Researcher discovers new pathway for heat transport in the ocean

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Professor Xiao-Hai Yan (third from right) works on climate change with the help of his students. Students, from left to right are Anglea Ditri, Lina Wang, Lingsheng Meng, Nan Chen, Hashei Sun and James Simkins. Credit: University of Delaware

Heat is transported through the ocean by a deep-ocean circulation system, known as the global heat conveyor belt, which constantly circulates water around the globe and helps to balance the earth's climate.

One of the upper branches of this conveyor belt, known as the Indonesian Throughflow (ITF), is an ocean current that flows through various channels between Borneo and New Guinea, more than 9,000 miles from Delaware.

While many of these channels have been known to researchers for years, the University of Delaware's Xiao-Hai Yan research team has uncovered a previously unaccounted for pathway transporting heat from the Pacific Ocean to the Indian Ocean, and even further to the Southern Ocean, which surrounds Antarctica.

A recent study, using models and data from 2003-2012 by Yan and colleagues at Princeton University, Xiamen University and University of Texas at Austin, revealed the warm water may be taking a shortcut in the Eastern Indian Ocean along the western coast of Australia. This warm water makes its way to the Southern Ocean more quickly than previously known or reported—revealing an important link between the Indo-Pacific Ocean and the Southern Ocean during a La Ninã weather pattern, which is the cooling down of the Pacific Ocean along the equator.

"When heat flows from the Pacific into the Indian Ocean, we expect that heat to follow the south equatorial current from the Indonesian Throughflow down to the eastern coast of Africa," said Yan, the Mary A.S. Lighthipe Professor in Marine Studies and director of UD's Center for Remote Sensing in the College of Earth, Ocean, and Environment. "Instead, the data and model results showed that the abnormally warm water traveled closer to Western Australia, suggesting that other processes were driving the water southward."

This increased transfer of warm water to the south has important climate consequences, Liao, a co-author from Princeton University said. It can affect the amount of rain that falls over Australia's western coast and increase the frequency of "hot events" that can cause coral bleaching, a phenomenon where coral expel the symbiotic algae living inside their tissues in response to heat stress, placing them at greater risk of mortality. Australia's Great Barrier Reef is still recovering from devastating bleaching events in 2016 and 2017, resulting from sustained high ocean temperatures amid a strong El Niño weather pattern.

The discovery has implications for the study of climate change and could inform what scientists currently know about global warming.

A globally connected system

In the study, Yan and his colleagues looked at how the ocean heat content varied 700 meters (nearly 3,000 feet) below the ocean surface in the Indian Ocean from 2003-2012, a time period when an abnormally large amount of heat is said to have been transported from the Pacific to the Indian Ocean.

This study of the heat content was conducted using numerical model simulations, data that was measured by ships and deep ocean remote sensing, which is data mining using satellite measured surface temperature, salinity and sea levels.

The researchers used a new, state-of-the-art global climate model known as the Community Earth System Model (CESM) to understand the physical processes, such as wind patterns, that may have contributed to this change.

Based on this finding, Yan and his colleagues theorize that this shortcut may have intensified heat transport between ocean basin waters in the different hemispheres by providing a new route for warmer water to travel directly from the tropical Indian Pacific Ocean to the Southern Ocean.

Understanding this link is important because the ocean is a globally connected system, and temperatures there can significantly affect sea surface temperatures (SST) and salinity in other places, such as the Atlantic Ocean. For example, higher tropical Atlantic SST can weaken the large system of ocean currents that carry warm water from the tropics northwards into the North Atlantic, known as the Atlantic Meridional Overturning Circulation (AMOC), but also can trigger warming or cooling-El Niño/La Niña-like SST anomalies in the tropical Pacific.

Both of these scenarios have profound impacts on climate systems that can manifest in extreme weather patterns, such as those experienced this fall with Hurricanes Florence and Michael, which made landfall in the Carolinas and along the Florida panhandle, but also affected coastal regions as far north as the Delmarva Peninsula, New Jersey and New York.

The researchers recently reported their findings in the scientific journal *Climate Dynamics*.

Co-authors on the study include Enhui Liao, the paper's lead author and a former doctoral student of Yan's now at Princeton University; Jiang Yuwu from Xiamen University in China and Autumn N. Kidwell from University of Texas at Austin.

Experts in heat redistribution

Yan and members of his lab have spent years studying what is known as the hiatus period of global warming, observed from 1998 to 2013 and caused by heat redistribution and storage in the deep ocean. Yan explained that during this time period almost all of the ocean basins' deep layers became warmer.

In a subsequent study, reported in *Nature Scientific Reports*, Yan and Lu Han, a former UD graduate student, looked specifically at the mechanisms that caused excessive heat accumulation in the Agulhas Region.

The Agulhas Region refers to the ocean waters off the southern tip of Africa, and is considered to be one of the fastest warming regions in the world over the last few decades. Data supports that waters in the Agulhas Region gained more heat during the hiatus period than previous global warming acceleration periods in the same region. It is also an important oceanic sink for excess heat found in the ocean because global mean surface temperature had shown that warming in most other areas of the ocean slowed down during the hiatus period.

"In the global warming hiatus period from 1998 through 2013, the Southern Ocean including the Agulhas Region had never slowed down. It was still warming," said Yan.

According to Han and Yan, increased salinity in the ocean during the hiatus period was mainly responsible for the interior ocean warming. This increase in salinity forced the heat to move horizontally, instead of following the water column's downward, vertical movement, as was typical during the acceleration period. This horizontal forcing, Yan said, led to higher temperatures in the ocean interior during a time when most of the ocean showed a decrease in surface temperature.

In addition, they found that the Agulhas Current and Agulhas Leakage—a current of water that drifts into the Atlantic Ocean rather than going to the Indian Ocean on its normal trajectory—serve as pathways for heat to be transported between the Indian Ocean and the South Atlantic Ocean.

Taken together, the findings from these two papers reveal important connections between the hidden heat transport and redistribution across ocean basins that can impact our global climate system significantly.

"They link the climate change "switch" at the Atlantic Ocean and "engine" at the Western Pacific Ocean together," Yan said.

More information: Enhui Liao et al. New findings on the route of heat transport between the Indo-Pacific and Southern Ocean, *Climate Dynamics* (2018). DOI: 10.1007/s00382-018-4436-4

Lu Han et al. Warming in the Agulhas Region during the Global Surface Warming Acceleration and Slowdown, *Scientific Reports* (2018). DOI: 10.1038/s41598-018-31755-1

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