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Going against the trend: Cooling in the Southern Ocean

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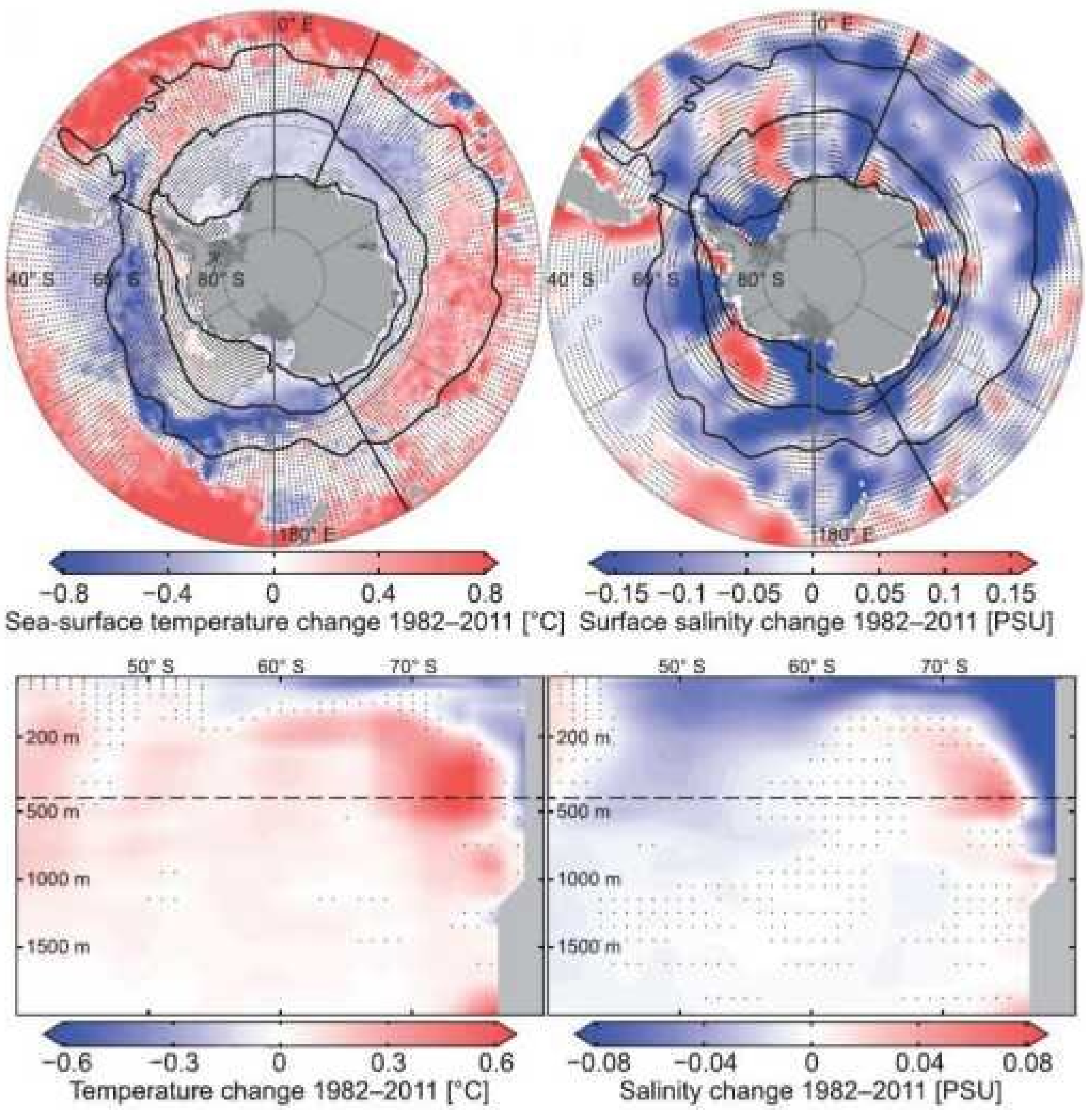

Changes in temperature and salinity of the Southern Ocean between 1982 and 2011. Credit: Haumann et al, AGU Adv 2020

Climate and marine scientists are observing pervasive warming of the ocean and land surfaces across the globe. Since the middle of the 19th century, the average global temperature recorded on the land surface has risen by around one degree centigrade, and by 0.6 degrees across the ocean surface. Global warming has been most pronounced in the alpine regions and the Arctic.

Over the period 1982 to 2011, however, a cooling trend was recorded in surface waters in some parts of the Southern Ocean around the Antarctic continent, specifically in the area south of 55 degrees latitude. This cooling was strongest in the Pacific sector of the Southern Ocean, where the ocean surface cooled by around 0.1°C per decade, and the weakest in the Indian and parts of the Atlantic sectors.

Climate and marine scientists have so far been unable to provide satisfactory explanations as to why parts of the Southern Ocean have bucked the trend of global warming. Now a group of scientists led by ETH Professor Nicolas Gruber has solved the puzzle with the help of simulations with a high-resolution ocean model.

Simulations highlight the influence of sea ice

In a paper just published in the journal *AGU Advances*, the scientists use a series of simulations to show that sea-ice changes are the most probable cause for the cooling of the surface waters in the Southern Ocean. Only when Alex Haumann, lead author and Professor Gruber's former doctoral student, and the team incorporated the observed changes in sea ice into the model were they able to correctly replicate the observed pattern of the temperature changes. When they omitted this effect and only took into account the other potential factors—such as a more vigorous ocean circulation or increased freshwater fluxes from the melting of the Antarctic glaciers—the pattern was not accurately simulated.

Their considering of the role of sea ice in causing the surface cooling was based on the observation that over the same period as the cooling took place, i.e., from 1982 to 2011, the sea-ice extent steadily increased in the Southern Ocean around Antarctica, while in the Arctic it shrunk significantly over the same period.

A few years ago, Haumann and Gruber and various colleagues already discovered the reason for this expansion of sea ice in the Southern Ocean. They noticed that stronger southerly winds over this period propelled more of the sea ice that is being formed along the coast out into the open sea, enhancing the melting there. The resulting stronger conveyor belt enhanced the transport of freshwater from near the continent out into the open ocean. This is because when sea ice is being formed from seawater, the salt is left behind, whereas when the sea ice melts in the summer well away from the coast, the freshwater is released into the surface, reducing the salinity of the seawater there.

This reduction in surface salinity strengthened the vertical stratification of the seawater: the fresher, and in this part of the ocean lighter water stays in the upper 100 m, while the denser saltier water remains below. In general, the saltier and colder the water, the greater its density and the greater its depth in the ocean.

Smaller heat exchange between the water layers

The stronger stratification reduced the exchange of heat between the deeper layers and the surface water, causing the heat to remain trapped at depth. In addition, the air above the Southern Ocean during winter is generally colder than the temperature of the seawater. Combined with the reduction of the vertical exchange of heat in the ocean, this ultimately created the observed situation where the surface water cooled and the subsurface warmed.

The strong role of salinity in controlling the vertical stratification is a peculiarity of the Southern Ocean, since there is actually very little difference in temperature between the ocean's surface water and the subsurface: only a few tenths of a degree. The strong salinity driven stratification also explains why the surface cooling did not induce deep mixing.

No material to feed global warming sceptics

"The cooling of the Southern Ocean over three decades is really unusual, bearing in mind that otherwise all other parts of the planet, especially the land surface, have warmed up," says Nicolas Gruber.

Cooling in just one area of the ocean should not be interpreted as a reduction of the long-term warming of the global climate system as a whole. It is merely a redistribution of heat in the Southern Ocean from the surface to the deeper layers of the ocean. "We assume the strong winds pushing the sea ice in the Southern Ocean northward are potentially a side-effect of climate change," Gruber stresses. "Climate change is clearly man-made and cannot be disputed simply because one area of the ocean shows signs of cooling."

In addition, the current study went only up to 2011. "We have observed a trend reversal since 2015. The sea ice around the Antarctic is now starting to recede at a rapid rate," says the ETH Professor. "And this is very much in line with the overall trend of continuing global warming."

More information: F. Alexander Haumann et al, Sea-Ice Induced Southern Ocean Subsurface Warming and Surface Cooling in a Warming Climate, *AGU Advances* (2020). DOI:

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