Deep ocean current may slow due to climate change

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As global warming increases precipitation in the Weddell Sea, sea-ice patterns are changing and a deep sea current is shrinking.

(Phys.org) —Far beneath the surface of the ocean, deep currents act as conveyer belts, channeling heat, carbon, oxygen and nutrients around the globe.

A new study by the University of Pennsylvania's Irina Marinov and Raffaele Bernardello and colleagues from McGill University has found that recent climate change may be acting to slow down one of these conveyer belts, with potentially serious consequences for the future of the planet's climate.

"Our observations are showing us that there is less formation of these deep waters near Antarctica," Marinov said. "This is worrisome because, if this is the case, we're likely going to see less uptake of human produced, or anthropogenic, heat and carbon dioxide by the ocean, making this a positive feedback loop for climate change."

Marinov is an assistant professor in Penn's School of Arts and Sciences' Department of Earth and Environmental Science, while Bernardello was a postdoctoral investigator in the same department and has just moved to the National Oceanography Centre in the United Kingdom. They collaborated with Casimir de Lavergne, Jaime B. Palter and Eric D. Galbraith of McGill University on the study, which was published in *Nature Climate Change*.

Oceanographers have noticed that Antarctic Bottom Waters, a massive current of cold, salty and dense water that flows 2,000 meters under the ocean's surface from near the Antarctic coast toward the equator has been shrinking in recent decades. This is cause for concern, as the current is believed to "hide" heat and carbon from the atmosphere. The Southern Ocean takes up approximately 60 percent of the anthropogenic heat produced on Earth and 40 to 50 percent of the anthropogenic carbon dioxide.

"The Southern Ocean is emerging as being very, very important for regulating climate," Marinov said.

Along with colleagues, Marinov used models to discern whether the shrinking of the Antarctic Bottom Waters could be attributed to anthropogenic climate change.

They looked to an unusual phenomenon that had been observed from satellite images taken between 1974 and 1976. The images revealed a large ice-free area within the Weddell Sea. Called a polynya, this opening in the sea ice forms when warm water of North Atlantic origin is pushed up toward the Southern Ocean's surface. In a separate process, brine released during the sea-ice formation process produces a reservoir of cold, salty waters at the surface of the Weddell Sea. Because this situation is not stable, the heavy surface waters mix with the warmer, lighter waters underneath in a process called open-sea convection.

Polynyas were not observed again in the Weddell Sea after 1976, leading researchers to believe they –- and hence open-sea convection -– were rare events.

In the new study, however, the team suggests that polynyas were likely more common in the pre-industrial era, before anthropogenic climate change took hold.

The reason has to do with the fact that climate change has led to more precipitation around the Antarctic continent, which leads to greater levels of fresh water at the surface. Fresh water is more buoyant than saltwater and thus doesn't sink through the layers of the ocean as saltier water does, leading to fewer polynyas and less open-sea convection in the Southern Ocean.

The origin of Antarctic Bottom Waters is near the West Antarctic Peninsula.

"This is important because this process of deep convection that happens in polynyas is a big contribution to the Antarctic Bottom Waters, these deep currents that feed the rest of the ocean," Marinov noted.

Examining 20,000 data points, the researchers showed that the Southern Ocean surface has freshened during the last 60 years. They also found that vertical gradients of salinity and density have increased in the Southern Ocean, suggesting that mixing has been reduced.

Using the latest generation of climate models, 36 finely tuned and complex models that simulate climate change patterns, they found that, in most of the models, convective events, such as the polynyas captured by satellite images in the 1970s, were much more common in pre-industrial conditions, before anthropogenic climate change took hold.

"We see that the convective process is shutting down as the water gets fresher and fresher," Marinov said.

Seven of the models suggest that increased fresh water in the Southern Ocean could stop the convection from occurring altogether by 2030, and most models show strong decreases in convection during the 21st century, reducing the Antarctic Bottom Waters' formation.

This has implications for current and future climate change, the researchers said. The absence of polynyas in recent decades could mean that heat is getting trapped in the deeper ocean, possibly contributing to the recent "hiatus" in global atmospheric warming and the increase in Antarctic sea ice extent that have been observed in recent years.

But overall, Marinov said, "the slow down of polynyas will likely be a positive feedback on warming, as the convective process is shutting down and reducing the amount of new, anthropogenic carbon and heat being taken out of the atmosphere. We are pursuing these implications in our current work."

In a related paper, published this month in the *Journal of Climate*, Bernardello, Marinov and colleagues examine how the ocean's natural ability to store carbon might respond as the climate warms.

The ocean contains about 50 times more carbon than the atmosphere, making it a crucial but sometimes overlooked player in climate change regulation.

Irina Marinov, standing on Weddell Sea sea-ice.

This ability, Marinov noted, stems in large part because of tiny organisms called phytoplankton that live near the ocean's surface.

"They are all microscopic so we don't see them, but they are mighty," Marinov said. "They account for 50 percent of the photosynthesis that occurs on the planet."

In conducting photosynthesis, the phytoplankton take up carbon, which is then passed down through the deep ocean layers as these organisms and the organisms that eat them die and decompose. If it were not for this process, atmospheric carbon dioxide levels would be about 200 parts per million higher than the currently observed 400 ppm.

The Penn-led team considered how wind, temperature and salinity may change during the 21st century and how these phenomena affect the natural ability of the ocean to store carbon.

Running climate simulations into the future, their findings suggest that the phytoplankton-driven biological carbon pump will strengthen, leading to increased carbon storage in the ocean. Yet this effect is not enough to outweigh the fact that a warmer ocean will not be able to hold onto as much carbon dioxide gas.

"Gases are more soluble in colder liquids," Marinov said. "With climate change we predict that the ocean will lose some of its deep, natural carbon in the future, partly because the temperature warming effect is so strong."

Looking ahead, Marinov plans to add to this complex picture of the ocean's role in climate change. She will participate in an effort to increase sampling from remote parts of the Southern Ocean, blending physical, biological and chemical analyses with further modeling.

"More and more, people interested in ocean and climate sciences must also be interested in interdisciplinarity, in linking physics, biology, chemistry in the global climate context," she said.

More information: "Cessation of deep convection in the open Southern Ocean under anthropogenic climate change." Casimir de Lavergne, et al. *Nature Climate Change* (2014) DOI: 10.1038/nclimate2132. Received 02 September 2013 Accepted 13 January 2014 Published online 02 March 2014

Bernardello, Raffaele, Irina Marinov, Jaime B. Palter, Jorge L. Sarmiento, Eric D. Galbraith, Richard D. Slater, 2014: "Response of the ocean natural carbon storage to projected twenty-first-century climate change." *J. Climate*, 27, 2033–2053. doi: dx.doi.org/10.1175/JCLI-D-13-00343.1

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