

Southern Ocean – Sentinel of Global Warming?

Rahul Mohan &
Swati Nagar

Is the Southern Ocean favoring us by absorbing excess carbon dioxide? How long can it absorb the excess burden of human-induced carbon dioxide generation?

Sea ice packed Southern Ocean (Pic: Rakesh Rao)

WITH rapid strides in development during the last hundred years, there has been an enhancement in the rate of increase in carbon dioxide concentration both in the atmosphere and in the oceans, in addition to an increase in temperature both atmospheric and sea surface. It is therefore imperative to decipher and document such changes and their influence on the biotic ecosystem along with the role of the colder oceans in a changing climate scenario.

Oceans cover about 70% of the Earth's surface. Oceans support the economy of a country (especially coastal nations) but above all they play an important role in circulating heat

energy around the globe. Amongst the youngest oceans is the Southern Ocean (SO), which plays a key role in ocean circulation that influences the world's climate.

In the year 2000, the International Hydrographic Organization created the fifth and the newest world ocean – the Southern Ocean – from the southern portions of the Atlantic Ocean, Indian Ocean, and Pacific Ocean. The Southern Ocean completely surrounds Antarctica. It is the fourth largest of the world's five oceans and larger than the Arctic Ocean.

When the Southern Ocean is just an extension of the Atlantic, Indian and Pacific Oceans towards the southern

hemisphere, then why was this extension considered a new ocean? Because it is not just any extension, but a mixing of waters from these oceans along with different climatological and geographical conditions, making this area distinct from the rest of the three (contributing) oceans.

For scientific purposes the Southern Ocean begins where you get the clubbing of isotherms (line joining points where temperatures are similar) with a drastic drop in the sea surface temperature. Therefore, to understand the Southern Ocean it is important to understand from around 40 degrees south onwards towards the Antarctic continent.



Oceans play a vital role of redistributing carbon dioxide as well as heat energy. The absorbed carbon dioxide from the atmosphere is used by the phytoplankton for photosynthesis (a process through which autotrophs prepare their food, just like plants do on land). Phytoplankton are microscopic organisms that form the basis of marine food web. Other tiny animals like Krill

(shrimp-like organisms) feed on planktons. Fish, seals and even whales feed on Krill.

When the organisms die, they settle down at the bottom of the ocean as sediments thus locking the carbon dioxide. That's why, oceans are considered as '*carbon sink*' (since they absorb excess carbon dioxide from the atmosphere and after passing through various trophic levels, finally locked in the form of sediments at the ocean bottom). The absorption of carbon dioxide is more in colder water than the warmer water.

Therefore, in today's global warming scenario, the Southern Ocean, a huge cold ocean, plays a pivotal role in the global carbon cycle by capturing carbon (also known as sequestration). Available studies indicate that the Southern Ocean sequesters about half of the anthropogenic carbon dioxide.

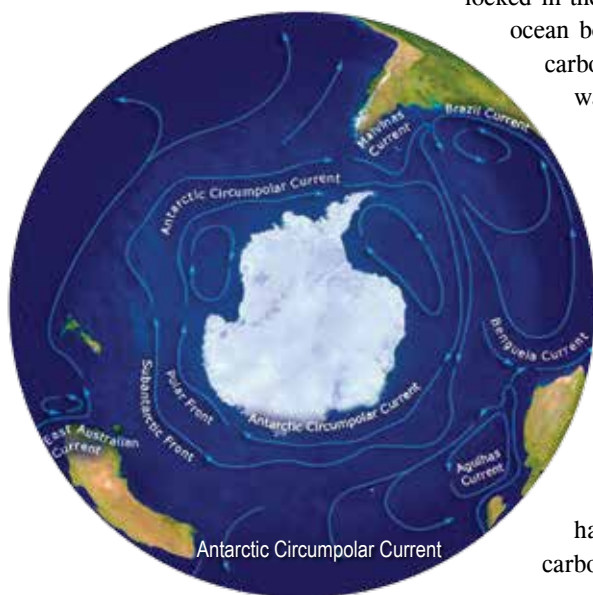
Uniqueness of Southern Ocean

The Southern Ocean is the fourth largest ocean. Its depth varies from 4000-4800 m (12000-14000 ft) with an average depth of about 3200 m (10700 ft). It is considered as the youngest ocean, formed when Antarctica and South America moved apart due to tectonic movement approximately 30 million years ago.

Movement of the tectonic plates opened the Drakes passage, allowing the Antarctic Circumpolar Current (ACC) to form. ACC is one of the largest water current surrounding Antarctica and a distinctive feature of the Southern Ocean.

The temperature in the Southern Ocean varies from -2 degrees to 10 degrees depending upon the season and location. As we move south towards Antarctica, the sea surface temperature decreases dramatically.

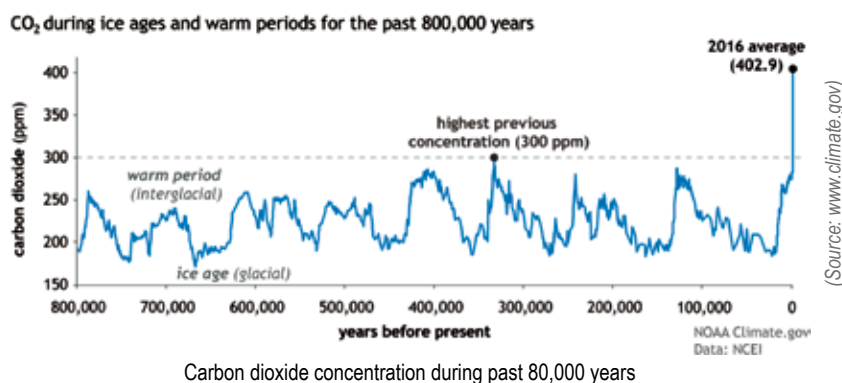
The Southern Ocean experiences harsh conditions, which is seemingly uninhabitable for most organisms, when compared with other oceans. Extreme cold, sea-ice cover for most of the year, short summers may expect to limit the diversity in the Southern Ocean.



(Source: www.teara.govt.nz)



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life and closely related to the Antarctic Treaty system) has designated certain areas of the Southern Ocean as Marine Protected Areas (MPAs). MPAs do not necessarily exclude fishing, research or other human activities. In fact, many MPAs are multipurpose areas. MPAs in which no fishing is allowed are known as 'no-take areas'.

The Southern Ocean is a challenging region due to its harsh weather conditions and remoteness from the mainland. The unpredictable weather of the Southern Ocean may bring in storm-like conditions which include huge waves and strong winds anytime in the year.

These strong winds are generated due to pressure gradients developing between the sub-Antarctic trough and the sub-tropical high pressure belt. The difference in the temperature of winds from sub-tropical and Antarctica creates a low pressure area around Antarctica. These conditions are very hostile for any sailor or marine vessel that happens to get caught in their path.

As one moves further towards Antarctica, the notorious conditions in the Southern Ocean increase, earning names such as '*Roaring Forties*', '*Furious Fifties*' and '*Screaming Sixties*'

However, the adaptability of cold-loving organisms enables them to thrive in such an extreme environment. The microorganisms and plankton generally inhabit the open ocean, endure the harsh sea-ice covered Southern Ocean winters in the brine channels (brine channels contain high saline water under sea ice, due to the expulsion of salt while sea ice formation), waiting for the summers, when breaking of sea-ice exposes them to open water for blooming.

Krill are well adapted for feeding under the sea ice during winters and so are some sea ice diatoms (siliceous plankton). A remarkable example of cold adaptation is ice-fish that uses anti-freeze proteins to prevent freezing of blood

in sub-zero temperature. An amazing species of ice-fish has white/colourless blood due to lack of hemoglobin. There are many such examples in the Southern Ocean that makes it unique from other oceans.

The Southern Ocean is home to unique diverse forms of life from the microscopic planktons and the little penguins to the wandering albatross and the biggest mammal – the Blue whale – and seals. To conserve the marine resources in the Southern Ocean, CCAMLR (Commission for Conservation of Antarctic Marine Living Resources), (an authority/convention established by international convention in 1982 to conserve Antarctic marine

based on their latitudes 40 degree, 50 degrees and 60 degrees South, respectively.

Another threat in the Southern Ocean is from icebergs. Although icebergs look mesmerizing, these huge chunks of freshwater ice (carved out from glaciers) pose a threat to marine vessels. These icebergs may sometimes be as big as hundreds of meters.

Role in Global Warming

However, the role of the Southern Ocean in the transport of huge amounts of heat and carbon between the atmosphere and oceans makes it one of the most critical regions to understand the linkages and processes of oceans as well as ocean-atmosphere coupled interactions. Changes in the Southern Ocean would have global implications. Thus, scientists from many countries including India launch scientific expeditions (almost every year) to study the processes and effects of climate change in the Southern Ocean.

The Southern Ocean is a huge ocean, divided into majorly three sectors based on its source of water from the contributing oceans viz., Atlantic sector, Pacific sector and Indian sector.

Indian scientists are trying to unravel the mysteries of this sector through India's Southern Ocean Expedition. Initiated in 2004 by the National Centre for Antarctic and Ocean Research, Goa under the aegis of the Ministry of Earth Sciences, Government of India, the Southern Ocean Expedition serves as a platform for an inter-disciplinary and multi-institutional team to study the role and response of the Southern Ocean to the changing climate through a designated route from Mauritius to the Antarctic coastal waters.

Besides understanding the biogeochemistry, chemical, physical and optical oceanography of the Southern Ocean, scientists are also trying to find the linkages between the ocean-atmosphere interactions to estimate the absorption of excess carbon dioxide by the ocean from the atmosphere.

For comprehensive understanding of the dynamic system, scientists study atmospheric sciences, geology of the ocean bottom, etc.

The hostile conditions of the Southern Ocean sometimes hinder data collection. However, new technology like moorings, floats, gliders, satellites, computer models and even seals fitted with sensors are helping scientists collect data forming a bigger picture to better understand the Southern Ocean and climate function.

For better monitoring of the ocean, scientists deploy the Argo Float – a machine that records various parameters from even the bottom of the ocean. These machines are programmed to record various parameters like temperature, salinity, etc. from the depths and transmitting the recorded data via satellite after popping up to the surface. Earlier, the floats could go up to 2000 m. However, recently improvised slender Argo Floats can go up to 5000 m, thus enabling scientists to better understand the Southern Ocean.

Sediment traps are deployed to estimate the sedimentation rate and the fluxes of settling particles in the Indian sector of the Southern Ocean. For better understanding and prediction of future climate, scientists need to study paleoclimatology (study of past climate). They reconstruct the Sea Surface Temperature (SST) of a study area for hundred years ago using different proxies. This study helps the scientists to understand the natural variability thus, differentiating human-induced change from natural change.

Scientific studies have revealed that excess absorption of carbon dioxide in the ocean causes acidification, which in turn affects the organisms. Available studies show ocean acidification may cause possible thinning of foraminiferal shells, decline in Southern Ocean seals and sea birds. Other impacts of acidification are presently uncertain.

However, these negative impacts should be considered along with the ability of the organism to adapt. Some studies shows that rise in temperature

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and consequent rise in ocean temperature may be posing a threat to more than 900 species of shelf-dwelling marine invertebrates in the Southern Ocean. Rise in temperature also causes freshening of the surface leading to increased stratification. Besides, changes in salinity of the Southern Ocean have potential implications for ocean circulation (also known as thermohaline circulation) that redistributes heat and carbon dioxide along with nutrients around the world.

For climate change studies, getting data on various aspects of the Southern Ocean is only one half of the task. Understanding and incorporating of data into the models is the other half, for which models need to be improved based on the understanding of the current situation. Only then, future climate may be predicted and accordingly suitable strategies can be planned.

Dr. Rahul Mohan is Scientist E and Group Director, International Affairs and Outreach Activities, National Centre for Antarctic and Ocean Research, Goa.

Dr. Swati Nagar is working as a Project Scientist (Outreach Activities) at ESSO-NCAOR. Address: National Centre for Antarctic and Ocean Research, Earth Science System Organization, Ministry of Earth Sciences, Headland Sada, Vasco-Da-Gama, Goa-403804; Email: swati23n@gmail.com/swatinagar@ncaor.gov.in