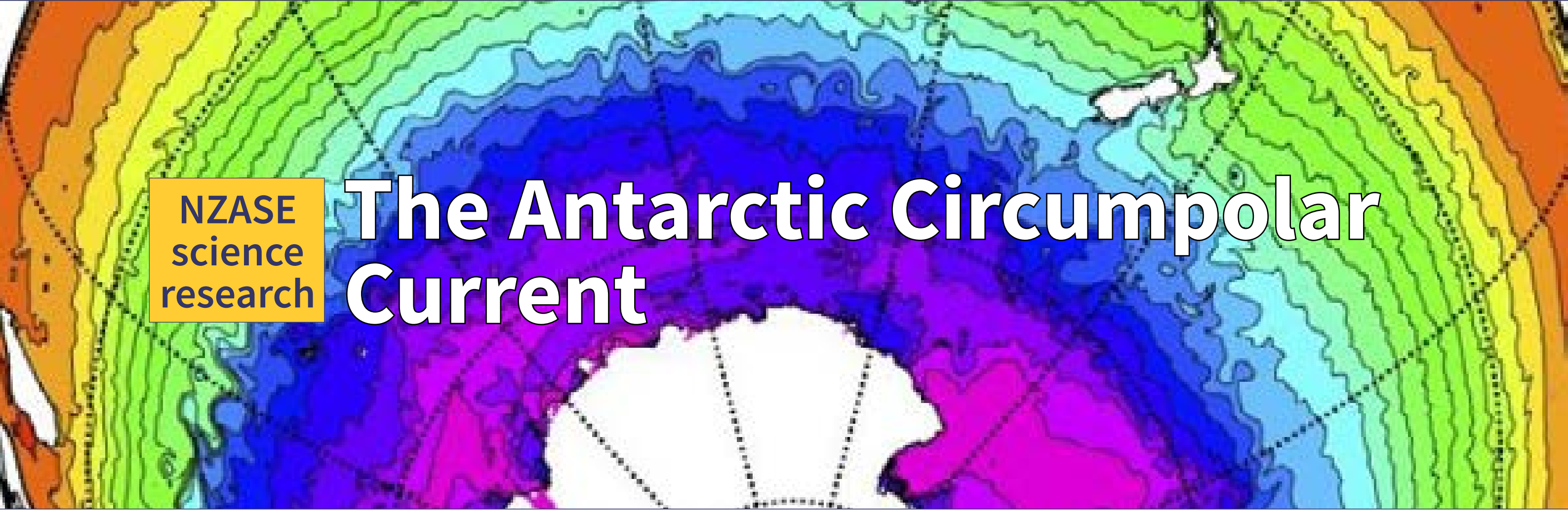
NZASE science research

The Antarctic Circumpolar Current



Water temperature in the southern oceans, ranging from 22° (lemon yellow) to almost 0° (deep pink); Australian National University.

Too often dicussions of ocean impacts on climate change mention only the Northern Hemisphere and the Gulf Stream. However, the Antarctic Circumpolar Current (ACC) and the Southern Ocean are crucial to our global climate system. By Jenny Pollock, CSRNZ, of ESSE, and Mike Williams, NIWA.

About ocean currents

As New Zealanders, we tend to think that we are at the edge of the world, with nothing but windswept sea between us and Antarctica. We are very aware of our dynamic landscape, but often don't realise that major currents that control the world's climate flow through the vast, restless oceans south of us.

An ocean current is like a huge river within the ocean, transporting masses of ocean water, and with it heat, salts, dissolved gases, nutrients and marine life.

Surface currents, which are generally no deeper than ten percent of the ocean's depth, are driven by wind. Deep currents are driven by gradients in density, which is a function of salinity and temperature – and all of these drivers are set up by solar radiation. The Earth's spin, the Coriolis Effect, and the topography of the ocean floor strongly affect the direction in which currents flow.

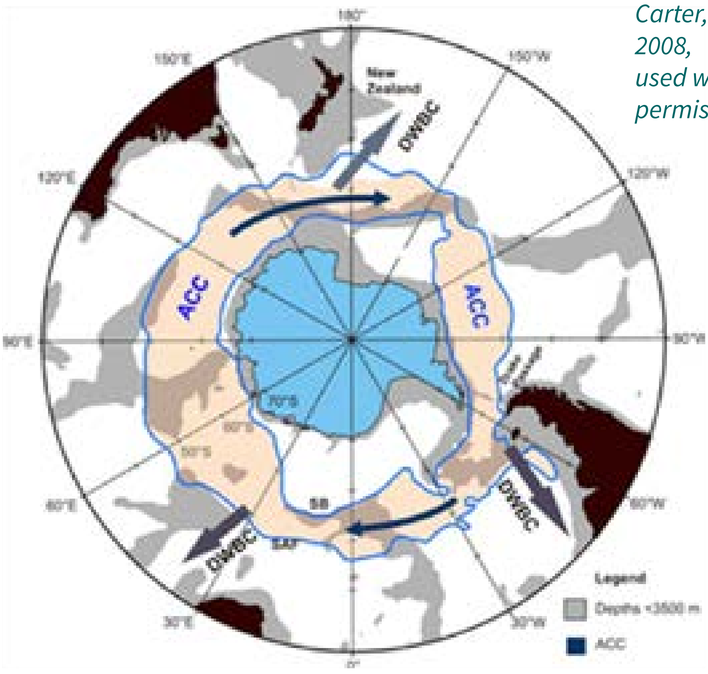
The Antarctic Circumpolar Current

Just south of New Zealand flows an ocean current that completely circles the globe – the cold Antarctic Circumpolar Current (ACC). This huge current is formed by persistently strong westerly winds - nicknamed by sailors the roaring forties, furious fifties and screaming sixties.

These winds transfer large amounts of momentum and energy to the current. The ACC flows eastward around Antarctica, connecting and mixing water from the Atlantic, Pacific and Indian Oceans. It transports 110–150 million cubic metres of water a second, which is up to 150 times the amount of water flowing out of all the worlds' rivers.

Unlike other major currents, the ACC reaches from the surface to the bottom of the ocean. It is as deep as 4,000 metres and as wide as 2,000 kilometres. The ACC consists of a series of linked flows affected by underwater topography, the underwater ridges and plateaus that deflect and alter its flow.

At gaps such as the Drake Passage between South America and Antarctica, and smaller gaps in the Macquarie Ridge, the ACC flows faster, and downstream of the gap collapses into a series of large eddies. These eddies are the oceanic equivalent of atmospheric weather systems, hundreds of kilometers wide and



The ACC and the Deep Western Boundary Currents (DWBC). SAF: South Antarctic Front; SB: Southern Boundary of the ACC. By Lionel Carter, 2008, used with permission.

hundreds of metres deep. They can be seen by satellites, because the warm eddies increase sea surface height, and cold eddies decrease it.

Tracking ocean currents

Different parts of the ocean have different properties – such as temperature, salt concentration (salinity), and density - and by measuring these across a vertical profile oceanographers can map water flow from one place to another. The properties of each water mass are set in the region in which they are formed, a process that remains fairly consistent from year to year. Once each water mass leaves the surface its properties remain constant, apart from some slow mixing with neighbouring water masses.

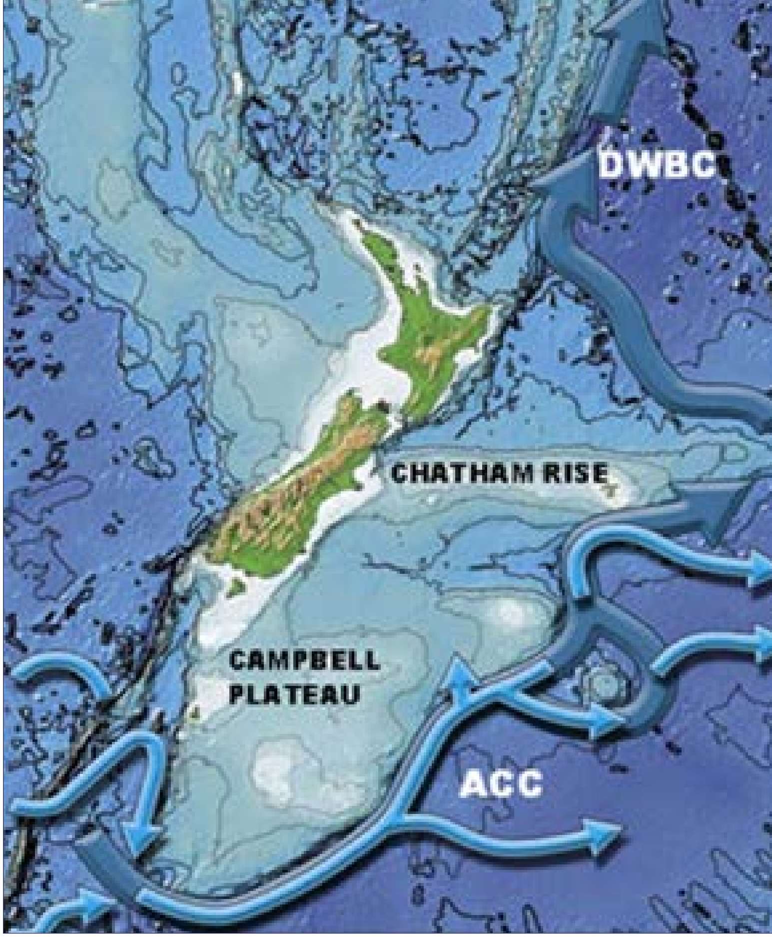
Salinity can be increased by evaporation, or by seawater freezing, as most of its salt is expelled as brine. Salinity can be reduced by the diluting effects of rain or snow. Temperature and salinity affect the density of water - the densest water masses are where it is very cold and salty, around Antarctica, and lighter water is found in the tropics where it is heated by the sun. When they meet, the denser ocean currents flow under the lighter ones. The large-scale ocean currents driven by this difference in density make up the Thermohaline Circulation.

Horizontal boundaries between water (or air) masses are called fronts. Across each ocean front, temperature, and salinity changes dramatically over relatively short distances. For example, in the Southern Ocean the Subantarctic Front is the boundary between salty, warm water to the north and a region of low salinity water which stretches to the Polar Front in the south.

The circumpolar Subantarctic Front and the Polar Front are important because the changes in temperature and salinity across the fronts set up density gradients that drive deep ocean currents such as the ACC.

The impact of the ACC

The ACC has a profound influence on the world’s climate because it is part of the global thermohaline circulation, which is driven



The Macquarie Ridge and the Campbell Plateau divert the ACC and DWBC. Lionel Carter, 2008, used with permission.

by the sinking of cold, dense water from the formation of sea ice, around Antarctica and in the North Atlantic.

Branching off the ACC, Deep Western Boundary Currents (DWBC) carry deep, dense water into the Indian, Atlantic and Pacific oceans, two to five kilometres below the surface. They rise near the surface to join warm equatorial currents and then travel further north and cool again, before flowing southward. Thus loops of ocean currents encircle the earth.

Surfacing every 600 years

If we could follow the track of a small amount of water around the globe, we would find that most of the time it is isolated in the dark and cold deep ocean. It would appear on the surface only about once every 600 years, and then only in the Southern Ocean south of the ACC. In the tropics and sub-tropics, a thin surface layer of warm, lighter water prevents deep water coming to the surface.

But south of the ACC, there is no warm layer to stop the upward movement of deeper water. When deep water reaches the surface, it gives up heat to the much colder atmosphere, and picks up dissolved atmospheric gases, including carbon dioxide and oxygen, which ventilates the ocean.

Challenges for researchers

Because the ACC is linked to the three major oceans and is important in global ocean circulation and ocean climate, it is essential that we detect any changes and understand and monitor its flow.

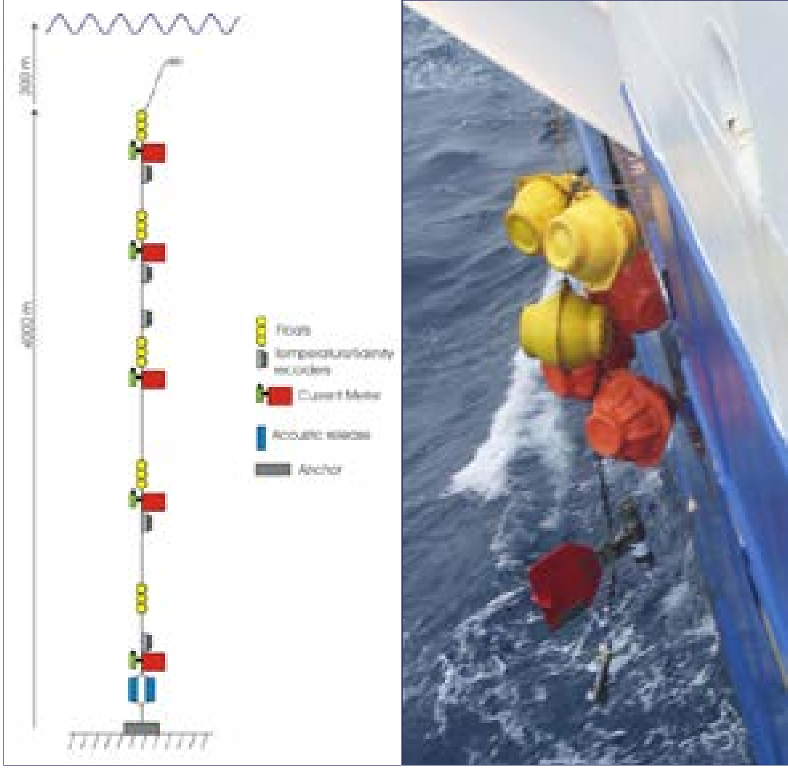
Research on circulation in the Southern Ocean is very difficult. Not only is the ocean stormy and good weather rare, but the area is vast. Gathering meaningful data about an ocean up to 4,000 metres deep and 2,000 kilometres wide is difficult. Oceanographers therefore choose their methods and sites for gathering data very carefully.

Aotearoa is well placed for studying the ACC. In 2007 NIWA scientists on the research vessel Tangaroa dropped nine moorings of metering instruments in two gaps in the Macquarie Ridge, through which the ACC squeezes.

The moorings were over 3.5km long, and anchored to the bottom of the ocean by old train engine wheels. The instruments measured and recorded the speed and direction of the current at fixed positions below the surface, aiming to build a picture of how the ACC flows through this ridge.

Scientists were astonished at the speed of the current - about four km/hr, about 10 times faster than most large ocean currents. This speed explains why underwater photographs showed the sea floor in the area to be bare rock, scoured clean of debris.

The data showed that about 40 percent of the ACC goes through the gap in the Macquarie Ridge – another surprise for scientists, who had expected most of it to go around the southern end. Forty percent of the ACC also flowed through Drake's Passage too. So the amount of water flowing southwards into the ACC matched the amount flowing out.



Left: The moorings used to gather data at the Macquarie Ridge; Mike Williams, and NIWA.
Right: The moorings being brought aboard the Tangaroa; Mireille Consalvey, and NIWA.

The ACC current has an affect on global climate as the thermohaline circulation is finely balanced. The energy and extent of the deep and shallow flows depend upon a balance between evaporation and fresh water supply, temperature distribution through the ocean, and wind patterns. Any or all of these factors may change as global warming proceeds so NIWA is continues to monitor changes in the ACC.

Ngā Kupu

Āhuarangi - Climate
Aro - Front
Au - Current
Kiato - Density
Mahana haere o te ao - Global warming
Mātaitai - Salinity, saline
Paemahana - Temperature
Te Pito Tonga - the South Pole
Ripo - Eddy

From Paekupu and Te Aka Maori Dictionary

Links

- Currents in the Southern Ocean, Science Learning Hub.
- Ocean currents and tides, Te Ara: The Encyclopedia of New Zealand.
- Deep waters spiral around Antarctica, *National Geographic*.
- How the Antarctic Circumpolar Current helps keep Antarctica frozen, *The Conversation*.
- Earth's strongest current even stronger than previously thought, *Ocean Bites*.