Circulation in the Southern Ocean

The Southern Ocean extends from the Antarctic landmass almost to New Zealand, and connects the Atlantic, Indian and Pacific Oceans. In this way the Southern Ocean plays a major part in connecting all the Earth's oceans, and influencing Earth's climate.

This is especially so as the Southern Ocean carries the Antarctic Circumpolar Current (ACC), which flows continuously eastward around Antarctica. The ACC is the worlds' largest current and estimated to equal 135 times the combined volume of all the world's rivers. This current resembles a major river, as if flows at 20 cm each second, with its path being determined by the shape of the sea floor and the forces that drive it.

What causes ocean currents?

Although the temperature of the Southern Ocean is low (-1.9°C to 10°C) it's not particularly salty with an average of only 34.5 grams of salt in each litre of water. However, as in all bodies of water, even small differences in temperature or salinity are sufficient to set up powerful currents.

1. Vertical currents

Sea ice forming in the Southern Ocean causes surface water to sink vertically, as the cold, salty water is heavier than the water underneath. When this dense water reaches the bottom it spreads out, to fill the depths of the world's oceans. As these currents travel the globe they carry dissolved gases such as oxygen and carbon dioxide, which means the Southern Ocean acts not only as the heart of a global ocean circulation, but as its lungs as well.

2. Surface currents

The currents on the surface of any ocean are not just the result of surface winds, but also factors working in three dimensions below the surface.

These include:

- the Earth's rotation (the Coriolis Effect)
- friction between layers within the water

These two factors combine to produce a surface current in the Southern Hemisphere, which usually flows at right angles to the left of the wind. Conversely in the northern hemisphere, due to the different Coriolis force, current flow is usually to the right of the wind.

3. Deeper currents

The way water moves at depth depends on other factors which include differences in temperature, salinity and density. Of these the most important is pressure, because as water becomes increasingly dense it is capable of reaching greater depths.

However it is not the vertical changes with depth and density which drive major ocean currents, but rather horizontal differences in water temperature and salinity - with only small differences (0.5% in density) required to send a large ocean current on its way.

Sunset on the Southern Ocean

Sea ice, still a bit salty

Below 0°C the density of water is mainly determined by salinity, rather than temperature. This helps to explain the important role of sea ice where, as ice forms, salt is expelled from the developing crystals. Within sea ice 85% of the salt is expelled, whereas from an ice shelf all of it is.

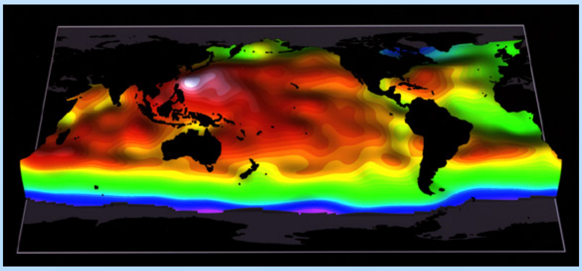
The especially salty, cold and dense water that is formed beneath sea ice and ice shelves is a major driver of ocean currents, especially during the months in which ice forms. Naturally the opposite also applies, so the melting of sea ice makes the underlying sea water less dense.

In warmer waters, away from the poles, it is temperature rather than salinity, which becomes the main factor in determining the density of the sea.

Why water masses stay together

The world oceans are made up of separate parcels of water, rather than one uniform mixture. The reason for this is that temperature and salinity change only at the ocean surface. Therefore once a body of water has left the surface its temperature and salinity will stay the same, so it will lie at the same depth as water with similar properties.

Between these water masses are boundaries called fronts. At the ocean surface most fronts show sharp changes in temperature and/or salinity.



The Antarctic Circumpolar Current flows eastward (left to right) and is steered by the continents and shape of the sea floor. As ocean currents are named for where they are going and winds for where they are came from, the ACC is driven eastward by westerly winds.

Adapted from material by Michael Williams by *Donald Reid, iMatters.co.nz* in association with *Gateway Antarctica, University of Canterbury*.

NZ Curricula: Science L4 - 8, Social Studies L3 - 4, Geography.

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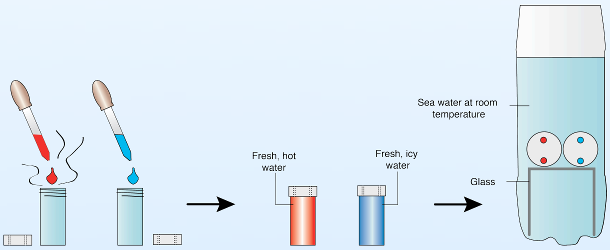
Practical: How water temperature and salinity affect convection.

Introduction

The annual formation of sea ice near Antarctica produces massive quantities of cold and very salty water which sinks downwards from the icy surface. This sinking mass of water helps to drive the deep ocean currents.

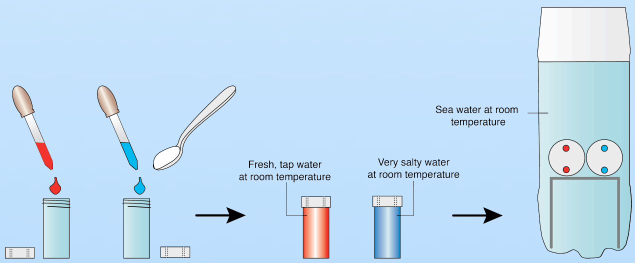
The follow tasks show how water temperature (thermo) and salinity (haline) each contribute to 'thermo-haline' circulation in the oceans.

A. 'Thermo' circulation - what to do



1. Cut the top from a large plastic drink bottle and three-quarters fill with tap water. Place a glass upside down in the container to make a small table. Allow to stand so that the water is about the same temperature as the room.
2. Make two holes in the top of two small plastic containers (e.g. medicine pottles)
3. Fill one small container with fresh hot water, the other with fresh cold (icy) water.
4. Add a drop of different food colouring to each.
5. After replacing their tops gently place them onto the glass table.
6. Which way does each coloured water sample move?

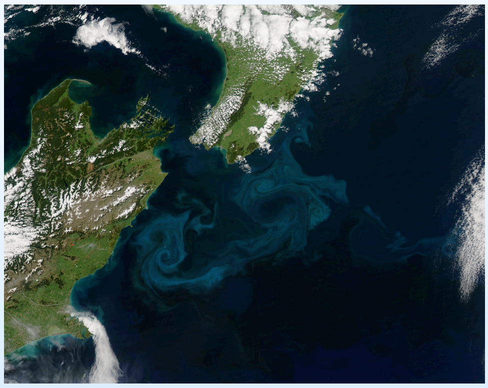
B. 'Haline' circulation - what to do



1. Cut the top from a large plastic drink bottle and three-quarters fill with sea water (or 2 heaped tablespoons of table salt in a litre of water). Place a glass upside down in the container to make a small table. Allow to stand so that the water is about the same temperature as the room.
2. Make two holes in the top of two small plastic containers (e.g. medicine pottles)
3. Fill one small container with fresh water that is about room temperature, the other with very salty water.
4. Add a drop of different food colouring to each.
5. After replacing their tops gently place them onto the glass table.
6. Which way does each coloured water sample move?

Relevance of thermo - haline effects

- Both salinity and temperature variation produce differences in density.
- Salinity and temperature combine to reinforce each other.
- In polar regions this combination pushes ocean currents around the planet.



Off the east coast of New Zealand, cold rivers of water that have branched off from the Antarctic Circumpolar Current flow north past the South Island and converge with warmer waters flowing south past the North Island. The surface waters where these meet is highly productive (due to the light and nutrients), to the extent that large blooms of phytoplankton can be seen from space, as blue-grey swirls.

Practical: The Coriolis Effect.

It is often stated that due to the Coriolis effect the water in a sink swirls out of the plug hole in different directions in each hemisphere.

The Coriolis Effect influences the way the atmosphere and weather systems rotate in each hemisphere.

However the Coriolis forces acting in a sink or bath are tiny, being about a millionth the force of gravity.

This means other factors are much more likely to influence the direction the water spins, these include:

- differences in water temperature
- the position of the plug hole
- how the plug is removed
- the shape of a bath
- water movement

Challenge:

Carry out trials to find ONE way you can influence which way water drains from a sink.From this you should be able to discretely control how the water drains - so you control if it spins clockwise or anti-clockwise.

Images: Donald Reid. NASA. Anders Persson, Wikicommons

For a full range of Antarctic and Southern Ocean resources visit: **The Antarctic Hub** www.antarctichub.org