# Tropical Pacific is major player in global ocean heat transport

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Aerial view of the coastline of Kauai Island. Credit: U.S. Geological Society

Far from the vast, fixed bodies of water oceanographers thought they were a century ago, oceans today are known to be interconnected, highly influential agents in Earth's climate system.

A major turning point in our understanding of ocean circulation came in the early 1980s, when research began to indicate that water flowed between remote regions, a concept later termed the "great ocean conveyor belt."

The theory holds that warm, shallow water from the South Pacific flows to the Indian and Atlantic oceans, where, upon encountering frigid Arctic water, it cools and sinks to great depth. This cold water then cycles back to the Pacific, where it reheats and rises to the surface, beginning the cycle again.

This migration of water has long been thought to play a vital role in circulating warm water, and thus heat, around the globe. Without it, estimates put the average winter temperatures in Europe several degrees cooler.

However, recent research indicates that these global-scale seawater pathways may play less of a role in Earth's heat budget than traditionally thought. Instead, one region may be doing most of the heavy lifting.

A paper published in April in *Nature Geoscience* by Gael Forget, a research scientist in the MIT Department of Earth, Atmospheric and Planetary Sciences (EAPS) and a member of the Program in Atmospheres, Oceans,and Climate, and David Ferreira, an associate professor in the Department of Meteorology at the University of Reading (and former EAPS postdoc), found that global ocean heat transport is dominated by heat export from the tropical Pacific.

Using a state-of-the-art ocean circulation model with nearly complete global ocean data sets, the researchers demonstrated the overwhelming predominance of the tropical Pacific in distributing heat across the globe, from the equator to the poles. In particular, they found the region exports four times as much heat as is imported in the Atlantic and

Arctic.

"We are not questioning the fact that there is a lot of water going from one basin into another," says Forget. "What we're saying is, the net effect of these flows on heat transport is relatively small. This result indicates that the global conveyor belt may not be the most useful framework in which to understand global ocean heat transport."

## Updating ECCO

The study was performed using a modernized version of a global ocean circulation model called Estimating the Circulation and Climate of the Ocean (ECCO). ECCO is the brain child of Carl Wunsch, EAPS professor emeritus of physical oceanography, who envisioned its massive undertaking in the 1980s.

Today, ECCO is often considered the best record of ocean circulation to date. Recently, Forget has spearheaded extensive updates to ECCO, resulting in its fourth generation, which has since been adopted by NASA.

One of the major updates made under Forget's leadership was the addition of the Arctic Ocean. Previous versions omitted the area due to a grid design that squeezed resolution at the poles. In the new version, however, the grid mimics the pattern of a volleyball, with six equally distributed grid areas covering the globe.

Forget and his collaborators also added in new data sets (on things like sea ice and geothermal heat fluxes) and refined the treatment of others. To do so, they took advantage of the advent of worldwide data collection efforts, like ARGO, which for 15 years has been deploying autonomous profiling floats across the globe to collect ocean temperature and salinity profiles.

"These are good examples of the kind of data sets that we need to inform this problem on a global scale," say Forget. "They're also the kind of data sets that have allowed us to constrain crucial model parameters."

Parameters, which represent events that occur on too small of a scale to be included in a model's finite resolution, play an important role in how realistic the model's results are (in other words, how closely its findings match up with what we see in the real world). One of many updates Forget made to ECOO involved the ability to adjust (within the model) parameters that represent mixing of the ocean on the small scale and mesoscale.

"By allowing the estimation system to adjust those parameters, we improved the fit to the data significantly," says Forget.

## The balancing act

With a new and improved foundational framework, Forget and Ferreira then sought to resolve another contentious issue: how to best measure and interpret ocean heat transport.

Ocean heat transport is calculated as both the product of seawater temperature and velocity and the exchange of heat between the ocean and the atmosphere. How to balance these events—the exchange of heat from the "source to sink"—requires sussing out which factors matter the most, and where.

Forget and Ferreira's is the first framework that reconciles both the atmospheric and oceanic perspectives. Combining satellite data, which captures the intersection of the air and sea surface, with field data on what's happening below the surface, the researchers created a three-dimensional representation of how heat transfers between the air, sea surface, and ocean columns.

Their results revealed a new perspective on ocean heat transport: that net ocean heat redistribution takes place primarily within oceanic basins rather than via the global seawater pathways that compose the great conveyor belt.

When the researchers removed internal ocean heat loops from the equation, they found that heat redistribution within the Pacific was the largest source of heat exchange. The region, they found, dominates the transfer of heat from the equator to the poles in both hemispheres.

"We think this is a really important finding," says Forget. "It clarifies a lot of things and, hopefully, puts us, as a community, on stronger footing in terms of better understanding ocean heat transport."

## Future implications

The findings have profound implications on how scientists may observe and monitor the ocean going forward, says Forget.

"The community that deals with ocean heat transport, on the ocean side, tends to focus a lot on the notion that there is a region of loss, and maybe overlooks a little bit how important the region of gain may be," says Forget.

In practice, this has meant a focus on the North Atlantic and Arctic oceans, where heat is lost, and less focus on the tropical Pacific, where the ocean gains heat. These viewpoints often dictate priorities for funding and observational strategies, including where instruments are deployed.

"Sometimes it's a balance between putting a lot of measurements in one specific place, which can cost a lot of money, versus having a program that's really trying to cover a global effort," says Forget. "Those two things sometimes compete with each other."

In the article, Forget and Ferreira make the case that sustained observation of the global ocean as whole, not just at a few locations and gates separating ocean basins, is crucial to monitor and understand ocean heat transport.

Forget also acknowledges that the findings go against some established schools of thought, and is eager to continue research in the area and hear different perspectives.

"We are expecting to stimulate some debate, and I think it's going to be exciting to see," says Forget. "If there is pushback, all the better."

**More information:** Gaël Forget et al. Global ocean heat transport dominated by heat export from the tropical Pacific, *Nature Geoscience* (2019). DOI: 10.1038/s41561-019-0333-7

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