

A schematic diagram of the surface ocean currents around Australia in autumn.

Credit: George Cresswell, CSIRO Oceanography

unknown to the population that is nearby and affected by it even though it compares with the famous Gulf Stream that runs east across the Atlantic Ocean from the Gulf of Mexico towards the British Isles and Europe, where it splits in two. The people of western and northern Europe widely recognise that the current has a warming effect on their climate.

The EAC flows south along Australia's east coast and carries about the same volume of water as the Gulf Stream, making it among the world's six largest. Yet few Australians would name it as a key influence on their climate.

The EAC flows year-round as a gigantic "river" some 200 nautical miles (370 km) across travelling at up to 4 knots (2 m/sec). It emanates from the warm Coral Sea which, due to its higher temperature, is a metre higher than the Tasman Sea. The current is driven by the "downhill" gravitational force. Off Newcastle, the current splits: a breakaway travels east towards Lord Howe Island and the north of New Zealand, leaving behind a series of large swirling eddies off the coast of NSW.

The huge volume of water has to be measured in units known as Sverdrups, which equate to 1 million cubic metres (or tonnes) per second. Iain Suthers, Professor of Oceanography at the University of NSW, says that the EAC is not easy to measure because it is not contained in linear boundaries like a land-based river. But he estimates it to carry, on average, 20–35 Sverdrups of water every second. In contrast the long skinny Leeuwin Current that flows south along the Western Australian coast, but only in winter, carries only 5 Sverdrups.

Suthers says it was very difficult to collect adequate data on the EAC in the 1980s, but some dramatic changes are still evident. The current is now running

Finding Nemo

By PETER POCKLEY

James Cook discovered the East Australia Current more than two centuries ago, but its profound influence on eastern Australia is only now coming to be understood.

Throughout his great voyage of discovery of Eastern Australia, Lieutenant James Cook kept a meticulous log of the position and progress of the *Endeavour*. After leaving his first landfall at Botany Bay on 7 May 1770 he sailed north, passing by the entrance to what he named Port Jackson (now Sydney Harbour).

On 11 May he noted: "At 8 we were abreast of a high point of Land, which made in 2 Hillocks; this point I called Cape Hawke [just south of Forster/Tuncurry, now in NSW]. It bore from us at this time West distant 8 Miles."

But at noon Cook observed the ship was "12 Miles to the Southward of that given by the Log, which I do suppose to

be owing to a Current setting that way". Despite a Southerly wind, the *Endeavour* had gone backwards.

Five days later, when further north off Point Danger [now on the NSW/Queensland border], Cook again recorded being borne southwards against the wind: "At daylight we were surprized by finding ourselves farther to the Southward than we were in the evening, and yet it had blown strong all night Southerly."

Cook was thus the first human to feel the power of what is now well-known to modern day seafarers as the East Australian Current (EAC), which they navigate through to take advantage of, or minimise, the effect on their speed.

The EAC, however, is largely



Slocum glider 2 after its launch into the East Australian Current off Crowdy Head south of Port Macquarie, NSW, on 17 March 2009. The communication link to the Iridium satellite network sits on top of the tail. Photo: courtesy Iain Suthers

faster and, most significantly, the temperature of the water has been rising by 2.3°C per century. The temperature figure is reliable as readings have been taken since 1944 by the same monitoring station on Maria Island off Tasmania's east coast. This is the fastest recorded rise of any regional sea in the world.

Like all analyses of the causes of climate change, an unambiguous, direct relationship between the temperatures

of the EAC and the eastern Australian mainland is not yet claimed, but Suthers says that the association is "very suggestive".

Further, Suthers says, the EAC is not only heating up progressively but it is flowing faster, meaning it is carrying more heat that has to be dissipated to other parts of the ocean and the atmosphere. This picture fits closely with the scenario envisaged for global warming.

Robots to the Rescue

Oceanography is seldom a "break-through" science as understanding of the nature, mechanics and biology of the oceans emerges steadily from masses of data collected over years. But the recent development of clever robotic instruments has accelerated the range of measurements accessible to scientists who do not have the funds for, or access to, large research vessels.

An Australian program to more closely study Australia's territorial waters, which now extend over 13.5 million km² (its land area spans 7.7 million km²) has been launched with the purchase and deployment of two kinds of robotic instruments, one an oceanic float and the other an oceanic glider. Together these constitute the Integrated Marine Observing System (IMOS) program funded by the former Howard government, with \$50 million for collaborative programs in marine research. Suthers is the IMOS leader for NSW.

In a program coordinated by SIMS in NSW waters, 300 ARGO floats are deployed in the oceans around Australia as part of 3000 floats in a worldwide program run by USA scientists. Looking like a small torpedo, each float is tethered to the ocean floor at depths of up to

Plugging Gaps in NSW Marine Science

The Australian public's knowledge of marine science is dominated by the Great Barrier Reef. While a high proportion of funding for research has been directed to institutes and centres based in Queensland, all the other states have substantial marine environments. For example, the Sydney Institute of Marine Science (SIMS) has been established as a consortium of four Sydney universities (Macquarie, NSW, Sydney and UTS) to correct this major imbalance in scientific knowledge of the marine ecosystems of the estuarine and coastal waters of NSW.

Until now there has been no major marine station covering the temperate waters of the NSW coast, which is special in its own right: as it lies midway between warmer tropical and colder southern waters it embraces unprecedented biodiversity. According to Dr John Paxton of the Australian Museum: "More fishes have been identified in Sydney Harbour than are found around the whole of the United Kingdom and north-western Europe combined".

Founding Chairman of SIMS and veteran marine biologist, Prof

Frank Talbot, told *Australasian Science*: "There's no better estuary in the world than Sydney Harbour. It's really a drowned valley and often has heavy inputs of fresh water which affects its organisms." Do we understand enough about its behaviour? Talbot is very firm: "Absolutely not! If you take the common fish in the harbour, for instance, I'd say anglers know more about the distribution of fish and their movement than scientists. That's horrifying."

"We should understand everything we can about these fish, including food fishes like bream, flathead, mulloway and sharks. We know a fair amount about contaminants in surface sediments. We don't know enough about the impact of those on the water and the organisms. The estuary is limping as it's continually getting input of nasties such as heavy metals and dioxins from old factories, and organochlorides, things we put on our gardens without proper care."

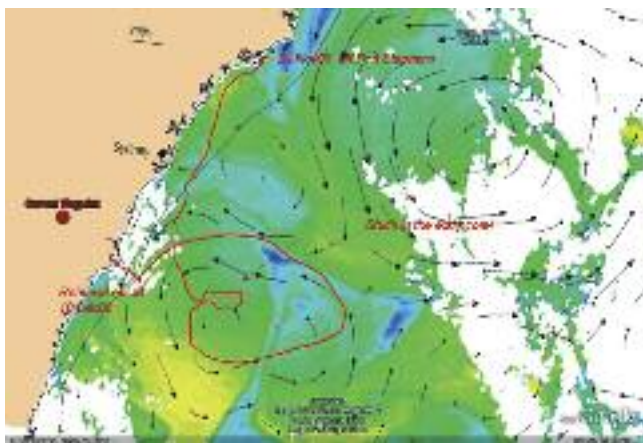
SIMS only has a small boat that is only suitable for Harbour work, but aims to expand to a 40-foot seagoing vessel. SIMS recently received a joint grant of \$1.2 million from the NSW government and

2000 metres. After recording sea temperatures and salinity down there, the floats are released periodically and rise to the surface. They take measurements progressively on the way up to the surface, where they transmit the information via satellite links to the controlling laboratory. The resulting wealth of information is helping oceanographers to monitor accurately changes in ocean conditions.

The innovative glider program has developed out of ARGO, with six American-built Slocum gliders costing \$120,000 each ordered for Australia. Two of the remotely piloted craft have recently been commissioned by SIMS scientists to take measurements in the giant eddies of the EAC. The SIMS program integrates closely with centres of marine science in other states.

Packed into the 1.8 metre tube are the key sensors for temperature, salinity and turbidity. There are no motors but the tube has wings and the nose can be tilted up or down by a rocking motion from the battery pack. This comprises 240 alkaline “C” cells – as used in torches – provides enough power for up to 4 weeks of “flying” though the ocean. The glider can ascend or descend by compressing or releasing a buoyancy tank, much like a submarine.

The Slocum glider is literally piloted from two shore-based labs in Perth and Sydney via a communications satellite. The scientists tell the on-board computer – a laptop minus the peripherals of keyboard, screen and disc drives – the precise attitude that the glider should be facing to maximise the speed it has gained from the current and then gliding along and down it to a specified depth. It navigates with an on-board compass while collecting data down to depths of 200 metres. On a schedule set in the computer’s memory by the scientists, the glider ascends to the surface, establishes communication with



The journey of Slocum glider Nemo 1 in eddies off Sydney, November–December 2008 Credit: SIMS

base via the Iridium satellite network and uploads 10% of the data it has collected while retaining the majority of information in its memory.

The precise position of the glider is obtained by a GPS reader on board, and this is reported to the “pilots” in the labs. Indeed, it is possible for anyone to log on to Google Earth with a computer and follow a glider’s path.

After 4 hours on the surface, the glider is piloted down to its next target area beneath the surface. As the battery life expires, the glider is instructed to surface and radio its precise GPS coordinates to enable a recovery team to retrieve it from the ocean and download its wealth of data back on shore.

“Nemo 1”, the first Slocum glider to collect data in the EAC, revealed a previously unknown feature of one of the giant eddies swirling in the waters from Newcastle down past Sydney. These eddies rotate clockwise, and range in size from 60 to 200 km across. They derive their momentum from the EAC, which fling them off to rotate for 1–2 years before they dissipate and

the Potter Foundation, which will help to build a new molecular biology lab and lease a new building to expand its headquarters.

SIMS is steadily establishing running seawater aquariums and other research facilities to share among its member universities after taking over a military establishment at Chowder Bay on the northern shores of Sydney Harbour (or Sydney Estuary, the more accurate description preferred by marine scientists). The site’s history dates back to the 1890s as Sydney’s first line of defence from a feared seaborne invasion. High explosive mines could be strung across the entrance from bunkers in the shore establishment, and in World War II the operation became involved during the invasion by three Japanese midget submarines on 30 and 31 May, 1942.

Research through SIMS is helping to unravel the complexities of the interaction between oceans and climate change, to understand better the changes in fisheries and to assist in the protection of the marine environment. SIMS has taken responsibility for running the

NSW segments of national research programs on the East Australian Current.

Among other Australian marine experts, SIMS researchers are generally pleased that the importance of their field has been recognised in a comprehensive “framework” released in March by an advisory panel to the Federal government. While the review values Australia’s marine industry sector at \$38 billion annually, the panel advocates “new investment in marine research and innovation infrastructure, particularly in national research vessel capability”.

The latter point relates to the ageing and inadequacies of the single research ship operated as a national facility by the CSIRO. The *Southern Surveyor* has to cover Australia’s 13.5 million km² marine jurisdiction – the world’s third largest – a manifest impossibility.

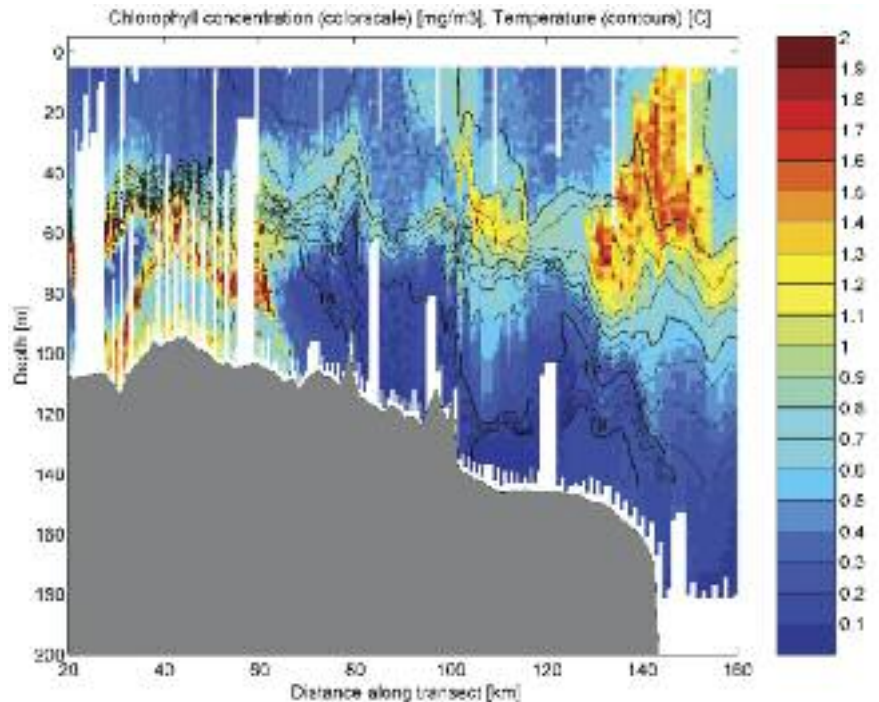
Dutifully, the panel made no recommendations on levels of funding needed. When the Science Minister, Senator Kim Carr, launched the strategy he made no financial commitments.



An ARGO float is cuddled by Prof Iain Suthers at SIMS. Photo: Peter Pockley

are replaced by another eddy. The task of the Slocum gliders is to measure the physical characteristics of the eddies.

The journey of Nemo 1's mission began off Port Stephens, south of Newcastle, on 24 November 2008. It made 370 dives over 17 days, but its trip became eventful when a previously unknown current carried it south and away from its planned path. It was then captured by another giant eddy and swept into its core as the on-shore pilots struggled to regain control of its trajectory. Reprogramming by satellite worked, though, and Nemo 1 radioed its precise position off Jervis Bay to enable it to be



The vertical profile of chlorophyll concentration obtained from the first leg of Slocum glider Nemo 1 along the continental shelf off Sydney. Temperature contours are shown every 0.25°C in black, with the 18°, 19°, 20° and 21° contours labelled. Credit: Mark Baird

retrieved by a rescue boat on 10 December with all its data intact.

“Nemo 2” was launched on 17 March further north than the first mission, and was still “flying” successfully through the eddies as *Australasian Science* went to press.

Scientific Challenges

The NSW IMOS plan explains: “The EAC influences the climate and marine economies of nearly half of the Australian population and yet we do not understand some of its most fundamental behaviour, such as the dynamics of current strength and separation from the coast, ecological effects of cross-shelf flow and larval trajectories”. There is a particular emphasis on determining the biological response to oceanographic and climate effects from fish movements to phytoplankton communities and to benthic habitats. Results are already coming in.

For example, the changes in the temperature, salinity and speed of the EAC and its eddies are now much better

understood. Suthers says this will have a big impact as coastal communities must face the prospect of sea level rise, beach erosion and the collapse of buildings nearby.

From Nemo 1's mission Dr Mark Baird of UNSW and colleagues have already analysed the turbidity data and have related the level of chlorophyll – the key indicator of life-giving photosynthesis – to temperature and depth.

Baird explains: “Phytoplankton are measured as biomass of chlorophyll through the turbidity of the water. From the entire 17-day mission we found that patches of chlorophyll occur at around 60 metres depth at the interface of warm sunlit surface water and cool nutrient-rich deep water. Patches of chlorophyll were seen where estuarine water pushes out offshore. A strong patch of chlorophyll extends to the surface as water crosses the continental shelf break (200 metre isobath).”

Much more valuable information is yet to be extracted from these productive devices.