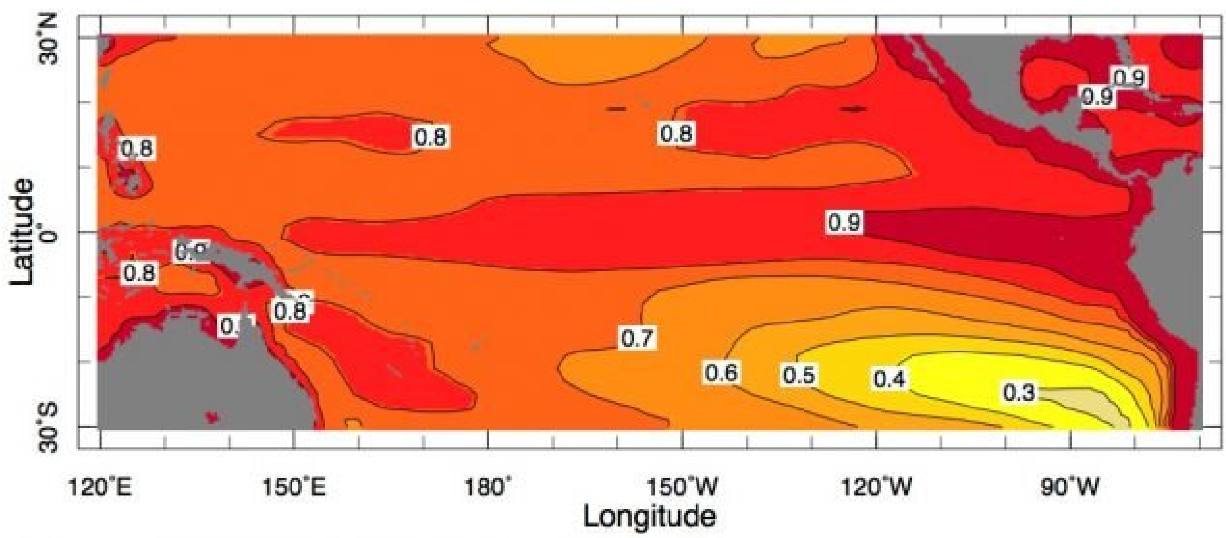
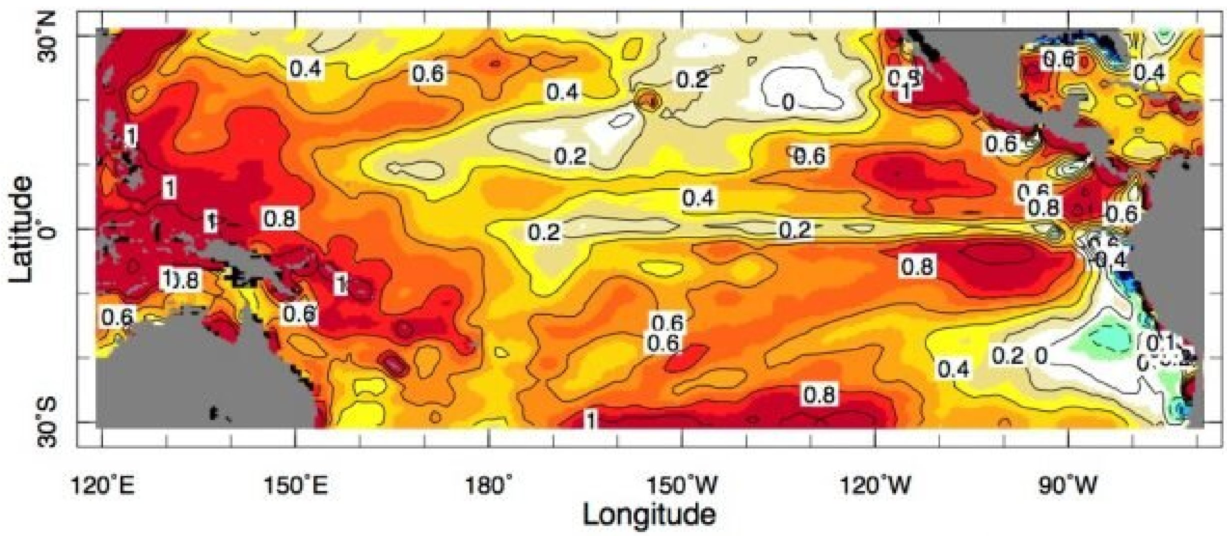
Part of the Pacific Ocean is not warming as expected, buy why?

June 25 2019, by Kevin Krajick



The tropical Pacific Ocean (Australia and South America in gray, left and right). Top map shows what climate models say sea-surface temperatures should be doing in response to rising greenhouse gases, including pronounced warming of waters along the equator. Bottom map shows what the waters are actually doing; the equatorial waters are remaining relatively cool. Credit: Seager et al., Nature Climate Change 2019



State-of-the-art climate models predict that as a result of human-induced climate change, the surface of the Pacific Ocean should be warming—some parts more, some less, but all warming nonetheless. Indeed, most regions are acting as expected, with one key exception: what scientists call the equatorial cold tongue. This is a strip of relatively cool water stretching along the equator from Peru into the western Pacific, across quarter of the earth's circumference. It is produced by equatorial trade winds that blow from east to west, piling up warm surface water in the west Pacific, and also pushing surface water away from the equator itself. This makes way for colder waters to well up from the depths, creating the cold tongue.

Climate models of global warming—computerized simulations of what various parts of the earth are expected to do in reaction to rising greenhouse gases—say that the equatorial cold tongue, along with other regions, should have started warming decades ago, and should still be warming now. But the cold tongue has remained stubbornly cold.

This troubles many scientists, because the cold tongue plays a key role in global climate. For example, it affects the El Niño-Southern Oscillation, a natural cyclic strengthening and weakening of the trade winds that causes cooling and warming of the eastern Pacific surface every two to seven years. ENSO is the world's master weather maker; depending on which part of the cycle it is in, its echoes in the atmosphere may bring heavy rains or drought across much of the Americas, east Asia and east Africa. Whether the cold tongue warms will likely affect weather across huge regions. Resulting shifts could affect world food supplies and outbreaks of dangerous weather. But our predictions of those shifts rest on climate models.

Richard Seager, a climate scientist at Columbia University's Lamont-Doherty Earth Observatory, has long suspected that climate models get the cold tongue wrong. In 1997, he and colleagues published a paper suggesting that it had not warmed at all during the 20th century. At the time, most scientists assumed that any discrepancy between real-world temperatures and those predicted by climate models were due to natural variability. We should just wait; eventually the signal of cold tongue warming would emerge. Now, two decades later, with more modern satellite data in hand, real-world observations are veering ever more obviously from the models. It is time to reconsider, says Seager.

In a new paper in the journal *Nature Climate Change*, he and colleagues use simplified models that isolate the fundamental dynamics of the tropical Pacific atmosphere-ocean system. These, they say, comport with the cold tongue's actual behavior—and show that it is consistent with rising greenhouse gases.

We recently spoke with Seager about climate models, the intricate workings of the Pacific climate system, and the wider implications for the world.

In general, how well do climate models match real-world observations?

The mismatch between observed changes in cold tongue temperature over past decades and the models is quite striking. There are scores of simulations with multiple models from research groups across the world. While these models are all forced by the same histories of greenhouse gases, volcanoes, solar radiation and other forces, they generate their own internal variability. Hence they create a range of estimates of climate history. For changes in cold-tongue temperature, the observed changes are at the far cold end or outside the model range. The average or median model says the cold tongue should have warmed by 0.8 degrees C or more over the past six decades, but the real value is only 0.4 degrees or less.

Why are the state-of-the-art climate models out of line with what we are seeing?

Well, they've been out of line for decades. This is not a new problem. In this paper, we think we've finally found out the reason why. Through multiple model generations, climate models have simulated cold tongues that are too cold and which extend too far west. There is also spuriously warm water immediately to the south of the model cold tongues, instead of cool waters that extend all the way to the cold coastal upwelling regions west of Peru and Chile. These over-developed cold tongues in the models lead to equatorial environments that have too high relative humidity and too low wind speeds. These make the sea surface temperature very sensitive to rising greenhouse gases. Hence the model cold tongues warm a lot over the past decades. In the real world, the sensitivity is lower and, in fact, some of heat added by rising greenhouse gases is offset by the upwelling of cool water from below. Thus the real-world cold tongue warms less than the waters over the tropical west

Pacific or off the equator to the north and south. This pattern of sea-surface temperature change then causes the trade winds to strengthen, which lifts the cold subsurface water upward, further cooling the cold tongue.

What do your models do that the more widely used ones don't?

Our models actually date back to the early 1980s, when people were first trying to use models to explain phenomena like the El Niño-Southern Oscillation. It was common then to make the problem simpler by assuming within the model the climatological mean state and simply simulating perturbations from that. We used that approach. By doing so, we were able to show within our one simple model that, if we assume the real-world climatological state, the response to rising greenhouse gases is warming everywhere, but not in the cold tongue. In contrast, if we assume the biased climatological state in the complex state-of-the-art models, the response to rising greenhouse gases has enhanced warming in the cold tongue. Hence this trip down modeling memory lane allows us to diagnose what is wrong with the complex models currently being used for climate projections and impact assessments.

If your ideas are correct, how might projections of ENSO's future behavior change?

Short answer, we don't know. One thing at a time! However, we do know that ENSO behavior depends on the mean state around which it is perturbing things. If we are right that the tropical Pacific is moving to a state where the waters are warming everywhere but not in the cold tongue, and cold subsurface waters are being lifted closer to the surface, then ENSO will almost certainly change in amplitude, frequency and other ways. We need to find out.

What are the implications for people?

They are many. The sea-surface temperature of the equatorial Pacific influences climate and its variability worldwide. Generally, warming of the atmosphere increases the amount of moisture the air can hold, and intensifies moisture transport. This tends to make subtropical dry zones drier and tropical and mid-latitude wet zones wetter. But on top of those changes there will be regional changes. If the cold tongue warms as the complex models say it should, analogous to an El Niño event, it will create a wet tendency in some regions, to offset subtropical drying in southwest North America and South America. It will also create a wetting tendency in east Africa, but a drying tendency in equatorial South America and the Sahel. If, instead, we are right and the cold tongue will not warm as much, then drying in southwest North America, subtropical South America and east Africa could be more severe than the complex models project. At the same time, equatorial South America and the Sahel might see wetter conditions. In developing climate impact assessments, scenarios should not be limited to the complex models. They should also consider the case in which the cold tongue continues to not warm. The implication for modelers is that they must find out why their models have biases, and fix them.

More information: Strengthening tropical Pacific zonal sea surface temperature gradient consistent with rising greenhouse gases. *Nature Climate Change*, doi.org/10.1038/s41558-019-0505-x

Provided by Columbia University