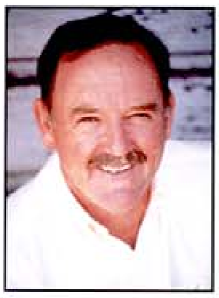
A tap on the hull by Royal Australian Navy rescuers brings Tony Bullimore to the stern of his yacht, Exide Challenger, capsized 1500 nautical miles south-west of Perth.

Royal Australian Navy

Going to extremes



'The Southern Ocean is a very special part of the world. When I got there (the waves) were certainly bigger than I had expected and somehow the air seemed denser. When it hits you, the bullets of wind hit harder. You have to treat it with the ultimate respect. If you don't, it has the ability to destroy you and your boat. It is a seriously powerful place, but with its own rugged beauty.'

– Solo yachtsman and founder of Clean Up Australia, Ian Kiernan AO

On Christmas Day, 1996, the eyes of the yachting world, senior navy and air force officials, and the Australian Maritime Safety Authority were fixed on the sub-Antarctic zone, 1500 nautical miles south of Western Australia. Raphael Dinelli, a competitor in the Vendee Globe, the Everest of ocean yacht racing, was in serious trouble. Ten days later two more solo racers, Tony Bullimore and Thierry Dubois, were in danger of losing their lives.

Known as the Furious Fifties, these high-latitudes zones are coveted by the around-the-world ocean racing fraternity. Competitors are chasing that adrenalin-pumping wind 'lift': a surge of speed driven by gale and storm-force winds gusting to 70 knots, accompanied by waves of 15 m. In these conditions, racing yachts are stretching their design capabilities.

This is territory rarely entered by the Royal Australian Navy, except for the odd rescue and when patrolling the Exclusive Economic Zone to protect against fish poaching. The only other visitors are long-line fishers; Antarctic base staff who venture south from New Zealand, Tasmania, South Africa and South America by ship; and a small but growing group of scientists keen to uncover the region's secrets.

Researchers at CSIRO Marine Research and the Cooperative Research Centre for the Antarctic and Southern Ocean Environment, together with US colleagues, have been studying the ocean between Australia and Antarctica for the past seven years. They are seeking to understand how interactions between the Southern Ocean, the sea ice, and the atmosphere influence regional and global climate. The research is part of CSIRO's multi-million dollar Climate Change Research Program.

Dr Steve Rintoul is a veteran of six research voyages across the Southern Ocean. In March, 1998, he will lead another voyage aboard the RV Southern Surveyor, into the 45-55°S latitudes of the sub-Antarctic. 'The Southern Ocean is the only ocean that circles the globe without being blocked by land and is home to the world's largest ocean current,' Rintoul says. 'The Antarctic Circumpolar Current connects the Indian, Atlantic and Pacific ocean basins and is a powerful influence on global climate, carrying 150 times more water around Antarctica than the flow of all the world's rivers combined.'

Rintoul says the Southern Ocean controls climate in three ways:

- The strong flow of the Circumpolar Current leads to a global circulation carrying heat from one region to another, influencing temperature and rainfall.
- The Southern Ocean is a source of intermediate and

deep water that renews the world's oceans. Cooling of the ocean and the formation of sea ice during winter increase the density of the water, which sinks from the sea surface into the deep sea. This dense water, produced on the Antarctic Shelf, controls the distribution of the physical and chemical properties of the deep ocean worldwide.

- At the sea surface, water exchanges gases such as oxygen and carbon dioxide with the atmosphere. As the water sinks it, heat, freshwater and gases are transferred into the deep ocean. Biological processes also play a role here, by influencing the content of carbon dioxide in the surface water.

Rintoul says understanding global circulation and conditions under which surface waters sink into the deep ocean is critical for scientists estimating the timing and magnitude of climate change. 'To improve our understanding of the link between Southern Ocean currents and climate, we have three scientific goals,' he says.

'The first is to measure how much water, heat and salt is being carried from the Indian Ocean to the Pacific Ocean, south of Australia. If we can work out how the transport of the currents varies today in response to winds and cooling by the atmosphere, we should be able to predict how the current might vary if the climate changes. Because ocean currents influence the overlying atmosphere, changes in the strength of the current may in turn drive further changes in the climate.

In meeting this goal, Rintoul and his colleagues will analyse data from the most comprehensive array of moored instruments ever deployed in the Southern Ocean south of Australia. The instruments, recovered by Australian and US scientists in 1997, included:

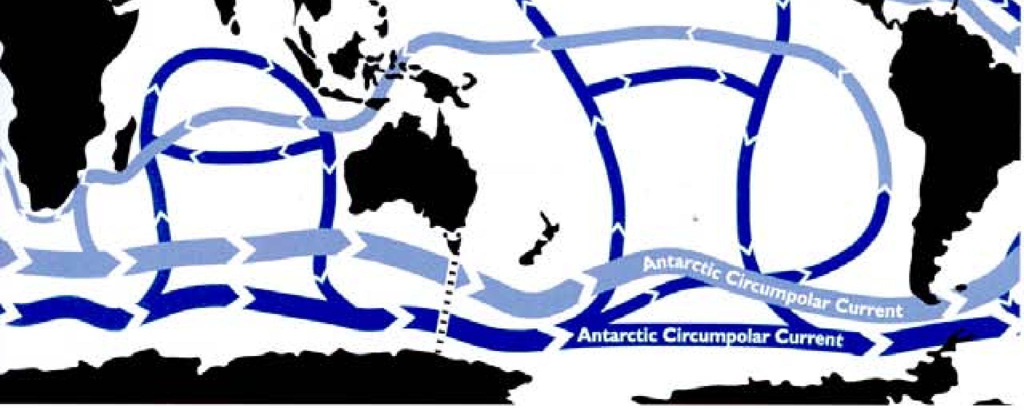
- Current meters which use a rotor and a vane to measure current speed and direction.
- Inverted echo sounders which measure changes in the time it takes a sound pulse to travel from the sea floor to the sea surface and return; changes in the travel time are related to changes in density of the overlying water, which are in turn related to changes in ocean currents.
- Sea floor electrometers which measure the average speed of an ocean current by sensing the electric field created by salty seawater moving through the earth's magnetic field.

Major ocean currents surrounding Australia. (EAC: East Australian Current, LC: Leeuwin Current, WAC: West Australian Current, ACC: Antarctic Circumpolar Current, SJC: South Java Current, SEC: South Equatorial Current.)

Seasonal and yearly variations in water movement between the Indian and Pacific Oceans have been measured six times since 1991 by the Australian research icebreaker Aurora Australis on the route from Tasmania to Antarctica. These measurements are complemented by upper ocean temperature observations collected by the French supply ship L'Astrolabe.

The second goal is to measure the rate at which water sinks from the sea surface. Near the axis of the Antarctic Circumpolar Current (midway between Tasmania and Antarctica), surface water sinks to depths of up to 1 km. Extreme cooling and ice formation over the Antarctic continental shelf can force surface water to sink all the way to the sea floor, as much as 5 km below the surface of the sea.

The rate of sinking determines how much heat the ocean can store and how much carbon dioxide and oxygen reach the deep sea. Scientists now believe that about 40-50% of carbon dioxide entering the atmosphere from the burning of fossil fuels ultimately enters the ocean to be contained in water masses. Water sinking to one kilometre will be isolated from the atmosphere for decades, while water



The Antarctic Circumpolar Current connects the Indian, Atlantic and Pacific ocean basins and is a powerful influence on global climate. Seasonal variations in the current are measured along the route between Tasmania and Antarctica.

sinking to the sea floor may be isolated for a thousand years. Chemical 'tracers' such as chlorofluorocarbons (CFCs) are used to measure the rate at which water sinks from the sea surface.

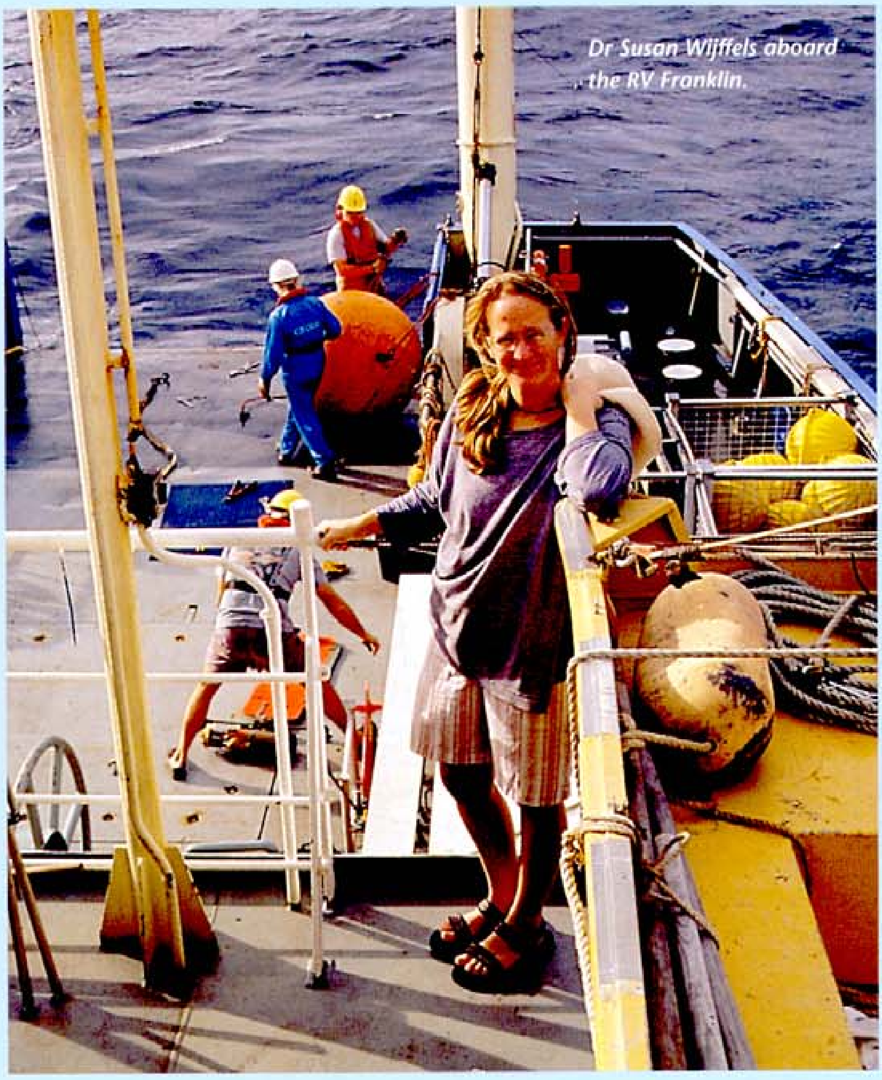
The third goal is to understand the role of ocean circulation (including the role of eddies in mixing cold and warm waters) in controlling the biological productivity of Southern Ocean surface waters. Rintoul says the Southern Ocean is not as productive as expected, given the abundant nutrients. Deep mixing associated with the high winds of the region, low light levels because of persistent cloudiness, and low levels of iron – an essential micro nutrient – may all play a role.

Biological and chemical measurements are taken from the research vessels Aurora Australis and Southern Surveyor. Properties measured include primary productivity, carbon dioxide concentrations, organic matter, fluorescence, nutrients (including trace nutrients such as iron), and the light available for phytoplankton growth.

To track the movement of icebergs, Synthetic Aperture Radar images from satellites are used. These large masses of ice act as deeply-drogued natural buoys moving with the ocean until they break-up or melt. The iceberg drift tracks will provide a further means of mapping currents near Antarctica. Another important satellite instrument is the altimeter which measures the height of the sea surface with an accuracy of a few centimetres. Ocean currents cause the sea surface to slope (the sea surface is about a metre higher near Tasmania than it is near Antarctica).

By combining state-of-the-art measurements with advances in computer modelling, scientists are now closer than ever before to the goal of making reliable predictions of future climate change, Rintoul says. 'The ocean models are combined with simulations of the atmosphere and sea-ice,' he says. 'These create comprehensive models of the global climate system that can predict how climate may change in the future, but for these climate predictions to be reliable, ocean currents must be accurately reproduced.

'To reach that point, we need to understand the circulation of the Southern Ocean and how it interacts with the atmosphere and sea-ice,' Rintoul says. 'Until our models can capture those interactions in a realistic way, reliable predictions of climate change are likely to remain out of reach.'



Dr Susan Wijffels aboard the RV Franklin.

Priceless observations

THE recovery in June 1996, of current meters anchored almost 1.5 km beneath the Indian Ocean surface completed a successful voyage to obtain valuable deep-ocean measurements north-west of Australia. The meters were recording deep-ocean movements far beneath the Leeuwin Current which flows southward down the Western Australian coast. They were part of an array of moorings deployed during the World Ocean Circulation Experiment, with other sets of instruments deployed off south-west Perth and in the Southern Ocean.

Chief scientist aboard the CSIRO's oceanographic research vessel, Franklin, during the June instrument recovery was Dr Susan Wijffels. She says while meteorologists receive thousands of atmospheric observations each day, deep-ocean information is comparatively meagre beyond the reach of satellites. 'Yet the oceans surrounding Australia could provide us with many answers about rainfall fluctuations and climate changes over decades,' she says.

Australia has contributed more than 1500 moored and shipboard observations from the Indian, Pacific and Southern oceans to the World Ocean Circulation Experiment, a project collating some 24 000 deep-ocean measurements as a baseline for diagnosing future changes due to the enhanced greenhouse effect.