Is the Deep Ocean Warming Too?

Source: Volkov, D. L., S.-K. Lee, F. W. Landerer, and R. Lumpkin (2017), Decade-long deep-ocean warming detected in the subtropical South Pacific, Geophys. Res. Lett., 44, 927–936, doi:10.1002/2016GL071661.

Our planet has been warming at unprecedented rates, largely due to greenhouse gases trapping heat in our atmosphere. There's more heat entering the atmosphere than leaving, and the ocean plays a critical role in absorbing some of this extra energy. If it weren't for the ocean, the atmosphere would be warming much faster than its current pace. But where in the ocean is this heat going, and does it matter?

It is certain that the upper ocean (sea surface down to a depth of 2000 meters) has been warming by taking up heat from the atmosphere, but whether or not this heat is making it down to the deep ocean is up for debate. There are two reasons why understanding how much heat is in the deep ocean is important. First, the deep ocean taking up heat could cause a slowdown in the rising atmospheric temperatures around the world, falsely leading us to believe that global warming has halted. The second is that there's a possibility that this deep water could eventually come to the surface, releasing its heat back into the air and causing our atmosphere to warm more rapidly. Characterizing the deep ocean has been particularly challenging, and this recent study is the first to show that in the South Pacific Ocean – one of the main heat accumulators on the planet – the deep ocean is getting warmer.

Deep-ocean data difficulty

In order to determine whether the deep ocean has been warming, temperature measurements in the deep ocean are needed. However, deep-

ocean temperature data is surprisingly tricky to acquire. Temperature measurements below 2000 meter depth in the South Pacific do exist; these measurements were taken directly in the water on a research cruise from January to February of 2005, and then again from March to May in 2014. But these data are only from one path within the South Pacific (Fig. 1) and aren't enough to draw conclusions about the entire South Pacific Ocean.

To complement this data, Volkov et al. measured deep-ocean temperature using satellite data. Because water expands as its temperature increases, warmer ocean water leads to higher sea levels. Satellites can be used to measure sea surface height by estimating how close or far the surface of the ocean is from the satellite. By relating sea level to temperature, this satellite data of sea surface height can be used to tease out changes in ocean temperatures at different depths. Volkov et al. used this data to come up with a satellite-based estimate of deep-ocean temperature changes, in addition to an estimate of warming from their ship-based measurements.

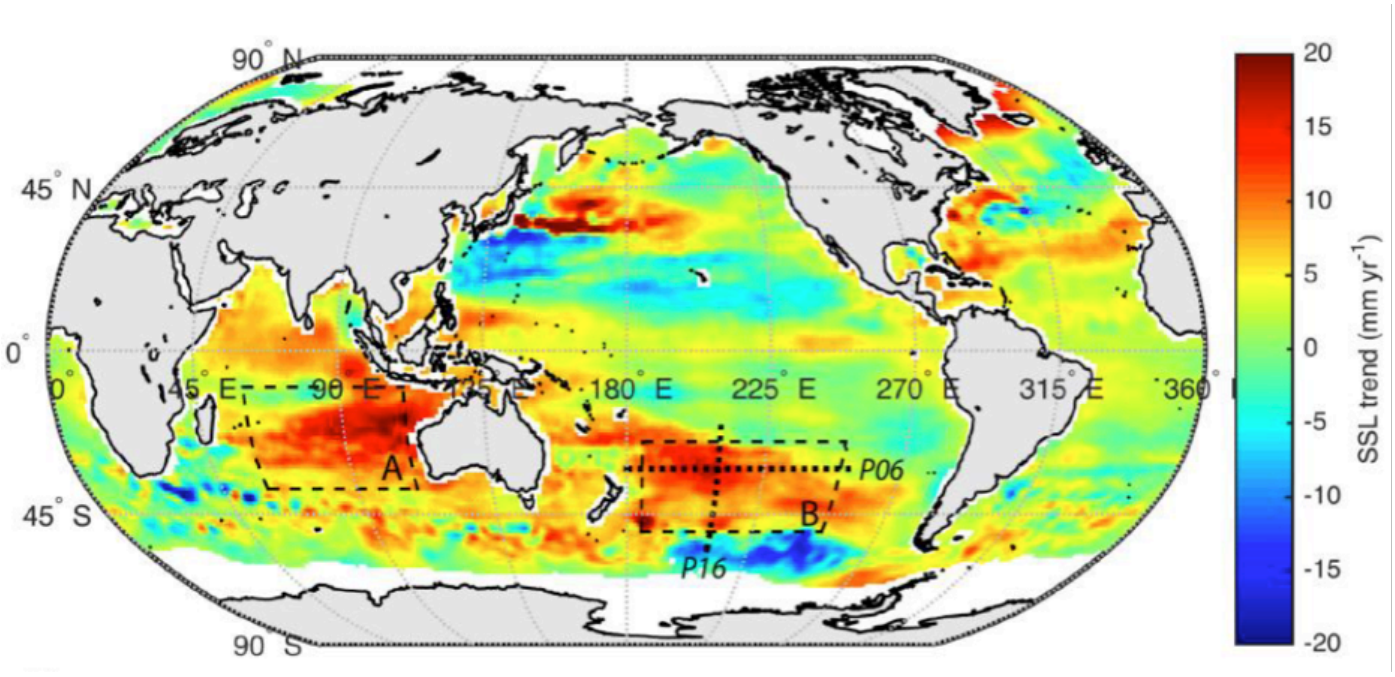

Figure 1. Map of path along which deep-ocean temperature measurements were taken in 2005 and 2014 (labeled on map as P16). Adapted from Volkov

et al. 2017.

Results from ship and satellite measurements

This study focused on temperature changes just within the region of a box (labeled B in Fig. 1) portion of the South Pacific Ocean. Using ship-based measurements, the temperature increase in the deep ocean was estimated to be 0.0216 ± 0.0126 ˚F between 2005 and 2014.

The other estimate from satellite data showed an increase in temperature in the deep ocean ranging from 0.0576 ± 0.0432 ˚F to 0.09 ± 0.0396 ˚F. There's a range in the possible temperature change because of the uncertainty in the satellite data relating to how accurately the satellite can make measurements.

Both ship-based and satellite-based estimates have strengths and weaknesses, including the sparseness of ship-taken measurements and the uncertainty in the satellite data. But the fact that the ship-based and satellite-based estimates of temperature change agree (meaning their values overlap within the range of uncertainty) affirms the likelihood of deep-ocean warming in the South Pacific.

Why has the deep ocean been warming?

The first obvious conclusion for why the South Pacific has been warming is because it has been taking up heat directly from the atmosphere. While this is the consensus for ocean warming on the whole, this theory contradicts recent observations that there has been less heat being directly transferred into the ocean from the atmosphere over the past decade.

The two things that determine heat content in any region of the ocean are 1) heat moving between the ocean and atmosphere at the sea surface, and 2)

movement of heat into or out of a region through exchange with other parts of the ocean. If the South Pacific has been warming, and there hasn't been an increase in heat exchange with the atmosphere, then it must be that heat has been entering the South Pacific from elsewhere in the ocean.

Other studies support this theory by suggesting that winds have been intensifying around Antarctica and over the tropics. These winds drive water towards the South Pacific Ocean at the surface; incoming surface water means that the water already at the surface in the South Pacific is forced downward, also known as Ekman pumping. As a result, the warm water at the surface in the South Pacific Ocean is being pushed deeper, causing the deep ocean to warm (Fig. 2). This theory of water transport has been supported by a number of studies and is the most likely cause of this deep-ocean warming.

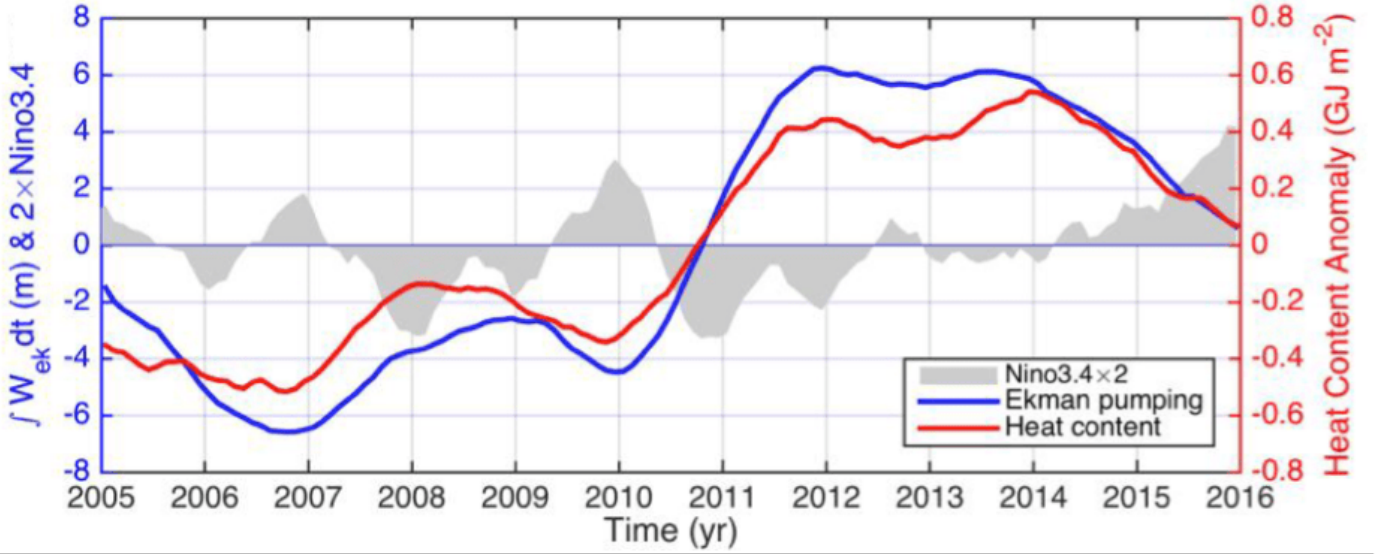

Figure 2. Chart showing relationship between Ekman pumping caused by winds and heat content of the deep South Pacific Ocean. Adapted from Volkov et al. 2017.

Conclusions

This is the first study to show agreement between ship-based and satellite-

based measurements of deep-ocean warming in the South Pacific Ocean, supporting the theory that the deep South Pacific has been warming. In addition to causing rising sea levels (warm water expands, making sea levels rise), deep-ocean warming can be a contributing factor to the observed hiatus in rising sea surface temperatures as heat instead moves deeper into the ocean. There is also reason to believe that if the wind forcing water downward was to reverse, this warmer deep water could be brought to the surface and release heat into the atmosphere.

This study is the first to show that the deep South Pacific is warming and highlights the importance of the deep ocean as a sink for excess heat in the atmosphere. Understanding where heat is being absorbed is important for predicting how sea levels and temperatures will change in the future as global warming continues.

Julia Dohner

Julia is a second-year PhD student at Scripps Institution of Oceanography in La Jolla, California. Her focus is on chemical oceanography, which often manifests as the intersection of the biology, chemistry, and physics of the ocean. She joined Dr. Ralph Keeling's group and is modeling large-scale air-sea gas exchange to better understand how much carbon dioxide the ocean is absorbing from the atmosphere. When not at her computer or reading papers, Julia is usually in the ocean on her surfboard and/or thinking about food.

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