelling east coast low weather systems but they can also lead to extreme storm events such as the one in 2007 that grounded the Pasha Bulker, eroded the coastline, damaged homes and killed nine people.

The EAC also makes south-east Australia a global hot spot for climate change and Sydney a perfect place to study it, says the director of SIMS, Professor Peter Steinberg.

A strengthening of the EAC has led to a temperature rise of more than 2 degrees in less than a century in the Tasman Sea - the fastest recorded increase in temperature of any regional sea in the world.

One disastrous consequence has been the expansion southwards of long-spined sea urchins, *Centrostephanus rodgersii*, into Tasmanian waters, where they eat the kelp, reducing biodiversity and posing a threat to that state's lobster and abalone industry.

To understand the massive movement of water past our shores, SIMS scientists are deploying the latest technology, including an autonomous underwater glider that swims through the eddies, as part of the Integrated Marine Observing System. They are also digging deep into sand dunes to discover what the NSW coastline looked like in the past and how future climate change could affect those who live on the coast.

The EAC is the western side of a giant anti-clockwise movement of water around the south

Pacific Ocean. It takes as long as two years for equatorial water to travel westwards from South America to Queensland.

This south Pacific circulation is driven at the southern end by polar winds, which have strengthened as the globe has warmed, pushing the tropical water south down the east coast of Australia at an increasing rate.

At Diamond Head, near Port Macquarie, the continental shelf narrows to a mere 15 kilometres, forcing the southward flow to accelerate and triggering the formation of eddies.

''Then the EAC does a big U bend just off Sydney and forms a series of undulations that travel across to Lord Howe Island,'' Suthers says. Other fingers of warm current continue down the coast to Tasmania.

Three or four big warm eddies form a year, lasting for more than 12 months and taking one to two weeks to rotate. ''We can see them from space in two dimensions but this gives us no information about depth,'' Suthers says.

Suthers and his team deployed a glider late last year to study a warm eddy that is still sitting off Jervis Bay and next week they will observe a cold one off Port Stephens. The gliders ride the eddies, like Nemo's dad Marlin, surfacing every four hours to transmit some of the data collected on temperature, depth and plankton levels, and the public can follow the progress of the glider trip from late next Tuesday via a link on the SIMS website (sims.org.au).

The research so far has revealed that anti-clockwise warm eddies lean inwards towards the coast and the depression at the top of clockwise cold eddies can fill up with hot warm water from elsewhere in the current.

''From space it looks like a puddle of warm water, when in fact it is a flooded cold-core eddy,'' Suthers says.

By sampling cold-core eddies, his team has also discovered they are filled with larval fish including sardines, leatherjackets, blue mackerel and trevally. The cold eddies, which usually form between the EAC and the shore, appear to sweep up the little fish, which are capable of swimming vigorously at this stage, along with nutrient-rich coastal waters.

While some scientists think cold eddies are a death trap for fish, Suthers believes they could provide the vulnerable larvae with some respite from predators. When the cold eddies, which only last a few weeks, break up the fish are big enough to swim back to the estuaries. ''We think the cold-core eddies are really important for fisheries,'' Suthers says. The rare occurrence of three shark attacks in Sydney in February-March 2009 also coincided with a large warm eddy spinning off Sydney, which squirted up deep, clear cold water on to the coast. ''There may be some connection but we don't know what it is yet,'' Suthers says.

Research to track the movement of tagged sharks could throw new light on the problem and soon the gliders will also be equipped to listen for any acoustically tagged sharks that venture into the eddies.

To better predict coastal erosion as the climate changes, NSW scientists plan to use a jet ski especially fitted with GPS and sonar to survey the ocean floor in up to 20-metre-deep water, both before and after storms hit.

''We want to calculate how much sand there is and where it is going,'' says Associate

Professor Ian Goodwin, of Macquarie University and SIMS.

SIMS colleague and an associate professor at the University of NSW, Ian Turner, says studies are planned for about 10 sites along the NSW coast, including Terrigal, Wamberal and Narrabeen. ''A big imperative is to understand why the coastline behaves the way it does today,'' he says.

A lot of attention has been given to the impact of sea-level rise from global warming. But until there is an increase of about half-a-metre, the biggest influence on coastal erosion and inundation will be changes in size, direction and power of waves that break on the shore, Goodwin says.

Warming of the EAC and weather patterns such as El Nino cycles are among the factors that can affect wave behaviour.

Long-term studies at Narrabeen and Collaroy beaches by Sydney researchers, for example, have shown that during periods when El Ninos are common, the Collaroy end of the beach is more eroded.

Meanwhile, during La Nina periods the Narrabeen end is hardest hit.

Although the EAC moves some sand southwards on the continental shelf, most sand on the NSW coast is transported from south to north because of the dominant south-easterly waves and winds.

Some climate-change models predict a rise in easterly winds in future, which would act with the EAC to change the curvature of beaches. Further strengthening and warming of the EAC could also result in an increase in the number of east coast lows and destructive storms.

Storms as fierce as the Pasha Bulker event were more frequent in the mid-1970s, leading to coastal erosion that took decades to recover naturally, Goodwin says. The more distant past also holds clues to the future, so he has been digging with colleagues in sand dunes in northern NSW and south-east Queensland. This research has revealed that 1000 years ago, the shoreline near Yamba was about 700 metres further inland and the coast accreted seawards to its present position.

''So we have developed our townships at the most seaward extremity of the natural system,'' he says. Thus, climate-change impacts on the coast from human activity such as sea-level rise, changes in waves patterns and storm surges, could be exacerbated by natural reversal of the shoreline position.